

Mechanizing the Merc: The Chicago Mercantile Exchange and the Rise of High-Frequency Trading

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Introduction

At around 2:40 p.m. on May 6, 2010, the US financial markets went into spasm. In five minutes, overall stock prices fell by over 5 percent, and the prices of many individual stocks fluctuated bizarrely. Shares in the global consultancy Accenture, for example, which had been trading at around \$40.50, dropped in price almost instantaneously to a single cent. Shares in Sotheby's leapt from \$34 to \$99,999.99. Then, almost as suddenly as it had begun, the spasm ended. By 3:00 p.m., overall prices had almost entirely recovered, shares such as Accenture's were back up and Sotheby's back down, and something approaching "normality" had returned.

Some aspects of those events – of the “flash crash,” as participants call it – remain contested.¹ The trigger is widely believed to have been the decision by a large mutual fund (never officially named, but thought by market practitioners to be the Kansas City investment managers Waddell & Reed) to sell a large quantity of S&P 500 stock-index futures, thereby protecting a big

¹ The official investigation of the episode is reported in CFTC/SEC, “The Market Events of May 6, 2010.” Dissenting views include those of the Chicago-based data feed analysts Nanex, who, for example contest dominant assumptions about the nature of the orders generated by the big sell algorithm: Nanex, “Flash Crash Analysis.” These issues are set aside here because the relevance here of the episode is simply as a “window” into the new world of automated trading.

portfolio of stocks from price falls.² Fifteen years previously, selling these futures during normal trading hours would have required telephoning a firm that was a member of the “Merc,” the Chicago Mercantile Exchange. The firm would then have passed the order (using wireless headsets, hand signals, or by writing the order on a piece of paper and giving it to a “runner”) from its booth at the side of the Merc’s trading floor to a broker standing in the S&P 500 trading pit. That broker would then have shouted out or hand-signalled the order to the hundreds of traders standing and jostling on the steps of the pit, and the requisite deals would have been struck verbally or by eye-contact and further hand signals.

By 2010, none of that was needed. At 2:32 p.m. on May 6, via the fiber-optic cables linking Kansas City to Chicago, the mutual fund manager set a computerized trading algorithm to work on Globex (the Chicago Mercantile Exchange’s automated trading system), choosing the algorithm’s parameters so that it would quickly sell 75,000 E-Minis: these are electronically-traded futures, each one corresponding to stocks worth around \$50,000. The algorithm entered a complex electronic ecosystem, brought together on Globex’s “matching engines,” the computer servers that consummate trades, which in 2010 were a couple of miles south of the Chicago Loop in a “carrier hotel”: a giant multi-user data center housed in a building once occupied by the presses that printed the Sears Catalog.³ The

² A “future” is a standardized contract for the purchase of a set quantity of a given asset at a set price on a given future date. The term is used also for contracts such as stock-index futures that are economically similar to such purchases but settled in cash rather than by transfer of ownership of assets. The seller of stock-index futures profits from falls in the prices of the underlying stocks, and those profits can therefore offset losses on the stocks themselves.

³ Rich Miller, “World’s Largest Data Center.”

ecosystem contained human traders entering orders with computer keyboard and mouse, but was mainly made up of other algorithms, especially “high-frequency trading” (HFT) algorithms, which make tiny profits but do so on huge volumes of orders and transactions. Some HFT algorithms “make markets” by posting bids to buy and offers to sell in electronic order books such as Globex’s; some watch for trends or reversals of trends on which to jump; some look for tiny discrepancies between prices, for example those of futures and the underlying shares; some seek to spot the digital footprints of big orders so as to exploit them.⁴

Normally, the ecosystem of trading on Globex would have been able to absorb even a huge set of orders such as those generated by the mutual fund’s sell algorithm. For the first few minutes that May afternoon it did so, but – for reasons that are still unclear, but may include the fast pace of the algorithm’s sales – at 2:41 p.m. an absorption limit seems to have been reached. The algorithms that had bought the E-Minis sold by the mutual fund themselves started to try to sell them as fast as they could. Prices on Globex plunged, and – via the fiber-optic cables connecting Chicago to the data centers in New York and northern New Jersey in which shares are traded – the sell pressure began to swamp the stock markets. Violent price movements triggered risk limits built in to many HFT algorithms; in other cases, their human supervisors switched them off. Either process caused the algorithms to try to liquidate whatever stock portfolios they held at the best prices they could find, while cancelling any existing orders, and then cease trading

⁴ This characterization is based on overall set of interviews described below.

altogether. The electronic order books for many stocks suddenly emptied, in some cases leaving only “stub quotes”: orders to buy at the lowest price that could be entered into them (a cent) or to sell at the highest (\$99,999.99). Stub quotes would of course under normal circumstances never lead to transactions: they are used, for instance, to test connections to matching engines or sometimes to meet formal obligations to exchanges always to quote both bids to buy and offers to sell. So complete, however, was the emptying of some order books on May 6 that in some cases the only orders left were stub quotes, and incoming “market orders” (orders to buy at the lowest available price, or sell at the highest) were therefore executed against them.

How did this new world of automated high-frequency trading, the world that suffered its first generalized crisis that day in May, come into being? This article traces one crucial set of threads in that process: the automation of trading on the Chicago Mercantile Exchange, the creation of its Globex trading system, and the birth of Chicago’s HFT firms. In so doing, the article speaks to the intersection of economic sociology and the history of technology. Economic sociology offers a view of markets far richer than the abstractions of simple, traditional economic models. For example, Mark Granovetter and those influenced by him have shown the significance for economic transactions of networks of interpersonal connections. Viviana Zelizer has explored the interweaving of those transactions with intimate relations and with moral and religious distinctions. Neil Fligstein has investigated the relationships between states and markets and the processes

– political in nature, in a broad sense of the word – by which participants in markets seek to create stable order.⁵

The “new economic sociology” created by scholars such as Granovetter, Zelizer and Fligstein is pioneering and insightful; in its explanatory structures, however, it can be read as traditionally sociological. As Bruno Latour, Michel Callon, and followers of their “actor-network theory” would put it, the explanatory mechanisms posited by economic sociology tend to involve “the social” being conceived implicitly as relations simply among human beings, as if those relations took place in a world devoid of things, of technologies and other non-human entities: a world in which humans interact only with their naked bodies and their voices.⁶ (Indeed, it can be argued that conventional economic sociology also often gives insufficient weight to the *embodied* aspects of economic life, which were particularly prominent in Chicago’s pits.) Certainly, thinking of “the social” in abstraction from the technological has clear limitations when dealing with automated trading, in which – in exemplary Latourian fashion – the economic actors are either machines or hybrids of humans and machines.

The social nature of automated trading can be investigated in a variety of ways. One, for example, is direct ethnographic observation of human traders interacting with machines and, via machines, with each other.⁷ Another – the route followed by this article – is to investigate how those

⁵ See, e.g., Granovetter, “Economic Action and Social Structure”; Zelizer, *Morals and Markets*; Fligstein, “Markets as Politics.”

⁶ See, e.g., Latour *Reassembling the Social*, and Callon, *Laws of the Markets*.

⁷ See, e.g., Caitlin Zaloom, *Out of the Pits*, and Alex Preda, “Tags, Transaction Types and Communication.”

machines and the systems of which they are part came to be the way they are. That, of course, is the route offered by the history of technology, with its focus on the multiplicity of remakings of a world composed of both humans and non-human entities, and thus on what Thomas P. Hughes called the “[c]reation of the material environment shaped by – and shaping – mankind.”⁸ The material environment of automated trading – the fiber-optic cables, data centers, computer servers, “matching algorithms,” and so on that make such trading possible – is a powerful shaping force, but has itself been shaped by humankind, by social and historical processes.

Those processes are the focus of this article, and particularly relevant to it are three themes in the historiography of technology. The first, which arises precisely because human beings and their technologies are intertwined so intimately, is what Merritt Roe Smith, in his classic study of Harpers Ferry Armory, called “the efforts of its inhabitants to preserve accustomed lifestyles and practices in the wake of accelerating technology.”⁹ Although one might imagine that in financial markets the dominant goal is always efficiency, the efforts by the traders in the pits of the Chicago Mercantile Exchange to protect their way of life were a strong and persistent feature of the history of its mechanization.

A subtle danger, however, attends the historiography of episodes in which “efforts … to preserve accustomed lifestyles” are prominent. Those efforts can be portrayed simply as resistance to technological change, and the

⁸ Hughes, *Networks of Power*, 1.

⁹ Merritt Roe Smith, *Harpers Ferry Armory*, 21.

latter can be viewed simply as “progress.” This “master narrative” historiography, as Francesca Bray calls it, tends to ignore or underemphasize a second classic theme in the historiography of technology: the contingency of technological change and the existence of other directions that change could have followed – what Ruth Schwartz Cowan, following Robert Frost, calls “the roads... that were not taken,” or what Bray terms “alternative constructions of the world.”¹⁰ As will be shown below, the mechanization of the Merc was not continuous, inexorable “progress,” but a contingent, episodic process largely driven by crises triggered by external events. There was also a “road not taken”: an alternative, radically different, form of mechanization that failed for contingent reasons.

The third directly relevant set of themes from the history of technology concerns transnationalism and the coproduction of technological systems, places, and connections between places. This theme is found in classic work, especially that of Thomas P. Hughes and William Cronon, but – at least in respect to transnationalism – is present more explicitly in more recent work, such as that of Gregory Clancey or Suzanne Moon.¹¹ On the one hand, the mechanization of the Merc is a local history, a story of events taking place in Chicago, indeed primarily in two buildings in Chicago: the twin-towered Chicago Mercantile Exchange Center on South Wacker Drive, and the

¹⁰ Francesca Bray, *Technology and Gender*, 3 and 11; Ruth Schwartz Cowan, *More Work for Mother*, 103.

¹¹ See, e.g., Hughes, *Networks of Power*; Cronon, *Nature’s Metropolis*; Clancey, *Earthquake Nation*; Moon, “Takeoff or Self-Sufficiency?”, Moon, *Technology and Ethical Idealism*. Also see other historical work on the remaking of place, such as in the special issues of *Technology and Culture* (July 2008) and *Social Studies of Science* (August 2012) on water, or Scott Kirsch, *Proving Grounds*, which documents a radical, and fortunately failed, effort to use nuclear explosions to reshape the earth’s surface and redirect rivers, excavate harbors, etc.

skyscraper of its great rival, the Chicago Board of Trade, astride LaSalle Street at its junction with Jackson Boulevard. On the other hand, though, the mechanization of the Merc was a transnational process, initially sparked by the rise of financial markets in East Asia and repeatedly shaped by developments emanating from Europe. The very name of the Merc's trading system, Globex, embodied an ambition – eventually unsuccessful – to link all the world's futures markets in a single technical system.

Transnationalism, however, does not imply the irrelevance of place or the “end of geography.”¹² As will be sketched at the end of the article – briefly, because of space limitations – what has come into being is certainly not a “flat world,”¹³ but a world in which particular places and specific connections between those places matter (for example, in terms of advantage and disadvantage in trading) as much – and maybe more – than ever, and in which those places, and especially the connections between them, are being actively re-engineered.

The mechanization of financial markets is only just beginning to attract its historians: it was, for example, too recent a development to be prominent in Tamarkin's 1993 history of the Merc or Falloon's 1998 account of the development of the Board of Trade.¹⁴ The best historical accounts we have of mechanization are of European exchanges: Pardo-Guerra's examination of the London Stock Exchange; and Muniesa's study of the automation of the Paris Bourse, a study that was pioneering its focus on the different ways in

¹² Richard O'Brien, *Global Financial Integration*.

¹³ Thomas Friedman, *The World is Flat*.

¹⁴ Bob Tamarkin, *The Merc*; William D. Falloon, *Market Maker*.

which trading can be automated, such as differences amongst possible “matching algorithms” bringing together supply and demand.¹⁵

There are no publicly-available archives bearing on the mechanization of the Chicago exchanges.¹⁶ Accordingly, the main source for this article is oral-history interviews conducted in Chicago with 33 people with experience of mechanization, including 12 involved with the automation of the Merc, two with the automation of the Board of Trade, and 13 who had set up or worked for automated trading firms.¹⁷ Those oral-history interviews (which are part of a larger set of 96 interviews on the development of automated trading in the US and Europe) were complemented by the most valuable written source on the mechanization of the Merc: the memoirs of Leo Melamed, leader of the push toward mechanization.¹⁸

To understand the process of mechanization in Chicago, however, it is also necessary to understand Chicago’s earlier “open-outcry” pit trading. By good fortune, earlier research on a different topic took me to Chicago in 1999 and 2000, when open outcry was still flourishing.¹⁹ While there, I interviewed Melamed, Barry Lind (another key figure in the development of the Merc), and five open-outcry traders, and was taken on tours of the trading floors of the Merc, the Board of Trade, and the Chicago Board Options Exchange; I was

¹⁵ Fabian Muniesa, “Des marchés comme algorithmes”; Muniesa, “Contenir le marché”; Muniesa, “Market Technologies and the Pragmatics of Prices”; Juan Pablo Pardo-Guerra, “Computerising Gentlemen”; Pardo-Guerra, “Creating Flows of Interpersonal Bits.”

¹⁶ The University of Illinois at Chicago, Special Collections, holds archival material from the Board of Trade up to 1973, but mechanization postdates this.

¹⁷ A further two interviews were conducted with well-placed observers of Chicago automated trading. In footnotes and the list at the end of this paper, interviewees are identified if they were content to be named; otherwise citations give only the date and place.

¹⁸ Leo Melamed and Bob Tamarkin, *Escape to the Futures*; Melamed, *For Crying Out Loud*.

¹⁹ That earlier research is reported in (author ref.)

also able to observe open-outcry trading on the Merc and the Board of Trade from viewing galleries, which were open to the public prior to September 11, 2001. (A further three former Chicago open-outcry traders were interviewed in New York and London between 1999 and 2001.) Those interviews and observations – and Caitlin Zaloom’s fine ethnography of the Board of Trade in the late 1990s – provided what is today historical material on open outcry, the world from which automated trading emerged in Chicago, but a world now almost entirely lost.²⁰

Pit Trading: Economic Life, Bodies, and Social Relations

Open-outcry trading in Chicago took place within a specific architecture: the trading pit, first introduced in the Chicago Board of Trade and Milwaukee Chamber of Commerce in the 1870s.²¹ Pits became the hallmark of Chicago’s agricultural futures exchanges (the Board of Trade, established in 1848, and the Mercantile Exchange, set up in 1919) and retained their central role in trading when those exchanges moved into financial futures from the 1970s onward. A pit was an octagonal or circular “amphitheater,” stepped around the sides so as to allow as many traders and brokers as possible to crowd together while still being able to see and hear each other. By the 1990s, some Chicago pits had become very large indeed: when I toured the trading floors of the Merc in November 2000, I was told that on some days 2,000 brokers and traders would crowd into the Eurodollar pit, which traded interest-rate

²⁰ Zaloom, *Out of the Pits*. The merged Merc and Board of Trade still has trading pits, but when I was taken on another tour of them, in October 2011, they were quiet and in some cases deserted. Not a single trader stood in the wheat futures pit, the original heart of the Board of Trade and central to Chicago’s development in the second half of the nineteenth century (see Cronon, *Nature’s Metropolis*).

²¹ Falloon, *Market Maker*, 72-77.

futures.²² (By the end of the 1990s, some 50,000 people had jobs immediately involved with Chicago's open-outcry exchanges, with perhaps 100,000 more indirectly dependent on them.)²³ As noted above, open-outcry deals were struck either by voice or by eye-contact and "arb," a hand-signalling system: palms toward the body, a bid to buy; palms away from the body, an offer to sell; fingers vertical, quantities; fingers horizontal, price. (Large standardized contract sizes, with a single contract often the equivalent of underlying assets worth \$250,000 or more, and the convention of quoting only the final digit of a price – the other digits being taken as common knowledge – meant that single-digit quantities and prices often sufficed.)

Crowded open-outcry trading pits were intensely bodily places. "Look at my glasses," said one trader interviewed in 2000 after the close of trading: "they're all dirty," the result of spittle from the shouting mouths that had surrounded him all day.²⁴ Another trader recalled in 2012: "it was so cramped in our pit that I was able to pick my feet up and was suspended between people." The crush of bodies meant he had to have his spectacles repaired almost every week, so he switched to wearing contact lenses.²⁵ In busy pits, there was constant jostling: in part simply because of crowding; in part because of competition for the best places to stand. For a trader, lines of sight to the brokers who brought big customer orders to the pit were very important. Quite commonly, jostling became verbal aggression; sometimes, verbal

²² Eurodollars have nothing to do with the European single currency: they are U.S. dollars on deposit in banks outside the U.S. Eurodollar futures track dollar LIBOR (London Inter-Bank Offered Rate), which is widely used as an interest-rate benchmark in the U.S. as well as overseas.

²³ Anon., "Chicago's Fallen Giants."

²⁴ Interview, November 10, 2000, Chicago

²⁵ Levin interview.

aggression became a fist fight. Even in the absence of fights, physical size mattered: taller traders were easier to see. Two interviewees said that it was particularly common for traders in the Merc's giant Eurodollar pit to be very tall: "basketball players, football players."²⁶ Indeed, at the end of the 1990s the Merc had to impose a ruling on the maximum size of platform heels that could be worn: "what happened when you wear shoes like this, you really have no balance. So there were some injuries there. So they outlawed those shoes. Now [November 2000] you can wear two-inch [heels], that's it."²⁷ It was an overwhelmingly male environment, but not exclusively so: as several interviewees reported, in the early 2000s the individual trader who took on the largest positions in the Eurodollar pit was a woman, Margery Teller.

Even in the most mathematicized form of Chicago trading, options trading, open outcry demanded bodily skills: "presence in a crowd so your voice can be heard ... when ... people [are] yelling and screaming," plus the "street smart" instinct of knowing "who's going to panic and who *needs* to have something."²⁸ Nassim Taleb, who had been a Chicago open-outcry trader before he became the well-known author of *The Black Swan*, emphasized in interview the importance of the bodily signs of fear:

It's chemistry between participants. ... You understand, these guys are looking at each other for ten years ... They go to each other's houses and they're each other's best friends and

²⁶ Interview, November 10, 2000, Chicago; Levin interview.

²⁷ Interview, November 10, 2000, Chicago.

²⁸ Struve interview. Another interviewee (November 10, 2000, Chicago) said that because of the preponderance of male voices, the minority of women traders could be easier to hear because of the different pitch of their voices.

everything. Now one of them is a broker. He has an order to sell. They can read on his face he's nervous or not. They can read it. They're animals. They detect things.²⁹

Seen from the viewing galleries, the pits of the Merc or Board of Trade could seem places of unbridled individualistic competition. However, the same people often turned up to trade in the same pit day after day, year after year. It was like forever being in high school, said one trader: fellow traders were not necessarily friends, and indeed were sometimes bitter enemies, but if they traded at all frequently they were people you knew, often by high-school-like nicknames.³⁰ In a situation in which deals involving large sums of money were struck by voice or hand-signal, brokers and traders had to trust that their counterparts would not later deny that they had entered into a deal if prices had subsequently moved against them. "Your reputation was everything," noted a trader who went on to set up an automated trading firm.³¹ Reciprocity was important, especially between traders and brokers. A broker could normally bring traders profitable business but might sometimes make clear that in return traders were being called on "to kind of help the broker out," for example when he shouted: "ten at five, *I need these.*"³²

Interaction did not take place only in the pits. Until November 2000, when the Merc became a publicly-traded corporation, the Chicago exchanges

²⁹ Taleb interview; Nassim Taleb, *The Black Swan*.

³⁰ Levin interview. Levin, for example, is known even today by those who traded with him as "Vinnie," from the acronym on his trading-floor badge, VIN.

³¹ Interview, October 10, 2011, Chicago.

³² Levin interview. In other words, the broker was indicating an urgent need to sell ten futures contracts at a price of which the final digit was 5.

had all been membership organizations, in which all important decisions (and some unimportant ones: “what went in the refrigerator, what kind of mustard ... in the break room”) could be the subject of votes.³³ “[W]e had 200 and something committees,” recalls Leo Melamed,³⁴ and to achieve change required classically political skills, which Melamed in particular was willing to spend large amounts of time and energy deploying. For example, in the crucial 1997 battle over the “E-Mini,” discussed below, Melamed and his supporters “held meetings with members individually as well as in groups ... arguing, cajoling, and imploring. I called in all the chits accumulated over the years.”³⁵

Endlessly fascinating as open-outcry pits were as places in which economic life involved intense embodiment, intricate politics, and deep sociality, they should not be romanticized. They took their toll on the human bodies that crowded into them: for instance, one of the interviewees, who had been in his own words “a screamer,” had needed several operations on his vocal chords. The subtle webs of reciprocity and trust needed to keep open-outcry trading flowing smoothly could turn into informal cartels that operated to the disadvantage of other pit traders or of external customers, orders from whom were called “paper,” a term that referred to the medium on which they most commonly arrived in a pit, but also drew an implicit contrast with the animated human bodies that crowded it. “Broker groups” – consortia of brokers who pooled their fee income – were particularly prone to become cartels. The rules of the Merc and Board of Trade permitted “dual trading”: a

³³ Serpico interview.

³⁴ Melamed interview (2012).

³⁵ Melamed, *For Crying out Loud*, 40.

broker could both act for external customers and trade on his or her own account. There were strong suspicions that a member of a broker group might steer potentially profitable “paper” to a fellow member who was acting at that moment as an own-account trader, and similar suspicions that brokers who owned clearing firms might favor traders who “cleared” through their firm, because of the clearing fees that would be generated.³⁶ In the late 1980s, two FBI agents worked undercover at the Merc and two at the Board of Trade, secretly tape-recording conversations and seeking to document breaches of the law, an operation that led to the August 1989 indictment of 45 traders and a clerk.³⁷

Although he was not alone in objecting to cartel behavior within broker groups (many independent brokers and traders did so), the Merc’s Leo Melamed, who had led its move into financial derivatives, was a particularly prominent opponent of cartels. The immigrant son of two members of the Jewish radical, socialist *Bund*, Melamed was also strongly committed to the free-market economics of his “personal hero,” the University of Chicago economist Milton Friedman.³⁸ Broker groups behaving as cartels offended both the Bundist and the free-marketeer in Melamed. When Melamed and

³⁶ Oliff interview. See below re the process of clearing.

³⁷ David Greising and Laurie Morse, *Brokers, Bagmen and Moles*. A decade later, there was still debate in the Chicago pits about how serious the violations had been. “[T]hey nail[ed] lots of people for doing Ginsey,” one trader told me (interview, November 10, 2000, Chicago). (“Ginsey” – I have not encountered the term outside the Chicago pits and my interviewees did not know its origins – involved a tacit understanding to circumvent the minimum unit of price by striking half of a deal at one price and the other half at the next permissible price.) This trader did not, however, deny that there was more serious malpractice: “They [the FBI agents] could have found lots of dirt, there’s no question about it, but they did not know where to look.”

³⁸ Melamed interview (2000). It may strike the reader as implausible that the socialist *Bund* could have an influence on the leader of a financial-derivatives exchange, but in this interview Melamed explained his willingness to devote time and energy to the exchange rather than to his private business by citing his father’s influence. The initials of the name Melamed chose for the Merc’s first foray into financial derivatives, the “International Monetary Market,” were a discreet homage to his father, Isaac Moishe Melamovich.

other members of the Equity Owners' Association, founded in January 1996 to contest the power of broker groups, sought to have the Merc adopt regulations limiting the amount of trading that a member of a broker group could do with fellow members, Melamed began to receive death threats, which the Merc took seriously: it "provided me with an off-duty Chicago policeman to act as a bodyguard and protect the entrance to my office."³⁹

The controversy about broker groups was interwoven with dispute over mechanization. A broker's "income, for practical purposes, was totally dependent on the open-outcry architecture."⁴⁰ With electronic trading, customers might no longer have to pay fees to brokers to bring their orders to market. The resultant reduced costs were the main reason why customers typically welcomed mechanization. In contrast to brokers, traders might hope to continue to flourish in electronic markets. However, they too were often ambivalent or hostile. Open-outcry trading was a demanding but familiar business, and much of its embodied skill – "you traded off of visceral reaction, noise, smell, look on someone's face" – could not be transferred to the computer screen.⁴¹ Particular objects and physical locations became emblematic of trading success. Traders had "lucky ties" – "We had somebody whose tie just became a matter of five or six threads but he wasn't going to change that tie" – and "lucky pencils." The decision by the Merc, demanded by regulators, to move from filling in the "trading tickets" on which deals were recorded in the pit by pencil to the use of pens "took eight months of negotiation." Enlarging a pit even a little could prove hugely contentious.

³⁹ Melamed, *For Crying out Loud*, 30.

⁴⁰ Melamed, *For Crying out Loud*, 26.

⁴¹ Levin interview.

Traders and brokers won the right to stand in a particular place by seniority and by fending off challengers (sometimes physically), and could be fiercely hostile if a change impacted “sightlines and locals’ [traders’] ability to have access to orders. So that became a … very long and difficult thing.”⁴²

Given that strength of attachment to even the physical details of open-outcry trading, it was unsurprising that mechanization, which threatened to sweep it away altogether, should be opposed implacably. It was a “mortal conflict,” a “life-or-death battle,” wrote Melamed.⁴³ James Oliff, another supporter of mechanization, “had people spit in my face. I’ve had people pour drinks all over me.”⁴⁴ The Merc did eventually mechanize, but it took nearly two decades for it to do so.

Globex

Leo Melamed, who led the push to mechanize the Merc, had not always been an enthusiast for electronic trading. Melamed joined the Merc as a “runner” in 1953, already entranced by the Merc’s pits:

The shouting among the traders, the movement of their bodies and hands, captivated me like nothing before. … [T]here was a life force on that floor that was magical and exciting, and … I wanted to be a part of it.⁴⁵

In 1977, with the Merc’s new financial-futures pits beginning to flourish, Melamed (by then chair of the Merc) responded to pro-automation papers at a

⁴² Oliff interview.

⁴³ Melamed, *For Crying out Loud*, 5 and 12; Melamed interview (2012).

⁴⁴ Oliff interview.

⁴⁵ Melamed and Tamarkin, *Escape to the Futures*, 87.

conference convened by the futures regulator, the Commodity Futures Trading Commission, by arguing that open outcry played an irreplaceable role in futures trading.⁴⁶

Melamed's private moment of conversion came in January 1986. He had just completed a science-fiction novel centering around a hugely powerful computer, and

was standing at my desk ... watching the S&P pit [which traded futures based on the Standard & Poor's 500 index] ... and seeing these runners running back and forth with the orders to the pit ... a maze of them back and forth and some of the orders being dropped on the floor and whatnot ... and said to myself, in *The Tenth Planet*, Leo, you created a computer that ran five different planets ... you don't need to tell me you can't figure out how to create one computer to run the orders between pits.⁴⁷

Melamed had no desire to kill his beloved pits, but "[c]onvinced that technology, whether we liked it or not, would force fundamental changes to our way of life," he chose to embrace it rather than "be left in the historical trash bin of status quo obstinacy. The idea grew into an obsession," the central project of the remainder of his working life.⁴⁸

An impetus broader than Melamed's private change of heart was provided by the rise of financial markets in Japan, Hong Kong, and Singapore. It was difficult for those who traded on them also to buy or sell Chicago

⁴⁶ Melamed, "The Mechanics of a Commodity Futures Exchange."

⁴⁷ Melamed interview (2012); Melamed, *The Tenth Planet*.

⁴⁸ Melamed, *For Crying out Loud*, 10.

futures: when the pits were open it was evening or night in East Asia. Traders there might, therefore, choose instead to send their orders to LIFFE, the London International Financial Futures Exchange. Its time zone enabled its pits “to open each day during the tail end of the Asian business hours,” potentially permitting LIFFE – a newcomer, established only in 1982 – to become a serious rival to the Merc, especially in the burgeoning market for Eurodollar futures, which were rapidly becoming the Merc’s most important financial product. “LIFFE’s time zone advantage made me very concerned,” recalls Melamed.⁴⁹

An electronic trading system could counter the threat from London by permitting trading to continue when Chicago’s pits were closed. Melamed approached the global news and foreign exchange giant Reuters, which had pioneered the on-screen dissemination of prices (with its 1973 Monitor service) and had developed the first system for electronically-mediated trading between banks (the Reuter Money Dealing service, launched in 1981).⁵⁰ Reuters agreed to join the Merc in the development of a system for the electronic trading of futures, which was christened Globex, because, as noted above, Melamed wanted it to be not simply the Merc’s system, but “the international standard for electronic trading.”⁵¹ MATIF, the Marché à Terme International de France, was persuaded to join, and approaches were also made to the New York Mercantile Exchange, LIFFE, and crucially – because without its support no system could truly claim to encompass the globe’s futures markets – the Chicago Board of Trade, still the world’s most prominent

⁴⁹ Melamed, *Escape to the Futures*, 316-317.

⁵⁰ Donald Read, *The Power of News*, 363-70.

⁵¹ Melamed, *For Crying out Loud*, 16.

futures exchange. A year of weekly meetings secured the Board's participation, but only temporarily: in April 1994, the Board withdrew.⁵² LIFFE agonized, fearing Globex as a competitive threat and uncertain whether the Merc and Reuters were genuine in their expressed intention "to open up GLOBEX to other exchanges." Eventually, LIFFE too stood aside, putting its main efforts into its own system, Automated Pit Trading.⁵³

Gaining the support of the Merc's own members for Globex was almost as hard. Its proponents knew that most members would accept the project to develop Globex only if they could be convinced it was not a rival to the pits, and that indeed was signalled by its initial name, Post Market Trade. Melamed and his supporters won an October 1987 referendum of the Merc's membership approving Globex, but only on the basis that the electronic system would never be used to trade the same products as the pits when the latter were open. Originally, indeed, Globex did not operate at all during the Chicago working day: the system opened for trading at 6 p.m. and ran until 6 a.m. the following morning.⁵⁴

The demanding task of constructing a potentially global trading network against the background of intricate, unstable exchange politics – some of it local, some transnational – made the technical development of Globex difficult. It began operation only in 1992, five years after the initial agreement with Reuters. Trading volumes remained modest: fewer, sometimes many fewer, than 25,000 contracts per night, and initially mostly in MATIF's

⁵² William Crawford, "CBOT Says Goodbye to Globex."

⁵³ David Kynaston, *LIFFE*, 182.

⁵⁴ Melamed and Tamarkin, *Escape to the Futures*, 337-39; Melamed interview (2012).

products, not the Merc's. By the mid-1990s, it was clear that Globex was "limping," says Melamed.⁵⁵ An interviewee who worked in this period for a Japanese bank remembers installing Globex terminals in its dealing rooms, but all that the terminals "accomplished was gathering a great deal of dust."⁵⁶ Reuters, which had spent around \$100 million developing the system in return for a fee of \$1 per trade, was not receiving an attractive return.⁵⁷ Not only had Globex failed to become truly global, but the very project of mechanizing the Merc seemed to be faltering.

Before we turn to the product that saved it, we need to consider what could have become a rival, radically different, form of mechanization. Before its temporary participation in Globex, the Board of Trade had an automation project of its own, known as Aurora. Also intended for trading when the pits were closed, and also designed to have a global reach (especially to East Asia), the Aurora project, announced in March 1989, involved the Board of Trade and three information-technology companies: Apple, Texas Instruments, and Tandem. The involvement of Apple indicated what was distinctive: Aurora sought visually to simulate a trading pit. "We chose to attempt to replicate the trading floor," says Burt Guterman, who served then on the Executive Committee of the Board of Trade. Traders would be represented on the screen of an Apple Macintosh by icons (avatars, as they would now be called), along with the quantities of contracts being bid for and/or offered by each trader who was quoting the highest bid or lowest offer prices. A user of the system could then choose which trader to deal with by

⁵⁵ Melamed interview (2012); Crawford, "CBOT Says Goodbye to Globex."

⁵⁶ Chicago interview, October 14, 2011.

⁵⁷ Melamed interview (2012); Crawford, "CBOT Says Goodbye to Globex."

clicking his or her computer mouse on the icon of the chosen trader. Even the most basic limitation of the trader's human body was to be reproduced electronically in Aurora: one's icon could not be present in more than one trading pit at any given time.⁵⁸

In Globex, no attempt was made to replicate a trading pit, and its representation of the market for a given product was a window on the terminal's screen with a simple, anonymous list of the prices at which the contract was being bid for and the prices at which it was being offered for sale, together with the quantities being bid for and offered: see figure 1. (Figure 2 shows the window a trader would use to place an offer on Globex and figure 3 an example of a full Globex screen.) Don Serpico, the Merc's then chief of Management Information Systems, and his team "were able to give them [Reuters] the rules for how to do trading in our world," but did not pressure Reuters to try to simulate the trading floor. In part, that was a matter of technical limitations, but it was also because Melamed and his supporters did not want the floor replicated, at least in any full way:

[T]hey [the Board of Trade] actually replicated the fact that you could pick a trader in [the] pit ... we wanted to give the fairest: first come, first served. They wanted to pick their brother-in-law ... for us it was the natural thing, "how do you avoid all of that?": first come, first served.⁵⁹

⁵⁸ Guterman interview.

⁵⁹ Serpico interview; Melamed interview (2012).

If one was fighting broker groups' hold on trading on the actual trading floor, as Melamed increasingly was, there was no reason to seek to design a virtual trading floor that would allow them to reproduce their practices electronically. Thus not only were the bids and offers on the screen of a Globex terminal anonymous, but "first come, first served" or "first in, first out" was the priority rule built into Globex's matching algorithm: if there was more than one bid or offer at a given price, the one that received priority was simply the one received first.

Aurora and Globex thus embodied two different visions of what it was to mechanize a market. Aurora was cancelled by the Board of Trade not because its vision was unattractive – most pit traders and brokers in most exchanges might well have preferred an Aurora-style system⁶⁰ – but because it became clear that its visual representation of trading pits overburdened the then-available bandwidths of global digital communications. The Aurora project "reached a point where we started describing ... what bandwidth was going to be required to transmit the data of where the icon was globally, and at the time the only really global bandwidth that was available was 19.2 [kilobytes per second]," says Guterman. "[A]ll of a sudden, I saw, wait a

⁶⁰ For example, LIFFE's Automated Pit Trading system was also intended for use after the end of the pit-trading day, and – as its name indicated – was an attempt to replicate a pit, albeit with a simpler visual interface than that planned for Aurora, and no directly global ambitions: it was "a closed network," said an interviewee who used it, "only available inside the M25 [the freeway circling Greater London]." Launched in 1989, Automated Pit Trading was usually no more than a minor supplement to the pits, but did have occasional successes, for example being heavily used on the evening of Friday, October 5, 1990, when the UK Treasury suddenly announced, just as LIFFE's pits were closing, that the UK was joining the European Exchange Rate Mechanism (Kynaston, *LIFFE*, 213). Its late-1990s' replacement, LIFFE Connect, made no attempt to emulate LIFFE's trading pits, which (as noted below) closed in 1999-2000.

minute, this isn't going to work," and he went back to the Executive Committee to report that Aurora was not feasible.⁶¹

In consequence, when the mechanization of markets finally began to gather momentum in Chicago in the late 1990s, it did so not via Aurora or a system like it, but via Globex. The "market" built into Globex's software was not the embodied "social" market of Aurora, but a more abstract, anonymous market, one in which offers and bids, supply and demand, were more completely disentangled from their human initiators. One could not, for example, choose with whom to trade: as noted, the first bid or offer to be filled was the one with "time priority," the first to have been entered at the appropriate price. "First in, first out" or "first come, first served" was thus the rule that structured how traders' orders encountered each other in Globex, at the point at which use of the system became serious. It was a contingent outcome, not an inevitability (the bandwidth constraints that doomed Aurora turned out to be historically transient), but it was a consequential one.

The Bigs and the Littles

The process by which electronic trading shifted from being an unimportant adjunct to the pit to becoming a replacement for it began with an external threat to the Merc's second most important financial product, Standard & Poor's (S&P) 500 index futures. Although the S&P 500 was the main performance benchmark for institutional investors, it was less well known to the wider public than the Dow Jones Industrial Average. Dow Jones & Co.,

⁶¹ Guterman interview.

however, had never licensed the index to the futures markets – “they refused to let some gamblers in Chicago use their instrument”⁶² – and had successfully fought a protracted legal battle to defeat the Board of Trade’s view that an index was not private property but a public fact on which it could legitimately base a futures contract. In 1997, however, Dow Jones finally relented, and there was fierce competition between the Board of Trade and the Merc for the license. In February 1997, the Board had opened a giant new open-outcry financial trading floor, the largest in the world, and badly wanted – and was prepared to pay heavily for – a Dow Jones future to trade on it.⁶³

Sensing that the Merc would lose, Melamed and those around him – Fred Arditti, Barry Lind, Bill Shepard, and Rick Kilcollin – began to plan their response. They feared that a Dow future would be especially attractive to retail investors, and knew that the Merc’s S&P 500 future contract was too large for most laypeople: a one-point move in the S&P 500 changed the contract’s value by \$500, making a single contract equivalent to stocks worth around \$500,000. In October 1997, the Merc reduced the “multiplier” from \$500 to \$250, but even with that change an S&P 500 future remained dauntingly large. Perhaps, though, a contract with a multiplier of only \$50 (thus the equivalent of stocks worth around \$50,000) might be attractive to retail investors, such as those who were customers of Lind’s firm? Perhaps, too, the new “mini” contract could be traded electronically, not just after hours, but also when the pits were open? Perhaps it could be an *E-Mini*?⁶⁴

⁶² Melamed interview (2012).

⁶³ Falloon, *Market Maker*, 263-75.

⁶⁴ Melamed interview (2012); Melamed, *For Crying out Loud*, 37-39.

The proposal for the E-Mini was fiercely controversial. “There was a big community on the [trading] floor [who] said that that was a violation of the [October 1987] referendum … that you could not list anything that was being traded [in a pit] on an electronic screen during the day.” Melamed, however, argued that the E-Mini was *not* the same contract as the pit-traded S&P 500 future, and the Merc’s counsel, Gerry Salzman, backed Melamed’s interpretation. The threats to Melamed’s life resumed – “You got little notes … and there were rumors, always a rumor” – but when on June 5, 1997, Dow Jones announced that it was indeed licensing its index to the Board of Trade, Melamed and those around him launched an all-out push to get the E-Mini up and running. Extraordinary technical effort led by Jim Krause of the Merc’s Information Systems Department made it possible for the Merc’s E-Mini to begin trading on September 9, 1997, a month before the launch of the Board of Trade’s new Dow Jones future.⁶⁵

The E-Mini would not, of course, be an effective response to the Dow Jones future if trading in it was as sporadic as that in most existing products on Globex. The crucial innovation in this respect was thought up by Bill Shepard, a Merc director and one of the leaders of the Equity Owners’ Association, and it exploited the fact that while the E-Mini was “different” from the pit-traded S&P 500 future, it was also economically the same: five E-Minis were economically identical to one pit-traded contract. If the relative prices of the two diverged, therefore, there would be an attractive opportunity for “arbitrage,” for riskless profit, by buying the cheaper instrument and selling the

⁶⁵ Melamed, *For Crying out Loud*; Melamed interview (2012).

dearer one. Shepard's key idea was to place Globex terminals in close vicinity to the S&P 500 trading pit, so that traders using them could see (and to some extent hear) what was going on in the pit, and exploit any temporary price discrepancies. A large semicircular structure was built overlooking the pit, with more than a hundred Globex terminals arranged on it in tiers (see Figure 4).⁶⁶

So was born "the bigs and the littles," the arbitrage between the pit-traded S&P 500 future and the E-Mini, a fifth its size. Pairs of traders would collaborate, one in the pit and one sitting above it at a Globex terminal, communicating by hand signals or radio headsets. A trader in the S&P 500 pit interviewed in November 2000 drew my attention to the new structure, which when viewed from the bottom of the pit seemed to loom over it:

[W]hen you went to the floor, did you see the almost towers, kind of towering by the S&P pit? Almost gets to the ceiling, and you get a bunch of guys sitting there with terminals? That's the guys that trade the E-Minis ... some of these guys are doing very, very, very well, extremely well.⁶⁷

Amongst the newly created firms that traded the bigs and the littles was Jump Trading, set up in 1999 by Merc pit traders Paul Gurinas and Bill Disomma, and Getco (Global Electronic Trading Co.), established, also in 1999, by Daniel Tierney, formerly a trader on the Chicago Board Options Exchange, and Merc broker Stephen Schuler.⁶⁸

⁶⁶ Melamed interview (2012); emails to author from Melamed, Krause and Serpico, September 11, 2012.

⁶⁷ Interview, November 10, 2000, Chicago.

⁶⁸ Interview, October 16, 2011, Chicago.

“The bigs and the littles” turned the S&P pit and Globex into what was in effect a single market. Trading volumes grew rapidly, with the electronic contract soon beginning to outstrip its pit-traded counterpart. Not only did the E-Mini succeed in warding off the threat to the Merc from the Board of Trade, but it became in a sense the primary overall price-discovery market for US shares: the market that responded most quickly to new information bearing upon the value of shares overall, rather than just the shares of particular corporations.

The bigs and the littles also began to change the logic of what it was to trade electronically. Recall that Globex’s matching algorithm was “first in, first out”: if there were, for example, multiple bids at the same price, the first to be executed (i.e., matched with an offer at the same price) would be the bid that had been first to arrive at Globex’s “matching engines.” (The matching engines are the parts of an exchange’s computer system that maintain the electronic order book and find bids and offers that match.) The “first in, first out” matching algorithm, together with the fact that the price discrepancies being arbitrated were fleeting, meant that those seeking to exploit discrepancies between the price of the “big” and the price of the “little” had to place a huge priority on speed: delay for even an instant, and either one’s Globex order for the “little” would not be filled, or the discrepancy would have vanished by the time it was filled. Dismissing the idea of electronic futures trading in 1977, Melamed imagined traders having to queue up to use a computer terminal.⁶⁹ Twenty years later, not only did a Globex trader

⁶⁹ Melamed, “The Mechanics of a Commodity Futures Exchange,” 155.

exploiting “the bigs and the littles” have to have exclusive use of a terminal, but soon at least two firms engaged in the trade took computer-gaming joysticks and reprogrammed them so as to simulate the keystrokes on a Globex terminal that placed orders for E-Minis, to allow their traders to be as fast as possible seizing evanescent opportunities.

Originally, the universal assumption had been that automated trading would involve a human being inputting orders into a computer terminal – all the early efforts to automate exchanges of which I am aware assumed this – but the growing liquidity of E-Minis and the need for speed when trading them undermined this assumption. Perhaps profits could be made purely within the market for E-Minis, without having to trade in the pit as well, and perhaps human beings, with their inevitably slow reaction times, could then be removed altogether from electronic trading and replaced by entirely automatic systems? Built as it was on the assumption of input from human beings at terminals, Globex did not originally have what would now be called an application programming interface, or API: a direct means by which users' computer programs could interact with the Globex system. However, firms such as those that had cut their teeth on “the bigs and the littles” began to develop what one interviewee involved called a “screen-scrape process,” in which incoming data intended to drive the visual display on a Globex terminal would be processed automatically by the firm's programs, and the requisite response to it formulated as the computer-generated equivalent of a human being hitting the keys of the terminal. As he pointed out, “[f]rom the

Exchange's viewpoint, it was no different from a human trader," but it was also a decisive step from partially to fully automated trading.⁷⁰

Automated trading of E-Minis (and especially of a new E-Mini, launched in 1999, based on the NASDAQ-100 index) also provided the springboard for Chicago's nascent HFT firms to expand their trading from futures to shares. Getco in particular began automated trading of the shares of the exchange-traded fund known to traders by its ticker symbol, QQQ. (A share in the QQQs is a fractional holding of a portfolio of NASDAQ-100 shares held by a trust of which the trustee is the Bank of New York.) Changes in the price of the NASDAQ-100 E-Mini would often give early indications of likely moves in the QQQs, and the risk of positions accumulated in the QQQs could be offset in the futures.⁷¹ From the QQQs it was a short step to automated trading of the underlying shares, setting Getco on a trajectory that saw it become the largest electronic market-maker in U.S. stocks, at times responsible for a fifth of all trading in some leading stocks.⁷²

The Threat from Europe and the End of the Pits

Within the Merc itself, however, E-Minis remained initially an island of mechanization: most members of the Merc were still strongly committed to open outcry. Nevertheless, developments in Europe in 1997-99 showed that even well-entrenched futures exchanges were potentially at risk from electronic competition and that pit trading itself might be in danger. LIFFE,

⁷⁰ Interview, October 10, 2011, Chicago.

⁷¹ Interview, October 10, 2011, Chicago.

⁷² Scott Patterson, "Meet Getco."

the London International Financial Futures Exchange, based like the Merc and Board of Trade on open-outcry pits, had dominated trading in futures on the *Bund*, the benchmark German government bond with a 10-year maturity. In a few short months, an electronic equivalent to LIFFE's open-outcry *Bund* future, traded by the all-electronic Frankfurt-based Deutsche Terminbörse, captured nearly all of LIFFE's *Bund* market. In 1998, MATIF in Paris switched from open outcry to electronic trading, and LIFFE followed suit in 1999-2000.⁷³ Together with the development of handheld devices (such as the Merc's Galax-C) that allowed them to trade electronically while standing in the pits, the potential threats to pit traders' way of life prompted what a few years earlier would have been unthinkable concessions. In August 1998, the members of the Board of Trade voted to allow electronic trading of its bond futures contracts while the pits were open, and in January 1999 a referendum of the Merc's membership produced an even clearer majority removing the constraint the 1987 vote had placed on Globex: from then on, all the Merc's futures could be traded electronically, whether the pits were open or not.⁷⁴

However, the Merc's most important pit, the Eurodollar pit, did not budge: "With few exceptions, the Eurodollar community – traders, independent brokers, members of broker groups – continued to trade in the pit as if nothing happened,"⁷⁵ and their counterparts in the Board of Trade also remained largely wedded to the pits. What finally broke Chicago pit traders' defense of their way of life was the potential threat from Europe becoming actual: indeed physically visible. In 2003, the all-electronic Eurex futures

⁷³ See, e.g., Susan V. Scott and Michael I. Barrett, "Strategic Risk Positioning."

⁷⁴ Melamed, *For Crying out Loud*, 56-57.

⁷⁵ Melamed, *For Crying out Loud*, 57.

exchange (formed in 1998 by a merger of the Deutsche Terminbörse and the Swiss Options and Financial Futures Exchange) announced its intention to begin trading in the U.S., and – despite alleged energetic lobbying by the Chicago exchanges to stop it – received permission to do so in February 2004.⁷⁶ That month, LIFFE also announced its intention to launch electronically-traded Eurodollar futures directly competing with the Merc's. Eurex leased space in the Sears Tower, the tallest building in the Americas (and a short walk from both the Board of Trade and Merc). It “handed out free coffee to traders on La Salle Street and lighted the top of the Sears Tower in the Eurex colors of green and blue,” even taunting the Board of Trade by playing a searchlight on its building.⁷⁷

Of the Merc and the Board, the latter was the more vulnerable. Such electronic trading as took place on the Board was conducted using A/C/E, a system provided by Eurex.⁷⁸ In addition, the Board did not own its own clearinghouse, which was a separate company. Eurex bought a stake in it and gained its agreement to clear Eurex's equivalents of the Board's futures. It was a critical move. Unlike in the case of shares, in which a trade can be finalized relatively quickly by the transfer of money and of ownership of those shares, in futures the clearinghouse can be involved in a transaction for many months, tying exchanges and clearing houses together intimately. The buyer and seller of a future do not have a direct contract with each other. Rather, each has a separate contract with the clearinghouse, which every day adjusts

⁷⁶ Joseph Weber, “Eurex Blows Into Chicago.”

⁷⁷ David Roemer, “Eurex Chief Insists Exchange in U.S. for Long Haul”; Melamed, *For Crying out Loud*, 102.

⁷⁸ The term was the acronym of Alliance/Chicago Board of Trade/Eurex.

the “margin” that the buyer and seller have to maintain on deposit with it to mitigate the risk of them not fulfilling their obligations.⁷⁹ The brevity and relative simplicity of the clearing and settlement of transactions in shares, and the fact that effectively all share trading in the U.S. clears through a single institution, the Depository Trust Clearing Corporation, mean that it is relatively straightforward for more than one venue to trade the same shares, while futures traded on exchanges with separate clearinghouses are not fully interchangeable. A futures exchange with its own clearinghouse is therefore in a strong position to fight off competition; an exchange such as the Board of Trade that does not own its clearinghouse can suffer fatal damage if it loses control over the latter.

The threat in 2003-4 from Eurex to the Board of Trade and from LIFFE to the Merc provoked months of tumultuous change in Chicago. The Board stopped using Eurex’s A/C/E at the end of December 2003, switched to LIFFE’s LiffeConnect trading system in great haste, and began pursuing electronic trading with unprecedented vigor. It opened negotiations to shift its clearing to the Merc’s clearinghouse, despite the decades of rivalry between the two exchanges. Agreement was struck in April 2003, and a huge, concerted technical effort achieved the transition by January 2004, beginning the process that led to the 2007 merger of the Merc and Board of Trade.

⁷⁹ Yuval Millo, Fabian Muniesa, Nikiforos S. Panourgias, and Susan V. Scott, “Organized Detachment.”

Knowing that the thousands of Eurodollar traders (“the most successful and hard-bitten open-outcry constituency in existence anywhere”)⁸⁰ would not of their own accord shift to electronic trading, the Merc’s leadership – its Chair, Terry Duffy, Chief Executive Craig Donohue, and Melamed – decided to bring matters to a head by threatening closure of the pit unless at least a quarter of Eurodollar trading took place on Globex. In a succession of huge meetings – Melamed remembers one with “1,000 angry faces in the room ... The fear, frustration, and distrust was palpable. The emotionally charged atmosphere had many characteristics of a lynch mob” – Duffy, Donohue, and Melamed convinced the majority of the need for change.⁸¹ Indeed, once the transition from the Eurodollar pit to the Globex screen began, it was faster and more complete than even the Merc’s leadership anticipated.

A way of life that was more than a century old effectively ended. Sensing that his two-decades long campaign for mechanization was now over, Melamed was suddenly overcome with “a wave of remorse,” a “flashback” to his first sight of the Merc’s trading pits half a century earlier.⁸² The almost complete demise of the pits affected some traders very deeply: one of the interviewees recalls his trading partner continuing to spend his days on the steps of a near-silent, virtually deserted pit, despite his efforts to persuade him to come to terms with what had happened.

However, even though Chicago’s pits lost their crowded, animated vigor, the way of life that was passing left its stamp in the matching algorithms

⁸⁰ Melamed, *For Crying out Loud*, 108.

⁸¹ Melamed *For Crying out Loud*, 108; Melamed interview (2012).

⁸² Melamed *For Crying out Loud*, 109.

at the heart of the electronic trading that succeeded it. The Merc's S&P 500 pit, the first successful site of mechanization, was in some respects unusual. Prices there nearly always moved substantially over the course of a day, and often changed very quickly indeed. Being first to a trade was thus always important, even before "the bigs and the littles" intensified the emphasis on speed. The "first in, first out" matching algorithm that seemed natural to Melamed and to the leaders of the technical development of Globex was thus a reasonable fit to the practices of the S&P 500 pit.

Not so with the Merc's Eurodollar pit. Prices there usually moved much more slowly – near-term Eurodollar prices, for instance, are closely tied to the interest rates set by the Federal Reserve, which usually change monthly at most – and there were long periods in which little happened. (Pits were not always frenetic places. For example, during a November 1999 tour of the trading floors of the Board of Trade, I noticed the traders in the giant Treasury Bond futures pit devoting their attention not to trading but to the lid of a large plastic tub being thrown as a frisbee from one side of the pit to the other.) A former broker in the Merc's Eurodollar pit recalls:

you could be standing there all day and the market's one bid at two, and you go to lunch and the market's one bid at two, and you have your early afternoon break and it's one bid at two ... whereas in the S&Ps you might have what is deemed to be a calm day and you might go through an array of fifty, sixty, seventy, eighty [price] ticks.⁸³

⁸³ Interview, October 14, 2011, Chicago.

A trader from one of the Merc's more volatile pits remembers being struck by the way Eurodollar traders felt able to leave the pit, even though they held huge positions:

I used to see guys in the washroom and they'd say to me "I'm long a hundred Euros [Eurodollar futures]." You're long a hundred Euros and *you're in the washroom!*⁸⁴

In the Eurodollar pit, with its slowly moving prices, "pit etiquette" (as an interviewee called it) typically demanded that the first trader to make a bid or offer at a given price had the right to be "filled" first, but thereafter there was "no real sense of [time] priority."⁸⁵ Indeed, it was common in Chicago's pits for informal sharing norms to emerge: for example, a broker who had a large customer order would divide it up "fairly" amongst multiple traders who had all been quoting the same price. Such norms were also to be found in open-outcry trading in Europe: as one of Muniesa's interviewees told him, "Trading floors have always been based on sharing."⁸⁶

Initially, electronic trading of Eurodollar futures employed Globex's original "first in, first out" time-priority matching algorithm. However, what was discovered was that with a slowly moving price, trading could easily be stifled by a few very large orders, because later orders might remain endlessly in the queue, with little chance of being filled:

⁸⁴ Levin interview.

⁸⁵ Interview, October 14, 2011, Chicago.

⁸⁶ Muniesa, "Des marchés comme algorithmes," 327, my translation.

[S]omebody can say, “I am going to put up twenty thousand contracts or fifty thousand contracts on bid and offer and I’ll sit there all day long,” and no-one can join in. That’s not very good for participation.⁸⁷

In consequence, around a year after the start of the transition of Eurodollar trading from the pit to Globex, the matching algorithm for Eurodollar futures was changed to “pro-rata allocation”: irrespective of when they submitted their order, all those quoting the highest bid price, for example, would receive a share of any incoming offer at that price proportional to the size of their bid. (Imagine, for example, that two traders, A and B, were both quoting the highest bid price, trader A bidding for forty contracts and trader B for twenty. If there was an incoming offer of thirty contracts at that price, A would receive twenty and B ten.) After the merger with the Board of Trade, this pro-rata allocation algorithm was further modified to incorporate the “pit etiquette” principle that the first trader to better the prevailing price (in other words, to quote a higher bid or a lower offer price) should have their order filled in full before the remaining contracts were shared out pro-rata.

It is unclear whether the intention of the shift away from first in, first out was “to mimic how things were done on the floor,” as one interviewee said, or whether it was simply a pragmatic response to a barrier to “broad participation.”⁸⁸ The outcome, however, was a matching algorithm that

⁸⁷ Interview, October 14, 2011, Chicago.

⁸⁸ Interview, October 14, 2011, Chicago. Eurex, which never had pits, had earlier encountered the same problem in Euribor and Euromark futures similar to Eurodollar contracts, and had also introduced pro-rata matching for those contracts: Eurex, “Circular 67/99.”

replicated pit traders' informal "sharing," and the modification following the merger does seem to have been directly modelled on customary behaviour in pits.⁸⁹ In that sense, an echo of the way of life in the pit continues at the very heart of electronic trading of Eurodollar futures.⁹⁰

To a degree, pro-rata allocation complicates the design of a fully automatic trading system: it normally needs to submit an order larger – often much larger – than the size it actually wants to trade (because only a proportion of the order will be filled), but just how much larger can never be known with certainty. However, by the time pro-rata matching was introduced, the automated trading firms that had cut their teeth on "the bigs and littles" (with the E-Mini's simple first in, first out matching) had gained experience, technical expertise, and capital, and the interviews suggest that they were able to take the challenges of the new matching algorithm in their stride.

Those firms had graduated from simple trades such as the bigs and the littles to more complete automation of the two generic strategies of the Chicago pit trader: "scalping" and "spreading."⁹¹ "Scalping" is the local term for the simplest form of market making. A scalper seeks to buy futures at the prevailing "bid" price, and sell them at the slightly higher "offer" price, liquidating his or her position very quickly and changing his or her bids and offers as the market in those futures moved. (Short-term price dynamics in trading pits were often to a degree predictable to experienced, alert traders,

⁸⁹ Interview, October 14, 2011, Chicago; Krause interview.

⁹⁰ Globex's matching algorithms, as they stood just after the merger with the Board of Trade, are outlined in CME Group, "Implied Price Functionality Overview."

⁹¹ For a clear account of scalping and spreading, see Melamed, "The Mechanics of a Commodity Futures Exchange."

who might, for example, notice the arrival on the pit's top rung of a broker known to act for a big customer.) Spreaders also made markets, but across different classes of future. Classically, they would buy and sell in the "back months" (those contracts whose expirations were still well in the future), while offsetting the risks of doing so by trading in the "front month": the contract closest to expiration, in which trading volumes would nearly always be greatest.

As trading moved from pit to screen, and as algorithms to perform scalping and spreading were developed, so Globex evolved. In September 1998, the original Reuters system was replaced by "Globex 2," which was built on the base of the electronic trading system of the Paris Bourse, which had taken over MATIF. (There was a technology swap between the Merc and the Bourse: in return for the trading system, the Merc providing the software of its new clearing system, "Clearing 21."⁹²) As automated trading grew in scale, the transaction load on Globex typically tripled every year.⁹³ Extensive further re-engineering from 2003 onward increased its capacity, improved its availability and reliability, and – crucially – reduced its response time.

Speed of response was, of course, a critical issue from the viewpoint of the nascent "high-frequency traders." Because scalping and spreading were universally-known strategies, a trader practising them electronically could expect competition. So, just as with the bigs and the littles, speed of execution

⁹² Krause and Serpico interview. The Paris Bourse system had itself been developed on the base of the Toronto Stock Exchange's CATS (Computer Assisted Trading System), which in its turn drew on Trans-Canada Airlines' (later Air Canada's) computerized reservation system: see Muniesa, "Des marchés comme algorithmes," 130-131.

⁹³ Krause interview; Serpico interview.

was crucial. Initially, simply removing the slow human being from the process gave a substantial advantage, but as others did that too, attention began to focus on which computers were faster. Thus one founder of an automated trading firm told me that he developed a “hunch” that the Globex terminals on the Merc’s trading floor were more directly connected to the matching engines than the terminals in his firm’s offices. So he slipped a floppy disc with an automated trading program on it into his pocket, used it to run the program on a terminal on the floor, “standing there pretending I was pointing and clicking,” and discovered he was right.⁹⁴ As time came to matter more and more, so he (and many others) discovered that place – spatial location – was still just as important in the new world of automated trading as it had been in Chicago’s pits. Soon, for example, Chicago’s nascent automated trading firms realized that simply having a fast fiber-optic connection between their offices and the Merc’s matching engines was not good enough: their computers had to be right beside the engines, in the same building.

Conclusion

Thus began the processes leading to the reshaped world of trading sketched at the start of this article. Unlike dams or the pylons carrying power cables, the material signs of this reshaping are seldom immediately visible: the buildings that contain data centers are typically anonymous, their locations semisecret; fiber-optic cables are buried underground or laid on the ocean bed. These are, nevertheless, major technological enterprises. For example, the data centers that house matching engines are huge consumers of

⁹⁴ Interview, October 10, 2011, Chicago.

electricity: by 2010, the “carrier hotel” containing Globex’s servers was Commonwealth Edison’s second-biggest consumer of power, second only to O’Hare Airport.⁹⁵ When, in 2012, the Merc opened its own huge new data center (see figure 5), in the Chicago suburbs – I have been asked not to reveal its exact location – it drew its power, for reasons of redundancy, direct from two separate nuclear reactors.

The demands of HFT are also reconfiguring the worlds’ networks of fiber-optic cables. Existing cables frequently do not follow the most direct “great circle” routes: they run alongside railroad lines, divert round mountain ranges, and avoid shallow seas in which cables have to be encased in metal and buried in the ocean floor because they are vulnerable to trawlers and sharks. Even with signals travelling at close to the speed of light, the result is a few extra microseconds or milliseconds of transmission time, and that matters hugely to HFT firms. For example, the transmission times between Chicago and the share-trading data centers in northern New Jersey is crucial to HFT firms using E-Mini prices as a guide to likely movements in the prices of the underlying shares. In March 2009, a new cable began to be laid – initially in secret – between Chicago and New York/New Jersey, running directly through the Allegheny Mountains in order to minimize those transmission times.⁹⁶ In April 2012, cable operator Hibernia Atlantic began to lay a new cable between New York and the UK, following a great-circle route across Canada’s continental shelf, thus shaving 2.6 milliseconds off the one-

⁹⁵ For this center, see Miller, “World’s Largest Data Center.”

⁹⁶ Miller, “World’s Largest Data Center”; Christopher Steiner, “Wall Street’s Speed War.”

way transmission time on the previously fastest cable, Global Crossing's AC-1.⁹⁷

There is a paradox intrinsic to these processes. On the one hand, automated trading seems to fit Thomas Friedman's depiction of a "flat world" in which place no longer matters.⁹⁸ In principle, one can set up an automated trading firm anywhere, and indeed important such firms are found in places as diverse as Charleston, Kansas City, Prague and Amsterdam.⁹⁹ Yet the location of the firm's trading hardware matters exquisitely – it *must* be in the same building as the exchange's matching engines, else the firm will suffer a fatal disadvantage – and the expensive new cables have been possible economically because HFT firms have to pay the large sums required to rent bandwidth on them, again because the cost of not doing so is serious competitive disadvantage.¹⁰⁰

Perhaps the most striking paradox of all is that the world's biggest single cluster of automated trading firms is still to be found inside or within a couple of blocks of one particular building, a building that is an National Historic Landmark: the Chicago Board of Trade's 1930 art-deco Holabird & Root skyscraper (figure 6). When the Board merged into the Merc, the latter

⁹⁷ Matthew Philips, "Trading at the Speed of Light."

⁹⁸ Friedman, *The World is Flat*.

⁹⁹ The main site of high-frequency trading outside North America, Europe and East Asia is Brazil, where in 1986 a futures exchange, the Bolsa de Mercadorias & Futuros, closely modelled on the Chicago exchanges, was created.

¹⁰⁰ In fiber-optic cable, light is of course slowed by the refractive index (around 1.5) of the medium through which it passes. This, together with the high fees charged by the new cables and the unavailability of other parts of the spectrum, has turned attention to an old technology – microwave transmission – despite the need for a series of towers, each within "line-of-sight" of its neighbors, and the risk of interference from rain and low cloud. Interviewees in 2013 reported that microwave links between Chicago and New Jersey to support HFT were now in place, although whether they would be reliable enough to replace fiber-optic links remained unclear.

consolidated the remaining open-outcry trading on the Board's trading floors. The residual links between pit trading and automated trading, the fast fiber-optic connections that were created between the Board of Trade building and the Merc's matching engines, and relatively cheap rents made the building an attractive location for Chicago's new high-frequency trading firms. As they grew, those firms generally moved out into the more spacious premises offered by Chicago's converted warehouses, but as they did so, they were replaced by others. As one trader who worked in the building told me, "you could walk down the hall in the Board of Trade and there's a door, no sign on it, but it's one room, maybe five people in there, but they could run a \$5 million a day high-frequency operation."¹⁰¹

At the end of the trading day, the traders in the Board of Trade building's HFT firms sometimes do what their pit-trading predecessors did: have a beer in (or, on warm evenings, at the tables outside) Ceres, its ground-floor bar, named after the goddess of grain whose three-stories-tall statue sits atop the building. Traders in different firms can (cautiously) chat, targets for hiring can be identified – despite HFT firms' efforts at secrecy, there is circulation of personnel between the firms, and thus trading strategies also circulate – and ideas for new ventures can start to crystallize. Which strategies are successful can also sometimes be gleaned. Whose algorithms have done well, and whose badly, can be learned from their authors' bodily demeanor, especially at "Month End" (a month's last trading day, when profit and loss over the month are calculated). "At one table you'll see cigars and

¹⁰¹ Interview, October 15, 2011, Chicago.

toothy smiles and at the next one over you'll see slumped shoulders and silent self reflection.”¹⁰²

The clustering of HFT firms in and around the Board of Trade building is a small marker of bigger things. Automation has changed the forms that sociality takes but not eliminated the sociality of trading; as just noted, on occasion even embodiment remains significant. The history of automated trading is not simply its now-irrelevant past: its traces are still there, even in its technological heart, its matching algorithms. That history is a transnational history, but that has not ended the significance of locality. Like sociality, like history, place still matters.

¹⁰² Email from interviewee, September 9, 2013.

Interviews

1999-2001

Thomas A. Bond	November 9, 2000	Chicago
Michael J. Carusillo & Clayton Struve	November 7 & 8, 2000	Chicago
Joseph Doherty	December 4, 2000	London
M. Blair Hull	November 10, 2000	Chicago
Barry Lind	November 9, 2000	Chicago
Leo Melamed	November 8, 2000	Chicago
William R. Power	November 10, 2000	Chicago
Nassim N. Taleb	November 14, 1999	New York
David Wenman	June 22, 2001	London

One further interview was conducted in Chicago on November 10, 2000 with an interviewee who preferred anonymity.

2011-13

Rick Cooper	March 28, 2012	Chicago
Richard G. DuFour	October 11, 2011	Chicago
Burt Guterman	March 28, 2012	Chicago
Michael Kane	May 8, 2013	Chicago
Stephen Levin	March 27, 2012 and May 6, 2013	Chicago
John McPartland	May 6 and May 9, 2013	Chicago
Leo Melamed, Jim Krause & Don Serpico	March 26, 2012	Chicago
James E. O'Neill	March 27, 2012	Chicago
William R. Power	October 11, 2011	Chicago
Miles Szczyrek	May 6, 2013	Chicago
Ben Van Vliet	March 26, 2012	Chicago

A further 20 people interviewed in Chicago in October 2011, March 2012, and May 2013 need to remain anonymous, e.g. because they work for high-frequency trading firms.

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Bid	Px	Qty	Offer	Px	Qty		
79410		1	79415		1		
79405		1	79425		1		
79400		1	79430		1		
79395		1	79435		1		
79390		1	79445		1		
79385		1	79450		1		
79380		1	79455		2		
79375		1	79465		1		
79370		1	79470		1		
79325		1	79510		1		

FIG. 1 Globex's representation of the market for the E-Mini, c.1997. The left-hand box lists the prices at which the E-Mini (discussed in the next section of the text) is being bid for and the quantities bid for; the right-hand box lists offers. This is a test screen: in actual use, the quantities of bids and offers were much larger. Screen shot courtesy Miles Szczeruk and Michael J. Kane.

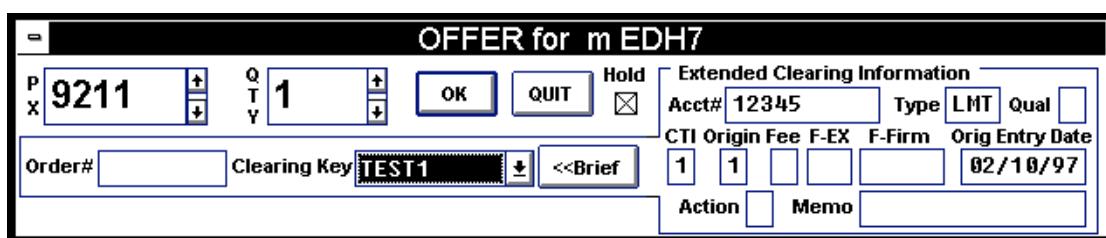


FIG. 2 The window on the screen of a Globex terminal used to submit an offer, c.1997. The product here ("m EDH7") is the Eurodollar future with a March 1997 maturity. Screen shot courtesy Miles Szczurek and Michael J. Kane.

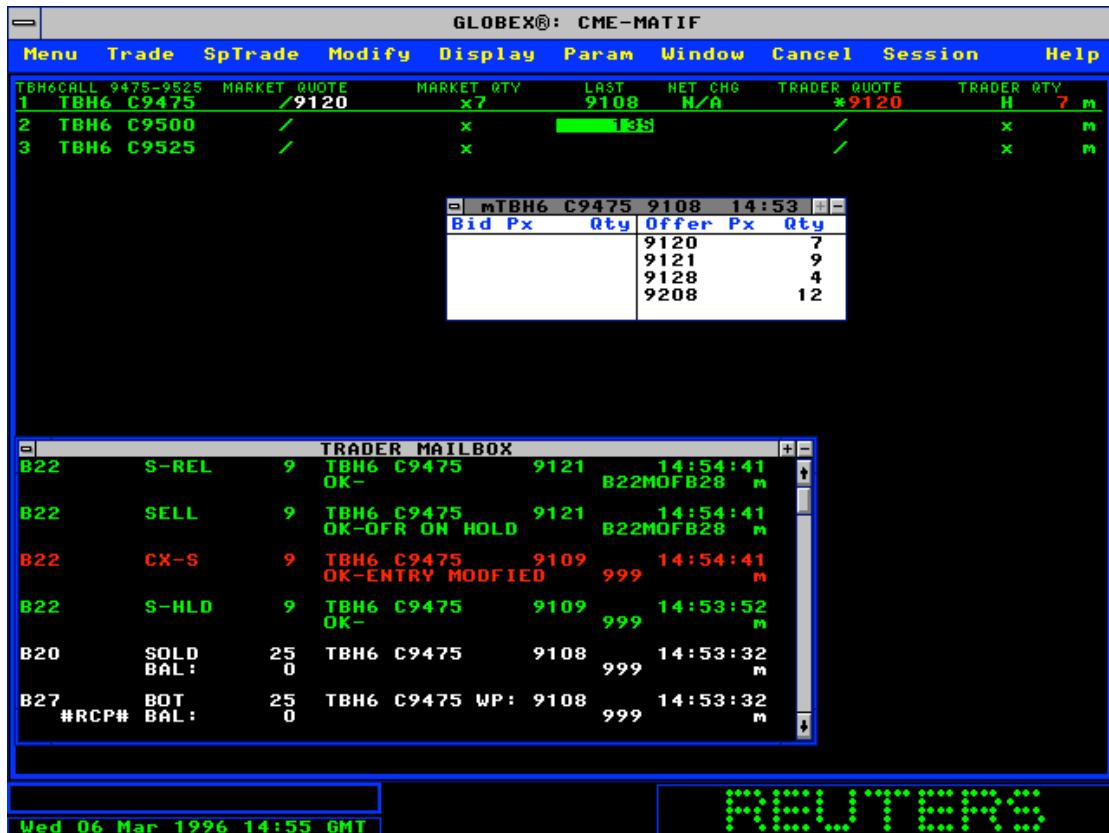


FIG. 3 A full Globex screen, 1996. Screen shot courtesy Miles Szczeruk and Michael J. Kane. The products being traded are US Treasury Bill call options with a March 1996 expiry and a “strike price” of 9475: such an option is roughly the economic equivalent of the right to buy Treasury Bills at a price corresponding to a yield on the Bills of 5.25%. The messages in the trader mailbox record his/her interactions with Globex. For example, the earliest, bottom-most message is a confirmation of the trader’s purchase of 25 options each at a price of \$91.08.



FIG 4 Globex terminals overlooking the Merc's S&P 500 trading pit, c. 2000.
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FIG. 5 Leo Melamed in the Merc's new data center, in the western suburbs of Chicago, which houses its matching engines and the co-located computer servers of trading firms, 2012. Photograph courtesy Melamed & Associates, Inc.



FIG. 6 The Chicago Board of Trade building, designed by Holabird & Root. 2011 photograph by Joe Ravi. Creative Commons license CC-BY-SA 3.0.