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THE TECHNOLOGICAL REVOLUTION

by Maury Klein

Most high schools and even colleges and universities do not offer courses on technology in America, which is extraordinary because technology plays such a dominant role in our life. For instance, of the many revolutions invoked by the invention of the telegraph, one had a profound effect on our language. The language of the nineteenth century had reflected the flowery, Victorian, slow, well-developed rhythm of the times. The telegraph changed that because every word cost money. Even slavery has a peculiar technological connection to the cotton gin. Two types of cotton were grown in the South: long-stem and short-stem. Long-stem was far preferable but hard to grow. Long-stem was preferred, not least because it was seedless, but its long growing season limited its growing range. Short-stem could be grown in more areas, but it was full of seeds, the removal of which was incredibly labor intensive. The creation of the cotton gin solved that problem and led to the spread of what became one of America's two great export industries. As a result, slavery spread to ever widening sectors of what became known as the South's "cotton belt," and the Cotton Kingdom was born.

The other great export industry, flour and milling, owes much of its spread to the automated mill, a piece of technology invented by one of America's most important but obscure inventors: Oliver Evans. He didn't make any money from it, any more than Eli Whitney did from the cotton gin, because he spent so many years trying to prove that it was really his invention. In fact, one of the themes of my book, *The Power Makers*, is what a miserable lot inventors have, once they have invented something, in proving their authorship and chasing those who used their creation without paying. At the end of his life Evans was so fed up with this ordeal that he piled up all of his papers, all of his inventions and sketches, called his family together and said "I am doing this for your benefit," and set fire to the whole stack. He was just so sick of spending his life in court.

Technology utterly dominates our lives in one way or another. On the first day of my technology course, I go around the room and ask everyone to name the one thing they can least do without. Students used to answer the computer; and in recent years it's been the cell phone. Out of 35 students, maybe two or three will get the correct answer: electricity. Without that, none of those other things are there. Incidentally, without the steam engine, electricity isn't there because electricity is not a primary source of power; it needs another source to generate it.

The word "technology" goes back a long way, at least to an 1829 book by Jacob Bigelow called *Elements of Technology*. It's a term that has multiple dimensions. For at least 70-80 years we have been engaged in a debate over the extent to which technology controls us or we control technology. One of the most famous of Ralph Waldo Emerson quotations is "Things are in the saddle and ride mankind"--and he only saw the beginning of what became the technological revolution.

When we talk about the role of religion in American life, it's important to remember that vast numbers of Americans were non-religious, and most Americans were materialistic. This country was about the opportunity to get ahead and build a better life for oneself. You did this by getting ahead in material terms. This is a huge country. How were people going to develop its vast resources? They needed not only communication but transportation. They needed technology, both tools and techniques for accomplishing some task. Technique is as important as tools. Put those two things together and you have a technological system. That system can be as simple as going to a well, lowering a bucket, pulling up water, and putting it on a wagon to carry it somewhere; or it can be as complex as a locomotive. They're all technological systems.

Technology is value neutral. It is neither good nor evil. It does whatever somebody wants it to do. The value that is attached to any given piece of technology depends who is using it and evaluating it, and what they do with it. The same technology can do vast good or vast harm. It develops and proceeds by a process of accretion. An inventor brings something into the world; once that something is there, whole hosts of other inventors look at it and try to figure out how to improve it or how to make it do other things. For an idea of how complicated and enthusiastic this process was to Americans in the nineteenth century, scan the pages of *Scientific American* from the 1830s-60s, available online. People were coming up with an incredible number of innovations.

Technology in broad terms has two forms: enhanced and replacement. Enhanced technology is something that improves an

existing invention, making it better, faster, or producing more of it. By contrast replacement technology is one in which one technology literally replaces another, using entirely different principles, and renders the first one obsolete. Often this process causes all kinds of economic chaos.

When the diesel locomotive replaced the steam locomotive, within one decade almost every American railroad had completely dieselized. That required a huge capital investment. Some of us once had music on LPs; we now have CDs. That's a replacement technology, as are MPEG files. Magnetic tape did not replace LPs because LPs were recorded from tapes. But digital recording eliminated that step. Look at how the telegraph changed language and how it is being changed again by text messaging, which threatens to be a replacement technology. These changes have profound consequences in both the economy and in people's lives.

The effects of technology are unpredictable. They are among the best examples of the law of unintended consequences. One reason for this is that inventors themselves often don't know what's going to be done with the thing they've invented. The first person who springs to mind as an American inventor is Thomas Edison. And yet he was wrong about his inventions almost as often as he was right. For example, we would not have had the incandescent bulb as quickly as we did without him, but he was absolutely convinced that the only way to go was direct current (DC) power. For numerous reasons, he was wrong; there could not have been an electrical revolution without alternating current (AC) power. When Edison invented the phonograph, he was convinced that its primary if not sole function was as a business machine. It took a long time for people to get through to him that it had entertainment value. When he invented the kinetoscope, the early movies in the nickelodeons that used individual machines for each viewer, he was convinced that this delivery system was the future. He adamantly resisted the contrary idea that, instead of having all these machines with each person looking into one, of putting the image up on a large screen in a room with lots of seats so that many people could watch at the same time.

When Edison came back to the phonograph later in life, he was absolutely convinced that the future of the technology lay in the cylinder rather than the flat disk. He was wrong about that as well. This is a common pattern throughout history. In the 1870s, when the telephone came along, *Scientific American* assured readers that it would never catch on. The reason, an editor said, was that "the art of conversation consists of having a listener. It seems absurd to be addressing a piece of iron."

We could go on and on with examples of these kinds of wrong thinking about what a piece of technology could do. Even after the telephone came into use, the telephone companies for a long time, and to a lesser degree the telegraph companies earlier, were convinced that only businessmen would be interested in using their service. It took a while for them to grasp that there was a huge market in the public at large that didn't necessarily *have* to talk to someone but just wanted to; that the telephone had this large social possibility, and with it a rather huge market. Here, too, the law of unintended consequences is deeply embedded in the history of how technologies affect our lives.

I framed *The Power Makers* around three world fairs: Philadelphia's in 1876, Chicago's in 1893, and New York's in 1939-40. All of the changes in American life that were celebrated in these world fairs took place in the lifetime of one fictional hero. The Philadelphia exposition trumpeted a century of American progress with endless miles of goods and machines, including the huge Corliss steam engine that was the main attraction. By 1893, however, Philadelphia was like a museum; almost all of its attractions had been surpassed by newer inventions. Chicago was the first great celebration of electric power. It was spectacularly lit at night. There were light shows, lights embedded in all the fountains, a monorail, and even battery-operated gondolas in the lagoons. It was the Great White City, which could not have happened with steam power alone. Visitors could walk through all the buildings in Chicago and see no sign of where the power was coming from--no soot, noise, clanking, or rattles. It was a whole new world of wonders and objects. New York billed itself as the "World of Tomorrow" and featured another generation of exciting new technologies such as the automobile and television.

Between 1876 and 1939 technology changed American life forever. I argue that it is the most profound single change in American and world history. It introduced industrialization, which separates one chapter in human history from another. With industrialization came large cities, the mass migration of people out of rural areas and into cities, as well as changes in the pace of American life. Technology speeded up and quantified American life. It promised a better tomorrow, a better life defined by material advances. More things and more goods for more people. Of course, it came at a huge price tag, but most Americans saw it as the march of progress to the point where they came to expect that whatever they had today, tomorrow would bring something newer and even better. The most significant thing that technology introduced into American life is change--the notion that tomorrow will be different. Not necessarily better, but different.

There is in American literature of the mid-late nineteenth century a large number of utopian novels, such as Edward Bellamy's *Looking Backward*, that are fascinating for what they reveal about the writers' vision of what the future would be. With only a few exceptions, like Ignatius Donnelly's *Caesar's Column* and Jack London's *The Iron Heel*, most are hymns to progress. When you read that literature, you see the extent to which Americans looked at their productivity increasing steadily and at the outpouring of available goods, regarding them as the promise of a better tomorrow. Not everybody welcomed change, of course. I would argue that the cultural crisis of the twentieth century is largely rooted in the great divide between those who worship that secular material advance and those who despise and/or fear it. Technology lies at the heart of the conflict.

HOW THE TECHNOLOGICAL REVOLUTION CAME ABOUT

There were in fact four revolutions, and three of them came in two parts. The first, the key foundational one, was the power revolution. Second was the communications revolution and third the transportation revolution. Together they succeeded in creating what I call the organizational revolution, which literally changed the way America organized itself and its activities. The organizational revolution began with the corporation, but the corporation was not just a business model; it became a model for other institutions in society. The power revolution came in two phases. Phase I was the steam engine, phase II the electric revolution. The communications revolution can also be viewed in two phases: the telegraph and the telephone, which are historically fairly close, followed later by movies, radio, television, the computer, the internet, and all the changes that flowed from their impact.

The transportation revolution began with the steamboat, which again required a steam engine. The steamboat was important because of America's rivers, particularly the Mississippi. Before the steamboat, delivering crops or any other kind of goods down to New Orleans was a long and torturous trip on a meandering river. Once arrived and the raft or keelboat was unloaded, you had either to break it up or sell it or try to haul it back, which would take two or three months. The alternative was to walk back home or go on horseback. The steam engine allowed riverboats for the first time to travel upstream. For ocean vessels it regularized schedules in transportation as had never been done before. The spread of the steamboat was astonishingly fast, but it was only a pittance compared to the revolution brought by the railroad.

A continent so vast, filled with mountains and rivers, could never have been developed, let alone settled, and the needed institutions created, without a growing railroad system. Railroads regularized and lowered the cost and time of transportation. They also literally changed the way we keep time.

Prior to the railroads, a boat leaving San Francisco to go around Cape Horn to come east or vice versa, required a six-month trip. If it went through Panama, assuming one survived the fever, the trip still took a couple of months. But after the first transcontinental railroad opened in 1869, you could make the trip in seven days.

America in the nineteenth century was very much a country of untrained inventors, people who did things on their own, who came up with things by trial and error. By the end of the nineteenth century a new age had dawned in which large corporations funded research laboratories to do systematically the things that lone inventors once did. Increasingly the outpouring of inventions came from organized, systematic, well funded research. In the nineteenth century, two very different streams of knowledge had started to come together.

The power revolution was the first place where this happened. On one hand, you had the tinkerers, people who didn't know anything about heat or electricity in any scientific sense. What they did was to tinker and fiddle to create a device to do something. Some of the first steam engines and boats were invented by men who literally had never seen a steam engine, didn't know what one was or have any theoretical knowledge of it. They just fiddled and faddled and came up with something. On the other hand, you had not really scientists as such but well-heeled people who were interested in nature and theoretical questions, who had the time and money to pursue in intellectual terms the nature of heat and electricity.

In the case of electricity that knowledge did not come together until the 1850s-70s through the work of people like Faraday, Maxwell, and others, who demonstrated that light and magnetism were the same thing. Up to that time, all the experimentation had been pretty much rule of thumb: if it works, do it. To make anything happen that had not occurred in the past thousands of human experiences required a different source of power, something beyond human or animal muscle, wind, wood, and water. The first breakthrough did not arrive until the 18th century in the form of the steam engine. Once coal was mined in England, a pressing need arose for some way to clear water from the mines mechanically. To perform that task, Thomas Newcomen created the first practical low-pressure steam engine, and James Watt improved it dramatically.

Enhancing the low-pressure steam engine became more important because England's huge textile industry also wanted a new source of power. Water power was fine for a factory next to a river, but wouldn't it be nice to locate a factory elsewhere than just next to water? Powering textile machinery was an entirely different use that required an entirely different kind of engine, which Watt and others created.

At first America had virtually none of this. In the first decade of the nineteenth century, there were six steam engines in the entire country. But a group of American inventors, Oliver Evans and others, were looking to use steam to perform tasks for a good reason. This republic had more resources and land than it had people. The more you could get machines to perform tasks, the more productive you could be. However, many of the tasks required portable sources of power, which led people like Evans and others to experiment with high-pressure steam engines. However, they had to be very careful about the pressure. Explosions of steamboats on the river occurred when people were careless. Until instruments were devised that upgraded the measurement of steam pressure, safe and efficient use of high-pressure engines continued to be very difficult.

A steam locomotive is essentially a boiler set down on a set of wheels. Flanges were put on the wheels so they could slide easily over a rail and carry a lot of weight; this marked the beginning of a whole new technology. Although it's a very intricate machine that requires a lot of parts, the locomotive was an incredible invention, clearly the technological symbol of the nineteenth century. Everybody from Walt Whitman to businessmen viewed it in that light. But it also required a lot of TLC. The locomotive is a very individual piece of machinery; that's one reason it became obsolete as rapidly as it did. It's not a very efficient machine, any more than the original automobiles were efficient.

In the nineteenth century, technology developed in a process that is important to understand. You know how a rocket when it's first launched seems hardly to move because it's gathering thrust; then it gathers momentum, goes upward, and then just shoots off. That's basically the image of the history of technology. Once invented, it gathers that initial momentum through all kinds of innovations to the original, then takes off to places people know not where. Is there any more familiar American phrase than "what will they think of next?" That is essentially what we're talking about. It soon became difficult if not impossible to imagine what the next astounding invention would be.

In the Civil War the telegraph proved vital. Much of the wartime correspondence on both sides was telegraphed. The instrument enabled commanders to send information and orders quickly, to get a view of what was going on at the battlefield, and to dispatch orders back. One of the first things marauders did when possible was to cut the other side's telegraph lines. Abraham Lincoln himself spent a great deal of time at the War Department poring over the telegraphic dispatches that came in.

The railroad played a major role in the Civil War in a curious way. The Confederate states had what in military terms were called the interior lines. If they wanted to move troops from one place to another, they could do it in a straight line, whereas the North had to do it in an arc. Although greatly outnumbered, the South was in theory able to use its forces more efficiently. The problem was that it had an inferior rail system that wore down quickly. The South had very few factories to make replacement parts or even to produce weaponry; much of its supply came off the battlefield, captured from the enemy. In this way the North's greatly superior railroad system neutralized the strategic advantage the South had.

A surprising number of weapons in their infancy made their first appearance in this country in the Civil War. Rifled muskets and cannons became important because a rifled piece shoots farther and straighter and is therefore more deadly. If you've seen the films *Gettysburg* and *Gods and Generals*, you were probably amazed at how soldiers in that day, even with the increasing firepower they were creating, could face each other in packed formations and shoot at each other until one side gave way. That might have worked in an earlier day and age but no longer. There also appeared the first repeating rifles, mostly for the Northern cavalry, early versions of hand grenades, rockets, the first primitive submarine, and, of course, the first primitive ironclad ships. These gave the North clear naval supremacy that proved vitally important to the war effort. The war also introduced the use of balloons, which were not military weapons per se but were useful for reconnaissance. It was the only way observers could actually look down on enemy positions. The North had several of them; the South had exactly one, made from dresses volunteered from ladies all over the South. All of these technologies are important not just for what they did in the Civil War but because they marked the beginning of a new type of warfare, one destined to come to a head in savage, bloody, horrible terms in World War I.

Here again can be seen the impact of change. Technology changed the art and practice of war faster than generals comprehended. Generals squandered huge numbers of lives trying to fight wars the old-fashioned way in the Civil War and even more so in World War I. In this way the technology of war became the dark side of the promise of American life in material terms. To comprehend the degree of change in civilian life, one needs to look at some of the machines that were invented to create everything from oatmeal to machine tools. The relationship of these inventions to labor and to the growing inequality of income and wealth, is another enormous effect.

One misconception is that the lot of American workers steadily worsened in the late nineteenth century. It did not. Most people's lives improved steadily. What changed was not their income going down but the level of the wealthy going up. The result was the growth of a yawning chasm that Henry George portrayed in *Progress and Poverty*. It seemed as if some great force were digging into society, pushing the vast majority of people down while elevating the favored few. This process of change accelerated in the 1920s, when electricity really took over American life. All of this technology changed American life far more than anything else. It had no ideology, no program, or agenda; it just happened, and it continues to happen at an ever increasing pace.

Maury Klein is Professor Emeritus of History, University of Rhode Island. His books include *The Power Makers* (2008), a history of steam and electric revolutions, and *Days of Defiance: Sumter, Secession, and the Coming of the Civil War* (1999). This essay is based on his presentation at the FPRI *Wachman Center's* May 17-18, 2008 history institute on America in the Civil War Era, held at and co-sponsored by Carthage College, Wisconsin. See www.fpri.org for videocasts and texts of lectures. Core history institute support is provided by The Annenberg Foundation; additional support for specific programs is provided by W.W. Keen Butcher, Bruce H. Hooper, John M. Templeton, Jr., the Lynde and Harry Bradley Foundation and the Ewing Marion Kauffman Foundation. The next history weekends are What Students Need to Know About America's Wars, Part I: 1622-1919, July 26-27, 2008 (Wheaton, IL); and Teaching the History of Innovation, October 18-19 (Kansas City, MO).

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