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He is a member of the editorial advisory boards to the journals *Science Communication*; *Science, Technology, and Human Values*; and *Review of Policy Research*; and has served as a consultant to government agencies, national laboratories, industrial firms and international organizations. Dr. Teich was president of the Washington Academy of Sciences in 2008–2009. He chaired the advisory committee to the National Science Foundation's Division of Science Resources Studies from 1987 through 1990. He is a founding member of the World Technology Network and currently belongs to several international advisory boards and committees, including the Board of Governors of the U.S.-Israel Binational Science Foundation; the Advisory Board of the Norwegian Research and Technology Forum in the United States and the Program Committee of the Euroscience Open Forum — ESOF. He is also an honorary member of the Washington Science Diplomats Club.

Dr. Teich is an accomplished amateur photographer and has had several one-person shows of his work. He is married to Jill Pace, director of the American College of Real Estate Lawyers, and has three children and four grandchildren. His home page may be found at http://www.alteich.com.

Preface

I am of two minds when it comes to technology.

One side of me is totally hooked on technology. While I do not necessarily feel compelled to be the first among my friends to own every new gadget, I do use and enjoy many technologies. I spend a great deal of my time at one or another of my computers (we have five in the house, six when our daughter is home), on my iPhone, listening to my iPod, or using one of my digital cameras. I love Google and the way it makes information about practically anything instantly available to me. I love letting my Roomba® robot vacuum clean my carpets while I'm occupied with other things. I am currently lusting after a plug-in electric car and hope to have one within the next year or two. I am a regular consumer of technology blogs and reviews of new technological products online as well as in newspapers and magazines. (Okay, so I do still read paper media.) And, perhaps most important of all (and under-appreciated), I am a beneficiary of modern, high-tech medicine – living a longer and healthier life because of scientific discoveries and biomedical technologies.

Still, I am fully aware that technology has its dark side and that much of the technology with which our society is suffused is designed to earn profits for high- (and low-) tech firms and entrepreneurs rather than to improve human well-being. I worry about where our technologies are taking us. Our man-made technological systems can be fragile and, as shown in the past several years by the failure of the levee system during Hurricane Katrina; the BP oil spill; and the devastating 2011 earthquake, tsunami, and consequent nuclear disaster in Japan, they are capable of causing or at least failing to prevent great harm. Many (perhaps most) beneficial technologies can also cause inadvertent harm to people, animals, or the environment — examples such as pesticides, polluting energy sources, and medical therapies with unanticipated side effects are legion. And of course technologies can also be used intentionally to harm people, to perpetuate social injustice, or to serve other destructive ends.

This book, now in its 12th edition and, at 40 years old, well into middle age, reflects the yin and the yang of my own understanding of and feelings about technology. The articles I've selected both extol the virtues and criticize the evils of technology and its role in society, although I have tried to avoid the extremes on both sides.

Except perhaps by science fiction writers, relatively few of the technologies that are discussed by the authors in this volume were even remotely imagined when I assembled the materials for the first edition of this book in 1971. (It was not actually published until the following year.) The preface for that first edition (and several subsequent editions) was written on a typewriter and the selections were cut and pasted into the manuscript using scissors and tape rather than Word's cut and paste functions. The manuscript was mailed to the publisher — not FedExed, not e-mailed. And the galleys and page proofs were returned to me the same way. I cannot imagine working like that again and wonder how I possibly could have assembled this book in such a primitive manner. The innovations of the past several decades are astounding for those of us who grew up without them, but for the current generation (and a couple of previous generations), they're routine — an ordinary part of life, taken for granted as if they had always existed.

Technology and society are both changing at an unprecedented pace. And a textbook on technology and society is hardly timeless. Experience shows that it needs to be substantially updated every few years. The development of this book since 1972 provides a mini-history of concerns about technology and society. (Take a look at the tables of contents of previous editions at http://www.alteich.com/history/index.htm to see what I mean.) Recognizing the pace of technological change, and taking into account the comments of users and reviewers as well as my own sense of the relative importance of various topics and the timeliness (or its lack) of various chapters, I have once again, for this new edition, performed major surgery on the book. I have dropped nine chapters that appeared in the 11th edition and replaced them with ten more current and/or more relevant articles.

Despite the changes, the structure of the book remains intact, and much of the content will look familiar to those who have used previous editions. In Part I, "Thinking about Technology," several well-known authors raise big questions: What is technology? Is it good, bad, or neutral (or good *and* bad)? Is it synonymous with progress? How does it influence society and how does society influence its development? Leo Marx and Robert Pool headline this section. Next, David Edgerton reminds us not to let the focus on new technology blind us to the importance of existing technologies, even those that may seem mundane. Alvin Weinberg's essay on the "technological fix," which follows, is one of only three articles that survive from the first edition. Though dated, it still raises important questions and seldom fails to provoke discussion. The chapters by engineer Samuel Florman and political scientist Langdon Winner (difficult, perhaps, but well worth the effort) should do the same. My hope in Part I, as elsewhere in the book, is to preserve the best elements of previous editions while also bringing in more current thinking.

The four-decade old, but still very relevant, debate over the role of technology in society between the late Emmanuel Mesthene and John McDermott, like the Weinberg chapter a feature of the book since the first edition, comprises Part II, "Debating Technology: 1960s Style." Both the substance and the rhetoric of the Mesthene–McDermott debate contrast sharply with Part III, "Debating Technology: Twenty-First-Century Style," in which Bill Joy, a computer scientist and entrepreneur responsible for several major software innovations, presents his rather scary vision of a future in which the products of nanotechnology, genetics, and robotics converge and threaten the existence of humanity. Responding to Joy rather critically are John Seely Brown and Paul Duguid, as well as inventor Ray Kurzweil, a friend of Joy's whose views of the future are quite different from his.

The next three sections on "Contemporary Technological Dilemmas" turn to more concrete, current issues and explore some of the ethical, social, and human dimensions of a number of specific areas of technology and have been subject to considerable updating. Part IV examines one of the most critical issues facing society today: global climate change. Many people believe climate change is the most vexing problem facing global society in the twenty-first century. While agreement on what to do about it is still far off, all but a few of the most ardent skeptics agree that the problem is real and must be addressed. The lead article included here, by Collins et al., describes the scientific basis for the increasingly powerful consensus among researchers on the nature of this problem. It is based on the 2007 report of the Intergovernmental Panel on Climate Change and explains, in terms that do not require a PhD in atmospheric physics to understand, how and why the Earth's climate is changing.

Still, the scientific consensus is not unanimous. A significant number of policymakers and a lesser number of scientists have a different view. Among the scientists who take a contrarian position, Richard Lindzen stands out. He is a highly respected professor at M.I.T. and his article (new to this edition), originally an op-ed in the *Wall Street Journal*, provides an excellent summary of the arguments against the scientific mainstream. Following Lindzen, the third and fourth articles in Part IV (also new) approach climate change from a rather different angle, that of geoengineering, fixing the problem with a massive technological intervention. The article by Victor et al. looks at the internationa political ramifications of such an approach; the piece by Robock marshals th arguments against it.

Part V looks at some of the social and ethical dimensions of recent advance in the life and biomedical sciences: stem cell research, synthetic biology, geneti engineering, and neuroscience. Research involving human embryonic stem cell offers the tantalizing prospect of breakthroughs in the treatment of diseases an injuries, but, in the minds of critics, it also opens the door to possible abuses o the sanctity of human life. Christopher Thomas Scott lays out the basic feature of both sides of this debate clearly and concisely.

Going a step beyond stem cell research, synthetic biology employs scientifi and engineering techniques to create artificial organisms capable of reproducin themselves. The idea is controversial, and in May 2010 President Obama charge his Presidential Commission for the Study of Bioethical Issues with examining i prospects and problems. An excerpt from the commission's report is included chapter 17, followed by an article from *Nature* examining the barriers faced by this exciting but controversial technology. Both are new to this edition.

In chapter 18, carried over from the 11th edition, Michael Sandel takes a conservative approach to the possibilities of designer children and other kinds of human enhancement created by developments in biotechnology. And, following Sandel, in chapter 20, Stanford law professor Henry Greely speculates on the meaning of advances in neuroscience which, some scientists believe, will soon provide a means of gauging an individual's mental state — i.e., reading his or her mind — with an imaging device.

Under the heading of information and communications technology in Part VI is an article by computer historian Paul Ceruzzi — a favorite of mine — on why those most responsible for originating the information technology revolution failed to anticipate its extent or its impact. It is followed by a curmudgeonly but entertaining piece by poet and farmer Wendell Berry, on why he rejects the idea of using a computer to do his writing, and by an up-to-date, broad-based survey by philosopher Deborah Johnson of the ethical issues raised by computers and information technology. New to Part VI is chapter 24, in which Nicholas Carr, writer about technology and culture, and author of the blog *Rough Type*, asks "Is Google Making Us Stupid?" More precisely, he explores the question of how the Internet is affecting our modes of reading, writing, and thinking. His thought-provoking piece is followed by two more new articles on one of the critical policy issues that will shape the future of the Internet: the matter of "net neutrality." Net neutrality is the principle that Internet service providers may not discriminate among different forms of content and applications that they carry on their lines. A short piece from *savetheinternet.com* argues against network operators who, the organization claims, want to change that principle and discriminate among different uses by charging differential fees to web site operators. In the following article, an analyst at the Information Technology and Innovation Foundation looks at the issue from a different perspective, that of broadband network managers, and asks what kinds of policies can balance the competing interests involved in using the Internet as well as future computer networks.

The last section, "Governance and Globalization," takes a step back from these rather technical concerns and returns to the broader questions of technology and society through the prism of governance. The first chapter is my own article on the relationships between governments and technology, an article I wrote originally for an encyclopedia of science, technology, and society. The other (new to this edition), by three-time Pulitzer Prize winning columnist for the *New York Times* Thomas Friedman, is a brief excerpt from his best-selling book, *The World Is Flat*. In it he describes life in a call center in Bangalore, India, using the story to illustrate how, in many respects and in many economic sectors, technology (again, especially the Internet) has made geography virtually irrelevant.

As in previous editions, my selections are — by design — a mixed bag. Not all students or all instructors will find every reading to their liking. Readers will probably love some and hate others, find some fascinating, others tedious. I have chosen the individual articles with an eye toward diversity in their authors' views of technology and political leanings. They do not necessarily represent my own views, and I do not necessarily endorse their perspectives. As a whole, however, the book reflects what I hope is a balanced view of the important issues in the field of technology and society, a view that I hope will be useful to others who are interested in these topics.

Technology and the Future has been a part of my professional life throughout my entire career. It is gratifying to have watched the growing interest in the study of technology, society, and the future in colleges and universities worldwide over the past several decades and to feel that the book may have made a modest contribution to this important intellectual development. Throughout the life of this book, I have benefited from the interest, suggestions, and feedback from the book's users. I am indebted to them all for the ideas that they shared with me, some of which have helped to shape this volume.

My thanks go also to the staff of my current publisher, Cengage Learning (formerly Thomson Wadsworth), especially Carolyn Merrill and Katie Hayes; to my previous publisher, Bedford/St. Martin's; and finally to St. Martin's Press's College Division, whose editors had the foresight to publish the first edition of this book in 1972 and who, through a generation of staff changes, mergers, acquisitions, and restructurings, remained helpful, interested, and unfailingly supportive. I have been fortunate in having a series of editors over the years with whom it has always been a pleasure to work.

I wish to acknowledge the advice of those who have contributed comments and suggestions that helped shape this edition:

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Finally, a very special note of gratitude goes to my family: my wife, Jill; my daughter, Samantha; and my sons, Mitch and Ken; their wives Gretchen and Sara; and my grandchildren, Calvin Avery, Madelyn Elise, Sylvi Reine, and Charlie Joel, for the meaning they give to my life and for the strength I draw from our relationships.

Once again I invite readers — both faculty and students — to contact me with comments and suggestions. I can be reached most readily by e-mail at *ateich@gmail.org*, through *ateich.com* or *alteich.com*. The latter site ("Al Teich's Technology and the Future Toolkit") contains supplementary resources related to the book, including the tables of contents of earlier editions, my personal home page, and more. You can also follow me on Twitter: @al_teich.

Albert H. Teich
Washington, D.C.
June 201

PART I

Thinking About Technology

Technology is more than just machines. It is a pervasive, complex system whose cultural, social, political, and intellectual elements are manifest in virtually every aspect of our lives. Small wonder, then, that it has attracted the attention of such a large and diverse group of writers and commentators. A small sampling of the range of writings on the social dimensions of technology is contained in this first section of *Technology and the Future.* All of the writers represented here are attempting to understand — from one perspective or another — these social dimensions of technology. Little else ties them together. From the oldest to the most recent they span nearly half a century. Their points of view are vastly different. Their common goal is not so much to prescribe particular courses of action as it is to explore the conceptual, metaphysical issues underlying technology–society interactions.

In the opening selection, historian Leo Marx explores the development of the American notion of progress and looks at its connections with technological advance. This seminal essay asks a simple-sounding question that sets the tone for this entire book: Does improved technology mean progress? Next, Robert Pool, former senior writer at *Science* and news editor at *Nature*, explains in lucid terms the ways in which technology and society shape one another. Pool's essay is drawn from a book that began as a straightforward treatment of the commercial nuclear industry. Instead of the simple story he expected to find, Pool discovered "a complex, often convoluted tale of how the technology had been shaped by a host of nontechnical factors in addition to the expected technical ones." His approach transcends both the notions of technological determinism (the idea that technology is an autonomous force that produces social change) and social constructivism (which views technology as purely a product of social and cultural influences) in favor of a more subtle explanation of the relations between technology and society.

The following chapter takes an entirely different approach to thinking about technology. In contrast to most of the other authors represented in Part I, British historian David Edgerton makes a powerful case for the global significance of *old* technologies. Edgerton directs his attention away from the idea of invention and toward the matter of how and by whom technologies are actually used. Through this lens he sees an entirely different world, one dominated by simple, mundane technologies rather than the newest, most advanced ones.

After the chapter by David Edgerton, in an essay dating from the mid-1960s that captures some of the heights of post–World War II technological optimism, physicist Alvin Weinberg suggests that we can find shortcuts to the solution of social problems by transforming them into technological ones, since technological problems are much easier to solve. This selection, though out of sync with much current thinking, has become a classic for the perspective it represents and for introducing the concept of the "technological fix," which continues to be the subject of debate and discussion.

In Chapter 5, Samuel Florman, a practicing engineer and industrialist as well as a humanist, proposes an alternative approach — a "tragic view" that recognizes the role of technology in human life, including its limits. The chapter that follows Florman is one of the best-known and most-discussed articles in the literature of technology and society. In it, Langdon Winner, professor at Rensselaer Polytechnic Institute, asks whether certain technological systems by their nature determine particular arrangements of power and authority among people. Understanding the significance of this and related questions is essential, Winner argues, to maintaining (or perhaps restoring) democratic control over the course of technological and social development.

The reader who is looking for unequivocal answers to the problems posed by technology will not find them here. On the whole, the readings in this section, like those in the remainder of the book, raise many more questions than they answer. They are intended to stimulate the reader to think critically about the relations between technology and society and the ways in which they shape the future.

1

Does Improved Technology Mean Progress?

LEO MARX

The concepts of technology and progress have been firmly linked in the minds of most Americans for the past 150 years. Only in the past three decades, however, has the question that Leo Marx asks in his essay, "Does Improved Technology Mean Progress?" begun to receive serious attention in our culture. This question is the perfect starting point for Technology and the Future. Deceptive in its simplicity, it underlies most of what follows in this book.

Leo Marx is Senior Lecturer and William R. Kenan Professor of American Cultural History Emeritus in the Program in Science, Technology, and Society at MIT. He is the author of The Machine in the Garden: Technology and the Pastoral Ideal in America *(1964) and is coeditor, with Merritt Roe Smith, of* Does Technology Drive History? *(1994). He holds a Ph.D. in history of American civilization from Harvard and has taught at that institution and at the University of Minnesota and Amherst College. He has twice been a Guggenheim Fellow and was a Rockefeller Humanities Fellow in 1983–1984. Marx was born in New York City in 1919.*

In this reading Marx examines how the concept of progress has itself evolved since the early days of the Republic and what that evolution means for understanding the technological choices that confront us today. Improved technology could mean progress, Marx concludes, "but only if we are willing and able to answer the next question: Progress toward what?"

Does improved technology mean progress? If some variant of this question had been addressed to a reliable sample of Americans at any time since the

Leo Marx, "Does Improved Technology Mean Progress?" from *Technology Review* (January, 1987), pp. 33–41.

early nineteenth century, the answer of a majority almost certainly would have been an unequivocal "yes." The idea that technological improvements are a primary basis for — and an accurate gauge of — progress has long been a fundamental belief in the United States. In the last half-century, however, that belief has lost some of its credibility. A growing minority of Americans has adopted a skeptical, even negative, view of technological innovation as an index of social Progress.

The extent of this change in American attitudes was brought home to me when I spent October 1984 in China. At that time, the announced goal of the People's Republic was to carry out (in the popular slogan) "Four Modernizations" — agriculture, science and technology, industry, and the military. What particularly struck our group of Americans was the seemingly unbounded, largely uncritical ardor with which the Chinese were conducting their love affair with Western-style modernization — individualistic, entrepreneurial, or "capitalist," as well as scientific and technological. Like early nineteenth-century visitors to the United States, we were witnessing a society in a veritable transport of improvement: long pent-up, innovative energies were being released, everyone seemed to be in motion, everything was eligible for change. It was assumed that any such change almost certainly would be for the better.

Most of the Chinese we came to know best — teachers and students of American studies — explicitly associated the kind of progress represented by the four modernizations with the United States. This respect for American wealth and power was flattering but disconcerting, for we often found ourselves reminding the Chinese of serious shortcomings, even some terrible dangers, inherent in the Western mode of industrial development. Like the Americans whom European travelers met 150 years ago, many of the Chinese seemed to be extravagantly, almost blindly, credulous and optimistic.

Our reaction revealed, among other things, a change in our own culture and, in some cases, in our own personal attitudes. We came face-to-face with the gulf that separates the outlook of many contemporary Americans from the old national faith in the advance of technology as the basis of social progress.

The standard explanation for this change includes that familiar litany of death and destruction that distinguishes the recent history of the West: two barbaric world wars, the Nazi holocaust, the Stalinist terror, and the nuclear arms race. It is striking to note how many of the fearful events of our time involve the destructive use or misuse, the unforeseen consequences, or the disastrous malfunction of modern technologies: Hiroshima and the nuclear threat, the damage inflicted upon the environment by advanced industrial societies, and spectacular accidents like Three Mile Island.

Conspicuous disasters have helped to undermine the public's faith in progress, but there also has been a longer-term change in our thinking. It is less obvious, less dramatic, and less tangible than the record of catastrophe that distinguishes our twentieth-century history, but I believe it is more fundamental. Our very conception — our chief criterion — of progress has undergone a subtle but decisive change since the founding of the Republic, and that change is at once a cause and a reflection of our current disenchantment with technology.

To chart this change in attitude, we need to go back at least as far as the first Industrial Revolution.

THE ENLIGHTENMENT BELIEF IN PROGRESS

The development of radically improved machinery (based on mechanized motive power) used in the new factory system of the late eighteenth century coincided with the formulation and diffusion of the modern Enlightenment idea of history as a record of progress. This conception became the fulcrum of the dominant American worldview. It assumes that history, or at least modern history, is driven by the steady, cumulative, and inevitable expansion of human knowledge of and power over nature. The new scientific knowledge and technological power were expected to make possible a comprehensive improvement in all the conditions of life — social, political, moral, and intellectual, as well as material.

The modern idea of progress, as developed by its radical French, English, and American adherents, emerged in an era of political revolution. It was a revolutionary doctrine, bonded to the radical struggle for freedom from feudal forms of domination. To ardent republicans like the French philosopher Condorcet, the English chemist Priestley, and Benjamin Franklin, a necessary criterion of progress was the achievement of political and social liberation. They regarded the new sciences and technologies not as ends in themselves, but as instruments for carrying out a comprehensive transformation of society. The new knowledge and power would provide the basis for alternatives to the deeply entrenched authoritarian, hierarchical institutions of *l'ancien régime*: monarchical, aristocratic, and ecclesiastical. Thus, in 1813 Thomas Jefferson wrote to John Adams describing the combined effect of the new science and the American Revolution on the minds of Europeans:

> Science had liberated the ideas of those who read and reflect, and the American example had kindled feelings of right in the people. An insurrection has consequently begun, of science, talents, and courage, against rank and birth, which have fallen into contempt.... Science is progressive.

Admittedly, the idea of history as endless progress did encourage extravagantly optimistic expectations, and in its most extreme form it fostered some wildly improbable dreams of the "perfectability of Man" and of humanity's absolute mastery of nature. Yet, the political beliefs of the radical republicans of the eighteenth century, such as the principle of making the authority of government dependent upon the consent of the governed, often had the effect of limiting those aspirations to omnipotence.

The constraining effect of such ultimate, long-term political goals makes itself felt, for example, in Jefferson's initial reaction to the prospect of introducing the new manufacturing system to America. "Let our work-shops remain in Europe," he wrote in 1785.

Although a committed believer in the benefits of science and technology, Jefferson rejected the idea of developing an American factory system on the ground that the emergence of an urban proletariat, which he then regarded as an inescapable consequence of the European factory system, would be too high a price to pay for any potential improvement in the American material standard of living. He regarded the existence of manufacturing cities and an industrial working class as incompatible with republican government and the happiness of the people. He argued that it was preferable, even if more costly in strictly economic terms, to ship raw materials to Europe and import manufactured goods. "The loss by the transportation of commodities across the Atlantic will be made up in happiness and permanence of government." In weighing political, moral, and aesthetic costs against economic benefits, he anticipated the viewpoint of the environmentalists and others of our time for whom the test of a technological innovation is its effect on the overall quality of life.

Another instance of the constraining effect of republican political ideals is Benjamin Franklin's refusal to exploit his inventions for private profit. Thus, Franklin's reaction when the governor of Pennsylvania urged him to accept a patent for his successful design of the "Franklin stove":

> Governor Thomas was so pleased with the construction of this stove as described in … [the pamphlet] that … he offered to give me a patent for the sole vending of them for a term of years; but I declined it from a principle which has ever weighed with me on such occasions, namely; viz., *that as we enjoy great advantages from the inventions of others, we should be glad of an opportunity to serve others by any invention of ours, and this we should do freely and generously* [emphasis in original].

What makes the example of Franklin particularly interesting is the fact that he later came to be regarded as the archetypal self-made American and the embodiment of the Protestant work ethic. When Max Weber sought out of all the world *the* exemplar of that mentality for his seminal study, *The Protestant Ethic and the Spirit of Capitalism*, whom did he choose but our own Ben? But Franklin's was a principled and limited self-interest. In his *Autobiography*, he told the story of his rise in the world not to exemplify a merely personal success, but rather to illustrate the achievements of a "rising people." He belonged to that heroic revolutionary phase in the history of the bourgeoisie when that class saw itself as the vanguard of humanity and its principles as universal. He thought of his inventions as designed not for his private benefit but for the benefit of all.

THE TECHNOCRATIC CONCEPT OF PROGRESS

With the further development of industrial capitalism, a quite different conception of technological progress gradually came to the fore in the United States. Americans celebrated the advance of science and technology with increasing fervor, but they began to detach the idea from the goal of social and political liberation. Many regarded the eventual attainment of that goal as having been assured by the victorious American Revolution and the founding of the Republic.

The difference between this later view of progress and that of Jefferson's and Franklin's generation can be heard in the rhetoric of Daniel Webster. He and Edward Everett were perhaps the leading public communicators of this new version of the progressive ideology. When Webster decided to become a senator from Massachusetts instead of New Hampshire, the change was widely interpreted to mean that he had become the quasi-official spokesman for the new industrial manufacturing interests. Thus Webster, who was generally considered the nation's foremost orator, was an obvious choice as the speaker at the dedication of new railroads. Here is a characteristic peroration of one such performance in 1847:

> It is an extraordinary era in which we live. It is altogether new. The world has seen nothing like it before. I will not pretend, no one can pretend, to discern the end; but everybody knows that the age is remarkable for scientific research into the heavens, the earth, and what is beneath the earth; and perhaps more remarkable still for the application of this scientific research to the pursuits of life.... We see the ocean navigated and the solid land traversed by steam power, and intelligence communicated by electricity. Truly this is almost a miraculous era. What is before us no one can say, what is upon us no one can hardly realize. The progress of the age has almost outstripped human belief; the future is known only to Omniscience.

By the 1840s, as Webster's rhetoric suggests, the idea of progress was already being dissociated from the Enlightenment vision of political liberation. He invests the railroad with a quasi-religious inevitability that lends force to the characterization of his language as the rhetoric of the technological sublime. Elsewhere in the speech, to be sure, Webster makes the obligatory bow to the democratic influence of technological change, but it is clear that he is casting the new machine power as the prime exemplar of the overall progress of the age, quite apart from its political significance. Speaking for the business and industrial elite, Webster and Everett thus depict technological innovation as a sufficient cause, *in itself*, for the fact that history assumes the character of continuous, cumulative progress.

At the same time, discarding the radical political ideals of the Enlightenment allowed the idea of technological progress to blend with other grandiose national aspirations. Webster's version of the "rhetoric of the technological sublime" is of a piece with the soaring imperial ambitions embodied in the slogan "Manifest Destiny," and by such tacit military figurations of American development as the popular notion of the "conquest of nature" (including Native Americans) by the increasingly technologized forces of advancing European-American "civilization." These future-oriented themes easily harmonized with the belief in the coming of the millennium that characterized evangelical Protestantism, the most popular American religion at the time. Webster indicates as much when, at the end of his tribute to the new railroad, he glibly brings in "Omniscience" as the ultimate locus of the meaning of progress.

The difference between the earlier Enlightenment conception of progress and that exemplified by Webster is largely attributable to the difference between the groups they represented. Franklin, Jefferson, and the heroic generation of founding revolutionists constituted a distinct, rather unusual social class in that for a short time the same men possessed authority and power in most of its important forms: economic, social, political, and intellectual. The industrial capitalists for whom Daniel Webster spoke were men of a very different stripe. They derived their status from a different kind of wealth and power, and their conception of progress, like their economic and social aspirations, was correspondingly different. The new technology and the immense profits it generated belonged to them, and since they had every reason to assume that they would retain their property and power, they had a vested interest in technological innovation. It is not surprising, under the circumstances, that as industrialization proceeded these men became true believers in technological improvement as the primary basis for — and virtually tantamount to — universal progress.

This dissociation of technological and material advancement from the larger political vision of progress was an intermediate stage in the eventual impoverishment of that radical eighteenth-century worldview. This subtle change prepared the way for the emergence, later in the century, of a thoroughly technocratic idea of progress. It was "technocratic" in that it valued improvements in power, efficiency, and rationality as ends in themselves. Among those who bore witness to the widespread diffusion of this concept at the turn of the century were Henry Adams and Thorstein Veblen, who were critical of it, and Andrew Carnegie, Thomas Edison, and Frederick Winslow Taylor and his followers, who lent expression to it. Taylor's theory of scientific management embodies the quintessence of the technocratic mentality, "the idea," as historian Hugh Aitken describes it, "that human activity could be measured, analyzed, and controlled by techniques analogous to those that had proved so successful when applied to physical objects."

The technocratic idea of progress is a belief in the sufficiency of scientific and technological innovation as the basis for general progress. It says that if we can ensure the advance of science-based technologies, the rest will take care of itself. (The "rest" refers to nothing less than a corresponding degree of improvement in the social, political, and cultural conditions of life.) Turning the Jeffersonian ideal on its head, this view makes instrumental values fundamental to social progress and relegates what formerly were considered primary, goal-setting values (justice, freedom, harmony, beauty, or self-fulfillment) to a secondary status.

In this century, the technocratic view of progress was enshrined in Fordism and an obsessive interest in economies of scale, standardization of process and product, and control of the workplace. This shift to mass production was accompanied by the more or less official commitment of the U.S. government to the growth of the nation's wealth, productivity, and global power and to the most rapid possible rate of technological innovation as the essential criterion of social progress.

But the old republican vision of progress — the vision of advancing knowledge empowering humankind to establish a less hierarchical, more just, and peaceful society — did not disappear. If it no longer inspired Webster and his associates, it lived on in the minds of many farmers, artisans, factory workers, shopkeepers, and small-business owners, as well as in the beliefs of the professionals, artists, intellectuals, and other members of the lower-middle and middle classes. During the late nineteenth century, a number of disaffected intellectuals sought new forms for the old progressive faith. They translated it into such political idioms as utopian socialism, the single-tax movement, the populist revolt, Progressivism in cities, and Marxism and its native variants.

THE ROOTS OF OUR ADVERSARY CULTURE

Let me turn to a set of these late-eighteenth-century ideas that was to become the basis for a powerful critique of the culture of advanced industrial society. Usually described as the viewpoint of the "counter-Enlightenment" or the "romantic reaction," these ideas have formed the basis for a surprisingly long-lived adversarial culture.

According to conventional wisdom, this critical view originated in the intellectual backlash from the triumph of the natural sciences we associate with the great discoveries of Galileo, Kepler, Harvey, and Newton. Put differently, this tendency was a reaction against the extravagant claims of the universal, not to say exclusive, truth of "the Mechanical Philosophy." That term derived from the ubiquity of the machine metaphor in the work of Newton and other natural scientists ("celestial mechanics") and many of their philosophic allies, notably Descartes, all of whom tended to conceive of nature itself as a "great engine" and its subordinate parts (including the human body) as lesser machines.

By the late eighteenth century, a powerful set of critical, antimechanistic ideas was being developed by Kant, Fichte, and other German idealists and by great English poets like Coleridge and Wordsworth. But in their time the image of the machine also was being invested with greater tangibility and social import. The Industrial Revolution was gaining momentum, and as power machinery was more widely diffused in Great Britain, Western Europe, and North America, the machine acquired much greater resonance: It came to represent both the new technologies based on mechanized motive power and the mechanistic mindset of scientific rationalism. Thus, the Scottish philosopher and historian Thomas Carlyle, who had been deeply influenced by the new German philosophy, announced in his seminal 1829 essay, "Signs of the Times," that the right name for the dawning era was the "Age of Machinery." It was to be the Age of Machinery, he warned, in every "inward" and "outward" sense of the word, meaning that it would be dominated by mechanical (utilitarian) thinking as well as by actual machines.

In his criticism of this new era, Carlyle took the view that neither kind of "machinery" was inherently dangerous. In his opinion, indeed, they represented *potential* progress as long as neither was allowed to become the exclusive or predominant mode in its respective realm.

In the United States, a small, gifted, if disaffected minority of writers, artists, and intellectuals adopted this ideology. Their version of Carlyle's critical viewpoint was labeled "romantic" in reference to its European strains, or "transcendentalist" in its native use. In the work of writers like Emerson and Thoreau, Hawthorne and Melville, we encounter critical responses to the onset of industrialism that cannot be written off as mere nostalgia or primitivism. These writers did not hold up an idealized wilderness, a pre-industrial Eden, as preferable to the world they saw in the making. Nor did they dismiss the worth of material improvement as such. But they did regard the dominant view, often represented (as in Webster's speech) by the appearance of the new machine power in the American landscape, as dangerously shallow, materialistic, and one sided. Fear of "mechanism," in the several senses of that word — especially the domination of the individual by impersonal systems — colored all of their thought. In their work, the image of the machine-in-the-landscape, far from being an occasion for exultation, often seems to arouse anxiety, dislocation, and foreboding. Henry Thoreau's detailed, carefully composed account of the intrusion of the railroad into the Concord woods is a good example; it bears out his delineation of the new inventions as "improved means to unimproved ends."

This critical view of the relationship between technological means and social ends did not merely appear in random images, phrases, and narrative episodes. Indeed, the whole of *Walden* may be read as a sustained attack on a culture that had allowed itself to become confused about the relationship of ends and means. Thoreau's countrymen are depicted as becoming "the tools of their tools." Much the same argument underlies Hawthorne's satire, "The Celestial Railroad," a modern replay of *Pilgrim's Progress* in which the hero, Christian, realizes too late that his comfortable railroad journey to salvation is taking him to hell, not heaven. Melville incorporates a similar insight into his characterization of Captain Ahab, who is the embodiment of the Faustian aspiration toward domination and total control given credence by the sudden emergence of exciting new technological capacities. Ahab exults in his power over the crew, and he explicitly identifies it with the power exhibited by the new railroad spanning the North American continent. In reflective moments, however, he also acknowledges the self-destructive nature of his own behavior: "Now in his heart, Ahab had some glimpse of this, namely, all my means are sane, my motive and my object mad."

Of course, there was nothing new about the moral posture adopted by these American writers. Indeed, their attitude toward the exuberant national celebration of the railroad and other inventions is no doubt traceable to traditional moral and religious objections to such an exaggeration of human powers. In this view, the worshipful attitude of Americans toward these new instruments of power had to be recognized for what it was: idolatry like that attacked by Old Testament prophets in a disguised, new-fashioned form. This moral critique of the debased, technocratic version of the progressive worldview has slowly gained adherents since the mid-nineteenth century, and by now it is one of the chief ideological supports of an adversary culture in the United States.

The ideas of writers like Hawthorne, Melville, and Thoreau were usually dismissed as excessively idealistic, nostalgic, or sentimental and hence impractical and unreliable. They were particularly vulnerable to that charge at a time when the rapid improvement in the material conditions of American life lent a compelling power to the idea that the meaning of history is universal progress. Only in the late twentieth century, with the growth of skepticism about scientific and technological progress, and with the emergence of a vigorous adversary culture in the 1960s, has the standpoint of that earlier eccentric minority been accorded a certain intellectual respect. To be sure, it is still chiefly the viewpoint of a relatively small minority, but there have been times, like the Vietnam upheaval of the 1960s, when that minority has won the temporary support of, or formed a tacit coalition with, a remarkably large number of other disaffected Americans. Much the same antitechnocratic viewpoint has made itself felt in various dissident movements and intellectual tendencies since the 1960s: the antinuclear movements (against both nuclear power and nuclear weaponry), some branches of the environmental and feminist movements, the "small is beautiful" and "stable-state" economic theories, as well as the quest for "soft energy paths" and "alternative (or appropriate) technologies."

TECHNOCRATIC VERSUS SOCIAL PROGRESS

Perhaps this historical summary will help explain the ambivalence toward the ideal of progress expressed by many Americans nowadays. Compared with prevailing attitudes in the United States in the 1840s, when the American situation was more like that of China today, the current mood in this country would have to be described as mildly disillusioned.

To appreciate the reasons for that disillusionment, let me repeat the distinction between the two views of progress on which this analysis rests. The initial Enlightenment belief in progress perceived science and technology to be in the service of liberation from political oppression. Over time, that conception was transformed, or partly supplanted, by the now familiar view that innovations in science-based technologies are in themselves a sufficient and reliable basis for progress. The distinction, then, turns on the apparent loss of interest in, or unwillingness to name, the social ends for which the scientific and technological instruments of power are to be used. What we seem to have instead of a guiding political goal is a minimalist definition of civic obligation.

The distinction between two versions of the belief in progress helps sort out reactions to the many troubling issues raised by the diffusion of high technology. When, for example, the introduction of some new labor-saving technology is proposed, it is useful to ask what the purpose of this new technology is. Only by questioning the assumption that innovation represents progress can we begin to judge its worth. The aim may well be to reduce labor costs, yet in our society the personal costs to the displaced workers are likely to be ignored.

The same essential defect of the technocratic mindset also becomes evident when the president of the United States calls upon those who devise nuclear weapons to provide an elaborate new system of weaponry, the Strategic Defense Initiative, as the only reliable means of avoiding nuclear war. Not only does he invite us to put all our hope in a "technological fix," but he rejects the ordinary but indispensable method of international negotiation and compromise.[1] Here again, technology is thought to obviate the need for political ideas and practices.

One final word. I perhaps need to clarify the claim that it is the modern, technocratic worldview of Webster's intellectual heirs, not the Enlightenment view descended from the Jeffersonians, that encourages the more dangerous contemporary fantasies of domination and total control. The political and social aspirations of the generation of Benjamin Franklin and Thomas Jefferson *provided tacit limits to, as well as ends for, the progressive vision of the future.* But the technocratic version so popular today entails a belief in the worth of scientific and technological innovations as ends in themselves.

All of which is to say that we urgently need a set of political, social, and cultural goals comparable to those formulated at the beginning of the Industrial Era if we are to accurately assess the worth of new technologies. Only such goals can provide the criteria required to make rational and humane choices among alternative technologies and, more important, among alternative long-term policies.

Does improved technology mean progress? Yes, it certainly *could* mean just that. But only if we are willing and able to answer the next question: Progress toward what? What is it that we want our new technologies to accomplish? What do we want beyond such immediate, limited goals as achieving efficiencies, decreasing financial costs, and eliminating the troubling human element from our workplaces? In the absence of answers to these questions, technological improvements may very well turn out to be incompatible with genuine, that is to say *social*, progress.

ENDNOTE

1. See Alvin M. Weinberg, "Can Technology Replace Social Engineering?" (Chapter 4), for a discussion of the concept of the "technological fix." — Ed.

2

How Society Shapes Technology

ROBERT POOL

Why did VHS cassette recorders succeed and Betamax fail, when most experts (and many nonexperts) agreed that Betamax was a better technology? The two formats came on the market around the same time in the mid-1970s. They are incompatible, however, so consumers had to choose one or the other. When VHS gained a small lead, perhaps because of better marketing, perhaps because it uses six-hour cassettes instead of Betamax's five, or perhaps for other reasons, video rental stores began to stock more VHS tapes. This led people to buy more VHS machines and started a self-reinforcing cycle that, in a few years, made Betamax as obsolete as eight-track audio players.

This kind of interplay between the developers of technology and the society that uses that technology is characteristic of the way in which technology and society interact. It's not technological determinism and it's not just social construction; it's a combination of the two. Robert Pool examines this fascinating interplay in depth in his book, Beyond Engineering: How Society Shapes Technology, *from which the following selection is taken. "Modern technology," he writes, "is like a Great Dane in a small apartment. It may be friendly, but you still want to make sure there's nothing breakable within reach." Pool, a freelance writer living in Tallahassee, Florida, who has written for* Science *and* Discover *and was news editor at* Nature, *is the author of* Fat: Fighting the Obesity Epidemic *(2001) and* Eve's Rib: The Biological Roots of Sex Differences *(1994).*

Any modern technology is the product of a complex interplay between its designers and the larger society in which it develops.

Consider the automobile. In the early part of this century, gas-powered cars shared the roads with those powered by boilers and steam engines, such as the Stanley Steamer.[1] Eventually, internal combustion captured the market, and the old steamers disappeared. Why? The usual assumption is that the two contenders went head to head and the best technology won. Not at all.

Although the internal combustion engine did have some advantages in performance and convenience, steam-powered cars had their own pluses: They had no transmission or shifting of gears, they were simpler to build, and they were smoother and quieter to operate. Experts then and now have called it a draw — the "better" technology was mostly a matter of opinion. Instead, the steamers were killed off by several factors that had little or nothing to do with their engineering merits. For one, the Stanley brothers, builders of the best steam-powered cars of the time, had little interest in mass production. They were content to sell a few cars at high prices to aficionados who could appreciate their superiority. Meanwhile, Henry Ford and other Detroit automakers were flooding the country with inexpensive gas-powered cars. Even so, the steamers might well have survived as high-end specialty cars were it not for a series of unlucky breaks. At one point, for example, an outbreak of hoof-and-mouth disease caused public horse troughs to be drained, removing a major source of water for refilling the cars' boilers. It took the Stanley brothers three years to develop a closed-cycle steam engine that didn't need constant refilling, but by then World War I had begun, bringing strict government limits on the number of cars that businesses could build for the consumer market. The Stanley company never recovered, and it folded a few years later. The remnants of the steam automobile industry died during the Depression, when the market for high-priced cars all but disappeared.

Nonengineering factors play a role in the development of all technologies, even the simplest. In *The Pencil*, Henry Petroski tells how pencil designers in the late 1800s, in order to get around a growing shortage of red cedar, devised a pencil with a paper wrapping in place of the normal wood.[2] It "worked well technically and showed great promise," Petroski writes, "but the product failed for unanticipated psychological reasons." The public, accustomed to sharpening pencils with a knife, wanted something that could be whittled. The paper pencil never caught on.

Today, particularly for such sophisticated creations as computers, genetic engineering, or nuclear power, nontechnical factors have come to exert an influence that is unprecedented in the history of technology. Invention is no longer, as Ralph Waldo Emerson's aphorism had it, simply a matter of "Build a better mousetrap and the world will beat a path to your door." The world is already at your door, and it has a few things to say about that mousetrap.

The reasons for this are several, some grounded in the changing nature of technology itself and others arising from transformations in society. A hundred years ago, people in western nations generally saw technological development as a good thing.[3] It brought prosperity and health; it represented "progress."

But the past century has seen a dramatic change in western society, with a resulting shift in people's attitudes toward technology.[4] As countries have become more prosperous and secure, their citizens have become less concerned about increasing their material well-being and more concerned with such aesthetic considerations as maintaining a clean environment. This makes them less likely to accept new technologies uncritically. At the same time, citizens of western democracies have become more politically savvy and more active in challenging the system with lawsuits, special interest groups, campaigns to change public opinion, and other weapons. The result is that the public now exerts a much greater influence on the development of technologies — particularly those seen as risky or otherwise undesirable — than was true one hundred, or even fifty, years ago.

Meanwhile, the developers of technology have also been changing. A century ago, most innovation was done by individuals or small groups. Today, technological development tends to take place inside large, hierarchical organizations. This is particularly true for complex, large-scale technologies, since they demand large investments and extensive, coordinated development efforts. But large organizations inject into the development process a host of considerations that have little or nothing to do with engineering. Any institution has its own goals and concerns, its own set of capabilities and weaknesses, and its own biases about the best ways to do things. Inevitably, the scientists and engineers inside an institution are influenced — often quite unconsciously — by its culture.

A closely related factor is the institutionalization of science and engineering. With their professional societies, conferences, journals, and other means of communion, scientists and engineers have formed themselves into relatively close-knit — though large — groups that have uniform standards of practice and hold similar ideas. Today, opinions and decisions about a technology tend to reflect a group's thinking more than any given individual's.

The existence of large organizations and the institutionalization of the professions allow a technology to build up a tremendous amount of momentum in a relatively short time.[5] Once the choice has been made to go a certain way, even if the reasons are not particularly good ones, the institutional machinery gears up and shoves everybody in the same direction. It can be tough to resist.

But the most important changes have come in the nature of technology itself. In the twentieth century, the power of our machines and devices has grown dramatically — along with their unanticipated consequences. When DDT was introduced, it seemed an unalloyed good: a cheap, effective way to kill insect pests and improve crop yields. It took years to understand that the pesticide made its way up the food chain to weaken the shells of birds' eggs and wreak other unintended havoc. Similarly, chlorofluorocarbons, or CFCs, were widely used for decades — as refrigerants, as blowing agents in making foams, and as cleaners for computer chips — before anyone realized they were damaging the ozone layer.

Even normally benign technologies can take on different complexions when multiplied to meet the needs of a world with five billion people. Burning natural gas is an economical, safe, and clean way to heat homes and generate electricity

Its only major waste material is carbon dioxide, the same gas that humans exhale with each breath. But carbon dioxide, in the quantities now being produced worldwide by burning fossil fuels (coal and oil as well as natural gas), is exaggerating the greenhouse effect in the earth's atmosphere and threatening major changes in the global climate.

Modern technology is like a Great Dane in a small apartment. It may be friendly, but you still want to make sure there's nothing breakable within reach. So to protect the china and crystal, government bodies, special interest groups, businesses, and even individuals are demanding an increasing say in how technologies are developed and applied.

Besides its power, modern technology has a second feature — more subtle, but equally important — that makes it qualitatively different from earlier technologies: its complexity. The plow, the cotton gin, even the light bulb — these are simple devices. No matter how much they are changed and improved, it is still easy to understand their functions and capabilities. But for better or worse, technology has reached the point where no individual can understand completely how, say, a petrochemical plant works, and no team of experts can anticipate every possible outcome once a technology is put to work. Such complexity fundamentally changes our relationship with technology.

Consider the accident that destroyed the space shuttle *Challenger*.[6] Although the cause was eventually established as the failure of O-rings at low temperatures, which allowed the escape of hot gases and led to an explosion of a fuel tank, the real culprit was the complexity of the system. Space-shuttle engineers had been concerned about how the O-rings would behave in below-freezing weather, and some even recommended the launch be postponed to a warmer day, but no one could predict with any certainty what might happen. There were too many variables, too many ways in which the components of the system could interact. Management decided to proceed with the launch despite the engineers' disquiet, and it was only months later that experts pieced together the chain of events that led to the explosion.

Complexity creates uncertainty, limiting what can be known or reasonably surmised about a technology ahead of time. Although the shuttle engineers had vague fears, they simply did not — could not — know enough about the system to foresee the looming disaster. And in such cases, when there is not a clear technical answer, people fall back on subjective, often unconscious reasoning — biases and gut feelings, organizational goals, political considerations, the profit motive. In the case of the *Challenger*, NASA was feeling pressure to keep its shuttles going into space on a regular basis, and no one in the organization wanted to postpone a launch unless it was absolutely necessary. In this case, it was, but no one knew.

For all these reasons, modern technology is not simply the rational product of scientists and engineers that it is often advertised to be. Look closely at any technology today, from aircraft to the Internet, and you'll find that it truly makes sense only when seen as part of the society in which it grew up.

The insight is not a particularly new one. Thoughtful engineers have discussed it for some time. As early as the 1960s, Alvin Weinberg, the longtime director of Oak Ridge National Laboratory, was writing on the relationship between technology and society, particularly in regard to nuclear power.[7] There have been others. But until recently no one had studied the influence of society on technology in any consistent, comprehensive way. Philosophically inclined engineers like Weinberg did not have the time, the temperament, or the training to make careful studies. They reported what they saw and mused about the larger implications, but nothing more. And social scientists, when they noticed technology at all, viewed it primarily in terms of how it shapes society. Sociologists, economists, and others have long seen technology as the driving force behind much of history — a theory usually referred to as "technological determinism"[8] — and they have happily investigated such things as how the invention of the printing press triggered the Reformation, how the development of the compass ushered in the Age of Exploration and the discovery of the New World, and how the cotton gin created the conditions that led to the Civil War.[9] But few of these scientists turned the question around and asked how society shapes technology.

In just the past decade or two, however, that has begun to change. Indeed, it has now become almost fashionable for economists, political scientists, and sociologists to bring their analytical tools to bear on various technologies, from nuclear power and commercial aviation to medical instruments, computers, even bicycles.[10] Part of the reason for this is, I suspect, the increasing importance of technology to our world, and another part is the realization by social scientists that science and technology are just as amenable to social analysis as politics or religion. Whatever the reason, the result has been to put technology in a whole new light. Scholars now talk about the push and pull between technology and society, rather than just the push of technology on society. Engineers have been brought down from the mountain to take their place as one — still very important — cog in the system by which technology is delivered to the world.

Unfortunately, very little of this has filtered down. It remains mostly specialists talking to other specialists in books and journals that few outside their fields ever see. [The book from which this chapter is taken] aims to change that. From its original design as a study of how engineers are creating a new generation of nuclear power, it has metamorphosed into a more general — and more ambitious — look at how nontechnical forces shape modern technologies. In it I collect and synthesize work from a wide variety of disciplines: history, economics, political science, sociology, risk analysis, management science, psychology. At various points, the book touches on personal computers, genetic engineering, jet aircraft, space flight, automobiles, chemical plants, even steam engines and typewriters. Such a book obviously cannot be comprehensive. Instead, my goal is to introduce a different way to think about technology and to show how many things make much more sense when technology is viewed in this way.

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Lurking just beneath the surface … is one of the most intriguing and frustrating questions of our time, although it seldom gets much attention outside universities and other scholarly places: How do we know what we know? Or, to put it differently, what is the nature of human knowledge? This may sound like the sort of abstract question that only a philosopher could love, but its answer has practical — and important — ramifications for how we deal with science and technology.

There are two schools of thought on the nature of human knowledge, and they have little common ground. One has its roots in the physical sciences and goes by such names as positivism or objectivism or rationalism. Positivism accepts as knowledge only those things that have been verified by the scientific method of hypothesis formation and testing. It is, of course, impossible to verify anything absolutely — no matter how many times the sun comes up right on schedule, there is no guarantee it won't be a couple of hours late tomorrow — but positivists are generally content with verifying something beyond a reasonable doubt. Karl Popper, the influential philosopher of science, put a slightly different spin on it: Scientific statements, he said, are those that can be put to the test and potentially proven wrong, or falsified. It's not possible to prove a hypothesis is true, but if the hypothesis is tested extensively and never proven false, then one accepts it as provisionally true. If it later turns out to be false in certain situations, it can be modified or replaced. By this method, one hopes to get better and better approximations to the world's underlying physical reality. Absolute knowledge is not attainable. This provisional knowledge is the best we can do.

The strength of positivism — its insistence on verification — is also its weakness, for there is much that people think of as "knowledge" that cannot be verified in the same way that theories in physics or biology can. "The United States is a capitalist country" is a statement most would accept as true, but how does one prove it? Or how about, "Santa Claus wears a red suit and rides in a sleigh pulled by eight reindeer"? This is clearly knowledge of a sort — everyone in our culture older than two or three "knows" it — and though it may not be in the same intellectual league as, say, the general theory of relativity, it's much more important to most people than anything Einstein came up with. Yet the positivist approach has no place for such folderol.

For many years, social scientists, impressed with the success of the physical sciences, modeled their methods along the same positivist lines. They made observations, formed hypotheses, and tested their theories, attempting to make their research as objective as possible. Many social scientists still do, but in the past few decades an influential new school of thought has appeared, one that offers a different take on human knowledge. This approach, often referred to as "social construction"[11] or "interpretation," is designed explicitly to deal with social reality — the web of relationships, institutions, and shared beliefs and meanings that exist in a group of people — instead of physical reality. It sees knowledge not as something gleaned from an underlying physical reality but as the collective product of a society. Social constructionists speak not of objective facts but only of interpretations of the world, and they set out to explain how those interpretations arise. They make no attempt to judge the truth or falsity of socially constructed knowledge. Indeed, they deny that it even makes sense to ask whether such knowledge is true or false.

Thus, positivism and social construction offer diametrically opposed views of knowledge. Positivists see knowledge as arising from nature; social constructionists see it as a product of the human mind. Positivists speak of proof, social constructionists of interpretation. Positivists assume knowledge to be objective; social constructionists believe it to be subjective. In general, positivists have been willing to defer to the social constructionists in the case of social knowledge. After all, information about Santa Claus or the importance of capitalism is not really what a positivist has in mind when he speaks about "knowledge." But the social constructionists have been unwilling to return the favor and so have triggered a sharp, if so far bloodless, battle.

All human knowledge is social knowledge, the social constructionists say, even science.[12] After all, scientific knowledge is created by groups of people — the scientific community and its various subsets — and so it inevitably has a collective character. There is no such thing as a scientific truth believed by one person and disbelieved by the rest of the scientific community; an idea becomes a truth only when a vast majority of scientists accept it without question. But if this is so, the argument goes, then science is best understood as socially constructed rather than derived in some objective way from nature.

The earliest and best-known example of this approach to science is Thomas Kuhn's *The Structure of Scientific Revolutions.*[13] In it, Kuhn depicts most science as taking place inside a "paradigm" — a set of beliefs and expectations that guide the research, defining which questions are important and designating the proper ways to go about answering them. Scientific revolutions — such as the shift from the Ptolemaic to the Copernican view of the universe — occur when a paradigm breaks down and the scientific community collectively settles on a new paradigm in which to work. Kuhn argued that because such a paradigm shift is a change of the rules by which science is done, there can be no objective reasons for making the shift or for deciding on one paradigm over another. The choice is a subjective one. Ironically, much of the positivist scientific community has accepted the general idea of paradigms without understanding the deeper implications of Kuhn's work. It's not unusual to hear a scientist speak of "working within a paradigm" even though that scientist would be appalled by Kuhn's claim that scientific paradigms have no objective basis.

Today, many social scientists agree with Kuhn that the positivist claims for science were a myth. For example, in 1987 the sociologists Trevor Pinch and Wiebe Bijker wrote:

> [T]here is widespread agreement that scientific knowledge can be, and indeed has been, shown to be thoroughly socially constructed.... The treatment of scientific knowledge as a social construction implies that there is nothing epistemologically special about the nature of scientific knowledge: It is merely one in a whole series of knowledge cultures (including for instance, the knowledge systems pertaining to "primitive" tribes). Of course, the successes and failures of certain knowledge cultures still need to be explained, but this is to be seen as a sociological task, not an epistemological one.[14]

Such comments anger many scientists. Physicists especially dispute the conclusions of the social constructionists.[15,16] Yes, they admit, of course the creation of scientific knowledge is a joint effort, but nonetheless it *is* epistemologically special. Quantum mechanics, for instance, provides predictions that are consistently accurate to a dozen or more decimal places. This is no accident, they insist, but instead reflects the fact that science is uncovering and explaining some objective reality.

On the whole, the physicists get the better of this particular argument. Social construction theory is useful in explaining social knowledge and belief, but it does little to explain why physicists accept general relativity or quantum mechanics as accurate portrayals of physical reality. Social constructionists like Pinch and Bijker ignore a key difference between science and other knowledge cultures: science's insistence that its statements be falsifiable.[17] As long as science restricts itself in this way and continues testing its theories and discarding those that disagree with experiments, it is indeed epistemologically special. This and nothing else explains why science has been so much more successful than other knowledge cultures. Science may not be as objective as the positivists would like to believe, but the positivist approach comes closer than any other to capturing the essence of science.

This all may seem to be a tempest in an academic teapot, a question of interest to no one besides philosophers and the handful of scientists with an interest in epistemology, but it underlies many of the debates on scientific issues that affect the public. Consider the controversy in the mid-1980s over the use of recombinant bovine growth hormone in dairy cattle. Although the scientific community pronounced it safe, opponents of its use suggested that the researchers were influenced more by the sources of funding for their research and by their own inherent biases than by evidence.[18] This argument depended implicitly upon the assumption that the scientific opinions were not objective but rather were socially constructed. In general, if science is accepted as objective, people will give a great deal of weight to the conclusions of the scientific community and to the professional opinions of individual scientists. But if science is seen as a social construct, vulnerable to biases and fashion, people will question or even dismiss its conclusions.

Which brings us back to our original subject. At its heart, [the book from which this chapter was taken is] about technological knowledge: What is it? and, How is it formed? Traditionally, engineers have seen their work in positivist terms. Like scientists, they take it for granted that their work is objective, and they believe that to understand a technology, all one needs are the technical details. They see a strict dichotomy between the pure logic of their machines and the subjectivity and the irrationality of the world in which they must operate. On the other hand, a growing school of social scientists sees technology as socially constructed. Its objectivity, they say, is a myth created and propagated by engineers who believe their own press. As with science, this is no mere academic debate. Our attitudes toward technology hinge, in large part, on what we believe about the nature of the knowledge underlying it.

To understand technological knowledge, this book argues, it is necessary to marry the positivist and the social constructionist perspectives. Technology combines the physical world with the social, the objective with the subjective, the machine with the man. If one imagines a spectrum with scientific knowledge on one end and social knowledge on the other, technological knowledge lies somewhere in the middle. It is falsifiable to a certain extent, but not nearly to the same degree as science. Conversely, much of technological knowledge is socially constructed, but there are limits — no matter what a group of people thinks or does, an airplane design that can't fly won't fly. In short, the physical world restricts technology. Some things work better than others, some don't work at all, and this leads to a certain amount of objectivity in technological knowledge. But, unlike scientists, engineers are working with a world of their own creation, and the act of creation cannot be understood in positivist terms.

Ultimately, any understanding of technological knowledge must recognize the composite nature of that knowledge. Our technological creations carry with them the traces of both the engineer and the larger society.

ENDNOTES

1. Charles McLaughlin, "The Stanley Steamer: A Study in Unsuccessful Innovation," *Explorations in Entrepreneurial History* 7 (October 1954), pp. 37–47.
2. Henry Petroski, *The Pencil* (New York: Alfred A. Knopf, 1989), p. 207.
3. Merritt Roe Smith, "Technological Determinism in American Culture," in Merritt Roe Smith and Leo Marx, eds., *Does Technology Drive History?* (Cambridge, MA: MIT Press, 1994), pp. 1–35.
4. Ronald Inglehart, *The Silent Revolution: Changing Values and Policy Styles among Western Publics* (Princeton, NJ: Princeton University Press, 1977), p. 3.
5. Thomas P. Hughes, "Technological History and Technical Problems," in Chauncey Starr and Philip C. Ritterbush, eds., *Science, Technology and the Human Prospect* (New York: Pergamon, 1980), p. 141.
6. Maureen Hogan Casamayou, *Bureaucracy in Crisis: Three Mile Island, the Shuttle Challenger and Risk Assessment* (Boulder, CO: Westview, 1993), pp. 57–85.
7. Alvin M. Weinberg, *Nuclear Reactions: Science and Trans-Science* (New York: American Institute of Physics, 1992). See also Alvin M. Weinberg, *The First Nuclear Era: The Life and Times of a Technological Fixer* (New York: American Institute of Physics, 1994).
8. For a critical review of technological determinism, see Merritt Roe Smith and Leo Marx, eds., *Does Technology Drive History?* (Cambridge, MA: MIT Press, 1994).
9. Leo Marx and Merritt Roe Smith, introduction to Marx and Smith, *Does Technology Drive History?* p. x.
10. There have been a number of books published recently that analyze technology from a social science perspective. They include Wiebe E. Bijker, Thomas P. Hughes, and Trevor Pinch, eds., *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology* (Cambridge, MA: MIT Press, 1987); Marcel C. LaFollette and Jeffrey K. Stine, eds., *Technology and Choice: Readings from Technology and Culture* (Chicago: University of Chicago Press, 1991);

Meinolf Dierkes and Ute Hoffmann, eds., *New Technology at the Outset: Social Forces in the Shaping of Technological Innovations* (Boulder, CO: Westview, 1992); Wiebe Bijker and John Law, eds., *Shaping Technology/Building Society: Studies in Sociotechnical Change* (Cambridge, MA: MIT Press, 1992); Wiebe E. Bijker, *Of Bicycles, Bakelites, and Bulbs: Toward a Theory of Sociotechnical Change* (Cambridge, MA: MIT Press, 1995). See also various issues of *Technology and Culture; Technology in Society; Science, Technology & Human Values*; and *Technology Review*.

11. The seminal work here is Peter L. Berger and Thomas Luckmann, *The Social Construction of Reality: A Treatise in the Sociology of Knowledge* (New York: Doubleday, 1966).
12. A good summary of the social constructionist approach to scientific knowledge can be found in Trevor J. Pinch and Wiebe E. Bijker, "The Social Construction of Facts and Artifacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other," in Bijker, Hughes, and Pinch, *The Social Construction of Technological Systems*, pp. 17–50.
13. Thomas S. Kuhn, *The Structure of Scientific Revolutions* (Chicago: University of Chicago Press, 1962).
14. Pinch and Bijker, "The Social Construction of Facts and Artifacts," pp. 18–19.
15. David Mermin, a very thoughtful physicist at Cornell University, offers a careful refutation of the social construction of physics in a two-part article: "What's Wrong with the Sustaining Myth?" *Physics Today* 49 (March 1996), pp. 11, 13; and "The Golemization of Relativity," *Physics Today* 49 (April 1996), pp. 11, 13.
16. In spring 1996, the dispute between physicists and social constructionists took an amusing turn — amusing, at least, for the physicists — when Alan Sokal published an article entitled "Transgressing the Boundaries: Toward a Transformative Hermeneutics of Quantum Gravity" in *Social Text*, a "postmodernist" journal devoted to social constructionist analyses. Sokal, a physicist at New York University, later revealed that it was all a hoax. He had cobbled together bad science, even worse logic, and a bunch of catch phrases from postmodernist theorizing and had somehow convinced the editors of *Social Text* that the nonsensical article was a contribution worthy of publication. The editors were understandably not amused but neither were they contrite. They did not seem to see it as a weakness on their part — or even less, on the part of the entire postmodernist movement — that they could not tell the difference between an obvious hoax and what passes for serious work in their field. The original article appeared in *Social Text* 46/47 (Spring/Summer 1996), pp. 217–252. Sokal revealed the hoax in "A Physicist Experiments with Cultural Studies," *Lingua Franca* (May/June 1996), pp. 62–64.
17. This argument is modified from one offered by Thelma Lavine, Clarence J. Robinson Professor of Philosophy at George Mason University in Fairfax, Virginia.
18. W. P. Norton, "Just Say Moo," *The Progressive* (November 1989), pp. 26–29. See also Gina Kolata, "When the Geneticists' Fingers Get in the Food," *New York Times* (February 20, 1994), sec. 4, p. 14.

3

The Shock of the Old

DAVID EDGERTON

The words "new" and "technology" seem to go together. We speak of "technological change," "technological innovation," and "technological revolutions." But what of old, commonplace technologies? Do they just disappear in the face of the new ones? David Edgerton contends that they remain with us and, although we tend to overlook them or take them for granted, in a global perspective they can be more important than those that supposedly take their place.

The focus on the new can blind us to the pervasiveness of the old. Edgerton calls on us to view technology not just as the latest inventions but in terms of what people — ordinary people around the world — actually use. Seen in that light, relatively simple and mundane technologies — for example, corrugated iron — take on much more importance than we recognize. Spread around the world by the military during the days of the British Empire, "Its cheapness, lightness, ease of use and long life made it a ubiquitous material in the poor world in a way it never had been in the rich world." Edgerton considers corrugated iron as it is used in developing countries, and other cheap building materials such as asbestos cement, to be "creole" technologies — hybrids resulting from local adaptations, especially in poor countries, of technologies imported from rich ones. Such a use-centered approach places the relations of technology and society in an entirely new perspective.

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Much of what is written on the history of technology is for boys of all ages. [The book from which this chapter is drawn] is a history for grown-ups of all genders. We have lived with technology for a long time, and collectively we know a lot about it. From economists to ecologists, from antiquarians to historians, people have had different views about the material world around us and how it has changed. Yet too often the agenda for discussing the past, present and future of technology is set by the promoters of new technologies.

When we are told about technology from on high we are made to think about novelty and the future. For many decades now the term 'technology' has been closely linked with *invention* (the creation of a new idea) and *innovation* (the first use of a new idea). Talk about technology centres on research and development, patents and the early stages of use, for which the term *diffusion* is used. The timelines of technological history, and they abound, are based on dates of invention and innovation. The most significant twentieth-century technologies are often reduced to the following: flight (1903), nuclear power (1945), contraception (1955), and the internet (1965). We are told that change is taking place at an ever-accelerating pace, and that the new is increasingly powerful. The world, the gurus insist, is entering a new historical epoch as a result of technology. In the new economy, in new times, in our post-industrial and post-modern condition, knowledge of the present and past is supposedly ever less relevant. Inventors, even in these post-modern times, are 'ahead of their time', while societies suffer from the grip of the past, resulting in a supposed slowness to adapt to new technology.

There are new things under the sun, and the world is indeed changing radically, but this way of thinking is not among them. Although the emphasis on the future itself suggests originality, this kind of futurology has been with us a long time. In the nineteenth century the idea that inventors were ahead of their time and that science and technology were advancing faster than the ability of human society to cope was a commonplace. By the early twentieth century this notion was made academically respectable with the label 'the cultural lag'. In the 1950s and even later, one could claim without embarrassment that scientists 'had the future in their bones'. By the end of the twentieth century, futurism had long been *passé*. The technological future was as it had been for a long time. Intellectuals claimed there was a new kind of future, one prefigured by 'post-modern' architecture. Yet this new kind of future was to be brought about by an old-style technological or industrial revolution which would change everything.

In the case of technology reheated futurism has held its appeal long after it was declared obsolete. The technological future marched on as before. Consider the case of the first successful flight of NASA's X-43A space aeroplane on 27 March 2004. Although it lasted all of ten seconds, it made the news the world over. 'From Kitty Hawk to the X-43A has been a century's steady advance', wrote one newspaper; from 'seven miles an hour to Mach Seven is a striking indication of how far powered flight has travelled in a hundred years'.[1] Soon we would be enjoying, yet again, almost instant travel to Australia from London.

Just below the surface was another history, which blew great holes in this old-fashioned story. Every few weeks between 1959 and 1968 B-52 aircraft took off from Edwards Air Force Base in California, with one of three X-15s under their wings. Once high up the X-15s fired their rocket engines and were actively flown by twelve 'research pilots', clad in silver pressurised space suits, reaching speeds of Mach 6.7 and touching the edge of space. These hard-drinking engineer-pilots, mostly combat veterans (among them Neil Armstrong, the first man to set foot on the moon), looked down on mere 'spam in the can' astronauts, as Tom Wolfe observed in *The Right Stuff*. While the astronauts became famous, the elite X-15 pilots were left to lament, as one did, that in the early 1990s he was still 'one of the fastest airplane pilots in the world. I am too old for that. Someone younger should have that honor.'[2] Past and present were connected even more directly. The B-52, which took the X-43A and its booster rocket up, was one of the same B-52s used on the X-15 programmes and was now the oldest flying B-52 in the world.[3] It was built in the 1950s. Not only that, but the key technology of the X-43A was the scramjet, a supersonic version of the ramjet. A technique decades old, it was used in a 1950s-designed British anti-aircraft missile, the Bloodhound, which was itself in service into the 1990s. In short, the story might well have been '1950s aeroplane launches unmanned ramjet plane which flies a little faster than 1960s Right Stuff pilots'.

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By thinking about the history of technology-in-use a radically different picture of technology, and indeed of invention and innovation, becomes possible.[4] A whole invisible world of technologies appears. It leads to a rethinking of our notion of technological time, mapped as it is on innovation-based timelines. Even more importantly it alters our picture of which have been the most important technologies. It yields a global history, whereas an innovation-centred one, for all its claims to universality, is based on a very few places. It will give us a history which does not fit the usual schemes of modernity, one which refutes some important assumptions of innovation-centric accounts.

The new history will be surprisingly different. For example, steam power, held to be characteristic of the industrial revolution, was not only absolutely but relatively more important in 1900 than in 1800. Even in Britain, the lead country of the industrial revolution, it continued to grow in absolute importance after that. Britain consumed much more coal in the 1950s than in the 1850s. The world consumed more coal in 2000 than in 1950 or 1900. It has more motor cars, aeroplanes, wooden furniture and cotton textiles than ever before. The tonnage of world shipping continues to increase. We still have buses, trains, radio, television and the cinema, and consume ever-increasing quantities of paper, cement and steel. The production of books continues to increase. Even the key novel technology of the late twentieth century, the electronic computer, has been around for many decades. The post-modern world has forty-year-old nuclear power stations as well as fifty-year old bombers. It has more than a dash of technological retro about it too: it has new ocean-going passenger ships, organic food and classical music played on 'authentic' instruments. Aging, and even dead, rock stars of the 1960s still generate large sales, and children are brought up with Disney films seen by their grandparents when they were children.

Use-centred history is not simply a matter of moving technological time forward. As Bruno Latour has aptly noted, modern time, where this behaved as moderns believed, has never existed. Time was always jumbled up, in the pre-modern era, the post-modern era and the modern era. We worked with old and new things, with hammers and electric drills.[5] In use-centred history technologies do not only appear, they also disappear and reappear, and mix and match across the centuries. Since the late 1960s many more bicycles were produced globally each year than cars.[6] The guillotine made a gruesome return in the 1940s. Cable TV declined in the 1950s to reappear in the 1980s. The supposedly obsolete battleship saw more action in the Second World War than in the First. Furthermore, the twentieth century has seen cases of technological regression.

A use-based history will do much more than disturb our tidy timelines of progress. What we take to be the most significant technologies will change. Our accounts of significance have been peculiarly innovation-centric, and tied to particular accounts of modernity where particular new technologies were held to be central. In the new picture, twentieth-century technology is not just a matter of electricity, mass production, aerospace, nuclear power, the internet and the contraceptive pill. It will involve the rickshaw, the condom, the horse, the sewing machine, the spinning wheel, the Haber-Bosch process, the hydrogenation of coal, cemented-carbide tools, bicycles, corrugated iron, cement, asbestos, DDT, the chain saw and the refrigerator. The horse made a greater contribution to Nazi conquest than the V2.

A central feature of use-based history, and a new history of invention, is that alternatives exist for nearly all technologies: there are multiple military technologies, means of generating electricity, powering a motor car, storing and manipulating information, cutting metal or roofing a building. Too often histories are written as if no alternative could or did exist.

One particularly important feature of use-based history of technology is that it can be genuinely global. It includes all places that use technology, not just the small number of places where invention and innovation is concentrated. In the innovation-centric account, most places have no history of technology. In use-centred accounts, nearly everywhere does. It gives us a history of technology engaged with all the world's population, which is mostly poor, non-white and half female. A use-perspective points to the significance of novel technological worlds which have emerged in the twentieth century and which have hitherto had no place in histories of technology. Among them are the new technologies of poverty. They are missed because the poor world is thought of as having traditional local technologies, a *lack* of rich-world technologies, and/or has been subject to imperial technological violence. When we think of cities we should think of *bidonvilles* as well as Alphaville; we should think not just about the planned cities of Le Corbusier, but the unplanned shanty towns, built not by great contractors, but by millions of self-builders over many years. These are worlds of what I call 'creole' technologies, technologies transplanted from their place of origin finding uses on a greater scale elsewhere.

A consequence of the new approach is that we shift attention from the new to the old, the big to the small, the spectacular to the mundane, the masculine to the feminine, the rich to the poor. But at its core is a rethinking of the history of all technology, including the big, spectacular, masculine high technologies of the rich white world. For all the critiques, we do not in fact have a coherent productionist, masculine, materialist account of technology and history in the twentieth century. We have big questions, and big issues to address, which are surprisingly open.

A use-centred account also refutes some well-established conclusions of innovation-centric history. For example, it undermines the assumption that national innovation determines national success; the most innovative nations of the twentieth century have not been the fastest growing. Perhaps the most surprising criticism that arises from the use perspective is that innovation-centric history gives us an inadequate account of invention and innovation. Innovation-centric history focuses on the early history of some technologies which became important later. The history of invention and innovation needs to focus on all inventions and innovations at a particular time, independently of their later success or failure. It needs to look too to invention and innovation in all technologies, not just those favoured by being well known and assumed to be the most significant. Traditional innovation-centric histories have space for Bill Gates, but a history of invention and innovation would also include Ingvar Kamprad, who made his money from mass-producing and selling wooden furniture. He founded IKEA and is, some think, richer than Gates. More importantly, our histories need to have a place for the majority of failed inventions and innovations. Most inventions are never used; many innovations fail.

The innovation-centric view also misleads us as to the nature of scientists and engineers. It presents them, as they present themselves, as creators, designers, researchers. Yet the majority have always been mainly concerned with the operation and maintenance of things and processes; with the uses of things, not their invention or development.

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Given the importance of innovation-centric futurism in discussing technology, history can be an especially powerful tool for rethinking technology. History reveals that technological futurism is largely unchanging over time. Present visions of the future display a startling, unselfconscious lack of originality. Take the extraordinary litany of technologies which promised peace to the world. Communications technologies, from railways and steamships, to radio and the aeroplane, and now the internet, seemed to make the world smaller and bring people together, ensuring a perpetual peace. Technologies of destruction, such as the great ironclad battleships, Nobel's explosives, the bomber aircraft and the atomic bomb were so powerful that they too would force the world to make peace. New technologies of many sorts would emancipate the downtrodden. The old class system would wither under the meritocracy demanded by new technology; racial minorities would gain new opportunities — as chauffeurs in the motor age, pilots in the air age, and computer experts in the information age. Women were to be liberated by new domestic technologies, from the vacuum cleaner to the washing machine. The differences between nations would evaporate as technology overcame borders. Political systems too would converge as technology, inevitably, became the same everywhere. The socialist and capitalist worlds would become one.

In order to be at all convincing these arguments had to deny their own history, and they did so to a remarkable extent. The obliteration of even recent history has been continuous and systematic. For example, in the middle of 1945 the bomber ceased to be a peace-creating technology; the atomic bomb took its place. When we think of information technology we forget about postal systems, the telegraph, the telephone, radio and television. When we celebrate on-line shopping, the mail-order catalogue goes missing. Genetic engineering, and its positive and negative impacts, is discussed as if there had never been any other means of changing animals or plants, let alone other means of increasing food supply. A history of how things were done in the past, and of the way past futurology has worked, will undermine most contemporary claims to novelty.

We need to be aware that this futurology of the past has affected our history. From it we get our focus on invention and innovation, and on the technologies which we take to be the most important. From this literature, the work of low and middle-ranking intellectuals and propagandists, ranging from, say, the books of H. G. Wells to the press releases of NASA's PR officials, we get a whole series of clichéd claims about technology and history. We should take them, not as well-grounded contributions to our understanding, for they rarely are that, but as the basis of questions. What have been the most significant technologies of the twentieth century? Has the world become a global village? Has culture lagged behind technology? Has technology had revolutionary or conservative social and political effects? Has new technology been responsible for the dramatic increase in economic output in the last hundred years? Has technology transformed war? Has the rate of technical change been ever increasing? These are … questions … [that] cannot be answered within the innovation-centric frame in which they are usually asked.

These questions become much easier to answer if we stop thinking about 'technology', but instead think of 'things'. Thinking about the use of things, rather than of technology, connects us directly with the world we know rather than the strange world in which 'technology' lives. We speak of 'our' technology, meaning the technology of an age or a whole society. By contrast 'things' fit into no such totality, and do not evoke what is often taken as an independent historical force. We discuss the world of things as grown-ups, but technology as children. For example, we all know that while the use of things is widely distributed through societies, ultimate control of things and their use has been highly concentrated, within societies and between societies. Ownership, and other forms of authority, on the one hand, and use on the other, have been radically separated. Most people in the world live in houses that do not belong to them, work in workplaces belonging to others, with tools that belong to others, and indeed many of the things they apparently own are often tied to credit agreements. Within societies, states and/or small groups have had disproportionate control; some societies have much more stuff than others. In many places of the world much is owned by foreigners. Things belong to particular people in ways which technology does not.

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We have long been told that we live with an 'ever-increasing rate of change', yet there is good evidence that it is not always increasing. Measuring change is extremely difficult, but let us start with economic growth in the rich countries as a crude measure. While there was rapid growth before the Great War, there was slower growth overall between 1913 and 1950. There was spectacular growth in the long boom, followed by less strong growth since. In other words, growth rates were lower in the interwar years than before 1914, and average rates of economic growth after 1973 were considerably lower than in the period 1950–1973. In the 1970s there was a 'productivity slowdown' and since then the rich world has continued to grow, but not at historically unprecedented rates.

Since the 1980s one could be forgiven for believing that high growth rates had returned, not least because of the constant evocations of the notion of 'ever increasing change', and all the talk of fundamental transitions to new economies and new times. But in the USA, Japan, the EU and Britain, growth rates were lower in the 1990s than in the 1980s, lower in the 1980s than in the 1970s and lower in the 1970s than in the 1960s.[7] In the USA it appears that productivity growth increased in the late 1990s, but there is still a dispute as to whether this was general, or concentrated in the computer-manufacturing sector.[8] Growth is not the same as change but there is no evidence that structural change in the rich countries was any faster in recent decades than in the long boom. Once again, our future-oriented rhetoric has underestimated the past, and overestimated the power of the present.

Not all parts of the world grew at these same rhythms. For example the USSR grew very fast in the 1930s, while the rest of the world did not. Especially since the 1970s many economies in the Far East have grown very fast, but from a low base. The increasing scale of the Chinese economy in particular has meant that its growth has been enough to alter the global statistics materially. For example, global steel production is growing at long boom rates again thanks to China.

Another important feature of change in the last three decades is that there has been a decline of economies, as well as growth. In some places the last years of the twentieth century saw retrogression. The income per head of the 700 million sub-Saharan Africans fell from $700 per head in 1980 to the even more miserable $500 at the end of the century; to make matters worse for the majority, 45 per cent of this output was produced in South Africa so the real fall elsewhere was even worse.[9] Malaria has become more common, and new diseases such a HIV/AIDS have swept through the continent as no other. Yet this is not a reversion to an old world, for this is a continent with cars and new kinds of shanty towns, a rapidly urbanising world without what is taken to be modern industry.

From 1989 there was a remarkably rapid collapse in the economies of the Soviet Union and its former satellites, of 20, 30 and 40 per cent, far outstripping the capitalist recession of the early 1980s. Although this dramatic fall in output cannot be characterised generally as a technological retrogression such a phenomenon was evident in some places. Now independent Moldova, formerly part of the USSR, lost 60 per cent of its output. Machines virtually phased out as the economy had developed since the Second World War, things such as 'spinning wheels, weaving looms, butter churns, wooden grape presses and stone bread ovens — are now back in use', it was reported in 2001. The 'only way to survive is to be totally self-sufficient,' claimed the curator of the ethnological museum in Belsama, 'and that means turning the clock back.'[10] Cuba, as we have seen, expanded the number of its oxen as it lost its supply of tractors.

In some industries, such as shipbreaking, there has been a move towards a new kind of low-tech future. By the 1980s Taiwan had become by far the largest shipbreaker, demolishing more than a third of the world's ships. By the early 1990s it was out of this industry, now dominated by India, Pakistan and Bangladesh, which between them had more than 80 per cent of the world market by 1995.[11] Taiwan used specialised dock facilities, but the new shipbreaking was on beaches, with the most minimal equipment, carried out by thousands of barefoot workers. The reason shipbreaking was done in these places was that scrap steel was in demand locally. But it is used in a markedly different way from other places and times: it is re-rolled, re-worked, rather than used to make fresh steel.

What seems at first technological retrogression was perhaps not unknown in earlier years of the century. No one had ever attempted to build such a large canal with what were then such primitive means as were used on the White Sea canal or in the erection of the great steel works of Magnitogorsk. Collective farming itself involved technological retrogression, for all the emphasis on the tractor. However, not for many centuries has a global industry retrogressed like shipbreaking has.

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This [chapter] has argued for the importance of the seemingly old. It is also a plea for a novel way of looking at the technological world, one which will change our minds about what that world has been like. And implicit in it is a plea for novel ways of thinking about the technological present.

We should be aware, for example, that most change is taking place by the transfer of techniques from place to place. The scope for such change is enormous given the level of inequalities that exist with respect to technology. Even among rich countries there are very important differences in, for example, carbon intensity. If the USA were to reduce its energy-use levels to those of Japan, the impact on total energy use would be very significant. But for poor countries, as well as for rich ones, such a message is often unwelcome. For *imitating* is seen as a much less worthy activity than innovating. To imitate, to replicate, is to deny one's creativity, to impose upon oneself what was designed for others by others. '*Que inventen ellos*' ('Let *them* invent') is seen not as sensible policy advice, but a recipe for national humiliation. To have technology or science is, it is often deeply felt, to create something new. The answer to such concerns that is implicit in this book is that all countries, firms, individuals, with rare and unusual exceptions, have relied on others to invent, and have imitated more than they have invented.

Arguments about imitating policies and practices for innovation might seem to fall in the same category. That is to say, that it might seem like a good thing that they should be the same or similar around the world. Indeed there is a remarkable lack of originality in innovation policies globally, and many explicit calls for copying those perceived as the most successful models. Yet while copying existing technology is very sensible, imitating innovation policies may be a mistake. For if all nations, areas and firms are agreed about what the research should be, by definition it will no longer be innovative; and it might not be a good thing that all nations pursue the same policies for research, because they are likely to come up with similar inventions only a few of which will be used even if technologically successful. 'If I knew the future of jazz I'd be there already,' said one wise musician.

Calling for innovation is, paradoxically, a common way of avoiding change when change is not wanted. The argument that future science and technology will deal with global warming is an instance. It is implicitly arguing that in today's world only what we have is possible. Yet we have the technological capacity to do things very differently: we are not technologically determined.

Getting away, as [the book from which this chapter is drawn] has, from the conflation of use and invention/innovation will in itself have a major impact on our thinking about novelty generation. The twentieth century was awash with inventions and innovations, so that most had to fail. Recognising this will have a liberating effect. We need no longer worry about being resistant to innovation, or being behind the times, when we chose not to take up an invention. Living in an inventive age requires us to reject the majority that are on offer. We are free to oppose technologies we do not like, however much interested pundits and governments tell us it is essential to accept, say, GM crops. There are alternative technologies, alternative paths of invention. The history of invention is not the history of a necessary future to which we must adapt or die, but rather of failed futures, and of futures firmly fixed in the past.

We should feel free to research, develop, innovate, even in areas which are considered out of date by those stuck in passé futuristic ways of thinking. Most inventions will continue to fail, the future will remain uncertain. Indeed the key problem in research policy should be ensuring that there are many more good ideas, and thus many more failed ideas. Stopping projects at the right time is the key to a successful invention and innovation policy, but doing this means being critical of the hype that surrounds, and often justifies and promotes funding for invention.

Although we can stop projects, it is often said that we cannot un-invent technologies, usually meaning that we cannot get rid of them. The idea is itself an example of the conflation of invention and technology. For most inventions are effectively un-invented, in being forgotten and often lost. A few things are going out of use as the world economy grows — among them are asbestos, declining since the 1970s, and refrigerants like CFC gases. And one of the new tasks faced by scientists and engineers is actively making old technologies disappear, some of which, like nuclear power stations, are extremely difficult to dispose of.

Thinking about the technological past can give us insights into 'the question of technology' — what is it, where does it come from, what does it do? But this book has attempted to do much more than take historical examples to address this perennially interesting question. It has been concerned primarily with asking questions not about technology, but about technology in history — asking questions about the place of technology within wider historical processes. This important distinction is not obvious, but it is central to a proper historical understanding of technology. It will help wean us off the idea that invention, 'technological change' and the 'shaping of technology' need to be the central question for the history of technology. Instead the history of technology can be much more; and it can help us rethink history.

If we are interested in the historical relations between technology and society we need a new account not only of the technology we have used but also of the society we have lived in. For existing histories of twentieth-century technology were embedded in particular assumptions about world history, while world histories had embedded in them particular assumptions about the nature of technological change and its impact — each was already defined, usually implicitly, in relation to the other. Hence the history of the society into which this new account is placed is very different from the one usually found: for example, it takes as central the expansion of a new kind of poor world, a world which has been almost continuously at war, and in which millions have been killed and tortured. This necessitates an account of the global technological landscape that is very different from those found implicitly and explicitly in existing global histories and histories of technology — and an account that might help revise our views about world history.

It is a measure of the importance of technology to the twentieth century, and to our understanding of it, that to rethink the history of technology is necessarily to rethink the history of the world. For example, we should no longer assume that there was ineluctable globalisation thanks to new technology; on the contrary the world went through a process of de-globalisation in which technologies of self-sufficiency and empire had a powerful role. Culture has not lagged behind technology, rather the reverse; the idea that culture has lagged behind technology is itself very old and has existed under many different technological regimes. Technology has not generally been a revolutionary force; it has been responsible for keeping things the same as much as changing them. The place of technology in the undoubted increase in productivity in the twentieth century remains mysterious; but we are not entering a weightless, dematerialised information world. War changed in the twentieth century, but not according to the rhythms of conventional technological timelines.

History is changed when we put into it the technology that counts: not only the famous spectacular technologies but the low and ubiquitous ones. The historical study of things in use, and the uses of things, matters.

ENDNOTES

1. Michael McCarthy, 'Second Century of Powered Flight is heralded by jet's 5,000mph record', *Independent*, 29 March 2004, pp. 14–15.
2. Milton O. Thompson, *At the Edge of Space: the X-15 Flight Program* (Washington: Smithsonian Institution Press, 1992).
3. *http://www.nasa.gov/missions/research/X-43_overview.html* (opened 29 March 2004).
4. See David Edgerton, 'De l'innovation aux usages. Dix thèses éclectiques sur l'histoire des techniques', *Annales HSS*, July–October 1998, Nos. 4–5, pp. 815–37; Svante Lindqvist, 'Changes in the Technological Landscape: the temporal dimension

in the growth and decline of large technological systems', in Ove Granstrand (ed.), *Economics of Technology* (Amsterdam: North Holland, 1994), pp. 271–88. This approach needs to be distinguished from the longstanding interest in the influence of users on invention and innovation, as seen in, for example, Ruth Schwartz Cowan, 'The consumption junction: a proposal for research strategies in the sociology of technology', in W. Bijker et al., *The Social Construction of Technological Systems* (Cambridge, MA: MIT Press, 1987), Ruth Oldenzeil, 'Man the Maker, Woman the Consumer: The Consumption Junction Revisited' in Londa Schiebinger et al., *Feminism in the Twentieth Century. Science, Technology and Medicine* (Chicago: Chicago University Press, 2001); and Nelly Oudshoorn and Trevor Pinch (eds.), *How Users Matter: the Co-construction of Users and Technology* (Cambridge, MA: MIT Press, 2003).

5. Bruno Latour, *We Have Never Been Modern* (New York: Harvester Wheatsheaf, 1993), pp. 72–6.
6. Lester Brown et al., *Vital Signs* (London: Earthscan, 1993), pp. 86–9.
7. John B. Harms and Tim Knapp, 'The New Economy: what's new, what's not', *Review of Radical Political Economics*, Vol. 35 (2003), pp. 413–36.
8. P. A. David, 'Computer and Dynamo: the Modern Productivity Paradox in a not-too-distant mirror', in OECD, *Technology and Productivity: the Challenge for Economic Policy* (Paris: OECD, 1991).
9. *Economist*, 17 January 2004.
10. *Observer*, 8 April 2001.
11. Martin Stopford, *Maritime Economics*, second edition (London: Routledge, 1997), pp. 485–6.

4

Can Technology Replace Social Engineering?

ALVIN M. WEINBERG

Since Alvin Weinberg's essay "Can Technology Replace Social Engineering?" was first published in the mid-1960s, it has become a classic in the literature of technology and society. Indeed, the term technological fix, *introduced here, has become part of the lexicon of the field. Weinberg, one of the pioneers of large-scale atomic energy research and development and an inveterate technological optimist, argues that technology is capable of finding shortcuts (technological fixes) to the solution of social problems. For example, faced with a shortage of fresh water, he suggests, society can try either social engineering — altering lifestyles and the ways people use water — or a technological fix, such as the provision of additional fresh water through nuclear-powered desalting of seawater. The reader should keep in mind that this article dates from 1966. Although aspects are anachronistic and out of tune with contemporary views of technology, society, and politics, the questions it raises are as relevant today as they were more than forty years ago.*

Alvin M. Weinberg was a physicist who joined the World War II Manhattan Project early in his career. He went to Oak Ridge National Laboratory in 1945 and served as its director from 1955 through 1973. Weinberg was a member of the President's Science Advisory Committee in 1960–1962 and was the recipient of many awards, including the President's Medal of Science and the Enrico Fermi Award. He was born in Chicago in 1915 and received A.B., A.M., and Ph.D. degrees from the University of Chicago. Weinberg died in 2006.

During World War II, and immediately afterward, our federal government mobilized its scientific and technical resources, such as the Oak Ridge

Alvin M. Weinberg, "Can Technology Replace Social Engineering?" Reprinted by permission.

National Laboratory, around great technological problems. Nuclear reactors, nuclear weapons, radar, and space are some of the miraculous new technologies that have been created by this mobilization of federal effort. In the past few years [i.e., the early 1960s], there has been a major change in focus of much of our federal research. Instead of being preoccupied with technology, our government is now mobilizing around problems that are largely social. We are beginning to ask what can we do about world population, about the deterioration of our environment, about our educational system, our decaying cities, race relations, poverty. Recent administrations have dedicated the power of a scientifically oriented federal apparatus to finding solutions for these complex social problems.

Social problems are much more complex than are technological problems. It is much harder to identify a social problem than a technological problem: How do we know when our cities need renewing, or when our population is too big, or when our modes of transportation have broken down? The problems are, in a way, harder to identify just because their solutions are never clear-cut: How do we know when our cities are renewed, or our air clean enough, or our transportation convenient enough? By contrast, the availability of a crisp and beautiful technological solution often helps focus on the problem to which the new technology is the solution. I doubt that we would have been nearly as concerned with an eventual shortage of energy as we now are if we had not had a neat solution — nuclear energy — available to eliminate the shortage.

There is a more basic sense in which social problems are much more difficult than are technological problems. A social problem exists because many people behave, individually, in a socially unacceptable way. To solve a social problem one must induce social change — one must persuade many people to behave differently than they have behaved in the past. One must persuade many people to have fewer babies, or to drive more carefully, or to refrain from disliking blacks. By contrast, resolution of a technological problem involves many fewer individual decisions. Once President Roosevelt decided to go after atomic energy, it was by comparison a relatively simple task to mobilize the Manhattan Project.

The resolution of social problems by the traditional methods — by motivating or forcing people to behave more rationally — is a frustrating business. People don't behave rationally; it is a long, hard business to persuade individuals to forgo immediate personal gain or pleasure (as seen by the individual) in favor of longer term social gain. And, indeed, the aim of social engineering is to invent the social devices — usually legal, but also moral and educational and organizational — that will change each person's motivation and redirect his activities along ways that are more acceptable to the society.

The technologist is appalled by the difficulties faced by the social engineer; to engineer even a small social change by inducing individuals to behave differently is always hard, even when the change is rather neutral or even beneficial. For example, some rice eaters in India are reported to prefer starvation to eating wheat that we send to them. How much harder it is to change motivations where the individual is insecure and feels threatened if she acts differently, as illustrated by the poor white's reluctance to accept the black as an equal. By contrast, technological engineering is simple: The rocket, the reactor, and the desalination plants are devices that are expensive to develop, to be sure, but their feasibility is relatively easy to assess and their success relatively easy to achieve once one understands the scientific principles that underlie them. It is, therefore, tempting to raise the following question: In view of the simplicity of technological engineering, and the complexity of social engineering, to what extent can social problems be circumvented by reducing them to technological problems? Can we identify "Quick Technological Fixes" for profound and almost 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 social attitudes, or would so alter the problem as to make its resolution more feasible? To paraphrase Ralph Nader, to what extent can technological remedies be found for social problems without first having to remove the causes of the problem? It is in this sense that I ask, "Can technology replace social engineering?"

THE MAJOR TECHNOLOGICAL FIXES OF THE PAST

To better explain what I have in mind, I shall describe how two of our most profound social problems — poverty and war — have in some limited degree been solved by the "Technological Fix," rather than by the methods of social engineering. Let me begin with poverty.

The traditional Marxian view of poverty regarded our economic ills as being primarily a question of maldistribution of goods. The Marxist recipe for elimination of poverty, therefore, was to eliminate profit, in the erroneous belief that it was the loss of this relatively small increment from the worker's paycheck that kept him poverty stricken. The Marxist dogma is typical of the approach of the social engineer: One tries to convince or coerce many people to forgo their short-term profits in what is presumed to be the long-term interest of the society as a whole.

The Marxian view seems archaic in this age of mass production and automation not only to us, but apparently to many Eastern bloc economists. For the brilliant advances in the technology of energy, of mass production, and of automation have created the affluent society. Technology has expanded our productive capacity so greatly that even though our distribution is still inefficient, and unfair by Marxian precepts, there is more than enough to go around. Technology has provided a "fix" — greatly expanded production of goods — which enables our capitalistic society to achieve many of the aims of the Marxist social engineer without going through the social revolution Marx viewed as inevitable. Technology has converted the seemingly intractable social problem of widespread poverty into a relatively tractable one.

My second example is war. The traditional Christian position views war as primarily a moral issue: If people become good, and model themselves after the Prince of Peace, they will live in peace. This doctrine is so deeply ingrained in the spirit of all civilized people that I suppose it is a blasphemy to point out that it has never worked very well — that people have not been good and that they are not paragons of virtue or even of reasonableness.

Though I realize it is terribly presumptuous to claim, I believe that Edward Teller may have supplied the nearest thing to a Quick Technological Fix to the problem of war. The hydrogen bomb greatly increases the provocation that would precipitate large-scale war — and not because people's motivations have been changed, not because people have become more tolerant and understanding, but rather because the appeal to the primitive instinct of self-preservation has been intensified far beyond anything we could have imagined before the H-bomb was invented. To point out these things today [in 1966], with the United States involved in a shooting war, may sound hollow and unconvincing, yet the desperate and partial peace we have now is much better than a full-fledged exchange of thermonuclear weapons. One cannot deny that the Soviet leaders now recognize the force of H-bombs and that this has surely contributed to the less militant attitude of the USSR. One can only hope that the Chinese leadership, as it acquires familiarity with H-bombs, will also become less militant. If I were to be asked who has given the world a more effective means of achieving peace, our great religious leaders who urge people to love their neighbors and, thus, avoid fights, or our weapons technologists who simply present people with no rational alternative to peace, I would vote for the weapons technologists. That the peace we get is at best terribly fragile, I cannot deny; yet, as I shall explain, I think technology can help stabilize our imperfect and precarious peace.

THE TECHNOLOGICAL FIXES OF THE FUTURE

Are there other Technological Fixes on the horizon, other technologies that can reduce immensely complicated social questions to a matter of "engineering"? Are there new technologies that offer society ways of circumventing social problems and at the same time do not require individuals to renounce short-term advantage for long-term gain?

Probably the most important new Technological Fix is the intrauterine device for birth control. Before the IUD was invented, birth control demanded very strong motivation of countless individuals. Even with the Pill, the individual's motivation had to be sustained day in and day out; should it flag even temporarily, the strong motivation of the previous month might go for naught. But the IUD, being a one-shot method, greatly reduces the individual motivation required to induce a social change. To be sure, the mother must be sufficiently motivated to accept the IUD in the first place, but, as experience in India already seems to show, it is much easier to persuade the Indian mother to accept the IUD once than it is to persuade her to take a pill every day. The IUD does not completely replace social engineering by technology, and, indeed, in some Spanish American cultures where the husband's manliness is measured by the number of children he has, the IUD attacks only part of the problem. Yet, in many other situations, as in India, the IUD so reduces the social component of the problem as to make an impossibly difficult social problem much less hopeless

Let me turn now to problems that from the beginning have had both technical and social components — broadly, those concerned with conservation of our resources: our environment, our water, and our raw materials for production of the means of subsistence. The social issue here arises because many people by their individual acts cause shortages and, thus, create economic, and ultimately social, imbalance. For example, people use water wastefully, or they insist on moving to California because of its climate, and so we have water shortages, or too many people drive cars in Los Angeles with its curious meteorology, and so Los Angeles suffocates from smog.

The water resources problem is a particularly good example of a complicated problem with strong social and technological connotations. Our management of water resources in the past has been based largely on the ancient Roman device, the aqueduct: Every water shortage was to be relieved by stealing water from someone else who at the moment didn't need the water or was too poor or too weak to prevent the steal. Southern California would steal from Northern California, New York City from upstate New York, the farmer who could afford a cloud-seeder from the farmer who could not afford a cloud-seeder. The social engineer insists that such shortsighted expedients have gotten us into serious trouble; we have no water resources policy, we waste water disgracefully, and, perhaps, in denying the ethic of thriftiness in using water we have generally undermined our moral fiber. The social engineer, therefore, views such technological shenanigans as being shortsighted, if not downright immoral. Instead, he says, we should persuade or force people to use less water or to stay in the cold Middle West where water is plentiful instead of migrating to California where water is scarce.

The water technologist, on the other hand, views the social engineer's approach as rather impractical. To persuade people to use less water, to get along with expensive water, is difficult, time-consuming, and uncertain in the extreme. Moreover, say the technologists, what right does the water resources expert have to insist that people use water less wastefully? Green lawns and clean cars and swimming pools are part of the good life, American style ... and what right do we have to deny this luxury if there is some alternative to cutting down the water we use?

Here we have a sharp confrontation of the two ways of dealing with a complex social issue: the social engineering way, which asks people to behave more "reasonably," and the technologists' way, which tries to avoid changing people's habits or motivation. Even though I am a technologist, I have sympathy for the social engineer. I think we must use our water as efficiently as possible, that we ought to improve people's attitudes toward the use of water, and that everything that can be done to rationalize our water policy will be welcome. Yet, as a technologist, I believe I see ways of providing more water more cheaply than the social engineers may concede is possible.

I refer to the possibility of nuclear desalination. The social engineer dismisses the technologist's simpleminded idea of solving a water shortage by transporting more water primarily because, in so doing, the water user steals water from someone else — possibly foreclosing the possibility of ultimately utilizing land now only sparsely settled. But surely water drawn from the sea deprives no one of his share of water. The whole issue is then a technological one: Can fresh water be drawn from the sea cheaply enough to have a major impact on our chronically water-short areas, like Southern California, Arizona, and the eastern seaboard?

I believe the answer is yes, though much hard technical work remains to be done. A large program to develop cheap methods of nuclear desalting has been undertaken by the United States, and 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.* At first, these plants will produce water at municipal prices. But, I believe, on the basis of research now in progress at ORNL [Oak Ridge National Laboratory] and elsewhere, water from the sea at a cost acceptable for agriculture — less than ten cents per 1,000 gallons — is eventually in the cards. In short, for areas close to the seacoasts, technology can provide water without requiring a great and difficult-to-accomplish change in people's attitudes toward the utilization of water.

The Technological Fix for water is based on the availability of extremely cheap energy from very large nuclear reactors. What other social consequences can one foresee flowing from really cheap energy eventually available to every country, regardless of its endowment of conventional resources? Though we now see only vaguely the outlines of the possibilities, it does seem likely that from very cheap nuclear energy we shall get hydrogen by electrolysis of water, and, thence, the all-important ammonia fertilizer necessary to help feed the hungry of the world; we shall reduce metals without requiring coking coal; we shall even power automobiles with electricity, via fuel cells or storage batteries, thus reducing our world's dependence on crude oil, as well as eliminating our air pollution insofar as it is caused by automobile exhaust or by the burning of fossil fuels. In short, the widespread availability of very cheap energy everywhere in the world ought to lead to an energy autarky in every country of the world and eventually to an autarky in the many staples of life that should flow from really cheap energy.

WILL TECHNOLOGY REPLACE SOCIAL ENGINEERING?

I hope these examples suggest how social problems can be circumvented or at least reduced to less formidable proportions by the application of the Technological Fix. The examples I have given do not strike me as being fanciful, nor are they at all exhaustive. I have not touched, for example, upon the extent to which really cheap computers and improved technology of communication can help improve elementary teaching without having first to improve our elementary teachers. Nor have I mentioned Ralph Nader's brilliant observation that a safer car, and even its development and adoption by the auto company, is a

*Here, as elsewhere in the chapter, the reader should bear in mind that the essay dates from the mid-1960s. — Ed.

quicker and probably surer way to reduce traffic deaths than is a campaign to teach people to drive more carefully. Nor have I invoked some really fanciful Technological Fixes — like providing air conditioners and free electricity to operate them for every black family in Watts on the assumption (suggested by Huntington) that race rioting is correlated with hot, humid weather, or the ultimate Technological Fix, Aldous Huxley's soma pills that eliminate human unhappiness without improving human relations in the usual sense.

My examples illustrate both the strength and the weakness of the Technological Fix for social problems. The Technological Fix accepts man's intrinsic shortcomings and circumvents them or capitalizes on them for socially useful ends. The Fix is, therefore, eminently practical and, in the short term, relatively effective. 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; if people insist on driving autos while they are drunk, one provides safer autos that prevent injuries even after a severe accident.

But the technological solutions to social problems tend to be incomplete and metastable, to replace one social problem with another. Perhaps the best example of this instability is the peace imposed upon us by the H-bomb. Evidently the pax hydrogenica is metastable in two senses: in the short term, because the aggressor still enjoys such an advantage; the long term, because the discrepancy and have-not nations must eventually be resolved if we are to have permanent peace. Yet, for these particular shortcomings, technology has something to offer. To the imbalance between offense and defense, technology says let us devise passive defense that redresses the balance. A world with H-bombs and adequate civil defense is less likely to lapse into thermonuclear war than a world with H-bombs alone, at least if one concedes that the danger of the thermonuclear war mainly lies in the acts of irresponsible leaders. Anything that deters the irresponsible leader is a force for peace: A technologically sound civil defense therefore would help stabilize the balance of terror.

To the discrepancy between haves and have-nots, technology offers the nuclear energy revolution, with its possibility of autarky for haves and have-nots alike. How this might work to stabilize our metastable thermonuclear peace is suggested by the possible politic effect of the recently proposed Israeli desalting plant. The Arab states I should think would be much less set upon destroying the Jordan River Project if the Israelis had a desalination plant in reserve that would nullify the effect of such actions. In this connection, I think countries like ours can contribute very much. Our country will soon have to decide whether to continue to spend $\$5.5 \times 10^9$ per year for space exploration after our lunar landing. Is it too outrageous to suggest that some of this money be devoted to building huge nuclear desalting complexes in the arid ocean rims of the troubled world? If the plants are powered with breeder reactors, the out-of-pocket costs, once the plants are built, should be low enough to make large-scale agriculture feasible in these areas. I estimate that for $\$4 \times 10^9$ per year we could build enough desalting capacity to feed more than ten million new mouths per year (provided we use agricultural methods that husband water), and we would, thereby, help stabilize the metastable, bomb-imposed balance of terror.

Yet, I am afraid we technologists shall not satisfy our social engineers, who tell us that our Technological Fixes do not get to the heart of the problem; they are at best temporary expedients; they create new problems as they solve old ones; to put a Technological Fix into effect requires a positive social action. Eventually, social engineering, like the Supreme Court decision on desegregation, must be invoked to solve social problems. And, of course, our social engineers are right. Technology will never replace social engineering. But technology has provided and will continue to provide to the social engineer broader options, to make intractable social problems less intractable; perhaps, most of all, technology will buy time — that precious commodity that converts violent social revolution into acceptable social evolution.

Our country now recognizes and is mobilizing around the great social problems that corrupt and disfigure our human existence. It is natural that in this mobilization we should look first to the social engineer. But, unfortunately, the apparatus most readily available to the government, like the great federal laboratories, is technologically oriented, not socially oriented. I believe we have a great opportunity here; for, as I hope I have persuaded you, many of our seemingly social problems do admit of partial technological solutions. Our already deployed technological apparatus can contribute to the resolution of social questions. I plead, therefore, first for our government to deploy its laboratories, its hardware contractors, and its engineering universities around social problems. And I plead, secondly, for understanding and cooperation between technologist and social engineer. Even with all the help he can get from the technologist, the social engineer's problems are never really solved. It is only by cooperation between technologist and social engineer that we can hope to achieve what is the aim of all technologists and social engineers — a better society and, thereby, a better life, for all of us who are part of society.

5

Technology and the Tragic View

SAMUEL C. FLORMAN

In Part Two of this book, which follows Chapter 6, two writers of an earlier generation engage in a famous debate that, in many ways, epitomizes the bitter divisions between the advocates and critics of technology in the late 1960s and early 1970s. Though no longer tied to the domestic conflict over U.S. participation in the Vietnam War or to the social revolution that was then raging in the United States, these pro- and anti-technology divisions still exist today. However, to treat a subject as complex as the relations of technology and society in such simplistic, for-or-against terms is ultimately less than satisfying. Samuel Florman's insightful essay, "Technology and the Tragic View," taken from his book, Blaming Technology, *suggests another approach. Florman draws on the classical Greek concept of tragedy to develop a new perspective on technology. In the tragic view of life, says Florman,*

> [it] is man's destiny to die, to be defeated by the forces of the universe. But in challenging his destiny, in being brave, determined, ambitious, resourceful, the tragic hero shows to what heights a human being can soar. This is an inspiration to the rest of us. After witnessing a tragedy we feel good, because the magnificence of the human spirit has been demonstrated.

The tragic view accepts responsibility but does not seek to cast blame. It challenges us to do, with caution, what needs to be done, and to consider at the same time the consequences of not acting. Florman's view is ultimately an affirmation of the value of technology in human life, tempered by a recognition of its limits in *sustaining human happiness. It is a uniquely constructive approach to thinking about technology and society.*

Samuel C. Florman, author of The Existential Pleasures of Engineering *(1976) and several other books, is a practicing engineer and chairman of Kreisler Borg Florman Construction Company in Scarsdale, New York, one of the top 100 construction firms in the United States. His more than 100 articles dealing with the relationship of technology to general culture have appeared in professional journals and popular magazines. His most recent book,* The Aftermath: A Novel of Survival *(2001), is an adventure story set on Earth after a cataclysmic collision with a comet. Florman was born in New York City in 1925. He was elected a member of the National Academy of Engineering in 1995 and is also a fellow of the American Society of Civil Engineers. He holds a bachelor's degree and a civil engineer's degree from Dartmouth College and an M.A. in English literature from Columbia University.*

The blaming of technology starts with the making of myths — most importantly, the myth of the technological imperative and the myth of the technocratic elite. In spite of the injunctions of common sense, and contrary to the evidence at hand, the myths flourish.

False premises are followed by confused deductions — a maligning of the scientific view, the assertion that small is beautiful, the mistake about job enrichment, an excessive zeal for government regulation, the hostility of feminists toward engineering, and the wishful thinking of the Club of Rome. These, in turn, are followed by distracted rejoinders from the technological community, culminating in the bizarre exaltation of engineering ethics.

In all of this it is difficult to determine how much is simple misunderstanding and how much is willful evasion of the truth, a refusal to face up to the harsh realities that underlie life, not only in a technological age, but in every age since the beginning of civilization.

Out of the confusion has come a dialogue of sorts, shaped around views that are deemed "pro" technology or "anti," "optimistic" or "pessimistic." I believe that we should be thinking in different terms altogether.

House & Garden magazine, in celebration of the American Bicentennial, devoted its July 1976 issue to the topic "American Know-How." The editors invited me to contribute an article, and, enticed by the opportunity to address a new audience, plus the offer of a handsome fee, I accepted. We agreed that the title of my piece would be "Technology and the Human Adventure," and I thereupon embarked on a strange adventure of my own.

I thought that it would be appropriate to begin my Bicentennial-inspired essay with a discussion of technology in the time of the Founding Fathers, so I went to the library and immersed myself in the works of Benjamin Franklin, surely the most famous technologist of America's early days. Remembering stories from my childhood about Ben Franklin the clever tinkerer, I expected to find a pleasant recounting of inventions and successful experiments, a cheering tale of technological triumphs. I found such a tale, to be sure, but along with it I found a record of calamities caused by the technological advances of his day.

In several letters and essays, Franklin expressed concern about fire, an ever-threatening scourge in Colonial times. Efficient sawmills made it possible to build frame houses, more versatile and economical than log cabins — but less fire resistant. Advances in transport made it possible for people to crowd these frame houses together in cities. Cleverly conceived fireplaces, stoves, lamps, and warming pans made life more comfortable, but contributed to the likelihood of catastrophic fires in which many lives were lost.

To deal with this problem, Franklin recommended architectural modifications to make houses more fireproof. He proposed the licensing and supervision of chimney sweeps and the establishment of volunteer fire companies, well supplied and trained in the science of firefighting. As is well known, he invented the lightning rod. In other words, he proposed technological ways of coping with the unpleasant consequences of technology. He applied Yankee ingenuity to solve problems arising out of Yankee ingenuity.

In Franklin's writings I found other examples of technological advances that brought with them unanticipated problems. Lead poisoning was a peril. Contaminated rum was discovered coming from distilleries where lead parts had been substituted for wood in the distilling apparatus. Drinking water collected from lead-coated roofs was also making people seriously ill.

The advancing techniques of medical science were often a mixed blessing, as they are today. Early methods of vaccination for smallpox, for example, entailed the danger of the vaccinated person dying from the artificially induced disease. (In a particularly poignant article, Franklin was at pains to point out that his four-year-old son's death from smallpox was attributable to the boy's not having been vaccinated and did not result, as rumor had it, from the vaccination itself.)

After a while, I put aside the writings of Franklin and turned my attention to American know-how in the nineteenth century. I became engrossed in the story of the early days of steamboat transport. This important step forward in American technology was far from being the unsullied triumph that it appears to be in our popular histories.

Manufacturers of the earliest high-pressure steam engines often used materials of inferior quality. They were slow to recognize the weakening of boiler shells caused by rivet holes and the danger of using wrought-iron shells together with cast iron heads that had a different coefficient of expansion. Safety valve openings were often not properly proportioned, and gauges had a tendency to malfunction. Even well-designed equipment quickly became defective through the effects of corrosion and sediment. On top of it all, competition for prestige led to racing between boats, and, during a race, the usual practice was to tie down the safety valve so that excessive steam pressure would not be relieved.

From 1825 to 1830, 42 recorded explosions killed upward of 270 persons. When, in 1830, an explosion aboard the *Helen McGregor* near Memphis killed more than fifty passengers, public outrage forced the federal government to take action. Funds were granted to the Franklin Institute of Philadelphia to purchase apparatus needed to conduct experiments on steam boilers. This was a notable event: the first technological research grant made by the federal government.

The institute made a comprehensive report in 1838, but it was not until fourteen years later that a workable bill was passed by Congress providing at least minimal safeguards for the citizenry. Today, we may wonder why the process took so long, but at the time Congress was still uncertain about its right, under the interstate commerce provision of the Constitution, to control the activities of individual entrepreneurs.

When I turned from steamboats to railroads I found another long-forgotten story of catastrophe. Not only were there problems with the trains themselves, but the roadbeds, and particularly the bridges, made even the shortest train journey a hazardous adventure. In the late 1860s, more than twenty-five American bridges were collapsing each year, with appalling loss of life. In 1873, the American Society of Civil Engineers set up a special commission to address the problem, and eventually the safety of our bridges came to be taken for granted.

The more I researched the history of American know-how, the more I perceived that practically every technological advance had unexpected and unwanted side effects. Along with each triumph of mechanical genius came an inevitable portion of death and destruction. Instead of becoming discouraged, however, our forebears seemed to be resolute in confronting the adverse consequences of their own inventiveness. I was impressed by this pattern of progress/setback/renewed creative effort. It seemed to have a special message for our day, and I made it the theme of my essay for *House & Garden*.

No matter how many articles one has published, and no matter how much one likes the article most recently submitted, waiting to hear from an editor is an anxious experience. In this case, as it turned out, I had reason to be apprehensive. I soon heard from one of the editors who, although she tried to be encouraging, was obviously distressed. "We liked the part about tenacity and ingenuity," she said, "but, oh dear, all those disasters — they are so depressing." I need not go into the details of what follows: the rewriting, the telephone conferences, the rewriting — the gradual elimination of accidents and casualty statistics and a subtle change in emphasis. I retreated, with some honor intact I like to believe, until the article was deemed to be suitably upbeat.

I should have known that the Bicentennial issue of *House & Garden* was not the forum in which to consider the dark complexities of technological change. My piece was to appear side by side with such articles as, "A House That Has Everything," "Live Longer, Look Younger," and "Everything's Coming Up Roses" (devoted to a review of Gloria Vanderbilt's latest designs).

In the United States today, magazines like *House & Garden* speak for those, and to those, who are optimistic about technology. Through technology we get better dishwashers, permanent-press blouses, and rust-proof lawn furniture. "Better living through chemistry," the old DuPont commercial used to say. Not only is *House & Garden* optimistic, that is, hopeful, about technology, it is cheerfully optimistic. There is no room in its pages for failure, or even for struggle, and in this view it speaks for many Americans, perhaps a majority. This is the lesson I learned — or I should say, relearned — in the Bicentennial year.

Much has been written about the shallow optimism of the United States: about life viewed as a Horatio Alger success story or as a romantic movie with a happy ending. This optimism is less widespread than it used to be, particularly as it relates to technology. Talk of nuclear warfare and a poisoned environment tends to dampen one's enthusiasm. Yet, optimistic materialism remains a powerful force in American life. The poll-takers tell us that people believe technology is, on balance, beneficial. And we all know a lot of people who, even at this troublesome moment in history, define happiness in terms of their ability to accumulate new gadgets. The business community, anxious to sell merchandise, spares no expense in promoting a gleeful consumerism.

Side by side with what I have come to think of as *House & Garden* optimism, there is a mood that we might call *New York Review of Books* pessimism. Our intellectual journals are full of gloomy tracts that depict a society debased by technology. Our health is being ruined, according to this view, our landscape despoiled, and our social institutions laid waste. We are forced to do demeaning work and consume unwanted products. We are being dehumanized. This is happening because a technological demon has escaped from human control or, in a slightly different version, because evil technocrats are leading us astray.

It is clear that in recent years the resoluteness exhibited by Benjamin Franklin, and other Americans of similarly robust character, has been largely displaced by a foolish optimism on the one hand and an abject pessimism on the other. These two opposing outlooks are actually manifestations of the same defect in the American character. One is the obverse, the "flip side," of the other. Both reflect a flaw that I can best describe as immaturity.

A young child is optimistic, naively assuming that his needs can always be satisfied and that his parents have it within their power to "make things right." A child frustrated becomes petulant. With the onset of puberty a morose sense of disillusionment is apt to take hold. Sulky pessimism is something we associate with the teenager.

It is not surprising that many inhabitants of the United States, a rich nation with seemingly boundless frontiers, should have evinced a childish optimism and declared their faith in technology, endowing it with the reassuring power of a parent — also regarding it with the love of a child for a favorite toy. It then follows that technological setbacks would be greeted by some with the naive assumption that all would turn out for the best and by others with peevish declarations of despair. Intellectuals have been in the forefront of this childish display, but every segment of society has been caught up in it. Technologists themselves have not been immune. In the speeches of nineteenth-century engineers, we find bombastic promises that make us blush. Today, the profession is torn between a blustering optimism and a confused guilt.

The past fifty years have seen many hopes dashed, but we can see in retrospect that they were unrealistic hopes. We simply cannot make use of coal without killing miners and polluting the air. Neither can we manufacture solar panels without worker fatalities and environmental degradation. (We assume that it will be less than with coal, but we are not sure.) We cannot build highways or canals or airports without despoiling the landscape. Not only have we learned that environmental dangers are inherent in every technological advance, but we find that we are fated to be dissatisfied with much of what we produce because our tastes keep changing. The sparkling, humming, paved metropolises of science fiction — even if they could be realized — are not, after all, the home to which humankind aspires. It seems that many people find such an environment "alienating." There can never be a technologically based utopia because we discover belatedly that we cannot agree on what form that utopia might take.

To express our disillusionment, we have invented a new word: "trade-off." It is an ugly word, totally without grace, but it signifies, I believe, the beginning of maturity for American society.

It is important to remember that our disappointments have not been limited to technology. (This is a fact that the antitechnologists usually choose to ignore.) Wonderful dreams attended the birth of the New Deal, and later the founding of the United Nations, yet we have since awakened to face unyielding economic and political difficulties. Socialism has been discredited, as was *laissez-faire* capitalism before it. We have been bitterly disappointed by the labor movement, the educational establishment, efforts at crime prevention, the ministrations of psychiatry, and, most recently, by the abortive experiments of the so-called counterculture. We have come face to face with limits that we had presumed to hope might not exist.

Those of us who have lived through the past fifty years have passed personally from youthful presumptuousness to mature skepticism at the very moment that American society has been going through the same transition. We have to be careful not to define the popular mood in terms of our personal sentiments, but I do not think I am doing that when I observe the multiple disenchantments of our time. We also have to be careful not to deprecate youthful enthusiasm, which is a force for good, along with immaturity, which is tolerable only in the young.

It can be argued that there was for a while good reason to hold out hope for utopia, since modern science and technology appeared to be completely new factors in human existence. But now that they have been given a fair trial, we perceive their inherent limitations. The human condition is the human condition still.

To persist in saying that we are optimistic or pessimistic about technology is to acknowledge that we will not grow up.

I suggest that an appropriate response to our new wisdom is neither optimism nor pessimism, but rather the espousal of an attitude that has traditionally been associated with men and women of noble character — the tragic view of life.

As a student in high school, and later in college, I found it difficult to comprehend what my teachers told me about comedy and tragedy. Comedy, they said, expresses despair. When there is no hope, we make jokes. We depict people as puny, ridiculous creatures. We laugh to keep from crying.

Tragedy, on the other hand, is uplifting. It depicts heroes wrestling with fate. It is man's destiny to die, to be defeated by the forces of the universe. But in challenging his destiny, in being brave, determined, ambitious, resourceful, the tragic hero shows to what heights a human being can soar. This is an inspiration to the rest of us. After witnessing a tragedy, we feel good, because the magnificence of the human spirit has been demonstrated. Tragic drama is an affirmation of the value of life.

Students pay lip service to this theory and give the expected answers in examinations. But sometimes the idea seems to fly in the face of reason. How can we say we feel better after Oedipus puts out his eyes, or Othello kills his beloved wife and commits suicide, than we do after laughing heartily over a bedroom farce?

Yet, this concept, which is so hard to grasp in the classroom, where students are young and the environment is serene, rings true in the world where mature people wrestle with burdensome problems.

I do not intend to preach a message of stoicism. The tragic view is not to be confused with world-weary resignation. As Moses Hadas, a great classical scholar of a generation ago, wrote about the Greek tragedians, "Their gloom is not fatalistic pessimism but an adult confrontation of reality, and their emphasis is not on the grimness of life but on the capacity of great figures to adequate themselves to it."[1]

It is not an accident that tragic drama flourished in societies that were dynamic: Periclean Athens, Elizabethan England, and the France of Louis XIV. For tragedy speaks of ambition, effort, and unquenchable spirit. Technological creativity is one manifestation of this spirit, and it is only a dyspeptic antihumanist who can feel otherwise. Even the Greeks, who for a while placed technologists low on the social scale, recognized the glory of creative engineering. Prometheus is one of the quintessential tragic heroes. In viewing technology through a tragic prism, we are at once exalted by its accomplishments and sobered by its limitations. We thus ally ourselves with the spirit of great ages past.

The fate of Prometheus, as well as that of most tragic heroes, is associated with the concept of hubris, "overweening pride." Yet pride, which in drama invariably leads to a fall, is not considered sinful by the great tragedians. It is an essential element of humanity's greatness. It is what inspires heroes to confront the universe, to challenge the status quo. Prometheus defied Zeus and brought technological knowledge to the human race. Prometheus was a revolutionary. So were Gutenberg, Watt, Edison, and Ford. Technology is revolutionary. Therefore, hostility toward technology is antirevolutionary, which is to say it is reactionary. This charge is currently being leveled against environmentalists and other enemies of technology. Since antitechnologists are traditionally "liberal" in their attitudes, the idea that they are reactionary confronts us with a paradox.

The tragic view does not shrink from paradox; it teaches us to live with ambiguity. It is at once revolutionary and cautionary. Hubris, as revealed in tragic drama, is an essential element of creativity; it is also a tragic flaw that contributes to the failure of human enterprise. Without effort, however, and daring, we are nothing. Walter Kerr has spoken of "tragedy's commitment to freedom, to the unflinching exploration of the possible." "At the heart of tragedy," he writes, "feeding it energy, stands godlike man passionately desiring a state of affairs more perfect than any that now exists."[2]

This description of the tragic hero well serves, in my opinion, as a definition of the questing technologist.

An aspect of the tragic view that particularly appeals to me is its reluctance to place blame. Those people who hold pessimistic views about technology are forever reproaching others, if not individual engineers, then the "technocratic establishment," the "megastate," "the pentagon of power," or some equally amorphous entity. Everywhere they look they see evil intent.

There is evil in the world, of course, but most of our disappointments with technology come when decent people are trying to act constructively. "The essentially tragic fact," says Hegel, "is not so much the war of good with evil as the war of good with good."

Pesticides serve to keep millions of poor people from starving. To use pesticides is good; to oppose them when they create havoc in the food chain is also good. To drill for oil and to transport it across the oceans is good, since petroleum provides lifesaving chemicals and heat for homes. To prevent oil spills is also good. Nuclear energy is good, as is the attempt to eliminate radioactivity. To seek safety is a worthy goal, but in a world of limited resources, the pursuit of economy is also worthy. We are constantly accusing each other of villainy when we should be consulting together on how best to solve our common problems.

Although the tragic view shuns blame, it does not shirk responsibility. "The fault, dear Brutus, is not in our stars, but in ourselves...." We are accountable for what we do or, more often, for what we neglect to do. The most shameful feature of the antitechnological creed is that it so often fails to consider the consequences of not taking action. The lives lost or wasted that might have been saved by exploiting our resources are the responsibility of those who counsel inaction. The tragic view is consistent with good citizenship. It advocates making the most of our opportunities; it challenges us to do the work that needs doing.

Life, it may be said, is not a play. Yet we are constantly talking about roles — role-playing, role models, and so forth. It is a primordial urge to want to play one's part. The outlook I advocate sees value in many different people playing many different parts. A vital society, like a meaningful drama, feeds on diversity. Each participant contributes to the body social: scientist, engineer, farmer, craftsman, laborer, politician, jurist, teacher, artist, merchant, entertainer.... The pro-growth industrialist and the environmentalist are both needed, and, in a strange way, they need each other.

Out of conflict comes resolution; out of variety comes health. This is the lesson of the natural world. It is the moral of ecological balance; it is also the moral of great drama. We cannot but admire Caesar, Brutus, and Antony all together. So should we applaud the guardians of our wilderness, even as we applaud the creators of dams and paper mills. I am a builder, but I feel for those who are afraid of building, and I admire those who want to endow all building with grace.

George Steiner, in *The Death of Tragedy* (1961), claimed that the tragic spirit was rendered impotent by Christianity's promise of salvation. But I do not think that most people today are thinking in terms of salvation. They are thinking of doing the best they can in a world that promises neither damnation nor transcendent victories, but instead confronts us with both perils and opportunities for achievement. In such a world, the tragic spirit is very much alive. Neither optimism nor pessimism is a worthy alternative to this noble spirit.

We use words to communicate, but sometimes they are not as precise as we pretend, and then we confuse ourselves and each other. "Optimism," "pessimism," "tragic view" — these are mere sounds or scratches on paper. The way we feel is not adequately defined by such sounds or scratches. René Dubos used to write a column for *The American Scholar* that he called "The Despairing Optimist." I seem to recall that he once gave his reasons for not calling it "The Hopeful Pessimist," although I cannot remember what they were. What really counts, I suppose, is not what we say, or even what we feel, but what we want to do.

By saying that I espouse the tragic view of technology I mean to ally myself with those who, aware of the dangers and without foolish illusions about what can be accomplished, still want to move on, actively seeking to realize our constantly changing vision of a more satisfactory society. I mean to oppose those who would evade harsh truths by intoning platitudes. I particularly mean to challenge those who enjoy the benefits of technology but refuse to accept responsibility for its consequences.

Earlier in this essay I mentioned the problems I encountered in preparing an article for *House & Garden*, and I would like to close by quoting the last few lines from that much-rewritten opus. The prose is somewhat florid, but please remember that it was written in celebration of the American Bicentennial:

> For all our apprehensions, we have no choice but to press ahead. We must do so, first, in the name of compassion. By turning our backs on technological change, we would be expressing our satisfaction with current world levels of hunger, disease, and privation. Further, we must press ahead in the name of human adventure. Without experimentation and change our existence would be a dull business. We simply cannot stop while there are masses to feed and diseases to conquer, seas to explore and heavens to survey.

The editors of *Home & Garden* thought I was being optimistic. I knew that I was being tragic, but I did not argue the point.

ENDNOTES

1. Moses Hadas, *A History of Greek Literature* (New York: Columbia University Press, 1950), p. 75.
2. Walter Kerr, *Tragedy and Comedy* (New York: Simon & Schuster, 1967), p. 107.

6

Do Artifacts Have Politics?

LANGDON WINNER

Do the properties of technological systems embody specific kinds of power and authority relationships? Are nuclear power systems inherently centralizing and authoritarian? Are solar power systems, as some of their advocates claim, more democratic and consistent with the values of pluralistic societies? Langdon Winner looks for answers to questions such as these in the following essay, originally published in a 1980 symposium issue of the journal Daedalus *entitled "Modern Technology: Problem or Opportunity?" Winner believes that, indeed, technological choices do have political consequences. He cites many examples, including a particularly egregious one: Robert Moses designed bridges over his parkways on Long Island too low for buses in order to keep members of the urban lower classes (who could not afford private automobiles) from crowding the suburban parks and beaches.*

"Technologies," Winner concludes, "are ways of building order in our world," which, by their nature, influence the way people live and work over long periods of time. We need to study and understand their consequences and to develop means of making technological choices in a more open and participatory fashion if we are to maintain a democratic society. A prolific writer whose works have appeared in both scholarly and popular publications and who served as contributing editor to Rolling Stone *magazine from 1969 to 1971, Langdon Winner is Thomas Phelan Chair of Humanities and Social Sciences at Rensselaer Polytechnic Institute (RPI) in Troy, New York. He teaches in the Department of Science and Technology Studies. Prior to coming to RPI in 1985, he taught at the Massachusetts Institute of Technology, Leiden University (in the Netherlands), and the University of California at Berkeley and at Santa Cruz. Among Winner's books are* Autonomous Technology *(1977) and* The Whale and the Reactor *(1986).*

"Do Artifacts Have Politics?" from *Daedalus, Journal of the American Academy of Arts and Sciences,* from the issue entitled, "Modern Technology: Problem or Opportunity?" Winter 1980, Vol. 109, No. 1. Reprinted by permission of the author.

In controversies about technology and society, there is no idea more provocative than the notion that technical things have political qualities. At issue is the claim that the machines, structures, and systems of modern material culture can be accurately judged not only for their contributions of efficiency and productivity, not merely for their positive and negative environmental side effects, but also for the ways in which they can embody specific forms of power and authority. Since ideas of this kind have a persistent and troubling presence in discussions about the meaning of technology, they deserve explicit attention.[1]

Writing in *Technology and Culture* almost two decades ago, Lewis Mumford gave classic statement to one version of the theme, arguing that "from late neolithic times in the Near East, 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."[2] This thesis stands at the heart of Mumford's studies of the city, architecture, and the history of technics and mirrors concerns voiced earlier in the works of Peter Kropotkin, William Morris, and other nineteenth-century critics of industrialism. More recently, antinuclear and prosolar energy movements in Europe and America have adopted a similar notion as a centerpiece in their arguments. Thus, environmentalist Denis Hayes concludes, "The increased deployment of nuclear power facilities must lead society toward authoritarianism. Indeed, safe reliance upon nuclear power as the principal source of energy may be possible only in a totalitarian state." Echoing the views of many proponents of appropriate technology and the soft energy path, Hayes contends that "dispersed solar sources are more compatible than centralized technologies with social equity, freedom, and cultural pluralism."[3]

An eagerness to interpret technical artifacts in political language is by no means the exclusive property of critics of large-scale, high-technology systems. A long lineage of boosters have insisted that the "biggest and best" that science and industry made available were the best guarantees of democracy, freedom, and social justice. The factory system, automobile, telephone, radio, television, the space program, and, of course, nuclear power itself have all at one time or another been described as democratizing, liberating forces. David Lilienthal, in *T.V.A.: Democracy on the March*, for example, found this promise in the phosphate fertilizers and electricity that technical progress was bringing to rural Americans during the 1940s.[4] In a recent essay, *The Republic of Technology*, Daniel Boorstin extolled television for "its power to disband armies, to cashier presidents, to create a whole new democratic world — democratic in ways never before imagined, even in America."[5] Scarcely a new invention comes along that someone does not proclaim it the salvation of a free society.

It is no surprise to learn that technical systems of various kinds are deeply interwoven in the conditions of modern politics. The physical arrangements of industrial production, warfare, communications, and the like have fundamentally changed the exercise of power and the experience of citizenship. But to go beyond this obvious fact and to argue that certain technologies in themselves have political properties seems, at first glance, completely mistaken. We all know that people have politics, not things. To discover either virtues or evils in aggregates of steel, plastic, transistors, integrated circuits, and chemicals seems just plain wrong, a way of mystifying human artifice and of avoiding the true sources, the human sources of freedom and oppression, justice and injustice. Blaming the hardware appears even more foolish than blaming the victims when it comes to judging conditions of public life.

Hence, the stern advice commonly given those who flirt with the notion that technical artifacts have political qualities: What matters is not technology itself, but the social or economic system in which it is embedded. This maxim, which in a number of variations is the central premise of a theory that can be called the social determination of technology, has an obvious wisdom. It serves as a needed corrective to those who focus uncritically on such things as "the computer and its social impacts" but who fail to look behind technical things to notice the social circumstances of their development, deployment, and use. This view provides an antidote to naive technological determinism — the idea that technology develops as the sole result of an internal dynamic, and then, unmediated by any other influence, molds society to fit its patterns. Those who have not recognized the ways in which technologies are shaped by social and economic forces have not gotten very far.

But the corrective has its own shortcomings; taken literally, it suggests that technical things do not matter at all. Once one has done the detective work necessary to reveal the social origins — power holders behind a particular instance of technological change — one will have explained everything of importance. This conclusion offers comfort to social scientists: It validates what they had always suspected, namely, that there is nothing distinctive about the study of technology in the first place. Hence, they can return to their standard models of social power — those of interest group politics, bureaucratic politics, Marxist models of class struggle, and the like — and have everything they need. The social determination of technology is, in this view, essentially no different from the social determination of, say, welfare policy or taxation.

There are, however, good reasons technology has of late taken on a specia fascination in its own right for historians, philosophers, and political scientists good reasons the standard models of social science only go so far in accountin for what is most interesting and troublesome about the subject. In another plac I have tried to show why so much of modern social and political though contains recurring statements of what can be called a theory of technologica politics, an odd mongrel of notions often crossbred with orthodox liberal conservative, and socialist philosophies.[6] The theory of technological politic draws attention to the momentum of large-scale sociotechnical systems, to th response of modern societies to certain technological imperatives, and to th all-too-common signs of the adaptation of human ends to technical means. I so doing, it offers a novel framework of interpretation and explanation fo some of the more puzzling patterns that have taken shape in and around th growth of modern material culture. One strength of this point of view is that i takes technical artifacts seriously. Rather than insist that we immediately reduc everything to the interplay of social forces, it suggests that we pay attention t the characteristics of technical objects and the meaning of those characteristic

A necessary complement to, rather than a replacement for, theories of the social determination of technology, this perspective identifies certain technologies as political phenomena in their own right. It points us back, to borrow Edmund Husserl's philosophical injunction, to the things themselves.

In what follows, I shall offer outlines and illustrations of two ways in which artifacts can contain political properties. First are instances in which the invention, design, or arrangement of a specific technical device or system becomes a way of settling an issue in a particular community. Seen in the proper light, examples of this kind are fairly straightforward and easily understood. Second are cases of what can be called inherently political technologies, man-made systems that appear to require, or to be strongly compatible with, particular kinds of political relationships. Arguments about cases of this kind are much more troublesome and closer to the heart of the matter. By "politics," I mean arrangements of power and authority in human associations as well as the activities that take place within those arrangements. For my purposes, "technology" here is understood to mean all of modern practical artifice,[7] but to avoid confusion I prefer to speak of technologies, smaller or larger pieces or systems of hardware of a specific kind. My intention is not to settle any of the issues here once and for all, but to indicate their general dimensions and significance.

TECHNICAL ARRANGEMENTS AS FORMS OF ORDER

Anyone who has traveled the highways of America and has become used to the normal height of overpasses may well find something a little odd about some of the bridges over the parkways on Long Island, New York. Many of the overpasses are extraordinarily low, having as little as nine feet of clearance at the curb. Even those who happened to notice this structural peculiarity would not be inclined to attach any special meaning to it. In our accustomed way of looking at things like roads and bridges we see the details of form as innocuous and seldom give them a second thought.

It turns out, however, that the 200 or so low-hanging overpasses on Long Island were deliberately designed to achieve a particular social effect. Robert Moses, the master builder of roads, parks, bridges, and other public works from the 1920s to the 1970s in New York, had these overpasses built to specifications that would discourage the presence of buses on his parkways. According to evidence provided by Robert A. Caro in his biography of Moses, the reasons reflect Moses's social-class bias and racial prejudice. Automobile-owning whites of "upper" and "comfortable middle" classes, as he called them, would be free to use the parkways for recreation and commuting. Poor people and blacks, who normally used public transit, were kept off the roads because the twelve-foot-tall buses could not get through the overpasses. One consequence was to limit access of racial minorities and low-income groups to Jones Beach, Moses's widely acclaimed public park. Moses made doubly sure of this result by vetoing a proposed extension of the Long Island Railroad to Jones Beach.[8]

As a story in recent American political history, Robert Moses's life is fascinating. His dealings with mayors, governors, and presidents, and his careful manipulation of legislatures, banks, labor unions, the press, and public opinion, are all matters that political scientists could study for years. But the most important and enduring results of his work are his technologies, the vast engineering projects that give New York much of its present form. For generations after Moses has gone and the alliances he forged have fallen apart, his public works, especially the highways and bridges he built to favor the use of the automobile over the development of mass transit, will continue to shape that city. Many of his monumental structures of concrete and steel embody a systematic social inequality, a way of engineering relationships among people that, after a time, becomes just another part of the landscape. As planner Lee Koppelman told Caro about the low bridges on Wantagh Parkway, "The old son-of-a-gun had made sure that buses would never be able to use his goddamned parkways."[9]

Histories of architecture, city planning, and public works contain many examples of physical arrangements that contain explicit or implicit political purposes. One can point to Baron Haussmann's broad Parisian thoroughfares, engineered at Louis Napoleon's direction to prevent any recurrence of street fighting of the kind that took place during the revolution of 1848. Or one can visit any number of grotesque concrete buildings and huge plazas constructed on American university campuses during the late 1960s and early 1970s to defuse student demonstrations. Studies of industrial machines and instruments also turn up interesting political stories, including some that violate our normal expectations about why technological innovations are made in the first place. If we suppose that new technologies are introduced to achieve increased efficiency, the history of technology shows that we will sometimes be disappointed. Technological change expresses a panoply of human motives, not the least of which is the desire of some to have dominion over others, even though it may require an occasional sacrifice of cost cutting and some violence to the norm of getting more from less.

One poignant illustration can be found in the history of nineteenth-century industrial mechanization. At Cyrus McCormick's reaper manufacturing plant in Chicago in the middle 1880s, pneumatic molding machines, a new and largely untested innovation, were added to the foundry at an estimated cost of $500,000. In the standard economic interpretation of such things, we would expect that this step was taken to modernize the plant and achieve the kind of efficiencies that mechanization brings. But historian Robert Ozanne has shown why the development must be seen in a broader context. At the time, Cyrus McCormick II was engaged in a battle with the National Union of Iron Molders. He saw the addition of the new machines as a way to "weed out the bad element among the men," namely, the skilled workers who had organized the union local in Chicago.[10] The new machines, manned by unskilled labor, actually produced inferior castings at a higher cost than the earlier process. After three years of use, the machines were, in fact, abandoned, but by that time they had served their purpose — the destruction of the union. Thus, the story of these technical developments at the McCormick factory cannot be understood adequately outside the record of workers' attempts to organize, police repression of the labor movement in Chicago during that period, and the events surrounding the bombing at Haymarket Square. Technological history and American political history were at that moment deeply intertwined.

In cases like those of Moses's low bridges and McCormick's molding machines, one sees the importance of technical arrangements that precede the use of the things in question. It is obvious that technologies can be used in ways that enhance the power, authority, and privilege of some over others, for example, the use of television to sell a candidate. To our accustomed way of thinking, technologies are seen as neutral tools that can be used well or poorly, for good, evil, or something in between. But we usually do not stop to inquire whether a given device might have been designed and built in such a way that it produces a set of consequences logically and temporally prior to any of its professed uses. Robert Moses's bridges, after all, were used to carry automobiles from one point to another; McCormick's machines were used to make metal castings; both technologies, however, encompassed purposes far beyond their immediate use. If our moral and political language for evaluating technology includes only categories having to do with tools and uses, if it does not include attention to the meaning of the designs and arrangements of our artifacts, then we will be blinded to much that is intellectually and practically crucial.

Because the point is most easily understood in the light of particular intentions embodied in physical form, I have so far offered illustrations that seem almost conspiratorial. But to recognize the political dimensions in the shapes of technology does not require that we look for conscious conspiracies or malicious intentions. The organized movement of handicapped people in the United States during the 1970s pointed out the countless ways in which machines, instruments, and structures of common use — buses, buildings, sidewalks, plumbing fixtures, and so forth — made it impossible for many handicapped persons to move about freely, a condition that systematically excluded them from public life. It is safe to say that designs unsuited for the handicapped arose more from long-standing neglect than from anyone's active intention. But now that the issue has been raised for public attention, it is evident that justice requires a remedy. A whole range of artifacts are now being redesigned and rebuilt to accommodate this minority.

Indeed, many of the most important examples of technologies that have political consequences are those that transcend the simple categories of "intended" and "unintended" altogether. These are instances in which the very process of technical development is so thoroughly biased in a particular direction that it regularly produces results counted as wonderful breakthroughs by some social interests and crushing setbacks by others. In such cases, it is neither correct nor insightful to say, "Someone intended to do somebody else harm." Rather, one must say that the technological deck has been stacked long in advance to favor certain social interests and that some people were bound to receive a better hand than others.

The mechanical tomato harvester, a remarkable device perfected by researchers at the University of California from the late 1940s to the present, offers an illustrative tale. The machine is able to harvest tomatoes in a single pass through a row, cutting the plants from the ground, shaking the fruit loose, and, in the newest models, sorting the tomatoes electronically into large plastic gondolas that hold up to twenty-five tons of produce headed for canning. To accommodate the rough motion of these "factories in the field," agricultural researchers have bred new varieties of tomatoes that are hardier, sturdier, and less tasty. The harvesters replace the system of handpicking, in which crews of farmworkers would pass through the fields three or four times putting ripe tomatoes in lug boxes and saving immature fruit for later harvest.[11] Studies in California indicate that the machine reduces costs by approximately five to seven dollars per ton as compared to hand harvesting.[12] But the benefits are by no means equally divided in the agricultural economy. In fact, the machine in the garden has in this instance been the occasion for a thorough reshaping of social relationships of tomato production in rural California.

By their very size and cost, more than $50,000 each to purchase, the machines are compatible only with a highly concentrated form of tomato growing. With the introduction of this new method of harvesting, the number of tomato growers declined from approximately 4,000 in the early 1960s to about 600 in 1973, yet with a substantial increase in tons of tomatoes produced. By the late 1970s, an estimated 32,000 jobs in the tomato industry had been eliminated as a direct consequence of mechanization.[13] Thus, a jump in productivity to the benefit of very large growers has occurred at a sacrifice to other rural agricultural communities.

The University of California's research and development on agricultural machines like the tomato harvester is at this time the subject of a lawsuit filed by attorneys for California Rural Legal Assistance, an organization representing a group of farmworkers and other interested parties. The suit charges that University officials are spending tax monies on projects that benefit a handful of private interests to the detriment of farmworkers, small farmers, consumers, and rural California generally and asks for a court injunction to stop the practice. The University has denied these charges, arguing that to accept them "would require elimination of all research with any potential practical application."[14]

As far as I know, no one has argued that the development of the tomato harvester was the result of a plot. Two students of the controversy, William Friedland and Amy Barton, specifically exonerate both the original developers of the machine and the hard tomato from any desire to facilitate economic concentration in that industry.[15] What we see here instead is an ongoing social process in which scientific knowledge, technological invention, and corporate profit reinforce each other in deeply entrenched patterns that bear the unmistakable stamp of political and economic power. Over many decades, agricultural research and development in American land-grant colleges and universities has tended to favor the interests of large agribusiness concerns.[16] It is in the face of such subtly ingrained patterns that opponents of innovations like the tomato harvester are made to seem "antitechnology" or "antiprogress." For the harvester is not merely the symbol of a social order that rewards some while punishing others; it is in a true sense an embodiment of that order.

Within a given category of technological change there are, roughly speaking, two kinds of choices that can affect the relative distribution of power, authority, and privilege in a community. Often the crucial decision is a simple "yes or no" choice — Are we going to develop and adopt the thing or not? In recent years, many local, national, and international disputes about technology have centered on "yes or no" judgments about such things as food additives, pesticides, the building of highways, nuclear reactors, and dam projects. The fundamental choice about an ABM [anti-ballistic missile] or an SST [supersonic transport] is whether or not the thing is going to join society as a piece of its operating equipment. Reasons for and against are frequently as important as those concerning the adoption of an important new law.

A second range of choices, equally critical in many instances, has to do with specific features in the design or arrangement of a technical system after the decision to go ahead with it has already been made. Even after a utility company wins permission to build a large electric power line, important controversies can remain with respect to the placement of its route and the design of its towers; even after an organization has decided to institute a system of computers, controversies can still arise with regard to the kinds of components, programs, modes of access, and other specific features the system will include. Once the mechanical tomato harvester had been developed in its basic form, design alteration of critical social significance — the addition of electronic sorters, for example — changed the character of the machine's effects on the balance of wealth and power in California agriculture. Some of the most interesting research on technology and politics at present focuses on the attempt to demonstrate in a detailed, concrete fashion how seemingly innocuous design features in mass transit systems, water projects, industrial machinery, and other technologies actually mask social choices of profound significance. Historian David Noble is now studying two kinds of automated machine tool systems that have different implications for the relative power of management and labor in the industries that might employ them. He is able to show that, although the basic electronic and mechanical components of the record/playback and numerical control systems are similar, the choice of one design over another has crucial consequences for social struggles on the shop floor. To see the matter solely in terms of cost cutting, efficiency, or the modernization of equipment is to miss a decisive element in the story.[17]

From such examples I would offer the following general conclusions. The things we call "technologies" are ways of building order in our world. Many technical devices and systems important in everyday life contain possibilities for many different ways of ordering human activity. Consciously or not, deliberately or inadvertently, societies choose structures for technologies that influence how people are going to work, communicate, travel, consume, and so forth over a very long time. In the processes by which structuring decisions are made, different people are differently situated and possess unequal degrees of power, as well as unequal levels of awareness. By far the greatest latitude of choice exists the very first time a particular instrument, system, or technique is introduced. Because choices tend to become strongly fixed in material equipment, economic investment, and social habit, the original flexibility vanishes for all practical purposes once the initial commitments are made. In that sense, technological innovations are similar to legislative acts or political foundings that establish a framework for public order that will endure over many generations. For that reason, the same careful attention one would give to the rules, roles, and relationships of politics must also be given to such things as the building of highways, the creation of television networks, and the tailoring of seemingly insignificant features on new machines. The issues that divide or unite people in society are settled not only in the institutions and practices of politics proper, but also, and less obviously, in tangible arrangements of steel and concrete, wires and transistors, nuts and bolts.

INHERENTLY POLITICAL TECHNOLOGIES

None of the arguments and examples considered thus far address a stronger, more troubling claim often made in writings about technology and society — the belief that some technologies are by their very nature political in a specific way. According to this view, the adoption of a given technical system unavoidably brings with it conditions for human relationships that have a distinctive political cast — for example, centralized or decentralized, egalitarian or inegalitarian, repressive or liberating. This is ultimately what is at stake in assertions like those of Lewis Mumford that two traditions of technology, one authoritarian, the other democratic, exist side by side in Western history. In all the cases I cited, the technologies are relatively flexible in design and arrangement and variable in their effects. Although one can recognize a particular result produced in a particular setting, one can also easily imagine how a roughly similar device or system might have been built or situated with very much different political consequences. The idea we must now examine and evaluate is that certain kinds of technology do not allow such flexibility and that to choose them is to choose a particular form of political life.

A remarkably forceful statement of one version of this argument appears in Friedrich Engels's little essay "On Authority," written in 1872. Answering anarchists who believed that authority is an evil that ought to be abolished altogether, Engels launches into a panegyric for authoritarianism, maintaining, among other things, that strong authority is a necessary condition in modern industry. To advance his case in the strongest possible way, he asks his readers to imagine that the revolution has already occurred. "Supposing a social revolution dethroned the capitalists, who now exercise their authority over the production and circulation of wealth. Supposing, to adopt entirely the point of view of the antiauthoritarians, that the land and the instruments of labor had become the collective property of the workers who use them. Will authority have disappeared or will it have only changed its form?"[18]

His answer draws upon lessons from three sociotechnical systems of his day: cotton-spinning mills, railways, and ships at sea. He observes that, on its way to becoming finished thread, cotton moves through a number of different operations at different locations in the factory. The workers perform a wide variety of tasks, from running the steam engine to carrying the products from one room to another. Because these tasks must be coordinated, and because the timing of the work is "fixed by the authority of the steam," laborers must learn to accept a rigid discipline. They must, according to Engels, work at regular hours and agree to subordinate their individual wills to the persons in charge of factory operations. If they fail to do so, they risk the horrifying possibility that production will come to a grinding halt. Engels pulls no punches. "The automatic machinery of a big factory," he writes, "is much more despotic than the small capitalists who employ workers ever have been."[19]

Similar lessons are adduced in Engels's analysis of the necessary operating conditions for railways and ships at sea. Both require the subordination of workers to an "imperious authority" that sees to it that things run according to plan. Engels finds that, far from being an idiosyncrasy of capitalist social organization, relationships of authority and subordination arise "independently of all social organization, [and] are imposed upon us together with the material conditions under which we produce and make products circulate." Again, he intends this to be stern advice to the anarchists who, according to Engels, thought it possible simply to eradicate subordination and superordination at a single stroke. All such schemes are nonsense. The roots of unavoidable authoritarianism are, he argues, deeply implanted in the human involvement with science and technology. "If man, by dint of his knowledge and inventive genius, has subdued the forces of nature, the latter avenge themselves upon him by subjecting him, insofar as he employs them, to a veritable despotism independent of all social organization."[20]

Attempts to justify strong authority on the basis of supposedly necessary conditions of technical practice have an ancient history. A pivotal theme in *The Republic* is Plato's quest to borrow the authority of techne and employ it by analogy to buttress his argument in favor of authority in the state. Among the illustrations he chooses, like Engels, is that of a ship on the high seas. Because large sailing vessels by their very nature need to be steered with a firm hand, sailors must yield to their captain's commands; no reasonable person believes that ships can be run democratically. Plato goes on to suggest that governing a state is rather like being captain of a ship or like practicing medicine as a physician. Much the same conditions that require central rule and decisive action in organized technical activity also create this need in government.

In Engels's argument, and arguments like it, the justification for authority is no longer made by Plato's classic analogy, but rather directly with reference to technology itself. If the basic case is as compelling as Engels believed it to be, one would expect that, as a society adopted increasingly complicated technical systems as its material basis, the prospects for authoritarian ways of life would be greatly enhanced. Central control by knowledgeable people acting at the top of a rigid social hierarchy would seem increasingly prudent. In this respect, his stand in "On Authority" appears to be at variance with Karl Marx's position in Volume One of *Capital*. Marx tries to show that increasing mechanization will render obsolete the hierarchical division of labor and the relationships of subordination that, in his view, were necessary during the early stages of modern manufacturing. The "Modern Industry," he writes, "... sweeps away by technical means the manufacturing division of labor, under which each man is bound hand and foot for life to a single detail operation. At the same time, the capitalistic form of that industry reproduces this same division of labor in a still more monstrous shape; in the factory proper, by converting the workman into a living appendage of the machine.[21] In Marx's view, the conditions that will eventually dissolve the capitalist division of labor and facilitate proletarian revolution are conditions latent in industrial technology itself. The differences between Marx's position in *Capital* and Engels's in his essay raise an important question for socialism: What, after all, does modern technology make possible or necessary in political life? The theoretical tension we see here mirrors many troubles in the practice of freedom and authority that have muddied the tracks of socialist revolution.

Arguments to the effect that technologies are in some sense inherently political have been advanced in a wide variety of contexts, far too many to summarize here. In my reading of such notions, however, there are two basic ways of stating the case. One version claims that the adoption of a given technical system actually requires the creation and maintenance of a particular set of social conditions as the operating environment of that system. Engels's position is of this kind. A similar view is offered by a contemporary writer who holds that "if you accept nuclear power plants, you also accept a techno-scientific-industrial-military elite. Without these people in charge, you could not have nuclear power."[22] In this conception, some kinds of technology require their social environments to be structured in a particular way in much the same sense that an automobile requires wheels in order to run. The thing could not exist as an effective operating entity unless certain social as well as material conditions were met. The meaning of "required" here is that of practical (rather than logical) necessity. Thus, Plato thought it a practical necessity that a ship at sea have one captain and an unquestioningly obedient crew.

A second, somewhat weaker, version of the argument holds that a given kind of technology is strongly compatible with, but does not strictly require, social and political relationships of a particular stripe. Many advocates of solar energy now hold that technologies of that variety are more compatible with a democratic egalitarian society than energy systems based on coal, oil, and nuclear power; at the same time, they do not maintain that anything about solar energy requires democracy. Their case is, briefly, that solar energy is decentralizing in both a technical and political sense: Technically speaking, it is vastly more reasonable to build solar systems in a disaggregated, widely distributed manner than in large-scale centralized plants; politically speaking, solar energy accommodates the attempt of individuals and local communities to manage their affairs effectively because they are dealing with systems that are more accessible, comprehensible, and controllable than huge centralized sources. In this view, solar energy is desirable not only for its economic and environmental benefits, but also for the salutary institutions it is likely to permit in other areas of public life.[23]

Within both versions of the argument there is a further distinction to be made between conditions that are internal to the workings of a given technical system and those that are external to it. Engels's thesis concerns internal social relations said to be required within cotton factories and railways, for example; what such relationships mean for the condition of society at large is for him separate question. In contrast, the solar advocate's belief that solar technologies are compatible with democracy pertains to the way they complement aspects of society removed from the organization of those technologies as such.

There are, then, several different directions that arguments of this kind can follow. Are the social conditions predicated said to be required by, or strongly compatible with, the workings of a given technical system? Are those conditions internal to that system or external to it (or both)? Although writings that address such questions are often unclear about what is being asserted, arguments in this general category do have an important presence in modern political discourse. They enter into many attempts to explain how changes in social life take place in the wake of technological innovation. More importantly, they are often used to buttress attempts to justify or criticize proposed courses of action involving new technology. By offering distinctly political reasons for or against the adoption of a particular technology, arguments of this kind stand apart from more commonly employed, more easily quantifiable claims about economic costs and benefits, environmental impacts, and possible risks to public health and safety that technical systems may involve. The issue here does not concern how many jobs will be created, how much income generated, how many pollutants added, or how many cancers produced. Rather, the issue has to do with ways in which choices about technology have important consequences for the form and quality of human associations.

If we examine social patterns that comprise the environments of technical systems, we find certain devices and systems almost invariably linked to specific ways of organizing power and authority. The important question is: Does this state of affairs derive from an unavoidable social response to intractable properties in the things themselves, or is it instead a pattern imposed independently by a governing body, ruling class, or some other social or cultural institution to further its own purposes?

Taking the most obvious example, the atom bomb is an inherently political artifact. As long as it exists at all, its lethal properties demand that it be controlled by a centralized, rigidly hierarchical chain of command closed to all influences that might make its workings unpredictable. The internal social system of the bomb must be authoritarian; there is no other way. The state of affairs stands as a practical necessity independent of any larger political system in which the bomb is embedded, independent of the kind of regime or character of its rulers. Indeed, democratic states must try to find ways to ensure that the social structures and mentality that characterize the management of nuclear weapons do not "spin off" or "spill over" into the polity as a whole.

The bomb is, of course, a special case. The reasons very rigid relationships of authority are necessary in its immediate presence should be clear to anyone. If, however, we look for other instances in which particular varieties of technology are widely perceived to need the maintenance of a special pattern of power and authority, modern technical history contains a wealth of examples.

Alfred D. Chandler in *The Visible Hand*, a monumental study of modern business enterprise, presents impressive documentation to defend the hypothesis that the construction and day-to-day operation of many systems of production, transportation, and communication in the nineteenth and twentieth centuries require the development of a particular social form — a large-scale, centralized, hierarchical organization administered by highly skilled managers. Typical of Chandler's reasoning is his analysis of the growth of the railroads:

> Technology made possible fast, all-weather transportation; but safe, regular, reliable movement of goods and passengers, as well as the continuing maintenance and repair of locomotives, rolling stock, and track, roadbed, stations, roundhouses, and other equipment, required the creation of a sizable administrative organization. It meant the employment of a set of managers to supervise these functional activities over an extensive geographical area; and the appointment of an administrative command of middle and top executives to monitor, evaluate, and coordinate the work of managers responsible for the day-to-day operations.[24]

Throughout his book, Chandler points to ways in which technologies used in the production and distribution of electricity, chemicals, and a wide range of industrial goods "demanded" or "required" this form of human association. "Hence, the operational requirements of railroads demanded the creation of the first administrative hierarchies in American business."[25]

Were there other conceivable ways of organizing these aggregates of people and apparatus? Chandler shows that a previously dominant social form, the small traditional family firm, simply could not handle the task in most cases. Although he does not speculate further, it is clear that he believes there is, to be realistic, very little latitude in the forms of power and authority appropriate within modern sociotechnical systems. The properties of many modern technologies — oi pipelines and refineries, for example — are such that overwhelmingly impressive economies of scale and speed are possible. If such systems are to work effectively efficiently, quickly, and safely, certain requirements of internal social organizatior have to be fulfilled; the material possibilities that modern technologies make available could not be exploited otherwise. Chandler acknowledges that as one compares sociotechnical institutions of different nations, one sees "ways in which cultural attitudes, values, ideologies, political systems, and social structure affec these imperatives."[26] But the weight of argument and empirical evidence ir *The Visible Hand* suggests that any significant departure from the basic patterr would be, at best, highly unlikely.

It may be that other conceivable arrangements of power and authority, fo example, those of decentralized, democratic worker self-management, coul prove capable of administering factories, refineries, communications system and railroads as well as or better than the organizations Chandler describe Evidence from automobile assembly teams in Sweden and worker-manage plants in Yugoslavia and other countries is often presented to salvage these pos sibilities. I shall not be able to settle controversies over this matter here, bu merely point to what I consider to be their bone of contention. The availabl evidence tends to show that many large, sophisticated technological systems ar in fact highly compatible with centralized, hierarchical managerial contro

The interesting question, however, has to do with whether or not this pattern is in any sense a requirement of such systems, a question that is not solely an empirical one. The matter ultimately rests on our judgments about what steps, if any, are practically necessary in the workings of particular kinds of technology and what, if anything, such measures require of the structure of human associations. Was Plato right in saying that a ship at sea needs steering by a decisive hand and that this could only be accomplished by a single captain and an obedient crew? Is Chandler correct in saying that the properties of large-scale systems require centralized, hierarchical, managerial control?

To answer such questions, we would have to examine in some detail the moral claims of practical necessity (including those advocated in the doctrines of economics) and weigh them against moral claims of other sorts, for example, the notion that it is good for sailors to participate in the command of a ship or that workers have a right to be involved in making and administering decisions in a factory. It is characteristic of societies based on large, complex technological systems, however, that moral reasons other than those of practical necessity appear increasingly obsolete, "idealistic," and irrelevant. Whatever claims one may wish to make on behalf of liberty, justice, or equality can be immediately neutralized when confronted with arguments to the effect: "Fine, but that's no way to run a railroad" (or steel mill, or airline, or communications system, and so on). Here we encounter an important quality in modern political discourse and in the way people commonly think about what measures are justified in response to the possibilities technologies make available. In many instances, to say that some technologies are inherently political is to say that certain widely accepted reasons of practical necessity — especially the need to maintain crucial technological systems as smoothly working entities — have tended to eclipse other sorts of moral and political reasoning.

One attempt to salvage the autonomy of politics from the bind of practical necessity involves the notion that conditions of human association found in the internal workings of technological systems can easily be kept separate from the polity as a whole. Americans have long rested content in the belief that arrangements of power and authority inside industrial corporations, public utilities, and the like have little bearing on public institutions, practices, and ideas at large.

That "democracy stops at the factory gates" was taken as a fact of life that had nothing to do with the practice of political freedom. But can the internal politics of technology and the politics of the whole community be so easily separated? A recent study of American business leaders, contemporary exemplars of Chandler's "visible hand of management," found them remarkably impatient with such democratic scruples as "one man, one vote." If democracy doesn't work for the firm, the most critical institution in all of society, American executives ask, how well can it be expected to work for the government of a nation — particularly when that government attempts to interfere with the achievements of the firm? The authors of the report observe that patterns of authority that work effectively in the corporation become for businessmen "the desirable model against which to compare political and economic relationships in the rest of society."[27] While such findings are far from conclusive, they do reflect a sentiment increasingly common in the land: What dilemmas like the energy crisis require is not a redistribution of wealth or broader public participation but, rather, stronger, centralized, public management — President Carter's proposal for an Energy Mobilization Board and the like.

An especially vivid case in which the operational requirements of a technical system might influence the quality of public life is now at issue in debates about the risks of nuclear power. As the supply of uranium for nuclear reactors runs out, a proposed alternative fuel is the plutonium generated as a by-product in reactor cores. Well-known objections to plutonium recycling focus on its unacceptable economic costs, its risks of environmental contamination, and its dangers in regard to the international proliferation of nuclear weapons. Beyond these concerns, however, stands another, less widely appreciated set of hazards — those that involve the sacrifice of civil liberties. The widespread use of plutonium as a fuel increases the chance that this toxic substance might be stolen by terrorists, [members of] organized crime, or other persons. This raises the prospect, and not a trivial one, that extraordinary measures would have to be taken to safeguard plutonium from theft and to recover it if ever the substance were stolen. Workers in the nuclear industry, as well as ordinary citizens outside, could well become subject to background security checks, covert surveillance, wiretapping, informers, and even emergency measures under martial law — all justified by the need to safeguard plutonium.

Russell W. Ayres's study of the legal ramifications of plutonium recycling concludes, "With the passage of time and the increase in the quantity of plutonium in existence will come pressure to eliminate the traditional checks the courts and legislatures place on the activities of the executive and to develop a powerful central authority better able to enforce strict safeguards." He avers that "once a quantity of plutonium had been stolen, the case for literally turning the country upside down to get it back would be overwhelming." Ayres anticipates and worries about the kinds of thinking that, I have argued, characterize inherently political technologies. It is still true that, in a world in which human beings make and maintain artificial systems, nothing is "required" in an absolute sense. Nevertheless, once a course of action is under way, once artifacts like nuclear power plants have been built and put in operation, the kinds of reasoning that justify the adaptation of social life to technical requirements pop up as spontaneously as flowers in the spring. In Ayres's words, "Once recycling begins and the risks of plutonium theft become real rather than hypothetical, the case for governmental infringement of protected rights will seem compelling."[28] After a certain point, those who cannot accept the hard requirements and imperatives will be dismissed as dreamers and fools.

* * *

The two varieties of interpretation I have outlined indicate how artifacts can have political qualities. In the first instance, we noticed ways in which specific features in the design or arrangement of a device or system could provide a convenient means of establishing patterns of power and authority in a given setting. Technologies of this kind have a range of flexibility in the dimensions of their material form. It is precisely because they are flexible that their consequences for society must be understood with reference to the social actors able to influence which designs and arrangements are chosen. In the second instance, we examined ways in which the intractable properties of certain kinds of technology are strongly, perhaps unavoidably, linked to particular institutionalized patterns of power and authority. Here, the initial choice about whether or not to adopt something is decisive in regard to its consequences. There are no alternative physical designs or arrangements that would make a significant difference; there are, furthermore, no genuine possibilities for creative intervention by different social systems — capitalist or socialist — that could change the intractability of the entity or significantly alter the quality of its political effects.

To know which variety of interpretation is applicable in a given case is often what is at stake in disputes, some of them passionate ones, about the meaning of technology for how we live. I have argued a "both/and" position here, for it seems to me that both kinds of understanding are applicable in different circumstances. Indeed, it can happen that within a particular complex of technology — a system of communication or transportation, for example — some aspects may be flexible in their possibilities for society, while other aspects may be (for better or worse) completely intractable. The two varieties of interpretation I have examined here can overlap and intersect at many points.

These are, of course, issues on which people can disagree. Thus, some proponents of energy from renewable resources now believe they have at last discovered a set of intrinsically democratic, egalitarian, communitarian technologies. In my best estimation, however, the social consequences of building renewable energy systems will surely depend on the specific configurations of both hardware and the social institutions created to bring that energy to us. It may be that we will find ways to turn this silk purse into a sow's ear. By comparison, advocates of the further development of nuclear power seem to believe that they are working on a rather flexible technology whose adverse social effects can be fixed by changing the design parameters of reactors and nuclear waste disposal systems. For reasons indicated above, I believe them to be dead wrong in that faith. Yes, we may be able to manage some of the "risks" to public health and safety that nuclear power brings. But as society adapts to the more dangerous and apparently indelible features of nuclear power, what will be the long-range toll in human freedom?

My belief that we ought to attend more closely to technical objects themselves is not to say that we can ignore the contexts in which those objects are situated. A ship at sea may well require, as Plato and Engels insisted, a single captain and obedient crew. But a ship out of service, parked at the dock, needs only a caretaker. To understand which technologies and which contexts are important to us, and why, is an enterprise that must involve both the study of specific technical systems and their history as well as a thorough grasp of the concepts and controversies of political theory. In our times, people are often willing to make drastic changes in the way they live to accord with technological innovation at the same time they would resist similar kinds of changes justified on political grounds. If for no other reason than that, it is important for us to achieve a clearer view of these matters than has been our habit so far.

ENDNOTES

1. I would like to thank Merritt Roe Smith, Leo Marx, James Miller, David Noble, Charles Weiner, Sherry Turkle, Loren Graham, Gail Stuart, Dick Sclove, and Stephen Graubard for their comments and criticisms on earlier drafts of this essay. My thanks also to Doris Morrison of the Agriculture Library of the University of California, Berkeley, for her bibliographical help.
2. Lewis Mumford, "Authoritarian and Democratic Technics," *Technology and Culture* 5 (1964), pp. 1–8.
3. Denis Hayes, *Rays of Hope: The Transition to a Post-Petroleum World* (New York: W. W. Norton, 1977), pp. 71, 159.
4. David Lilienthal, *T.V.A.: Democracy on the March* (New York: Harper & Brothers, 1944), pp. 72–83.
5. Daniel J. Boorstin, *The Republic of Technology* (New York: Harper & Row, 1978), p. 7.
6. Langdon Winner, *Autonomous Technology: Technics-out-of-Control as a Theme in Political Thought* (Cambridge, MA: M.I.T. Press, 1977).
7. The meaning of "technology" I employ in this essay does not encompass some of the broader definitions of that concept found in contemporary literature, for example, the notion of "technique" in the writings of Jacques Ellul. My purposes here are more limited. For a discussion of the difficulties that arise in attempts to define "technology," see Winner, *Autonomous Technology*, pp. 8–12.
8. Robert A. Caro, *The Power Broker: Robert Moses and the Fall of New York* (New York: Random House, 1974), pp. 318, 481, 514, 546, 951–58.
9. Ibid., p. 952.
10. Robert Ozanne, *A Century of Labor–Management Relations at McCormick and International Harvester* (Madison: University of Wisconsin Press, 1967), p. 20.
11. The early history of the tomato harvester is told in Wayne D. Rasmussen, "Advances in American Agriculture: The Mechanical Tomato Harvester as a Case Study," *Technology and Culture* 9 (1968), pp. 531–43.
12. Andrew Schmitz and David Seckler, "Mechanized Agriculture and Social Welfare: The Case of the Tomato Harvester," *American Journal of Agricultural Economics* 52 (1970), pp. 569–77.
13. William H. Friedland and Amy Barton, "Tomato Technology," *Society* 13:6 (September/October 1976). See also William H. Friedland, *Social Sleepwalkers: Scientific and Technological Research in California Agriculture*, University of California, Davis, Department of Applied Behavioral Sciences, Research Monograph No. 13, 1974.
14. University of California Clip Sheet, 54:36, May 1, 1979.
15. Friedland and Barton, "Tomato Technology."
16. A history and critical analysis of agricultural research in the land-grant colleges is given in James Hightower, *Hard Tomatoes, Hard Times* (Cambridge, MA: Schenkman, 1978).
17. David Noble, "Social Change in Machine Design: The Case of Automatically Controlled Machine Tools," in *Case Studies in the Labor Process*, A. Zimbalist, ed. (New York: Monthly Review Press, 1979), pp. 18–50.
18. Friedrich Engels, "On Authority" in *The Marx-Engels Reader*, 2nd ed., ed. Robert Tucker (New York: W. W. Norton, 1978), p. 731.

19. Ibid.
20. Ibid., pp. 732, 731.
21. Karl Marx, *Capital*, vol. 1, 3rd ed., trans. Samuel Moore and Edward Aveling (New York: The Modern Library, 1906), p. 530.
22. Jerry Mander, *Four Arguments for the Elimination of Television* (New York: William Morrow, 1978), p. 44.
23. See, for example, Robert Argue, Barbara Emanuel, and Stephen Graham, *The Sun Builders: A People's Guide to Solar, Wind, and Wood Energy in Canada* (Toronto: Renewable Energy in Canada, 1978). "We think decentralization is an implicit component of renewable energy; this implies the decentralization of energy systems, communities and of power. Renewable energy doesn't require mammoth generation sources or disruptive transmission corridors. Our cities and towns, which have been dependent on centralized energy supplies, may be able to achieve some degree of autonomy, thereby controlling and administering their own energy needs" (p. 16).
24. Alfred D. Chandler, Jr., *The Visible Hand: The Managerial Revolution in American Business* (Cambridge, MA: Belknap, Harvard University Press, 1977), p. 244.
25. Ibid.
26. Ibid., p. 500.
27. Leonard Silk and David Vogel, *Ethics and Profits: The Crisis of Confidence in American Business* (New York: Simon & Schuster, 1976), p. 191.
28. Russell W. Ayres, "Policing Plutonium: The Civil Liberties Fallout," *Harvard Civil Rights–Civil Liberties Law Review* 10 (1975), pp. 374, 413–14, 443.

PART II

Debating Technology: 1960s Style

Chapter 7, Emmanuel Mesthene's essay, "The Role of Technology in Society," and the piece that follows it, "Technology: The Opiate of the Intellectuals" by John McDermott (Chapter 8), constitute a classic debate about the role of technology in society. The articles date from the late 1960s, when the war in Vietnam was in full swing, and intellectual and political life in the United States was torn by bitter conflicts between the "establishment" and the "New Left." The use of high tech weapons by U.S. forces in the war provoked an intense debate about technology and its impacts.

These two articles are included here, as they have been in every edition of *Technology and the Future* since the book was first published in 1972, as a means of illustrating in sharp relief the different perspectives on technology of the powerful and powerless. Mesthene, a Harvard professor and former RAND Corporation analyst, head of a large research program funded by a multimillion dollar grant from IBM, is comfortable with technology. He and his colleagues feel that technology is something that they can control and use. It is a neutral tool that can be employed for purposes that are good and evil, and it often has both positive and negative effects on society.

McDermott, on the other hand, sees technology from the lower rungs of society's ladder. A professor of labor studies writing in the then-radical left-wing *New York Review of Books*, he adopts the viewpoint of a factory worker struggling to make ends meet rather than the highly paid industry executive. He is the foot soldier slogging through the jungles of Vietnam in a war whose purpose he does not understand, rather than the systems analyst comfortably ensconced in the Pentagon or in RAND's Santa Monica headquarters. Technology, seen from McDermott's side of the fence, is hardly a neutral tool; it is the means by which those in power maintain their control of society while perpetuating social injustice.

Some of the illustrations the authors use in these two essays — which were instantly recognizable and conjured up clear images to readers of their day — may be unfamiliar to readers in the twenty-first century. But the issues they raise and the differing perspectives on technology of the rulers and the ruled are as important today as they were almost four decades ago.

7

The Role of Technology in Society

EMMANUEL G. MESTHENE

Emmanuel Mesthene's essay, "The Role of Technology in Society," originated as the overview section of the fourth annual report of the Harvard Program on Technology and Society, an interdisciplinary program of academic studies funded by a $5 million grant from the IBM Corporation. Mesthene (pronounced mess-then-ee) was the program's director, and this essay was his general statement of what the program had learned during its first four years about the implications of technological change for society.

According to Mesthene, technology appears to induce social change in two ways: by creating new opportunities and by generating new problems for individuals and for societies. "It has both positive and negative effects, and it usually has the two at the same time and in virtue of each other." By enlarging the realm of goal choice, or by altering the relative costs associated with different values, technology can induce value change. In all areas, technology is seen to have two faces, one positive and one negative.

Emmanuel G. Mesthene directed the Harvard Program on Technology and Society from 1964 through 1974, following eleven years with the RAND Corporation. He joined Rutgers University in 1974, serving as dean of Livingston College for several years, then as distinguished professor of philosophy and professor of management. Mesthene died in 1990. Among his books are Technological Change: Its Impact on Man and Society *(1970) and* How Language Makes Us Know *(1964).*

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SOCIAL CHANGE

Three Unhelpful Views about Technology

While a good deal of research is aimed at discerning the particular effects of technological change on industry, government, or education, systematic inquiry devoted to seeing these effects together and to assessing their implications for contemporary society as a whole is relatively recent and does not enjoy the strong methodology and richness of theory and data that mark more established fields of scholarship. It therefore often has to contend with facile or one-dimensional views about what technology means for society. Three such views, which are prevalent at the present time, may be mildly caricatured somewhat as follows.

The first holds that technology is an unalloyed blessing for man and society. Technology is seen as the motor of all progress, as holding the solution to most of our social problems, as helping to liberate the individual from the clutches of a complex and highly organized society, and as the source of permanent prosperity; in short, as the promise of utopia in our time. This view has its modern origins in the social philosophies of such nineteenth-century thinkers as Saint Simon, Karl Marx, and Auguste Comte. It tends to be held by many scientists and engineers, by many military leaders and aerospace industrialists, by people who believe that man is fully in command of his tools and his destiny, and by many of the devotees of modern techniques of "scientific management."

A second view holds that technology is an unmitigated curse. Technology is said to rob people of their jobs, their privacy, their participation in democratic government, and even, in the end, their dignity as human beings. It is seen as autonomous and uncontrollable, as fostering materialistic values and as destructive of religion, as bringing about a technocratic society and bureaucratic state in which the individual is increasingly submerged, and as threatening, ultimately, to poison nature and blow up the world. This view is akin to historical "back-to-nature" attitudes toward the world and is propounded mainly by artists, literary commentators, popular social critics, and existentialist philosophers. It is becoming increasingly attractive to many of our youth, and it tends to be held, understandably enough, by segments of the population that have suffered dislocation as a result of technological change.

The third view is of a different sort. It argues that technology as such is not worthy of special notice, because it has been well recognized as a factor in social change at least since the Industrial Revolution, because it is unlikely that the social effects of computers will be nearly so traumatic as the introduction of the factory system in eighteenth-century England, because research has shown that technology has done little to accelerate the rate of economic productivity since the 1880s, because there has been no significant change in recent decades in the time periods between invention and widespread adoption of new technology, and because improved communications and higher levels of education make people much more adaptable than heretofore to new ideas and to new social reforms required by technology.

This view is supported by a good deal of empirical evidence; however, it tends to ignore a number of social, cultural, psychological, and political effects of technological change that are less easy to identify with precision. It thus reflects the difficulty of coming to grips with a new or broadened subject matter by means of concepts and intellectual categories designed to deal with older and different subject matters. This view tends to be held by historians, for whom continuity is an indispensable methodological assumption, and by many economists, who find that their instruments measure some things quite well while those of the other social sciences do not yet measure much of anything.

Stripped of caricature, each of these views contains a measure of truth and reflects a real aspect of the relationship of technology and society. Yet they are oversimplifications that do not contribute much to understanding. One can find empirical evidence to support each of them without gaining much knowledge about the actual mechanism by which technology leads to social change or significant insight into its implications for the future. All three remain too uncritical or too partial to guide inquiry. Research and analysis lead to more differentiated conclusions and reveal more subtle relationships.

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How Technological Change Impinges on Society

It is clearly possible to sketch a more adequate hypothesis about the interaction of technology and society than the partial views outlined [here]. Technological change would appear to induce or "motor" social change in two principal ways. New technology creates new opportunities for men and societies, and it also generates new problems for them. It has both positive and negative effects, and it usually has the two at the same time and in virtue of each other. Thus, industrial technology strengthens the economy, as our measures of growth and productivity show.... However, it also induces changes in the relative importance of individual supplying sectors in the economy as new techniques of production alter the amounts and kinds of materials, parts and components, energy, and service inputs used by each industry to produce its output. It thus tends to bring about dislocations of businesses and people as a result of changes in industrial patterns and in the structure of occupations.

The close relationship between technological and social change itself helps to explain why any given technological development is likely to have both positive and negative effects. The usual sequence is that (1) technological advance creates a new opportunity to achieve some desired goal; (2) this requires (except in trivial cases) alterations in social organization if advantage is to be taken of the new opportunity; (3) which means that the functions of existing social structures will be interfered with; (4) with the result that other goals, which were served by the older structures, are now only inadequately achieved.

As the Meyer–Kain[1] study has shown, for example, improved transportation technology and increased ownership of private automobiles have increased the mobility of businesses and individuals. This has led to altered patterns of industrial and residential location, so that older unified cities are being increasingly transformed into larger metropolitan complexes. The new opportunities for mobility are largely denied to the poor and black populations of the core cities, however, partly for economic reasons, and partly as a result of restrictions on choice of residence by blacks, thus leading to persistent black unemployment despite a generally high level of economic activity. Cities are thus increasingly unable to perform their traditional functions of providing employment opportunities for all segments of their populations and an integrated social environment that can temper ethnic and racial differences. The new urban complexes are neither fully viable economic units nor effective political organizations able to upgrade and integrate their core populations into new economic and social structures. The resulting instability is further aggravated by modern mass communications technology, which heightens the expectations of the poor and the fears of the well-to-do and adds frustration and bitterness to the urban crisis....

In all such cases, technology creates a new opportunity and a new problem at the same time. That is why isolating the opportunity or the problem and construing it as the whole answer is ultimately obstructive of, rather than helpful to, understanding.

How Society Reacts to Technological Change

The heightened prominence of technology in our society makes the interrelated tasks of profiting from its opportunities and containing its dangers a major intellectual and political challenge of our time.

Failure of society to respond to the opportunities created by new technology means that much actual or potential technology lies fallow, that is, is not used at all or is not used to its full capacity. This can mean that potentially solvable problems are left unsolved and potentially achievable goals unachieved, because we waste our technological resources or use them inefficiently. A society has at least as much stake in the efficient utilization of technology as in that of its natural or human resources.

There are often good reasons, of course, for not developing or utilizing a particular technology. The mere fact that it can be developed is not sufficient reason for doing so....

But there are also cases where technology lies fallow because existing social structures are inadequate to exploit the opportunities it offers.... Community institutions wither for want of interest and participation by residents. City agencies are unable to marshal the skills and take the systematic approach needed to deal with new and intensified problems of education, crime control, and public welfare. Business corporations, finally, which are organized around the expectation of private profit, are insufficiently motivated to bring new technology and management know-how to bear on urban projects where the benefits will be largely social. All these factors combine to dilute what may otherwise be a genuine desire to apply our best knowledge and adequate resources to the resolution of urban tensions and the eradication of poverty in the nation....

Containing the Negative Effects of Technology

The kinds and magnitude of the negative effects of technology are no more independent of the institutional structures and cultural attitudes of society than is realization of the new opportunities that technology offers. In our society, there are individuals or individual firms always on the lookout for new technological opportunities, and large corporations hire scientists and engineers to invent such opportunities. In deciding whether to develop a new technology, individual entrepreneurs engage in calculations of expected benefits and expected costs to themselves and proceed if the former are likely to exceed the latter. Their calculations do not take adequate account of the probable benefits and costs of the new developments to others than themselves or to society generally. These latter are what economists call external benefits and costs.

The external benefits potential in new technology will thus not be realized by the individual developer and will rather accrue to society as a result of deliberate social action, as has been argued above. Similarly with the external costs. In minimizing only expected costs to himself, the individual decision maker helps to contain only some of the potentially negative effects of the new technology. The external costs and therefore the negative effects on society at large are not of principal concern to him and, in our society, are not expected to be.

Most of the consequences of technology that are causing concern at the present time — pollution of the environment, potential damage to the ecology of the planet, occupational and social dislocations, threats to the privacy and political significance of the individual, social and psychological malaise — are negative externalities of this kind. They are with us in large measure because it has not been anybody's explicit business to foresee and anticipate them. They have fallen between the stools of innumerable individual decisions to develop individual technologies for individual purposes without explicit attention to what all these decisions add up to for society as a whole and for people as human beings. This freedom of individual decision making is a value that we have cherished and that is built into the institutional fabric of our society. The negative effects of technology that we deplore are a measure of what this traditional freedom is beginning to cost us. They are traceable, less to some mystical autonomy presumed to lie in technology, and much more to the autonomy that our economic and political institutions grant to individual decision making....

Measures to control and mitigate the negative effects of technology, however, often appear to threaten freedoms that our traditions still take for granted as inalienable rights of men and good societies, however much they may have been tempered in practice by the social pressures of modern times: the freedom of the market, the freedom of private enterprise, the freedom of the scientist to follow truth wherever it may lead, and the freedom of the individual to pursue his fortune and decide his fate. There is thus set up a tension between the need to control technology and our wish to preserve our values, which leads some people to conclude that technology is inherently inimical to human values. The political effect of this tension takes the form of inability to adjust our decision making structures to the realities of technology so as to take maximum advantage of the opportunities it offers and so that we can act to contain its potential ill effects before they become so pervasive and urgent as to seem uncontrollable.

To understand why such tensions are so prominent a social consequence of technological change, it becomes necessary to look explicitly at the effects of technology on social and individual values.

VALUES

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Technology as a Cause of Value Change

Technology has a direct impact on values by virtue of its capacity for creating new opportunities. By making possible what was not possible before, it offers individuals and society new options to choose from. For example, space technology makes it possible for the first time to go to the moon or to communicate by satellite and thereby adds those two new options to the spectrum of choices available to society. By adding new options in this way, technology can lead to changes in values in the same way that the appearance of new dishes on the heretofore standard menu of one's favorite restaurant can lead to changes in one's tastes and choices of food. Specifically, technology can lead to value change either (1) by bringing some previously unattainable goal within the realm of choice or (2) by making some values easier to implement than heretofore, that is, by changing the costs associated with realizing them....

One example related to the effect of technological change on values is implicit in our concept of democracy. The ideal we associate with the old New England town meeting is that each citizen should have a direct voice in political decisions. Since this has not been possible, we have elected representatives to serve our interests and vote our opinions. Sophisticated computer technology, however, now makes possible rapid and efficient collection and analysis of voter opinion and could eventually provide for "instant voting" by the whole electorate on any issue presented to it via television a few hours before. It thus raises the possibility of instituting a system of direct democracy and gives rise to tensions between those who would be violently opposed to such a prospect and those who are already advocating some system of participatory democracy.

This new technological possibility challenges us to clarify what we mean by democracy. Do we construe it as the will of an undifferentiated majority, as the resultant of transient coalitions of different interest groups representing different value commitments, as the considered judgment of the people's elected representatives, or as by and large the kind of government we actually have in the United States, minus the flaws in it that we would like to correct? By bringing us face to face with such questions, technology has the effect of calling society's bluff and thereby preparing the ground for changes in its values.

In the case where technological change alters the relative costs of implementing different values, it impinges on inherent contradictions in our value system. To pursue the same example, modern technology can enhance the values we associate with democracy. But it can also enhance another American value — that of "secular rationality," as sociologists call it — by facilitating the use of scientific and technical expertise in the process of political decision making. This can in turn further reduce citizen participation in the democratic process. Technology thus has the effect of facing us with contradictions in our value system and of calling for deliberate attention to their resolution.

* * *

ECONOMIC AND POLITICAL ORGANIZATION

The Enlarged Scope of Public Decision Making

When technology brings about social changes (as described in the first section of this essay) that impinge on our existing system of values (in ways reviewed in the second section), it poses for society a number of problems that are ultimately political in nature. The term "political" is used here in the broadest sense: It encompasses all of the decision making structures and procedures that have to do with the allocation and distribution of wealth and power in society. The political organization of society thus includes not only the formal apparatus of the state but also industrial organizations and other private institutions that play a role in the decision making process. It is particularly important to attend to the organization of the entire body politic when technological change leads to a blurring of once-clear distinctions between the public and private sectors of society and to changes in the roles of its principal institutions.

It was suggested above that the political requirements of our modern technological society call for a relatively greater public commitment on the part of individuals than in previous times. The reason for this, stated most generally, is that technological change has the effect of enhancing the importance of public decision making in society, because technology is continually creating new possibilities for social action as well as new problems that have to be dealt with.

A society that undertakes to foster technology on a large scale, in fact, commits itself to social complexity and to facing and dealing with new problems as a normal feature of political life. Not much is yet known with any precision about the political imperatives inherent in technological change, but one may nevertheless speculate about the reasons why an increasingly technological society seems to be characterized by enlargement of the scope of public decision making.

For one thing, the development and application of technology seems to require large-scale, and hence increasingly complex, social concentrations, whether these be large cities, large corporations, big universities, or big government. In instances where technological advance appears to facilitate reduction of such first-order concentrations, it tends to instead enlarge the relevant system of social organization, that is, to lead to increased centralization. Thus, the physical dispersion made possible by transportation and communications technologies, as Meyer and Kain have shown, enlarges the urban complex that must be governed as a unit.

A second characteristic of advanced technology is that its effects cover large distances, in both the geographical and social senses of the term. Both its positive and negative features are more extensive. Horse-powered transportation technology was limited in its speed and capacity, but its nuisance value was also limited, in most cases to the owner and to the occupant of the next farm. The supersonic transport can carry hundreds across long distances in minutes, but its noise and vibration damage must also be suffered willy-nilly by everyone within the limits of a swath 3,000 miles long and several miles wide.

The concatenation of increased density (or enlarged system) and extended technological "distance" means that technological applications have increasingly wider ramifications and that increasingly large concentrations of people and organizations become dependent on technological systems.... The result is not only that more and more decisions must be social decisions taken in public ways, as already noted, but that, once made, decisions are likely to have a shorter useful life than heretofore. That is partly because technology is continually altering the spectrum of choices and problems that society faces, and partly because any decision taken is likely to generate a need to take ten more.

These speculations about the effects of technology on public decision making raise the problem of restructuring our decision making mechanisms — including the system of market incentives — so that the increasing number and importance of social issues that confront us can be resolved equitably and effectively.

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The Promise and Problems of Scientific Decision Making

There are two further consequences of the expanding role of public decision making. The first is that the latest information-handling devices and techniques tend to be utilized in the decision making process. This is so (1) because public policy can be effective only to the degree that it is based on reliable knowledge about the actual state of the society, and thus requires a strong capability to collect, aggregate, and analyze detailed data about economic activities, social patterns, popular attitudes, and political trends, and (2) because it is recognized increasingly that decisions taken in one area impinge on and have consequences for other policy areas often thought of as unrelated, so that it becomes necessary to base decisions on a model of society that sees it as a system and that it is capable of signaling as many as possible of the probable consequences of a contemplated action.

As Professor Alan F. Westin points out, reactions to the prospect of more decision making based on computerized data banks and scientific management techniques run the gamut of optimism to pessimism mentioned in the opening of this essay. Negative reactions take the form of rising political demands for greater popular participation in decision making, for more equality among different segments of the population, and for greater regard for the dignity of individuals. The increasing dependence of decision making on scientific and technological devices and techniques is seen as posing a threat to these goals, and pressures are generated in opposition to further "rationalization" of decision making processes. These pressures have the paradoxical effect, however, not of deflecting the supporters of technological decision making from their course, but of spurring them on to renewed effort to save the society before it explodes under planlessness and inadequate administration.

The paradox goes further and helps to explain much of the social discontent that we are witnessing at the present time. The greater complexity and the more extensive ramifications that technology brings about in society tend to make social processes increasingly circuitous and indirect. The effects of actions are widespread and difficult to keep track of, so that experts and sophisticated techniques are increasingly needed to detect and analyze social events and to formulate policies adequate to the complexity of social issues. The "logic" of modern decision making thus appears to require greater and greater dependence on the collection and analysis of data and on the use of technological devices and scientific techniques. Indeed, many observers would agree that there is an "increasing relegation of questions which used to be matters of political debate to professional cadres of technicians and experts which function almost independently of the democratic political process."[2] In recent times, that process has been most noticeable, perhaps, in the areas of economic policy and national security affairs.

This "logic" of modern decision making, however, runs counter to that element of traditional democratic theory that places high value on direct participation in the political processes and generates the kind of discontent referred to above. If it turns out on more careful examination that direct participation is becoming less relevant to a society in which the connections between causes and effects are long and often hidden — which is an increasingly "indirect" society, in other words — elaboration of a new democratic ethos and of new democratic processes more adequate to the realities of modern society will emerge as perhaps the major intellectual and political challenge of our time.

The Need for Institutional Innovation

The challenge is, indeed, already upon us, for the second consequence of the enlarged scope of public decision making is the need to develop new institutional forms and new mechanisms to replace established ones that can no longer deal effectively with the new kinds of problems with which we are increasingly faced. Much of the political ferment of the present time — over the problems of technology assessment, the introduction of statistical data banks, the extension to domestic problems of techniques of analysis developed for the military services, and the modification of the institutions of local government — is evidence of the need for new institutions....

CONCLUSION

As we review what we are learning about the relationship of technological and social change, a number of conclusions begin to emerge. We find, on the one hand, that the creation of new physical possibilities and social options by technology tends toward, and appears to require the emergence of, new values, new forms of economic activity, and new political organizations. On the other hand, technological change also poses problems of social and psychological displacement.

The two phenomena are not unconnected, nor is the tension between them new. Man's technical prowess always seems to run ahead of his ability to deal with and profit from it. In America, especially, we are becoming adept at extracting the new techniques, the physical power, and the economic productivity that are inherent in our knowledge and its associated technologies. Yet we have not fully accepted the fact that our progress in the technical realm does not leave our institutions, values, and political processes unaffected. Individuals will be fully integrated into society only when we can extract from our knowledge not only its technological potential but also its implications for a system of values and a social, economic, and political organization appropriate to a society in which technology is so prevalent....

ENDNOTES

1. Unless otherwise noted, studies referred to in this article are described in the Fourth Annual Report (1967–68) of the Harvard University Program on Technology and Society.
2. Harvey Brooks, "Scientific Concepts and Cultural Changes," in G. Holton, ed., *Science and Culture* (Boston: Houghton Mifflin, 1965), p. 71.

8

Technology: The Opiate of the Intellectuals

JOHN McDERMOTT

Several months after the report containing Emmanuel Mesthene's article was published by Harvard, a sharply critical review-essay by John McDermott appeared in The New York Review of Books. *McDermott's essay, which follows here, is not a point-by-point analysis or rebuttal of the Mesthene work. Rather, it is McDermott's attempt to critique the entire point of view that he sees as epitomized by Mesthene — "not of a new but of a newly aggressive right-wing ideology in this country." McDermott focuses on a notion he calls* laissez innover, *from the French for "let them innovate," an adaptation of the more common* laissez faire *meaning "let them do as they please (i.e., in a free market economy)." The idea behind* laissez innover *(which McDermott rejects) is that technology can be seen as a self-correcting system. Mesthene, he claims, finds this principle acceptable because he defines technology abstractly. McDermott himself, however, rejects* laissez innover *because he claims to see specific characteristics in contemporary technology that contradict the abstraction.*

Concentrating on the application of technology to the war in Vietnam, McDermott examines its nature and concludes that "technology, in its concrete, empirical meaning, refers fundamentally to systems of rationalized control over large groups of men, events, and machines by small groups of technically skilled men operating through organized hierarchy." Using this definition, he proceeds to discuss the social effect of modern technology in America, concluding that the ideology of laissez innover *is attractive to those in power since they are in a position to reap technology's benefits while avoiding its costs.*

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From "Technology: The Opiate of the Masses," from *The New York Review of Books*, July 31, 1969.

Time: A Theoretical Reconstruction *(2003). McDermott received his B.A. from Brooklyn College, a unit of CUNY, the City University of New York.*

I

If religion was formerly the opiate of the masses, then surely technology is … … the opiate of the educated public today, or at least of its favorite authors. No other single subject is so universally invested with high hopes for the improvement of mankind generally and of Americans in particular….

These hopes for mankind's, or technology's, future, however, are not unalloyed. Technology's defenders, being otherwise reasonable men, are also aware that the world population explosion and the nuclear missile race are also the fruit of the enormous advances made in technology during the past half-century or so. But here, too, a cursory reading of their literature would reveal widespread though qualified optimism that these scourges, too, will fall before technology's might. Thus, population (and genetic) control and permanent peace are sometimes added to the already imposing roster of technology's promises. What are we to make of such extravagant optimism?

In early 1968, Harvard University's Program on Technology and Society … issued its Fourth Annual Report to the accompaniment of full front-page coverage in *The New York Times* (January 18). Within the brief (fewer than 100) pages of that report, and most clearly in the concluding essay by the Program's director, Emmanuel G. Mesthene, one can discern some of the important threads of belief that bind together much current writing on the social implications of technology. Mesthene's essay is worth extended analysis, because these beliefs are of interest in themselves and, of greater importance, because they form the basis not of a new but of a newly aggressive right-wing ideology in this country, an ideology whose growing importance was accurately measured by the magnitude of the *Times*'s news report.

… Mesthene believes there are two distinct problems in technology's relation to society, a positive one of taking full advantage of the opportunity it offers and the negative one of avoiding unfortunate consequences that flow from the exploitation of those opportunities. Positive opportunities may be missed because the costs of technological development outweigh likely benefits (e.g., Herman Kahn's "Doomsday Machine"). Mesthene seems convinced, however, that a more important case is that in which

> … technology lies fallow because existing social structures are inadequate to exploit the opportunities it offers. This is revealed clearly in the examination of institutional failure in the ghetto carried on by [the Program]….

His diagnosis of these problems is generous in the extreme:

> All these factors combine to dilute what may be otherwise a genuine desire to apply our best knowledge and adequate resources to the resolution of urban tensions and the eradication of poverty in the nation.

Moreover, because government and the media "are not yet equipped for the massive task of public education that is needed," if we are to exploit technology more fully, many technological opportunities are lost because of the lack of public support. This, too, is a problem primarily of "institutional innovation."

Mesthene believes that institutional innovation is no less important in combating the negative effects of technology. Individuals or individual firms that decide to develop new technologies normally do not take "adequate account" of their likely social benefits or costs. His critique is anticapitalist in spirit, but lacks bite, for he goes on to add that

> [most of the negative] consequences of technology that are causing concern at the present time — pollution of the environment, potential damage to the ecology of the planet, occupational and social dislocations, threats to the privacy and political significance of the individual, social and psychological malaise — are *negative externalities of this kind.* They are with us in large measure because it has not been anybody's explicit business to foresee and anticipate them. [Italics added]

Mesthene's abstract analysis and its equally abstract diagnosis in favor of "institutional innovation" place him in a curious and, for us, instructive position. If existing social structures are inadequate to exploit technology's full potential, or if, on the other hand, so-called negative externalities assail us because it is nobody's business to foresee and anticipate them, doesn't this say that we should apply technology to this problem, too? That is, we ought to apply and organize the appropriate *organizational* knowledge for the practical purpose of solving the problems of institutional inadequacy and "negative externalities." Hence, in principle, Mesthene is in the position of arguing that the cure for technology's problems, whether positive or negative, is still more technology. This is the first theme of the technological school of writers and its ultimate First Principle.

Technology, in their view, is a self-correcting system. Temporary oversight or "negative externalities" will and should be corrected by technological means. Attempts to restrict the free play of technological innovation are, in the nature of the case, self-defeating. Technological innovation exhibits a distinct tendency to work for the general welfare in the long run. *Laissez innover!*

I have so far deliberately refrained from going into any greater detail than does Mesthene on the empirical character of contemporary technology, for it is important to bring out the force of the principle of *laissez innover* in its full generality. Many writers on technology appear to deny in their definition of the subject — organized knowledge for practical purposes — that contemporary technology exhibits distinct trends, which can be identified or projected. Others, like Mesthene, appear to accept these trends, but then blunt the conclusion by attributing to technology so much flexibility and "scientific" purity that it becomes an abstraction infinitely malleable in behalf of good, pacific, just, and egalitarian purposes. Thus, the analogy to the *laissez-faire* principle of another time is quite justified. Just as the market or the free play of competition provided in theory the optimum long-run solution for virtually every aspect of virtually every social and economic problem, so too does the free play of technology, according to its writers. Only if technology or innovation (or some other synonym) is allowed the freest possible reign, they believe, will the maximum social good be realized.

What reasons do they give to believe that the principle of *laissez innover* will normally function for the benefit of humankind rather than, say, merely for the belief of the immediate practitioners of technology, their managerial cronies, and for the profits accruing to their corporations? As Mesthene and other writers of his school are aware, this is a very real problem, for they all believe that the normal tendency of technology is, and ought to be, the increasing concentration of decision-making power in the hands of larger and larger scientific-technical bureaucracies. *In principle,* their solution is relatively simple, though not often explicitly stated.[1]

Their argument goes as follows: The men and women who are elevated by technology into commanding positions within various decision-making bureaucracies exhibit no generalized drive for power such as characterized by, say, the landed gentry of pre-industrial Europe or the capitalist entrepreneur of the last century, for their social and institutional position and its supporting culture as well are defined solely by the fact that these men are problem-solvers. (Organized knowledge for practical purposes again.) That is, they gain advantage and reward only to the extent that they can bring specific technical knowledge to bear on the solution of specific technical problems. Any more general drive for power would undercut the bases of their usefulness and legitimacy.

Moreover, their specific training and professional commitment to solving technical problems creates a bias against ideologies in general, which inhibits any attempts to formulate a justifying ideology for the group. Consequently, they do not constitute a class and have no general interests antagonistic to those of their problem-beset clients. We may refer to all of this as the disinterested character of the scientific-technical decision-maker, or, more briefly and cynically, as the principle of the Altruistic Bureaucrat....

This combination of guileless optimism with scientific tough-mindedness might seem to be no more than an eccentric delusion were the American technology it supports not moving in directions that are strongly antidemocratic. To show why this is so, we must examine more closely Mesthene's seemingly innocuous distinction between technology's positive opportunities and its "negative externalities." In order to do this, I will make use of an example drawn from the very frontier of American technology: the war in Vietnam.

II

* * *

Advanced technological systems such as those employed in the bombardment of South Vietnam make use not only of extremely complex and expensive equipment but, quite as important, of large numbers of relatively scarce and expensive-to-train technicians. They have immense capital costs: a thousand aircraft of a very advanced type; literally hundreds of thousands of spare parts; enormous stocks of rockets, bombs, shells, and bullets; in addition to tens of thousands of technical specialists — pilots, bombardiers, navigators, radar operators, computer programmers, accountants, engineers, electronic and mechanical technicians, to name only a few. In short, they are "capital intensive."