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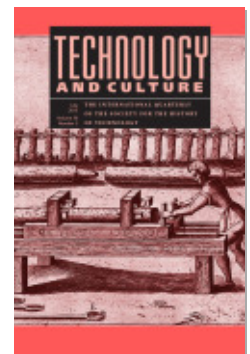
## Mechanizing the Merc: The Chicago Mercantile Exchange and the Rise of High-Frequency Trading

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# Mechanizing the Merc

## The Chicago Mercantile Exchange and the Rise of High-Frequency Trading

DONALD MacKENZIE

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**ABSTRACT:** This article investigates one important strand in the evolution of today's high-frequency trading or HFT (the fast, automated trading of large numbers of financial securities). That strand is the history of the automation of trading on what has become the world's most prominent futures exchange, the Chicago Mercantile Exchange or Merc. The process of the automation of the Merc was episodic, often driven by responses to perceived external threats, and involved both "local" politics and transnational considerations. The article discusses the relationship between the Merc's automation and the embodied, deeply social trading practices of the Merc's open-outcry trading pits, and compares how the Merc was mechanized with the quite different—and in a sense more explicitly "social"—project of automation launched by the Merc's rival, the Chicago Board of Trade.

### Introduction

At 2:40 p.m. on 6 May 2010, the U.S. 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 firm Accenture, for example, which had been trading at \$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, and something approaching "normality" had returned.<sup>1</sup>

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1. The official investigation of the episode is CFTC/SEC, "Findings Regarding the Market Events of May 6, 2010." A particularly useful academic analysis is Albert Menkveld and Bart Yueshen, "The Flash Crash."

The trigger of those events—the “flash crash,” as participants call it—seems to have been the decision by a large mutual fund (thought by market practitioners to be Kansas City investment managers Waddell & Reed) to sell a large quantity of Standard & Poor’s (S&P) 500 stock-index futures, thereby protecting a big portfolio of stocks from price falls.<sup>2</sup> 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-signaled 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 6 May, via the fiber-optic cables linking Kansas City to Chicago, the mutual-fund manager set a computerized trading algorithm to work on Globex (the exchange’s automated trading system), choosing the algorithm’s parameters so that it would quickly sell 75,000 E-minis—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 few miles south of the Chicago Loop in a “carrier hotel”: a giant, multiuser data center housed in a building once occupied by the presses that printed the Sears catalog.<sup>3</sup> The 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 typically 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 search for tiny discrepancies between prices—for example, those of futures and the underlying shares; while still others seek to spot the digital footprints of big orders so as to exploit them.<sup>4</sup>

Normally, the ecosystem of trading on Globex would have been able to absorb even a huge set of orders like those generated by the mutual fund’s

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 these profits can therefore offset losses on the stocks themselves.

3. Rich Miller, “Special Report: The World’s Largest Data Centers.”

4. This characterization is based on an overall set of interviews, described elsewhere in this article.

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sell algorithm. For the first few minutes on that May afternoon it did so, but—for reasons that are still unclear though 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 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 northern New Jersey in which shares are traded, the sell pressure began to swamp the stock markets. Violent price movements triggered risk limits built into 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 to be found while canceling any existing orders, and then cease trading 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). Under normal circumstances, stub quotes never lead to transactions: they are used 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 6 May that, in some cases, the only orders left were stub quotes, and incoming “market orders” (orders to buy at the lowest available price or to sell at the highest) were therefore executed against them.

How did this new world of automated trading, the world that suffered its first generalized crisis that day in May, come into being? This article traces one aspect of that process: the automation of trading on the Merc, 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 moral and religious distinctions; and Neil Fligstein has investigated the processes—*political* in a broad sense of the word—by which participants in markets seek to create stable order.<sup>5</sup>

This new economic sociology created by scholars like Granovetter, Zelizer, and Fligstein is pioneering and insightful; for example, the processes of the mechanization of the Merc are marked by the efforts of incumbents to defend the existing order, just as Fligstein would anticipate. In its explanatory structures, however, even “new” economic sociology can be read as traditionally sociological: in actor-network theory terms, it implicitly conceives the *social* as relations simply among human beings, as if those

5. See Mark Granovetter, “Economic Action and Social Structure”; Viviana A. Rotman Zelizer, *Morals and Markets*; and Neil Fligstein, “Markets as Politics.”

relations took place in a world devoid of things, of technologies and other nonhuman entities, with humans interacting only with their bodies and voices.<sup>6</sup> (Indeed, it can be argued that economic sociology also often gives insufficient weight to the embodied aspects of economic life, which were particularly prominent in Chicago's pits.) Thinking of the *social* in abstraction from the *technological* has clear limitations when dealing with automated trading in which, just as actor-network theory suggests, economic actors are either machines or hybrids of humans and machines.

One way of investigating the social nature of automated trading is ethnographic observation of human traders interacting with machines and, via machines, with one another.<sup>7</sup> Another way—the method followed by this article—is to investigate how those machines, and the systems of which they are part, came to be the way they are. This is the method offered by the history of technology, with its focus on the multiplicity of remakings of a world composed of both humans and nonhuman entities, and thus on what Thomas Hughes called the “[c]reation of the material environment shaped by—and shaping—mankind.”<sup>8</sup> 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 human and sociohistorical processes.

These processes are the focus of this article. Particularly relevant 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 the armory at Harpers Ferry, called “the efforts of its inhabitants to preserve accustomed lifestyles and practices in the wake of accelerating technology.”<sup>9</sup> The efforts by the traders in the pits of the Merc to protect their way of life were a 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. These efforts can be portrayed simply as resistance to technological change, and the latter can be viewed simply as “progress.” This “master narrative,” as Francesca Bray calls it, tends to ignore or underemphasize a second historiographic theme: the contingency of technological change and what Ruth Schwartz Cowan, following Robert Frost, calls “the roads . . . that were not taken,” or what Bray terms “alternative constructions of the world.”<sup>10</sup> As

6. On actor-network theory, see Bruno Latour, *Reassembling the Social*; and Michel Callon, ed., *The Laws of the Markets*.

7. See Caitlin Zaloom, *Out of the Pits*; and Alex Preda, “Tags, Transaction Types and Communication in Online Anonymous Markets.”

8. Thomas P. Hughes, *Networks of Power*, 1.

9. Merritt Roe Smith, *Harpers Ferry Armory and the New Technology*, 21.

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

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will be shown below, the mechanization of the Merc was not continuous, inexorable “progress,” but a contingent, episodic process largely driven by externally triggered crises. There was indeed a “road not taken”—an alternative, radically different form of mechanization that failed for contingent reasons.

The contingencies that shape technological change are typically local, but seldom *purely* local. A third, directly relevant set of themes from the history of technology concerns transnationalism and the coproduction of technological systems, places, and connections among places. These themes are found in classic works, especially those of Hughes and William Cronon, but, at least in respect to transnationalism, are present more explicitly in more recent work, such as that of Gregory Clancey and Suzanne Moon.<sup>11</sup> On the one hand, the mechanization of the Merc is a story of events taking place in Chicago, primarily in just two buildings: the twin-towered Merc Center on South Wacker Drive, and the skyscraper of its rival, the Chicago Board of Trade, astride LaSalle Street; on the other, 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.”<sup>12</sup> As will be sketched briefly at the end of this article, what has come into being is not a “flat world,” but a world in which particular places, and specific connections among those places, matter as much as, perhaps more than, ever, and in which those places, and especially the connections among them, are being actively reengineered.<sup>13</sup>

The mechanization of financial markets has only recently begun to attract historians; it was too recent a development to be prominent in Bob Tamarkin’s 1993 history of the Merc and William Falloon’s 1998 history of the Board of Trade.<sup>14</sup> The best historical accounts we have of mechanization are of European exchanges: Juan Pablo Pardo-Guerra’s examination of the London Stock Exchange, and Fabian Muniesa’s study of the automation of the Paris Bourse—a study that was pioneering in its focus on the different ways in which trading can be automated, such as differences among possible matching algorithms bringing together supply and demand.<sup>15</sup>

11. See, for example, Hughes, *Networks of Power*; William Cronon, *Nature’s Metropolis*; Gregory Clancey, *Earthquake Nation*; and Suzanne M. Moon, *Technology and Ethical Idealism*.

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

13. Thomas Friedman, *The World Is Flat*.

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

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

There are no publicly available archives bearing on the mechanization of the Chicago exchanges.<sup>16</sup> Accordingly, the main sources for this article are the oral-history interviews conducted in Chicago with thirty-three individuals having experienced this mechanization, including twelve involved with the automation of the Merc, two with the automation of the Board of Trade, and thirteen who had set up or worked for automated trading firms.<sup>17</sup> These interviews were complemented by a valuable written source: the memoirs of Leo Melamed, leader of the Merc's push toward mechanization.<sup>18</sup>

To understand the process of mechanization in Chicago, it is also necessary to understand the earlier "open-outcry" pit trading in the city. By good fortune, research on a different topic took me to Chicago in 1999 and 2000, when open outcry still flourished.<sup>19</sup> While there, I interviewed Melamed, Barry Lind (another key figure in the development of the Merc), and five open-outcry traders, and was able to observe such trading at the Merc and Board of Trade on tours of their trading floors and from viewing galleries. (An additional three former Chicago open-outcry traders were interviewed in New York and London between 1999 and 2001.) These interviews and observations, and Caitlin Zaloom's excellent ethnography of the Board of Trade, provide what is to be today regarded as historical material on open outcry, the world from which automated trading emerged in Chicago, but which is now almost entirely lost.<sup>20</sup>

### 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 1870s.<sup>21</sup> 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 they remained central when those exchanges started trading financial futures during the 1970s. A pit was an octagonal or circular "amphitheater," stepped

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

17. These interviews are part of a larger set of 105 interviews on the development of automated trading in the United States and Europe. In footnotes and "Oral Sources" of the Bibliography, interviewees are identified if they consented to be named; otherwise, citations provide only the date and place of the interview. Even though every interviewee listed in "Oral Sources" is not specifically cited in the footnotes, each contributed to this history of the development of automated trading. A further twenty people interviewed in Chicago in October 2011, March 2012, and May 2013 need to remain anonymous—some, for example, because they work for high-frequency trading firms.

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

19. Donald MacKenzie, *An Engine, Not a Camera*.

20. Zaloom, *Out of the Pits*.

21. Falloon, *Market Maker*, 72–77.

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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 one another. By the 1990s, some Chicago pits had become very large: 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 futures.<sup>22</sup> As noted above, open-outcry deals were struck either by voice or by eye-contact and hand-signals: palms toward the body signaled 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. 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 contact lenses. In busy pits there was constant jostling, in part because of crowding, in part from the 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. Commonly, jostling became verbal aggression; occasionally, verbal aggression turned into fistfights. Even in the absence of fights, however, physical size mattered: taller traders were easier to spot. 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.” Indeed, at the end of the 1990s, the Merc imposed a ruling on the maximum height 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.”<sup>23</sup> It was an overwhelmingly male environment, but not exclusively so; in the early 2000s, the individual trader who took on the largest positions in the Eurodollar pit was a woman, Margery Teller.

22. Eurodollars have nothing to do with the European single currency: they are U.S. dollars on deposit in banks outside the United States. Eurodollar futures track dollar LIBOR (London InterBank Offered Rate), which is widely used as an interest-rate benchmark in the United States, as well as overseas. By the end of the 1990s, some 50,000 people had jobs immediately involved with Chicago’s open-outcry exchanges, with perhaps an additional 100,000 indirectly dependent on them. See Anonymous, “Chicago’s Fallen Giants Make Progress of Sorts.”

23. The quotes here and in the following paragraph are from Anonymous, interview with the author, 10 November 2000; and Stephen Levin, interview with the author.



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,” in addition to the “street smart” instinct of knowing “who’s going to panic and who needs to have something.”<sup>24</sup> Pits were also far from anonymous places; 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, because fellow traders were not necessarily friends, and indeed sometimes were bitter enemies, but if they traded frequently they were people you knew and often addressed by high school–like nicknames.<sup>25</sup> 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 subsequently turned against them. “Your reputation was everything,” noted a trader who went on to set up an automated trading firm.<sup>26</sup> Reciprocity was important, especially between traders and brokers. A broker would normally bring traders profitable business, but could sometimes also call on them “to kind of help the broker out”—for example, by shouting “ten at five, *I need these*.”<sup>27</sup>

Interaction took place not only in the pits. Up until November 2000, when the Merc became a publicly traded corporation, the Chicago exchanges had all been membership organizations in which all important decisions were decided by votes.<sup>28</sup> “[W]e had 200 and something committees,” recalls Melamed, and to achieve change required political skills, which Melamed in particular spent large amounts of time and energy deploying.<sup>29</sup> For example, in the crucial 1997 battle over the E-mini (discussed below), he 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.”<sup>30</sup>

Endlessly fascinating as open-outcry pits were as places in which economic life involved intense embodiment and, as economic sociology would predict, 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 trad-

24. Michael J. Carusillo and Clayton Struve, interview with the author.

25. Levin interview. Levin, for example, is known even today as “Vinnie” by those who traded with him, from the identifier on his trading-floor badge, “VIN.”

26. Anonymous, interview with the author, 10 October 2011.

27. Levin interview. Here, the broker was emphasizing an urgent need to sell ten futures contracts at a price of which the final digit was “5.”

28. Leo Melamed, Jim Krause, and Don Serpico, interview with the author.

29. Ibid.

30. Melamed, *For Crying Out Loud*, 40.

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ing flowing smoothly could turn into informal cartels that operated to the disadvantage of other pit traders or 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 becoming cartels. The rules of the Merc and Board of Trade permitted dual trading: a broker could both act for external customers and trade on his or her own account. There were strong suspicions that members of broker groups steered profitable paper orders to fellow members who were acting at that moment as own-account traders, and that brokers who owned clearing firms favored traders who cleared through their firms because of the fees that would be generated.<sup>31</sup> In the late 1980s, two FBI agents working undercover at the Merc and two at the Board of Trade secretly tape-recorded conversations and documented breaches of the law, which led to the August 1989 indictment of forty-five traders and a clerk.<sup>32</sup>

Although he was not alone in objecting to cartel behavior within broker groups (many independent brokers and traders also did so), the Merc’s Melamed, who had led its move into financial derivatives, was a prominent opponent of cartels. The immigrant son of two members of the Jewish radical, socialist Bund, Melamed was, paradoxically, also strongly committed to the free-market economics of his “personal hero,” University of Chicago economist Milton Friedman.<sup>33</sup> Broker groups behaving as cartels offended both the Bundist and free-marketer in Melamed. When he and 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 take on with fellow members, Melamed began receiving 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.”<sup>34</sup>

The controversy about broker groups was interwoven with disputes over mechanization. A broker’s “income, for practical purposes, was totally dependent on the open-outcry architecture.”<sup>35</sup> With electronic trading, customers might no longer have to pay brokers simply to bring their orders to market; the resultant reduced costs meant that many customers welcomed mechanization. In contrast to brokers, traders might hope to continue to flourish in electronic markets; however, they also were often ambivalent or even hostile. Open-outcry trading was a demanding though familiar business, and much of its embodied skill—“you traded off of vis-

31. James E. Oliff, interview with the author.

32. David Greising and Laurie Morse, *Brokers, Bagmen, and Moles*.

33. Leo Melamed, interview with the author.

34. Melamed, *For Crying Out Loud*, 30.

35. *Ibid.*, 26.

ceral reaction, noise, smell, look on someone's face"—could not be transferred to the computer screen.<sup>36</sup> 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, which had been 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 slightly could prove contentious. Traders and brokers won the right to stand in a particular place by both seniority and fending off challengers (sometimes physically), and they could be fiercely hostile if a change impacted "sight-lines and locals' [traders'] ability to have access to orders. So that became a . . . very long and difficult thing."<sup>37</sup>

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 have been so adamantly opposed. It was a "mortal conflict," a "life-or-death battle," wrote Melamed.<sup>38</sup> James Oliff, another supporter of mechanization, "had people spit in my face. I've had people pour drinks all over me."<sup>39</sup> Ultimately, the Merc did mechanize, but it took nearly two decades.

## Globex

Melamed, who led the push to mechanize the Merc, had not always been an enthusiast for electronic trading. He joined the exchange as a runner in 1953, already fascinated 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."<sup>40</sup> Two decades later, with the Merc's new financial-futures pits beginning to flourish, Melamed (by then chairman of the exchange) still firmly believed that open outcry played an irreplaceable role in futures trading.<sup>41</sup> His moment of conversion came only in 1986. He had just finished writing 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 S&P'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

36. Levin interview.

37. Oliff interview.

38. Melamed, *For Crying Out Loud*, 5, 12; Melamed, Krause, and Serpico interview.

39. Oliff interview.

40. Melamed, *Escape to the Futures*, 87.

41. Leo Melamed, "The Mechanics of a Commodity Futures Exchange."

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.<sup>42</sup>

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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.<sup>43</sup>

An impetus broader than Melamed's 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 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 recently established London International Financial Futures Exchange. Its time zone meant that its pits started trading before the end of the business day in East Asia. “LIFFE's time-zone advantage made me very concerned,” Melamed recalled.<sup>44</sup>

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 been among the pioneers of the onscreen dissemination of prices (with its 1973 Monitor service) and developed the first system for electronically mediated trading among banks (the 1981 Reuter Money Dealing services).<sup>45</sup>

Reuters agreed to join the Merc in the development of a system for the electronic trading of futures, which was named “Globex” because, as noted above, Melamed wanted it to be “the international standard for electronic trading.”<sup>46</sup> 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 futures exchange. A year of weekly meetings secured the board's participation, but only temporarily; in April 1994 it withdrew.<sup>47</sup> 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 also withdrew, placing its main efforts into its own system, Automated Pit Trading.<sup>48</sup>

42. Melamed, Krause, and Serpico interview; Leo Melamed, *The Tenth Planet*.

43. Melamed, *For Crying Out Loud*, 10.

44. Melamed, *Escape to the Futures*, 316–17.

45. Donald Read, *The Power of News*, 363–70.

46. Melamed, *For Crying Out Loud*, 16.

47. William B. Crawford, “CBOT Says Goodbye to Globex.”

48. David Kynaston, *LIFFE*, 182.

Gaining the support of the Merc's own members for Globex was almost as difficult. Its proponents knew that most members would support the developing of Globex only if they could be convinced it was not to be a rival to the pits, and that indeed was signaled 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 time zone's working day: the system opened for trading at 6:00 p.m. and ran for twelve hours, until 6:00 a.m. the following morning.<sup>49</sup>

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 Globex's technical development difficult. It began operation only in 1992, five years after the initial agreement with Reuters. Trading volumes remained modest: fewer (usually many fewer) than 25,000 contracts per night, and initially mostly in MATIF's products, not the Merc's. By the mid-1990s it was clear that Globex was "limping," says Melamed.<sup>50</sup> An interviewee who worked for a Japanese bank during this period remembers installing Globex terminals in its dealing rooms, but all that the terminals "accomplished was gathering a great deal of dust."<sup>51</sup> 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.<sup>52</sup> Not only had Globex failed to become truly global, but the very project of mechanizing the Merc was faltering.

Before we turn to the product that saved it, we need to consider the road not taken: a 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 designed to have a global reach (especially to East Asia), the Aurora project, announced in March 1989, involved the board and three information-technology companies: Apple, Texas Instruments, and Tandem. The involvement of Apple indicates what was distinctive about the project: Aurora sought to visually simulate a trading pit. "We chose to attempt to replicate the trading floor," says Burt Gutterman, who at that time served 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

49. Melamed, *Escape to the Futures*, 337–39; Melamed, Krause, and Serpico interview.

50. Melamed, Krause, and Serpico interview; Crawford, "CBOT Says Goodbye to Globex."

51. Anonymous, interview with the author, 14 October 2011.

52. Melamed, Krause, and Serpico interview; Crawford, "CBOT Says Goodbye to Globex."

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mSPH7 79410S 17:05						+	-
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 (ca.1997). The left-hand box lists the prices at which the E-mini 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. (Source: Screen shot courtesy of Miles Szczurek and Michael J. Kane.)

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 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 simulated pit at any given time.<sup>53</sup>

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 (fig. 1). (Figure 2 shows the window that a trader would use to place an offer on Globex, and figure 3 is 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: “they [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.”<sup>54</sup> If one was fighting the broker groups’ hold on trading on the actual trading floor, as Melamed increasingly was, there was no reason to design a virtual trading floor that would allow them to reproduce their practices electronically.

53. Burt Gutterman, interview with the author.  
54. Melamed, Krause, and Serpico interview.

OFFER for m EDH7

PX

9211

QTY

1

OK

QUIT

Hold

Extended Clearing Information

Acct#

12345

Type

LHT

Qual

CTI Origin Fee

F-EX

F-Firm

Orig Entry Date

02/10/97

Order#

Clearing Key

TEST1

<<Brief

Action

Memo

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

GLOBEX®: CME-MATIF									
Menu	Trade	SpTrade	Modify	Display	Param	Window	Cancel	Session	Help
TBH6CALL 9475-9525	MARKET	QUOTE	MARKET	QTY	LAST	NET CHG	TRADER	QUOTE	TRADER
1 TBH6 C9475		9120		x7	9108	N/A		9120	x7
2 TBH6 C9500		/		x				/	x
3 TBH6 C9525		/		x				/	x

TBH6 C9475 9108 14:53

Bid	Px	Qty	Offer	Px	Qty
			9120		7
			9121		9
			9128		4
			9208		12

TRADER MAILBOX

B22	S-REL	9	TBH6 C9475	9121	14:54:41
			OK-		B22MOFB28 m
B22	SELL	9	TBH6 C9475	9121	14:54:41
			OK-OFR ON HOLD		B22MOFB28 m
B22	CX-S	9	TBH6 C9475	9109	14:54:41
			OK-ENTRY MODIFIED	999	m
B22	S-HLD	9	TBH6 C9475	9109	14:53:52
			OK-	999	m
B20	SOLD	25	TBH6 C9475	9108	14:53:32
	BAL:	0		999	m
B27	BOT	25	TBH6 C9475 WP:	9108	14:53:32
	#RCP# BAL:	0		999	m

Wed 06 Mar 1996 14:55 GMT

REUTERS

FIG. 3 A full Globex screen (1996). The products being traded are U.S. Treasury bill call options, with a March 1996 expiration date and "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 of 5.25 percent. The messages in the trader mailbox record the interactions with Globex; for example, the earliest, bottom-most message is a confirmation of the trader's purchase of twenty-five options each at a price of \$91.08. (Source: Screen shot courtesy of Miles Szczurek and Michael J. Kane.)

Thus not only were the bids and offers on the screen of a Globex terminal anonymous, but if there was more than one bid or offer at a given price, its matching algorithm gave priority to the one received first.

Aurora and Globex thus embodied two different visions of what it was to mechanize a market. Aurora was canceled by the Board of Trade not

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because its vision was unattractive—pit traders and brokers in most exchanges might well have preferred an Aurora-style system—but because it became clear that its visual representation of trading pits overburdened the then-available bandwidths of global digital communication.<sup>55</sup> 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 Gutterman. “[A]ll of a sudden, I saw, wait a minute, this isn’t going to work,” and he reported to the executive committee that Aurora was not feasible.<sup>56</sup>

Consequently, 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 similar to 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 executed was the first to have been entered at the appropriate price. Time priority—“first come, first served”—thus structured how traders’ orders encountered one another in Globex’s algorithms in the late 1990s, when use of the system first became important. 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, S&P 500 stock-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, however, had never licensed the index to the futures markets—“they refused to let some gamblers in Chicago use their instrument”—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.<sup>57</sup> In 1997, however, Dow Jones finally

55. For example, LIFFE’s automated pit-trading system was, as its name indicates, an attempt to replicate a pit, albeit with a simpler visual interface than 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].” See Anonymous interview, 15 October 2011.

56. Gutterman interview.

57. Melamed, Krause, and Serpico interview.



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 new, giant, open-outcry trading floor, the largest in the world, and badly wanted, and was prepared to pay heavily for, the right to trade a futures contract based on the Dow Jones index.<sup>58</sup>

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 contract was too large for most laypeople: a one-point shift 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 then an S&P 500 contract remained dauntingly large. Perhaps, however, 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 this 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*?<sup>59</sup>

The proposal for the E-mini was 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 futures, 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 5 June 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. An extraordinary technical effort led by Jim Krause of the Merc's information systems department made it possible for the E-mini to begin trading on 9 September 1997, a month before the launch of the Board of Trade's new Dow Jones futures.<sup>60</sup>

The E-mini would not, of course, be an effective response to the Dow Jones futures if trading in it was as sporadic as in most existing products on Globex. The crucial innovation in this respect was the brainchild of Melamed's ally Bill Shepard. It exploited the fact that while the E-mini was "different" from the pit-traded S&P 500 futures, it was, economically, also the same: five E-minis were economically identical to one pit-traded contract. If the relative prices of the two diverged, therefore, an attractive opportunity would arise for arbitrage, for riskless profit, by buying the

58. Falloon, *Market Maker*, 263–75.

59. Melamed, Krause, and Serpico interview; Melamed, *For Crying Out Loud*, 37–39.

60. Melamed, *For Crying Out Loud*; Melamed, Krause, and Serpico interview.

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FIG. 4 Globex terminals overlooking the Merc's S&P 500 stock-index futures trading pit (ca.2000). (Source: Reprinted with permission from CME Group Inc.)

cheaper instrument and selling the dearer. Shepard's 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 thus exploit any temporary price discrepancies. A large, semicircular structure was built overlooking the pit, with more than a hundred Globex terminals on it arrayed in tiers<sup>61</sup> (fig. 4).

So was born "the bigs and the littles"—the arbitrage between the pit-traded S&P 500 futures and the E-mini. Pairs of traders would collaborate, one in the pit and one sitting above at a Globex terminal, communicating by hand-signals or radio headsets. A trader in the pit, interviewed in November 2000, drew my attention to the new structure, which when viewed from below seemed to loom over it: "when 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 [*sic*] the guys that trade the E-minis . . . some of these guys are doing very, very, very well—extremely well."<sup>62</sup> Among 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 Company), established, also in 1999, by Daniel Tierney, formerly a trader on the Chicago Board Options Exchange, and Merc broker Stephen Schuler.<sup>63</sup>

The bigs and the littles turned the S&P futures 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

61. Melamed, Krause, and Serpico interview; Melamed, Krause and Serpico, personal communications (emails) with the author, 11 September 2012.

62. Anonymous, interview with the author, 10 November 2000.

63. Anonymous, interview with the author, 16 October 2011.

the Board of Trade, but in a sense it became the primary overall price-discovery market for U.S. shares: that is, the market that responded most quickly to new information bearing on 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 in Globex, the first order to be executed was simply the first to arrive at the “matching engines” (the parts of the Globex computer system that maintain the electronic order book and find bids and offers that match). “First in, first out,” together with the fact that the price discrepancies being arbitrated were fleeting, meant that those seeking to exploit discrepancies between the prices of the “big” and those of the “little” had to place a huge priority on speed: delay, even for an instant, meant either that one’s Globex order for the little would not be filled, or that the discrepancy would have vanished by the time it was filled. At least two firms took computer-gaming joysticks and reprogrammed them to simulate the keystrokes on a Globex terminal that placed orders for E-minis so as to allow their traders to outpace those using keyboards.

Originally, the common assumption had been that automated trading would involve a person 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 humans, 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 humans at terminals, Globex did not originally have what would now be called an application programming interface (API)—a direct means by which users’ computer programs could interact with the Globex system. However, firms that had cut their teeth on the bigs and the littles began to develop what one interviewee 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 person hitting the keys of the terminal.<sup>64</sup>

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

64. Anonymous, interview with the author, 10 October 2011.

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early indications of likely moves in the QQQs, and the risk of positions accumulated in the QQQs could be offset in the futures.<sup>65</sup> 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, occasionally responsible for a fifth of all trading in some leading stocks.<sup>66</sup>

### The Threat from Europe and the End of the Pits

Within the Merc itself, however, E-minis remained an anomaly of mechanization: most members of the Merc were still strongly committed to open outcry. Nevertheless, developments in Europe during 1997–99 showed that even well-entrenched futures exchanges were potentially at risk from electronic competition, and that pit trading itself might be endangered. LIFFE, 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. 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 switched from open-outcry to electronic trading, and LIFFE followed suit during 1999–2000.<sup>67</sup> 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' modus operandi precipitated what just 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 that the 1987 vote had placed on Globex. From then on, all of the Merc's futures could be traded electronically, whether or not the pits were open.<sup>68</sup>

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," as did their counterparts in the Board of Trade.<sup>69</sup> What finally broke Chicago pit-traders' defense of their way of operating was the potential threat from Europe becoming real—indeed, actually present. In 2003, the all-electronic Eurex futures exchange (formed in 1998 by a merger of the Deutsche Terminbörse and the Swiss Options and Financial Futures Exchange) declared its intention to begin trading in the

65. Ibid.

66. Scott Patterson, "Meet Getco, High-Frequency Trade King."

67. See, for example, Susan V. Scott and Michael I. Barrett, "Strategic Risk Positioning as Sensemaking in Crisis."

68. Melamed, *For Crying Out Loud*, 56–57.

69. Ibid., 57.

United States. In February 2004, LIFFE also announced it was planning electronically traded Eurodollar futures, thus directly competing with the Merc. Eurex leased space in the Sears Tower, the tallest building in the Americas (and a short walk from both the Board of Trade and the 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.<sup>70</sup>

Regarding the Merc and the Board of Trade, the latter was the more vulnerable. Unlike the former, it did not have 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. This was a critical move because in futures, the clearinghouse can be involved in a transaction for many months, thus intimately linking exchanges and clearinghouses together. The buyer and the seller of a future do not have direct contract with each other; instead, each has separate contract with the clearinghouse, which adjusts daily the margin that both the buyer and the seller need to maintain on deposit with it in order to mitigate the risk of either not fulfilling its obligations. Consequently, 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 fend 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.

Eurex’s threat during 2003–04 to the Board of Trade and LIFFE’s to the Merc provoked months of tumultuous change in Chicago. The board began pursuing electronic trading with unprecedented vigor and opened negotiations to shift its clearing to the Merc’s clearinghouse, despite the decades of rivalry between the two exchanges. An agreement was reached in April 2003 and a complex technical effort achieved the transition by January 2004, thus commencing the process that led to the 2007 merger of the Merc and the Board of Trade.

Knowing that the thousands of Eurodollar traders (“the most successful and hard-bitten open-outcry constituency in existence anywhere”) would not shift to electronic trading on their own, the Merc’s leadership—its chairman, Terry Duffy; chief executive officer, Craig Donohue; and Melamed—resolved to bring matters to a head by threatening closure of the pit unless at least a quarter of Eurodollar trading was transacted in Globex.<sup>71</sup> In a succession of large meetings—Melamed recalls one with “1,000 angry faces in the room”—Duffy, Donohue, and he convinced the majority of traders of the need for change.<sup>72</sup> Indeed, once the transition from the Eurodollar pit to the Globex screen began, it was faster and more complete than even the Merc’s management anticipated.

A way of life for more than a century thus effectively ended. Sensing

70. Ibid., 102; David Roemer, “Eurex Chief Insists Exchange in U.S. for Long Haul.”

71. Melamed, *For Crying Out Loud*, 108.

72. Ibid.; Melamed, Krause, and Serpico interview.

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that his two-decades-long campaign for mechanization was now at an end, 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.<sup>73</sup> The almost complete demise of the pits affected some traders very emotionally; for example, 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 occurred.

However, even though Chicago’s pits lost their crowded, animated verve, the way of life that was passing left its mark in the matching algorithms at the heart of the electronic trading that was succeeding it. The Merc’s S&P 500 futures pit, the first successful site of mechanization, was, in some respects, unusual. Prices there nearly always substantially fluctuated 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 the leaders of the technical development of Globex thus largely mirrored the practices of the pit.

But this was not the case with the Merc’s Eurodollar pit, where prices usually moved much more slowly—for example, near-term Eurodollar prices are closely linked to interest rates set by the Federal Reserve and, at most, change monthly—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 that the traders in the large Treasury Bond futures pit were devoting their attention not to trading, but to a plastic lid being thrown Frisbee-style from one side to the other.) A former broker in the Merc’s Eurodollar pit recalls that

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.<sup>74</sup>

With slowly moving prices, Eurodollar 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.”<sup>75</sup> 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” among multiple traders who had all been quoting the same price.

Initially, the electronic trading of Eurodollar futures employed Globex’s original first in, first out, time-priority matching algorithm. However,

73. Melamed, *For Crying Out Loud*, 109.

74. Anonymous, interview with the author, 14 October 2011.

75. *Ibid.*

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: “somebody 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.”<sup>76</sup> In consequence, about 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*, which meant that 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, A bidding for forty contracts and 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 his 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.”<sup>77</sup> The outcome, however, was a matching algorithm that replicated pit traders’ informal sharing, and the modification following the merger does seem to have been directly modeled on customary behavior in pits.<sup>78</sup> In that sense, an echo of the way of life in the pit continues at the very heart of electronic trading of Eurodollar futures.

To a degree, *pro rata* allocation complicates the design of a fully automatic trading system because 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, automated trading firms had already gained their experience, technical expertise, and capital on bigs and littles (with the E-mini’s simple first come, first served matching), and the interviews suggest that they were able to take the challenges of the new matching algorithm in stride.

These firms had graduated from simple trades like bigs and littles to more complete automation of the two generic strategies of the Chicago pit

76. Ibid.

77. Ibid. 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; see Eurex, “Circular 67/99.”

78. Anonymous, interview with the author, 14 October 2011; Melamed, Krause, and Serpico interview.



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trader: *scalping* and *spreading*.<sup>79</sup> *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 positions very quickly and changing bids and offers as the market in those futures fluctuates. (Short-term price dynamics in trading pits were often predictable, to a degree, to experienced, alert traders, 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 futures. Historically, 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 foundation of the electronic trading system of the Paris Bourse, which had taken over MATIF.<sup>80</sup> As automated trading grew in scale, the transaction load on Globex typically tripled annually. Extensive further reengineering from 2003 onward increased its capacity, improved its availability and reliability, and, crucially, reduced its response time.

The speed of response was, of course, a critical issue from the viewpoint of the nascent high-frequency traders. Because scalping and spreading were well-known strategies, a trader practicing them electronically could expect competition; therefore, just as with bigs and littles, the speed of execution was crucial. Initially, simply removing the human from the process provided a substantial advantage, but as others followed suit, 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.<sup>81</sup> 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 alongside the engines, in the very same building.

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

80. Melamed, Krause, and Serpico interview; for the Paris Bourse system, see Muni-esa, "Des marchés comme algorithmes."

81. Anonymous, interview with the author, 10 October 2011.





**FIG. 5** Leo Melamed in the Merc’s new data center in the suburbs of Chicago that houses the exchange’s matching engines and the co-located computer servers of trading firms (2012). (Photo: Courtesy of Melamed & Associates, Inc.)

## 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 semi-secret; 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 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.<sup>82</sup> When, in 2012, the Merc opened its own huge data center in the Chicago suburbs (fig. 5), 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 around mountain ranges, and avoid shallow seas because then the cables, which are

82. Miller, “Special Report: The World’s Largest Data Centers.”

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vulnerable to trawlers and sharks, would have to be encased in metal and buried in the ocean floor. Even with signals traveling at close to the speed of light, the result is a few extra micro- or milliseconds of transmission time—very disadvantageous to HFT firms. For example, the transmission times between Chicago and the share-trading data centers in northern New Jersey are crucial to HFT firms using E-mini prices as a guide to likely movements in the prices of underlying shares. In March 2009, work commenced on laying down a new transmission cable, initially secretly, between Chicago and New York/New Jersey and running directly through the Allegheny Mountains in order to minimize transmission times.<sup>83</sup> More recently cable operator Hibernia Atlantic began to lay a new cable between New York and the United Kingdom, following a great-circle route across Canada's continental shelf, thus shaving 2.6 milliseconds off the one-way transmission time on the previously fastest cable, Global Crossing's AC-1.<sup>84</sup>

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.<sup>85</sup> In principle, one can set up an automated trading firm anywhere, and indeed important firms are found in such places as Charleston, Kansas City, Prague, and Amsterdam.<sup>86</sup> Yet, the location of the firm's trading hardware matters critically—it must be in the same building as the exchange's matching engines or else the firm will be at a serious disadvantage—and the expensive new cables have been financially possible because HFT firms must pay large sums to rent bandwidth on them, again because the cost of not doing so is a serious competitive disadvantage.<sup>87</sup>

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 National Historic Landmark: the Chicago Board of Trade's 1930 art deco skyscraper (fig. 6). When the board merged with the Merc, the latter consolidated the remaining open-outcry trading on the board's trading floors. The residual links between pit trading and automated trading, the rapid connections that were created between the skyscraper and the Merc's matching engines, and relatively cheap rents made the building an attractive location for Chicago's new

83. Christopher Steiner, "Wall Street's Speed War."

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

85. Friedman, *The World Is Flat*.

86. 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 modeled on the Chicago exchanges, was created.

87. In fiber-optic cable, light is 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, has turned attention to an old technology—microwave transmission—despite its limited bandwidths, the need for a series of towers (each within the line-of-sight of its neighbors), and the risk of interference from adverse weather.



FIG. 6 The Chicago Board of Trade skyscraper, designed by Holabird & Root and opened in 1930. (Photo: Joe Ravi [2011], Creative Commons license CC-BY-SA 3.0.)

HFT firms. As they grew, these firms generally relocated to the more spacious premises offered by the city's converted warehouses, but as they did so they were replaced by other firms. 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."<sup>88</sup>

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, in warmer weather, at the tables outside) Ceres, its ground-floor bar, named after the goddess of grain whose statue sits atop the building. Traders in different firms can chat (cautiously); potentials for hiring can be identified; despite HFT firms' efforts at secrecy, there is a circulation

88. Anonymous, interview with the author, 15 October 2011.

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of personnel among 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 deduced from their authors' "body language," especially at the end of the month, when the month's profits and losses are calculated: "At one table you'll see cigars and toothy smiles and at the next one over you'll see slumped shoulders and silent self reflection."<sup>89</sup>

The clustering of HFT firms in and around the Board of Trade skyscraper is a small indicator of bigger things. Automation has changed the forms that sociality takes, but has not eliminated the sociality of trading; as noted above, on occasion, even embodiment remains significant. The history of automated trading is not simply its now-irrelevant past because its traces are still apparent—even in its technological heart, its matching algorithms. The history is a transnational history, but this has not ended the significance of locality. Just as sociality and history still matter, so does place.

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