Markets and Supercomputing
David Leinweber
LBL
Berkeley Lab's Center for Innovative Financial Technology

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"Financial markets have evolved into high-speed complex systems that play a central role in our nation's—and the world's—economy. Many of the challenges facing the market—security, stability and monitoring—are similar to those in other complex systems where Berkeley Lab is applying its computational expertise. We view this as another strong opportunity to address a problem of great importance to our country," says Horst Simon, Deputy Director for Lawrence Berkeley National Laboratory.

"Security and stability of markets is a national security issue of the first order. This has been made clear by recent events on both macro and micro time scales. We hope this center will stimulate discussion of these topics, and lead to a larger role for advanced computing researchers in understanding markets that have become advanced computers," says David Leinweber, head of the Berkeley Lab's Center for Innovative Financial Technology.

http://www.lbl.gov/CS/CIFT.html
Economical Numbers

There are $10^{11}$ stars in the galaxy. That used to be a huge number. But it's only a hundred billion. It's less than the national deficit!

We used to call them astronomical numbers.

Now we should call them economical numbers.

- Richard Feynman
Flash Crash
May 6, 2010

• 1000 DJ points in minutes
• Many stocks went to pennies
• Complex unexpected interactions within and across markets
• Convergence of technology & regulation
Much worse than your average flash crash.
Key Developments

• Up till 90s, two places to trade US stocks:
  – ~only NYSE & NASDAQ, and each had their own listings
• Automation started for small orders to let brokers handle jumbo trades blocks
• Proverbial camel nose in tent, no more large orders.
  – Streams of small ones
• Move from single dealer quote-driven markets to open order-driven markets
  – Fragmented & complex
Transformation of Markets

• From 1/8s, 1/16s to Penny pricing

• Computing & Communication
  – Easy to create new ‘exchanges’

• Now ~50 closely coupled stock trading venues
  – up from 2 – NYSE/NASDAQ, Fragmentation

• SEC ‘97 “Best Price Execution” rule couple them together

• Structural coupling to other securities & electronic markets
  – ETFs, futures, options, also ever faster and more complex

• Moore, Metcalf & Malcom
  – Functions of exchanges move onto networked systems
  – Complex unexpected behaviors
  – Positive feedback loops for ever-faster information push machines to limits

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Who’s Malcom?

Dr. Ian Malcom (Jeff Goldblum)

“...a mathematician and chaos theorist and refers to himself as a "chaotician". He goes on many long lectures on chaos theory and the results of meddling with nature, and other subjects, often turning out to be correct.” - IMDB
MALCOLM
How do you know they can't breed?

MALCOLM
If there's one thing the history of evolution has taught us, it's that life will not be contained. Life breaks free. It expands to new territories. It crashes through barriers. Painfully, maybe even... dangerously, but and...well, there it is.
US Equity Markets – May 6, 2010
Fat Finger?
Fat Finger? Manipulation?
Fat Finger? Manipulation? CyberAttack?
Months of “What hit us?”

Fingers don't get that fat. Error, Manipulation or Cyberattack?

Call me a paranoid old nerd, but the “fat finger” explanation for the 1000 point drop in the US stock market on Thursday just doesn't make any sense.

When I ran 56B in quant equities as an institutional manager in the 90s, we had multiple redundant layers of checks and checks-on-checks to avoid that kind of error. The early electronic orders (high frequency trading when frequencies weren't as high) had their own safety nets. Additional layers were in place at the receiving end, at the brokers and the market centers.

There were stories of temp employees or traders coming back after a liquid lunch and offering to sell 900,000 shares of a stock at 1000 yen instead of 1000 shares at 900,000 yen, and getting whacked, but they didn't crash the market. (Things can be more extreme in Japan - there are no 590,000 US stocks.)

Legitimate traders who make these errors fess up fast, and work with the guys at the other end to tweak the filters so there are no encore. No one is stepping up on this one. (Added 3/9: Theory B is that there is a programmer with soiled trousers hiding in a Chicago basement who is too petrified to tell the management, who would report.)

So what happened? Maybe a market manipulation. Always a good way to make a lot of money in a hurry. There's an old (and very funny) novel called 'Green Monday', by Michael Thomas, that tells a similar tale. It's been out of print for 29 years, but can be had on Amazon for $0.01 (plus five bucks shipping). It tells the story of a down-in-the-royal-woods lower level Saudi prince who gets no respect as a garden variety multi-millionaire and wants to impress the family by making himself a mega-multi-billionaire. He goes to a thinly disguised version of BARRA (an early quant firm), where the Certified Neuralgic Investment Theorists (who take great pride in bragging ‘I am a fully certified NIT’) design a program trade to rapidly take and then rapidly unwind positions in stocks that would have large price moves after a manufactured oil shock engineered by the upwardly mobile junior prince, moving him up to the major leagues of prince-dom. Today, fast turns in leveraged index futures and options would be a turbocharged version.
Potentially, a Grand Problem
"The SEC's efforts to reconstruct the trading on that day are substantially more challenging and time consuming than we would have liked because no standardized, automated system exists to collect data across the various trading venues, products and market participants," Schapiro said.

Commissioner Luis Aguilar questioned, however, whether the SEC would have the human and technological resources to evaluate the projected 100 gigabytes of data expected to come in daily to the repository. He made a plea to Congress to approve a measure approved by the Senate that would allow the SEC to be self-funded, a provision that would significantly increase the agency's annual budget.

"The SEC's staff must be equipped with the best resources to do the job," Aguilar said. "Most Americans assumed the SEC has these tools. It is shocking that the SEC does not have its own access to this data."

"The SEC must have this data and the tools to identify egregious conduct, identify trends and reconstruct market movements."

SEC officials estimate that the CAT project will cost a whopping $4 billion to build, take three years to complete and will require $2 billion a year to operate.

"These costs will be substantial. The benefits will be substantial." - Kathleen Casey, SEC commissioner

A Supercomputing Grand Challenge

• Economic simulations on early DARPA Grand Challenge Lists
• Greater motivation now
  – micro (flash crash) level and
  – macro (wreck of 2008) risk management
• Amply qualifies on data size and computational complexity
  – 100s of Gigs per day
    • US stocks alone
  – “What if” combinatoric
• Visualization, Analysis, Simulation Challenges
• Funded & Explicitly identified

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FINDINGS REGARDING THE MARKET EVENTS OF MAY 6, 2010

REPORT OF THE STAFFS OF THE CFTC AND SEC TO THE JOINT ADVISORY COMMITTEE ON EMERGING REGULATORY ISSUES
A Useful Digression:

*Market Microstructure and Market Technology*
NYSE in 1792. Shouting under the Buttonwood Tree
NYSE moves indoors. Tontine Coffee House. 1794
NYSE Posts - 1850

Specialist Quote Market
NYSE Posts - early 1900s

Multi-core version!
What’s posted at these posts?
Dealer Quotes

- Buy price, Buy size
  - The Bid
- Sell price, Sell Size
  - The Ask
Simple Balanced Quote

1000 to sell at $101, will buy 1000 at 100
Building inventory (or reducing shorts)

500 to sell at $102, will buy 1000 at 101
On Sale Now! (or informed trading)

1000 to sell at $99, will buy 100 at 98
A worried dealer

*Wide spread, small sizes*
What else happens at posts?

The Limit Order Book
NYSE Horseshoe Post With LOB 1939
NYSE Posts - 1955

NYSE Photo
Limit Orders (20th Century)

• Initially kept in actual books, at the posts
  – Slow and tedious to change
  – And seen only by the specialist at NYSE
  – Later NASDAQ Market Makers

• Now open to all in connected markets

• 21st Century
  – Open book, half life in milliseconds
  – Liquidity probes
  – Latency wars

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Limit Order Book

Much more information

Shares

Price

The Inside Quote, BBO
Limit Order Book

Much more information

The Inside Quote, BBO
Limit Order Book

Much more information

Buy Depth

Sell Depth

Shares

Price

The Inside Quote, BBO
Trades and the Limit Order Book

*Executions – Actual Buys or Sells*

A seller-initiated trade at the best offered buy price
Trades and the Limit Order Book

*Executions – Actual Buys or Sells*

A buyer-initiated trade at the best asking sell price
Limit Order Book

Stub Quotes

Shares

Sure, I’ll buy for a penny

Sure, I’ll sell for $1000

Price

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Quote Driven & Order Driven Markets

• Quote driven – Dealer sets prices, LOB private
• Order driven – Limit orders public, LOB “competes” with dealer
• NYSE was Quote Driven until 2001, when they phased in “OpenBook”, slowly
  – Under competition from NASDAQ & MANY Others
• Now markets are order driven
  – With HPC scale data: 100s G/day
  – Speeds accelerating rapidly
    • Talk of $M/microsecond, ASICs
  – Convergence of tech, regulation, structure
oculus
People and paper become endangered
Timeline

1968  Central Certificate Service
The Central Certificate Service (CCS) is established to transfer securities electronically, eliminating their physical handling for settlement purposes. CCS is later succeeded by Depository Trust Company.

1972  Securities Industry Automation Corp. Established
The Securities Industry Automation Corporation (SIAC) is organized. The subsidiary company, jointly owned by the NYSE and the American Stock Exchange, provides automation and data processing services.

1973  Depository Trust Company
Depository Trust Company is established to provide a central depository for securities certificates and electronically record transfers of stock ownership.
Timeline

1975 Full Consolidated Tape Introduced
   June 18:
   NYSE introduces its full consolidated tape.

1976 NYSE Launches Designated Order Turnaround
   The fully automated Designated Order Turnaround (DOT) system is introduced to electronically route smaller orders.

1978 ITS
   The Intermarket Trading System (ITS) is inaugurated. ITS provides an electronic link between the NYSE and competing exchanges, enabling brokers to access all markets nation-wide to find the best purchase or sale price for a security.
NASDAQ

- World’s first electronic stock market – 1971
  - Electronic bulletin board,
  - Phone execution
- Electronic execution
  - SOES 1985
- SuperSOES
- Many ECNs
- SuperMontage 2002
Software: Programs that buy and sell shares are becoming ever more sophisticated. Might they replace human traders?
Coupled Fragmented Markets

• >50 venues for US equities & Futures
• Different structures, order types, info
• Dynamic elements
  – Circuit breakers, active order types, HFT
  – Error/Perceived Error breaks
• Vanishing specialists
  – No obligation to quote
  – HFTs again
• Coupled markets & securities
  – Futures, ETFs
## Liquidity Payments

**BATS Market Volume**

<table>
<thead>
<tr>
<th>Data for Oct 22</th>
<th>Tape A (NYSE)</th>
<th>Tape B (Regionals)</th>
<th>Tape C (Nasdaq)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BZX Exchange Volume</strong></td>
<td>208,255,065</td>
<td>119,766,566</td>
<td>177,123,750</td>
<td>506,145,381</td>
</tr>
<tr>
<td><strong>BZX Exchange % Market</strong></td>
<td>6.19%</td>
<td>13.99%</td>
<td>10.52%</td>
<td>8.55%</td>
</tr>
<tr>
<td><strong>BYX Exchange Volume</strong></td>
<td>9,311,501</td>
<td>1,274,135</td>
<td>2,186,212</td>
<td>12,771,848</td>
</tr>
<tr>
<td><strong>BYX Exchange % Market</strong></td>
<td>0.26%</td>
<td>0.15%</td>
<td>0.13%</td>
<td>0.22%</td>
</tr>
</tbody>
</table>

*(Data is delayed at least 20 minutes)*

**BATS Exchange Platform Continues to Offer Sustained Low Latency**

Orders now acknowledged or executed in less than 250 microseconds on average and are visible via Multicast PITCH in 265 microseconds on average.

**Simple Pricing**

- **Adding Liquidity**
  - BZX Exchange (Displayed Book - All Tapes): **+$0.0024**
  - BYX Exchange (Displayed Book - All Tapes): **FREE**

- **Removing Liquidity**
  - BZX Exchange (Displayed Book - All Tapes): **-$0.0025**
  - BYX Exchange (Displayed Book - All Tapes): **+$0.0003**

- **Routing Out**
  - BZX Exchange (Displayed Book - All Tapes): **-$0.0020 / .0028**
  - BYX Exchange (Displayed Book - All Tapes): **-$0.0020 / .0028**

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Pipeline Control Center

Alpha Pro™
Algorithm Switching Engine Savings
Switching Engine Demonstration
Contra Targeting™
Blind Bid Options Cross™

Pipeline Switch Board

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>TRADING</th>
<th>ACTIVE</th>
<th>PROGRESS</th>
<th>SWITCHING ENGINE</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNL</td>
<td>72%</td>
<td>725,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DP</td>
<td>37%</td>
<td>425,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>COST</td>
<td>25%</td>
<td>850,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PG</td>
<td>6%</td>
<td>505,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>APZI</td>
<td>4%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>3%</td>
<td>1,300,000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>TRADING</th>
<th>ACTIVE</th>
<th>PROGRESS</th>
<th>SWITCHING ENGINE</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>2,190,000</td>
<td>3%</td>
<td>2,190,000</td>
<td>750,000</td>
</tr>
</tbody>
</table>

CANCEL ALL
(800) 680-7473

FILTER HDU
### Current Order Types | Reg NMS Order Types (effective 05 March 2007)

Users may enter both proprietary orders and agency orders for the account of a customer. Proprietary orders entered into NYSE Arca are subject to the same display and execution processes as agency orders.

<table>
<thead>
<tr>
<th>Order Type</th>
<th>Description</th>
<th>Eligible Sessions</th>
<th>Eligible Stocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market Order</td>
<td>An order to buy or sell that is to be executed at the best price obtainable.</td>
<td>Market Order Auction; Core</td>
<td>Listed, OTC</td>
</tr>
<tr>
<td>Limit Order</td>
<td>An order to buy or sell at a specified price or better. A marketable limit order is a limit order to buy (sell) at or above (below) the consolidated best offer (bid) for the security.</td>
<td>All</td>
<td>Listed, OTC</td>
</tr>
<tr>
<td>Inside Limit Order</td>
<td>Marketable Inside Limit Orders will be matched within the Book at the best obtainable price or routed to the market participants at the NBBO. Any residual volume will not be routed to the next price level until all quotes at the current best bid or offer are exhausted. Non-marketable Inside Limit Orders will be posted in the Book at the limit price.</td>
<td>All</td>
<td>Listed, OTC</td>
</tr>
<tr>
<td>Reserve Order</td>
<td>A limit order that replenishes the displayed order size as executions are received, up to the total order quantity; away markets are routed at their quoted size or larger (if applicable) when hitting the bid or taking the offer.</td>
<td>All</td>
<td>Listed, OTC</td>
</tr>
<tr>
<td>Good-Til-Cancel Order (GTC)</td>
<td>A market order that is to be routed as a market-on-open order to the primary market for participation in the primary market opening or re-opening process. A primary order entered after the primary market opens is processed as a normal market order.</td>
<td>Until 10:00 a.m. ET</td>
<td>Listed, OTC</td>
</tr>
<tr>
<td>Primary Only Order (POO)</td>
<td>A market order that is to be executed in whole or in part on NYSE Arca as soon as the order is received. Any residual balance is canceled.</td>
<td>Market-Core, Limb-Al</td>
<td>Listed, OTC</td>
</tr>
<tr>
<td>Immediate-Or-Cancel (IOC)</td>
<td>A limit order that is to be executed in whole or in part on NYSE Arca as soon as the order is received. Any residual balance is canceled.</td>
<td>Market-Core, Limb-Al</td>
<td>Listed, OTC</td>
</tr>
<tr>
<td>Post No Preference (PNP) Order</td>
<td>A limit order to buy or sell that is to be executed in whole or in part on NYSE Arca. The portion not executed is posted in the Book without routing any portion of the order to another market center.</td>
<td>All</td>
<td>Listed, OTC</td>
</tr>
<tr>
<td>Tracking Limit Order</td>
<td>A Tracking Limit Order is an undisplayed, priced round lot that is eligible for execution in the Tracking Order Process against orders equal to or less than the aggregate size of the order if interest is available at that price. Orders may be entered at any price. However, if the price will lock or cross the market, the order will be priced at the NBBO. Orders will only execute at the NBBO.</td>
<td>Core</td>
<td>OTC</td>
</tr>
<tr>
<td>Passive Liquidity (PL) Order</td>
<td>An undisplayed Limit Order that resides in the NYSE Arca limit order book. All displayed orders at the same price as a PL Order will have priority over a PL Order unless the PL Order is priced more aggressively. The PL Order is available in NYSE Arca Primary Listings to Lead Market Makers (LLMMs) only.</td>
<td>All</td>
<td>NYSE, AMEX, NASDAQ</td>
</tr>
<tr>
<td>Discretionary Order</td>
<td>An order with two price components — a display price and a discretionary price — that is displayed at your specified price, not your discretionary price. When a bid or offer appears at or within your discretionary price range, your order will be matched on NYSE Arca or proactively routed externally at the quoted price.</td>
<td>All</td>
<td>Listed, OTC</td>
</tr>
</tbody>
</table>

### Discretion Limit Order (DL)

An order that is displayed at your specified price, not your discretionary price, along with a share quantity minimum requirement for routing discretionary prices outside the Book. When a bid or offer appears on an away market at or above your share quantity minimum, your order will be routed to that market participant at their quoted price. NBBO price protection does not apply to these orders.

### Passive Discretionary Order

The order is displayed at your specified price (not your discretionary price) and is not eligible to route. When a bid or offer appears in the Book at or within your discretionary price range, it will be executed against the Book even if the Book order is outside the NBBO in OTC stocks only. A discretionary price can be used in combination with a reserve order.

### Cross Order

A Cross Order is a two-sided order with both a buy and sell component combined that trades at a stated price for a stated size specified by the user. Cross Orders must satisfy better prices displayed in the Book or in the market before matching the remaining shares as a cross.

### Midpoint Cross Order (MCO)

A two-sided order with both a buy and sell component combined that trades at the midpoint of the NBBO. Orders will never be broken up and will always execute as “clean crosses.” Orders cannot trade ahead of the Book.

### IOC Cross Order

A two-sided order with both a buy and sell component combined that trades at a price specified by the user. An IOC Cross will not interact with the Book or outside markets, and will be rejected if order interaction would occur. Orders will never be broken up and will always execute as “clean crosses.” Orders cannot trade ahead of the Book.

### Post No Preference (PNP) Cross and Post Order

A cross order to buy or sell that is to be executed in whole or in part on NYSE Arca. Any residual share balance that has been broken up and not cross initially is immediately posted in the Book without routing any portion of the order to another market center. The posted share balance will be treated as a normal limit order.

### Pegged Order

An order with a price that will track the national best bid or offer. Pegged orders may also make use of offsets from the same side bid (offer) or offsets from the contra side (peg buy offset from offer). The order is displayed in the Book.

### Now Order

A limited price order that is executed in whole or in part that will be routed to one or more NOW recipients (those venues that respond immediately with a fill or a cancel) for immediate execution if the order cannot be executed on NYSE Arca. Orders are immediately canceled if not executed at the quoted price or better.

### Limit-On-Close Order (LOC)

A market order that is to be executed only during the closing auction.

### Market-On-Close (MOC)

Closing Order Auction  NYSE Arca Exclusives

### Auto-Q Order

An order that enables NYSE Arca Regulated Market Makers to automatically update their quotes. The Auto-Q order automatically reposts a Q Order (Market Maker quote) in the Book at a designated increment away from the original quoted price and for the original amount of displayed shares. Upon execution, the Auto-Q order continues to repost in the Book at the determined increment and size until the total designated tradable size is executed.
Liquidity Agents

PREVIOUSLY:

TRUST ME JAN.
I CAN FIND LIQUIDITY ANYWHERE.

MORE NEW REGS?
MARKET STRUCTURE DEVELOPMENTS MAKE ME SWEAT...

CAN'T DEAL WITH NEW REGS? CLICK HERE.

c. 2010 D. Leinweber
Back to the **crash**...
FINDINGS REGARDING
THE MARKET EVENTS
OF MAY 6, 2010

REPORT OF THE STAFFS OF THE CFTC
AND SEC TO THE JOINT ADVISORY
COMMITTEE ON EMERGING
REGULATORY ISSUES

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(202) 418-5000
www.cftc.gov

U.S. Securities & Exchange Commission
100 F Street, NE
Washington, D.C. 20549
(202) 551-5500
www.sec.gov
CONTENTS

EXECUTIVE SUMMARY
What Happened? .................................................. 1
Liquidity Crisis in the E-Mini .................................... 3
Liquidity Crisis with Respect to Individual Stocks ........... 4
Lessons Learned .................................................. 6
About this Report ................................................. 8

I. TRADING IN BROAD MARKET INDICES ON MAY 6 ..... 9
I.1. Market Conditions on May 6 Prior to the Period
     of Extraordinary Volatility .................................. 9
I.2. Stock Index Products: The E-Mini Futures Contract
     and SPY Exchange Traded Fund ......................... 10
I.3. A Loss of Liquidity ........................................ 11
I.4. Automated Execution of A Large Sell Order in the E-Mini
     ................................................................. 13
I.5. Cross-Market Propagation .................................. 16
II. MARKET PARTICIPANTS AND THE WITHDRAWAL OF LIQUIDITY

II.1. Overview ........................................................................................................... 32
II.2. Market Participants ............................................................................................ 35
   II.2.a. General Withdrawal of Liquidity ............................................................... 35
   II.2.b. Traditional Equity and ETF Market Makers .............................................. 37
   II.2.c. ETFs and May 6 ....................................................................................... 39
   II.2.d. Equity-Based High Frequency Traders ..................................................... 45
   II.2.e. Internalizers .............................................................................................. 57
   II.2.f. Options Market Makers ............................................................................ 62
II.3. Analysis of Broken Trades .................................................................................. 63
   II.3.a. Stub Quotes ............................................................................................... 63
   II.3.b. Broken Trades ........................................................................................... 64

III. POTENTIAL IMPACT OF ADDITIONAL FACTORS ....................................... 68
   III.1. NYSE Liquidity Replenishment Points ...................................................... 68
   III.2. Declarations of Self-Help against NYSE Arca .......................................... 73
      III.2.a. Overview of Rule 611 and the Self-Help Exception ........................... 73
      III.2.b. Evaluation of Self-Help Declarations on May 6 ................................. 75
   III.3. Market Data Issues ...................................................................................... 76

IV. ANALYSIS OF ORDER BOOKS ....................................................................... 80
   IV.1. Analysis of Changes in Liquidity and Price Declines ................................. 80
   IV.2. Detailed Order Book Data for Selected Securities ..................................... 83
SEC Explanation in Brief

• Liquidity crisis in E-Mini future
• Caused by automated sell order in E-Mini by Waddell & Reed (“Fundamental Trader”)
  – 75,000 E-minis (@$50*SP = $4.1B)
• Cross market propagation
  – Futures to stocks
FIGURE 1.3: E-Mini Buy-Side and Sell-Side Market Depth (all quotes)

E-Mini Market Depth
All Quotes

Resting Contracts (beginning-of-minute)

Buy Depth
Sell Depth

Totals of each side of the book

May 6, 2010 Market Event Findings

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FIGURE 1.6: E-Mini Buy-Side Market Depth, Second-by-Second (note time is in CT)

E-Mini Total Buy Depth
Second-by-Second (Time in CT)

Down >90%

6 minutes
FIGURE 1.8: SPY Buy-Side and Sell-Side “Near-Inside” Market Depth within 10 basis points of mid-quote

SPY Near-Inside Market Depth
Within 10 basis points of mid-quote

<table>
<thead>
<tr>
<th>Time</th>
<th>Buy Depth</th>
<th>Sell Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:30</td>
<td>2,000,000</td>
<td>1,750,000</td>
</tr>
<tr>
<td>9:45</td>
<td>1,500,000</td>
<td>1,250,000</td>
</tr>
<tr>
<td>10:00</td>
<td>1,250,000</td>
<td>1,000,000</td>
</tr>
<tr>
<td>10:15</td>
<td>1,000,000</td>
<td>750,000</td>
</tr>
<tr>
<td>10:30</td>
<td>750,000</td>
<td>500,000</td>
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<tr>
<td>11:00</td>
<td>500,000</td>
<td>250,000</td>
</tr>
<tr>
<td>11:15</td>
<td>250,000</td>
<td>0</td>
</tr>
</tbody>
</table>

May 6, 2010 Market Event Findings
Cross market liquidity crisis
Time Zoom Views

Chart 1.A: S&P 500
Market Depth (within 500 basis points) and Net Aggressive Buy Volume

The order book depth reflects the total number of shares in unfilled limit orders, by buyer and seller. The data combines the information from Limit Order Book, Best Bid and Offer, and best bid order book data.

Aggressive bids/quotes is reflected in a request volume associated with aggressive buy orders; average current demand associated with aggressive sell orders.

Aggressive buy orders are market buy orders and key orders at or above the offer price; aggressive sell orders are market sell orders and sell orders at or below the bid price.
Chart 1.B: S&P 500
Full Market Depth and Net Aggressive Buy Volume

Time Zoom Views
Time Zoom of Flash Crash
S&P 500 Market Depth

c. 2010 D. Leinweber
Time Zoom Views
Time Zoom Views
Time Zoom Views

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Chart 1.A: S&P 500
Market Depth (within 500 basis points) and Net Aggressive Buy Volume
What is the machinery? Role of HFT?
Anatomy of Oil Price Manipulation: High-Frequency Trading on Commodities Markets

Posted by Steven Zweig on September 9, 2009 at 2:05 pm

High-frequency trading, an electronic trading technique that uses complex software to make financial transactions on the equities and derivatives markets, has come to the commodities market. As reported by the New York Times on Friday, the CFTC has charged trading company Optiver with manipulating the price of oil using high-frequency trading, the supercomputer-driven ability to react to market trends and place orders faster than anyone else.
HFT Pioneers
Liquidity providing array of limit orders: ATD 1988

Source: Schwartz & Whitcomb 1988
Figure 2.2: Dollar Volume of High Frequency Traders for NYSE Arca-Listed Securities

Dollar Volume of 12 High Frequency Traders
NYSE Arca Listed
(FINRA Data Set)
Figure 2.7: HFT Buying and Selling Ratios for Securities Listed on Nasdaq, NYSE Arca, and NYSE

HFT %Sell Dollar Volume
NASDAQ, NYSE Arca, and NYSE Listed
(FINRA Data Set)
“(TRF) provides FINRA members with a mechanism for the reporting of transactions effected otherwise than on an exchange.”
“(TRF) provides FINRA members with a mechanism for the reporting of transactions effected otherwise than on an exchange.”
The SEC/CFTC continues...

• Stub Quotes
• Broken Trades
• Liquidity Replenishment Points
  – Circuit breakers
• Individual Stock Horror Stories
Chart 4.A: Accenture plc. (ACN)
Market Depth (within 500 basis points) and Net Aggressive Buy Volume

Time Zoom Views
Liquidity and Price Head to Zero
Chart 5.B: Procter & Gamble Company (The) (PG)
Full Market Depth and Net Aggressive Buy Volume
Chart 6.A: 3M Company (MMM)
Market Depth (within 500 basis points) and Net Aggressive Buy Volume

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The chart shows the market depth and net aggressive buy volume for 3M Company (MMM) from 2:00pm to 3:00pm. The x-axis represents time, and the y-axis represents price and volume. Each graph provides a detailed view of the market depth and net aggressive buy volume during different time intervals.
Chart 10.B: Russell 2000 Index (Barclays) (IWM)
Full Market Depth and Net Aggressive Buy Volume
Much Discussion of the SEC/CFTC Report
"The 75,000 contracts represented 1.3% of the total E-Mini volume of 5.7 million contracts on May 6 and less than 9% of the volume during the time period in which the orders were executed. “
Nanex

Crop Circles Of the Market


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Nanex Discovery 1

• Rapid quoting behavior
  – Looks like Denial of Service
  – A Race to be faster, positive feedback
  – Can/does overload market systems

• Looking at much finer time scales
Nanex “Bandsaw”

http://www.nanex.net/20100506/FlashCrashAnalysis_Part4-1.html

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5 min
Nanex “Bandsaw II”
Nanex “Crystal Triangle”

30 second period
Nanex Discovery 2

• Lagging NYSE quotes create situations where NYSE Best Bid > Best Ask Quote (all other markets)
  – Instant profit, buying low outside, sell high at NY

• Microstructure version of a short-circuit
Chart 1-b:
Total number of NYSE listed stocks where the Exchange's Bid price is above the Best Ask price.
Nanex Chart 2-a, CVX on 05/06/2010
Nanex on the W&R Theory

We have obtained the Waddell & Reed (W&R) May 6, 2010 trade executions from the executing broker in the June 2010 eMini futures contract. There were 6,438 trades totaling 75,000 contracts.

We matched them by time, price and size to the 147,577 trades (844,513 contracts) in the CME time and sales data between 14:32 and 14:52 (they matched exactly). One-second resolution charts of the W&R trades along with other eMini trades are shown below in various time frames.

The SEC report identified a Sell Algorithm selling 75,000 contracts as the cause of the flash crash. If the "Sell Algorithm" in the SEC report refers to the Waddell & Reed trades, then there is a problem. A big one. Looking at the trades in context with the other trades during that time, they do not appear to be significant.
Nanex on the W&R Theory
The W&R trades also do not occur near the ignition point (14:42:44.075) we identified earlier. Furthermore, the W&R trades are practically absent during the torrential sell-off that began at 14:44:20.

The bulk of the W&R trades occurred after the market bottomed and was rocketing higher -- a point in time that the SEC report tells us the market was out of liquidity. Finally, the data makes it clear that the algorithm does take price into consideration; you can see it stops selling if the price moves down over a short period of time.

Something is very wrong here.
Why did it take 5 months to understand 5 minutes of data?

• And do we really understand it now?
• How long should it take?
• How close to real-time needed?
Current Technology

Order Audit Trail System (OATS™)

FINRA has established the Order Audit Trail System (OATS), as an integrated audit trail of order, quote, and trade information for Nasdaq and OTC equity securities. FINRA uses this audit trail system to recreate events in the life cycle of orders and more completely monitor the trading practices of member firms. Under FINRA Rules 7410 - 7470, FINRA member firms are required to develop a means for electronically capturing and reporting to OATS specific data elements related to the handling or execution of orders, including recording all times of these events in hours, minutes, and seconds, and to synchronize their business clocks. These Rules were approved by the SEC on March 6, 1996.

http://www.finra.org/Industry/Compliance/MarketTransparency/OATS/
FINRA Rule 7430 - Synchronization of Member Business Clocks

Rule 7430 requires any FINRA member firm that records order, transaction or related data to synchronize all business clocks used to record the date and time of any market event. Clocks, including computer system clocks and manual time stamp machines, must record time in hours, minutes and seconds with to-the-second granularity and must be synchronized to a source that is synchronized to within three seconds of the National Institute of Standards’ (NIST) atomic clock.

Clocks must be synchronized once a day prior to the opening of the market, and remain in synch throughout the day. In addition, firms are to maintain a copy of their clock synchronization procedures on-site. Clocks not used to record the date and time of market events need not be synchronized.
2. Clock Synchronization

FINRA Rule 7430 requires member firms that record order, transaction, or related data required by the By-Laws or other rules of FINRA to synchronize all business clocks, including both computer system clocks and mechanical time stamping devices, that are used to record the date and time of any market event. In addition, the rule requires that member firms maintain the synchronization of such business clocks. These requirements were effective according to the following schedule:

By August 7, 1998, for all computer system clocks, and
By July 1, 1999, for all mechanical clocks.

The rules also require that the granularity of all order event timestamps for OATS reportable events, generated by both computer systems and mechanical time stamping devices, be in seconds. This time must be reported to OATS in Eastern Military (24 hour clock) Time. All computer system clocks and mechanical time stamping devices must be synchronized to within three seconds of the National Institute of Standards and Technology (NIST) atomic clock. Any time provider may be used for synchronization, however, all clocks and time stamping devices must remain accurate within a three-second tolerance of the NIST clock. This tolerance includes all of the following:

- The difference between the NIST standard and a time provider’s clock
- Transmission delay from the source
- The amount of drift of the member firm’s clock
HFT firms work in microseconds. Current audit system records in seconds. Like timing a swim meet with a calendar.
THUNDERBOLT E GPS DISCIPLINED CLOCK

Off-the-shelf 15 ns clock

PERFORMANCE SPECIFICATIONS

General ........................................... L1 frequency, CA/code (SPS), 12-channel continuous tracking receiver
Update rate ........................................... 1 Hz
PPS accuracy ........................................... UTC 15 nanoseconds (one sigma)
10 MHz accuracy .................................... 1.0 x 10^-10 (one day average)
10 MHz stability ..................................... See graph below
WM Lawyer Seeks Supercomputer

“The securities industry generates an awesome amount of information. Gathering the information is one thing. Sifting through the information haystack to find the useful needles buried within is another matter, and that requires extremely robust computing power.

I suspect that this cannot be accomplished without using systems that rival the type of computer technology used by scientists to study global warming or astronomy.”


c. 2010 D. Leinweber
WM Lawyer Seeks Supercomputer

Assuming for the sake of argument that such systems exist within the limits of current technology, my guess is that they are very expensive to own and operate.

Will the SEC mandate that such systems be maintained by the industry, or is it planning to ramp up its own data-mining capabilities in-house?

WM Lawyer Seeks Supercomputer

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Grand Challenge Scorecard

• National importance
• Lots of data
  – Petascale store at TR archive
  – 100s of Gig added per day
• Lots of computation
  – Combinatoric complexity in simulation
  – Near Real Time, or Real Time
• Excellent match for Supercomputing paradigms
  – Visualize, Analyze, Simulate, Test
The worthwhile problems are the ones you can really contribute something to.

- Richard Feynman

This slide satisfies The Law of Feynman Quotational Symmetry


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I believe that a scientist looking at nonscientific problems is just as dumb as the next guy.

- Richard Feynman
Excellent news site.

http://tabbforum.com/
Berkeley Lab's Center for Innovative Financial Technology

Contact: David Leinweber, dieinweber@lbl.gov

UPDATE:

- Click here to read the SEC Consolidated Audit Trail System proposal.
- Click here to download a PDF of the response to the SEC from Horst Simon and David Leinweber.

http://www.lbl.gov/CS/CIFT.html