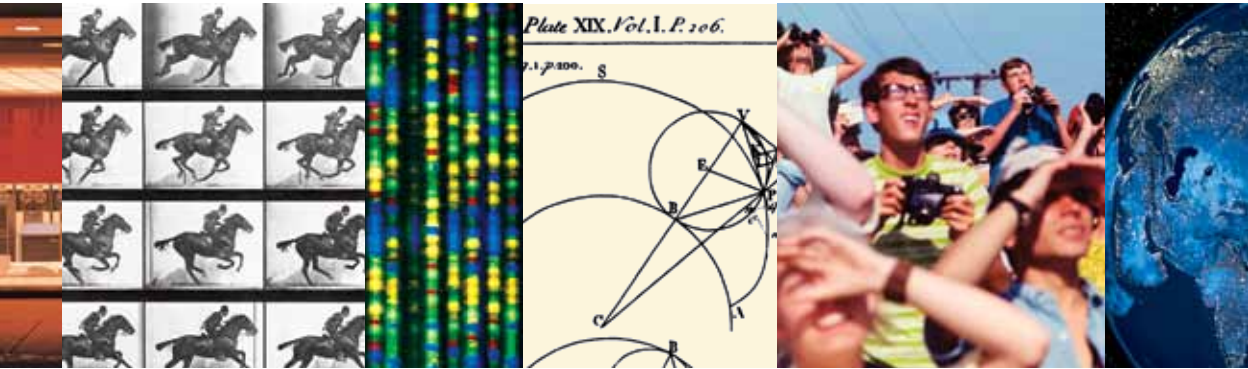


MAKING THE WORLD WORK BETTER



THE IDEAS THAT SHAPED A CENTURY AND A COMPANY

Kevin Maney • Steve Hamm • Jeffrey M. O'Brien

Foreword by Samuel J. Palmisano

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Of Change and Progress

Samuel J. Palmisano

CHAIRMAN, PRESIDENT AND CHIEF EXECUTIVE OFFICER
IBM CORPORATION

One simple way to assess the impact of any organization is to answer the question: how is the world different because it existed?

The date of this volume's publication, June 16, 2011, is a meaningful one for IBM. On it, we celebrate our centennial as a corporation. For IBMers today—women and men who have lived through an eventful part of that history—that means reconnecting to a storied past, and understanding its implications for a still-unfolding story.

But we believe the lessons of our history apply more broadly. Whether you seek to understand the trajectory of technology or to build and sustain a successful enterprise or to make the world work better, there is much to learn from IBM's experience. And because these lessons have significance that goes far beyond our company—and because we wish to understand them better ourselves—we decided to do something different from a typical commemorative publication.

Rather than simply chronicle the company's long list of achievements, we reached out to three journalists who have covered our industry for years. In fact, all of them have interviewed me at one time or another. They have a wealth of knowledge about technology, business and history, and each one offers a distinct perspective on what it all means. Plus, they're all crack reporters. We

asked them to take a deep dive into three aspects of how the world has changed and to explore IBM's role in that change.

I have been fascinated by the results of their research—in particular, the underlying beliefs they discovered. Our company, of course, became famous for Thomas Watson Sr.'s Basic Beliefs, the principles that were intended to guide IBMers' behavior. And in recent years, we have come together as a workforce to reexamine and redefine our core values. Interestingly, what the research for this book uncovered was another set of ideas that were never written down, but that nonetheless have pervaded IBM from its birth up to the present day.

One of those has to do with the nature of computation and information science. Kevin Maney's exploration of the history of this technology and the industry it spawned reminds us that it is a lot richer and more nuanced than most people today realize. If your knowledge comes from the media, you might think that the story of IT is divided into two phases—hardware and software. Or that it all falls into pre-Internet and post-Internet eras. Kevin's longer lens does much to clarify the far more multidimensional history of computation, IBM's role in shaping it and how its foundational components are advancing and recombining today.

But he does even more. As Kevin argues, the core elements of computing mirror key dimensions of the human brain. The story of their evolution shows how our thinking changes the tools we create, and how the tools we create then change the way we think. And this deeper understanding makes it clear that scientific truth isn't either/or, and discovery isn't simply before-and-after. At the start of the twenty-first century, we find ourselves at an inflection point in both scientific thought and technological capability—a moment whose implications leaders and citizens must study if they wish to ride the waves of our planet's information-shaped future.

Similarly, Steve Hamm's look at IBM's growth into a new kind of business institution doesn't just chronicle the triumphs, mistakes and repeated reinvention of one company. Steve offers intriguing new perspectives on some well-worn truisms. For one: the emergence of an information-based economy. We are all familiar with the shift from atoms to bits as the source of economic value. But it has further implications. Because information knows no borders, it also leads inevitably toward a global economy—and toward the increasing convergence of business and society. We learn how becoming global is about a lot more than geography, a lot more than simply having a presence all around the world. Finally,

this narrative underscores how an enduring organizational culture isn't just a fact of nature but a deliberate act of its people—one that involves a lot more than dress codes and team-building exercises.

Neither Thomas Watson nor his son had available to him the sophisticated language we use today to describe this complex system—much less the scientific and business disciplines that have arisen over the past half century to study it. What they did have was the intention to build a particular kind of enterprise—a set of gut impulses, if you will, about what a business should be. As a result of those impulses, IBM's experience through the twentieth century did much to shape the modern corporation. And as Steve's essay persuasively argues, what IBM is still becoming offers interesting perspectives on the new ways any organization—in business, government, education or beyond—can answer basic questions like: How does it create value? How does it attract, develop and retain people? How does it organize and manage itself? What role does it play in society at large? What makes it unique?

Finally, Jeff O'Brien's research reveals compelling examples of what is required to accomplish the hard work of progress in an increasingly complex and interconnected world. When you look at the work IBM and

others have done decade after decade—work that is accelerating today—a certain pattern of activity and mode of thought emerge. Technology alone, no matter how powerful, cannot bring about systemic change. It turns out that deliberately changing the way the world works requires a broader, longer-term approach, with the mastery of a few basic steps.

Looking at advances over the past century, Jeff uncovers a simple, intuitive and powerful model of progress. Today, that model is being renewed by our technology-powered capacity to see, map and understand vast amounts of new data about every dimension of both nature and society, opening up ways to make our world literally work better. And yet, these stories argue that acting—actually changing the complex systems of our planet in lasting ways—relies most fundamentally not on data but on belief. Our learning depends on a prior faith in our capacity to learn—as Thomas Watson Sr. often said, to *think*.

The lead actor through these narratives is a collective enterprise based on the power of ideas—their economic power, their galvanizing and structuring power, their transformational power. These are the ideas that drive progress—and by progress, I mean building a world that is not only more prosperous, more sustainable and

fairer, but also better able to continually transform itself; a world that learns. When IBMers are at their best, the pursuit of this form of progress infuses everything they do.

Now, one way to explore and chronicle that idea is through science. We can also look at it within the framework of management theory. But the discipline that actually seems most appropriate is history—hence this volume and these writers.

On a personal note, let me say that this approach is encouraging for an old liberal arts major like me. More than once during my 38-year career here, I have jokingly apologized for my lack of scientific background. In truth, it can be intimidating to be surrounded by brilliant engineers, scientists, MBAs and other such thinkers. And without question, the amazing stories in these chapters do nothing to counter that feeling. On the contrary, they instill a deep sense of humility. I can't help being surprised to find myself in this position at this institution at this moment. I've been very lucky, indeed.

Still, it is gratifying to see what the lens of history reveals about our company, the world in which it has grown and the trajectories it has influenced. Without doubt, the perspective of history allows us to see IBM in a way that IBMers could not have done in earlier eras—

which seems appropriate on the occasion of our 100th birthday.

How is the world different because IBM existed? The stories in this volume provide a fascinating set of answers, and an even more intriguing set of yet-to-be-answered questions.

My fellow IBMers and I are proud to have been part of this journey during our own time here. We are inspired by the legacy of the pioneers who built this company. We are committed to serve as stewards of the collective enterprise they left in our care. And we are excited about the fundamental transformations that lie ahead, as the trajectories of the past converge and point us toward a very different future.

For IBM's clients, and for the communities of which we are a part, this convergence promises a smarter planet. For IBMers, it points toward a future that will be built by a new generation—the IBMers of tomorrow. It is these women and men for whom this book is intended, and to whom it is dedicated.

• • •



IBM

Pioneering
the Science of
Information
Kevin Maney

On March 28, 1955, the cover of *Time* featured a drawing of IBM president Thomas Watson Jr. in front of a cartoonish robot, along with this caption: “Clink. Clank. Think.” At the time, few but a small cadre of experts had ever seen—much less touched—a computer. The magazine story marveled at the machinery, built by IBM and operating inside a Monsanto office building.

“To IBM, it was the Model 702 Electronic Data Processing Machine,” the story said. “To Monsanto and awed visitors, it was simply ‘the giant brain.’”

We can’t help considering computers this way. No matter the year—1911, 1955 or 2011—we continue to equate the functions of the hard, rigid, electric-powered computer with the squishy, pliable, biologically powered human brain. Computers have always been tools but function no more like a brain than a hammer works like a hand. Yet we mix the metaphors, with the idea that as computers advance, we can hand them more of the work of the mind, making them partners in our efforts to improve the world and manage its increasing complexity. IBM had thought of computing that way for much of its existence. As *Time* put it in that 1955 article:

IBM’s new brain is a logical extension of the company’s famed slogan, “THINK.” In the age of giant electronic brains, IBM’s President Thomas J. Watson Jr. is applying to machines the slogan which his father, IBM’s Board Chairman Thomas J. Watson Sr., applied only to men. President Watson hopes to mechanize hundreds of processes which require the drab, repetitive “thought” of everyday business. Thus liberated from grinding routine, man can put his own brain to work on problems requiring a function beyond the capabilities of the machine: creative thought.

Of course, the world’s information scientists and technologists haven’t spent the past 100 years trying to build a computer that can mimic the workings of the human brain. The goal has always been to augment the uniquely human capacity to think. Even though a computer beat the world chess champion and won against the two all-time champions on the TV quiz show *Jeopardy!*, a computer can’t reason any more than a pitching machine can be a star baseball player. Still, the evolution of computing has done more than solve really hard math problems.

INFORMATION TECHNOLOGY LITERALLY CHANGES THE WAY WE THINK. It moves ahead, showing us what’s possible and freeing our minds to dream of what we can do next. The dreams inspire us to build better technology, which in turn unleashes new ideas about what technology can do.

But there’s a part of the information revolution that Watson Jr. missed. All of the pieces of computing—sensors, storage, processors, software, networks—have conspired to abstract information and thought processes from individual brains. What people know—even the decisions they know how to make—is captured and shared. It’s combined with data about nature and human activity—information we’ve recently begun to capture in unprecedented volume and with unprecedented speed through sensors and electronic transactions. Technology is pumping the world’s knowledge into a global pool, creating a higher plane—or, at least, a broader field—of consciousness. The quest to make machines think has delivered not a parody of individual human thought but a new kind of thinking. Many interconnected individuals can have access to the same wealth of information at nearly the same time and work on it together with the help of machines. We’re creating a humming hive of knowledge, people and computers, all feeding one another.

Ultimately, the goal of this symbiotic relationship is to make the world work better. We are constantly creating systems that raise the level of existence on our planet.

The story of how we got here begins in 1911 with crude punched card machines and charges into the future with technology that can deliver supercomputer-like simulations to handheld devices through a cloud computer network and embed computing and networking into the very fabric of business and life. The details of that journey can be understood by examining the breakthroughs in six pillars of how information technology has evolved.

Sensing

The mechanisms for getting information from people and events into computers.

Memory

The way computers store and access information.

Processing

The core speed and capabilities of computers.

Logic

The software and languages that let computers do work.

Connecting

The ways computers talk to people and machines.

Architecture

The changing nature of computing and of the way we think about information.

Together, those pillars mesh and make up the modern computing environment. The stories behind the development of the pillars have heroes from all over the world. They worked at Bell Labs, Machines Bull, Cray Research, Intel, Xerox PARC, Sony, Apple and other companies and entities. IBM has played a significant role throughout the story of computing, through every decade of the past 100 years.

In 1911, financier Charles Flint merged three small technology companies: one making computing scales (which automatically figured out the total price of an item sold by weight); one making tabulating machines; and one making time-recording clocks that workers punched at factories. At first it was called the Computing-Tabulating-Recording-Company, or C-T-R, joined in 1914 by Thomas Watson Sr. In 1924, he changed the name to International Business Machines. The company has thrived for 100 years by building on those first simple information products and in every way continually making them better, faster, more efficient—smarter.

From his start in 1914, Watson introduced the iconic slogan “Think.” And since then, his company has played a lead role in reinventing thought.

• • •

Processing

At its core, computation is about processing ones and zeros. Computing power is the art of doing so faster and faster.

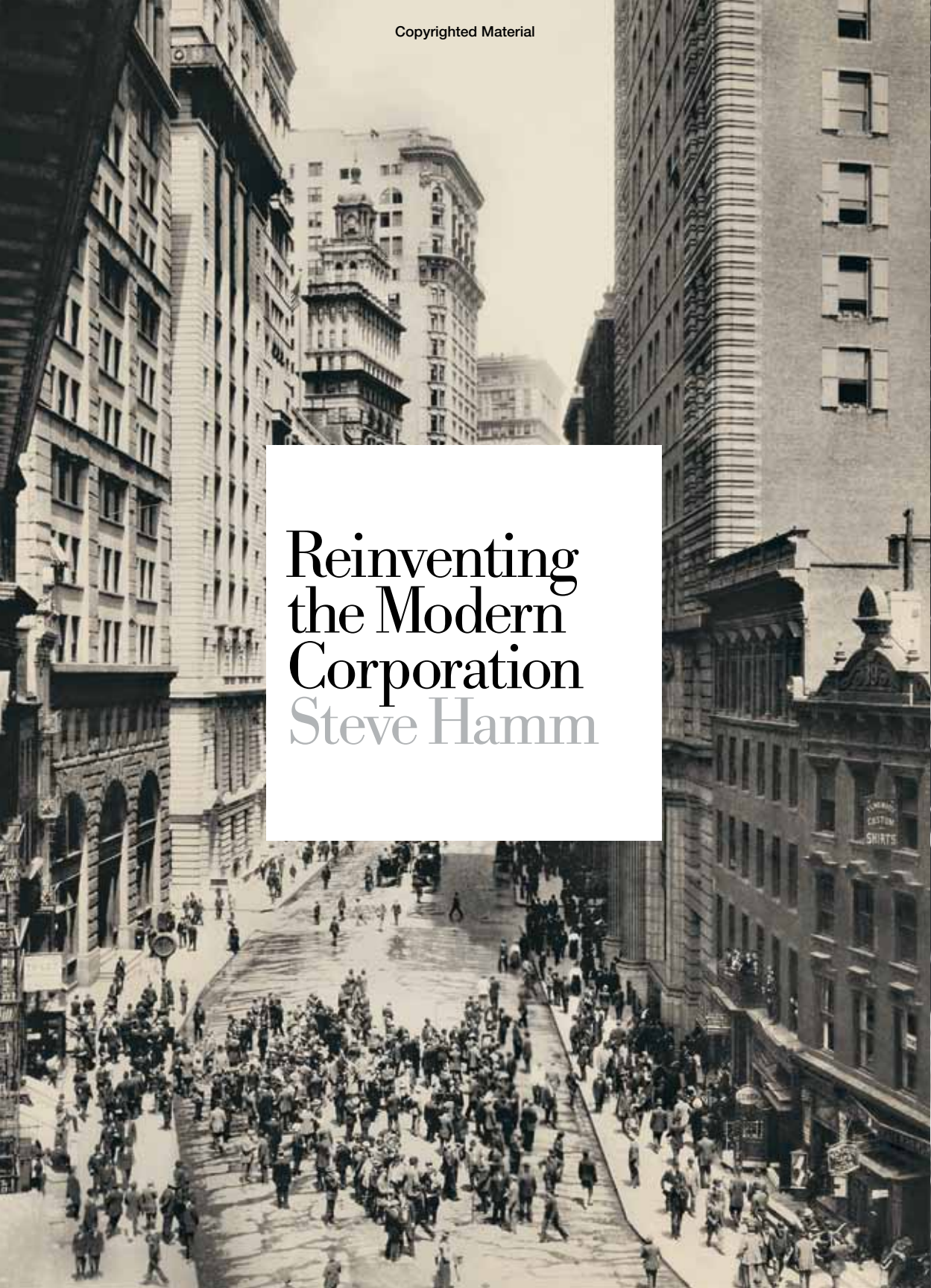
These vacuum tubes, from a 1953 system, could multiply two 10-digit numbers 2,000 times per second.





The System/360 was an end-to-end compatible system that could adapt to different uses and changing needs, bringing computing into the core infrastructure of business and society.

The 360 family included six processor models covering a 50-fold range in performance and 54 different peripheral devices, including several types of magnetic storage devices, visual display units, communication equipment, card readers and punches, printers, and an optical character reader. Monthly rentals at the time ranged from \$2,700 for a basic configuration to \$115,000 for a typical large multisystem configuration.



Reinventing the Modern Corporation

Steve Hamm



When Thomas Watson Sr. joined the Computing-Tabulating-Recording-Company as general manager in 1914, he stood at the epicenter of American capitalism at the dawn of a new era. The fledgling company, which he later renamed International Business Machines, had been formed three years earlier through the merger of three small manufacturing firms that sold mechanical accounting machines, scales and time recorders. Headquarters was a suite of offices in a newly built 20-story building at 50 Broad Street in New York City, 50 yards from the New York Stock Exchange and a short distance from the Lower East Side, the original home of New York's bustling garment industry.

To enter the building, Watson sometimes had to shoulder his way through an unruly crowd of traders who bought and sold securities at the so-called curb market on the cobblestones of Broad Street. Up on the 18th floor at C-T-R, the 40-year-old executive sat each day at a simple wooden desk dressed in a three-piece suit with a stiff Edwardian collar, poring over ledgers and correspondence. He could glance through the windows at the hubbub in the street far below—where the traders' derby hats and dark suits made them look like ants swarming at a picnic. His perch turned out to be a perfect spot from which to help invent the modern corporation.

New York was bursting with humanity in those days. Immigrants from Russia, Italy, Ireland, Germany and elsewhere poured off ships and into the city's narrow streets and warrens of rattletrap tenements. The human

torrent had nearly doubled the population over the previous two decades, to 4.8 million.⁶⁰ New York was both the nation's financial capital, home of the moneymen and traders who funded the industries of a burgeoning economy, and a manufacturing dynamo, jammed with clothing factories, printing plants, machine shops and gritty metal foundries. For more than a century, captains of industry had built empires by extracting value from natural resources or by building mammoth steel mills and continent-spanning railroads and harnessing the strong backs and nimble fingers of laborers. In 1920, the US census revealed that 30 percent of the working population was employed in manufacturing and 26 percent worked in farming, forestry and fishing. The other major categories were trade (10.2 percent), domestic and personal service (8.2 percent), clerical (7.5 percent) and transportation (7.4 percent).⁶¹ Indeed, the leaders of heavy industry and commerce made up C-T-R's client base.⁶²

Yet Watson fashioned C-T-R into a very different sort of company from those that surrounded him. He realized that his company's counting and calculating devices could help those railroads, steel companies, manufacturers and merchants manage their data. He saw that in the new century, a company's most valuable assets would be the information it amassed, the knowledge it created and the ideas of its employees—intellectual capital rather than money, muscle or raw material. “Tom Watson should be credited with the idea that information was going to be the big thing in the twentieth century,” said Harvard Business School professor Richard Tedlow, author of *The Watson Dynasty*.⁶³

When Watson took over C-T-R, the idea of the modern corporation was just beginning to form, and he played a significant role in laying its foundation. An outgrowth of the large industrial and financial organizations that had dominated commerce in Western societies, the modern corporation was also, in the United States, a reaction against the excesses of the Gilded Age, when market manipulators and anticompetitive trusts distorted the economy. In the new century, the form and function of the

Previous pages:

Broad Street in New York City, 1903 (left),
and Thomas Watson Sr., 1913.

corporation were to undergo rapid change as the world's great commercial organizations mastered the science of applying new ways to extract and manage information to harness capital, natural resources and people and put them to work in increasingly effective, efficient and ambitious ways.

In 1914, this transformation was hardly clear—including in Watson's own mind. His belief in information and thinking was both fervent and unformed. It was clear to him that information would be the basis of economic value. It was also clear to him that commerce was destined to become global. He was convinced that businesses would have responsibilities not just to their shareholders but also to society at large. And he doggedly aimed to build an organization that self-consciously embodied his mantra, "Think." Over the next 40 years, he would start a process of discovery—with many missteps but with more successes—translating these gut impulses into policies and practices, scientific discoveries and the then-radical notion of an intentionally created corporate culture.

Today, we are again at a turning point in the history of the corporation. Faced with a potent mix of economic, environmental and political challenges, corporate leaders are reexamining basic assumptions. Just as diverse populations once poured into the commercial and societal melting pot of New York City, so, today, those who previously sat on the sidelines are becoming players in the global economy—as both consumers and producers. Business powerhouses are emerging from China, India, Korea, South Africa and elsewhere. They're inventing business models that give them the power to reshape established industries and leapfrog the twentieth century's giants. The Internet is disrupting traditional ways of doing business in one market after another, from media and music to manufacturing and retailing. It levels the playing field globally for businesses and individuals. Jobs that were once anchored in one place by tradition and convenience now can be done anywhere in the world. And the barriers to entry—once insuperable to all who could not amass large amounts of capital—are dramatically lower.

Individual citizens can become global capitalists. To combine two of the most widely used metaphors of our era, the global economy is becoming a long, flat tail.

How should businesses respond? As before, leaders are asking themselves fundamental questions about what their company should be and how it should operate—the kinds of questions that have shaped business thinking from ancient Greece to modern Silicon Valley. But today the answers are changing—and with neck-snapping speed. So it's time to reinvent the corporation once more. This essay lays out a point of view on the past and present of the modern corporation—and on what progress will look like in the twenty-first century. It is organized around four basic questions that leaders must ask and answer:

HOW DOES A COMPANY DEFINE AND MANAGE ITSELF? Over the past 100 years, corporate management has shifted away from the nineteenth-century mode of centering a company around a single powerful leader, adopting a more networked, horizontal approach. Though, of course, there are exceptions, today more and more organizations are guided by deliberately created corporate cultures, often grounded in shared values, that survive even when a leader departs. IBM was a pioneer in this shift—not simply in inculcating ethics, but also in seeking differentiation, organizational identity and the definition of the company's *raison d'être*. In the future, the challenge will be to create ultra-flexible organizations made up of empowered professionals who can anticipate and prepare for change rather than merely sense and respond to it.

HOW DOES THE ORGANIZATION CREATE VALUE? Through the lens of one company's evolution—but drawing broadly on modern business history—we can trace the shift from Industrial Age modes of value

creation to the twentieth century's monetization of knowledge and intellectual capital. This takes multiple forms and not just in product development but in every aspect of a company's operations. This progression suggests that organizations will increasingly create value by collaborating openly and deeply with other companies, and governments and even individuals, participating fully in a network economy.

HOW DOES THE ORGANIZATION OPERATE IN A GLOBAL ECONOMY? In the nineteenth century, being international meant having a presence all around the world. During the twentieth century, it came to mean something quite different: seeing the world holistically, both as a market and as a supply of resources and talent. As a result, the modern corporation has changed in form, from the international model of the nineteenth century to the multinational model of the twentieth to the globally integrated model of the twenty-first. Those companies that have succeeded, including IBM, have created new skills, processes and governance systems in order to manage the tensions inherent in being at once global and local.

HOW DOES THE ORGANIZATION ENGAGE WITH SOCIETY? Once, businesses answered only to their shareholders. Philanthropy was a personal matter for wealthy industrialists. Over the course of the twentieth century, the most enlightened corporations realized that how they defined themselves would hinge in part on developing responsible relationships with society—to the point that engaging with society has become woven into doing business, essential to nearly every decision an organization makes.

IBM's evolution over the past 100 years—including its near-death experience in the early 1990s—has made it a vastly different company from the one that Thomas Watson joined in 1914. Indeed, the company has changed enormously over the past decade. Throughout this journey, its leaders have asked those same fundamental questions, reaffirming some of the things the company once believed and coming up with some new answers. IBMers today know all too well what can happen if an organization loses sight of business fundamentals and fails to respond aggressively to satisfy its customers' deepest needs. And they understand that in today's business climate, what's required to last is nothing less than continuous transformation.

IBM is still reinventing itself—and it knows that the process will never be finished. Asked to name the most important lesson that IBM's history teaches us about leadership, chief executive Sam Palmisano didn't hesitate: "You have to be willing to change your core, and you have to be ahead of the shift."⁶⁴

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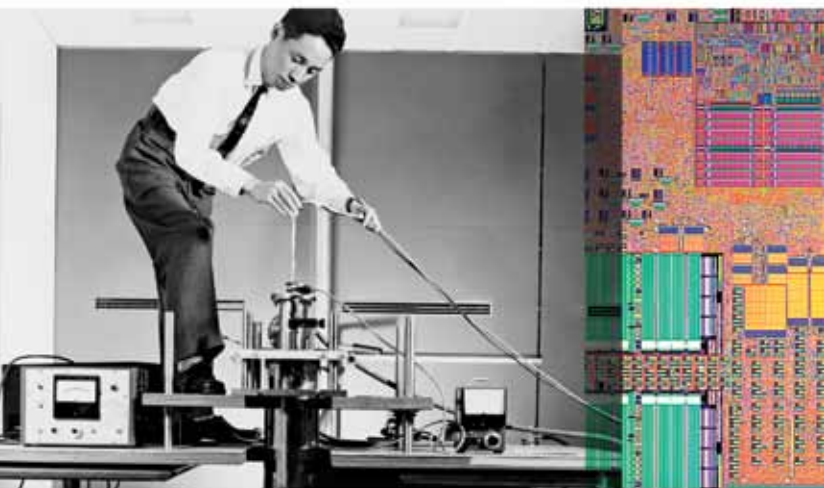
The Intentional Creation of Culture

When Soichiro Honda started the Honda Motor Company in 1948 to design and build motorcycles in war-ravaged Japan, his ambitions were audacious. A blacksmith's son who usually wore the blue overalls of a mechanic, Honda stood on an orange crate in the company's factory four years later and declared his intention to make Honda not just the number one motorcycle company in Japan but number one in the world.

He didn't achieve his goal overnight, but right from the start he set out to build a corporate culture that would enable a tiny company to grow to greatness.⁶⁵ He did it by establishing a respectful rapport with the company's employees and by giving them clear direction about the company's values and ambitions. For instance, in 1956 he published a "company principle" in Honda's newsletter, distilling the company's purpose down to its essence: "Maintaining a global viewpoint, we are dedicated to supplying products of the highest quality, yet at a reasonable price, for worldwide customer satisfaction."



In classrooms and data centers, assembly lines and sales training facilities, Thomas Watson's mantra, "Think," gave visible form to the novel idea that a company could deliberately create its culture.

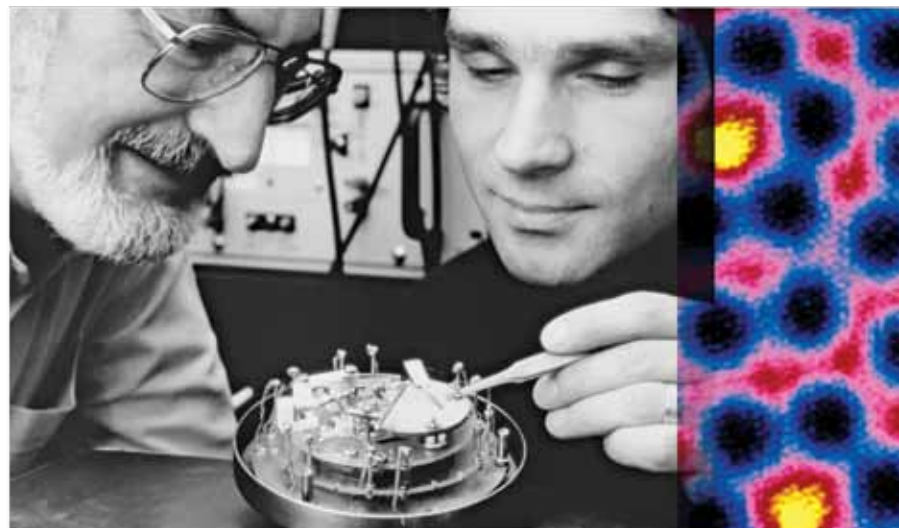


Leo Esaki was awarded a Nobel Prize in Physics in 1973 for his invention of the electron tunneling effect in semiconductors.

instinct was to institutionalize and expand what had been a comparatively informal organization, dominated by the outsized personality of his father. And here, IBM had a model: AT&T's Bell Laboratories. Established in 1925, the labs provided fundamental scientific research for the telephone company's business units.

In 1956, Watson hired Emanuel Piore, the former chief scientist at the US Office of Naval Research, as research director, and Piore assigned three senior IBM scientists, whom he called the Three Wise Men, to study the alternatives. After touring IBM's product development facilities and speaking to leaders in the research community, they recommended setting up an independent research organization that would focus on long-range projects rather than incremental advances that would be immediately useful for product development. Piore and Watson agreed and set the wheels in motion. "Some of these projects led to blind alleys, but others led to discoveries that put IBM in the lead," said Gardiner Tucker, one of the Three Wise Men and who later headed up IBM Research.¹²⁰

One such notable discovery came in 1981 at IBM's laboratory in Zurich, Switzerland. Working together, physicists Gerd Binnig and Heinrich Rohrer invented the scanning tunneling microscope, which for the first



Heinrich Rohrer (left) and Gerd Binnig received the Nobel Prize in Physics in 1986 for their invention of the scanning tunneling microscope.

time allowed scientists to see individual atoms. The STM became an essential tool in the emerging science of nanotechnology. Rohrer had hired Binnig right out of graduate school and asked him to study materials at a near-atomic level, but Binnig found that no existing microscopes were up to the job. So they decided to invent one. Binnig broke the lab rules and worked at night, when nobody else was around, to avoid sounds and vibrations that might disrupt his experiments. After months of trial and error, they invented a powerful tool that had an even higher resolution than they had expected. What made this discovery possible, according to Binnig, was a culture that gave scientists the freedom to pursue lines of inquiry wherever they led. "IBM was a place where you could go very deep and invent something completely new," said Binnig, who now works at Definiens, an imaging equipment company. For their work on the scanning tunneling microscope, the two scientists received the Nobel Prize in Physics in 1986.¹²¹

The results of this freedom were palpable. IBM scientists and engineers helped invent the Information Age, producing breakthroughs in information storage, semiconductor technology, database software, programming languages and computer systems. Along the way, researchers won nearly

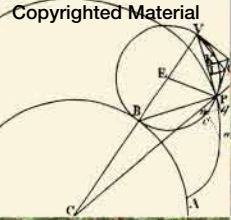


Alex Müller (left) and Georg Bednorz were awarded a Nobel Prize in 1987 for their discovery of high-temperature superconductivity in a new class of materials.



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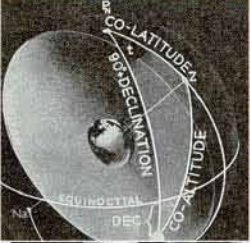
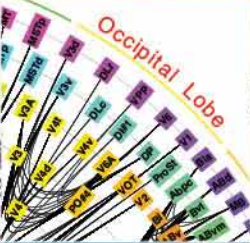
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Making the World Work Better

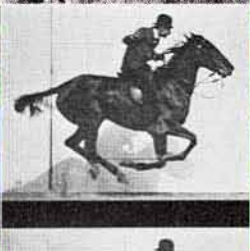
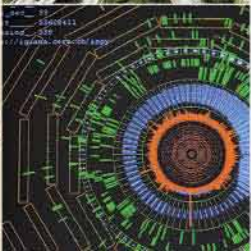
Jeffrey M. O'Brien

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More than a decade after his fateful operation, Mike May still tends to close his eyes for long stretches of conversations. It's a habit that developed in the weeks and months after he underwent an experimental stem cell procedure to restore his vision. After 43 years without sight, May was suddenly confronted by a torrent of imagery that flooded his navigational system and toppled his understanding of the world. As a blind man, May had been an independent, productive, self-assured member of society. Then he was crippled by vision.²²⁴

Blinded by a freak chemical accident at age 3, May spent decades making sense of the world using incomplete information. He became an accomplished technologist and inventor of a GPS navigation device for the blind, an avid traveler, a husband and father of two boys and a world-class skier capable of barreling down mountainsides at 65 miles an hour. Regaining sight in one eye (the other was damaged beyond repair) changed everything—and not always in a good way. Many everyday scenarios became too disturbing to bear. People's moving lips, contorted facial expressions, wild gesticulation—they all rendered conversation difficult. Skiing became far more dangerous when complicated by mountaintop vistas, bluebird skies, towering shadows and the appearance of other skiers. So May began closing his eyes to help him concentrate. "I am sure there will come a time when all this visual communication will mean more to me," May wrote in the *Guardian* not long after the operation, "but for now it is just distracting."²²⁵

As amazing as the procedure was from a medical standpoint, it was just the beginning of the incredible story, chronicled in the best-selling book *Crashing Through*, of a man traveling from self-sufficiency to functional paralysis and back.²²⁶ We don't usually think of seeing as a learned process because it occurs so early in life. But as May's tribulations demonstrate, seeing is a journey in itself. Overload wasn't the only complication. New visual data challenged May's long-held perceptions. Crashing waves were particularly confounding. His ears told him that shorelines were thunderous and intimidating; his vision told him they were soft and peaceful.

May also had to rethink the way the world operates. He always imagined his surroundings in a vectored grid; vision revealed a far messier reality. Interstate highways don't travel north-south and east-west; they curve and undulate with the terrain. He had drawn diagrams of entire airports in his mind to negotiate mazes of boarding gates, escalators, baggage turnstiles and taxi lines. But those maps turned out to be woefully incomplete. They advised him how to get from A to B but ignored much of the complexity—the shops, restrooms, alternative pathways and organized mayhem—in between.

May is a man with a vigorous spirit and an impressive desire to do more in life than merely get by. But he's also a metaphor. We're all coping with a barrage of vision. Data is overwhelming our navigational systems and challenging our notions of how the world works. Billions of sensors, cameras, microphones, telescopes, microscopes and mobile phones are constantly capturing streams of information about everything happening around us—the smallest movements, the slightest changes in chemical composition, the subtlest activities at the farthest reaches of space, inside atoms and nearly everywhere in between. May is in a perpetual struggle to reinterpret the world in full awareness. And so are we.

If we can find the meaning in all of the data, the effects will be transformative. Again, May stands as evidence. Like many proud fathers, he holds



After 43 years of blindness, Mike May underwent a stem cell procedure to restore his vision. The risky operation worked, but the results were far different from what he imagined. Seeing confused everything, overthrew his navigational system and upended his understanding of how the world worked.

his wife and two sons above his many other accomplishments. He never imagined that anything could make him love his family more. And then something suddenly did—it was the moment he saw, for the first time in his life, the color of his sons’ eyes and the beauty of his wife’s smile.

WHAT DOES IBM DO? It’s a question that many of the company’s more than 425,000 employees undoubtedly have encountered.²²⁷ Brand recognition remains strong around the globe, but since selling the personal computer division, the business has become more difficult to explain to casual observers. Financial analysts and the media use categorical shorthand like “software and services,” “information technology” or “consulting.” And while all of those are at least partly true, they hardly paint a full picture of the company’s enduring mission over a century. Chairman and CEO Sam Palmisano has an idea why the question can be so difficult to answer. “We’ve never defined ourselves by a hit product. From the beginning, the Watsons felt that IBM always had a bigger purpose,” he told me at corporate headquarters in Armonk, New York.²²⁸ “IBM has always been about a culture of innovation and doing things that are profound. We have always tried to make the world work better. And that certainly remains true today.”

IBMers make the world work better. It’s catchier than “software and services”—but only marginally more enlightening. Perhaps it would help to cite some examples. Over the course of a century, IBM has established itself as an innovation partner for enterprises and institutions around the globe. The company has enabled space travel, and designed social welfare programs, smart electricity grids, travel reservation systems and more efficient supply chains. All of those projects—and hundreds of others—seem to qualify as making the world work better. But what separates them from, say, building a sexier smartphone, which in many people’s eyes certainly contributes to a better world?

It’s partly a matter of scale. IBM’s greatest achievements involve designing and improving the sprawling architectures of our planet. There’s a scientific catchall term for these architectures: complex systems. Complex systems are hugely complicated, but that’s not what earns them their name. Here, the word *complex* is a synonym for “unpredictable”—or at least not easily predictable. Complex systems comprise thousands or even millions of cooperating parts whose interactions are not linear, but emergent. Working together, they produce surprising outcomes.

You know a complex system when you see one. In fact, they’re everywhere. We interact with dozens every day. They exist both in nature and by design and make up the fabric of our lives. A cardiovascular system is the collaboration of a heart and lungs, veins, capillaries, blood and chemicals—all complex systems in themselves—that in turn cooperates with a digestive system, nervous system and so forth to produce a surprising outcome: animal life. Wheat is a combination of roots, stem, leaves, chaff and grain kernel, along with many molecular-level components, all of which interact with sunshine, soil and water to produce the largest source of vegetable protein in the world. An e-commerce website is the front end of a complex retail system that conspires with a supply chain, an energy grid and a financial system to deliver goods and services to customers at the click of a button. The engine, brakes and design of a car; the roads, bike lanes, pedestrians and traffic lights; trains, buses and airplanes—they’re all components of a highly complex transportation system that takes us where we want to go.

We’d all like these systems to work better, more efficiently, more sustainably. But how do we get our arms and minds around something as vast as, say, education, much less figure out how to change it? A good start is determining what’s wrong. Unfortunately, that alone involves analyzing myriad variables to assess the effect of everything from funding and teacher quality to age of textbooks, emphasis on standardized testing, length of a school day and year, and even nutrition and sleep cycles. Healthcare is

worse. Improving overall health would go a long way toward reducing the inefficiency and bloat of our healthcare system (and vice versa). Even tackling one scourge, like childhood obesity, would free up resources to improve other aspects of the system. But where does obesity come from? A morass of factors, including nutrition, economic conditions, agricultural subsidies, self-esteem, pervasive advertising, the quality of public transit, school lunch policies and access to supermarkets, insurance and playgrounds.

Humans can be pretty impressive. Every day we combine observation and experience to navigate a complex world. But generally we're far more aware of symptoms than root causes. Even if we had the time to make sense of something as complex as global warming, we'd be ill-equipped on the strength of our own brain power to consider the relationships among seasonal weather patterns, energy efficiency, aerodynamics, ice cap degradation, pesticide usage, stock market performance and algal blooms. We can't untangle complex systems in our minds, and we can't intuit our way to a better-working world. Computers aren't much better on their own. It's pointless just to plug in a supercomputer in a back room and expect it to make a complex system work better. Computers are processors. They must be augmented with perception, reasoning, cognition and intuition. And that, simply put, is IBM's business. It's been true for a century and remains true today.

Making the world work better is about untangling and managing complexity. Doing so—whether to transform industries, markets, societies or nature—requires serious science. But curiosity and experimentation aren't enough. Solving systemic problems also requires a particular combination of vaulting ambition and profound humility—the level of ambition to tackle seemingly unsolvable problems and enough humility to recognize that no single entity can make the world work better and no single entity can control a complex system. What we're really talking about here is progress, which by definition is communal.

Over the course of more than a year, a small team of researchers and I interviewed dozens of IBM scientists, engineers, executives and partners. We immersed ourselves in the archives in Somers, New York, and studied the arc of the company's business. We were indifferent about how, when or whether IBM made money. Instead, we focused on when and how it has made the world work better. Considering both the company's centennial and the degree of system failure all around us, now seems like a good time to shed light on our findings.

Change is easy. It happens by itself. The universe, operating by the laws of natural selection, is inherently innovative. Progress, on the other hand—the form of innovation practiced consciously by human beings—is deliberate and difficult. But it's not random. Climate, transportation, healthcare and retail may seem to have nothing in common beyond inherent unpredictability. But as it turns out, there is a common path to follow when attempting to manipulate any complex system. Our exploration revealed some key steps on that path. We learned how our predecessors struggled to complete each step in their paths to progress, and we saw how new tools are augmenting our abilities to complete the journey more quickly, safely and inclusively.

Even to start on this path requires inspiration, which can come from many places—from a calamitous event or from a moment of clarity in the shower after 20 years of noodling the same problem. It can be spurred by a work order, a dream or the proverbial pebble in the shoe. But whatever initiates the desire to improve a system, the first step is always the same: seeing.

Seeing is not just about photons hitting a retina. It's about employing all available methods to collect data about a situation. Any complex system churns out massive amounts of information—about what's working, what's broken, about cause and effect. Every element of behavior, every phenomenon is a data point ready to be captured: the march of time, the steps from your desk to the coffee shop, the rotations of a sharp curveball, the radiant energy of a solar flare, the milliliters of oil on the garage floor, the contagion

rate of the latest strain of seasonal flu. This data has always existed; what's changing is our ability to capture it.

But without context, data is just noise. To be useful, it must be organized. That's precisely what maps do. A map tells us where we are. It filters irrelevant information, reveals behavioral patterns and presents an argument for what to explore. A map of the galaxy shows Earth's proximity to the other planets and the sun. Calendars segment Earth's orbit into 365 equal parts. The Dewey decimal system categorizes the contents of all knowledge in a library. We've been organizing data in maps for many thousands of years. Now real-time data and visualization tools allow us to create dynamic maps from many points of view, inspiring us not just to explore but also to think.

A map shows when, where and even how often something happens. Understanding is the quest to answer why. Why is Earth the only planet we know of in our solar system capable of supporting life? Why does it take 365 days to orbit the sun—and why is there an orbit in the first place? In the process of understanding, we follow causal chains to determine what levers affect which outcomes. For much of history, this daunting process, which can span many lifetimes and transcend scientific disciplines, has been limited to the work of trial and error. But lately the process has been hastened by more advanced tools designed to help interpret maps, explain mysterious behaviors and virtually test hypotheses. Understanding is where entire fields of science reside, where Nobel Prizes are won and where urgency is born.

We may understand why something happens, but that doesn't tell us what to do about it. There are always many possible paths forward, and history's pioneers are the ones who make the best choices among them. Amid uncertainty, they find belief. Believing is about trusting the analysis and marshaling the will to overcome the status quo. History's greatest believers typically have been charismatic visionaries able to transmit their conviction and mobilize collaborators by force of personality—or force of arms. In more recent times, belief has begun to spread in other ways,

particularly through the rigor of the scientific method. Lately, believers of all stripes have become enabled and emboldened by multivariate models, simulations and other visualization tools that allow us all to more effectively predict outcomes.

Last, progress requires putting wisdom and will to work. Even with consensus and a clear view of the future, acting on a complex system is hard. Taking action is not an isolated or solitary event. Sustainable progress requires organization, cooperation, precision and reaction—because our systems are alive and respond to our every intrusion. What's more, “better” is a moving target. As the world has become smaller, our complex systems have become more intertwined. This interdependence has increased the likelihood that breakage in one system will cause damage in others. It's also made it more difficult to fix anything in isolation. But we're not helpless. Increasingly sophisticated tools of networking, collaboration and automation are giving us greater insight into systemic behavior and allowing us to collectively intervene in a timelier, more directed fashion to make our systems faster, more efficient and more sustainable.

These steps, then, constitute a model for how to instigate progress: *seeing, mapping, understanding, believing* and *acting*. IBM has never articulated this model to explain its business, but as you'll see, the company—like many other enterprises, institutions and individuals over the past century—has followed this path in the course of making the world work better. Nearly every one of the dozens of scientists and executives to whom we described it—for short, we wound up calling the model *smuba* (after all, IBMers have a penchant for acronyms)—accepted it as a useful articulation of how systemic progress occurs. Some quibbled with the order, others with the boundaries. Some warned against applying the framework too rigidly. But such is the nature of debating an idea among an inordinately intelligent and accomplished set of actors. I'll attempt to address some of these objections and caveats in the course of this essay.

How Do We Master Complex Systems?

By following a discernible path:

Seeing

Every phenomenon is a set of data points ready to be captured...



For example:

We built ever more sophisticated telescopes to accurately measure the placement and movement of celestial bodies.

Mapping

... and organized in the form of a meaningful map...



By organizing those measurements, we created detailed maps of our solar system.

Understanding

... which becomes the basis for describing and anticipating complex behaviors...



Those maps revealed behavioral patterns and spurred us to explore and articulate the laws governing astrophysics, rocket propulsion and space navigation.

Believing

... inspiring confidence that progress is possible...



Clearer understanding emboldened us to believe it would be possible to send three astronauts to the moon—and to bring them home safely.

Acting

... and enabling forward thinkers to design, build, adapt, optimize and automate the world's systems.



A team of thousands of scientists and engineers collaborated on a historic mission: Apollo 11.

Before we dive into an exploration of large-scale changes in business, society and technology, however, consider a mundane example of progress: changing lanes on a freeway. A commuter is behind a slow-moving truck and eager to make it home in time for dinner. It's the kind of mindless problem solving that many of us engage in every day—but we actually go through the steps of smuba to make it happen.

Seeing: We gather data from the rearview and side-view mirrors. We hear the roar of a motorcycle bearing down from behind. We survey the distance to the truck ahead, notice an available space in a parallel lane and steal a quick glance at the car's blind spots. Mapping: We organize the data within our existing knowledge—our mental maps—of the rules of the road, the typical behavior of car drivers (and bikers), the horsepower underfoot, the upcoming curve of the freeway. Understanding: We combine the variables and anticipate the conditions that will allow us to safely move the car to the adjacent lane and pass the truck. Believing: We decide that, yes, we have the time, power and driving skill, and so the time to act is now. Acting: Flip the blinker, one last check of the data and make the move.

Passing one truck won't achieve the goal. To get home while the food's still hot, we must overcome a whole range of obstacles. Like the components of any complex system, cars on a freeway are in a constant state of flux and so require continual monitoring. Every time we consider another move, we complete the process again. Of course, people change lanes all the time without gathering information—or, sometimes, without any apparent knowledge of the rules of the road. But such behavior is not sustainable. And therefore it is not, in the sense of this essay, progress. A home-cooked meal (or really good takeout) is progress.

The example of changing lanes in freeway traffic illustrates another important point about our interactions with dynamic, complex systems. The path to progress is not about machines; it's about human decisions. In the changing lanes scenario, we have various tools (the car and its mirrors, and our ears and eyes), but we are the actors. Tools and technologies are here to help us, but they're not doing the driving—even if we may soon have automobiles that can do just that. When that day comes, it just means we will have mastered one more system and freed our decision-making minds to focus on bigger challenges.

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