
ICL and the Evolution of the British Mainframe

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ICL was created in 1968 as Britain's national flagship computer manufacturer through a government-inspired merger in response to the increasing dominance the UK computer market by American computer suppliers. This paper describes the R&D issues facing ICL and its predecessor companies in developing their mainframe ranges over a period of half a century. The technological issues are set in their the economic and political contexts.

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1. INTRODUCTION: THE PUNCHED-CARD MACHINE ERA (~1880–1945)

To understand the history of ICL, it is necessary to appreciate that both ICL and IBM have a common ancestor, and that for over 40 years they had something of a love-hate relationship (Campbell-Kelly, 1989).

The era of modern data processing really began with the invention of the punched-card tabulating machine by Herman Hollerith in the 1880s. In 1896 Hollerith incorporated a small firm in New York, the Tabulating Machine Company, to market a range of punched-card office machines. In 1924 this company was renamed International Business Machines. In 1907 a London-based syndicate formed the British Tabulating Machine Company (BTM) to exploit the Hollerith technology in the UK. The arrangement between the British company and Hollerith was formalized in an agreement dated 1908, which gave BTM the exclusive right to work the Hollerith patents in Britain and the Empire in exchange for a payment of 25% of its revenues to the American company. This was an astonishingly high royalty rate, which did much to inhibit BTM's growth potential.

In the US a rival punched-card machine company, Powers Accounting Machines, was formed in 1911 by the entrepreneur James Powers. A subsidiary of this company, the Accounting and Tabulating Machine Company of Great Britain Ltd, was formed in Britain in 1915. The British subsidiary was acquired by the Prudential Assurance Company in 1919, by which it secured the British and Empire rights to the Powers machines; and in 1923 a French subsidiary Société Anonyme des Machines à Statistiques (SAMAS) was formed. Thus the rivalry between Hollerith and Powers in America now spread to the British territories and to continental Europe. The British Powers operation was later renamed Powers-Samas.

Although the Powers organization in the US was acquired by the office-machine giant Remington Rand in 1927, the Powers machines were not nearly so successful in America as those of IBM; it was estimated that in the 1930s the American market was split 90:10 in favour of IBM. By contrast, in the British territories the market split was approximately 50:50. While IBM and BTM

had sales territories roughly in the proportion 2:1, throughout the inter-war period, BTM's revenues were approximately 1/20th of those of IBM. BTM attributed its slow growth to the onerous royalty rate, while IBM's President, Thomas J. Watson Sr, blamed BTM's poor management and its poorly developed selling organization: the truth lay somewhere between these two views.

During the 1920s and 1930s, both BTM and Powers-Samas had ceased to be just importers of punched-card machines from America, but had developed their own R&D and manufacturing operations (Campbell-Kelly, 1986–1989). As early as 1923, the British Powers company demonstrated the first alphabetic equipment in the world. A decade later, BTM developed the Rolling Total Tabulator, its first wholly British designed accounting machine (Figure 1). R&D in the punched-card machine companies—both in the UK and the US—conformed the pre-World War II tradition of the inventor-engineer; R&D programmes were conducted in an *ad hoc* fashion and few, if any, development staff were university trained (Pugh, 1995).

By the end of the 1930s, Powers-Samas had about 2500 employees and BTM (which relied more heavily on imports) had about 1200. In the US, IBM had about 10 000 employees—which made it significantly larger than either of the British punched-card firms, but still only a medium-sized company—barely a 1/40th of the size of its post-war peak in the 1980s. With the onset of World War II there was a hiatus in punched-card machine R&D, as the British, American and European punched-card machine companies made over their R&D facilities to war-related research. The firms also devoted a high proportion of their manufacturing capacity to producing military equipment.

2. ELECTRONICS AND COMPUTERS (1945–1959)

At the close of World War II, the punched-card machine companies faced two formidable R&D challenges: the emergence of electronics and the invention of the stored-program computer. In the US, IBM took an approach to electronics that was evolutionary rather than revolutionary. Thus its first electronic product was the 602

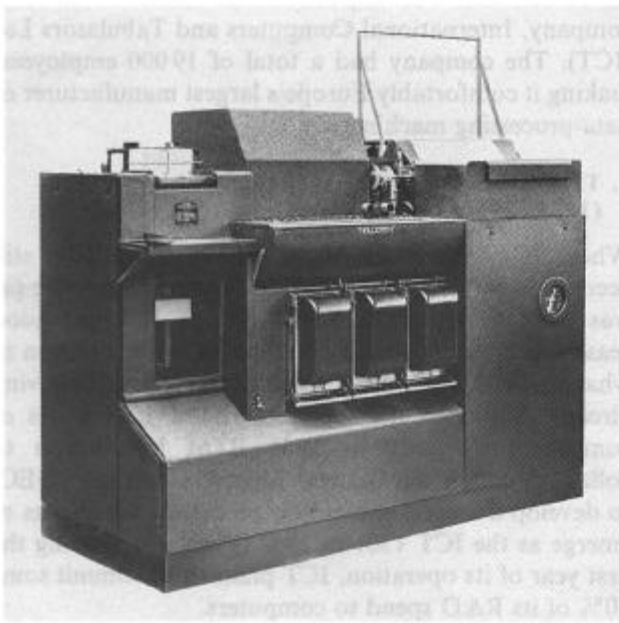


FIGURE 1. Rolling Total Tabulator (~1935). The BTM Rolling Total Tabulator was the first accounting machine to be completely designed and built in Britain. The machine rented for about £60 a month—equivalent to a purchase price of over £3000.

multiplying punch, announced in 1946 (Bashe *et al.*, 1985). This machine incorporated electronics to achieve an order of magnitude increase in calculating speed, but functionally the machine was no different to its electro-mechanical predecessor. Two years later, in 1948, IBM introduced the model 604 calculating punch, which performed four-function calculations and had a limited programming capability of a few dozen program steps. Taking their lead from IBM, BTM and Powers-Samas began to develop electronic multipliers and calculators

that reached the market in the early 1950s. These all sold in relatively high volumes—that is to say hundreds.

At this time, the market for computers was perceived as being a small one—selling ‘mathematical instruments’ to a largely technical market. The punched-card machine manufacturers, long used to selling or renting a high volume of relatively low-cost machines, did not see electronic computers as being an appropriate business into which to make a major entry.

The year 1949 was a watershed for the British data-processing industry. In that year BTM and IBM decided by mutual consent to break their long-standing agreement, and go into open competition world-wide. So far as BTM was concerned the end of the agreement would mean the end of paying royalties; this would enable it to at least treble its R&D spend and thus develop products it believed would match any that could be made by IBM. In hindsight this seems an extraordinarily naive judgement; however, it must be remembered that IBM was not then the giant company it is today and BTM had no appreciation whatever of the computer revolution that was about to unfold. It is tempting, though quite pointless, to speculate on how very different would be the British information-systems scene today if BTM had not given up its agreement with IBM. The following year, 1950, Powers-Samas terminated its agreement with Remington Rand. From this point onwards, the British data-processing market became very much more competitive.

Although the British punched-card machine companies had been reluctant to embark upon computer manufacture, this was not the case with the British electronics manufacturers who were more willing. At least part of this enthusiasm for computers was engendered by the National Research Development



FIGURE 2. BTM 1201 computer (1955). The BTM 1201 was the most successful first-generation British computer for commercial electronic data processing. The purchase price of a medium-sized installation was about £25 000.

Corporation (NRDC), which had been formed by the Labour Government in 1949, to foster the exploitation and patenting of British inventions. Under its energetic managing director Lord Halsbury, the NRDC immediately targeted computers as being *the* industry in which Britain should secure a strategic position (Hendry, 1989; Halsbury, 1991). The corporation encouraged and cajoled several electronics manufacturers, including Ferranti, English Electric, EMI and Elliott Brothers, to develop computers. The punched-card machine manufacturers, however, remained sceptical of the potential of the computer market and remained solely committed to the punched-card machine market until the mid-1950s.

By 1956 BTM—though not Powers-Samas—had made a tentative entry into the computer market with its 'HEC 4' computer. Marketed as the BTM models 1201 and 1202, over 100 machines were eventually delivered, making it commercially the most successful first-generation British computer (Figure 2). By this time, IBM had developed into a serious competitor for the British computer companies, both at home and in their overseas markets. However, the competition was not in computers, as some commentators had feared, but in the traditional accounting machines which still accounted for most of IBM's turnover. In fact, IBM delivered only two computers in Britain during the whole of the 1950s—far fewer than the number supplied by BTM.

It was to meet this competition from IBM that in 1958 BTM and Powers-Samas decided to merge. By this time the computer market in Britain had grown significantly, and the eventual ascendancy of computers was plain for

all to see; this was implicit in the name of the new company, International Computers and Tabulators Ltd (ICT). The company had a total of 19 000 employees making it comfortably Europe's largest manufacturer of data-processing machinery.

3. THE SWITCH TO COMPUTERS (1959–1963)

When ICT was formed in 1959, computers still accounted for only 10% of the company's turnover (as was the case with IBM World Trade). ICT had good reason to consider it had a sound defensive position in what was still a relatively small market: besides having already developed the successful BTM 1200 series of computers, as early as 1956 BTM had begun to collaborate with the General Electric Company (GEC) to develop a second-generation successor, which was to emerge as the ICT 1301 in 1962 (Figure 3). During the first year of its operation, ICT planned to commit some 50% of its R&D spend to computers.

The event which completely transformed the outlook for computers, and precipitated the collapse of the punched-card machine market, was the announcement of the IBM 1401 computer in October 1959. The 1401 was originally intended by IBM to be a second-generation successor to its first-generation model 650 in much the way that ICT's 1300 series was intended as a successor to its 1200 series. However, the 1401 captured the American EDP computer market to an extent that took IBM by surprise and exceeded all forecasts: 100 orders were taken in the first few weeks following the



FIGURE 3. ICT 1301 (1962). The ICT 1301 was a medium-sized second-generation computer intended to compete with the IBM 1401. The price of typical installation was £100 000.

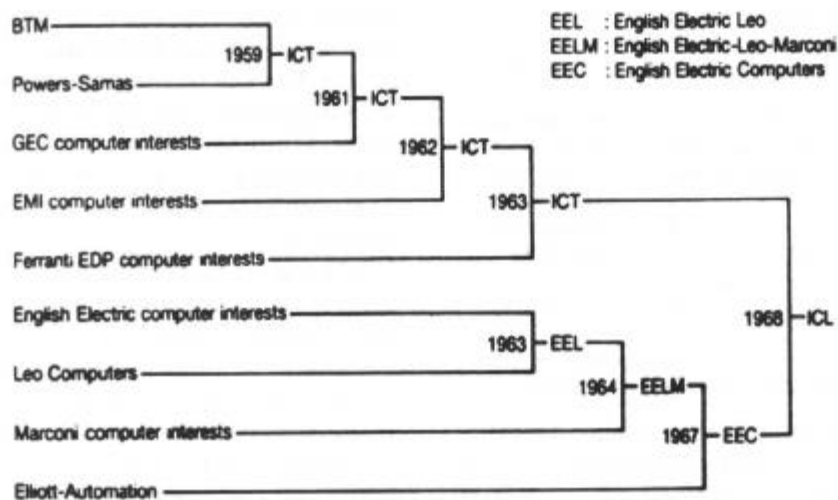


FIGURE 4. Evolution of ICL (1959–1968).

announcement and the machine went on to sell a total far in excess of 10 000 installations. The success of the 1401 has often been attributed to the model 1403 chain printer that accompanied it; printing at 600 lines per minute, it enabled a single 1401 to replace four conventional tabulators (Bashe, 1986). The IBM 1401 was an instant success in the UK too, and in May 1960 ICT was forced to make a premature announcement of the 1301.

The IBM 1401, which was a second-generation machine using discrete transistor electronics, significantly increased the pace of computer R&D, and rendered many of the British tube-based first-generation machines obsolete. Another effect of the IBM 1401 launch was to transform the computer industry from one which had been based on the sale of high-cost capital electronic goods in low volumes, to one selling relatively low-cost machines in a much higher volume (Freeman *et al.*, 1965). The selling organizations of the traditional business-machine manufacturers were well adapted to this new market environment; whereas the electrical-engineers and control manufacturers, who had prospered in the earlier conditions, now found themselves in a market in which it was much more difficult to compete.

Thus each of the electronics and control firms was faced with a choice: either to stay in the computer business for the long-haul and accept short-term losses; or to withdraw from the computer business altogether. One by one, the companies made their decisions, so that by the end of the first merger wave of 1959–1963 there were just three British computer manufacturers: ICT, English Electric-Leo-Marconi and Elliott-Automation (Figure 4).

The result of this merger activity was to leave ICT, in particular, with an ill-assorted range of incompatible machines which included those developed by itself and in collaboration with GEC, computers acquired from EMI and Ferranti, as well as machines being made under license or imported from Univac and RCA in the US. The software and hardware compatibility between these machines was negligible.

In autumn 1963, ICT's product planners began to try to rationalize the product line and develop a coherent plan for the future. In the short term there was little that could be done other than to accept the position as it was; but clearly ICT was supporting too many machines with incompatible architectures, and few of the machines were particularly price-competitive. In fact, the only machine with real merit was the Ferranti Packard 6000 which had been acquired from Ferranti's Canadian subsidiary when ICT took over the Ferranti's mainframe computer interests; the FP6000 was a machine with considerable future potential and this was one of the main reasons that the take-over of the Ferranti computer division went through.

For the longer term, it was intended that all of ICT's medium to large EDP computers would be made from a single 'project set' which would have compatible software and peripherals throughout the range. It was planned that such a range of computers would be available by 1968. ICT had two options for its compatible range. The first was to develop the FP6000 from a single mid-range machine into a fully compatible range. The second option was to take advantage of an agreement that it had with RCA in the US, by which it could manufacture RCA's next generation of computers under licence. Which way to go—the RCA route or via the FP6000—was still under active investigation when IBM astounded the computer industry by announcing System/360.

4. THE IMPACT OF SYSTEM/360 (1964/65)

The IBM System/360, announced on 7 April 1964, was a compatible family of third-generation computers (Pugh *et al.*, 1991). The range consisted of six distinct processors and 40 peripherals, which were intended to replace all of IBM's current computers, except the smallest and largest. A major feature of System/360 was the use of Solid Logic Technology (SLT), a short-lived semiconductor technology that lay between

TABLE 1. ICL 1900 series announcements (1964/65)

Model	Price (£000s)	Announced	Delivered
1901	65	September 1965	October 1966
1902	105	September 1964	September 1965
1903	175	September 1964	August 1965
1904	260	September 1964	May 1965
1905		September 1964	January 1965
1906	700	September 1964	mid 1967
1907		September 1964	mid 1967
1909		September 1964	October 1965

Models 1905, 1907 and 1909 were scientific versions of the 1904, 1906 and 1903, respectively, equipped with a floating-point processor.

discrete transistors and true integrated circuits. The scale of the announcement was entirely unprecedented and all the evidence is that it took the rest of the industry largely by surprise.

From about mid-1963, well before the 360 announcement, both RCA and ICT had been independently evolving plans for compatible ranges of computers. While ICT had been contemplating a range based on the FP6000, RCA had quite separate plans that would include some form of IBM compatibility. These were, however, long-term plans; in the case of ICT there was certainly no intention of delivering a compatible range much before 1968. The effect of the 360 announcement in April 1964 was therefore to compress into months development programs that had been intended to take years.

In spring 1964, RCA had invited ICT planners to make an appraisal of its long-term computer plans in the hope that they would decide to adopt the RCA range (as yet unspecified), and of course to assume some of the R&D and manufacturing load. As luck would have it, the System/360 announcement of 7 April 1964 occurred at the very moment of the ICT visit. There was no

industrial espionage and RCA obtained details of the 360 from the publicly available manuals. While the ICT team toured the US on other business, RCA immediately investigated the implications of System/360 for the RCA range. When the ICT team returned a week later, RCA had decided to make its new line fully 360 compatible. The new RCA range was subsequently announced as Spectra 70.

ICT was entitled to manufacture the RCA series under licence, but declined to do so on two main grounds. First, on the policy of IBM compatibility and, second, on the question of lead-times. IBM compatibility was seen to be a poor competitive strategy for ICT. The only logical reason for a user buying an IBM-compatible computer in preference to a machine manufactured by IBM, it was argued, was because it had a better price/performance or technical superiority. ICT doubted if it could achieve this superiority; but in any case there was a deep cultural resistance towards slavishly following the IBM line. The question of lead-times was at least as decisive. Although the RCA planners believed they could bring machines onto the market in 18–24 months, the ICT team was highly sceptical. In any case, they would be left without any product at all during the development period. RCA was a rich company and willing to withstand a short-term loss for the eventual high rewards, but ICT did not have this luxury. Although the FP6000 was less architecturally advanced than System/360, it had the great advantage of being fully designed, working and already in the field.

Before flying back to England, the ICT team had decided to recommend that the FP6000 be developed into what was to become the 1900 series. The recommendation was accepted by top management and in a matter of days all of the major processor and peripheral projects were redirected to the fulfilment of

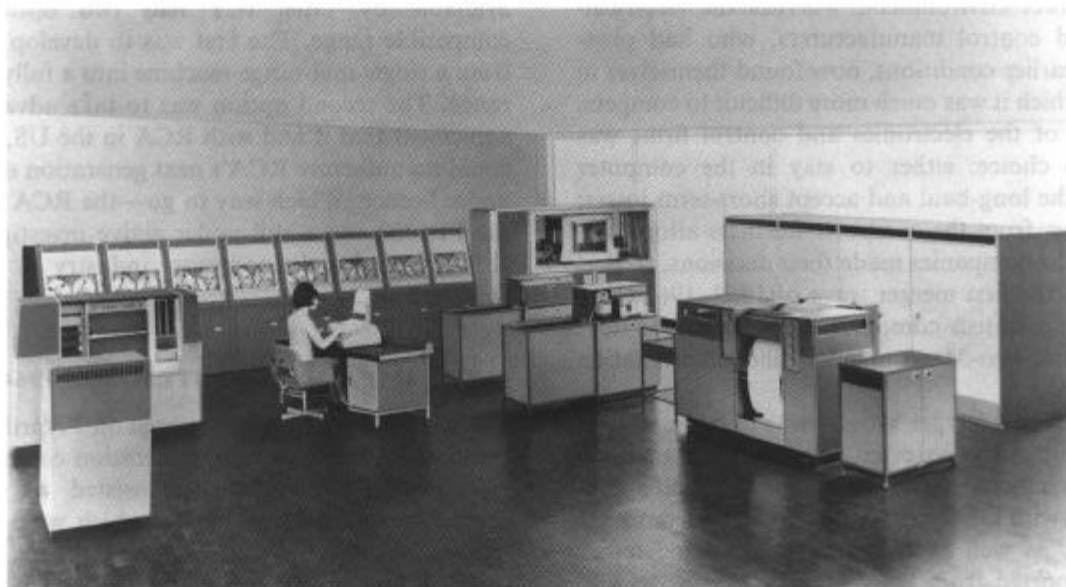


FIGURE 5. ICT 1900 series (1965). The ICT 1900 series was a range of computers announced in September 1964 to compete with the IBM System/360.

TABLE 2. English Electric System 4 announcements (1965)

Model	Price (£000s)	Announced	Delivered
10	100	September 1965	cancelled
30	172	September 1965	June 1967
50	271	September 1965	May 1967
70	600	September 1965	mid 1968

Models 40, 45, 60, 65, 72 and 85 were added to the range during 1966–70.

the 1900 series. The original FP6000—already announced as the ICT 1900—now became the 1904, the middle of the range. Below this in size there were three models, the 1901, 1902 and 1903; and above it the 1906; there were also scientific variants, the 1905, 1907 and 1909 (Table 1).

The press launch for the 1900 series took place on 29 September 1964. In addition to the processors, a total of 27 different peripherals were announced. The first production model was delivered in January 1965—only 4 months after the 1900 series announcement. The short lead-time of the 1900 series proved to be a major competitive advantage over System/360—although the first machines from the IBM range were delivered in the US in spring 1965, there were production problems that held back deliveries in the UK until spring 1966. The promise of early delivery largely overcame the disadvantage that the ICT machines used discrete transistor

electronics, which were technically inferior (though cheaper) than IBM's SLT. The market acceptance of the 1900 series exceeded all expectations and orders poured in, both from Britain and around the world. Morale in ICT soared. The 1900 series, once thought of as a stop-gap, now looked to be a major success (Figure 5).

Turning to Britain's other major EDP computer manufacturer, English Electric-Leo-Marconi, planning activity had begun on a range of third-generation machines soon after the merger with Leo Computers had taken place in April 1963. These plans were initially focused on an entirely new range which was known internally as 'Project KLX'. With the announcement of System/360 and the 1900 series during the course of 1964, however, the pace and scale of innovation had increased, and it was clear within English Electric that there was a need to contain development costs within realistic bounds. As it happened, English Electric had a long-standing technology sharing agreement with RCA, so it decided to abandon the KLX project, and take up the option to manufacture Spectra 70 which ICT had declined.

English Electric's range of four machines was announced as System 4 in September 1965 (Table 2), with deliveries promised for early 1967. The model 4-50 was derived directly from the Spectra 70/45; it was therefore the first to be delivered, although deliveries in



FIGURE 6. English Electric System 4-70. The English Electric System 4 was an IBM System/360 compatible range, based on the RCA Spectra 70 series. The large System 4 machines were particularly competitive in real-time applications.

quantity were much later than originally had been planned. The two small machines, the 4-10 and 4-30, were developed by the Marconi division of English Electric. Although the functional specifications from RCA were used for these machines, English Electric decided to exploit Marconi's advanced integrated-circuit technology to build the processors. The use of integrated circuits, however, meant that the machines were not particularly economic. The 4-10, in particular, was not price competitive against the IBM 360/20 or the ICT 1901, and was eventually cancelled before any were delivered.

The large 4-70, however, was a considerable technical triumph (Figure 6). Unlike System/360, it had been designed in the expectation that the future growth in large-scale computing would be in real-time transaction processing and multi-access systems. During 1966/67 many of the prestige orders for large systems from the British Government and nationalized industries went to the 4-70: these included several machines for the Post Office, the National GIRO Bank, the electricity boards, the UK Atomic Energy Authority and universities. The 4-70 completely outclassed the ICT 1906, which had to be withdrawn from the market until a faster model (the 1906A) could be announced in 1967.

Thus a major effect of System 4 was to force ICT into introducing integrated circuits into the 1900 series as rapidly as possible, particularly to restore the competitiveness of the 1906. One interpretation of this situation was that ICT and English Electric were not so much competing against the Americans, as nibbling at each other's share of the British market.

5. THE FORMATION OF ICL (1964-1968)

The decisions of ICT and English Electric to independently embark on their own third-generation computer ranges took place against a backdrop of growing political concern at the increasing dominance of the high-technology industries by American multinational companies. This mood was captured admirably by J.-J. Servan-Schreiber's popular book *The American Challenge* (1967), which was a best-seller in both France and England.

When, in October 1964, Harold Wilson's Labour Government came into power, one of its first acts was to establish a Ministry of Technology, envisaged as an organization to 'guide and stimulate a major national effort to bring advanced technology and new processes into British industry'. Wilson (1971, p. 8) placed the British computer industry at the very top of Mintech's agenda:

My frequent meetings with leading scientists, technologists and industrialists in the last two or three years of Opposition had convinced me that, if action was not taken quickly, the British computer industry would rapidly cease to exist, facing as was the case in other European countries, the most formidable competition

from the American giants. When, on the evening we took office, I asked Frank Cousins to become the first Minister of Technology, I told him that he had, in my view, about a month to save the British computer industry and that this must be his first priority.

Accordingly, in November 1964, the newly appointed Minister of Technology held talks with both ICT and English Electric, in what was to be the first of many attempts to persuade them to bring together their computer interests. But these talks came to nothing.

By spring 1966, the condition of the three main British computer companies—ICT, English Electric-Leo-Marconi and Elliott-Automation—had changed considerably. ICT's position, following the success of the 1900 series, was easily the strongest of the three companies. The position of English Electric-Leo-Marconi, following the launch of System 4, had worsened considerably; the high development costs had produced the anticipated heavy losses during 1966 and the delivery of machines in early 1967, on which success depended, was problematical. The third company, Elliott-Automation, was in still deeper trouble. A sizeable proportion of Elliott-Automation's business had been defence contracts associated with the TSR-2 aircraft programme, which had been cancelled in April 1965, and the company was actively seeking some form of merger.

With the changing fortunes of ICT and English Electric-Leo-Marconi, the possibility of a merger surfaced again within Mintech, now under the control of Anthony Wedgewood-Benn. In order to gain a clearer picture, Mintech commissioned an independent inquiry into the affairs of the two companies. The inquiry was led by S. John Pears, a senior partner of a London-based accountants, and his report appeared in September 1966. The Pears Report (1966) came down firmly against the idea of a merger between ICT and English Electric-Leo-Marconi. The main reason for this recommendation was the incompatibility of the 1900 series and System 4, and the fact that both developments had passed the point of no return.

The Ministry therefore decided to deal with the rationalization of the British computer industry in two stages: first, the rationalization of the process-control computer industry and, second, that of the EDP computer industry. The former proved relatively straightforward and English Electric absorbed Elliott-Automation in June 1967. The new English Electric subsidiary was named English Electric Computers Limited. It now remained to rationalize the EDP sector of the industry. In April 1967, the minister and his technical advisors once again called a meeting with the top managements of ICT and English Electric to persuade them to merge their EDP computer interests. Mintech accepted the conclusions of the Pears Report that the main impediment to a merger was the incompatibility of the current ranges, and therefore offered *inter alia* a non-repayable grant in the region of

£25 million towards the development of a new range of computers for delivery in the early 1970s.

Before a merger could proceed, however, there was a major technological uncertainty. Would a new range be possible? Would it be possible to design a new range of computers that was not only competitive with System/360, but was also compatible with both the 1900 series and System 4 in order to retain existing customers? In order to determine this a joint ICT/English Electric working party was established for a feasibility study. The working party met in secret for an intense 3-day session in early July 1967. The working party was not, in fact, able to give a categorical assurance on the compatibility criterion for the new range, but was guardedly optimistic:

We are agreed that there is no *prima facie* reason why it should not be possible to plan a range of systems meeting the basic requirements of competitiveness and of acceptable compatibility with the current ranges of both companies. (Anon., 1967)

This was accepted as a good enough technological basis for the merger to proceed, although it still remained to hammer out the financial terms. If ICT and English Electric had moved decisively an early merger would no doubt have been achieved; but the terms of the merger were not agreed until early 1968, and the delay—each hoping for marginally better terms—was to prove disastrous. During the autumn of 1967, the UK economic climate had worsened dramatically, culminating in the devaluation of the pound in November 1967 and the public expenditure cuts of January 1968. A government subvention of the order of £25 million was now seen as politically unacceptable, and the Treasury was thinking in terms of about half that amount—in fact, £13.5 million was eventually provided. But the merger plans were now so far advanced that there was no going back. On 21 March 1968 the Minister of Technology presented a White Paper on the computer merger to the House of Commons; and ICL was vested on 9 July 1968 (Anon., 1968). ICL was the largest non-American computer manufacturer, with a workforce of 34 000.

6. THE NEW RANGE (1969–1977)

For ICL, the scene for the 1970s was set by a mission to develop a new range of computers, but with R&D resources that were not really sufficient.

The specification of a completely new range of computers was a once-in-a-lifetime opportunity, and inevitably the protagonists of the various architectural solutions within ICL, and without, were anxious to see their particular vision implemented. In order to defuse the situation, and to avoid emotional commitment from determining the new-range architecture, it was decided to create a formal planning structure to try to arrive at a rational solution. The New Range Planning Organiza-

TABLE 3. New Range processors (1974–1980)

<i>Processor</i>	<i>Model</i>	<i>Announced</i>	<i>Delivered</i>
P-series			
P4	2980	October 1974	June 1975
P3	2970	October 1974	December 1974
P2L	2960	March 1976	December 1975 ^a
P2S	2950	cancelled	
P1	2940	cancelled	
P0	2930	cancelled	
S-series			
S4		cancelled	
S3	2966	June 1981	
S2	2956	November 1980	
S1	2950	November 1977	June 1978

Delivery dates are given for the first four principal processors in the new range, the 2970, 2980, 2960 and 2950. The P-series and S-series used MSI and LSI technology respectively. Other models were derived from the S-series processors: from S1, model 2946; from S3, models 2955, 2977, 2988 and others.

^a Delivered early to fulfil a government contract.

tion was formed in January 1969 and the specification of the new range was to occupy most of that year.

The new range planning exercise was a highly bureaucratic affair, in which seven small study groups each evaluated one particular architectural 'option'. The seven options, however, amounted to three basic choices: first, to extend the life of one of the existing ranges; second, to manufacture an existing mainframe architecture, either by collaborating with an American company or through a licensing agreement; or, third, to create an entirely new architecture—the so-called 'synthetic option'. The New Range Planning Organization recommended that the company should take the pursue the third course. The decision to create a new architecture was only partly rational—the not-invented-here syndrome and the technological enthusiasm of the times both played a contributory role. The new-range architecture was developed internally by ICL, but drew heavily from both the Basic Language Machine project inherited from ICT (Iliffe, 1968) and the Manchester University MU5 (Buckle, 1978).

In early 1970, work was started on detailed planning of the new range. It was intended to support a range of six processors (P0–P5) within the new-range architecture (Table 3), ranging from a low power machine (P0) up to a machine as powerful as any mainframe then available (P5). In fact, the low power P0 processor was viewed only as an entry-level machine of limited appeal; and the P5 processor was seen as being too expensive to develop without a guaranteed government purchase of at least 10 machines, so it was never much more than a paper exercise. Attention was therefore focused on processors P1–P4, which were viewed essentially as a replacement range for ICL's current computers.

Even though the new range development was now committed to only the P1–P4 processors, funding remained a problem. ICL's total R&D spend, which was projected at about £90 million for the 5-year period

from 1968 to 1973, had not only to support the new range development, but also the continued enhancement of the current ranges. These difficulties were compounded by the first world-wide recession in the computer industry in 1970/71 (Fisher *et al.*, 1983). The first major casualties of the recession were the giant American company General Electric (GE), which sold its computer interests to Honeywell in 1970; and RCA, which decided to sell its computer interests to Sperry Rand the following year. The demise of GE and RCA as computer manufacturers illustrates the fiercely competitive environment in which ICL found itself in the early 1970s. It had always been realized in ICL that developing the new range would stretch the company to the limit; but the impact of the computer recession on turnover and profits meant that ICL would eventually have to call on the government to provide launching aid in addition to the £13.5 million it had agreed to at the time of the merger.

In June 1970, the new Conservative Government of Edward Heath had been elected. Unfortunately for ICL, the Heath Government had come into office pledged to a disengagement from the direct intervention in industry that had been so much a feature of the out-going Labour administration. This was the famous 'lame duck' policy

(Mottershead, 1978). Consequently, when in early 1971 ICL faced an impending financial crisis, it had to deal with it unaided: during the first half of 1971 over 3000 workers were laid off and R&D spending had to be reined back.

Gradually, however, the political climate began to change in ICL's favour—particularly following the government rescue of Rolls Royce in February 1971. In early 1971, an inquiry into the British computer industry was conducted by the Select Committee on Science and Technology, and the appearance of its report the following November *The Prospects for the United Kingdom Computer Industry in the 1970's* provided a firm basis for government action. The report was sharply critical of the government's role, stating: 'We found it difficult to describe present Government action regarding computer research and development as a policy' (Anon., 1971, Vol. 1, p. lx). It called for a much higher level of government support for the computer industry. It was estimated that the government's total support for computer R&D had been only £30 million during 1969–1973—a sum that was believed to be only one-fifth that spent for the same purpose in France and one-tenth that spent in Germany. The Select Committee recommended that the government should increase its funding of



FIGURE 7. ICL 2900 series (1974). The ICL 2900 series was announced 1974. The new range was the most ambitious mainframe project ever undertaken in Britain and it remains the architectural base for ICL's current mainframes. The photograph—a publicity shot for the October 1974 launch—shows a mid-range model 2970.

computer-related R&D to the extent of 'not less than £50 million per annum'.

In 1972, the government finally yielded to the pressure and made ICL a loan (not a grant) of £40 million to help sustain the momentum of the new-range R&D for the period 1972–1977. But a pre-condition of the loan was that ICL should change its top management: a new American managing director was brought in from Univac, and the former managing director of IBM (UK) was appointed chairman.

With ICL's long-term R&D funding finally assured, the new range took centre place in ICL's 5-year strategic plan for 1973–1978. In October 1974, some two years later than originally anticipated, the new range was finally announced as the ICL 2900 series (Figure 7). The new range launch was, of course, only the end of the beginning. There remained the monumental R&D and manufacturing challenge of actually bringing the machines and software into the field. This task was to consume most of ICL's technical resources during 1975–1978. At the time of the initial launch, only the two larger models—the 2970 (processor P3) and the 2980 (processor P4)—were announced, the first deliveries being made in December 1974 and June 1975, respectively. It had originally been planned to announce the remaining machines within the following 18 months; but none of the deadlines were met.

The development delays were in large part due to problems with the operating-system software. During the 6-year period of the new-range development, software was to consume 35%, or £56 million, of ICL's R&D expenditure, and the operating systems were to account for most of this. The main new-range operating system, known as VME/B, was a classic evolution-versus-revolution situation. American vendors were supplying mature, stable and reliable operating systems aged 7 or 8 years, based on older computer architectures though running on the latest processor technology. In moving to a new architecture, ICL had been forced to abandon its own acclaimed and fairly resilient 1900 operating systems.

One consequence of the long gestation of the new range—which was to be some 5–7 years in the making—was that the project became caught up with the problem of contracting semiconductor life-cycles that were such a feature of the 1970s. In order to keep pace with the change of semiconductor technology, it was decided in late 1975 to develop the S1 and S2 processors in place of P1 and P2; this further delayed deliveries of mid-range machines until 1977 and 1978. And as realistic development and manufacturing costs became available, it became clear that the small 2930 was not economically feasible, so it was cancelled.

7. THE R&D CHALLENGE (1978–1981)

There is no question that if ICL had been wholly dependent on its mainframes in the 1970s, it would have found it difficult to sustain an adequate market share.

Fortunately, in 1973 it had made a very effective entry into the small-business systems market with the model 2903 (which was in fact based on the 1900 series and was not compatible with the new-range 2900 series). In 1976, it acquired the European customer base of Singer Business Machines and access to its very successful System Ten computer. These products, which sold particularly well in continental Europe, enabled ICL to achieve an annual growth rate of well over 20% during 1973–1978; this was the fastest rate of growth of any of the mainframe manufacturers, excepting only Fujitsu in Japan.

One of the main objectives of this rapid revenue growth was to ensure the survival of ICL's R&D when the £40 million government loan terminated in 1977. During the 5-year period from 1974 to 1978, ICL's annual R&D spend increased from about £22 million to £36 million, although as a proportion of revenues R&D fell from 10.8% to a very respectable 7.1%.

The late 1970s, however, saw a quite unprecedented escalation in the pace of innovation in the computer industry—and this escalation took place against a background of declining profit margins. One of the main causes of this technological acceleration and erosion of profits was the emergence of manufacturers of Plug-Compatible Mainframes (PCMs). The PCM concept was pioneered by the Amdahl Corporation in the US in the mid-1970s; the strategy aimed to compete with IBM's high-end machines (which were not competitively priced due to IBM's cost-performance pricing constraints) by using advanced semiconductor technology. Amdahl obtained its semiconductor technology from Fujitsu in Japan, and this entrée into the American computer market encouraged Fujitsu to compete with IBM in its own right for the first time. By the end of the 1970s, Fujitsu together with Hitachi and NEC, had developed from supplying the domestic Japanese market only, to becoming world-class computer manufacturers (Flamm, 1988, pp. 192–196).

The arrival of the PCM manufacturers caused IBM to assert its technological leadership, and to shorten the life-cycle of its processor technology, from about 4 to 3 years. In 1978, ICL now considered it was perhaps 3 years behind IBM on key aspects of processor technology, and that progressive enhancement of all the P-series processors had become urgent. During 1978, plans were laid for replacement of the P3 and P4 processors by LSI versions (S3 and S4), and eventually by full VLSI processors (S3L and S4L) during 1982–1984. This evolution would provide price/performance improvements of an order of magnitude over a period of about 5 years.

Although the new-range development program represented the major part of ICL's R&D effort, it was by no means the whole of it. There was also an urgent need to enhance the small business systems, to invest in networking software and to make an effective entry into the office systems market.

Thus in 1978 the central issue facing ICL, as in the past, was in selecting an appropriate level of R&D expenditure and generating sufficient business to sustain it. The R&D programmes underway in 1978 indicated swiftly rising costs, from £36 million a year in 1978 increasing to £89 million in 1983. During the previous 5-year period, 1973–1977, total R&D expenditure had been £123 million and this was now set to more than double to £266 million in the next 5-year period, 1978–1982.

In May 1978, the ICL was faced with choice as to the long-term future of R&D: either it could be maintained at the projected levels, which implied a further period of sustained growth of over 20%; or it could aim for a lower, more realistic growth rate, rein back R&D and take the first steps towards becoming a niche supplier. ICL opted for the former course—a high-growth, high-risk strategy. The risks were that if ICL entered a period of economic turbulence, or price/performance norms fell rapidly, then its forward plans would be thrown into disarray and threaten the existence of the business. This is exactly what happened (Marwood, 1985).

The first blow came on 31 January 1979, when IBM responded to the increasing competition from the Japanese PCM manufacturers by replacing its System/370 mid-range processors with the 4300 series. The new machines offered an unprecedented 4-fold price/performance improvement over the machines they replaced. For all the mainframe manufacturers the 4300 launch created the competitive environment of 1979. In effect, they were caught in the cross-fire between IBM and the Japanese, and during the early months of 1979 they all cut prices and announced new models.

By the summer of 1979 it was clear that ICL's 5-year R&D programme was seriously endangered: profits had fallen, which in turn led to a shortfall in the R&D budget of the order of 10–20% and it seemed likely that it would eventually have to call on the government for some financial support. In fact, when government assistance became necessary, it would not prove so straightforward as ICL had supposed. On 3 May 1979 Margaret Thatcher's Conservative Government had been elected into power. Like the Heath Government of 1971, the Thatcher administration was pledged to a disengagement from direct involvement in industry. Early in 1980 the UK fell into a major economic recession: domestic interest rates rose and the sterling-dollar exchange rate soared from its 1978 level of \$1.80 to a peak of \$2.35. Sales, both at home and abroad, became exceptionally difficult, and ICL's trading position deteriorated steadily throughout the year. By January 1981, ICL was forecasting a £50 million loss for the year and the future existence of the company was very much in doubt. It was at this point that it decided to approach the government for aid.

ICL's major problem was the widening gap between its earnings and the R&D expenditure necessary to keep its products competitive. While previous governments had

provided direct R&D support, this was not the route chosen by the new Thatcher administration. Rather, the view was taken that ICL's shareholders and bankers should save it; but ICL's position was now so precarious that this was unthinkable. Finally in March 1981, in a meeting between ICL, its bankers and the government, a highly imaginative solution to ICL's cash problems was put forward in the form of a loan guarantee. Provided ICL's bankers would extend it the £200 million it needed, the government would guarantee the loans against ICL's defaulting. In fact a total of £270 million was provided, of which the government guaranteed £200 million for a period of 2 years. Since ICL subsequently repaid the loans and the guarantees never had to be called, the direct financial assistance given to ICL by the government was nil—although it can be argued that it underwrote some very high-risk insurance.

8. RATIONALIZATION OF R&D (1981–1983)

In reaching the decision to provide the loan guarantees, the government had concluded—on the advice of management consultants—that ICL's problems were in large part managerial. The loan guarantees were therefore made conditional upon ICL accepting a new management team.

Within a few days of taking office in May 1981, the new management began to restructure ICL's affairs, both operationally and in terms of products. The operational measures taken were all very standard, very unpleasant, but unavoidable if ICL was to become viable again: several plants were closed, workers were laid off and other cost-saving measures introduced. The work force cutting continued throughout the ICL recovery, the total headcount reducing from a peak of 33 000 in 1980 to about 20 000 by 1985.

The key to ICL's survival, however, lay in its products—and these in turn depended on getting the balance of R&D right. Within 6 months, ICL's product strategy had been radically re-oriented around two themes: mainframe rationalization and a new 'Networked Product Line'. A review of ICL's mainframe products, the unprofitable core of its business, disclosed some alarming trends. The most important of these was that the 2900 series accounted for a disproportionate fraction of ICL's R&D spend: mainframes which produced about one-third of turnover, consumed two-thirds of overall R&D costs. This R&D burden was inhibiting ICL's participation in the market for small and micro computers, and office systems. The short-term strategy for the 2900 series was therefore aimed at reducing the on-going R&D commitment and to divert resources to small systems. In the longer term, however, it was chip technology that was at the heart of the problems of the 2900 series. Both the new-range architecture and operating system were well proven and competitive, but ICL lacked the semiconductor technology to manufacture systems price competitive

TABLE 4. ICL-Fujitsu agreement (October 1981)

Processor	Mips	Architecture	Design	Software	Manufacture	Technology
DM/1 ^a	0.8-2.6	ICL	ICL	ICL	ICL	Fujitsu
Estriel ^b	7-20	ICL	ICL	ICL	Fujitsu	Fujitsu
Atlas 10 ^c	15-25	Fujitsu	Fujitsu	Fujitsu	Fujitsu	Fujitsu

Notes

^a Announced as System 39 level 30, April 1985.^b Announced as System 39 level 80, April 1985^c Announced as Atlas 10, models 15 and 25, May 1981.

with IBM. In October 1981, ICL—assisted by some behind the scenes activity from the government—succeeded in obtaining an agreement with Fujitsu to obtain access to its semiconductor technology.

The ICL-Fujitsu agreement fell into three broad areas (Table 4), corresponding to three main product lines: the small S1L processor (now renamed DM/1 for 'distributed mainframe'), the medium-sized S3L processor (now known as Estriel—the name Estriel arose because the Japanese had difficulty in getting their tongues around 'ess-three-ell') and the large Atlas 10 IBM-compatible mainframe. All the architecture, design and software of the new range processors would remain in Britain, with Fujitsu supplying semiconductor design tools and components, and some limited manufacturing facilities. A particular attraction of the new range's 'nodal architecture' was that the entire mainframe range was now based on just two processors—a major advantage over ICL's competitors. The DM/1 and Estriel processors were eventually launched in August 1985 as the first two members of Series 39—the successor to the 2900 series. The ICL-Fujitsu agreement was perceived as an exceptionally innovative solution to ICL's mainframe challenge and has since come to be regarded as a classic example of technology transfer in the 1980s (Pastalos-Fox, 1983).

The third part of the ICL-Fujitsu agreement was for ICL to market Fujitsu's largest IBM-compatible mainframes as the ICL Atlas 10 series. This agreement did not really harmonize with ICL's mainframe range, but it was part of the give-and-take between Fujitsu and ICL. In fact, the Atlas 10 was a marketing failure and ICL withdrew in 1984. This effectively closed any future likelihood of ICL becoming IBM compatible.

The rationalization of the mainframe R&D enabled resources to be diverted to the Networked Product Line (NPL), which was ICL's strategy both to address the technical deficiencies of its product line and to seize a new marketing opportunity in office systems. An entry into the office systems market had, of course, been a key feature of ICL's product strategy since the late 1970s, but it had been overshadowed by mainframes. The essential change was to shift resources away from mainframes and towards distributed systems based on small and micro computers. Although rationalization of the mainframe programmes effectively doubled the resources available for the NPL, it was still necessary both for reasons of

development cost and lead-times to make collaborative or licensing agreements to fill out the product range. During 1981-1983 licensing deals were made with several companies including: the Three Rivers Computer Corporation for engineering workstations; Mitel Corp for digital exchanges; Logica and Nexos for word-processing technology; Rair for the ICL Personal Computer; and Sinclair and Psion for the innovative One-Per-Desk computer-phone. Advantage was also taken of the emerging OSI international open-networking standards.

The effect of these collaborations was to force ICL into becoming an outward-looking company instead of an inward-looking one. Of course not all the geese turned out to be swans and several of the collaborations were commercial failures. However, the open R&D culture within ICL appears to have survived these setbacks.

9. A TURBULENT DECADE (1984-present)

In the last decade the mainframe computer industry has experienced a period of unprecedented turbulence. Overshadowing everything has been IBM's fall from grace in 1992/93. From being arguably the most successful enterprise in business history, in early 1993 it announced the largest ever annual corporate loss. In the last few years its workforce has been cut to two-thirds of its mid-1980s peak of over 400 000. Nor has IBM been alone in its troubles. Most of the mainframe makers have experienced major transformations—the merger of Burroughs and Univac to form Unisys in 1986, the takeover of NCR by AT&T in 1991, the restructuring of Groupe Bull in France, the relative decline in profitability of the Japanese mainframe makers, and so on. Remarkably, ICL has been consistently profitable since its traumas in the early 1980s. How do we explain this?

Generally, computer historians are cautious about describing events more recent than a decade ago—the analysis of contemporary events is more properly the province of science and technology policy, which has its own particular problems and research methodologies. Judgements based on ephemeral events often prove wide of the mark within a few years. For example, when ICL was taken-over by the British telecommunications firm STC in 1984, this was seen at the time as reflecting a global trend in the convergence of computing and telecommunication technologies (IBM took over the

Rolm telecommunications firm at about the same time) and a great deal was written about the synergistic possibilities. Yet by 1990 ICL had been demerged from STC and taken over by Fujitsu. Only now is it clear that projections of a widespread computer and telecommunications convergence were premature—as were similar projections in the 1960s.

We face a similar problem today in trying to evaluate the long-term future of the mainframe, and specifically ICL's mainframes. For example, in the last two or three years there has been an immense outpouring of journalism and several books about the decline of IBM (see Fallows, 1994, for a review of several books from the genre). Almost all of this literature contrasts IBM's decline with the rise of Microsoft, and attributes IBM's troubles to a mixture of corporate fossilization and a failure to spot the decline of the mainframe and the rise of the personal computer. Clearly, there is a grain of truth in this thesis, but it is very far from being the whole story, and to conclude that the mainframe is dead is almost certainly mistaken. Although the mainframe business is now more competitive than ever, the sheer investment in computer infrastructure and software in major corporations will ensure, at the very least, that there is a replacement market for mainframes for decades to come.

In fact there are at least three other factors that need to be considered when discussing the decline of the mainframe makers: these include the recent demise of vertical integration strategies; the sophistication of modern software that has made sales engineers largely unnecessary; and the dynamics of the modern business corporation (Usselman, 1993). IBM reacted very slowly to all of these trends—probably a decade later than ICL. Thus in the early 1980s, ICL progressively closed its manufacturing plants and began to buy in semiconductors from Fujitsu. It dramatically cut down on its sales force and it restructured into business units of the kind now favoured by IBM. All of these are ordinary business issues that have very little to do with the existence or otherwise of the mainframe.

REFERENCES

- Anon. (July 1967) *Report of the Working Party on a New Range of Computing Systems*. ICL Archives.
- Anon. (1968) *Industrial Investment: The Computer Mergers Project*. Cmnd. 3660, HMSO, London.
- Anon. (1971) Select Committee on Science and Technology (Sub-Committee A), Session 1970–71, *The Prospects for the United Kingdom Computer Industry in the 1970's*, 3 vols. HMSO, London, 1971.
- Bashe C. J., et al. (1985) *IBM's Early Computers*. MIT Press, Cambridge, MA.
- Buckle, J. K. (1978) *The ICL 2900 Series*. Macmillan, London.
- Campbell-Kelly, M. (1986–1989) ICL company research and development. *ICL Technical J.*, part 1, 5, 2–17, 1986; part 2, 6, 2–17, 1988; part 3, 7, 781–813, 1989.
- Campbell-Kelly, M. (1989) *ICL: A Business and Technical History*. Oxford University Press, Oxford.
- Fallows, J. (1994) The computer wars. *The New York Review*, 24 March, 34–41.
- Fisher, F. M., et al. (1983) *IBM and the U.S. Data Processing Industry*. Praeger, New York.
- Flamm, K. (1988) *Creating the Computer*. Brookings Institution, Washington, DC, 1988.
- Freeman, C., et al. (1965) Research and development in electronic capital goods. *National Institute Economic Rev.*, 34, 40–91.
- Halsbury, Lord (1991) Innovation for failure—some reflections on the work of the NRDC relevant to the early history of the computer industry in the UK. *Comp. J.*, 34, 272–279.
- Hendry, J. (1989) *Innovating for Failure: Government Policy and the Early British Computer Industry*. MIT Press, Cambridge, MA.
- Iliffe, J. K. (1968) *Basic Machine Principles*. Macdonald, London.
- Marwood, D. C. L. (1985) ICL: crisis and swift recovery. *Long Range Planning*, 18, 10–21.
- Mottershead, P. (1978) Industrial policy. In Blackaby, F. T. (ed.), *British Economic Policy, 1960–74*. Duckworth, London.
- Pastalos-Fox, M. (1983) How to buy technology. *Management Today*, December, 78–81.
- Pears, S. J. (September 1966) *Rationalisation of Certain Companies in the British Computer Industry*. ICL Archives.
- Pugh E. W., Johnson L. R. and Palmer J. H. (1986) *IBM's 360 and Early 370 Systems*. MIT Press, Cambridge, MA.
- Pugh, E. W. (1995) *Building IBM: Shaping an Industry and its Technology*. MIT Press, Cambridge, MA.
- Servan-Schreiber, J.-J. (1967) *The American Challenge*. Hamish Hamilton, London.
- Usselman, S. W. (1993) IBM and its imitators: organizational capabilities and the emergence of the international computer industry. *Business and Economic History*, 22(2), 1–35.
- Wilson, H. (1971) *The Labour Government 1964–1970*. Weidenfeld and Nicolson and Micheal Joseph, London.