U.S. Market Structure

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SECTOR REVIEW

HFT 101 with Tradeworx

We had the pleasure of hosting Manoj Narang, CEO of Tradeworx for an in depth discussion of high frequency trading and U.S. market structure. Enclosed is a summary of the topics discussed.

- **Tradeworx, Inc.** is a financial technology company based in Red Bank, New Jersey that operates an equity market neutral hedge fund, a high frequency trading business and a technology solutions business through Thesys Technologies. Tradeworx today comprises ~5% of U.S. equity volume
- **Key Takeaways (details in the note). 1)** Diminishing marginal returns to squeezing an additional microsecond out of the equation **2)** Latency has been compressed to a point where speed advantages have become more random rather than deterministic **3)** Democratization of technology has leveled the playing field **4)** Size determines the conversion of an individual trade winning percentage (52-53% for Tradeworx) to a daily winning percentage (86%) to a weekly winning percentage (99.9%) **5)** HFT liquidity is valuable given the provision of immediacy, diffusion of price pressure and transference of holding period risk **6)** HFT firms do not trade in microseconds, Tradeworx holds trades for 10 minutes on average **7)** Need to cancel orders reflects risk management **8)** Poor fill rates are a function of inadequate trading infrastructure **9)** HFT firms needs to be passive and not active to do large amounts of volume **10)** Price-time priority and narrow trading increments increase the important of speed **11)** Tradeworx is agnostic to the existence of the maker-taker model **12)** Eliminating the maker-taker model would reduce displayed size at each quote and increase cancellation rates **13)** SIP is unsuitable for trading as it doesn't show depth of book **14)** Using direct feeds is not just a speed game but also involves skill in processing order messages **15)** Market structure regulation will be data-driven **16)** Retail broker price improvement execution statistics need to be improved.
- **Stock positioning–we like NDAQ.** We view recent share price weakness from concerns around regulation as a buying opportunity for a cash flow rich franchise (9% FCF Yield). We believe the regulatory overhang on NDAQ will gradually be lifted and investor focus will return to the 10%+ EPS growth over the next two years from share buybacks (starting in 2Q), technology solutions revenue growth and operating leverage from modestly higher volumes. We view the ongoing $0.16-$0.20 investment in NLX (5-7% of 2013 EPS) and success of Nasdaq Private Market initiatives as free options. More here in our note: Regulation Looks Manageable; Buyback and Technology Opportunity Underappreciated.

Key Takeaways

We had the pleasure of hosting Manoj Narang, Founder and CEO of Tradeworx for an in depth discussion of high frequency trading and U.S. market structure. Here are the key takeaways:

Tradeworx and Market Makers

- **Who is Tradeworx?** Tradeworx is a financial technology company based in Red Bank, New Jersey that operates an equity market-neutral hedge fund, a high frequency trading business and a technology solutions business through Thesys Technologies. Tradeworx today comprises ~5% of U.S. equity volume.

- **Who is Manoj Narang?** Manoj Narang is the Founder and CEO of Tradeworx, Inc. An internationally recognized expert on algorithmic trading and market structure, Mr. Narang has taken a leading role in educating the public about these complex issues. His response to the SEC's 2010 Concept Release is one of the most detailed and highly cited primers available on high-frequency trading and market structure. In December 2010, he provided expert testimony to a joint Senate Subcommittee hearing on Market Structure and Stability. Mr. Narang was named one of the "Seven Most Influential Players in High Frequency Trading" by CNBC.com, and in January 2014 was recognized by Institutional Investor magazine as one of the top financial technology executives in the world. *Please see his complete bio at the end of the note.*

- **What does a market-maker do?** In an effort to earn the bid-ask spread, large-scale market makers tend to passively provide liquidity by constantly calculating the fair price of a security on a real-time basis and then proceed to manage risk by hedging exposure with correlated securities and indices and cancelling quotes as prices become stale. While providing liquidity they take into consideration the size of the rebate, size of the trading increment and liquidity of the security amongst other factors. They utilize state of the art technology and market tools to minimize latency and navigate markets efficiently.

Speed & Technology

- **Need for speed–"the arms race is dead".** Tradeworx believes the outsized attention that high frequency trading (HFT) and the low latency arms race has received overstates the importance of speed in today's markets. It is undeniable that we have witnessed an arms race over the past 5-10 years to compress latencies and consequently market participants have far lower latency when it comes to prices discovery and market access than they have ever had before. That brings us to today, where we are very close to the natural lower bound for latency (as close to zero as possible). As such, we have reached a point of diminishing marginal returns to squeezing an additional microsecond out of the equation. It is now far more important to intelligently employ a variety of market structure tools within the confines of current rules while navigating current cash equity microstructure.

- **Can latency go lower? Yes,** but it is extraordinarily expensive and harder to do so. It is important to appreciate that as the differential between fast and slow players has compressed from minutes (20 years ago) to milliseconds or microseconds today, the benefit of latency becomes more random (uncertain) rather than deterministic (certain)–said another way at a 1 minute speed differential, it is deterministic the faster trader will "win" 100% of the time, at a 1 microsecond differential it is not guaranteed that the faster trader will "win". Even if two fast traders send their orders at exactly the same time it is not guaranteed that they will both arrive at the same time–in fact Tradeworx only wins 52-53% of the time.

- **Democratization of technology–"a great equalizer".** One of the prevailing trends over the past few years has been HFT firms monetizing their R&D investments by selling their technology on a commercial basis thereby diffusing the advantages of speed across a broader population. For example, all of Tradeworx' HFT infrastructure is available on a commercial basis through their affiliate, Thesys Technologies LLC. Solutions span the trading chain from algorithms to surveillance and data feeds to colocation and back-office infrastructure. We note that even IEX, recently chose a competitor, Redline Trading Solutions for their ultra-low latency ticker plant.

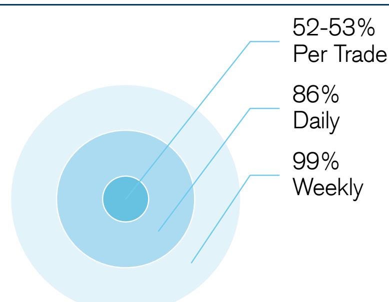
HFT Economics and Win Rates

- **HFT Economics—-slim margins, volume matters.** Mr. Narang believes that an unfair advantage would be reflected in the winning percentage of an *individual* trade–Tradeworx wins 52-53% of the time. This translates into an 86% *daily* winning percentage and 99.9% *weekly* winning percentage. **Why do the percentages increase with the size of the time frame being observed?** The law of large numbers states that if the sample gets sufficiently large, the *individual* trade winning percentage (53%) becomes a more reliable indicator of the proportion of winning trades at the end of a trading day.

  For example, with a large sample of trades (100 shares per trade) and assuming a standard losing and winning trade is around $0.01 which means that over 100 trades, a firm would make $0.53 (assuming a win rate of 53%) and lose $0.47 (assuming a loss rate of 1- the win rate), netting to $0.06. In fact, Tradeworx today makes about 6 mils per share which is in line with what the probabilities would suggest–$0.06/(100 trades x 100 shares).

  The only difference between Tradeworx and other larger HFT firms is that that Tradeworx is 4-5 times smaller–-therefore Tradeworx has an 86% daily winning percentage vs. other larger firms at 99.9%. *Said another way, the importance of size is manifested in Tradeworx's weekly winning percentage of 99.9%--a number that is based on 4-5 days of aggregated volume that is equivalent to a large HFT firm's daily volume.* Another way to observe the law of large numbers is to take 4-5 firms the size of Tradeworx and aggregate their daily P&L without any integration–the result theoretically would be a higher daily winning percentage.

Exhibit 1: Winning % and the Law of Large Numbers
As stated



Source: Company data, Credit Suisse estimates

- **Is $0.06 per 100 shares too high?** Mr. Narang argues that if one believes that HFT liquidity provision is valuable (more on this below), then it deserves to be compensated. SEC makes $0.05 per 100 shares (Section 31 fees) and the broker is paid ($0.015). **Why are margins this low?** Over time profit per share has declined, despite providing more liquidity–this is because of technology and automation benefiting real money investors.

- **53% win rate?** Tradeworx's win rate per individual trade has declined from 54% to 52-53%. For context, the pay-off win rates tends to be exponential–Mr. Narang believes that 56% is "astronomical" while 57-58% would catapult one to "billionaire status". **Why has profit per share declined?** Principally because of increasing adoption of technology by the buy-side via proprietary direct investments or via sell-side firms offering their infrastructure as a gateway to the equity markets. Furthermore, volatility has declined and given that volatility is a manifestation of the imbalance between supply and demand, liquidity provision has become less profitable as demand for liquidity has declined. We note that, several market-making and HFT firms have shuttered their doors (Eladian Partners, Infinium), trimmed staff (Sun Trading, Getco) or re-oriented their business strategy (Interactive Brokers) as volatility has declined.

Value of HFT Liquidity & Holding Periods

- **The value of HFT liquidity–how to judge whether valuable or superfluous?** Tradeworx defines liquidity as the immediate availability of transactable shares at a fair price. Mr. Narang not surprisingly believes that HFT firms play a valuable role in the market place as immediate liquidity providers. Objectively, he believes the value of liquidity provision is determinable by the length of a HFT firm's holding period (more on this in "How long do HFT firms hold positions for?")–holding a trade for a second is not valuable (i.e. buying a stock and then selling the same stock a second later or vice-versa)–the amount of immediacy provided by a HFT firm here is very limited, arguably the buy-side would have been better off in waiting for a second or fraction of second to find a natural counterparty. Similarly there is no need for intermediation between a natural (willing) buyer and seller at the same time in a liquid market. However, there is value in providing the buy-side the ability to immediately lock in a price for a trade and also transfer the volatility of stock price movements and thereby the task of risk management to a HFT firm. If this was not a valuable function then markets would ensure that HFT profits per trade would be uneconomical.

- **How long do HFT firms hold positions for?** Mr. Narang noted that many people falsely believe that HFT trading firms hold trades for seconds or milliseconds or microseconds. In reality, Tradeworx holds positions for 10-12 minutes on average and this has gone up with time, although this in part can be explained by the inverse relationship between holding periods and price volatility. **How short can holding periods get?** Tradeworx believes they are "middle of the road" as far as holding periods go but noted that profitability is positively correlated with the length of a holding period. **Why?** By being exposed to volatility longer a HFT firm can extract more alpha (explainable variance) but that means they don't transact a lot of volume.

- **More thoughts on the value of HFT firms.** HFT firms tend to be passive providers of liquidity to natural/real-money buyers and sellers– in fact 95% of the orders in an order book emanate from a HFT firm. Mr. Narang noted that they rarely trade with other HFT firms as peers tend to use similar strategies that in turn create herd-like trading behavior. In order to provide liquidity immediately, HFT firms have to hedge the risk they choose to take with a correlated stock–that has value as it diffuses the price impact of a buy-side order to a related stock while also exerting a counter-acting force to dampen price volatility of the stock being traded by the buy-side. For example, if the buy-side wants to sell shares of Apple, the HFT firm would buy Apple and then sell a correlated stock in the technology sector to hedge their risk thereby limiting the downward pressure on Apple's stock and then diffusing the downward pressure to a correlated stock they sell.

- **Two time periods that matter–latency and holding period.** Mr. Narang noted that the media has conflated latency (times taken to discover the price for an order that arrives at an exchange and process it) with the length of the holding period–as such the assertion that HFT firms trade in microseconds is false. Latency has been compressed to microseconds but holding periods have not. Mr. Narang believes that holding periods can never go to sub-seconds or even a couple of seconds–it is a "pipe dream" to think that one can passively buy on the bid and sell on the offer.

Order Cancellations

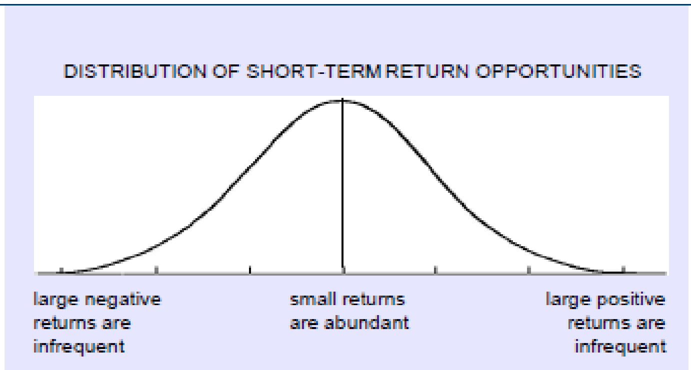
- **The need to cancel orders reflects risk management.** The market doesn't operate in a vacuum and HFT firms are trying to make money by managing risk while providing liquidity–in one popular strategy Tradeworx tends to be buyers of securities when prices of SPDRs or E-mini futures are moving up and sellers when they are moving down. HFT firms such as Tradeworx try to maintain bids and offers that reflect their estimate of the fair price of every stock and do so with tight spreads in order to maximize their chances of being the liquidity provider for a transaction (more on this in "Price priority vs. time priority" below). This means, that if the S&P is trading up or down they have to re-price (or cancel) all the stocks they have quoted prices for to reflect the new price as implied by the beta of a stock (the statistically derived movement of a stock due to the market). If they don't, their orders will be picked off by other arbitrageurs who drive stocks to their fair price. In addition, HFT firms are usually not designated market makers and do have the ability to select which stocks to make markets for.

- **Poor fill rates–a function of trading infrastructure.** Mr. Narang believes that media attention around poor fill rates or the inability to trade on a displayed quote is not a function of liquidity being "fake" but rather driven by the usage of delayed data, unsophisticated algorithms, poorly designed smart order routers or an underlying trading network that is not sufficiently low latency. He cited several proprietary and sell-side algorithms that can be availed by the buy-side that have 99%+ fill rates on active orders. In addition, Tradeworx has not had a problem within their hedge fund where they run quantitative strategies with holding periods that run multiple days.

Need to be Passive

- **Need to be passive to do large amounts of volume–thereby the notion that manipulative trading is widespread is false.** Asset price returns or alpha opportunities tend to have a normal or thin-tailed distribution (time of stress being the exception)–fat middle and thin tails. This means that there are very few large alphas (in the thin tails) and plenty of small alphas (in the fat middle).

Exhibit 2: Distribution of Short Term Return Opportunities
As stated



Source: Tradeworx

Couple this statistical reality with the 30 mil take fee for active traders or 5x Tradeworx's net profit margin means there are very few alphas that have a 10 minute duration or even a 1 hour or 1 day duration that are sufficiently large enough to offset the magnitude of the take fee. If the alpha does somehow offset the take fee, there are also SEC fees and brokerage fees to consider. In other words, large alphas are definitely present in the thin tails but there are not enough of them to trade "hundreds or even tens of millions" of shares a day. Hence, Mr. Narang asserts that a HFT trader has to be passive (provide liquidity) and not active (seek large alphas) if they intend to do a lot of volume–this means that the assertion that manipulative HFT trading (which implies an active disposition towards trades) is "widespread" is statistically provable to be false.

Price vs. Time

- **Price priority vs. Time priority.** Equity markets typically are governed by price-time priority and also prioritize visible orders over hidden orders. In a nutshell, price-time priority stipulates that higher prices move up the queue in an order book to trade against an inbound order and if there is a tie in price, the bid or offer that came in first gets prioritized for execution. **What does this mean for HFT firms?** A market maker is only as successful as their ability to extract the bid-ask spread, therefore, being as close to the current bid-ask spread in the order book is paramount to minimizing losses. However, this is no easy task (Tradeworx earns 6% of the $0.01 spread on average) as the market maker usually doesn't earn the bid-ask spread–they capture a small portion of the spread because prices usually move against them (more on this in the role of rebates below). Apart from competition from other market-makers, the challenge to earn the spread is exacerbated by internalizers and wholesalers that usually match balanced flow leaving unidirectional flow for the exchanges to display (more on this in "payment for order flow" below).

- **Size of the trading increment dictates the trade-off between price and speed.** Tradeworx believes the size of the trading increment is a powerful lever that is underappreciated by regulators. The finer the trading increment the more important price priority becomes relative to time priority. In other words, if the market was designed to trade at continuous (vs. discrete) non-penny increments you could always win a trade by quoting the best price and the "speed game would be non-existent". Moreover, cancellation rates would also increase as fair price estimates will now fluctuate in a much smaller band. Conversely, the wider the trading increment, the more size starts aggregating at each price level and the more ties you have in prices as there are fewer prices to be at. This elevates the importance of time priority becomes relative to price priority thereby making the role of speed more important. In addition, wider trading increments also reduce cancellation rates as the fair price of a security can now fluctuate in a wider band.

Maker-taker & Rebates

- **Maker-taker model and rebates.** Tradeworx noted they are agnostic to the existence of the maker-taker model. However, Mr. Narang does believe that rebates do effectively widen bid-ask spreads from 1 cent to 1.6 cents, thereby allowing market makers to display quotes for a longer period of time. It becomes more valuable to keep an order in force and bear the consequences of adverse selection rather than cancel it as the rebate offsets some of the adverse price movement. Consequently, if rebates are abolished, displayed size at each quote would decline and average quote life spans would also shorten (i.e. cancellation rates would increase).

  With respect to market manipulation by passive market-makers (i.e. the assertion that market makers move their quotes as an order comes in to create a fill at an inferior price), Tradeworx believes that any unfair advantage would be reflected in the P&L of a trade favoring the market maker. In 2010, Tradeworx analyzed all the trades in the equity market over one year and found that on average regardless of when you marked a trade (one minute, hour, end of day), prices on average moved against the market maker. The magnitude of price movement against a market maker was strongly correlated with the size of a rebate offered by an exchange. They found that prices on NDAQ move against the market-maker the most (given the relatively larger rebate being offered at that time) while on Direct Edge market-makers refused to experience any adverse price movement in light of the inverted pricing model (market maker paid charged a fee to be passive).

Exhibit 3: Adverse Price Movement of Posted Orders–2010
As stated

	average daily	AVERAGE PROFITABILITY OF POSTED ORDERS*				
	dollar volume	Nasdaq	NYSE Arca	BATS	NYSE	EdgeA
superliquid stocks	>50M	-0.28	-0.24	-0.26	-0.1	0.08
liquid stocks	10M-50M	-0.27	-0.23	-0.23	-0.08	0.1
semi-liquid stocks	1M-10M	-0.11	-0.06	-0.02	0.06	0.14
illiquid stocks	<1M	0.19	0.23	0.32	0.3	0.25

Source: Tradeworx

SIP vs. Direct Data Feeds

- **Securities Information Processor (SIP)–needs to be abolished or upgraded.** Mr. Narang believes the SIP should be abolished and that it serves no purpose other than providing a benchmark to observe whether one is locking the market. In addition, he believes the SIP is unsuitable for trading and thereby should not be used by market participants. He noted that the fact that the SIP shows the best bids-offers of multiple exchanges has confused trading professionals who mistake the SIP for an order book showing depth of market. If the SIP is not abolished, he believes it should be upgraded and run by a non-exchange party. The cost of an upgrade is "not much"–Tradeworx is one of the firms bidding for the contract to operate the SIP. Furthermore, he noted that his firm does offer a commercially available SIP that can be used to trade as it integrates the full depth of market at each exchange for those that chose to avail of technology at a "relatively low cost".

- **Direct data feeds–not just a speed but also a game of skill.** Tradeworx believes that direct data feeds should not be banned or slowed down–they are the only way to discern the depth of market at each exchange and it does not make sense to slow it down to the speed of the SIP that is "not suitable for trading". He noted that the main reason that people don't subscribe to direct feeds of an exchange is "not the cost". Historically, even when direct data feeds were available for free, buy-side traders didn't use it and instead were comfortable using third party aggregators such as Thomson Reuters or Bloomberg despite the product being slower. **Why?** This is because the direct data feed only gives you raw orders, you have to process all the messages to build your own order book which is a "monumentally complex" algorithmic and computational challenge that involves skill given the sheer volume of data–-people also compute it differently (usage of software vs. hardware). In addition, the speed game "doesn't end when the quotes hit the server, that's where it begins". There is a speed and skill differential in how data (especially microbursts of data) is processed as well to inform trading strategies. All in, Mr. Narang doesn't believe the premium charged for direct data feeds will be impacted.

- **Front-running using the SIP–not possible.** Mr. Narang asserts that the notion of HFT firms using direct data feeds to predict an order that would appear on a SIP 1-2 milliseconds later is analogous to using the SIP to predict what will appear on Yahoo Finance or other delayed quote systems. Yes, you can do it but there is no economic value created in "predicting the past". Specifically, a HFT firm cannot "jump in front of an order" because the fact that the order is in the direct feed automatically means that the quote is already in the order book of the exchange. With respect to predatory algorithms and pinging, Mr. Narang referred the audience to his SEC Comment Letter in which he demonstrates that such a claim made by Themis Trading is false on Slide 16.

Thoughts on Regulation

- **Market structure regulation will be data-driven.** Tradeworx believes that the SEC has whole-heartedly embraced the idea of data-driven regulation and therefore will try to thoroughly understand the impact of rules before they are enacted. As such, Mr. Narang doesn't believe that the current prescriptions in the market such as market maker obligations, slowing down direct data feeds and minimum time enforced for orders will be enacted. He believes that the main rules we have seen so far such as coordinated circuit breakers (believes will prevent a flash crash from occurring) and market access rule (helps avoids fat finger errors and trading in excess of buying power) are excellent rules.

- **Rule 611–promotes fragmentation.** Mr. Narang believes the markets are too fragmented which makes trading very expensive given the incredible investment needed as far as connectivity to the variety of trading venues goes–-the number of connections grows at the rate of n^2! Specifically, Mr. Narang believes that the fragmentation is a direct result of Reg NMS Rule 611 (which he believes should be eliminated) or the order protection rule that prevents locked (zero bid-ask spread) or crossed (trading at a price that is not the current national best bid or offer) markets from existing. Back in 2007, one could trade on any exchange without the need to be aware of the quotes on other markets. Specifically, Rule 611 encouraged fragmentation (by necessitating trading at the NBBO thereby introducing competition for best prices) and also amplified the role of speed in accessing quotes at other exchanges. The need to know where other exchanges were trading became increasingly important in order to minimize the possibility of exchanges rejecting or re-pricing orders that are not compliant with the NBBO. Rejections and re-pricing create trading inefficiencies for HFT firms. It also encouraged the proliferation of order types designed to circumvent the ban of locked parts as per Rule 611 such as Hide not Slide (hides a quote that would lock the market and then releases it once the market has moved).

- **Payment for order flow–measurement of price improvement needs to be improved.** Mr. Narang noted that retail order flow is valuable because it tends to be balanced or uninformed flow and thereby profitable to make markets against—a firm is able to more easily earn the bid-ask spread from an order stream with roughly the same amount of buys and sells. In contrast, informed flow or news-driven flow tends to be directional. He believes that if the statistics show that retail investors are getting better prices, non-retail buy-side firms must be getting worst execution because this order flow is taken out of the larger pool of orders–this is a "zero-sum game". With respect to statistics that measure price improvements he believes that suggestions to improve the calculation are valid. Specifically, he believes that the statistics probably look better than they actually are because 1) they exclude large orders and 2) the time stamp has a one second periodicity which gives firms the flexibility to select the benchmark for price improvement within a one second interval. With that said, Mr. Narang believes even after correcting for these shortcomings, there probably still is some price improvement.

Biography

Manoj Narang is the Founder and CEO of Tradeworx, Inc. An internationally recognized expert on algorithmic trading and market structure, Mr. Narang has taken a leading role in educating the public about these complex issues. His response to the SEC's 2010 Concept Release is one of the most detailed and highly cited primers available on high-frequency trading and market structure. Mr. Narang has met with dozens of prominent industry executives, journalists, and influential policy makers at the SEC, FINRA, and the U.S. Senate, in order to provide educational background on algorithmic trading. In

December 2010, he provided expert testimony to a joint Senate Subcommittee hearing on Market Structure and Stability.

As part of his educational outreach on high-frequency trading, Mr. Narang and Tradeworx have been profiled extensively on television and in the print media, including appearances on CNBC, CNN, Bloomberg TV, 60 Minutes with Steve Kroft, PBS's Nightly Business Report, the New York Times (front page), the Wall Street Journal, the Washington Post, and Institutional Investor magazine (cover story). Mr. Narang has penned guest columns for Institutional Investor, and has keynoted a number of international conferences on market structure, regulation, and algorithmic trading. Mr. Narang was named one of the "Seven Most Influential Players in High Frequency Trading" by CNBC.com, and in January 2014 was recognized by Institutional Investor magazine as one of the top financial technology executives in the world.

Mr. Narang graduated from MIT in 1991 with a degree in Mathematics and Computer Science. Prior to founding Tradeworx, he spent several years working in technology and quantitative trading positions at major Wall Street firms including Citibank, Credit Suisse, and Goldman Sachs.

CREDIT SUISSE

Companies Mentioned *(Price as of 19-May-2014)*

Interactive (IBKR.OQ, $22.3)
IntercontinentalExchange, Inc. (ICE.N, $191.56)
Investor Technolgy Group INC (ITG.N, $18.56)
KCG Holdings (KCG.N, $11.72)
NASDAQ OMX Group Inc. (NDAQ.OQ, $36.21)

Disclosure Appendix

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