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Trading Shares in Milliseconds

Today's stock market has become a world of automated transactions executed at lightning speed. This high-frequency trading could make the financial system more efficient, but it could also turn small mistakes into catastrophes.

By Bryant Urstadt

If Manoj Narang is about to bring down the markets, he's certainly relaxed about it. Narang, who wears a goatee and wire-frame glasses, is casually dressed in a brown shirt and dark gray sweatshirt. Sitting on a swivel chair with one leg tucked under the other, he seems positively composed, especially for a man who has just bought and sold 15 million shares with a total value of \$600 million. For Narang, however, such volume represents just the start of a normal day. Though it's about noon on a Friday morning, he has barely begun.

Narang is the head of Tradeworx, a hedge fund and financial-technology firm that makes purely automated trades; all decisions are reached and acted on at near light speed by computers running preprogrammed algorithms. "Actually, we run two businesses," he says. "The first trades in and out of shares in about a second and holds them for an average of two or three days. That's the medium-speed fund. The high-speed fund could make thousands of trades a second and holds them for a matter of minutes."

By the end of the day, his computers will have bought and sold about 60 million to 80 million shares, with the heaviest activity in the last hour of trading, from three to four in the afternoon. Tradeworx and similar firms around the country will race to close billions of bets that hinge on things like tiny differences between the prices of shares in an exchange-traded fund holding the S&P 500 and the individual shares that make up the same index. The profits go to the company with the fastest hardware and the best algorithms--advantages that enable it to spot and exploit subtle market patterns ahead of everyone else. At the end

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of a typical day, the Tradeworx high-speed business holds no shares at all. Come Monday, Narang will look to trade millions more shares. It seems like a lot, and it is, but Narang estimates that he's probably only somewhere in the middle of the top 50 traders by volume.

Just five years ago, automated trades made up about 30 percent of the market, and few of those moved as quickly as today's trades do. Since then, however, automated trading has become much more widespread, and much quicker. Narang acknowledges starting his ultrafast group as a defensive maneuver when he began to notice faster traders eroding the performance of his medium-speed strategy. Now the medium-speed fund is adopting the techniques he developed in the ultrafast fund.

TheTabb Group, a consultancy based in Westborough, MA, estimates that high-frequency automated trading now accounts for 61 percent of the more than 10 billion shares traded daily across the numerous exchanges that make up the U.S.

market. Tabb estimates profits from high-

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frequency trading in the first nine months of last year at \$8 billion or more. With the rise of automation, the bulk of U.S. stock trading has moved from the once-crowded floor of Manhattan's New York Stock Exchange (NYSE) to silent server farms run by exchanges and broker-dealers across the country: the proportion of all trades that the NYSE handles has shrunk from 80 percent in 2005 to 40 percent today. Trading is now essentially a virtual art, and its practitioners put such a premium on speed that NASDAQ has considered issuing equal 100-foot lengths of cable to the brokers who send orders to its exchange servers. (Though Narang and his team program their algorithms on PCs in their own office, actual trading is done through brokers' servers located on the premises of an exchange--NASDAQ, the NYSE, and dozens of others.)

The NYSE itself is just finishing construction of a 400,000-square-foot data center in Mahwah, NJ. The new complex, slated to open in the spring, will have enough computing power to handle every trade on every market in the world, though

the exchange will probably have trouble grabbing much of that business back. Hardware used at the facility will operate at a 40-gigabyte-per-second standard, enabling it to handle as many as a million messages a second. (The limit, in many cases, is not the speed at which the information travels but the ability of switches to route it quickly enough.)

The Tradeworx office in Red Bank, NJ, a wealthy shore town about an hour from Manhattan, is a far cry from Wall Street. A quieter place would be hard to imagine. About a dozen employees, most of whom graduated from top-tier schools with degrees in science, math, or engineering, work largely in silence. On this morning, as those 15 million shares come and go, the Tradeworx staff says hardly a word.

In Narang's office, the shades are drawn, the better to read a large monitor on one wall. There are no tickers scrolling by, no flashing updates on the value of the Dow Jones index. Narang's strategy is "market neutral," meaning that when it works--and it usually does--he makes money no matter which way the market goes. His profits don't depend on whether share prices rise or fall; instead, he relies on a set of algorithms that can find and instantly take advantage of tiny, fleeting movements in trading activity. On the wall across from the window is a whiteboard filled with code: a scribbled flowchart in different colors, with variables and occasional amounts in boxes and the words *buy* or *sell*. In the middle of the monitor is a large number in a box, going up and down but mainly up. That is Tradeworx's profit so far that morning.

A crash waiting to happen?

High-frequency trading has become controversial, with critics charging that traders are manipulating the

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market, taking advantage of the little guy, and even courting a full-scale financial meltdown. The critical voices are growing louder and more united, and they're reaching higher up the rungs of power. In September, Senator Edward Kaufman (D-Delaware), speaking on the floor of the U.S. Senate, worried that the United States was moving toward a situation with "one market for huge-volume, high-speed players, who can take advantage of every loophole for profit, and another market for retail investors, whose orders are seemingly filled as an afterthought." The Securities and Exchange Commission has recently proposed a rule to eliminate one controversial tactic of high-frequency traders: the "flash trade," in which exchanges alert designated traders to incoming orders. Critics call it a variation of front-running, an old (and illegal) practice that involved traders buying and selling in advance of large orders.

But accusations of unfairness are not the only issue. Any trend that becomes as dominant as high-frequency trading should be studied to consider potentially serious side effects, warns

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Paul Wilmott, the publisher of the quantitative-finance journal *Wilmott* and the founder of the mathematical-finance diploma program at the University of Oxford. "High-frequency trading is the latest bandwagon, and everyone is jumping on board," he says. "Wall Street always piles on to the next thing, and it always blows up."

Wilmott, a self-described "instinctive contrarian" who correctly warned in 2000 that the derivatives market was dangerously unstable, sees particular threats from this trend. The increasing dominance of algorithmic trading and the growing speed of execution, he says, could cause tiny price changes to snowball, rolling down the hill at exponentially increasing speed--either because the machines are trading too fast or because too many funds are trading in the same style. "The potential is there for a crash to happen quite quickly," he says.

Bernard Donefer, who oversaw electronic trading at Fidelity Investments from 1996 to 2002 and now teaches about information technology in financial markets at Baruch College's business school in New York, worries that

high-speed algorithmic trading will lead to a smaller-scale version of the crash of 1987, when the market dropped 22 percent in one day. Many now blame that crash on simple automated "portfolio insurance" systems, which were meant to keep a fund's holdings from losing more than a preset amount of value by automatically selling shares when

the price dropped by a certain amount. They had their roots in a practice used by floor traders: the "stop loss" order, which initiates the sale of a given share if it falls below a given price. But the herd of computers issuing stop-loss orders created a stampede that pushed the then-dominant floor traders to sell as well. Donefer worries that if such a sell-off happened now, it would happen many times faster.

While such "forced selling" can be the result of forethought (misguided or not), it can also start with a mistake: pressing an extra button (what traders call "fat-finger syndrome") or botching the code that drives an automated algorithm. In 2003, shares of Corinthian Colleges, a company that manages for-profit educational institutions, plummeted when faulty code or human error caused a computer to begin selling shares its user did not have. The system had been programmed to sell if the security returned to the price at which it had been bought. When that time came, the computer sold the shares the customer held and just kept going. In 12 minutes, it sold short nearly three million shares at prices from \$57.50 all the way down to \$39.50. In a market dominated by high-frequency trading, such glitches could mushroom within seconds.

Even some high-frequency traders worry about what Donefer calls "algos gone wild." John Jacobs, the COO of the

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New York City-based Lime Brokerage, wrote the SEC in 2009 to voice concerns over the proliferation of brokers who allow major clients to engage in high-frequency trading without validating their margins--that is to say, without making sure they actually have enough money to back a trade. Lime provides high-speed market access and order validation to hedge funds and other traders, some of whom cannot, or don't want to, place their own servers on an exchange floor. In his position, Jacobs regularly sees algorithms executing more than 1,000 orders a second. At that rate, one algorithm trading the wrong way could execute 120,000 orders in two minutes. At 1,000 shares per order and an average price of, say, \$20 a share, that's \$2.4 billion in unintended trades. In his letter, Jacobs warned of "the potential for trading-induced multiple domino bankruptcies." He cautioned that "unrestrained computer-generated trading has the potential to create catastrophic economic damage to the U.S. national market system."

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Penny Pinching

The players in high-frequency trading are many and varied. Some are institutional investors like pension funds, endowments, and mutual funds; others are brokerages or trading desks at banks, using the banks' own money. Enormous hedge funds like the

Citadel Investment Group in Chicago use these techniques, and so do startups like PhaseCapital in Boston, which began trading with just the partners' money in the spring. Designated "market makers"--traders licensed by an exchange to create a stable market in a security by making it available to both buyers and sellers in an orderly fashion--use high-frequency strategies to fill orders and to hedge positions, constantly rebalancing inventory so as not to get caught with too many or too few shares. And the field will only grow. Companies now offer high-frequency packages that include software, brokerage hookups, and as much consulting as you can afford.

Indeed, in many ways, practices associated

with high-frequency trading have become a routine part of how the market operates. When a customer places a trade through a Charles Schwab account, for example, that order is likely to be handled by a high-speed algorithm. Institutional traders like Fidelity, which buy large blocks of shares for their mutual funds, use algorithmic trading to split their enormous orders into blocks of 100 to 300 shares so that other traders don't recognize the true demand and take advantage of that knowledge for their own profit.

Hedge funds with high-frequency operations, like Tradeworx, work between and around the institutional traders and the market makers, and against each other, attempting to profit by anticipating the moves of others. Their reliance on statistical patterns and quantitative analysis has won them the name of "quant funds." (A quant fund typically holds a portfolio derived from statistical analysis, but its trades may take place over months as well as microseconds. Though most high-frequency funds are quant funds, not all quant funds trade at high frequency.) The explosion in high-speed automated trading has engendered a massive buildup in technology; Renaissance Technologies, a hedge fund based in East Setauket, NY, boasts that its computing power is equal to that of the Lawrence Livermore National Laboratory.

Just one example of what speed can do explains a lot about how high-frequency trading works and why it angers some observers, as Joseph Saluzzi and Sal ArnuK, the principals of the New Jersey-based Themis Trading, made clear in their 2008 white paper "Toxic Equity Trading Order Flow on Wall Street." Imagine that a mutual fund enters a buy order, telling its computer to start by offering the current market price of \$20.00 a share but to take any asked price up to \$20.03. A high-speed trader,

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Saluzzi and ArnuK explained, can use a "predatory algo" to identify that limit by "pinging" the market with sell orders that are issued in fractions of a second and canceled just as fast. It might start at \$20.05 and work its way down to \$20.03, canceling and reordering until the mutual fund bites. The trader then buys closer to the

current \$20.00 price from another, slower investor, reselling to the fund at \$20.03. Because the high-frequency trader has a speed advantage, he is able to do all this before the slower party can catch up and offer shares for \$20.01. This speedy player has found the buyer's limit, gathered up and sold an order, and snipped a few pennies off for himself.

Liquidity and Order

Picking up all those pennies can be risky, Narang says, but he makes what he considers an important distinction. "There is risk, definitely, but quant funds like us take it all," he says. "If a quant meltdown happens, it won't affect the retail investor."

Narang turns to his computer and brings up two graphs, superimposing one on the other. The

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first shows the erratic up-and-down crawl of the S&P 500, the value of the largest 500 companies in the United States, over the last six years. The second shows Tradeworx's profit and loss over the same period. It is a steady march up; in Tradeworx's worst year, it made 15 percent. "All [high-frequency] funds have a profit-and-loss line like this," he says. Then he magnifies the graphs to show just the weeks around August 2007, when many quant funds self-destructed as they sold off their portfolios to meet increasing margin calls (see "[The Blow-Up \(http://www.technologyreview.com/business/19529/\)](http://www.technologyreview.com/business/19529/)" November/December 2007). In those days, his P&L dropped by 7 percent, and many other funds saw similar losses. But the S&P 500, overall, was little affected.

"And here's the second quant meltdown, in January of '08," Narang says, zooming out and then in on another blip in the graph, showing the value of the S&P 500 when a second, albeit smaller, dislocation occurred. "It's tiny. You can hardly see it. That's because funds running quantitative strategies are mostly market neutral. When we take a position, we're always

balanced somewhere else, and when we unwind, it doesn't affect the market either." By this he means that forced selling by quant funds may be painful for the funds themselves, but that pain is barely reflected in the market, because the funds' long and short positions--positive and negative bets on the direction of given securities--cancel one another out. "We don't take from the retail guy," he says. "We make the market more efficient. Things are better for the retail investor because of high-frequency trading."

Narang, and academics like Donefer, say that high-frequency traders are making money by delivering a service: liquidity. In today's highly decentralized market,

defenders say, their systems are simply the most efficient way to match buyers and sellers. And because they can capitalize on small differences between the prices at which a seller is willing to sell and a buyer is willing to buy, those differences stay small. The upshot is that retail buyers pay a little less to buy a share and can sell it for a little more. Indeed, since electronic trading has come to dominate the market, spreads between buying and selling prices have decreased dramatically, and so have fees. Ten years ago an investor might have paid \$150 in fees to trade 500 shares with a broker, facing a spread of maybe a dime on each share. Today's retail investors pay \$10, with spreads of a penny or so in most big stocks, and most of their trades are filled almost instantly.

Understanding how high-frequency trading improves liquidity explains a lot about why many such traders do well when the market is plunging or volatile, as it was

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last year. "We don't make volatility happen," says Narang. "We reduce it, but it is how we make our money. We create order. When the markets are disorderly, we make a lot of money, but we are doing it by restoring the markets to order."

If Narang is right, the new ways are good for the retail investor. But the argument that high-frequency funds improveliquidity, as if they were providing a public service, is disturbingly reminiscent of the justifications offered by hedge funds and banks that created complicated derivatives in the years leading up to the recent crash. When things went bad in that case, the liquidity disappeared--along with many of the funds invested in them, and much of the investors' money. And this type of history doggedly repeats itself. Wilmott, for one, is not convinced that high-

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frequency trading is useful to the economy. "People have to say things are fine because they're being rewarded for it," he suggests.

At least for now, though, things are calm, and the spreads are narrow. After lunch, Narang's day at Tradeworx starts to get busier as hundreds of high-frequency funds jostle to close out their positions to their best advantage. Narang says good-bye at the door, his words the only sound in the quiet office. On the wall behind him, Tradeworx's daily profit-and-loss line still ticks up and down, but mostly up.

Bryant Urstadt is a writer based in New York.

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Upcoming Events

[SXSW Interactive \(http://www.sxsw.com/\)](http://www.sxsw.com/)

Austin, TX

Friday, March 12, 2010 - Tuesday, March 16, 2010

<http://www.sxsw.com/> (<http://www.sxsw.com/>)

[FEI 2010 – The Annual Front End of Innovation Conference A New Front End: The Era of Collaboration \(http://www.iirusa.com/feiusa/fei-home.xml?registration=FEI2010TECHREV\)](http://www.iirusa.com/feiusa/fei-home.xml?registration=FEI2010TECHREV)

Boston, MA

Monday, May 03, 2010 - Wednesday, May 05, 2010

<http://www.iirusa.com/feiusa/fei-home.xml?registration=FEI2010TECHREV>
(<http://www.iirusa.com/feiusa/fei-home.xml?registration=FEI2010TECHREV>)

[2010 IEEE Conference on Innovative Technologies for an Efficient and Reliable Electricity Supply \(http://www.ieee-energy.org/\)](http://www.ieee-energy.org/)

Waltham, Massachusetts

Sunday, September 27, 2009 - Tuesday, September 28, 2010

<http://www.ieee-energy.org/> (<http://www.ieee-energy.org/>)

[MIT Sloan CIO Symposium \(http://www.mitcio.com\)](http://www.mitcio.com/)

MIT Campus, Cambridge, MA

Wednesday, May 19, 2010

<http://www.mitcio.com> (<http://www.mitcio.com>)

[BIO International Convention \(http://convention.bio.org\)](http://convention.bio.org/)

Chicago, IL

Monday, May 03, 2010 - Sunday, May 10, 2009

<http://convention.bio.org> (<http://convention.bio.org>)