

Turn of the Century

We live in a standardized world. Whether made by the Gap or American Eagle, a pair of khakis with a 32-inch inseam and a 34-inch waist will fit you just about the same. A Panasonic phone will plug into the jacks in your home as easily as a phone from AT&T. A new CD from the smallest record label in Holland will sound as good in your car stereo as the latest release from BMG. And *Diablo II* will run just as well on a Dell as on a PC from IBM. We take this kind of standardization for granted, but without standardization, there would be no mass production or mass communication. Which is to say, without standardization there wouldn't be a modern economy.

Today, according to the National Institute of Standards and Technology, there are close to 800,000 global standards. But go back a century and a half and you find an American economy in which there were literally none. On April 21, 1864, a man named William Sellers began to change that. Sellers initiated the first successful standardization fight in history, over the humble screw. That struggle was not just about a particular standard. It was about the importance of standardization itself. To win, Sellers relied on technical savvy - as well as political connections, clever strategy, and a willingness to put progress ahead of the self-interest of his own friends and colleagues.

On that April evening, a crowd of Philadelphia engineers and machinists gathered in the lecture hall of the Franklin Institute, the professional society to which they belonged. Sellers was the institute's new president, and they were there to hear him speak publicly for the first time. In the world of these men, Sellers was a legend, the finest tool builder of his time. After starting as an apprentice machinist at 14, Sellers had his own shop by the age of 21, and a decade later he was the head of the most important machine-tool shop in Philadelphia, the city at the center of America's machine-tool industry. If Sellers was going to insist that national standards were necessary, then it was definitely an idea worth taking seriously.

The speech, "On a Uniform System of Screw Threads," played against the backdrop of war between North and South, which added resonance to Sellers' call for a national standard. "In this country," Sellers noted, "no organized attempt has as yet been made to establish any system, each manufacturer having adopted whatever his judgment may have dictated as the best, or as most convenient for himself." At the time, American screws, nuts, and bolts were custom-made by machinists, and there was no guarantee that bolts made by shops on different streets, let alone in different cities, would be the same. "So radical a defect should exist no longer," Sellers proclaimed.

But even if Sellers was right and the nation needed to adopt a standard, what should it be? Sellers acknowledged that something called the Whitworth screw standard was rapidly gaining ground in England, and that some American machinists were using it as well. But Sellers believed America needed a benchmark of its own, one that met the needs of a fast-growing, rapidly industrializing economy. So he spent the bulk of his speech unveiling a new, and all-American, screw of his own design.

The key to that design - which applied to nuts and bolts as well as to screws - was the shape of the threads, the raised metal ridges that run around the body of a screw. The threads determine the strength and durability of the screw, as well as ease of production. In cross section, virtually all screw threads were triangular, but the particulars of that triangle were matters of intense debate. The two sides of a Whitworth thread formed an angle of 55

degrees, and its tip was rounded off at the top. The Sellers thread, by contrast, had a 60-degree angle, but its apex was flattened.

These differences may sound minor, but in practical terms they were revolutionary. The 55-degree angle of Whitworth's screw was difficult to measure accurately without specially designed gauges. By contrast, Sellers' 60-degree thread - one angle of an equilateral triangle - could be measured with ease. Similarly, the rounded top of Whitworth threads made it more difficult to fit nuts and bolts together, since the threads often did not match perfectly. Flattening the threads made it easier to ensure that they locked into place with one another. Finally, producing a flat thread was something any machinist could do quickly and efficiently by himself. Building a Whitworth screw required "three kinds of cutters and two kinds of lathe," Sellers noted that night. His screw required just one cutter and one lathe.

Sellers won over the crowd. After the speech, C.T. Parry of the Baldwin Locomotive Works announced that he hoped Sellers "planned to do more than just talk." Then a machinist named Algernon Roberts proposed that a committee be formed to weigh the Sellers standard against the Whitworth. A month later, Roberts' committee voted unanimously in favor of the Sellers standard. Machine-tool shops and government agencies across the country soon received word urging them to adopt it.

The American machine-tool industry was to the second half of the 19th century what the computer and networking industry was to the second half of the 20th: the country's most important driver of technological innovation. The machinists of the Franklin Institute, and their colleagues in cities like Cincinnati and Providence, Rhode Island, built lathes and planers and drills and screw cutters so that other companies could build rifles and clocks and sewing machines. They provided the infrastructure that allowed the Industrial Revolution to take off.

It was a small community, made up of men who were the products of what historians call "shop culture." Like Sellers, they had been sent out as apprentices when they were just boys and grew up on the shop floor. They tended to talk about the virtues of experience, the things a man could learn only after working with machines for many years. And they disdained men who'd been trained at college - "paper engineers." The knowledge the machinists were interested in was not theoretical. It was knowledge that could be put to use.

The shop culture engineers were, nevertheless, devoted to science and, in fact, referred to themselves as "scientific mechanics." The science they were interested in, though, was *applied* science. As the engineering historian Monte Calvert puts it, "In spite of paying lip service to eclectic, intuitive, 'practical' methods, the shop elite were among the first to use precise experimentation and science in the shop." The Franklin Institute itself was founded because the shop culture elite wanted a place to meet and talk about scientific discoveries and innovations.

In all this, the machine-tool industry was a lot like Silicon Valley (at least as it once was). In the Valley's heyday, the cliché was that engineers and programmers got up in the morning and went to work for Silicon Valley, not for Intel or HP or Fairchild. Programmers traded tips and secrets with one another because they were more interested in solving problems than in protecting their competitive advantage. In the same way, the scientific machinists Sellers was appealing to were devoted to something bigger than their individual companies, something you might as well call "technological progress." We're engaged in a common project here, Sellers was saying. To get further, we have to have a common standard.

Sellers' proposal seemed rational. But many machinists viewed it as a threat to their way of life. They saw themselves as craftsmen. While they built machines designed to mass-produce goods, the machinists did not use mass-production techniques themselves. Take gun-making: In the early part of the century, gunsmiths custom-made muskets to the specs

of each buyer. By the time of the Civil War, rifles were being churned out by the million. Interchangeable parts helped win the war, but in the process they reduced the American gunsmith to little more than a maintenance man.

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Yet the machines that stamped out gun parts for the Union armories were themselves one-offs. The machinists liked it that way. They didn't want to end up like gunsmiths. Bringing small components like nuts and bolts into line was not the same thing as standardizing the machines that pumped out uniform parts, but machinists saw it as the first step down a slippery slope to the hell of commoditization. In economic terms, after all, anything tailor-made has the advantage of locking in customers. If someone bought a lathe from you, that person had to come back to you for screw repairs or replacements. But if screws became interchangeable, customers would need you less and worry about price more.

Sellers understood this. He was himself a craftsman, and to the end of his life his tools were custom-made. But Sellers knew that interchangeable parts and mass production were inevitable. That's why, when he designed his screw, he concentrated on making one that would be easier, cheaper, and faster to produce than any other. His screws fit the new economy, where a premium was placed on speed, volume, and cost. Yet Sellers was not so naive as to think that just building a better mousetrap would be enough. Especially since the very world that he aimed to conquer had a lot to lose by abandoning the custom-made screw.

Sellers knew that fighting his own people would be tough, so even before announcing his proposal, he was hard at work behind the scenes, laying the groundwork for its success. By the time of the speech, he had already persuaded four of the biggest machine shops on the East Coast to start using his screw. Sellers' standard was a good one, but the fact that he was extraordinarily well connected didn't hurt. He came from a well-established Philadelphia family. He was friends with the city's captains of industry. He had run a machine shop in Providence, another key manufacturing center. And his customers included some of the biggest corporations in the country, like the locomotive manufacturers and the railroads.

Sellers tapped all these connections because he understood from the beginning that when it came to establishing a standard, momentum was everything. Success would breed success. He followed a strategy called "expectations management." As Hal Varian, the dean of the School of Information Management and Systems at Berkeley, puts it: "In standards wars, there is a very real sense that the product people expect to win *will* win." The rapid adoption of the Sellers screw by just a few key players created an air of inevitability. Somewhere in there, Sellers must have figured, a tipping point existed. Get enough weight behind the screw, and everybody - even the most independent machinists - would fall in line.

The proof of this strategy came in the spring of 1868, when the secretary of the Navy, Gideon Welles, commissioned an investigation into the need for a standard. The Navy started by ordering a technical review, which found that the Sellers was superior to the Whitworth. But the difference was not decisive. Top brass wanted to get behind the screw that "would be most likely to be generally acquiesced in and adopted." So a board of naval officers fanned out across the Eastern seaboard, visiting New York, Newark, and Pittsburgh. They toured Brown and Sharpe in Providence, where Singer sewing machines were made. They went to the Brooklyn Navy Yard. They talked to the men at Baldwin Locomotive, the nation's largest locomotive maker, in Philadelphia. And everywhere they went they asked two basic questions: Are your screws standardized? If so, what standard do you use?

What the Navy found was that the Sellers screw, just 3 years old, was far more popular than the Whitworth, which was 27. This impressed the naval officers. So too did the fact that when they talked to companies that hadn't yet adopted any standard, most of them

said they were leaning toward Sellers'. The Navy took this popularity as a sign of quality. It trusted the judgment of the marketplace. And so it came back with a resounding recommendation in favor of Sellers, a decision that showed just how effective expectations management can be.

Of course, the Navy's vote of confidence also showed just how effective the old-boys' network could be, since many, if not most, firms the Navy surveyed were companies that Sellers had close ties to. The same phenomenon was at work a year later, when the Pennsylvania Railroad became the first railroad to adopt the Sellers standard. The railroads knew that they needed to establish a national network, which was why the Central and Union Pacific tracks had been joined in a transcontinental link. But if the railroads were going to exploit those kinds of links, their cars had to use screws that could be readily found anywhere in the US. So there was a pressing need for what Sellers was offering. Still, it must have helped that Sellers was on the Pennsylvania Railroad's board of directors.

Three years later, the Master Car-Builders' Association and the Master Mechanics' Association - the organizations of the people who actually built and maintained rail cars - fell in line, and by 1883 there was hardly a railroad in the country that was not using it. If a railroad adopted Sellers screws, of course, so too did all of its suppliers, and since the railroads were then the nation's largest corporations, this created a mass market for standardized screws. By the end of the century, the Sellers standard was effectively universal in America, and in 1901 it was adopted by Europe at the International Congress for Standards and Gauges.

Britain, however, stuck with the Whitworth screw. This didn't create any obvious problems until the winter of 1941-42, when the panzers of Germany's Afrika Korps started to pummel the Eighth Army. Under the strain of desert warfare, British tanks and trucks broke down. Screws loosened. Bolts wore out. American factories were churning out vehicles and parts for the British. But when those supplies arrived in North Africa, everyone was surprised to discover that American nuts did not fit British bolts, and vice versa. The broken-down tanks stayed broken-down.

American factories immediately retooled and, for the last three years of the war, ran two separate assembly lines, one to make British engines and weapons and another to make American engines and weapons. After the war, both countries decided that using incompatible screws was a foolish reason to risk losing a battle, and in 1948, the British acquiesced to the Sellers standard, which by then was known as the US standard. Within a few years, all British companies were using the new screw. Sellers' victory was complete.

The process of standardization is always a political struggle, with winners and losers. Had the screw not been standardized, the entire course of the American economy might look different.

These days, the really crucial standards govern information technologies like wireless communications and the Internet. And although the economy has changed since Sellers' time, the way America establishes standards has not. The markets, rather than the state, still set the standards, with the exception of environmental and public health issues.

This hands-off attitude is often portrayed as a mistake that's held back technological progress. One much-cited example is the contrasting experience with cell phones in Europe and in the United States. As conventional wisdom has it, European governments mandated a standard, and wireless services thrived. The US let the market decide, and wireless services floundered. But a closer look at what actually happened suggests a very different conclusion.

In the 1980s, there was no cell phone standard in Europe. Each of the big national phone companies wanted to control the standard that would be used in its country, so the first generation of cell phones involved a host of competing, and incompatible, technologies.

That cacophony, according to a 2000 Rand Institute study, "reaped confusion." So in 1991, during the transition to the second generation - the digital generation - of cell phones, European industry came together, laid aside national differences, and rolled out Group Spéciale Mobile. In essence, the Europeans decided that the important thing was not which standard won, but that a standard win, especially once the leap to digital was made. And indeed, with a single standard in place, Europeans were able to roam the continent and still use their phones. The size of the market exploded, which encouraged cell phone manufacturers to invest in new products and R&D, and by 1998, GSM - which had spread to every continent - was the standard in 90 percent of the world outside North America.

In the US, the transition to digital happened very differently. AT&T, which had invented the analog cell phone, introduced its TDMA in 1992. In 1996, little startup Qualcomm rolled out CDMA (a competing standard). TDMA had a significant lead, but Qualcomm aggressively marketed CDMA to the Baby Bells and wireless startups. It built its own cell phones when the established handset manufacturers wouldn't, then carried out a vigorous and successful propaganda war in the press, emphasizing that CDMA offered better security and a far greater capacity than AT&T's standard. Many consumers agreed, leaving the nation with three separate wireless networks.

This story is often told as a cautionary tale. The standards war, it is said, came at a tremendous cost: Americans don't use cell phones anywhere near as much as Europeans do, and they're behind the curve when it comes to things like text messaging.

This analysis leaves out the most important detail, though, which is that until the mid-1990s there was no real competition in the US cell phone industry. Between 1983 and 1993, every major market in the country had two cell phone carriers. These duopolies didn't compete, keeping prices high and quality low. In a sense, neither the marketplace nor the government set cell phone standards. Inertia did. The slow growth of wireless services in the US wasn't the result of competing standards. It was the result of the lack of competition between carriers.

After the FCC finally opened the market in 1993, by auctioning off spectrum and breaking up the local duopolies, wireless took off. Once the marketplace was allowed to work, it quickly converged to CDMA, which proved to be superior. CDMA is ascendant in America. More important, it's the foundation for the next generation of cell phone technology - 3G - since it turned out to be the only technology capable of making the leap to fast and capacious wireless data transmission. Had the US government mandated a standard, by contrast, it would undoubtedly have picked TDMA or GSM, since those were the dominant technologies at the time. And then we wouldn't have CDMA leading the way to 3G today.

In William Sellers' day, there was no way for the government to step in, even if it had wanted to. Today there are myriad governmental and quasi-governmental agencies dedicated to standards. And the obvious importance of standards in the world of information technology makes it tempting to look to some expert body to lay down the law. But the argument for allowing the marketplace to do the work of rules-making is, if anything, stronger in the case of information technology. IT standards are naturally fluid and flexible. Linux and XML, even Windows for that matter, are constantly under revision. They both embrace the past - that is, they are backward-compatible - and are extensible into the future. The market may seem messy, but it's actually much better at dealing with a situation of permanent revolution than official standards organizations are. As Hal Varian puts it, official standards bodies have "the advantage of experience and authority; however, they tend to be rather slow-moving." Slow-moving is the last thing you want in the world of IT.

Yet setting standards will never be easy or cost-free. One of the most important lessons of Sellers' story is that no matter who sets the standards, the process of standardization is always a political struggle, with winners and losers. The victory of the Sellers screw was not inevitable. It won only because Sellers fought so hard for it, using the connections and

influence at his disposal. And the real victory was of standardization itself. Had the screw not been standardized, the entire course of the American economy might look very different.

The Sellers screw helped to usher in the assembly line and mass production, and usher out the world of craftsmen and customized production. Sellers did not gain personally, but he created a host of winners, including factory owners and consumers looking for a better price. He also created a whole group of losers, including all those machinists who had so feared commoditization. The same process is still at work today. It's obvious, when you look at a company like Microsoft, that the victory of its standards has turned companies across the world into losers. (Just think of Borland or WordPerfect, or even Lotus.) But even the most benign and open standards still shape the world in their own image. When did you last meet a Betamax repairman? Standardization may be necessary and, on the whole, beneficial. But as William Sellers demonstrated, it is never innocent.

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