

All About HIGH-FREQUENCY TRADING

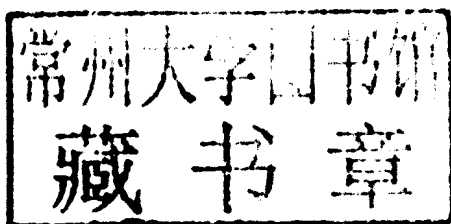
THE EASY WAY TO GET STARTED

Everything You Need to Know, Including:

- The internal configuration of a high-frequency trading system
- Comparisons of benefits and drawbacks, as well as analyses of inherent risks
- Who profits from high-frequency trading—and how they do it

MICHAEL DURBIN

All About HIGH-FREQUENCY TRADING



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PREFACE

Customer: How much are these?

Merchant: A buck fifty.

Customer: I'll take some.

Merchant: They're a buck fifty-one.

Customer: Um, you said a buck fifty.

Merchant: That was before I knew you wanted some.

Customer: You can't do that.

Merchant: It's my shop.

Customer: But I need to buy a hundred!

Merchant: A hundred? Then it's a buck fifty-two.

Customer: You're ripping me off.

Merchant: Supply and demand, pal. You want 'em or not?

What is high-frequency trading? Great question! And it's about time for an answer, because everyone seems to be talking about it—and forming strong opinions about it—and when that happens, it's usually a good thing to know just what *it* is. Does high-frequency trading relate only to stock trading? Or does it include automated trading of stock derivatives such as options? Does it encompass any type of automated trading, where computers make the decisions humans once did? Or does it pertain only to the dubious practices of the ~~sharks~~ sophisticated trading firms who, like the merchant above, move markets in their favor just because they can get away with it? Well, since nobody can quite answer these questions, let's just make our own definition and get on with it.

In general, *high-frequency trading* (HFT) refers to the buying or selling of securities wherein success depends on how

quickly you act, where a delay of a few thousandths of a second, or milliseconds,¹ can mean the difference between profit and loss. HFT happens not only in the stock markets but in the markets for stock options and futures as well. Naturally, not every reason for trading requires speedy execution. Certainly not, say, buying stock because you think the company will do well over the coming years or cashing out your 401(k) to buy the Harley you've had your eye on since you were sixteen. But plenty of trading strategies do indeed depend on how quickly you can spot a profitable trading opportunity in the market—and how quickly you respond with a trade order to seize that opportunity before somebody else does. We'll describe a number of such strategies later on.

The high-frequency trader evolved from the ranks of the traditional market-maker, or *specialist*, whose primary source of profit was the spread between the prices at which he bought and sold. Unlike the traditional market-maker, however, and owing to developments like decimalization² and advances in technology, the high-frequency trader must settle for much narrower spreads—razor-thin margins of a penny or less. As such, high-frequency traders operate in massive scales. Indeed, the larger high-frequency trading firms now glide through the markets scooping up vast mouthfuls of trades like a whale does krill.

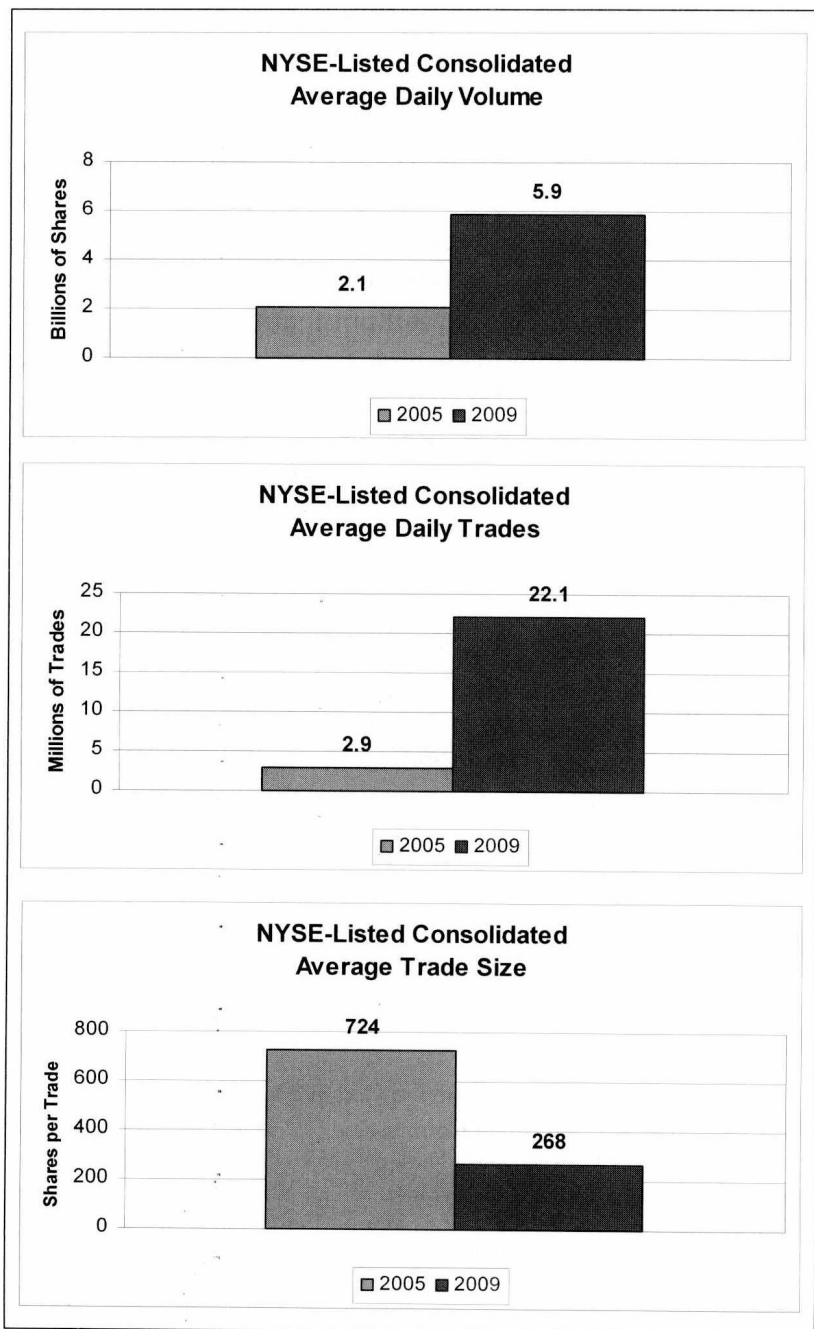
Signs of the likely effects of high-frequency trading, and the growth of the number of firms practicing it, are not hard to find. Figure 1 shows the Security and Exchange Commission's (SEC) calculation of the nearly threefold increase in daily

¹ Increasingly, and perhaps by the time you read this book, microseconds—or millionths of a second—also matter. And it's only a matter of time before we're talking about nanoseconds, or billionths of a second.

² *Decimalization* refers to the shift, in the early 2000s, from trading stocks in fractions of dollars to doing so in pennies, dramatically reducing the potential spread between the prices at which one can buy and sell a stock.

FIGURE 1

NYSE Trading Statistics



trading volume³ of New York Stock Exchange (NYSE)–listed stocks between 2005 and 2009, alongside the nearly *eight-fold* increase over the same period in the number of trades executed each day, which together imply the shrinkage of the average trade size, as also shown.⁴ Such data is reasonably consistent with what you would expect with more and more firms competing to make markets.⁵ The real indicator that computers have taken over, however, is in Figure 2, which shows the reduction in average trade execution time from more than ten seconds in 2005 to less than one second four years later. Humans are fast, but not that fast.

The speeds required of high-frequency trading exceed anything a human could ever match. As such, HFT is, by necessity, a form of automated trading. It's trading wherein computers make the real-time tactical decisions that used to be made by humans back in the olden days. It's rather like an autopilot in this respect. On most modern aircraft, a computer makes the moment-to-moment decisions that keep the plane aloft and on track—flap positions, air speed, and so on. That computer was designed and programmed based on decades of manual flying experience. The strategies and procedures humans developed for flying a plane have been expressed in the electronics and software of a machine. There is still a human pilot in the cockpit, however. She keeps an eye on the autopilot, turning it on when safe to do so, setting its controls correctly, and taking over when necessary.

High-frequency trading represents the same sort of evolution. And *evolution* is just the right word because, just like

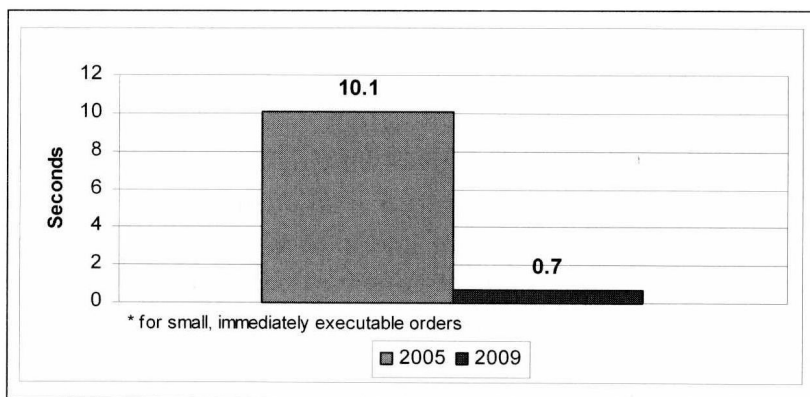
³ Volume gives the number of shares traded in a given period.

⁴ U.S. Securities and Exchange Commission, "Concept Release on Equity Market Structure," 1/14/2010 [Release 34-61358; File S7-02-10].

⁵ It's also consistent with the concern, which we'll get to later on, that much of this new trading volume is among high-frequency trading firms themselves, trading for the sake of trading.

FIGURE 2

NYSE Average Speed of Execution*



the autopilot, high-frequency trading wasn't invented overnight. HFT represents the current evolution of the technological element of the securities markets. That evolution has been going on for decades and will continue indefinitely. Speeds we consider fast today are likely to be considered pathetically slow before we know it.

While quite a lot of trading qualifies as high-frequency trading in this general sense, there is a very specific type of HFT getting loads of attention these days, not much of it positive, centering as it does on concerns over safety and fairness. The controversial style of high-frequency trading—the type of HFT this book is mainly about—uses amazingly fast computation and networking capabilities to perform a type of trading strategy known rather ignobly as *scalping*. Like a ticket scalper at a ballpark, the securities scalper attempts to buy at one price and quickly sell at a higher price, or vice versa, pocketing the so-called bid-ask spread between the two. One of those prices typically belongs to a mispriced security, for example, a stock priced lower or higher than it should be. The chief work of the high-frequency trader, then,

is to find these opportunities and exploit them before anyone else does. (More later on how this is done.)

This book, a flyover of the high-frequency trading landscape, is written and organized for the reader with little or no prior knowledge of, well, anything to do with trading. The first thing we'll do is lay a foundation for understanding high-frequency trading by reviewing the various types of equity securities and the crucial relationships among them. We'll also take some time to understand what actually happens at the exchange and get ourselves good and comfortable with the order book, where trading actually happens. After a review of fundamental trading concepts, and a segregation of traders into four archetypes we'll call *investor*, *market-maker*, *arbitrageur*, and *predictor*, we'll dive promptly into their respective strategies and see where the high-frequency trader fits into the picture. As already noted, there is no shortage of concern these days about the perceived risks of high-frequency trading, so we'll dutifully summarize those and attempt to give equal time to its supposed benefits as well as discuss the more dubious purported practices of some high-frequency trading firms.

The information and assertions in this book are based on my own direct experience, as well as that of a number of traders, exchange officials, and others in the industry who were kind enough to talk with me. To the best of my knowledge, nothing revealed in this book could reasonably be considered proprietary to any individual firm. While high-frequency traders are well known for zealously guarding their trade secrets, there is still plenty of common knowledge to be had about high-frequency trading, certainly enough for you to get your bearings if you are new to this corner of the financial universe. Oh, and before I forget, let me say with no equivocation that as of the publication of this book, there is no way of telling which of the trading strategies discussed

herein would be considered legal and which would not. The propriety (whether by legal or ethical standards) of HFT is itself currently one of the subjects of a rather heated debate at the SEC, on Wall Street, and on exchanges around the world, so I do not offer up these words as anything even remotely resembling investment advice. Not to put too fine a point on it, but please don't attempt to employ any trading methodologies discussed in this book just because you read about them here.

You may have heard how much money can supposedly be earned by high-frequency trading. As such, I know what at least some of you might be thinking: "Can I do this at home?" Would that you could. Sure, you can pick up a gaming computer at Best Buy with processing power comparable to what the HFT firms have inside their servers. But you can also buy the same football they use in the Super Bowl at Sports Authority and the same Stratocaster you might see in the hands of Eric Clapton at Guitar Center. As you'll hopefully begin to appreciate after reading these pages, fast computers, like pigskins and guitars, are not the only gear one needs to play in this game.

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CHAPTER 1

Busted

I always wondered when word would get out. I got my own look in 2003. That's when I went to work for the Citadel Investment Group, Ken Griffin's stealthy Chicago hedge fund, to help them build a high-frequency trading system for the U.S. equity options market. There was only one fully automated options exchange in the United States at that time, the International Securities Exchange (ISE) in New York. Before the ISE opened for business in 2000, no options exchange would allow market-makers (a type of trader we'll learn about presently) to submit their all-important quotations—bids to buy and offers to sell—electronically. For the most part, those were still communicated verbally by human traders with loud voices and sharp elbows, standing all day in open outcry trading pits wearing sensible shoes. ISE founders David Krell and Gary Katz knew it was time to change that, and the success of their enterprise proved to any remaining doubters how absolutely right they were. The ISE was the quintessential game changer. Their explosive success forced the traditional, floor-based options exchanges to make their own plans for electronic quoting. And Ken Griffin wanted Citadel to be all over it.

I had been managing financial systems development for several years by this time, mostly for the pricing of derivative securities. The Citadel system, though, would not only calculate hundreds of thousands of option prices simultaneously—an impressive feat in its own right—but also inject streams of bids and offers into the markets at literally superhuman speed. The custom-built quoting engines would tirelessly inject many millions of quotes into the markets every day, each of them a binding commitment to buy or sell a listed option contract at some specified price, each one the result of a software program running on a computer. And while the quoters were busy doing that, “electronic eyes” would scan everyone else’s quotations and orders—hundreds of millions per day—all in real time. It would be like standing at the end of an open fire hose and examining each drop of water before it hit the ground. When the electronic eye (or EE) found someone offering to buy an option for more than it was worth, or to sell it for less, it would immediately submit an order to take the other side of the trade for a tiny profit.

It was a dazzling sight, watching these machines pick the markets clean of its inefficiencies. I would have loved to talk about it back then, to tell friends and family what was going on in the gleaming glass tower at the intersection of Dearborn and Adams. But the confidentiality agreements one has to sign for employers like Citadel are very, very effective. In this business, everyone knows that loose lips get pink slips. So like everyone else, I kept my mouth shut and talked only with my small group of colleagues on the 37th floor.¹

¹ Even within the sanctum sanctorum at Citadel, information was purely need-to-know. I once asked a quantitative analyst about one of the factors that went into the all-important volatility model. “What does ‘v’ mean?” “It means ‘v,’” she replied. “Ahh. What about ‘h’?” “It means ‘h.’” This little badinage went on for quite a few more letters of the alphabet.

By the time I left Citadel in 2005, their options market-making system—the work of a team not much larger than the Chicago Cubs’ starting lineup—was responsible for more than 10 percent of all options trading in the United States, or more than a million contracts a day. Within three years, its market share had reportedly grown to a commanding 30 percent. The U.S. options market had become dominated by the extraordinary machines of just a handful of secretive firms like Citadel. Still, nobody on the outside seemed to have a clue—or a care—that trading was no longer done by traders.

That all changed in 2009. As people licked their wounds in the aftermath of the 2008 market meltdown, wondering where all the money went, word got out that something like \$20 billion of it went to these folks known as high-frequency traders. The term was well known inside firms like Citadel but not so much outside. Now, it was bad enough that *anyone* made out like bandits in the horrible year that was 2008, but a far more frightening contemplation caused more than a few people to go grab a pitchfork from the shed: Was high-frequency trading (HFT) somehow culpable? Did it cause the mother of all crashes or accelerate it once it began? After all, the 1987 market crash was widely attributed to automated trading, then known as program trading. Did the computers do it again?

Word went around that 50 percent of all stock trading—maybe 60 percent or even 70 percent—was attributable to HFT computers trading with each other, supposedly just to collect tiny kickbacks, known as rebates, from the exchange. The HFT firms weren’t even holding on to their stock. Once bought, they’d immediately turn around and sell it, sometimes buying and selling the same stock hundreds or thousands of times a day. What was up with that? All this trading at ungodly speeds, it was said, was creating massive price volatility that otherwise wouldn’t exist. Could this be good?

Nerves were not settled when a former Goldman Sachs employee was arrested for allegedly stealing proprietary computer code for high-frequency trading, with the bank asserting ominously, "There is a danger that somebody who (knows) how to use this program could use it to manipulate markets in unfair ways."² Computer code to manipulate markets? What the heck was going on here?

Anyone following the HFT stories in 2009 learned a handful of new terms from the modern trading lexicon—none of them particularly comforting. The HFT firms were supposedly using something called "flash orders" to get advance looks at customer trade orders before the rest of the market, then using those peeks to make their own trades at a profit. Wasn't that front-running and wasn't it illegal? The flash order robbers supposedly had only 30 milliseconds to do their dirty work, but this was plenty of time because they "colocated" their computer servers in the same data centers as the exchange computers, at great expense. This also let them get their own orders in before any investor possibly could. Uneven playing field, anybody?

Unsatisfied with flash order thievery, the HFT smarties supposedly submitted something called *immediate-or-cancel* (IOC) orders with no intention of trading, but only to force investors to reveal the true prices at which they were willing to trade, information the HFT guys would use to move market prices against the investor. Whoa. Were the HFT firms even qualified to be so close to the exchange and trade at lightning speeds? Nobody could say, because it was nearly impossible to know even the identities of high-frequency traders. They didn't need to make the infrastructure investments themselves. They could use *direct market access* (DMA)

² "Goldman May Lose Millions From Ex-Worker's Code Theft," Bloomberg, July 7, 2009.

or *naked access*, using their broker's exchange connection to get in anonymously, then perform their lightning-fast derring-do as if wearing a mask.³

"Dude," you could almost hear people asking, fatigued and more than a little ticked off, "What happened to our stock market?" Was it no longer what it used to be, a place to simply invest in companies with the idea of holding on to that stock for a while? Were we all foolishly naive to still think like that? Maybe we had all been reduced to easy marks for sharpies with fast computers and math skills far better than our own, like dummies on the boardwalk, sized up and taken by the hucksters. Do the markets still work? Or have they been hijacked by cutthroat information technology and runaway greed?

It can sure seem that way.

The year 2008 was indeed the year of wonders for high-frequency traders, especially options traders, and this struck plenty of folks as somehow wrong. A headhunter told me that his client, a high-frequency options market-making firm, had made over \$800 million in 2008. Another well-known firm was said to have cleared \$1.3 billion of net profit—and that was just trading options. Who knows what the stock HFT desk pulled in.

Having worked in this business and performed mind-numbing P&L⁴ calculations myself, I found those rumored numbers entirely plausible. Three billion option contracts were traded in 2008⁵ with a net profit to the market-maker

³ SEC Chairman Mary Schapiro likens the practice of DMA to lending the car keys to your unregistered Ferrari to someone who may not even be licensed to drive.

⁴ Profit and loss.

⁵ optionsclearing.com/webapps/historical-volume-query.