ICL: Taming the R&D Beast

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In this paper, it is argued that a successful mainframe-computer company of the 1960s needed a portfolio of five organizational capabilities: prudent management, R&D, manufacturing, marketing, and applications knowhow. In the post-World War II decade, a fragmented computer industry developed in the United Kingdom, with no single player having the full range of capabilities. Responding to the competition from IBM and other U.S. computer companies in the 1960s, a government-inspired series of mergers led in 1968 to the formation of a single national-champion computer company, ICL, with the organizational capabilities and scale to meet the American challenge.

Pre-eminent among the objectives for the creation of ICL was the desire to maintain an indigenous R&D capability. This overshadowed all the other objectives—especially high-quality management—and resulted in recurrent financial crises and subsequent government rescues. In the face of escalating R&D costs in the late 1970s, ICL made a high-risk dash for growth that led to the firm's near bankruptcy in 1981. Only when the R&D costs had been contained was the company brought back to a profitable, if unglamorous, position.

Background: IBM and ICL

To understand the development of ICL, one needs to understand its origins as an office-machine firm, and its brittle relationship with IBM.

Mechanized data processing originated in the 1880s with the invention of the punched-card machine by Herman Hollerith [1]. In 1896, Hollerith incorporated the Tabulating Machine Company of New York to develop his machines for industry and commerce. This company was later to become IBM. In 1907, Hollerith made an agreement which enabled an English business syndicate to market the Hollerith machines in Great Britain and its Empire. This firm, the British Tabulating Machine Company (BTM), was later to become ICL [4]. In 1911, Hollerith sold the American business in a merger operation which resulted in an office-machine conglomerate, the Computing-Tabulating-Recording Company (C-T-R). Under the leadership of a thrusting NCR-trained manager, Thomas J. Watson Sr., C-T-R trebled in size

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from 1300 employees in 1911 to nearly four thousand in 1924 when the company changed its name to International Business Machines. During the 1920s and 1930s IBM developed superb organizational capabilities in general management, R&D, manufacturing, marketing, and business applications. (These capabilities were precisely those that, in terms of Nelson and Winter's *Evolutionary Theory of Economic Change* [13], would make IBM uniquely adapted for, and thus able to dominate, the mainframe computer market of the 1950s.) Although not the huge company of its later days, IBM was a by-word for profitability and corporate governance [5]. Its only competitor in punched-card machines was Remington Rand, whom it outsold by a factor of more than eight—essentially because of the technical superiority of IBM's machines and more effective marketing [14, p. 771].

BTM had an extraordinary opportunity due to Hollerith's relatively benign license (which had no time limit and no mechanism for changing the terms). In exchange for an admittedly hefty 25 per cent royalty on sales to the American company, BTM had access to all of IBM's R&D and manufacturing operation. But to Watson's justifiable irritation, the company failed to make the most of its opportunities and successfully develop the British markets. Thus while the British and American companies had respectively approximately one-third and two-thirds of the world market, IBM out-sold the British company by a factor of twenty, rather than the factor of two that the market split might have suggested. Like IBM, the British company had a local competitor, the British Powers organization. In spite of access to IBM's superior technology, BTM captured only a fifty per cent share of its markets. In the 1920s, the British Powers organization developed its own technical division and manufacturing operation, and its sales force was trained by an American recruit from the Underwood typewriter company. By contrast, throughout the 1920s BTM was largely importing machines directly from IBM, and its sales operation was typically British, low-key, and uninformed by IBM's expertise. During the 1930s, not least because of the Buy British Movement, BTM began to design and manufacture some of its own machines to substitute for IBM imports, and its sales force improved in response to the competition from British Powers.

In the late 1930s, both firms recovered strongly in the post-depression office-machine boom. Thus by the outbreak of World War II in 1939, there were two moderately successful British punched-card machine firms, BTM employing 1200 people, and Powers employing about the same. But between them they had only one-fifth of the employees of IBM, and one-tenth of its revenues.

Computers and the Post-War Scene, 1945-59

During World War II the U.S. and British punched-card machine firms experienced a hiatus in R&D. Their electromechanical manufacturing capabilities were quickly recognized by their respective governments and were utilized for making high-precision military apparatus such as bombsights, gun aimers and cryptographic machines. Punched-card machines also played an important role in military organization, so the manufacturing operations were kept in tact, but the firms did no active punched-card R&D until the end of the war was in sight. Likewise, sales and applications activities were mothballed for the duration, but were quickly re-established as demobilized employees returned from the forces. Hence, emerging from the war, the key operational problems faced by all the punched-card machine manufacturers were to resume business-as-usual to satisfy the pent-up demand for punched-card machines, and to modernize their electromechanical products.

However, all the punched-card machine manufacturers recognized two threats (or opportunities) that could impact their business. The first was the emergence of electronics during the war, and the second was the invention of the stored-program computer in 1945. Immediately following the end of the war, electronics was "in the air", and all the manufacturers of electromechanical capital goods were forced to respond to the mood of the times. IBM responded quickly, building up an electronics capability by recruiting large numbers of college graduates in electrical engineering. Its product strategy was cautious, however—indeed the firm even coined a phrase "evolution not revolution" for its advertising literature. Electronics was incorporated in its electromechanical machines where this provided an operational advantage, but without changing functionality. This was a highly successful strategy, and by the late 1940s it had several strongly-selling electronic punched-card calculators—which were functionally identical to their predecessors but were much faster [2, pp. 34-72].

The computer market was at first consciously eschewed by IBM. Thomas Watson Sr. was reported, apocryphally, to have stated that the world would only ever need a dozen computers: if he said this, then he was being perfectly rational. In 1945 a computer—as the name implied—was a mathematical instrument. The market for $1 million-plus scientific computers was a very small one, and IBM did not have the organizational capabilities to deal with it. IBM did, however, maintain a defensive R&D position in computers, and in 1950 it contracted with the U.S. Government to build a prototype "defense calculator"—this later became the model 701, IBM's first scientific computer.

In fact, the firms best equipped to respond to the computer were the electronics and control manufacturers. The scientific-computer market needed high-class electronics R&D and manufacturing capabilities, and knowhow in scientific applications, which these firms had in abundance; by contrast little marketing expertise was required for boardroom sales of scientific computers to other engineering firms. Thus, while the office-machine manufacturers such as IBM, NCR and Burroughs had little more than a defensive position in computers, electronics and control manufacturers such as GE, RCA, Honeywell, and many smaller companies, were rushing into computers. Likewise in the U.K., while BTM and British Powers had done little more than dabble in electronics, there were three British electronics firms who were strongly committed to computers—Ferranti, English Electric, and Elliott Brothers.

The British presence in computer manufacturing, which greatly exceeded that of any country other than the United States, was in large part due to a quasi-government organization, the National Research Development

Corporation (NRDC). The NRDC was formed in 1949, the brain-child of the Labor Government's industry minister Harold Wilson. Then, as now, there was political concern that the U.K. was good at innovation but poor at exploitation, and the NRDC was formed to remedy this situation. The organization was established with a loan capital of £5 million, and with a respected scientific administrator, Lord Halsbury, as its managing director [8].

The NRDC's Halsbury instantly lighted upon the computer as the critical technology of the future in which Britain needed to secure a dominant position. In summer 1949 he visited IBM in New York, and came away convinced that it was only a matter of time before IBM developed an electronic data-processing (EDP) computer. This would of course be an entirely different market to the one for scientific computers which then existed; and Halsbury realized that no single British firm had the capabilities to succeed in it. All of the electronics firms lacked marketing and applications experience; while both of the punched-card machine firms lacked electronics R&D and manufacturing capability. Halsbury now began a patient round of negotiations to bring all the manufacturers together around a table so that he could urge on them the necessity of consolidation in the industry. It was to be six months before this meeting took place.

Meanwhile an event of great significance to the nascent British computer industry was taking place. In October 1949, IBM and BTM had decided to dissolve their territorial agreement by mutual consent. Because IBM was under some antitrust pressure to dissolve its agreement with BTM, it provided reasonably generous terms. In exchange for the right of IBM to compete with BTM in all the world's markets, BTM would no longer have to pay IBM any royalties, and would have access to all its existing punched-card machine technology. Although BTM would no longer have access to IBM's future R&D, the relief from royalty payments would treble its net income, and the company intended to use the money to develop its R&D division under the delusion that "British effort and British skill can be matched successfully against any competitor in our business, whether national or international" [4, p. 143].

In December 1949, Halsbury finally managed to bring together the top management from all of the British electronics and punched-card firms, to try to persuade them to form a consortium to develop an EDP computer. Unfortunately, as the minutes of that meeting record "both the electronics manufacturers and the punched-card machine manufacturers respectively represented that they were individually in positions to tackle the problems of an electronic computer development project as well as, for example, the International Business Machines Corporation in the United States" [4, p. 166]. Halsbury could do little more than urge on the firms the need to co-operate and hold out the carrot of loans for R&D; but none of the firms was tempted. With his game plan in ruins, Halsbury was to spend the next ten years at the NRDC, until he retired in 1959, on tactical interventions to prop-up a highly fragmented British computer industry.

The British punched-card machine firms pursued their product strategies by consciously imitating IBM [cf. 13, pp. 123-24]. BTM had recruited as many electrical engineering graduates as it could find, built up an R&D capability in electronics, and had introduced a number of electronic punched-card machines. It had also, like IBM, produced a scientific computer developed through links with the University of London. Thus, when in 1955 IBM introduced its first EDP computer (the model 650), BTM was well-placed to produce a similar machine for the British and Commonwealth market. By contrast, although pursuing the same strategy, Powers had never been able to successfully integrate electronics within its R&D operation, as its background was entirely mechanical rather than electromechanical like BTM's. Also, it had no effective links with university research and no clear vision of the stored-program computer. A number of product failures effectively brought the company to its knees by 1958.

Although by 1959 IBM still had only a foot-hold in the British business-machine market, it was starting to take-over BTM's and British Powers' overseas markets—such as Australia, India, and South Africa. BTM realized that it would be only a matter two or three years before IBM began to dominate the U.K. market too. Even so, BTM's concern was not over the computer market, but punched-card machines. In 1959, punched-card machines still accounted for 90 percent of BTM's turnover, and the punched-card machine boom showed no signs of abating [4, p. 201]. Because the British Powers organization was in such a critical condition, BTM was able to take it over at very little cost, and this enabled it to ramp-up its punched-card machine manufacturing capacity to satisfy the market. The Powers R&D division, however, was a mechanically-minded albatross that would take several years to kill off. The new company, with a total of 17,000 employees, was called International Computers and Tabulators Limited (ICT): computers was to be the market of the future, but tabulating machines was very much the market of the present.

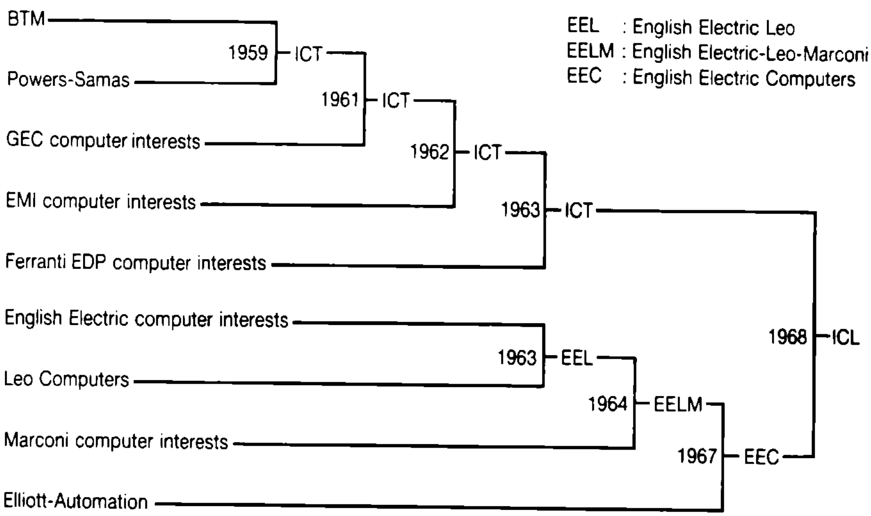
The Escalation of R&D, 1959-64

The single event that transformed the market for computers was the launch of the IBM model 1401 in October 1959. IBM's new "second generation" computer substituted transistors for electronic tubes, and was consequently an order of magnitude cheaper, faster and more reliable. More than that, however, the IBM 1401 was a complete data-processing system that only a company of IBM's resources could have produced: the computer was equipped with an integrated set of peripherals, mass-storage devices, and comprehensive operating and applications software, all of which were superior to that of the competition. IBM had originally planned to sell on the order of one thousand machines, and was itself taken by surprise when it went on to sell over ten thousand. In 1962 IBM's computer sales overtook its punched-card machinery sales, and the 1401 became its single most important product [2, pp. 465-74].

The 1401 completely changed the nature of the computer market, from one in which high-priced machines sold in small numbers, to one dominated by medium-priced EDP business machines selling in their thousands. To succeed in this new market, the British companies had to develop the appropriate organizational capabilities: EDP-computer R&D and volume manufacturing, effective marketing to the business community, and applications software.

Each manufacturer had to decide whether to invest in these new capabilities, or sell-off its computer operations. Clearly ICT, if it was to stay in the office-machine business as a competitor to IBM at all, had no option other than to become a mainstream EDP-computer manufacturer. Although ICT had strength in electromechanical R&D and manufacturing (inherited from its punched-card machine business), as well as strength in marketing and applications development, it urgently needed to improve its electronics R&D and manufacturing capabilities. On the other hand, the electronics firms, who *did* have these capabilities, had three choices: to stay in the mainstream EDP computer business and develop a marketing organization and applications software; to retreat into a niche market; or to withdraw completely from making computers. One by one the firms made their decisions (Figure 1). First, GEC, EMI, and then Ferranti, decided to withdraw from the computer business; in each case, ICT was an enthusiastic buyer of their computer R&D staff and manufacturing plants. Both English Electric and Elliot Automation decided to remain in the computer business. English Electric, which was a multidivisional firm far larger than ICT, decided to invest heavily in its computer division; it took over Marconi's computer operation and bought out Leo Computers Ltd, which had a small but capable sales and applications experience in the EDP computer market. This left English Electric with a very strong R&D and manufacturing capability, but still rather weak in sales and applications. The third firm, Elliott-Automation, decided to retreat to a niche area making small process-control computers.

Figure 1 Evolution of ICL, 1959-68



Thus in 1964, Britain had essentially two competing firms in EDP computers, ICT and English Electric. Both firms had a motley collection of computer models acquired from their take-overs, and were developing plans to rationalize and modernize their product lines towards the end of the decade. However, in April 1964, IBM astounded the computer world by announcing an entirely new third-generation product line, System/360, which was to replace all of its existing computer products [12; 6, pp. 101-42]. IBM had recognized in 1962 that, in supporting several different computer models, its R&D operation—especially for software—was expanding more rapidly than the market. The new range of computers addressed this problem by having a single "architecture" which would achieve scale economies in R&D, software development, and manufacturing. The R&D cost of System/360 was estimated at $500 million, which was more than the annual turnover of any of IBM's competitors. Despite the scale of the new product launch, all the evidence is that it took the rest of the industry entirely by surprise. Every one of IBM's competitors now had to respond very rapidly. In the U.S. some firms, such as GE, Univac and Burroughs, made tactical responses by *ad hoc* transformations of existing products into computer ranges, while others, such as RCA and Honeywell, embarked on the full-scale development of computer families directly competitive with System/360.

In Britain, ICT opted for the first, tactical, strategy. The firm took its best existing second-generation machine, and introduced larger and smaller models to turn it into a range. This approach required an order of magnitude less R&D funding than the launch of a completely new range, and by eliminating hardware R&D, the company was able to focus on the development of software and applications. Thus, the company saw System/360 as essentially a marketing challenge rather than an R&D challenge. By contrast, English Electric decided in the autumn of 1964 that it would develop its own third-generation range of computers. However, when the enormity of the System/360 challenge came into perspective, it decided to make use of a long-standing licensing agreement with RCA and make the latter's third-generation range under license.

The Technology Gap and the Formation of ICL, 1965-68

ICT's low-key R&D (however commercially justified), and English Electric's dependence on U.S. R&D, was emblematic of a deep-seated technology gap between the United States and Europe, that was shortly to become a highly charged political issue.

When, in October 1964, Harold Wilson's Labor Government came into power, one of its first acts was to establish a Ministry of Technology (MinTech), envisaged as an organization to "guide and stimulate a major national effort to bring advanced technology and new processes into British industry" [4, p. 246]. Wilson 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 [4, p. 246].

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. Initially, both companies were unresponsive to the government's overtures. This was partly because they had both embarked upon their new third-generation ranges, which had now passed the point of no return. In addition they were both experiencing a temporary surge of confidence from their new product plans, and the prospect of merging with a partner they considered commercially inferior was not attractive—ICT viewing English Electric as lacking marketing capability, and English Electric viewing ICT's computer R&D as weak.

Outside of the companies, however, the gloom over the technology gap was sweeping across Europe. In 1966, France launched its Plan Calcul to foster a national-champion computer firm [11], and the British and French shortly embarked on the *Concorde* project to revive their ailing aerospace industries. The mood of the time was admirably captured by J.J. Servan-Schreibers' *The American Challenge*, which was a best seller in both countries [15].

On 31 March 1966, Wilson's Labor Government was re-elected with a safe 97 seat majority, ever more determined to revitalize Britain's industrial base. The Ministry of Technology was expanded and given new powers, while an entirely new organization The Industrial Reorganization Corporation (IRC), was created with the power of "promoting industrial efficiency and profitability and assisting in the economy of the U.K." [7, p. 189].

The MinTech commissioned an independent report on the British computer industry, and by spring 1967 the ICT-English Electric computer merger was back on the agenda. MinTech took the view that the central issue facing the industry was the development of a new range of computers which would be competitive with whatever new range IBM introduced in the early 1970s. As an inducement for the companies to merge, the government offered a grant of £25-30 million to assist in the new-range development costs.

Ironically, by this date ICT's market-driven, low-key R&D strategy had proved highly effective, and the company was experiencing its best-ever profits. However, the R&D beast was about to be woken from its slumbers, for a new managing director (Basil de Ferranti—a member of the Ferranti electrical engineering dynasty) had been appointed. The new R&D strategy was that the company had to develop a world-class range of computers in order to stay in the EDP computer business; and to support that R&D it had to drastically increase its scale of operations. Meanwhile, as ICT's fortunes improved, those of English Electric computers were declining. It was losing money heavily in its third-generation computer development, and was now anxious to exit from the industry on the best terms it could get. In August 1967 the two firms agreed to merge in principle, and it merely remained to hammer out the financial terms. This was to take several months, and the delay proved disastrous.

During the autumn of 1967, the U.K. economic climate had worsened dramatically, culminating in the devaluation of the pound sterling 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$^1/_2$ 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. ICL was the largest non-American computer manufacturer, with a workforce of 34,000.

R&D versus Management Capabilities, 1970-82

The need for Britain to maintain an R&D capability in computers had both economic and emotional causes. Clearly there were economic benefits such as the balance of trade and the need to maintain employment in high-technology manufacturing. But these needs could just as easily have been met by the presence of multi-nationals such as IBM, NCR and Honeywell—all of which had U.K. plants and positive trade balances. The emotional reasons were connected with national security and prestige. To quote a Ministry of Technology memorandum:

> To fail to produce an indigenous industry would expose the country to the possibilities that industrial, commercial, strategic or political decisions made in America could heavily influence our ability to manufacture, to trade, to govern or to defend [9, p. 227].

An indigenous R&D capability in computing effectively meant ICL's R&D. Although the importance of maintaining this national R&D capacity oscillated with different governments in the 1970s and 1980s, it was always a shotgun that ICL could hold to the head of the reigning government.

ICL started out in 1968 with both a mission and a legal obligation to develop a new range of mainframe computers that would be competitive with those of IBM. This fixation on mainframe computers was, in the early 1980s, to be ICL's downfall, just as in the early 1990s it was to become IBM's. For ICL's R&D division, the new-range development was a once-in-a-lifetime opportunity that was eagerly grasped, and soon had an inertia that over-rode ordinary commercial prudence. Only in its best trading years did ICL manage to keep its R&D/sales ratio to the industry norm of around ten percent. This made the company's R&D extremely vulnerable to any economic downturn, since it could only eliminate short-term losses by cutting back on R&D, which was essentially the only non-revenue generating part of the business it could retrench.

In 1970-71, the worldwide computer industry was hit by a major downturn that caused, for example, General Electric and Honeywell in the U. S. to withdraw from the computer business entirely. By 1971 ICL was experiencing a major loss of orders and turned to the government for help. By this time the Conservative Government of Edward Heath had come to power in Britain, and it was firmly opposed to any form of government intervention. However, reports from a Parliamentary Select Committee on the computer industry, the government's own Central Policy Review Staff, and the independent Rothschild Report, unanimously recommended that the government should make a further R&D subvention [3, pp. 131-33]. The government took the view, however, that whatever the case for R&D support, ICL's financial problems were largely due to a failure of management. In terms of the theory of economic capabilities [10], ICL had failed to effectively coordinate its organizational competences in response to the evolving computer market, an ability that is always implicit in Nelson and Winter's *Evolutionary Theory*, but—in ICL's case at least—needs to be regarded as an explicit capability, which I can only call "prudent management."

Thus, as a condition of government R&D loans, a new management team was brought in from the American Univac company in 1972. Under the new American regime, ICL developed financial management capabilities to match its R&D capability. For example, new products with low R&D inputs were developed, some of them made under license, which sustained ICL's revenues as the market began to switch from mainframe computers to small business systems. However, the primary objective of maintaining the R&D on the new range of computers was never really questioned. The new range was finally launched in 1976; it was a technological triumph in architectural and software terms, although it was never sufficiently profitable to justify the R&D costs.

In 1977, after a five-year reign, the American management team left the company and a new insider managing director was appointed. Almost overnight, financial prudence vanished and the R&D beast once again took control of the firm. But by now the competition was coming from Japan, as well as from IBM. The entry of the Japanese into the computer industry had produced a further escalation of R&D costs, especially in semiconductor fabrication. Product lives of mainframes had shortened to three years, and ICL's own semiconductor plants had become uneconomic. The new management team embarked on a high-risk dash for growth of 20-25 percent a year to match the escalation of R&D costs.

Catastrophe was not long in coming. The monetarist government of Margaret Thatcher had come into power in May 1979 determined to conquer inflation, and within a year of taking office the country was in the grip of its worst post-war recession. By early 1981, ICL was losing £50 million a year on a turnover of £1 billion. Once again it turned to the government for help. Although the Thatcher Government was doctrinally non-interventionist, ICL was fortunate that the government had just launched an information technology initiative—"IT82"—which made the bankruptcy of ICL politically unacceptable. The government leaned on the British clearing banks to loan ICL £200 million to sustain it during a major restructuring under new management. Once again an American-trained management team was brought in—this time from Texas Instruments—which set out on a path of "creative destruction" [10] of ICL's organizational capabilities.

The single most important contribution made by the new management team was to recognize that ICL's R&D had become completely detached from the markets for its products. An analysis of the company's R&D spending revealed that mainframes which consumed 70 percent of R&D, accounted for only 30 percent of its profits. A complete reorganization of the R&D division was undertaken, breaking it up into cost and profit centres. But most significantly, the new management recognized that it could no longer compete with the Japanese in semiconductor manufacture, and a licensing arrangement was made with the Japanese Fujitsu Company to obtain access to its semiconductor technology. This eliminated a huge R&D and manufacturing burden.

Conclusion

In November 1990, ICL was taken over to become a wholly owned subsidiary of the Fujitsu Corporation. The takeover came as a minor national shock, although industry watchers were well aware that ICL had long given up its role as a national R&D champion following the 1981 government rescue. Less widely appreciated was the fact that ICL had retreated from manufacturing far more than it had given up R&D—it had withdrawn not only from semiconductor production, but had also given up most of its electromechanical and electronics manufacturing, obtaining components from the cheapest source and reconfiguring them into computer systems with much higher value-added potential. By reducing its commitment to mainframe R&D and by eliminating the inertia of owning its own manufacturing plants, ICL was positioned to respond much more rapidly to the non-mainframe-based IT market of the 1980s. In order to broaden its market share, ICL also refocused on developing industry-specific software applications. In effect, a new set of organizational capabilities for the 1990s had been put into place: prudent management, vertical marketing, and applications knowhow had come to the fore; while systems integration had replaced manufacturing; and the R&D beast has been turned into a poodle.

References

1. Geoffrey D. Austrian, *Herman Hollerith: Forgotten Giant of Information Processing* (New York, 1982).
2. Charles J. Bashe *et al.*, *IBM's Early Computers* (Cambridge Ma., 1985).
3. Tessa Blackstone and William Plowden, *Inside the Think Tank: Advising the Cabinet 1971-83* (London, 1988).
4. Martin Campbell-Kelly, *ICL: A Business and Technical History* (Oxford, 1989).
5. Saul Englebourg, *International Business Machines: A Business History* (New York, 1976).

6. F. M. Fisher, J. W. McKie, and R. B. Mancke, *IBM and the U.S. Data Processing Industry* (New York, 1983).
7. A. Graham, "Industrial Policy", W. Beckerman, ed., *The Labor Government's Economic Record: 1964-1970* (London, 1972).
8. John Hendry, *Innovating for Failure: Government Policy and the Early British Computer Industry* (Cambridge Ma., 1989).
9. Stuart Hodges, *Multinational Corporations and Government: A Case Study of the United Kingdom's Experience, 1964-1970* (Farnborough, England, 1974).
10. Richard N. Langlois, and Paul L. Robertson, "Business Organization as a Coordination Problem: Toward a Dynamic Theory of the Boundaries of the Firm," *Business and Economic History*, 22 (Fall 1993).
11. Pierre Mounier-Kuhn, "Bull: A World-Wide Company Born in Europe," *Annals of the History of Computing*, 11 (1989).
12. Emerson W. Pugh *et al, IBM's 360 and Early 370 Systems* (Cambridge Ma., 1991).
13. Richard R. Nelson and Sidney G. Winter, *An Evolutionary Theory of Economic Change* (Cambridge, Ma., 1982).
14. Arthur L. Norberg, "High-Technology Calculation in the Early 20th Century: Punched Card Machinery in Business and Government," *Technology and Culture*, 31 (October 1990).
15. J.-J. Servan-Schreiber, *The American Challenge* (London, 1968).