From Minutes to Microseconds
A Modern History of Securities Markets

By Christopher R. Petruzzi, PhD

Like much of our culture, securities markets appear to have originated in Babylon around 2000 BC with the trading of tokens representing various commodities.1 The purpose of this article, however, is to explain how U.S. securities markets went within a few short years from trading floors to high-speed computers where one-millionth of a second makes a difference in execution. Consequently, I will skip about 4,000 years of very interesting history and flash forward to the 18th century.

Background
The Philadelphia Stock Exchange (PHLX), founded in 1790, was America’s first stock exchange. The New York Stock Exchange (NYSE) was founded two years later, and it quickly overtook the PHLX in volume and importance. During the 19th century, other major U.S. cities created their own stock exchanges, largely because local investors needed to make transactions, and doing business with New York was too difficult and expensive. Hence, the Boston Stock Exchange appeared in 1834, and Chicago and San Francisco exchanges formed in 1882.

The inventions of the telegraph in 1838 and the ticker tape machine in 1856 made communications easier and diminished the need for these regional exchanges. The regional exchanges that survived did so by providing unique services to the national market. Transmitting current securities prices was one of the first uses of the telegraph, and the ticker tape was the most sophisticated communications device in existence when it was invented. Indeed, as in the present day, the greatest communications advances of the day were being used for military applications and transmitting stock prices and trades. Arbitrage profits were the incentive. If stock was trading at different prices in New York and Philadelphia, an arbitrager would buy in the lower-priced market and sell in the higher-priced market. Only traders with the fastest data sources and the fastest order execution could succeed. Because success meant a great deal of money, securities arbitragers were willing to pay higher prices than anyone else for the fastest communication. Telegraph and telephone lines were installed and new devices were invented to satisfy this demand. The results changed the nature of securities markets—in the 19th century and the 21st century.

Modern Electronic Securities Markets
Modern electronic securities markets began with the creation of Instinet, which became operational (for institutional investors only) in 1970, and NASDAQ (the National Association of Securities Dealers Automated Quotation system), which became operational in 1971.

Brokers and Dealers
When NASDAQ was created, most large U.S. companies were listed on the NYSE or the American Exchange. A large number of publicly traded companies were traded informally "over the counter" (OTC), however, either because they did not meet the listing requirements of these major exchanges or because they chose to not be listed. Because it was unlikely for a buyer (or seller) to find a seller (or buyer), some people became dealers. Dealers would keep inventories of stock in a few companies and quote prices at which they were willing to buy (the bid) and higher prices at which they were willing to sell (the ask). Dealers generally had relationships with brokers, who sent them customer orders and let them profit from the bid-ask spread. Dealers then made payments to the brokers (typically two cents per share), who were prohibited from also charging a commission to customers. Large brokerage firms had their own dealers in order to capture profit due to the spread.

The 1933 and 1934 Acts of Congress, which created the Securities and Exchange Commission (SEC), required that participants in the trading of securities be registered. Most brokers and dealers chose to be regulated indirectly through the quasi-public National Association of Securities Dealers (NASD). Registration directly with the SEC was possible but legally cumbersome. Brokers also could register through stock exchanges. OTC dealers were trading off of the exchanges, so they registered with the NASD and were classified as "market makers."

Market Makers
Market makers kept an inventory of stock and offered to buy at one price and sell at another. Market makers needed to be sure that they were quoting near market prices and they needed to know which other market makers would make trades to replenish their inventory of stock or buy up excess inventory. They needed a central system to contact other market makers. This system became NASDAQ.

NASDAQ displayed quotes and showed bid and ask prices along with
quantities to both market makers and brokers who had NASDAQ terminals. The terminals allowed brokers to easily shop among the market makers for the best price. This likely resulted in smaller bid-ask spreads, to the consternation of the market makers. Because quotes remained in eighths and quarters, however, market making continued to make high profits.

Madoff Brothers was one of the largest market-making firms, and its founder—the now infamous Bernard Madoff—was behind the creation of NASDAQ. Indeed, Bernard Madoff was NASDAQ’s first chairman of the board.

NASDAQ displayed automated quotes, but until 1988 all NASDAQ transactions took place over the phone. Brokers would consult NASDAQ quotes, then call a market maker. Trades were recorded on paper that was sent to the Depository Trust and Clearing Company for clearing.

When the market melted down on October 19, 1987, informed market participants knew the market was crashing, but they didn’t know how low prices would go. Market makers were afraid to buy stock from selling retail customers. Their solution was to not answer their phones. When the SEC investigated, it determined that market makers’ not answering their phones deprived retail investors of their right to a continuous market. So the SEC ordered NASDAQ to create a system that would allow any retail investor to buy or sell up to 1,000 shares electronically. This became the Small Order Entry System (SOES).

When SOES was implemented in 1988, securities traders noticed that some NASDAQ market makers were slow to adjust their quotes. Traders could look at their NASDAQ terminals and see most market makers raising (or lowering) prices simultaneously, with a few market makers taking several seconds or even minutes to adjust their quotes.

Because SOES allowed automatic executions only for retail accounts, the traders who were aware of the delay in quote changes made arrangements with customers of retail accounts that they could trade. The trader would watch a couple of active stocks and look for signs that quotes were about to change. The traders then would make a SOES transaction with a market maker who was slow to change quotes. After taking a position on SOES, the trader would lay off the position in another transaction. The retail customer would be charged a commission that resulted in most of the profits going to the trader. Generally, these commissions were set so that the retail customer earned a consistent rate of return from 12 percent to 20 percent per annum on his account.

Fully Electronic Stock Markets—Automated Trading
The market makers felt ripped off by these “SOES bandits.” Indeed, SOES bandits were so profitable that several firms formed just to trade their accounts. Datek, founded by Sheldon Maschler and Jeffrey Citron, became very successful, leading Citron to call for a fully electronic stock market that quoted in decimals rather than eighths and quarters. One of Datek’s young computer programmers, Josh Levine, created a computer system called Island for a fully electronic stock market in 1996. Island provided instantaneous executions with quotes in decimals (and increments as small as a tenth of a cent) and was an immediate success.

Fully electronic stock markets offered the possibility of fully automated trading, i.e., all decisions made by a computer with no human interference.

David Whitcomb, a professor at New York University (where he and I were colleagues) who specialized in securities-trading, saw this possibility in the late 1980s. Whitcomb sought venture capital to create a fully automated trading company, Automated Trading Desk (ATD), but no one would back him, so he started ATD with his own money and investments from a few colleagues and former students. ATD initially traded on the NYSE using the NYSE’s fully electronic system, which nevertheless had a delay between the times when orders were received and filled. The NYSE specialist (i.e., the individual who made the market in one stock) could see all the orders and the names of the brokers who placed orders. This “specialist book” was open to all participants, but as a practical matter it was available only to the specialist. Thus, ATD traded NYSE stocks with a computer that made decisions that, compared to trading by humans, were instantaneous and costless, but those decisions all went to the specialist, who had additional information and could change his quotes based on the identity of the parties who were sending orders. Regardless, ATD became the first company to profitably trade stocks with full automation.

In the meantime, I had developed portfolio analysis software and my programmer, Glenn Rosen, became a SOES bandit. I quickly realized that SOES banditry would be fairly easy to automate. Rosen and I went to ATD with a plan for fully automated software to trade on SOES. We developed it with ATD in a joint venture. By the end of 1994, ATD began trading on NASDAQ with full automation using SOES. This was the first software to trade with full automation on NASDAQ. ATD later traded on Island and was reputed to be its largest liquidity provider by the late 1990s. Citigroup acquired ATD in 2007.

In 1996 the U.S. Department of Justice brought an antitrust suit against the NASDAQ market makers. Phone taps had revealed that NASDAQ market makers colluded to keep bid-ask spreads large and had threatened market makers who tried to reduce the spreads. The settlement required paying hundreds of millions of dollars to investors who had traded NASDAQ stocks (including, ironically, the customers of SOES bandits). Pressure increased
for markets to cease quoting in eighths and quarters. A bipartisan House bill to require decimal pricing and hearings on the issue led the exchanges to agree to price in decimals beginning in April 2001. Around the same time, securities markets were required to display all limit orders so that any investor could effectively act as a market maker. Before then, limit orders on OTC stock existed in name only. Buy (sell) limit orders were simply held by market makers until the ask (bid) price equaled the limit. That had meant that traders who weren’t market makers couldn’t profit from the spread.

Decimalization and the fully electronic NASDAQ opened the way for more automated traders. Dave Cummings, a trader with a computer-programming background, created Tradebot with his own funds in 1999. Tradebot quickly became a major liquidity provider to electronic stock markets. I had left the partnership with ATD in 1995. Backed by Paloma Partners, a family of hedge funds, I created Smart Execution in 2001. I realized that I would need to be faster than other automated traders, so I located Smart Execution’s computers in the same building as Island’s computers. That co-location let Smart Execution respond to price changes a fraction of a second faster than any other company, and we soon were trading as much as 8 percent of the total volume of OTC stocks. Smart Execution was also the first company to co-locate with Archipelago (ARCA) and the first to co-locate with NASDAQ. More than 99 percent of Smart Execution’s volume was from adding liquidity (buying at the bid and selling at the ask); electronic communications networks (ECNs) paid Smart Execution and other liquidity providers a rebate of $0.002–$0.003 per share for this service.

These automated liquidity providers replaced the market makers and specialists who provided liquidity to NASDAQ and stock exchanges. By 2005, more than 30 other trading firms had computers co-located with Island. Today, about 90 percent of all orders and about 50 percent of all trades in securities in the United States are generated by co-located computers. (The percentage of orders generated by co-located computers is higher than the percentage of trades because automated traders quickly cancel and replace orders as conditions change.) Another trading firm acquired Smart Execution in 2008.

Other electronic stock exchanges were created, too, but for institutional investors or private transactions only. Madoff took control of the Cincinnati Stock Exchange (re-named National Stock Exchange) and made it fully electronic in 1976, apparently to facilitate Madoff Brothers’ off-board transactions. Madoff Brothers had a profitable business paying institutions for order-flow on NASDAQ stocks. The firm wanted to expand to exchange-listed stocks, and the Cincinnati exchange provided the opportunity. Steven Wunsch founded the fully electronic Arizona Stock Exchange, which had single-price call auctions, but it closed in 2001 due to lack of volume.

Electronic Communications Networks

Instinet was the largest private electronic stock market (officially an electronic communications network or ECN) from its founding in 1970 until 2000, but it was available only to financial institutions. As Instinet watched Island surpass its volume, Instinet opened to non-institutional traders. Still, Island grew faster than Instinet, apparently because Island had better software. Island distributed data, entered orders, and filled them faster than Instinet or any other electronic trading platform. So Instinet bought Island in 2003 and changed the platform name to INET. INET quickly became the most popular trading destination, and its volume surpassed NASDAQ’s, despite NASDAQ’s technology investment of hundreds of millions of dollars. In 2006, NASDAQ acquired INET largely to get Josh Levine’s program, which had beaten everything else that Wall Street had produced.

Island’s success prompted entrepreneurs to create other ECNs, including ARCA. When ARCA founder Jerry Putnam found financial backing for creating an ECN similar to Island, the backers agreed to send some of their customer orders to ARCA. Those trades provided an incentive for professional traders to use ARCA, too.

ECNs and other platforms were permitted to trade NYSE stocks away from the exchange, but SEC rules required that there be no “trade through.” This meant that no transactions could take place at prices below the NYSE bid or above the NYSE ask. Fully electronic stock markets were faster and more efficient than the old-fashioned NYSE, but the mandate to stay within NYSE prices eliminated much of the advantage. When ECNs complained, the SEC proposed eliminating this rule effective in mid-2006, and the writing was on the wall for the NYSE. It was going to lose most of its market because its executions took seconds instead of milliseconds.

John Thain, the newly appointed NYSE chief executive officer, responded by buying ARCA, a purchase that instantly gave the NYSE technology competitive with that of other exchanges.

With the leading ECNs merged into NASDAQ or NYSE, Tradebot’s Dave Cummings saw a need for a new ECN. With the support of other trading organizations, Cummings founded the Better Alternative Trading System (BATS). BATS is currently the third-largest stock exchange in the United States.

Within just two years of decimalization and the fully electronic market, bid-ask spreads had fallen from fractions of dollars to fractions of cents. Market makers and specialists were going out of business. Following the traditional path

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of failing businesses, they complained to regulatory authorities.

SEC Chairman William Donaldson, the former NYSE chief executive officer and a Bush appointee, proposed that stock prices should only be quoted in full cents to stop traders from competing for orders by simply paying higher fractions of cents. Two other Republican SEC members opposed the suggestion, noting that higher fractions of a cent would turn into better prices for investors. Nevertheless, Donaldson voted with the two Democrats on the SEC to make full cents the minimum quote increment on all stocks in the United States trading at more than $1.00.

As a result, liquidity providers now compete at the same price, only faster. Indeed, automated traders now measure their program speeds in microseconds, not milliseconds.

**Conclusion**

Technological changes continue to present new regulatory challenges. Those who stand to win or lose lobby about proposed rules. The latest rules require that automated traders send orders through software that has been approved to control against spurious orders that might adversely affect the stock market. As ever, the wisdom of favoring or opposing these new rules has been overshadowed by the participating parties’ financial incentives.

Securities markets will continue to respond to technological change. The big change, however—the change from human beings making transactions face to face to computers that make decisions and transact with other computers—already has taken place. It took place, for the most part, within just one decade.

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**Endnote**