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10 The Automated House

The Digitalization of the London Stock Exchange, 1955–1990

Juan Pablo Pardo-Guerra

INTRODUCTION

In 1971, Fischer Black, a key contributor to modern portfolio theory, published two articles that succinctly captured the imaginaries of the future of corporate finance. In his assessment of the structure and operations of American financial intermediaries—from brokers and stock exchanges to over-the-counter trading services—Black concluded that, with a handful of changes, these could be:

> embodied in a network of computers, and the costs of trading can be sharply reduced, without introducing any additional instability in stock prices, and without being unfair either to small investors or to investors at large. (1971: 87)

Merely seven years after Black's articles on automation, Kenneth Garbade and William Silber provided empirical evidence connecting technology with improvements in the quality of market pricing. In their study of the telegraph and telephone in American and British stock markets, Garbade and Silber (1978) observed enhanced integration, reduced information delays, and a significant narrowing of inter-market price differentials after technological adoption. For Black and his contemporaries, technology was increasingly a handmaiden of the market, the visible skeleton of a global, invisible hand.

Illustrated by the preceding vignettes, the histories and imagined futures of finance—and particularly those of corporate finance—are written too often as triumphal sagas of efficiency, the collusion of tales of bold technological innovation and stories of decreasing trading costs, wider corporate ownership, and greater regulatory control. The subsection of this literature that deals with the digitalization of financial intermediaries and trading venues follows, indeed, the broad thrust of triumphalism. Systematic studies on the most recent wave of technological change within corporate finance approach the topic as a fundamental disruptive innovation, often leaving unexamined the nuances of technological development and its association with changing institutional arrangements. For instance, the relatively late adoption of computers and telecommunications in the securities industry is presented as the most important change in finance in the last century. Likewise, the structure of financial markets is deemed a consequence of the rise and consolidation of the (digital) information age and the technological networks upon which it is based (Cortada 2006; Castells 2000).

In presenting technology as a transformative force, however, authors have committed three omissions. First, following the basic metaphors of the neoclassical theory of production, they have presented information technologies as readymade inputs that emerge from the black box of the information age. Second, by rendering technologies as external inputs, they have tended to present financial organizations as adopters rather than developers, clients rather than designers. The financial services industry, it would seem, only embraced innovations "once it made economic sense to do so" (Cortada 2006: 187). Third, even in the rare instances when innovation is the explicit object of analysis, it has been portrayed as a linear process driven by the diverging telos of market demand or technological pull.

Examples of these omissions are numerous. Charles R. Geiss's history of Wall Street, for instance, conspicuously leaves technological change unattended (see Geiss 2004). Similarly, Ranald Michie's comprehensive history of the London Stock Exchange (LSE) mentions the proliferation of technological systems in the market almost in passing, without reference to the trials and tribulations of their development (see Michie 1999).

This chapter seeks to address these omissions by focusing on the history of the development of market information systems in the LSE between 1969 and 1992. These years bound an epoch of technological innovation within the City of London, inaugurated by the introduction of the first standardised market information dissemination system in Britain—the Market Price Display Service (MPDS)—and closed by the outsourcing of the Stock Exchange's technical services teams to Andersen Consulting.

In reconstructing the technological history of the LSE, this chapter contributes to a growing body of literature that engages with the minutiae of technological innovation in financial institutions, which is exemplified throughout this volume. Notably, it complements similar narratives that discuss in detail the development of the global communication networks that structure contemporary financial markets and serve as the material frames for economic calculation.[1] Inspired in the insights of science and technology studies,[2] this chapter stresses the co-evolution of markets,

1. The former chief technology officer of the New York Stock Exchange provides a detailed account of the process of innovation within that organization. See Keith and Grody (1988). Similarly, Wells (2000) provides an interesting account of the adoption of computers in Wall Street.

2. Science and technology studies is a complex and illustrious tradition of intellectual engagement with the social world. An introduction to its approach in relation to the analysis of technology is given by MacKenzie and Wajcman (2003). Also see Williams and Edge (1996).

institutions, and technologies by presenting and contextualizing the often disguised innovation efforts of the technologists of the LSE.

The history presented in the following pages is the product of multiple sources. The *Stock Exchange Journal*, official publication of the Stock Exchange between 1955 and 1975, provided the narrative of early developments. Most of this chapter, however, is based on a series of interviews in the style of oral histories conducted by the author between 2006 and 2007 with former employees and members of the Stock Exchange. Internal Stock Exchange documents provided by the interviewees as well as articles from the *Stock Exchange Quarterly* were additional inputs.

The reminder of this chapter proceeds as follows: first there is a focus on the adoption of computer hardware. The second and third sections tell of the early mechanization of the LSE, the arrival of computer technology to the trading floor, and the creation of the MPDS. The fourth section narrates the challenges for the expansion of MPDS. This section also helps to change the focus of the chapter from hardware to the software. The fifth and sixth sections discuss the LSE fending off competition from a (failed) alternative system to MPDS, named Automated Real-Time Investments Exchange (ARIEL), and offer evidence of the role of the LSE's technical team in shaping the process of technological change as applications around MPDS evolve to create an electronic database of market prices (called Exchange Price Input Computer or EPIC). In the seventh section the LSE's technical team are given a mandate for the planning and development of new systems while being renamed the Special Systems Group (SSG). The eighth, ninth, and tenth sections tell of the travails of SSG to overcome the limitations of MPDS to respond to new requirements by users, the emergence of alternative providers of price information (such as Reuters and Datastream), and the loss of internal capabilities with the outsourcing of technological services to Arthur Andersen. The last section offers the conclusions to the chapter.

ANALOGUE DAYS ON THE FLOOR OF THE HOUSE

Throughout its history, the LSE has provided the largest and most important centre for dealing in British bonds and equities. Between its foundation in 1801 and Big Bang in 1986, the basic mechanism for making markets in the Stock Exchange changed little, providing a stable institutional reference for market practitioners and investors alike.

Although admittedly an idealization, the basic market mechanism of the Stock Exchange can be seen as constituted by three elements. The first was a division of labour known as single capacity. Formalized in 1909, single capacity separated the membership of the Stock Exchange into two groups. Stockbrokers provided advice to investors and took their orders to the market for execution. Conversely, jobbers acted as market-makers, buying and selling shares from brokers and profiting from the price differential between bids and asks. Under normal market conditions, brokers were prohibited from buying or selling shares on their account, whilst jobbers were not allowed to deal directly with investors.

The second element was thoroughly material. The business of creating a market occurred in a restricted space, the trading floor of the Stock Exchange. Located in a building that had undergone numerous alterations since its erection in the mid-nineteenth century (and known by the membership as "the House"), the trading floor was the physical centre of liquidity for the British securities market. On the periphery of the floor, brokers had "boxes" that served as a pied-à-terre, providing communication with their offices and the world at large. As orders arrived to the box, brokers or their authorized clerks took them to the trading floor. There, they would search for the best price available, walking from jobbing pitch to jobbing pitch. In effect, the process could be laborious: prices were seldom explicit, and brokers had to approach jobbers individually to obtain a quote. Only the most active shares were marked on whiteboards, and often the written prices differed from those ultimately provided by the jobbers.

The third element was intrinsically regulatory. The Stock Exchange not only defined the rules and regulations of its membership, it also acted as a trade association, a provider of settlement services, and a listing authority. The different roles occupied by the Stock Exchange transformed it into an undisputed point of passage for corporate information, having disclosure requirements that often exceeded those of the government.

With its large trading volumes, restricted admission, and privileged access to corporate information, the prices created on the floor of the Stock Exchange were valuable commodities in themselves. Indeed, for non-members such as merchant banks, access to Stock Exchange prices facilitated buying and selling shares without paying broking commissions or incurring in search costs.

COMPUTERS IN THE STOCK EXCHANGE

As such, the Council of the Stock Exchange—which since 1947 controlled the rules, regulations, and institutional policies of the organization—was not keen on mechanisms, technological or otherwise, that could reveal its prices to either domestic or overseas competitors. Such leaks could result in market fragmentation (namely, the emergence of alternative trading venues and the subsequent reduction in liquidity) and could potentially reduce the perceived quality of the prices of bonds and shares. Whereas the Exchange avoided the fragmentation of the market during the nineteenth century despite the introduction of the telegraph, telephone, and transatlantic cable in London, the digital technologies of the 1950s and 1960s presented a novel suite of challenges for the

organization. Theoretically, they made practical the dissemination of prices off the trading floor of the Stock Exchange in real time, thus facilitating the consolidation of markets outside of its organizational and regulatory reach.

In the United Kingdom, the risk of fragmentation was enhanced by the fact that, by the 1940s, London and the provincial exchanges had established a stable division of labour within the market for bonds and shares.[3] Indeed, rather than seeking to expand its reach or compete with the provinces, the Stock Exchange's foray into computing responded to two broad incentives: first, the perceived economic benefits of rationalising operations in the back office; second, as a mechanism to manage innovations within the marketplace in order to avoid the unregulated dissemination of information off the trading floor.

Computers thus entered the Stock Exchange through settlement, an area that was particularly amenable to technologies of record-keeping and arithmetic calculation. The adoption of computers in settlement followed trends initiated as early as 1949, when the Stock Exchange acquired Hollerith punched-card equipment to reduce the labour requirements of matching trades conducted on the floor. Effectively, settlement was a labour-intensive process that required considerable numbers of skilled personnel. It was, nevertheless, an activity that could be initially mechanized, subsequently computerized. Hence, the Stock Exchange purchased its first computer in 1966—an International Computer and Tabulators (ICT) 1903—for use in the Settlement Department marking the beginning of an organizational trajectory that built in relation to the adoption of digital technologies for their use in and around the marketplace.[4]

Shortly after, the Council of the Stock Exchange introduced computing to other operational areas of the organization. For the Council, computers and modern telecommunications could be used to create—and, more importantly, control—a market-wide price and company news dissemination system. The proof of concept existed as early as 1956, when a handful of broking firms introduced a rudimentary service that recorded the prices on the trading floor with a conventional camera and transmitted the images to television screens in their offices. The system, however, depended on the state of the whiteboards on the floor, provided an unreliable service, and, more importantly, was only accessible to a minority

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3. Although dominant, London was not the only financial centre in Britain. Since 1836, it had shared the market for British securities with exchanges in Birmingham, Manchester, Liverpool, Cardiff, Bristol, and Glasgow, among others. Provincial stock exchanges, however, tended to specialise in raising capital for, and trading shares in, regional companies. See further Thomas (1973).

4. A brief description of the Stock Exchange's early automation efforts in the Settlement Department is provided by Keen (1966).

of firms. Whereas large firms were able to finance such systems, small firms could not afford the high costs related to installing and maintaining even the most rudimentary electronic price information systems. For the Council of the Stock Exchange, such imbalance was dangerous, as it could lead to an erosion of confidence within the organization and, in an extreme case, to the fracturing of the membership. A system sponsored by the Stock Exchange would provide not only higher levels of technical reliability and uniformity to the visualization of market prices; such a system would also guarantee both institutional control and the equality of access to all member firms—or at the very least, to those willing to pay for a subscription.

In 1969, the Council of the Stock Exchange announced the introduction of a new price and company news dissemination service based on state-of-the-art British computing. Developed jointly by Ferranti, the computer manufacturer, and the Stock Exchange's Computer Services Group (*Stock Exchange Journal*, 1970a), the MPDS was designed to broadcast the middle prices of approximately 650 stocks (out of approximately two thousand traded shares) on sixteen black-and-white channels through closed circuit television within the City of London. Subsequently, the design was expanded by adding four channels, two featuring the prices of new issues, special stocks, currencies, and commodities, and two dedicated to company announcements and other relevant pieces of information.[5]

MPDS consisted of two broad elements: first, the visualization system that took the shape of a coaxial network that transmitted images to a number of black-and-white television screens; second, an information capturing and processing system composed of input terminals located on the floor of the Stock Exchange that were linked to a central computer. Data from the floor would be processed by the computer only then to be distributed to the screens in the network.

The development of MPDS ensued in a planned and careful fashion. The service initially operated on a restricted number of channels (sixteen, solely for prices) and during a limited period in the day (from 9:30 to 15:30). As testing and debugging continued, and as the suggestions from the users were compiled and analysed, both the number of channels and the time of operation expanded. By the time it was formally introduced in early 1970, nearly one thousand MPDS television receivers were operating in 220 offices of member firms, the result of seventy thousand hours of work by 250 engineers. In October of the same

5. The development and operative scope of MPDS was a matter of several articles in the *Stock Exchange Journal*, including "House Notes", *Stock Exchange Journal* 14, no. 1 (1969), and "House Notes", *Stock Exchange Journal* 15, no. 1 (1970).

year, the service reached 145 member firms and twenty-two institutions, including press agencies, insurance companies, an arbitrage house, and merchant banks, who were reportedly very satisfied with the operation of the price and news announcement channels of MPDS.[6]

MPDS was an immediate success. As Margaret Hughes reported in the *Stock Exchange Journal* in 1971, in little over a year, the city's brokers became a group of "push button devotees" (Hughes 1971). Success came despite the odd fact that the service was more an instrument of convenience than a tool for trading: as the former broker Scott Dobbie recalled, the service was "extremely crude"[7]; the mid-prices displayed on the television screens of MPDS were useless for dealing and the floor remained the undisputed source of market prices. MPDS was neither the result of technological push nor the product of a pre-existing market demand. Technological change derived, rather, from an organizational imperative to provide equality of access to market services to all member firms.

MPDS GOES TO THE COUNTRY

The development of MPDS had two consequences. First, it demonstrated that investments in sophisticated technological services were profitable: soon after its introduction, MPDS became the source of a secure income stream for the Stock Exchange. In 1970, the annual subscription to the service was £500 for members and £1,000 for non-members (members were the predominant users of the system, although some merchant banks and institutional investors were early subscribers). Additional television receivers were charged at £50 each, per annum, and subscribers covered both the equipment and the installation costs. The costs of developing and maintaining the system were recovered in little time.

Second, MPDS introduced a standardised mechanism for collecting and processing quotes from the jobbers on the floor. To keep the prices on MPDS "as fresh as possible", the Stock Exchange devised a system whereby price collectors would update the computer of MPDS throughout the trading day according to a preset routine.[8] The standardisation of price collection made MPDS a source of reliable information.

The system was limited, nonetheless, and in 1973, its technical specifications were tested by a reorganization of the British securities industry. In particular, the amalgamation of the LSE with provincial exchanges

6. See "Stock Exchange Information Computerised", *Accountancy* 81, no. 924 (1970); also "House Notes", *Stock Exchange Journal* 20, no. 4 (1970).

7. Scott Dobbie, interview with author, London, February 2008.

8. Ian McLelland, interview with author, York, October 2007.

(which created the Stock Exchange of Great Britain and Ireland) entailed guaranteeing access to the services offered in London across the regional financial centres of the United Kingdom. MPDS was no exception. Nevertheless, based on a coaxial distribution network that was limited to the City of London, the expansion of the service in its existing design was prohibitive.

The eventual solution to MPDS's expansion came from the development of remote data entry terminals for settlement. Although the introduction of computers in the 1960s reduced the labour requirements of the Settlement Room, checking remained physically centralised. Before feeding data into the ICT 1903 (replaced in 1973 by an IBM 158) for batch-processing daily and fortnightly accounts, the details of the deals struck on the floor had to be checked and ordered by specialised clerks (Grimm 1977).

In order to decentralise the scrutiny of individual tickets (whereby the trades conducted on the floor were matched in order to settle the accounts between buyers and sellers) and to reduce the number of clerks working in settlement, the Stock Exchange designed an electronic system that allowed each firm to report bargain details (that is, the details of trades) from their offices. Larger firms possessing computerized management systems of their own could enter the information of the bargains by sending their magnetic tapes and punch cards directly to the Stock Exchange Computer Centre on Wilson Street. For firms that could not afford investments in computing, the Stock Exchange developed the equivalent of a banking terminal that connected their offices to the Stock Exchange's dedicated settlement computer.

With checking and reporting decentralised, the Stock Exchange reduced the costs of settlement services. However, the new system required examining and processing inputs before submitting them to the central computer. This intermediate step involved validating data so as to maximize the use of the dedicated computer. A Digital Equipment Corporation (DEC) PDP-11/40 minicomputer hosted the validation processes by providing a flexible architecture to the remote data entry system.

Designed by the Stock Exchange in co-operation with Logica, a firm of computer consultants, the expansion of MPDS—known as Country MPDS (cMPDS)—used the remote data entry architecture of settlement to overcome the obstacles of space. Whereas the original design of MPDS relied on a distribution network of coaxial cables, the verification system used in settlement that used PDP 11s could transmit signals through conventional telephone networks. By installing a PDP-11/40 in each of the regional centres, the Stock Exchange could distribute digital feeds from its Argus 400 (the computational core of MPDS) across the country via dedicated telephone lines. In each regional centre, the PDP-11/40s would transform the digital feed of the Argus 400 into an analogue signal that

could be distributed to the local users, "creating the so-called fairness with everybody seeing the same thing".[9]

ARIEL

A critical event overshadowed the introduction of cMPDS in 1974. In the early 1970s, the growing body of British institutional investors showed clear signs of discontent with the restrictive practices of the LSE. Their inability to access the market other than through a stockbroker together with the fixed commission structure established by the Council of the Stock Exchange were increasingly objects of resentment.

Challenging the centrality of the Stock Exchange, a select group of merchant banks known as the Accepting Houses Committee proposed in 1971 creating an alternative electronic trading platform based on the architecture of Instinet's bloc-trading system. The threat was real and imminent. In May of 1972, the Issuing Houses Association (formed by members of the Accepting Houses) announced the introduction of the computerized ARIEL, providing "an inexpensive efficient trading market which will transcend National boundaries". The seventeen merchant banks that initially subscribed to ARIEL found inspiration in the fragmented markets of the United States. If Americans had managed to compete with technology, so could British firms. The system, set for introduction in 1974, was envisioned to capture 10 per cent of the institutional business, equivalent to 4 per cent of the total equity market (Littlewood 1998; Kynaston 2002).

Opposition to ARIEL did not take long to emerge and consolidate around a common discourse. For the Stock Exchange, ARIEL was simply "incompatible with the established methods of dealing in securities in this country". By ignoring the separation of functions that defined securities dealings in London, they argued, ARIEL jeopardized the fairness of the market, reducing "the effective establishment of fair prices", and avoiding the regulatory disciplines "which are imposed on the members of the Stock Exchange in the interests of the whole securities industry".[10]

Although ARIEL subsequently failed to command much influence on the market, it catalysed the consolidation of the Stock Exchange's information services. In effect, as Dundas Hamilton, former deputy chairman of the Stock Exchange, wrote, ARIEL led the Council to press for the development of instruments that would obtain "the maximum advantage in the distribution of dealing information to institutions [by creating] a system which instantly recorded prices at which deals

9. Michael Newman, interview with author, London, November 2007.
10. Council of the Stock Exchange, "ARIEL—the Council's View", *Stock Exchange Journal* 23, no. 2 (1973).

took place and a further communication system through which brokers could inform institutions of their interest in lines of stock" (Hamilton 1986: 5).

THE EPIC MARKETPLACE

The computer that fed the screens of MPDS, however, was not an adequate platform upon which to erect new, sophisticated services. Whereas the Argus 400 could handle the mid-prices on a limited number of shares, its architecture made further expansions technically undesirable. Importantly, however, was the fact that the analogue signals sent to the MPDS television receivers across the country could not be processed by in-house computer systems. In a sense, they "were only used on that system. They could not be put to any other use".[11] With views to expand the repertoire of services offered by the Stock Exchange, both the Council and the technologists deemed that time had come to upgrade the system.

The upgrade of MPDS became an independent project involving the replacement of the Argus 400 with a PDP-11/70 from DEC.[12] The new computer allowed for a critical innovation, namely, the construction of an electronic database of market prices. The project, initially labelled EPIC, was a joint financial venture between the Stock Exchange and Exchange Telegraph, a long-standing provider of information services of the City of London.

Although Extel & Co. participated in name (the "E" in EPIC referred indistinctly to Extel & Co. or the Stock Exchange), the ultimate design of the system was in the hands of the Stock Exchange's technical team. Given their experience in managing and maintaining MPDS, the organizational template for EPIC came from the known and tested collection protocol of MPDS, where current prices were entered from the market via price input terminals on the edge of the trading floor. The system, however, went further than MPDS. As the project evolved, other types of information (including company announcements and, later on, regulatory news) were added to the service, leading to is renaming as EPIC. EPIC incorporated such elements as market-related news items and headlines, and specialised programmes that managed official publications requiring accurate and up-to-date data.

11. McLelland interview.

12. By the mid-1970s, the engineers and technologists of the Stock Exchange had developed a strong commercial relationship with DEC. The previous mash-up of IBM, ICT, Olivetti, and Ferranti systems took a new shape: whereas IBMs were used primarily in settlement, DECs were used mostly in real-time market applications (Newman interview; Peter Buck, interview with author, Dartford, September 2007).

Particularly important to EPIC's design was the ability to create malleable data feeds for the press, a task that had been impossible under the architecture of the Argos 400. EPIC, for instance, facilitated the production of the *Stock Exchange Daily Official List* (SEDOL)—which contained the official prices of all the securities in the market. In effect, guaranteeing the smooth production of SEDOL was not merely an issue of internal bureaucracy. All tax, probate, and portfolio valuations carried out in the United Kingdom referred to the prices in the *Official List*. Before EPIC, maintaining the list was a laborious task, involving record-keeping for ten thousand shares. EPIC, however, automated the production of SEDOL and facilitated other editorial tasks, such as the creation of the *Weekly Official Intelligence* (WOI), a collection of company announcements and news deemed relevant for the market (Buck 2008).

EPIC went online in 1977 amid little pomp. For the users of the Stock Exchange, the introduction of the system was surreptitious: EPIC did not transform the screens of MPDS nor the quality of the documents published on a daily and weekly basis by the Stock Exchange. Everything seemed to be the same.

At the level of infrastructure, however, EPIC embodied a change in the role of information technologies within the Stock Exchange. In particular, EPIC demonstrated that digital data feeds could become the core of the financial marketplace. EPIC was able to gather within a single computational unit the different inputs from the floor—from prices to company announcements—moulding them into data feeds that reached distant corners of the British Isles through cMPDS and overseas countries through the distribution networks of Extel. Centralisation of services and information, it seemed, could be achieved through the computer.

SPECIAL SYSTEMS GROUP (SSG) AND BEYOND

The development of EPIC was correlated to a significant organizational innovation within the Stock Exchange, that is, the creation of a specialised group charged with the planning and development of new systems. Established circa 1977, the SSG was constituted by a few dozen technologists that, for all intents and purposes, defined the Stock Exchange's technological policy for the next fifteen years. The creation of SSG responded to an internalization of the technological efforts at the Stock Exchange: whereas MPDS and cMPDS were built in co-operation with external service providers (Ferranti and Logica, respectively), the development of EPIC—the cornerstone of the new suite of services offered by the Stock Exchange—was driven almost in its entirety by internal staff.

The SSG was not the first division of the Stock Exchange to deal with market technologies, though. The acquisition of punched-card equipment and computers for settlement in the 1960s, for instance, had led to the creation of the Computer Services Group (CSG), which took part of the development of MPDS and survived until roughly 1971.

The expansion of settlement and market information services in the early 1970s encouraged the establishment of the Directorate of Information Systems and Settlement (DISS), headed initially by Michael Jenkins and subsequently by George Hayter. As a directorate, DISS had more freedom and resources than its predecessor, the CSG, and enjoyed a dedicated channel of communication with the Council of the Stock Exchange in Patrick Mitford-Slade, the chairman of the Information and Communications Committee.

In 1979, and only two years after the establishment of the SSG, DISS was rebranded as Technical Services (similarly, the Information and Communications Committee became the Technical Services Committee). Finally, in 1984, a splinter of the SSG headed by Peter Bennett established a small, blue-skies research team, the Advanced Systems Group (ASG).

Whereas the organizational diagram of the Stock Exchange changed considerably from 1970 to 1992, the core group of technologists and engineers behind the development of the Stock Exchange's systems remained relatively stable. At its apex, technology in the Stock Exchange was commanded by two individuals: Peter Bennett, who joined in 1971, and George Hayter, hired in 1976 from the British Overseas Airways Corporation to lead DISS. In addition to Hayter and Bennett, innovations were driven by John Scannell, in charge of systems operations (engineering) and who joined from Olivetti circa 1972; Michael Newman, hired in 1975; Ian McLelland, seconded from Logica in 1975; Peter Cox, hired from IBM in 1979; and Peter Buck, trained at Imperial College London, and who joined in 1979.

The success of the innovations of the early and mid 1970s provided the SSG and DISS the undivided trust of the Council of the Stock Exchange. The technologists "could do no wrong. I mean, they gave me more or less a carte blanche to automate everything inside", recalled Bennett. Indeed, for Patrick Mitford-Slade, the process was "definitely bottom up", with ideas coming from people who "knew what technology was available", particularly, the Peter Bennetts and George Hayters of the world. Built upon trust, the systems of the Stock Exchange thus continued to expand.[13]

13. Patrick Mitford-Slade, interview with author, Hampshire, November 2007.

Table 10.1 History of Market Information Systems at the London Stock Exchange, 1968–1992

A TOPIC OF CONVERSATION

The expansion of finance in 1970s Britain provided the Stock Exchange with an incentive to replace MPDS.[14] The old system was marvellous "as far as it went", recalled Mitford-Slade. "It only had twenty-two pages of information, and it was really just listing the shares on those twenty-two pages with an up-to-date market price on it". The growth of data services—from Reuters to Hoare and Govett's Datastream—provided strong incentives for the modernization of MPDS. Effectively, what the Stock Exchange needed was a system capable of dealing with "an unlimited amount of information".[15]

The SSG was particularly aware of the technical limitations of MPDS and had considered as early as 1975 "moving the system forward".[16] There were, nevertheless, important technical roadblocks to overcome. Increasing the number of channels was prohibitive due to the architecture of the system. The twenty-two channels already "squeezed every available bandwidth [...] so much so that the gap between [them] started to get almost blurred." MPDS was "absolutely at its limits".[17]

Pressure to expand the system only increased with time. As new instruments entered the market, users of MPDS demanded more from the service. For instance, when the Stock Exchange introduced traded options into the floor, SSG had to implement a time-sharing system on the channels in MPDS. The data displayed on the screens would switch every ten seconds between market sectors, allowing for the visualization of the prices of traded options while keeping the system at twenty-two channels. However, "people really didn't like it, because if you were trading you didn't want the bloody thing to switch on to the other page when you were looking at the stock prices".[18]

The replacement of the visualization systems of MPDS came as a serendipitous confluence between real-time computing and Prestel, the data-dissemination standard developed by the British Post Office. Prestel was a "marriage of industries, technologies, processes and skills" in "telecommunications, the telephone, the computer, and publishing".[19] A service that integrated colour television, conventional telephone lines, dial-up modems,

14. From the mid-1960s onwards, the financial services sector in the City of London grew both in volume of trading and in the complexity of operations. The consolidation of Eurobonds, for instance, represented the emergence of a new market and new financial actors that required ever-expanding information services. See Michie (1999) and Kynaston (2002).
15. Mitford-Slade interview.
16. John Scannell, interview with author, London, November 2007.
17. Newman interview.
18. Ibid.
19. For an example of the promissory language surrounding Prestel, see Fedida and Malik (1979).

and digital computing, Prestel provided a bidirectional interactive videotext system for the delivery of information.

Prestel, however, did not meet the technical requirements of the Stock Exchange. The architecture of the service made updating pages both slow and expensive. To meet user specifications, Bennett and the SSG adapted Prestel's design, making it "formal and reliable".[20] The system developed, and known as Teletext Output of Price Information by Computer (TOPIC), utilised EPIC as the source of market data. Whereas EPIC was the source of information—from prices to company announcements and regulatory data—terminals built by the Belgium electronics manufacturer BARCO served to navigate, access, and visualize the digital repository of the central computer. Connected to colour television screens, the terminals allowed users to update the information on their screens at will.

For the Council, TOPIC "was quite an investment to launch into [requiring] quite a lot of persuasion", recalled Mitford-Slade. To convince the Council of the need of the investment, Mitford-Slade found inspiration in a well-known slogan for Heineken. "TOPIC", he assured, "reaches parts MPDS cannot reach". Trust in the SSG and the DISS, however, was strong, leading to the ultimate approval of the project. "In fairness to them", mentioned John Scannell about the Council, "we'd got the proper documentation. They were quite confident we knew what we were doing. Their own firms were suffering because they'd really needed this equipment for their business, so it was very interesting times".[21]

Introduced in 1979, the only restriction to the number of pages available in TOPIC was the storage capacity of EPIC. Soon, the twenty-two channels on MPDS became several hundred pages on TOPIC. The sixteen channels of prices moved to a "magazine" of one hundred pages; the four channels for company news and announcements became more than one hundred pages; and pages for indices, currencies, and traded options proliferated throughout the new system.[22] TOPIC was "ahead of anything that Reuters was running at the time",[23] providing a completely novel service for the market. Introduced in 1980, TOPIC was an immediate success. Within two years, the four hundred terminals initially authorized by the Council grew to more than five thousand.

CHANGE AT THE EXCHANGE

The digital ambitions of the technologists did not stop with TOPIC. In 1979, what initiated as a relatively innocuous review of the settlement

3. Peter Bennett, interview with author, London, July 2007.
4. Scannell interview.
5. McLelland interview.
6. Bennett interview.

mechanisms for government-issued debt transmuted into a unique opportunity to standardise and integrate the mash-up of systems run by the Stock Exchange. Conceived by George Hayter and Peter Bennett, the plan envisioned reassembling the heterogeneous networks of market information and settlement systems under a single technological umbrella, creating a general purpose network to replace those in place.

In May 1982, the Council of the Stock Exchange embraced the strategy of an integrated data system for the British securities industry. A year later, in 1983, the upgrade in settlement effectively became the first step in the ambitious development of an Integrated Data Network (IDN). As George Hayter announced, the IDN was set to have "a widespread impact on the working of the Securities Industry over many years" (Hayter 1983). Based on the growing communications method of packet switching, IDN responded to the "proliferation of networks" within the Stock Exchange which, in the views of the Technical Services department, resulted in "high cost, inflexibility and inconvenience to service users". Offering a unique communication platform, IDN would permit the interoperability of the existing systems at the Stock Exchange, providing "faster, easier and cheaper communications" for the UK securities industry through the use of "a common data network operating to a set of recognized international standards" (Hayter 1983).

With its forward-looking design and its overtly strategic intent, IDN became the flagship project of the Stock Exchange, acknowledging the importance of owning and controlling the principal communications facilities used for business in order to facilitate the Stock Exchange's regulatory control over the market and its member firms. Standardisation meant not only a more fluid, efficient, and reliable operation of the marketplace; it symbolized too the centralisation of services and the possibility of real-time surveillance.

IDN would have been a tremendous technological feat had it come to fruition. On paper, the system made a cost-effective use of the most sophisticated systems available at the time. The plans integrated the "IBM personal computer, or one of its look-alikes [as] the basis for [a new] terminal system". Brokers, jobbers, and clients of all types should have been able to use a single terminal, or a limited range of terminals, for a multiplicity of functions. Finally, IDN would have freed users from the costs and time involved in building and maintaining their own communications networks by providing a common dealing, settlement, and market information platform (Hayter 1983).

Times were difficult, nevertheless. Since the challenge of ARIEL in the early 1970s, the Stock Exchange had been under great political pressure to open its markets, reform its membership, and alter fundamentally its organizational structure. In effect, in 1974 the *Rules and Regulations* of the Stock Exchange became an object of governmental evaluation, following complaints from users in the City of London that considered fixed commissions,

closed membership, and other practices uncompetitive. In 1978, the organ in charge of the review—the Office of Fair Trading—identified seventeen restrictions to competition and referred the Stock Exchange to the Restrictive Practices Court. Several years of negotiation eventually led to an agreement between the chairman of the Stock Exchange, Sir Nicholas Goodison, and the secretary of state for Trade and Industry, Cecil Parkinson, to bring the court case to a halt. Reached in 1983, the agreement created a nonnegotiable deadline: the court case would be dismissed if and only if the Stock Exchange "[dismantled], by stages and with no unreasonable delay, all the rules which at present prescribe minimum scales of Commissions, and to complete this dismantling by 31 December 1986" (Michie 1999).

The political realities of the 1980s cooled the technological ambitions of IDN. The network in its complete incarnation would have to wait, if not be completely forgotten. On account of time, the efforts of the Stock Exchange shifted to pragmatics. The deadline on 27 October 1986, known as Big Bang, was less than two years away, and implementing an integrated data network was too risky a route to follow. Indeed, the market of the future was terra incognita for the Stock Exchange. Big Bang implied more than the removal of fixed broking commissions. It encompassed abandoning single capacity, allowing firms to act as brokers and market-makers, and opening the membership to foreigners and banks. For Hayter, there was "a wide river to be crossed and time only to build a Bailey bridge initially". Time was scarce for blue-sky innovation. The Stock Exchange needed a system delivered in time for Big Bang. However elegant and ambitious, IDN was not the Bailey bridge to cross the turbulent waters of a market in constant reform.

With hindsight, the technological trajectory of the Stock Exchange was fixed years before Big Bang with the selection and design of TOPIC and EPIC. In late 1984, Hayter presented London's newest bridge. Initially codenamed SEMANTIC (for Stock Exchange Market and Trade Information Computer) and later known as SEAQ (for Stock Exchange Automated Quotations), the system implied a modification of TOPIC and EPIC that allowed the bidirectional distribution of bid/ask prices (quotations) from either the trading floor or the offices of member firms. Whereas SEAQ served as a mechanism for capturing quotations and reporting deals, a modified version of TOPIC enabled the visualization of market prices. Under the version of SEAQ introduced ultimately for Big Bang, competing market-makers (formerly known as jobbers) were required to keep continuous quotes for the securities in which they traded. Rather than being uttered on the floor, these quotes were entered into SEAQ terminals. Upon seeing a satisfactory quote on the screen, a broker would phone a jobber to close the deal.

Such radical transformation of the market's structure entailed some modifications to the systems of the Stock Exchange, however. The PDP-11/70s that served as computational core of EPIC, for instance, were replaced by VAXes, also from DEC. EPIC was also transformed: in the new arrangement, the database would be subjected to a constant influx of quotations and trades, putting great strain on the system. Existing technologies—such as relational databases, which are at the core of well-known programmes such as Microsoft Access—were simply too slow. As Peter Buck, development manager for SEAQ, recalled:

> We talked to [to several vendors], and the new version of Oracle [was] coming out [soon] and they could guarantee on a VAX 80–600 [...] an average of a transaction a second, on a good day, with a trailing wind. [...] One transaction a second was where it was at.

Experience in developing systems, however, provided the technologists of the Stock Exchange with the instruments necessary for finding a solution. In particular, by transforming EPIC into a memory-resident database, the system introduced by the Stock Exchange could handle more than one thousand transactions per second, "a little bit more than Oracle".[24]

Yet from an engineering perspective, SEAQ was "not exactly rocket science", recalled Peter Buck. "It was it was just TOPIC and EPIC brought together. [The system was] two legacy systems [put] together essentially, which was actually quite a safe route".[25] As Hayter explained in December 1984, in arriving at this design, the Technical Services department:

> had to face up to a number of practical problems. Firstly, we have a short time scale in computer developments [which] will not allow us to build radically new services from scratch with any degree of confidence that they will work effectively and reliably under high volumes of loading from the first day of the new market. Secondly we have a fundamental uncertainty about the real requirements of the system. [...] Finally we have little idea about the absolute level of trading which is likely to take place and the consequent level of system activity. (Hayter 1984)

SEAQ responded to the constraints faced by the Stock Exchange, basing the platform of the future market on "solid and reliable systems", and adopting a "low-risk implementation plan". For technologists like Hayter, Big Bang had become a series of "scarcely discernible pops".[26]

BEYOND REVOLUTION

On 27 October 1986, the harmony of planning gave way to the cacophony of reality. Thirty minutes into Big Bang, TOPIC was overloaded with a

7. Buck interview.
8. Bennett interview.
9. *Guardian*, 3 April 1985.

"tidal wave" from users. Then standing in one of the operations rooms, the chief of engineers, John Scannell, recalled the scene:

> Eight o'clock comes and the systems all come up. And we're looking at the page response request and it goes up to 1.7 million almost immediately, which is a little bit bloody worrying. Then it crept up to sort of two million, three million, and four million. What's going on? This is quarter past eight. Then it got to five million, then everything is going berserk. Bells, and whistling, and ringing, and popping and banging.

It took some clever on-site programming, a restart of the system, and bringing the government-debt market off-line to establish order. Dealers in the government securities were not amused. "'It's the government's market, you can't take it off the system', they said. But we said 'You've been dealing perfectly satisfactorily without the system for god knows how many years, you can continue without it for a little bit longer' and of course they did, to satisfaction".[27]

As trading came to a close, the chairman of the Stock Exchange reflected on Big Bang. "The fact that the system worked at all this morning was a triumph", said Sir Nicholas Goodison.[28] As the days followed, normality kicked in. Glitches continued to surface from time to time, but SEAQ remained the core of the market. "So much for being a Bailey bridge. It was still there some years later".[29]

With Big Bang behind them, the technologists of the Stock Exchange continued their relentless expansion into the market. Indeed, investments in computing and telecommunications were essential: catalysed by the introduction of SEAQ, dealings in bonds and equities went off the floor in March 1987, transferred to the dealing rooms of member firms and their rows of telephones and screens. As Ian McLelland remarked:

> It was literally while one release were being developed, we got the programmers working on that as soon as we could, the designers would be looking at what are the next stages, and you either had like a major requirement coming or we had what we called change requests which would drive us. Then we said, "okay, what's the next release going to look like" and start designing that. And we could even have three releases on the go. You know, once we'd got a release into testing whereby we were supporting any fixes that had to be done, we'd probably have a team working on the next release and the designers working on the release after that, so it was kind of like a

10. Mitford-Slade interview.
11. *The Times*, 21 October 1986.
12. Buck interview.

continuous cycle because this is what the Exchange and its membership demanded.[30]

The Stock Exchange was more than ever before a technological marketplace. While Hayter and his team concentrated on expanding the repertoire of services offered to the membership (which including the development of a small order automated execution system, SAEF, in 1989[31]), Bennett's team—the Advanced Systems Group—sought to enlarge the technical horizons of the organization, experimenting with artificial intelligence, satellite communications, and the possibilities offered by the personal computer.

Expansion, however, came at a price. The initially compact group of technologists had grown into a veritable army. George Hayter alone commanded over two thousand people (out of three thousand Stock Exchange employees) responsible for specifying, designing, developing, implementing, managing, and selling systems to the membership of the Stock Exchange. Organizationally, the Technical Services department was experiencing the problems of scale: whilst the technological services provided by the Stock Exchange continued to generate revenues, margins decreased by the year and were pushed to the limits in times of crisis.

The technological culture of the Stock Exchange was likewise compromised. The interim Bailey bridge, recalled Ian McLelland, became the cornerstone of future systems. Services that departed too much from the template of SEAQ "would not be developed; we would build on the existing limited capability due to time pressure". The growth of the technical staff also presented problems. Developers spent much more time in meetings, updating designs, reporting developments, and involved in "all the bureaucracy of big organizations". Critically, the "rapid development culture" of the Stock Exchange was "lost". "Developers were no longer allowed to develop without a long process of approval. For many […] it was time to move on".[32]

The crash of October 1987 and the ensuing reorganization of the securities industry marked the beginning of the decline of the Stock

13. McLelland interview.

14. The development of SAEF was a symptomatic of problems faced by the technologists of the Stock Exchange. Inspired by IDN, SAEF was built as a compromise with SEAQ. Given their investments in the lead up to Bog Bang, member firms were unwilling to install systems that deviated from SEAQ. The design of SAEF was thus subordinated ultimately to SEAQ. This, however, presented technical problems that translated into a long development cycle. Programmed to go live in 1987, SAEF was only introduced in 1989, despite similar products developed by member firms in a matter of weeks—notably, BZW's small order automated execution system, TRADE (Nic Stuchfield, interview with author, London, November 2007).

15. McLelland, personal communication.

Exchange's Technical Services department. Expenditure continued to increase while income fell from 1987 onwards (see Figure 10.1). In late 1989, the Stock Exchange incurred its first loss.[33] Tensions mounted, and the autonomy of the technologists became a liability. For the new Stock Exchange, development was not a priority. For them, Bennett recalled, large investments in innovation were "not the way to run an exchange".

The *coup de grâce*, however, came in 1990. With mounting pressure from member firms to reduce expenditure, the spiralling cost of technological development, and the continuing influence of the technologists on the Stock Exchange's policies, Peter Rawlings, the chief executive, commenced a two-year process of outsourcing. "In a funny way", reminisced Hayter in 2007:

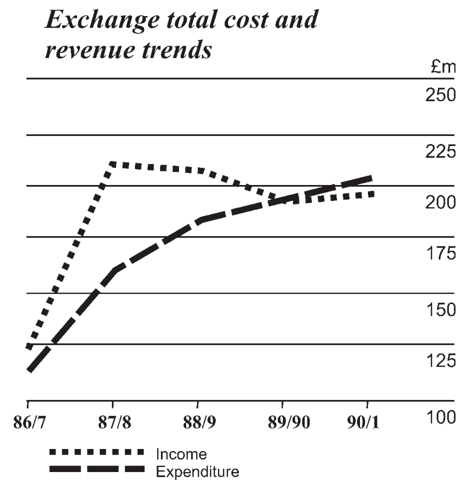

Figure 10.1 Stock Exchange expenditure vs. revenue, 1986–1991.

16. Scannell interview.

> the Big Bang which everybody said was going to rid us of the club mentality and make the whole thing more commercial ended up coming full circle to the point where the members were saying "We don't want the Stock Exchange to do commercial things. We want it to just be the place that coordinates the regulation of the market, and not very much else".[34]

The ranks of the Technical Services department were slowly depleted. In April 1992, *The Times* reported that an agreement was reached between the Stock Exchange and Arthur Andersen whereby latter would "run the exchange's market support systems" and take on the "312 exchange staff".[35] The exodus began, and soon enough the original members of the SSG had left.

CONCLUSIONS

With hindsight, the images heralded by Fischer Black and his peers in the 1970s seem prophetic. More than two decades after Big Bang, the LSE is one among many competing electronic marketplaces, providing execution facilities to investors located in every corner of the world. Indeed, a cursory glance at the Stock Exchange might seem to confirm "traditional" views on technological change in finance, presenting innovation as a process driven by the market and fuelled by the pervasive yet ultimately alien emergence of modern information and telecommunication technologies.

Upon closer examination, however, the smooth road that created the digital present reveals many pebbles and particles from the past. Above all, the history of the Stock Exchange demonstrates that technological change in finance involved armies of individuals, batteries of things, and centuries of work-hours, shaping the marketplace through the everyday politics of the trading floor, the Council chambers, and Britain at large.

The history presented in this chapter provides three specific lessons on technological change in modern finance that highlight some omissions encountered in accounts of the digitalization of financial institutions.

The first is relatively straightforward: to be effective in day-to-day operations, technologies (particularly large-scale, sector-wide systems) require implementation (Fleck 2003: 244–57). Although based on components that were commercially available at the time, the market information services introduced by the Stock Exchange were implemented to meet the specifications of the Council. In the Stock Exchange's technological history, there were no such things as off-the-shelf solutions. MPDS involved adapting the

17. Hayter interview.
18. *The Times*, 12 April 1992.

Ferranti Argus 400—initially designed for use in missile control—to process and transmit data from the market floor. To make the Argus 400 an operational piece of financial technology, however, the Stock Exchange had to transform the computer, design new organizational routines, and adopt additional systems including coaxial cables and television receivers.

Importantly, the fact that technological systems require some degree of implementation makes their origin relevant. Because it involves working with external providers to reconfigure devices for specific uses, implementation entails forging commercial relations that can affect future decisions within the firm. For instance, whereas the first information services introduced by the Stock Exchange involved different providers—including ICT, IBM, Olivetti, Ferranti, and DEC—the market information systems launched after 1977 relied primarily on DEC minicomputers. As Ian McLelland recalled, the Stock Exchange's technical teams "worked very closely [with DEC] particularly on the technology changes". On the contrary, IBM systems, widely used in Wall Street, were deemed too "rigid" and "hierarchical",[36] explaining their ultimate confinement to settlement where batch-processing was seen as the technical norm. These path dependencies in the technological trajectory of the Stock Exchange were not the product of some inherent technical quality of the system; rather, they originated from the networks of relations formed between the Stock Exchange's engineering teams and particular technology suppliers.[37]

The second lesson is equally simple: technological adoption creates new types of work—for instance, routine maintenance. In providing market information services, the Stock Exchange hired computer and telecommunication engineers that guaranteed the reliable operation of its systems (perhaps recognizing that the implementation and use of technologies requires local, tacit forms of knowledge). Yet as demand for the systems grew, and with it the pressure for increased reliability, the number of technologists climbed. Decisions to update systems only accelerated the process, leading the Stock Exchange to increase the size of the Technical Services department and expand the expertise of the organization, hiring analysts, programmers, managers, developers, and support staff. The work associated with the market information services transformed the Stock Exchange into a centre of technological innovation. Growth was not inconsequential, though, as Figure 10.1 demonstrates. By the early 1980s, recalled Bennett, technologists "were effectively setting policy".[38] In a very tangible way, the sheer size of the Technical Services department implied a deep modification the organizational politics of the Stock Exchange facilitated, in part, by the income streams generated from the provision of market information services.

19. Newman interview.
20. A sociological analysis is provided by White (2002).
21. Bennett interview.

Innovation was nevertheless a rocky enterprise. Despite the armies of technologists, updates to the Stock Exchange systems often departed from plans. That technological change is not a smooth linear process is the third and final lesson. The technological trajectories of the Stock Exchange were as much products of organizational imperatives, economic justifications, and technological design as they were reactions to external political pressures and the fixed investments of users. Notably, the deadline set by Big Bang altered the plans for the Stock Exchange's IDN, transforming EPIC and TOPIC into the unexpected core of the new market. A regulatory decision "locked in"[39] the systems at the Stock Exchange, making SEAQ the obligatory—and in some people's opinion, suboptimal—referent for market participants. The road from floor to screen, from the analogue stock exchange to its modern digital incarnation, was indeed technological. Yet, as other technological histories, the digitalization of the LSE was a product of sweat, blood, electrons, and artifice.

22. Processes of lock-in can be conceptualized in line with David (1985).