Not long ago, trading on a stock market meant you would be in a crowd of people energetically shouting, running around and making a mess with great quantities of paper. No more. Visiting a financial market now is more like visiting the “cloud,” a big data center. Computers and network gear hum in racks. Fans blow. Rows of tiny lights flicker. Occasionally someone shows up, but don’t count on much water cooler conversation.

Technology did not suddenly transform our markets. It has been a gradual process, and understanding how we got here, and the simpler machines we used along the way, provides insight into today’s complex markets. It turns out that going back to the basics, from the buttonwood tree and hand signals, is a good way to explain technology that can seem hopelessly complex and buried in jargon.

Looking into the workings of modern securities markets is like looking under the hood of a Prius hybrid car. There are so many complex and obscure parts it’s hard to discern what’s going on. If one looks under the hood of an auto from a simpler era, for example a ’64 Mustang, it is possible to see the parts and what they do, and have a better chance at understanding their complex modern replacements.

History repeats and informs in market technologies. From the days when front-running involved actual running to the “Victorian Internet era” brought on by telegraphy, we can learn a great deal from looking back at a simpler era.

We think that the overwhelming influence of computers remarking the landscape around Wall Street today is something new, but a pair of before-and-after photographs show an even more dramatic technological invasion. Before telegraphy, in the 1850s, the sky over Wall Street was open and clear.
It took only a short time for telegraphy’s compression of time and space to transform the scenery. Here’s what the Street looked like shortly thereafter when everybody had to have it. 2

In its day, telegraphy was seen as the same kind of overwhelming transformation that the Internet is today. In many ways, the telegraph was more dramatic since it was the first time in history that a message could be sent beyond the horizon instantaneously.

Changes in markets brought about by technology are anything but subtle: The exchange floors are an endangered species. Here’s a photogenic example, the London Stock Exchange trading floor the day before and the day of the introduction of screen trading — the “Big Bang” — on October 27, 1986. 3 4

The trading floors that have been emblematic of financial markets around the world are an endangered species. Brokers and traders who once relied on fast reflexes and agile elbows and knees now rely on computer programs, tweaked to be microseconds faster than the next guy’s program.

Closing the floor and rolling in the machines has a sentimental cost. When markets become technology, the human price of progress is high. Anyone who has been on the 20th century floor in New York or Chicago knows those markets are really personal, face-to-face, elbow-to-elbow and knee-to-knee experiences. People are justifiably saddened that when too much technology gets mixed up with markets, some of the vibrancy that makes them so fascinating is lost.

A trading floor peopled with traders and brokers also makes for some colorful moments in market history, such as the opening of the live hog futures contract on the Chicago Mercantile Exchange (CME) in 1966. (These guys are definitely having more fun than loading the hog program onto a Unix box in New Jersey.) 5 The CME continued the lively tradition for financial futures as well. 6

There’s so much technology in modern markets that it’s easy to forget that some of our favorite markets, like the New York Stock Exchange (NYSE), started out as very low-tech places. In 1792, the NYSE was a bunch of guys standing around a buttonwood tree at 68 Wall Street shouting at each other on days when it didn’t rain or snow. 7

We like our markets to be liquid, efficient, resilient and robust. But this is hard to do when all of the participants have to crowd around a tree and hope for good weather. So in 1794 came the first big technological solution: the roof. 8

Everybody moved inside, to the Tontine Coffee House at the corner of Water and Wall Streets. Even under a nice cozy roof only so many shouters could participate in the market, and more participants is a good thing. Pretty soon technology solved this problem.

Hand signals and chalkboards worked really well. Now hundreds of people could participate in the market. Of course, this made for more broken trades. Here we see how they resolved them back in those days: the buyer dresses up in a bull suit, the seller dresses like a bear, and they duke it out up front. 9

So far, these innovations may sound rather low-tech: roofs, chalk, hands. Here’s what a computer looked like in 1823,
the Difference Engine, invented by the famously brilliant, eccentric and obnoxious Charles Babbage: 10

Babbage was stunningly smart, and even more stunningly insufferable. He lost his government funding, and the idea of automatic computing languished for many years. It was not used in financial markets or anywhere else in the 19th century. Babbage only built pieces of his machine; but when the Royal Museum in London put a whole one together from his designs in 1995, it worked perfectly. The world could have been a very different place if Babbage had had better manners. Instead, traders were still signaling each other with their hands, dancing and dressing up in bear suits, and there was still a problem: they had to be present to participate in the market. This problem was solved with more technology, namely telegraphy. The earliest telegraphs weren’t the electric variety. They were guys standing on hills waving flags, like the ones used at sea. 12

There were lots of problems with the flag system. For one, it was hard to see a little guy way up on a hill. In most places, people starting building big mechanical guys like this one, with large wooden arms, and put them up on the hill instead. 13

There were a few variations on this theme, such as the smoke-and-fire telegraph tower 14, which had a problem with burning down mid-message…and the decoder-ring-on-a-stick design. 15

These towers are the reason so many cities have a place called “Telegraph Hill.” Around the world, the builders and first users of these early telegraph systems were the military, for obvious reasons. The second users were traders disseminating market information. The third users typically were con men perpetrating financial frauds on the traders by sending out false signals or front-running the real ones. There were many problems with the flag system, namely privacy, bad weather and darkness. It took about half an hour for a price change to work its way from New York to Philadelphia.
There were some really marvelous early attempts at electric telegraphs to enhance the communication system. Here’s an electrostatic model, with a wire for each letter and number, and a range from the living room to the parlor, powered by some fur rolling over a piece of rubber—sort of the rub-a-balloon-on-your-head approach.  

Here’s another British multi-wire device with a battery and a saltwater receiver. Remember how in high school chemistry lab if you put wires from a battery into saltwater, one of them bubbled? It was the same deal here. There was a ball for each letter, and you looked to see where the bubbles showed up.

Here’s one that tried to use tones for letters. It was the first singing telegraph and made signals like the keyboard at the end of Close Encounters of the Third Kind. I have no idea how this one was supposed to work, but when they said “sell,” you sold.

Julius Reuter and his son Herb decided to try another approach. They got into the messenger pigeon business. Edward G. Robinson played Reuter in the 1941 classic film, This Man Reuter. The pigeons played themselves.

Finally, in 1837, Samuel Morse got it right: a nice, simple, single wire and ground design. This quickly caught on all over the world. Instantaneous communication! Notice here that “the electric fluid travels at the rate of 280,000 miles per second,” or about one and a half times the speed of light. Maybe they knew something we don’t.

For the first time in history, a message could be sent instantly over the horizon. An entire book could be filled with the stories of how all facets of human endeavor were transformed by telegraphy:

Traders picked up on telegraphy in a big way. Here we see a broker in New York with his 19th-century BlackBerry, a telegraph key, cradled in his arm.

In its day, telegraphy was seen as the same kind of overwhelming transformation that the Internet is today. It was a big advance, but to participate in the market as things were happening, the participant had to know Morse code.

The technological revolution of the 1850s needed more technology to allow people to cope with the dramatic changes in the information landscape. This time
the technological advance was the invention of the stock ticker in 1867 by Edward Callahan. The first models were a little too delicate for boisterous NYSE crowds, so Thomas Edison was hired to improve them to meet Wall Street combat standards. Edison just kept dropping the ticker out of a second-floor window and fixing it when it broke until it didn’t break anymore. Finally, he ended up with this design. These can still be seen in museums, Wall Street offices and the occasional sidewalk sale. Ticker tape, like the roof, hand signals and the telegraph, was a huge success, probably the most important technology in finance up to that time. People even set up jumbo magnifying lens devices to project them onto walls.

People saved tapes and studied them — the first high-frequency market microstructure studies. Here’s a fellow doing just that.

On the floor, there were “human Quotrons” who used to pick up the most recent end of tape and follow it back in time to find the latest price quotes for specific stocks. This wasn’t that long ago. Frank Baxter, former chairman at Jefferies and a recent US ambassador to Uruguay, started out doing this.

All that ticker tape also made for nice parades. Here we see a group of specialists celebrating the one-millionth bagging of a buy-side trader.

Technological progress brought bigger, better and faster ticker machines. The ticker tape became the public symbol for the market.

Tickertape became de rigueur for blowout parades, like this one for General Douglas MacArthur after President Harry Truman fired him from commanding the US armed forces in Korea in 1951. In one form or another, the ticker is still with us today — on the wall, or on the bottom of your TV screen.

On the floor of the NYSE, traders using all the information available to them did their trading at posts, where specialists made a market for all buyers and sellers. Understanding what happens at the posts is step one in understanding our ever higher frequency markets. The posts themselves have changed with the market.

Note that the limit order book, a central feature of electronic markets that trade in microseconds, is seen as an actual book in those slower, simpler days.

With the progress of technology, prodigious amounts of information can be moved quickly. But all of this information moving around in a hurry can get overwhelming. Telephones moved into exchanges alongside the ticker machines. This greatly expanded the capacity of the market to handle external order flow and connected the exchanges to the public network. Some eager adopters got carried away, as seen in the photo of a German trading room in the 1950s.

So far, this article has been about technologies for moving information around: hand signals, semaphores, telegraphy, stock tickers and telephones.

When it comes to using information, however, we’re talking about computers. In the 1930s, if a person said he had six computers in his office, this is what he meant — the six women of the NYSE computing department circa 1925.
“Computer” was a job, not a thing. If you said you had a supercomputer, this is what you meant.

At about this time, the technological legacy of Charles Babbage stirred again at the Moore School of Engineering in Philadelphia. ENIAC (electronic numerical integrator and calculator), the first electronic computer, was developed in 1946 by J. Presper Eckert and John Mauchly.

It weighed 30,000 pounds, had a 900-bit memory, ran at .017 MIPS (million instructions per second), and blew a tube every 45 minutes. It was programmed by someone moving plugs and wires around. Computers got a little better in the early 1950s (more memory and longer times between failures). But a battalion of nerds was still needed to get them to do anything useful twice in a row.

This modest-looking little science project is what unleashed the torrent of computation we see all around us today.

It’s the very first transistor, developed at Bell Labs in 1948 by Walter Brattain, William Shockley and John Bardeen. They were awarded a Nobel Prize for it in 1956, around the time transistors started being manufactured in quantities large enough to show up in things like radios and, a few years later, computers.

Computers became much more manageable. One could fit in a room smaller than a barn, and it might work for a whole week without breaking down. It had enough memory that a programmer didn’t have to move wires or think in binary to program it. The NYSE had to have one. In 1966, they got it. And there he is, the first nerd on Wall Street: Keith Funston, then president of the NYSE.

Computers continue to get better, faster, smaller and cheaper. They’re everywhere in trading. Floor traders can interact directly with algorithms using the NYSE handheld. » continued on page 74
They have surpassed even telegraphy and ticker tape as a transformational market technology. The progress we’ve seen in computing technology that brought this about is really unprecedented. The rapid technology trajectories forecast by the laws of Moore and Metcalfe continue unabated.  

Electronic markets started back when the Internet was a gleam in someone’s eye at the Defense Advanced Research Projects Agency (DARPA). Now the future of electronic finance is profoundly intertwined with the World Wide Web, removing intermediaries in services ranging from trading to research. A lot of people think the three great technological ideas in history are fire, the wheel and storing instructions as data. Based on the first 15 or so years of widespread use of the Internet, we might add the URL to the list.

All this innovation is what has brought us to where we are today, wired markets in a wired world—a global financial system made of bits. And, as we were reminded by the flash crash of May 2010 and the little ones that occur daily, there are some serious questions about how the investment business is going to cope with markets and market information in cyberspace.

Everything connects to everything else, if you want it to, and sometimes when you don’t. There’s more to this than just moving information around. Managing and trading assets in a world of fragmented electronic markets requires enormous technological expertise. Computer programs increasingly take over tasks from people, and people amplify their abilities using machines.

Along the path from hand signals to HFT, Watson and the World Wide Web, we’ve seen some remarkable market applications of technology. This isn’t going to stop. We’ve come a long way since the traders moved from under the buttonwood tree into the Tontine Coffee House, but we’ve really just moved indoors in our use of information technologies. There is so much written about information overload that we have an information overload information overload. But as we have seen, technological patterns repeat, and understanding how this happened in the past helps us understand today’s ever faster and more complex markets.

Notes

1. An excellent book comparing the development of the telegraph with the modern Internet is The Victorian Internet by Tom Standage (New York: Berkley Classics, 1999).

2. Moore’s Law is the well-known doubling of computational power every 18 months. Metcalfe’s Law is the less well-known maxim that the utility of a network grows as the square of the number of users.

David Leinweber, author of Nerds on Wall Street: Math, Machines and Wired Markets, was recently named one of the “Top Ten Innovators of the Decade” by Advanced Trading magazine. As founder of two financial technology firms, and as manager of multi-billion dollar quantitative equity portfolios, he brings a practical approach to innovation. He is now principal of Leinweber & Co., and in a public service role, co-founder of the Center for Innovative Financial Technology at Lawrence Berkeley Lab.

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