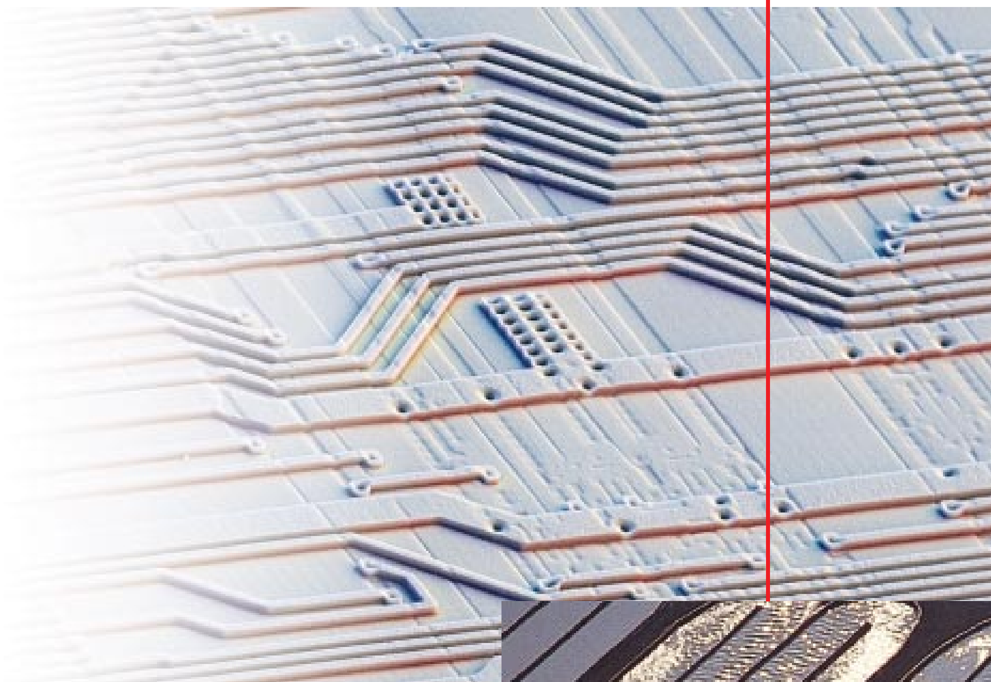
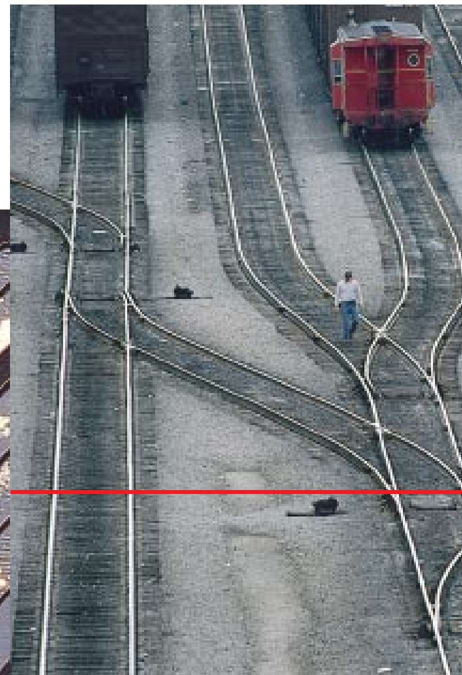
# LIVING WITH NEW TE





# CHNOLOGIES

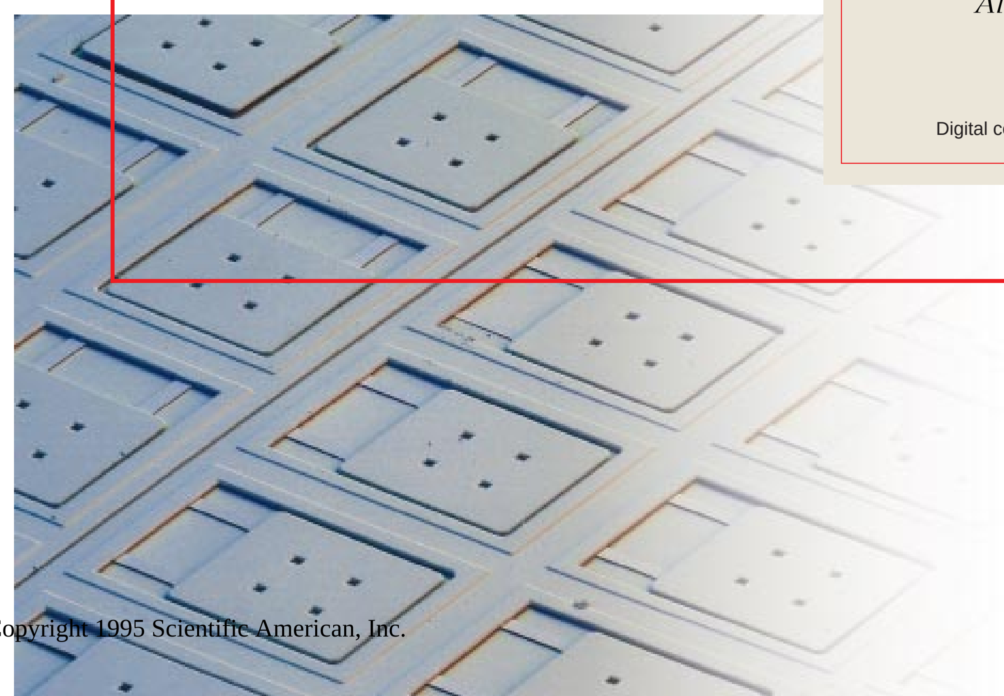
*Technology will not solve all our problems. It may even create some. But, despite its shortcomings, it continues to offer us ever more ways to work, play, and order our lives.*

## COMMENTARIES

Contents



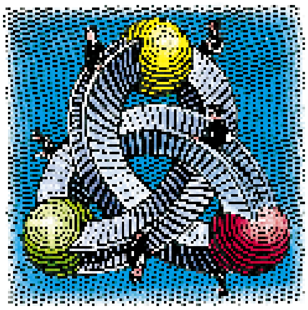
Digital composition by Tom Draper



# Technology Infrastructure

## *Industrial advances will depend on setting new standards*

by Arati Prabhakar



The dictionary defines "infrastructure" as an underlying foundation. In society, that means such basic installations as roads, power grids and communications systems. It is the stuff we take for granted, at least when it works. Because this support is often out of sight, its essential role tends to be out of mind. For the most part, it should be. As technology advances, however, the infrastructure must evolve as well. Thus, now is the time to think about the enabling tools and underpinning technologies that will be needed in the next century.

The information revolution and global marketplace are demanding an increasingly diverse array of infrastructural technologies. When the National Bureau of Standards—now the National Institute of Standards and Technology (NIST)—was founded in the U.S. at the turn of the century, its mission was to create measurement standards so that items such as automobiles could be mass-produced most efficiently. For the automotive industry today, such guidelines pertain to far more than the sizes of interchangeable parts. To analyze properly the chemical composition of a car's exhaust, standardized samples of carbon monoxide and nitrous oxides, among other gases, are needed. So, too, thermocouples, which feed temperature readings into a car's microprocessor-based engine controller, must be made according to strict specifications so that their signals are accurate.

In a decade the automotive infrastructure will have expanded even more. Cars will very likely be designed and manufactured using standardized product data exchange specifications (PDES). Over computer networks, these digital blueprints will pass like relay batons between designers and engineers, making it easier to simulate the performance of sundry auto parts before they are made. Standardized formats for these specifications should also allow for more agile manufacturing practices, making it economically feasible to produce more custom-tailored models.

In addition, future cars may contain more parts made from composite materials, including mixes of polymers and ceramic reinforcements. These substitutes are as strong as steel yet much lighter. Hence, they could yield highly fuel-efficient, clean vehicles. Such materials were originally devised for defense applications; at the moment, they are too expensive to use in large amounts in automotive manufacturing. But the Advanced Technology Program (ATP)—unfolding at many high-tech companies in partnership with NIST—aims to develop affordable, high-performance varieties of composites. Companies that are arch rivals outside the ATP framework are now collaborating toward this end. ATP is enabling the industry as a whole to pursue this promising technology, which is too risky for any one company to take on.

Looking even further ahead, a variety of powerful sensors, computers and communications devices may innervate cars, roads, bridges and traffic management systems. Some of these additions may result from new chip designs that will themselves require new infrastructural technologies. Microprocessor chips, for example, will soon have parts only about 0.25 micron in size, putting them in the realm of large viruses. Innovations in microlithography and other microfabrication techniques should soon lower that scale to 0.1 micron or less—at which point new measuring devices will be needed.

NIST has already begun testing one such device, the Molecular Measuring Machine, or $M^3$. This instrument can map out subatomic detail over an area the size of a credit card. Equipped with the $M^3$, semiconductor manufacturers will be able to trace their measurements to references that are accurate to within less than 2.5 nanometers (or the width of about eight water molecules in a row). Such precision will assist in continuing efforts to shrink the size of integrated circuits and to increase the power of devices that contain them.

A team at NIST has worked on the hardware and software for the $M^3$ since 1987. To minimize errors caused by vibrations or temperature changes, the tiny probe at the heart of the instrument—a sophisticated scanning tunneling microscope—is housed within a basketball-size copper sphere; this sphere is then nested within a series of successively larger shells. A computer system uses laser interferometers, a meticulously machined sliding carriage and piezoelectric flexing elements to produce controllable displacements as small as 0.075 nanometer (or less than the diameter of a hydrogen atom). To validate the machine's performance for these minute motions, the team will turn to a nanoruler: an atomically smooth surface of a crystal such as tungsten diselenide. The accurately measured distance between single atoms in this crystal can serve as the ruler's gradations. Also, because the crystal is flat over an uncommonly large area, it can serve as an ultrahigh-accuracy geometry reference for $M^3$, much as a square does for a machinist.

On long road trips, your children might be entertained by electronic and communications devices manufactured with the help of $M^3$. To that end, the infrastructure of the coming century will probably include digital video standards so that interactive programs can be broadcast over complex information networks. Another focused program within the ATP is bringing together the many different players who hope to make this scenario real.

The list goes on. Workers are trying to devise fingerprint- or face-recognition systems that could allow you to enter your car quickly and easily without a key. Such systems will call for sophisticated software algorithms, however: they will need to recognize the same fingerprint, for example, even when its appearance varies slightly from one press to the next. Vendors and buyers will need standard benchmarks to compare the performance of these future software programs. Benchmarks will also be needed to judge the quality of laboratories doing genetic testing and other biotechnology-based analyses. Such procedures will probably be far more commonplace in 21st-century clinical settings than they are now.

Adam Smith wrote two centuries ago in *The Wealth of Na-*

*tions* that the state is responsible for "erecting and maintaining those public institutions and those public works, which though they may be in the highest degree advantageous to a great society, are, however, of such a nature, that the profit could never repay the expense to any individual or small number of individuals, and which it, therefore, cannot be expected that any individual or small number of individuals should erect or maintain." These words have never been more true.

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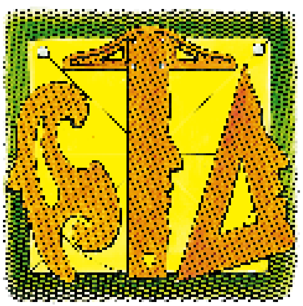
# Designing the Future

## *Too frequently, product designers disregard the psychology of the user*

by Donald A. Norman



The difficulty of programming videocassette recorders has become a worldwide joke. "I'm a rocket scientist," one engineer complained to me. "I design missile systems, but I can't figure out how to program my VCR." Why is it that we sometimes have so much trouble working apparently simple things, such as doors and light switches, water faucets and thermostats, to say nothing of computers and automated factory equipment? The answer lies not with the hapless user but with designers who fail to think about products from the operator's point of view. The steps required to run modern devices frequently seem arbitrary and capricious often because they are indeed confusing.

Although most problems arise with electronic equipment, certain fundamental design flaws can be illustrated with simple mechanical objects. Consider the door. With most doors, there are only two possible actions: push or pull. But which? Where? Poorly designed doors turn the operation into a guessing game, requiring the posting of signs to indicate the appropriate action. Now suppose a door had a flat metal panel along one side. The panel by itself would essentially say, "Push here." You would immediately know how to proceed, because the maker included a visible cue to the door's operation. The best cues offer an intuitive indication of the things you can do with an object—what James J. Gibson of Cornell University had termed the object's "affordances." In general, if a simple piece of equipment such as a door or a kitchen stove requires labeling, that need is a sign of design failure. Wonderful capabilities become meaningless if they are hard to discover and use.

Providing unambiguous cues to the operation of a device is only one part of good design. A few other, related principles need to be invoked as well. First, people can manipulate things better when they understand the logic behind how the objects work. Designers can help convey this information by giving users a "conceptual model," or a simple way to think about how the device operates. For example, the modern computer often labels stored information as being in files and folders, as if our central processing units contained metal cabinets in which manila files were stuffed into hanging green folders. Of course, there are no physical files or folders inside the computer, but this model helps users understand how to save and retrieve their work.

Second, each operation should be followed promptly by some sort of feedback that indicates the operation was successful, even in cases where the output is not immediately apparent. The spinning clock or hourglass displayed by some computer systems is useful for indicating that a command was understood but that its instructions will take some time to complete.

Finally, the controls on a machine should be positioned in a way that correlates with their effects. On well-designed stoves, for example, if the burners are arranged in a rectangular pattern, the controls should also be arranged in a rectangular pattern, so the left rear control operates the left rear burner, and so on. Today most stoves have the burners arranged in a rectangle with their controls in a line: no wonder people frequently make mistakes, despite the labels.

As automation increases, the need to apply such principles becomes more urgent. Once upon a time, technology was mostly mechanical. Everything was built of levers, gears, cogs and wheels. Workers who operated tools could view many of the parts and could see the effects of their actions. People had some hope of understanding how large machinery and small gadgets worked, because the parts were visible. The operation of modern machines and the concepts behind their design are invisible and abstract. There may be nothing to see, nothing to guide understanding. Consequently, workers know less and less about the inner workings of the systems under their control, and they are at an immediate disadvantage when trouble erupts.

Such alienation has startling effects: most industrial and aviation accidents today are attributed to human error. When the majority of accidents stem from mistakes made by operators, the finding is a sign that the equipment is not designed appropriately for the people who must use it. Many manufacturers—and much of society—still follow the "blame and train" philosophy: when an accident occurs, blame the operators and retrain them. A more appropriate response would be to redesign devices in a way that minimizes the chance for error in the first place. And when errors do occur, the machinery should ensure that the mistakes are readily caught and corrected before they do damage. Most technologists do not have the proper training or knowledge needed to design such error-resistant systems. To cope with this gap, a discipline in applied cognitive science—variously called human factors, ergonomics or cognitive engineering—has arisen. Scientists in this field develop design concepts emphasizing the mental rather than physical side of design.

As the articles in this issue attest, we are in the midst of a sweeping technological transformation. But this revolution is also a human and social one. The great promised advances in knowledge, communications, cooperative work, education and entertainment will come about only if the technology truly fits the needs and capabilities of its users. To make technology that fits human beings, it is necessary to study human beings. But now we tend to study only the technology. As a result, people are required to conform to technology. It is time to reverse this trend, time to make technology conform to people.

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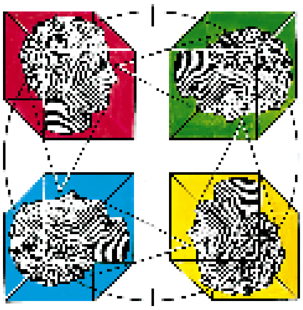
# Digital Literacy

## *Multimedia will require equal facility in word, image and sound*

by Richard A. Lanham



The word "literacy," meaning the ability to read and write, has gradually extended its grasp in the digital age until it has come to mean the ability to understand information, however presented. Increasingly, information is being offered in a new way: instead of black letters printed on a white page, the new format blends words with recorded sounds and images into a rich and volatile mixture. The ingredients of this combination, which has come to be called multimedia, are not new, but the recipe is.

New, too, is the mixture's intrinsic volatility. Print captures utterance—the words are frozen on the page. This fixity confers authority and sometimes even timeless immortality. That is why we value it, want to get things down in "black-and-white," write a sonnet, in Horace's words, "more lasting than bronze." The multimedia signal puts utterance back into time: the reader can change it, reformat and rescale it, transform the images, sounds and words. And yet, at the end of these elegant variations, the original can be summoned back with a keystroke.

Print literacy aimed to pin down information; multimedia literacy couples fixity and novelty in a fertile oscillation. Contrary to the proverbial wisdom, in a digital universe you can eat your cake and have it, too: keep your original and digest it on your own terms. And because digital code is replicable without material cost, you can give your cake away as well.

Printed books created the modern idea of "intellectual property" because they were fixed in form and difficult to replicate. One could therefore sell and own them, and the livelihoods of printer and author could be sustained. This copyright structure dissolves when we introduce the changeable multimedia signal. We will have to invent another scaffolding to fit the new literacy. Judging from the early signs, it won't be easy.

There is one other way in which digital flexibility is radical. If we ask, looking through the wide-angle lens of Western cultural history, "What does multimedia literacy do?", a surprisingly focused answer comes back. It recaptures the expressivity of oral cultures, which printed books, and handwritten manuscripts before them, excluded.

In writing this text, for example, I have been trying to create a credible "speaking voice," to convince you that I am a person of sense and restraint. Now imagine that you can "click" on an "author box." I appear as a moving image, walk into the margin and start to speak, commenting on my own argument, elaborating it, underlining it with my voice, gesture and dress—as can happen nowadays in a multimedia text.

What has changed? Many of the clues we use in the oral culture of daily life, the intuitive stylistic judgments that we depend on, have returned. You can see me for yourself. You can hear my voice. You can feed that voice back into the voiceless prose and thus animate it. Yet the writing remains as well. You can see the author with stereoscopic depth, speaking in a space both literate and oral.

Oral cultures and literate cultures go by very different sets of rules. They observe different senses of time, as you will speedily understand if you listen to one of Fidel Castro's four-hour speeches. Oral cultures prolong discourse because, without it, they cease to be; they exist only in time. But writing compresses time. An author crams years of work into some 300 pages that the reader may experience in a single day.

Oral and literate cultures create different senses of self and society, too. The private reflective self created by reading differs profoundly from the unselfconscious social role played by participants in a culture that knows no writing. Literacy allows us to see human society in formal terms that are denied to an oral culture that just plays out its drama.

The oral and written ways of being in the world have contended rancorously throughout Western history, the rancor being driven more often than not by literate prejudice against the oral rules. Now the great gulf in communication and in cultural organization that was opened up by unchanging letters on a static surface promises to be healed by a new kind of literacy, one that orchestrates these differences in a signal at the same time more energizing and more irenic than the literacy of print.

If we exchange our wide-angle cultural lens for a close-up, we can observe the fundamental difference between the two kinds of literacies. In the world of print, the idea and its expression are virtually one. The meaning takes the form of words; words generate the meaning. Digital literacy works in an inherently different way. The same digital code that expresses words and numbers can, if the parameters of expression are adjusted, generate sounds and images. This parametric variation stands at the center of digital expressivity, a role it could never play in print.

The multiple facets of this digital signal constitute the core difference between the two media, which our efforts in data visualization and sonification have scarcely begun to explore. If we think of the institutional practices built on the separation of words, images and sounds—such as separate departments for literature, art and music—we can glimpse the profound changes that will come when we put them back together.

To be deeply literate in the digital world means being skilled at deciphering complex images and sounds as well as the syntactical subtleties of words. Above all, it means being at home in a shifting mixture of words, images and sounds. Multimedia literacy makes us all skilled operagoers: it requires that we be very quick on our feet in moving from one kind of medium to another. We must know what kinds of expression fit what kinds of knowledge and become skilled at presenting our information in the medium that our audience will find easiest to understand.

We all know people who learn well from books and others who learn by hands-on experience; others, as we say in music, "learn by ear." Digital literacy greatly enhances our ability to suit the medium both to the information being offered and to the audience. Looked at one way, this new sensory targeting makes communication more efficient. Looked at another, it simply makes it more fun.

The multimedia mixture of talents was last advanced as an aristocratic ideal by the Renaissance humanists. The courtly lord and lady were equally accomplished in poetry, music and art. The Renaissance ideal now presents itself, broadened in scope and coarsened in fiber perhaps, as the common core of citizenship in an information society.

At its heart, the new digital literacy is thus profoundly democratic. It insists that the rich mixture of perceptive talents once thought to distinguish a ruling aristocracy must now be extended to everyone. It thus embodies fully the inevitable failures, and the extravagant hope, of democracy itself.

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# The Information Economy

## *How much will two bits be worth in the digital marketplace?*

by Hal R. Varian

Advances in computers and data networks inspire visions of a future "information economy" in which everyone will have access to gigabytes of all kinds of information anywhere and anytime. But information has always been a notoriously difficult commodity to deal with, and, in some ways, computers and high-speed networks make the problems of buying, selling and distributing information goods worse rather than better.

To start with, the very abundance of digital data exacerbates the most fundamental constraint on information commerce—the limits of human comprehension. As Nobel laureate economist Herbert A. Simon puts it: "What information consumes is rather obvious: it consumes the attention of its recipients. Hence a wealth of information creates a poverty of attention, and a need to allocate that attention efficiently among the overabundance of information sources that might consume it." Technology for producing and distributing information is useless without some way to locate, filter, organize and summarize it. A new profession of "information managers" will have to combine the skills of computer scientists, librarians, publishers and database experts to help us discover and manage information. These human agents will work with software agents that specialize in manipulating information—offspring of indexing programs such as Archie, Veronica and various "World Wide Web crawlers" that aid Internet navigators today.

The evolution of the Internet itself poses serious problems. Now that the Internet has been privatized, several companies are competing to provide the backbones that will carry traffic between different local networks, but workable business models for interconnection—who pays how much for each packet transmitted, for example—have yet to be developed. If interconnection standards are developed that make it cheap and easy to transmit information across independent networks, competition will flourish. If technical or economic factors make interconnection difficult, so that transmitting data across multiple networks is expensive or too slow, the largest suppliers can offer a significant performance advantage; they may be able to use this edge to drive out competitors and monopolize the market.

Similar problems arise at the level of the information goods themselves. There is a growing need for open standards for formats used to represent text, images, video and other collections of data, so that one producer's data will be accessible to another's software. As with physical links, it is not yet clear how to make sure companies have the right economic incentives to negotiate widely usable standards.

In addition to standards for the distribution and manipulation of information, we must develop standards for networked economic transactions: the actual exchange of money for digital goods. There are already more than a dozen proposals for ways to conduct secure financial transactions on the Internet. Some of them, such as the DigiCash system, involve complex encryption techniques; others, such as that used by First Virtual, are much simpler. Many of these protocols are implemented entirely in software; others enlist specialized hardware to support electronic transactions. "Smart" credit cards with chips embedded in them can perform a variety of authentication and accounting tasks.

Even when the financial infrastructure becomes widely available, there is still the question of how digital commodities will be priced. Will data be rented or sold? Will articles be bundled together, as is done today in magazines and newspapers, or will consumers purchase information on an article-by-article basis? Will users subscribe to information services, or will they be able to buy data spontaneously? How will payment be divided among the various parties involved in the transaction, such as authors, publishers, libraries, online services and so on? Not one of these questions has a definitive answer, and it is likely that many market experiments will fail before viable solutions emerge.

The shared nature of information technology makes it critical to address issues of standardization and interoperability sooner rather than later. Each consumer's willingness to use a particular piece of technology—such as the Internet—depends strongly on the number of other users. New communications tools, such as fax machines, VCRs and the Internet itself, have typically started out with long periods of relatively low use followed by exponential growth, which implies that changes are much cheaper and easier to make in the early stages. Furthermore, once a particular technology has penetrated a significant portion of the market, it may be very difficult to dislodge. Fortunes in the computer industry have been made and lost from the recognition that people do not want to switch to a new piece of hardware or software—even if it is demonstrably superior—because they will lose both the time they have invested in the old ways and the ability to share data easily with others. If buyers, sellers and distributors of information goods make the wrong choices now, repairing the damage later could be very costly.

This discussion about managing, distributing and trading in information is overshadowed by the more fundamental issue of how much data authors and publishers will be willing to make available in electronic form. If intellectual property protection is too lax, there may be inadequate incentives to produce new electronic works; conversely, if protection is too strict, it may impede the free flow and fair use of information. A compromise position must be found somewhere between those who suggest that all information should be free and those who advocate laws against the electronic equivalent of browsing at a magazine rack.

Extending existing copyright and patent law to apply to digital technologies can only be a stopgap measure. Law appropriate for the paper-based technology of the 18th century will not be adequate to cope with the digital technology of the 21st; already the proliferation of litigation over software patents and even over the shape of computer-screen trash cans makes the need for wholesale revisions apparent.

Computer scientists have been investigating various forms of copy protection that could be used to enforce whatever legal rules may be put into place. Although such protection often inconveniences users and requires additional hardware and software, ubiquitous network access and more powerful machines may eventually allow for unobtrusive and effective protection. File servers, for example, can track who owes how much to whom for the use of particular information, and documents can be subtly encoded so that investigators can trace the provenance of illicit copies.

Faced with such a daunting list of problems, one might be led to question whether a viable information economy will ever take shape, but I believe there are grounds for optimism. During the 1980s, 28,000 for-profit information libraries sprang up in the U.S. alone. Every week more than 50 million people visit these facilities, where they can rent 100 gigabytes of information for only two or three dollars a day.

Although these video rental stores faced many of the same problems of standards, intellectual-property protection, and pricing that the Internet faces today, the industry grew from nothing to $10 billion a year in only a decade. Ten years from now we may find the economic institutions of the information economy a similarly unremarkable part of our day-to-day life.

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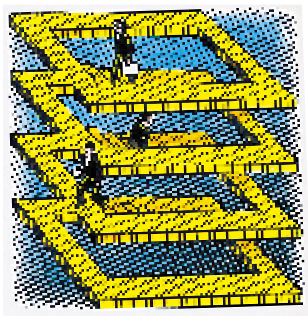
# The Emperor's New Workplace

## *Information technology evolves more quickly than behavior*

by Shoshana Zuboff



According to the U.S. Department of Commerce, 1990 was the first year capital spending on the information economy—that is, on computers and telecommunications equipment—exceeded capital spending on all other parts of the nation's industrial infrastructure. Scholars and commentators have cited these data as evidence the U.S. economy is now firmly rooted in the information age. They routinely declare that an "information economy" has replaced the industrial economy that dominated most of the 20th century. I heartily dissent.

In a true information economy, information is the core resource for creating wealth. Constructing such an economy demands more than just a proliferation of computers and data networks. It requires a new moral vision of what it means to be a member of an organization and a revised social contract that binds members of a firm together in ways radically different from those of the past. So far patterns of morality, sociality and feeling are evolving much more slowly than technology. Yet without them, the notion of an information economy is much like the foolish emperor of the fairy tale, naked and at risk.

A historical perspective makes the problem clearer. Early in the 20th century an organizational form—the functional hierarchy—was invented to meet the business challenges of increasing throughput and lowering unit costs. Business processes were divided into separate functions—manufacturing, engineering, sales and so on. Other innovative features included mass-production techniques, the minute fragmentation of tasks, the professionalization of management, the growth of the managerial hierarchy to standardize and control operations, and the simplification and delegation of administrative functions to a newly contrived clerical workforce. Collectively, these components were incredibly successful; they came to define the modern workplace.

The industrial hierarchy rested on the premise that complexity could constantly be removed from lower level jobs and passed up to the management ranks. That is, clerks and factory workers became progressively less involved in the overall business of a firm as their jobs were narrowed and stripped of opportunities to exercise judgment. Automation was a primary means of accomplishing this. Meanwhile the manager's role evolved as guardian of the organization's centralized knowledge base. His legitimate authority derived from being credited as someone fit to receive, interpret and communicate orders based on the command of information.

We have come to accept that a managerial hierarchy operating in this way reflects a reasonable division of labor. We are less comfortable discussing the moral vision at its heart, something I call the "division of love." I suggest that the managerial hierarchy drew life not only from considerations of its efficiency but also from the ways in which some members of the organization were valued and others devalued.

In the brave new age of the information economy, this system cannot hold. Mass-market approaches have been forced to give way to a highly differentiated and often information-saturated marketplace in which firms must distinguish themselves through the value they add in response to customers' priorities. Information technologies now provide the means for generating such value with speed and efficiency.

Doing so means using the modern information infrastructure to cope with the complexities of a business outside a central managerial cadre. It is more efficient to handle complexity wherever and whenever it first enters the organization—whether during a sale, during delivery or in production.

This approach is now possible because of the way the unique characteristics of information technologies can transform work at every organizational level. Initially, most people regarded computers in the workplace as the next phase of automation. But whereas automation effectively hid many operations of the overall enterprise from individual workers, information technology tends to illuminate them. It can quickly give any employee a comprehensive view of the entire business or nearly infinite detail on any of its aspects.

I coined the word "informate" to describe this action. These technologies informate as well as automate: they surrender knowledge to anyone with the skills to access and understand it. Earlier generations of machines decreased the complexity of tasks. In contrast, information technologies can increase the intellectual content of work at all levels. Work comes to depend on an ability to understand, respond to, manage and create value from information. Thus, efficient operations in the informated workplace require a more equitable distribution of knowledge and authority. The transformation of information into wealth means that more members of the firm must be given opportunities to know more and to do more.

To avail themselves of the opportunities, firms must be prepared to drive a stake into the heart of the old division of labor (and the division of love sustaining it). Exploiting the informated environment means opening the information base of the organization to members at every level, assuring that each has the knowledge, skills and authority to engage with the information productively. This revamped social contract would redefine who people are at work, what they can know and what they can do.

The successful reinvention of the firm consistent with the demands of an information economy will continue to be tragically limited as long as the principal features of modern work are preserved. Unlocking the promise of an information economy now depends on dismantling the very same managerial hierarchy that once brought greatness. Only then can the emperor come in from the cold, because we will have found the way to clothe him.

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# What Technology Alone Cannot Do

## *Technology will not provide us all with health, wealth and big TVs*

by Robert W. Lucky

The subway sways and creaks as it travels away from Manhattan on the elevated tracks through Queens. Looking at the passing cityscape, I see the familiar skeletal steel of the Unisphere rising above the apartment buildings like some dark moon. As the subway rushes toward that rusting remnant of the 1964 World's Fair, I am transported in memory back to my eager visits there as a young technologist. I see again through youthful eyes the excitement and the promises for the future made in the exhibitions of that now demolished fair.

Surely every reader remembers some similar experience—an exposition, an exhibit or a theme park portraying a glittering technological future, where smiling people clustered around large television sets in solar homes that required no maintenance. As this standard demographic family basked in the glow of mindless electronic entertainment, "smart" toasters and robot vacuum cleaners hummed subserviently in the background. Even the standard demographic dog watched attentively, sporting a slight smile of superiority.

I remember the vision of a future in which drudgery had been eliminated, where everyone had health and wealth and where our chief preoccupation had become filling the void of expanding leisure time. Life had become effortless and joyful, and science and technology had made it all possible. Like most visitors, I suppose, I was caught up in the euphoria of that vision and believed in it completely.

The subway rounds a bend, and the sudden jolt brings me back to the present. I am once again enveloped in the microcosm of contemporary society randomly gathered in the drab confines of the rushing car. Where is that World's Fair family today, I wonder? What happened to those plastic people with their plastic home and their plastic lives? Surely none of my fellow passengers fit their description. These people look as though they have experienced continuous drudgery. The group seems to be divided into two nonoverlapping categories—those with no leisure time and those with nothing but leisure time. If technology was going to solve their problems, then technology has apparently failed.

Even as I consider that possibility, though, I vehemently reject it. What we accomplished in the three decades since that fair closed went far, far beyond the most outrageous projections we could have then conceived: we walked on the moon; we brought back pictures from the farthest reaches of the solar system and from orbiting telescopes peering into the very origins of the universe; we blanketed the earth with fiber-optic links and networked the planet with high-speed digital communications; we created microchips containing millions of transistors and costing so little that many homes could have a computer more powerful than the mainframes of that earlier day; we unraveled DNA and probed the fundamental building blocks of nature. No, science and technology did not fail. They just weren't enough.

There is a simplistic notion, which is crystallized in exhibitions such as World's Fairs, that we can invent the future. Alas, it does not seem to be so. Those awesome scientific developments of the past three decades have apparently missed my subway companions. Life's everyday problems, as well as the deeper problems of the human condition, seem resistant to quick technological fixes. The solutions shown in that forgotten World's Fair now appear at best naive or superficial, if not misleading or just plain wrong. Nevertheless, if you visit a similar exhibit today, I am sure it will acquire over time these same attributes.

If we could go back to 1964 and create in retrospect an exhibition of the future, what would we now include? Certainly the scientific accomplishments would deserve mention, but they would be framed in a social context. In our imaginary fair we would shock our disbelieving visitors by predicting the end of the cold war and the disintegration of the Soviet Union. We would say that nuclear missiles would cease to occupy people's fears but that, unfortunately, smaller wars and racial and ethnic strife would proliferate.

Sadly, we would have to predict that the inner cities would decay. We would report that a new disease of the immune system would sweep over the earth. We would tell of pollution cluttering the great cities and mention that environmental concerns would drive government policies and forestall the growth of nuclear power. Malnutrition, illiteracy and the gap between the haves and the have-nots would be as great as ever. Illegal drugs, terrorism and religious fundamentalism would become forces of worldwide concern. Only a small fraction of families would have two parents and a single income. Oh, and by the way, we would have big television sets.

Some years ago I was invited to be a guest on a television show hosted by a well-known, aggressive and sometimes offensive character. The host's producers assured me that this would be a serious show, marking the beginning of a new image for their client. The program would be devoted to a look at the future through the eyes of experts. Somehow, in spite of the firmly voiced apprehensions of my company's public relations people, I ended up in front of a television camera alongside scholars of education, medicine, finance, crime and the environment. I was "the technologist."

Somewhere I have a tape recording of that televised show, but I intend never to watch it. The educator told how illiteracy was on the rise and test scores were plummeting. The medical researcher said that progress in conquering the dread diseases was at a standstill. The financial expert forecasted that world markets would crumble. The criminologist gave statistics on the rise of crime, and the environmentalist predicted ubiquitous and unstoppable pollution. All agreed that the future would be bleak.

When the host finally turned to me, I said something to the effect that technology was neat, and it would make work easier and leisure time more fun. I think I said we all would have big television sets. I remember the way the other guests stared at me. "Can you believe such naiveté?" they seemed to say to one another. The host looked pained; he was into predictions of doom. Stubbornly, if feebly, I insisted that life would be better in the future because of technology.

Even today I blush remembering my ineptitude. But I do still believe there is a germ of truth in optimistic predictions. The continuous unraveling of nature's mysteries and the expansion of technology raise the level on which life, with all its ups and downs, floats. Science and technology, however, depend for their effect on the complex, chaotic and resistant fabric of society. Although they cannot in themselves make life better for everyone, they create a force that I believe has an intrinsic arrow, like time or entropy, pointing relentlessly in one direction: toward enhancing the quality of life.

I sometimes reflect on the historical contributions technology has made to human comfort. When I visit the ancient castles of Europe, I imagine the reverberant call of trumpets and the pageantry and glory that once graced those crumbling ruins. But then I shiver in the dampness and cold and notice the absence of sanitation. Life now is unquestionably better, and there is no reason to think it will not be similarly improved in the future.

Overall progress is assured, but science and technology interwork with societal factors that determine their instantaneous utility and ultimate effect. This interplay is especially apparent in the current evolution of cyberspace. Ironically, the term was coined by William Gibson in *Neuromancer,* a novel that depicted a future in which the forces of computerized evil inhabited a shadowy world of networked virtual reality. Gibson's vision of gloom seems in step with those of my televised companions. In reality, though, cyberspace is a place where new communities and businesses are growing, and it seems largely to benefit its participants.

There are a multitude of meetings and conferences at which scientists and engineers talk about the evolution of the information infrastructure. But what do we talk about? Not the technology, to be sure. We talk about ethics, law, policy and sociology. Recognizing this trend, a friend recently wondered aloud if, since technologists now regularly debate legal issues, lawyers have taken to debating technology. At my next meeting with lawyers, I asked if this were indeed the case. They looked at me blankly. "Of course not," someone finally said. In fact, lawyers are just as comfortable in cyberspace as are scientists. It is a social invention. The problems that we all debate pertain to universal access, rights to intellectual property, privacy, governmental jurisdiction and so forth. Technology was the enabler, but these other issues will determine the ultimate worth of our work.

The Unisphere is receding from view, and my memories fade. As I look around the subway, I sense that my companions do not care about cyberspace or anything else so intangible. The never-ending straight track ahead and the relentless forward thrust of the car seem indicative of technology and life. Despite continuous motion on the outside, life on the inside seems still and unaffected. The Unisphere and the technology that it represents drift silently by, perceived only dimly through the clouded windows. The only real world—the one inside the car—remains unmoved in the midst of motion. Science urges us ever forward, but science alone is not enough to get us there.

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