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The entry of established electronics companies into the early computer industry in the UK and USA.

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PhD.

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Abstract.

This thesis studies the efforts of a number of large electronics firms to enter and survive in the computer industries of the USA and Britain, from the Second World War to the early 1970s. It contrasts the relative failure of these firms with the greater ability to survive in this sector displayed by single product business machine companies and a number of new, start up, computer firms.

The potential advantages that the multi-product electronics enterprise should have had in the new computer market are seen to have been outweighed by these firms being over burdened by the very scope of their operations. Their efforts to cover the whole electronics industry, rather than concentrating on a few sectors, mitigated the potential that they had.

A number of case studies of such firms, both British and American, form the heart of this study. The main studies are:-

UK: Ferranti, Electrical and Musical Industries and
English Electric.

US: Radio Corporation of America, and General Electric.

To contrast the strategies and structures of the electronics combines, a number of short studies are made of British and American business machines and start-up companies:

UK: International Computers and Tabulators.
US: International Business Machines,
and shorter studies on Burroughs, Control Data Corp.,
Digital Equipment Corp., Honeywell, National Cash
Register, and Sperry-Rand.

Study of the electronics firms in the computer industry sheds light on the overall weakness of the broad-based, multi-product, British and American electronics company in the electronics industry as a whole.

There is also some comment on the roles of the two governments in shaping the computer industry.

Acknowledgements

A Ph.D. is often seen as the ultimate in individual effort. The reality is that little can be achieved without the help and guidance of others. This thesis owes much to the time and effort that my supervisor, Professor Leslie Hannah, put into guiding me. His excellent commentary on the many essays and draft chapters and his amiable encouragement made the completion of this work possible. Many others in the Department of Economic History have also contributed, especially Linda Sampson. At the start of my research the staff of the London School of Economic's Business History Unit offered every help possible.

I owe an equal debt of gratitude to everyone at the University of Minnesota's Charles Babbage Institute. Their generosity in awarding me the Erwin and Adelle Tomash Fellowship allowed me to go to the Institute and work in what must surely be the world's premier centre for the history of computing. Professor Arthur Norberg gave me encouragement in my work. Much of the archival work I have done was at the Babbage Institute, the stalwart help of the archivist Bruce Brummer and his assistant Pat Hennessey helped me to look at material no other British researcher has had site of. Again the administrative staff, especially Judy Cilcain, were very helpful, particularly in overcoming the many the difficulties in employing an overseas researcher.

My UK research was made possible by the very kind support of a number of people and organisations. The archivists at the Institute of Electrical Engineers gave me invaluable help while I researched the documents of the National Research and Development Corporation. Cliff Wimpenny helped me with material in the Ferranti Archive, while I also received valuable help in the Marconi Archive. An excellent source of material was made available to me by Dr John Hendry, who allowed me to use interview notes he had made while he was researching the computer industry, together with some letters and papers he has collected on the subject, these proved invaluable in my studies of EMI.

Special thanks go to Dr Geoff Tweedale, who not only helped with my research at the National Archive for the History of Computing, but also read through a substantial part of my thesis and gave me some valuable comments. John Armstrong of the Polytechnic of West London helped with comments on a number of chapters. Francesca Carnevali, Dr Paul Johnson, Dr Bob Humphreys, John Hickson, Dr Peter Howlett, Rob Keam and Adam Tooze also helped with the sub-editing of this work.

My thanks go to my mother and brother who have put up with the rather idiosyncratic life style of a Ph.D. student.

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Concluding Remarks.

Glossary of terms.

APL: (GE's) Advanced Product Line

ADG: (RCA's) Advanced Development Group.

BoT: Board of Trade.

CBI: Charles Babbage Institute, University of Minnesota.

CDC: Control Data Corporation.

COBOL: COmmon Business Orientated Language, US military language which became standard for business applications.

(Magnetic) (Ferrite) Core Memory: core memory was the major random access fast computer memory used up until the introduction of semiconductor memory in the early 1970s.

CSD: (RCA's) Computer Systems Division.

DEC: Digital Equipment Corporation.

Delay line: a first generation computer memory using loops of nickel or mercury to data as either a loop of electrical impulses or in acoustic waves in a mercury bath.

Diode: discrete electronic component usually thought of as a second generation device made out of semiconductor material. However, first generation diode valves were a common device.

(Magnetic) Disk Memory: the most important form of mass computer storage, a technology dominated by IBM.

(Magnetic)Drum memory: the first magnetic storage device, an extremely large device which stored small amounts of data in the same way as a fixed disk. It had the advantage of very fast access time.

EMI: Electrical and Musical Industries.

ERA: Engineering Research Associates, became a part of Remington (Sperry) Rand.

FORTRAN: standard engineering and science language, developed by IBM.

GE: General Electric (America).

GEC: General Electric Company (Britain).

IC: Integrated Circuit, third generation electronic component, a number of components on a single semiconductor wafer.

LSI: Large Scale Integration, refers to density of components on an integrated circuit.

MinTech: Ministry of Technology.

MIT: Massachusetts Institute of Technology.

MSI: Medium Scale Integration.

NCR: National Cash Register.

NAHC: National archive for the history of computing (UK).

NRDC: National Research and Development Corporation (UK).

ONR: Office of Naval Research (USA).

Operating System: the control program of a computer.

RCA: Radio Corporation of America.

Real-Time: a computer used to interact with a number of peripherals simultaneously to offer nearly instant response, such as a ticket booking application.

(Magnetic) Tape Drive: The standard form of mass data storage, its great weakness is that information has to be stored sequentially making access very slow, thus the move to disk technology.

Time-Sharing: method by which a number of users can simultaneously run their own programs on a single computer.

Transistor: second generation electronics, individual electronic component made out of semiconductor material.

USAF: United States Air Force.

Vacuum tube: first generation electronic component.

Valve: same as vacuum tube.

VLSI: Very Large Scale Integration.

Williams Tube: first generation computer memory storing data in a cathode ray tube, used in early Ferranti and IBM machines.

Notes on archival references.

A number of archival sources form the basic raw material of this thesis. The reference format used for the various collections will be outlined here (for firther information see Bibliography).

The major British source used is the National Archive for the History of Computing's collection of the papers of the National Research and Development Corporation. The format of these references is:

NRDC 86/box number/file number.
i.e. NRDC/86/31/5.

Other papers from the National Archive use the appropriate collection number:

NAHC/collection reference/paper reference.
i.e. NAHC/Fer/b1.

The major source of material in the US half of the thesis is the Charles Babbage Institute's collection of the records of the anti-trust case, US vs IBM. There are two major sources within this body of material. The first are the exhibits that were lodged with the court as supporting evidence. The format of the reference to this are:

US vs IBM, px*** or dx***.
px=plaintiff's exhibit: dx=defendants exhibit.
i.e., US vs IBM, px344 or US vs IBM, dx3453.

The second sub-sector of material is the collection of the transcripts of the examination of witnesses. Here the format of the reference will include both the page number of the transcript and the name of the person giving evidence:

ie US vs IBM, tr2420, Beard,

A second major source of material from the CBI archive is the collection of papers donated by General Electric engineer George Jacobi. The format of these references is:
CBI Jacobi Collection, (description of material)

The many other sources used are individually annotated.

Chapter 1

Studying the electronics and computer industries.

For an established industrial power like the United Kingdom, maintaining its economic standing in the world depends on either preserving its competitive advantage in established industries, or using its economic power to develop new industries and markets. In traditional industries Britain has been losing market share for many decades. Even in the early part of the century declining world market share was the trend in many industries including coal mining, shipbuilding and textiles, to name but the classic examples. Since then, relative decline has spread to most of Britain's older manufacturing industries.

In itself this does not matter to the overall manufacturing strength of a country. Past profits from the older sectors could have been invested in new industries. The pace of technological change in the twentieth century has been astounding. This has meant that the leading industries have changed. Many of the world's top companies now come from the ranks of the automobile, electronics, pharmaceuticals, and aerospace industries, industries that barely existed before the 1914-18 war. Leadership in these industries would more than make up for relative decline in older sectors. Britain was undoubtedly well placed to exploit these new industries, after all Britain had on call the resources accruing to it from having been the world's most powerful nation. Indeed in many of the new industries Britain was one of the great innovators, but it has not been able to build on its early position and has seen relative decline even in newer technologies.

The purpose of this thesis is to take one of these sectors, and to examine its internal structure to see if there was any deficiency which could explain the lack of success. The broad area chosen is the electronics industry. In many respects this is strategically the most important industry in the world. Electronics are now all-pervasive, not only forming the core of electronic products, but also performing the control functions of much of industry and providing the information needed for the service sector of the economy. Successful application of electronics technology is vital to improving competitiveness in new and old industries; it is at the heart of competition between manufacturing nations. This consideration has led many countries to use state intervention to underpin their electronics industry. France is the current leader in this trend, having state support for both the computer and electronics industries, and is trying to create a nuclear-power-to-microchip, state-backed conglomerate. Whether or not state support is appropriate[1], it does show that weakness in the electronics sector is seen by governments as fundamental.

Before 1939, Britain was able to compete with the United States in most areas of electronics. For example, it was the UK that first commercialised television[2]. After the war, Britain was the USA's only serious competitor in electronics. Indeed many of the most important electronics innovations had been developed in Britain to aid the war effort. From this position of relative strength, the UK's position has slipped, which is not surprising as other countries were bound to catch up. However, the UK's overall loss of competitiveness is excessive. In 1963 the UK had a positive balance of trade in electronics, amounting to £105.7m. By 1982, this had become a negative balance of -£1,504m[3]. In 1982 one of the largest negative features was electronic consumer goods at -£922m[4], a figure recently counterbalanced by Japanese inward investment into low wage districts of Britain, producing televisions for the European market. While this is useful, many of the skill based activities of R&D, design and marketing remain outside the UK.

The UK has fared better in some areas. In 1982 the capital electronics and the scientific instruments sub-sectors posted trade surpluses of £227m and £78m respectively[5]. Capital electronics is dominated by military production, the major strength of Britain's large electronics companies. However, in two other areas, both of which directly underpin productivity elsewhere in the economy, the UK has seen a major fall in competitiveness. In the field of active electronic components the UK is running a significant trade deficit[6]. Almost all mass produced large scale semiconductors manufactured in Britain are made by satellite factories of overseas firms; British companies have tended to concentrate on specialist chips, mainly used in military products. In the field of

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[1]It is the general conclusion of this thesis that increasing conglomerate size and scope does not necessarily lead to greater market power.

[2]See below, chapter 3, p101.

[3]L. Soete and G. Dosi, Technology and Development in the Electronics Industry, 1986, p67.

[4]Ibid p67; see also E. Arnold Competition and technical change in the television industry, 1982. This gives an outline of Britain's declining fortune in the consumer electronics industry.

[5]Soete and Dosi, Technology and Development, p67.

[6]F. Malerba (The Semiconductor Industry, Madison, Wisconsin, 1985) outlines the inability of Britain to maintain its position in this market.

computers, the trade deficit has grown significantly. From being the only competitor to the US computer industry, Britain's position has collapsed.

The following graphs show the deterioration in this trading situation. Figure 1.1 gives an estimate of how the balance of trade in electronics deteriorated in the early 1970s. This was mainly due to the end of the UK's isolation from the world consumer electronics trade, following the adoption of the PAL colour television system, which replaced the UK's unique black and white system. However, Figure 1.2 shows that computers were already a significant contributor to the electronics trade deficit:

Figure 1.1

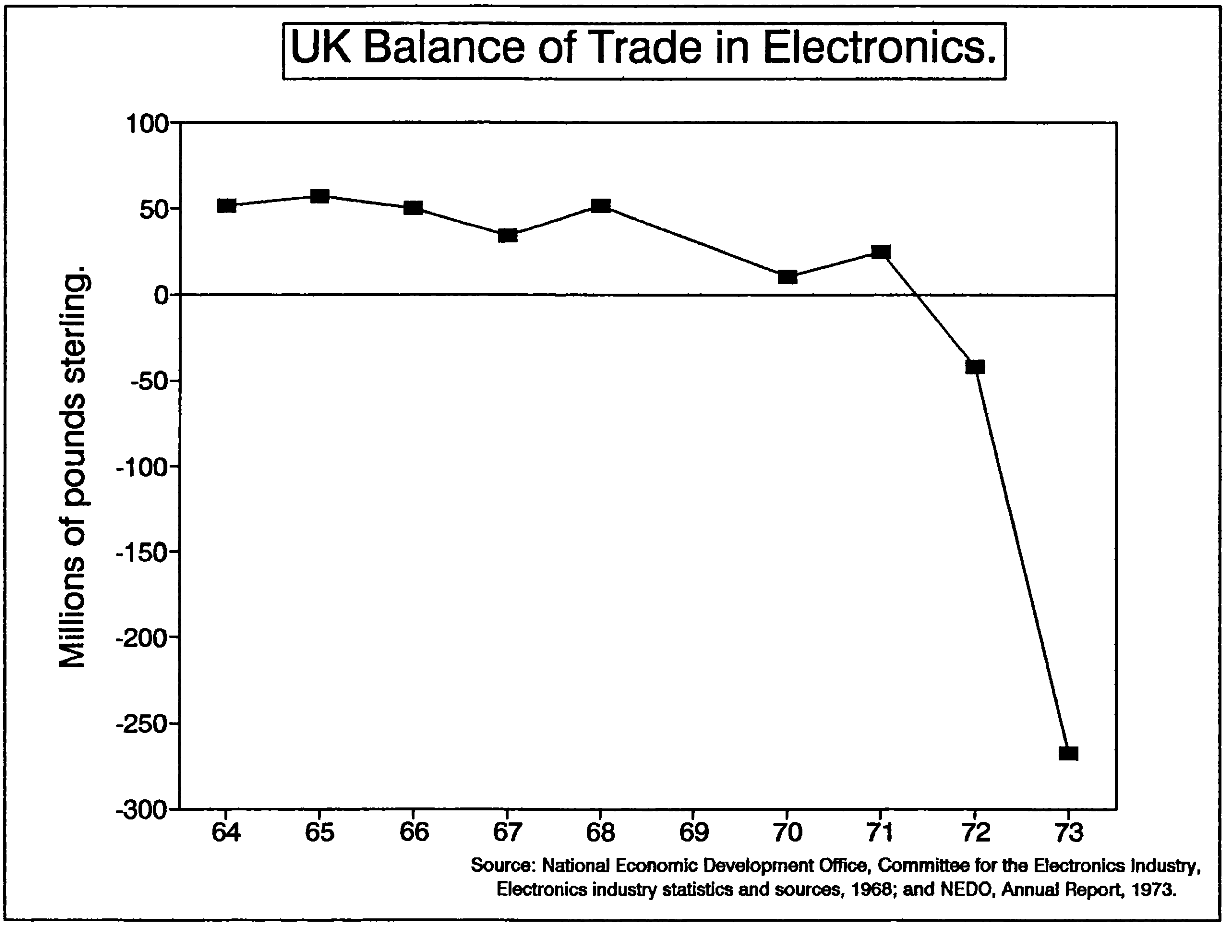
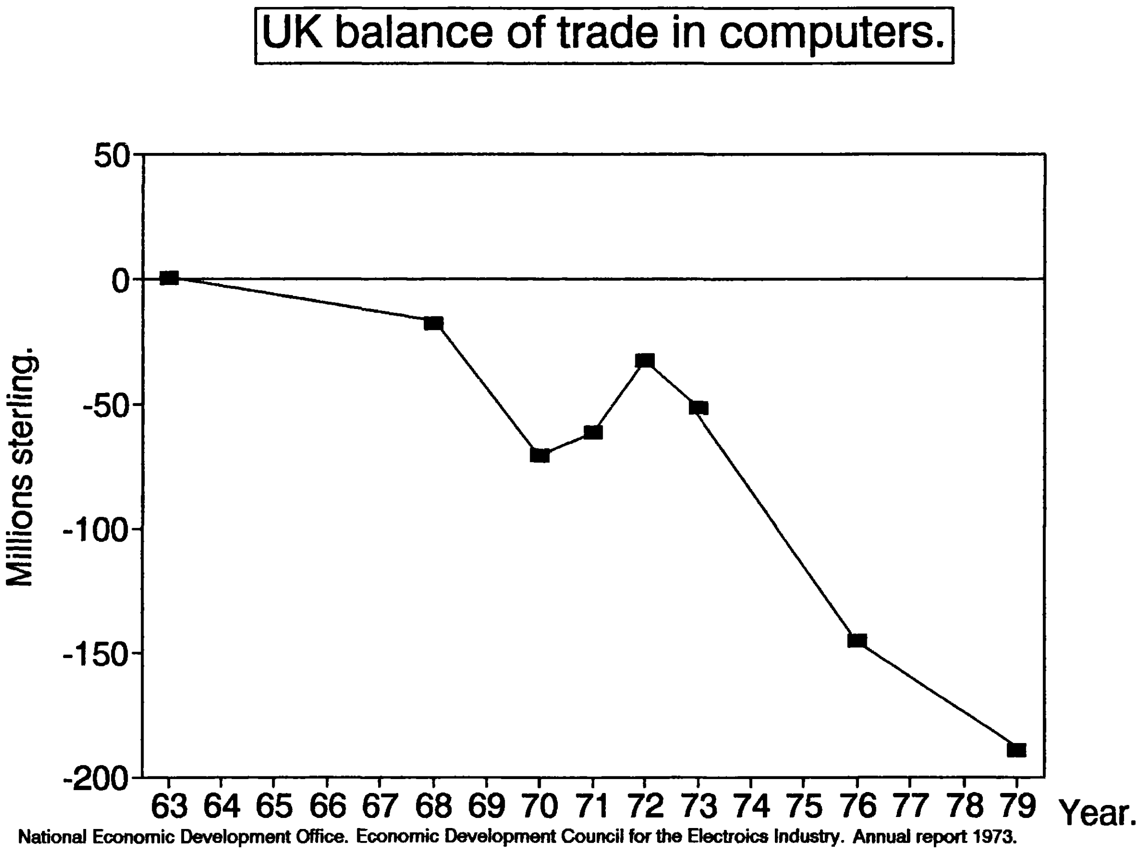

UK Balance of Trade in Electronics.
Millions of pounds sterling.
100
50
0
-50
-100
-150
-200
-250
-300
64
65
66
67
68
69
70
71
72
73
Source: National Economic Development Office, Committee for the Electronics Industry, Electronics industry statistics and sources, 1968; and NEDO, Annual Report, 1973.

Figure 1.2



National Economic Development Office. Economic Development Council for the Electroics Industry. Annual report 1973.
Additional data; L.Soete & G.Dosi, Technology and development in the electronics industry, 1986, p67.

To aid policy makers to assess whether this trade deficit in electronics has been important, it is necessary to know how it occurred, whether the trend is reversible, and whether past policy has contributed to the problem or has slowed down the loss of world market share. Only then can the weakness be assessed in the context of the whole British economy.

An initial look at British industry shows that the failure of the UK in the consumer, component and computer markets is linked via the same group of companies. Equally, the same firms that showed weakness in these three sub-sectors, were also the ones to show greater resilience in military, capital and telecommunications technologies.

The UK market for electronics has tended to be dominated by large, multi-product electrical/electronic combines. Almost every electronics technology was introduced to the UK by the large generalist electronics companies. Up until the 1970s, firms such as AEI, EMI, English Electric, Ferranti, GEC, and Plessey dominated almost every electronics market. There was also a second level of firms which, though more reliant on a single market, also tried to expand into other aspects of electronics; examples were Elliott Automation, Decca and STC.

By the 1990s, much of the industry had been merged into a single major conglomerate, GEC, with particular strengths in defence and capital electronics, together with a significant stake in the UK's leading telecommunications and electrical engineering companies. Around this single firm are a few smaller companies with a base in the same markets, RACAL, STC and Thorn-EMI, being the prime examples. However, the consumer electronics industry is now controlled by foreign multi-nationals. The computer market is dominated by foreign computer specialist plus the UK-based, but Japanese controlled, ICL. Standard electronic components are also now produced (or sold) in the UK by overseas specialist firms.

The question therefore begins to shift: away from whether the UK has been particularly weak in certain areas of electronics, to whether Britain's multi-product electronics companies have been the main cause of the UK's declining competitiveness in the electronics market? The weakness in certain areas of the electronics industry coincides with the withdrawal of the multi-product combines into core, protected product areas. Strength and safety seems to have been synonymous with the defence and telecommunications markets, both of which have been isolated from international competition. Commercial strength in capital electronics is a spin-off from the military electronics fortes of these companies.

If such a hypothesis is true, then in order to understand why Britain has slipped from near duopoly with the USA to being an 'also-ran' by the

1990s, the workings of the broad-base electronics corporation has to be understood. This must be framed within the context of how other corporate structures have performed in the electronics market. Many mass produced, commercial products, such as integrated circuits and computers, became dominated by specialist organisations which displaced the generalist producers, not only in the UK but also in the USA; most of these specialist producers came from the USA.

However, a comprehensive study of electronics corporations is not easy. Information on these organisations is sparse. To understand how they operated in the market, and how they evaluated investment opportunities, requires detailed internal information. Archival records are a problem in many industries; in the electronics industry documents covering the business operations of the firms are not usually accessible to academics. Few companies admit to having archives and those that do do not encourage access. At the time of this research, Ferranti and Marconi stood out by having archives-cum-museums. These are useful sources, but they emphasise the proud technical history of the companies and their notable founders, rather than having a great amount of operational information.

Research into the electronics industry is particularly difficult for a number of reasons. The withdrawal of many of these firms into defence contracting is used as an excuse to compound the usual reluctance in Britain to allow access to records. Security is used as a convenient excuse. An industry which can be perceived as being comparatively unsuccessful will not want close scrutiny by academics. Firms recognise that studies of the post-war electronics industry may not be wholly complimentary.

Nevertheless, study of the industry is possible. It is feasible to take one sub-sector of the industry and gather enough information from disparate sources to produce a worthwhile study of this single area. The study can look at the relative success of different types of company in the sector and can be used to see if the same patterns are found in the same sector in other countries, and also whether the same pattern can be expected in other parts of the industry.

One sub-sector which can be used to study the operations of these multi-product electronics firms, and which also offers a chance to contrast their methods to those of more specialist companies, is the computer market. This was one of the key post-war industries, being one of the driving forces behind economic growth since 1945. It was an area in which electronics companies tried unsuccessfully to establish themselves as major producers. There were also a number of other types of business in this sector to compare with the electronics companies. Additionally the British experience can be compared with the experience of companies in the world's largest market for computers, the USA. The US information gives further insight into the industry in general and the methods employed by broadly based electronics companies; the weakness of the concentrically diversified electronics company seems consistent in both countries. The greater availability of information in the USA allows for more in-depth study of the electronics firm, as well as allowing an opportunity to investigate more successful business forms.

Material available on the British and American companies in the computer market.

The sources of information available in Britain and the United States vary a great deal. In Britain the information is dispersed and fragmentary, although the establishment of the National Archive for the History of Computing (NAHC) in Manchester University has improved the situation. The starting point for studying these companies was the company annual reports and the business and trade press, the aim being to ascertain which firms were active in the industry and what they were marketing. However, these sources only give an external view. The NAHC has product literature and some archival material collected from individuals who were in the industry. The NAHC also holds a copy of a private paper written by the computer sales manager of Ferranti. This forms a nearly complete history of the Ferranti Computer Department[7]. However, the NAHC's most important asset is the archive of the National Research and Development Corporation, previously held by the Institution of Electrical Engineers. The NRDC helped to fund many of the computer activities of the British electronics companies. Its aim was to underpin the UK's technological and industrial base by encouraging the development of new technology-based products. The NRDC's relationship with the companies that it funded, and its involvement with the industry, can be studied through these archives. This gives some insight into how the firms that were supported worked. An excellent history of the NRDC's involvement in the computer industry already exists[8] and uses much the same sources. John Hendry has also carried out interviews with leading figures involved in the computer industry, a resource that has

[7]NAHC, B.B. Swann 'The Ferranti Computer Department', private paper prepared for the Manchester University Computer Department, 1973.

[8]John Hendry, Innovating for failure: Government policy and the early British computer industry, Cambridge, Massachusetts, 1989.

been made available for this thesis.

Another interesting source is the collection of seminar papers held by the London School of Economics, from the Edwards and Townsend series of talks given by leading industrialists on the organisational history of their companies[9]. A number of electronics companies were included in this series. Useful information on specific points can also be gleaned from the archives of Ferranti and Marconi.

Outside the electronics industry, the records of the British business machines firms that were merged into International Computers and Tabulators, which then went on to form International Computers Limited, have been made available to academics. Martin Campbell-Kelly's history of that company[10] is a significant source for the chapter on ICT.

Further information on the British industry is available in the United States. The Charles Babbage Institute (CBI) in the University of Minnesota has a collection of product data on British computers. In common with the NAHC in Manchester, it has copies of the computer sales statistics compiled by Computer Consultants Ltd in the 1960s[11]. It also has a collection of American investment appraisal documents that cover the computer industry. Of these, the bi-weekly publications of International Data Publishing[12] prove a useful source of information on the UK as well as the USA, especially after the launch of its European appraisal paper[13]. A real bonus in analyzing the UK computer industry is the CBI's copy of a large and comprehensive evaluation document prepared by the London Branch of the United States Navy's Office of Naval Research[14]. This document seems to have been an assessment of the British industry carried out to evaluate competition to the US industry, though this is not

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[9]London School of Economics, archival collection, 'Seminar on the problems in industrial administration'.

[10]Martin Campbell-Kelly, ICL: a business and technical history, Oxford 1989.

[11]Computer Consultants Ltd, British Commercial Computer Digest, 1963 and 1965.

[12]International Data Publishing Co. EDP Industry (and Market) Report, Newtonville, Mass., published from 1964. The company name was changed in the late 1960s to International Data Corporation, and is commonly referred to as IDC.

[13]International Data Corp., EDP Europa Report, London, published from 1970.

[14]CBI Archive, J. Cowie, J.W. Hemann, P.D. Maycock, 'The British Computer Scene', Office of Naval Research Branch Office London, Technical Report, ONRL 27-67, unpublished, 17/5/67.

explicitly stated.

This pulling together of various sources is not such a problem in the United States. The CBI has been in existence for a number of years and has acquired a wide ranging collection. The trade press, regularly published investment reviews, and product literature are all readily available. As well as the aforementioned IDC publications, Moody's industry appraisals are useful[15], much more so than the standard trade press. The CBI also has a large oral history collection.

The most important asset that the CBI has for studying the business history of the industry is its near complete copy of the evidence and transcripts of the 1970s anti-trust case US v IBM. This is a vast body of information, some of which has already been drawn on[16].

The evidence from this trial can be used in a number of ways. This thesis has concentrated on the evidence and transcripts which were submitted during discussions of the roles played by the Radio Corporation of America and General Electric in the computer industry. A significant proportion of the business records of these companies were submitted to the court, both from the corporate level and the operational level. These records were used in the trial to argue that RCA and GE had been forced out of the computer industry by unfair competition from IBM. This information allows a very detailed study of their history in the computer industry and substantially improves our ability to understand why broad-based electrical/electronics companies were inherently fragile in the computer market. This material is also used to assess the different strategies adopted by the specialist US business machines companies compared to those adopted by the concentrically diversified electronics companies.

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[15]Moody's Investors Service Inc. Moody's Computer Industry Survey. New York.

[16]K.D. Fishman, The computer establishment, New York, 1981; R. Malik, And tomorrow the World? Inside IBM, 1975; F.M. Fisher, J.W. McKie, R.B. Mancke, IBM and the U.S. data processing industry: an economic history, New York, 1983. An early draft of this latter book was actually submitted as evidence in the case itself.

Themes and questions.

The aim of this thesis is to explain why large, multi-product, electronics companies did not succeed in their attempts to become major players in the computer industry. It draws upon as much archival material as possible and uses this to determine which corporate structures stood the best chance of success. Five major case studies on such firms are presented:

From the UK: Ferranti; English Electric; EMI
From the USA: RCA; GE.

There is also a shorter study of the more successful US firm, Honeywell, which is used to show an alternative approach to the new industry. Many other British and American electronics firms became involved in the commercial computer industry. Some of these had a moderately important role, including firms such as Elliott Automation, Plessey, Bendix and Philco. However, there is little information on most of these firms, or they have been excluded from the study because what information is available adds little to the analysis. The five major studies plus that of Honeywell cover the main electronics firms which made a major and structured attempt to capture a large market share.

Two chapters, one covering the UK and the other the USA, look at the businesses which outlasted the electronics firms in the industry, many of which still survive in one form or another in today's computer market. Some of these were established business machines firms, others were newly established companies specialising in computer technology:

Chapter 4: ICT/L.

Chapter 8: IBM; NCR; Burroughs; Remington/Sperry-Rand;
Honeywell; CDC; DEC.

This study looks at the development of the various types of firm over a period of twenty five years. While this is a relatively short period, even in the lives of many of the firms studied, in a world of ever accelerating technological change it covers the development of the mainframe computer from infancy through to near maturity. The study of any industry over such a period involves the understanding of numerous topics. Business historians, industrial economists and management scientists have all presented frameworks for analysis. A few of these themes are: the structure of the firm, the prospects for innovation in an oligopolistic market, the incentives to innovate, strategies to compete with a dominant market leader, multi-product company structures versus single product strategies, and resource allocation within the firm.

However, none of these themes should be viewed as fixed or dominant. As a market develops the relative importance of different features changes and the firms can react to this changing climate in a number of ways. As the computer industry developed, as briefly described below[17], the factors crucial to the success or failure of firms changed. This thesis comes to the conclusion that electronics firms coped less well with the commercial computer market than business machines firms; but it does not conclude that electronics firms were the weakest firms in the industry at every stage, nor that they had no freedom of action to deal adequately with this new industry if they had adopted different strategies.

The case studies presented below, basically divide the history of each firm into two stages. The first phase is the entry of the company into the new market. The second phase is the process of coping with the rapid growth in demand for computers - the phase when companies needed to develop a strategy to deal with both rapid growth and increasing competition in the market for computers. The important issues changed during this process and companies needed to adapt to this change.

Such arguments resemble the life cycle hypothesis[18]. Life-cycle theory argues that the factors causing change in an industry alter as it develops. This hypothesis suggests that change in an industry is initially driven by product innovation and that technological competition is based on the properties of the product itself. As the technology develops and the market expands, emphasis shifts to process innovations, the target being to produce the product more efficiently. Abernathy and Utterback concluded that innovation in an industry shifts from a fluid period to a static period[19]. In the initial stages of a new industry when the product is not completely settled on, there is room for further improvements to it. At this stage there may not even be a single view on what is the best format for the product. Competition and further innovation improves the product and shakes out the less successful product ideas, eventually reaching a point of near standardisation. This is the start of the static stage where technical competition is primarily focused on the efficient production of a known commodity, leading to greater emphasis on process innovation and

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[17]See below pp.35-43.

[18]M.E. Porter, <u>Competitive Strategy: Techniques for analyzing industries and competitors</u>, New York, 1980, chapter 8.

[19]W.J.Abernathy and J.M.Utterback, 'Patterns of industrial innovation', <u>Technology Review</u>, vol 9, 1978.

the growing importance of scale economies. The examples they used to show this development were the semiconductor industry[20] and the automobile industry[21].

The last section of this chapter outlines the growth of the computer market. Undoubtedly the market did change, as did the nature of innovation and the scale of production. However, it would be wrong to describe the technological basis of the product as stable, though by the early 1970s change had become more predictable. The focus of this thesis is how the firms altered their strategies to deal with the changing market and whether firms with different structures and strategies were better able to cope with changing conditions. Fundamentally, we want to know whether the different structures of the broad based electronics firms and business machines firms led to different strategies for dealing with the developing market.

The first question to consider in each case study is, how and why the firm entered the market for commercial computers. It is important to establish why a firm should divert resources from its other activities into a new technology. While this thesis is not about the scientific development of the computer, the technology had to be acquired by the firm; it cannot be assumed that a firm could produce a computer. Firms have actively to develop technology, or acquire those skills from elsewhere, if they intend to enter the industry. Two factors are looked at in some detail in the case studies. Firstly, it has to be established from where the technology came, especially whether the firm in question developed technology internally or whether it had to look for skills from outside. Secondly, given that the firms in question were able to acquire the necessary skills, the underlying decision to use these skills to build commercial computers has to be considered. There are two basic driving forces behind innovation: changes in market demand requiring firms to introduce new technology, or a push from technology itself which changes market supply conditions, or which makes it easier for outside firms to enter the industry.

In these sections, an attempt is made to decide the relative weight of incentives to enter the industry. A major question is whether the incentive for a firm to develop a commercial computer was driven by external factors, changing demand or the threat of new products from other

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[20]Ibid, the example used in Abernathy's and Utterback's article comes from J.Tilton, <u>International diffusion of technology, the case of semiconductors</u>, 1971.

[21]W.J.Abernathy, <u>The productivity dilemma: roadblock to innovation in the automobile industry</u>, Baltimore, 1978, chapters 4 and 7.

suppliers, or by the desire to diversify, based on internal factors, such as the internal availability of technology. This analysis takes into account the previous history of the company, the markets in which it already operated, its internal resources, and its propensity to undertake concentric diversification. It is not difficult to show that the incentive for the electronics firms and the business machines firms to develop computers was different. It is shown below that, after an initial period when the computer was used for enhancing scientific and engineering calculation, computers started to be used both to extend the possibilities of commercial automation and to replace the old data processing techniques. The business machines firms' main interest in computers was a measure of self preservation; they had to produce computers once digital technology started to replace the older types of business machines. However, some moved earlier than others and some were actually at the forefront of the new technology: a good example is Sperry-Rand[22]. This thesis investigates why there were leads and lags between the companies. The most important aspect of this was the attitude taken by the market leader, IBM, to the new technology and the way it entered the market is considered in chapter eight.

The same questions can be asked of the electronics firms. It is important to establish at what time in the industry's life the electronics firms tried to enter the market. A second issue is whether the managements' view of this new industry changed as both the market and the technology of computing developed. At what time did the corporation perceive the computer operation as a new business activity in its own right? This is an important issue and a number of case studies will point to the electronics industry making a major push into computers at a turning point in the technology and at a point when the market was becoming significant in size.

The question to be answered when looking at the business machines firms is: if the entry of these firms was different to the entry of the electronics companies, both in timing and rationale, did this lead to any substantive difference in strategy? An attempt is made to establish how the strategies of the business machines firms, which already had experience of the market for commercial automation equipment, differed from those of the electronics firms. A second issue, and one which is taken up in the conclusion, is whether the different entry motivations led to commercial computer technology being viewed differently at the corporate level[23].

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[22]See below chapter 8, pp358-367.

[23]See below, chapter 9, pp379-382.

The building of computers was an extension of the electronics firms' horizontal scope, an extension of the ways in which they exploited their core technology. There is some discussion in each chapter of where the product champions came from in this 'internal corporate venturing process'[24]. The position of the product champion is an important issue and greatly affects the political standing of divisions within a company, which in itself influences the likelihood of successful diversification[25]. It is important to establish whether the product champions of a new activity in the electronics firms, in this case those building computers, had as much influence as those representing older activities. This is vital in determining who had the most say in how corporate resources were allocated between different divisions. The single most important theme of this thesis is how the electronics companies handled this process of allocating limited resources between their many potential growth paths. This process of decision making is greatly affected by the political standing of the various divisions in each company, this political issue will be considered in the case studies and in the conclusion.

The rest of each case study looks at how the firms altered their strategies as the computer market grew. Growing scale and growing R&D expenditures increased the opportunity costs of staying in the computer industry, especially when this meant taking on one of the world's most entrenched monopolists, IBM. This thesis examines whether the strategies adopted by the electronics firms differed from the strategies of the single product companies that also competed against IBM. It also considers whether the electronics firms were helped or hindered by their structure and whether they were handicapped by legacies from their past.

A major theme in this thesis is the failure of vertically integrated and concentrically diversified British and American companies when faced with competition from firms that were concentrated on a single market segment. The development of the firm has been analyzed by Chandler[26] and

[24]R.A Burgelman 'Managing the internal corporate venturing process: some recommendations for practice', in, Strategic management of technology and innovation, R.A. Burgelman & M.A. Maidique eds, Homewood, Illinois, 1988, pp348-362.

[25]R. Rothwell et al, 'SAPPHO Updated - Project SAPPHO Phase II', Research Policy, 1974, vol 3, pp258-291.

[26]A.D. Chandler jr, Strategy and Structure, New York, 1966.

built on by Williamson[27]. The case studies consider the development of each firm and whether the structure of the electronics firms differed from that of the business machines firms. Channon's work on British industry illustrates a difference between multi-product firms and single product companies[28]. Channon showed that single product firms were less likely to adopt the decentralised m-form structure than multi-product firms. He showed that the single product firm was more likely to use a functional framework. This study will illustrate just how much decentralisation there was in the electronics firms compared to the business machines companies and why this was significant.

It is important to establish how the structure of the firm affected strategy and performance. This requires an understanding of the different structures of the two types of firm. Key to whether concentrically diversified companies can achieve an advantage over single product companies is the significance of the interrelationships between business units[29]. Williamson suggests that the m-form structure is optimized when general management is isolated from the day to day operations of the company and confined to strategic decision making[30], but that the amount of divisionalisation depends on the 'firm's size, functional separability, and the state of information technology'[31]. Following this line, the ultimate organisation becomes an internal capital market, where the decision makers have perfect knowledge of the operating divisions on which to base their investment judgements. Porter looks more closely at the organisational gains that a firm can achieve by exploiting vertical and horizontal links between business units. Achieving the advantages predicted by industrial economics for the large vertically and concentrically diversified firm depends on getting the balance of operations and the internal structure of the firm right. Separating operational units too much can lead to the firm not achieving the advantages of synergy between closely related products: they can lose out on shared economies of scale

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[27]O.E. Williamson, Markets and hierarchies, analysis and antitrust implications, New York, 1975, pp148-154.

[28]D.F. Channon, The strategy and structure of British enterprise, 1973.

[29]Porter, Competitive Advantage, 1985. Porter considers in detail the interrelationships within companies and the likely advantages horizontal diversification can give.

[30]Williamson, Market and Hierarchies, pp148-150.

[31]Ibid.

and scope.

Industrial economics has suggested that there are a number of potential advantages to be obtained through horizontal and vertical diversification. These strengths are considered here to provide a gauge against which to test firms in the case studies.

The electronics firms were both vertically integrated and concentrically diversified. There are two levels at which this structure may have given the electronics companies a competitive advantage. Firstly, they could benefit from the technical base shared by many of their products, leading to advantages of scale and scope. Scale advantages arose from the production of common components; scope advantages from utilising facilities and skills obtained in one area of electronics in another[32]. A major factor in obtaining this advantage is sharing technical resources in research and development. Having a wide ranging development programme, based on a core technology, could lead to economies in the use of resources; engineers with similar skills could be moved around several projects. There is also the possibility of technological cross-over between the various developments; projects can feed off each other. A development made for an advanced military electronics application could be 'value engineered'[33], which then means it can be used in a commercial computer application. This sharing of skills can also advance the firm along the learning curve faster than if it was just developing a single product. Once a firm has developed a process for one of its product lines it will be cheaper to exploit the same process in another; learning by doing, accomplished in one product line, can be transferred to another. Sutton considers this to be one of the advantages of 'specialised diversification'[34]. He also suggests that the learning effect can go beyond the physical production level: firms can learn organisational lessons, as well as manufacturing lessons. This thesis considers which firms had the best base to learn from. The electronics firms had the scope to share internal learning-by-doing in electronic equipment; the business machines firms could learn from their past experience in selling punched

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[32]The general concepts of the economies of scope are discussed in E.E. Bailey and A.F. Friedlaender, "Market structure and multi-product industries", Journal of Economic Literature, 1982, 20, pp1024-48; W.J. Baumol, J.C. Panzer, R.D. Willig Contestable Markets and the theory of industrial structure, New York, 1982.

[33]Reduced in complexity and price.

[34]C.J. Sutton, Economics and corporate strategy, Cambridge, 1980, pp66-7.

card machines.

Secondly, horizontally diversified firms could also be strengthened by not being reliant on a single market: having a number of products gave them some security of income. In other words, there was a possibility that these firms could have achieved the advantages of the diversified conglomerate, while retaining the operational advantages of working within one technology, electronics. A core question is whether this balance was achieved, or whether there were some organisational factors which negated the possibility of having both the advantages of the conglomerate and those of a core technological base.

A third advantage which these firms should have been able to bring to bear in their assault on the computer market was the success that they were having in other electronics markets. During the period covered by the case studies, the electronics industry as a whole was booming. Television, capital electronics, and a whole gamut of military electronics were in very heavy demand, which benefited the large electronics companies. This thesis considers whether these firms managed to use the resources thus generated to enter the computer market, a new sector which they had identified as a potentially large outlet for electronics.

Taking the Schumpeter[35] and Galbraith[36] thesis of scale, scope and size giving firms market power, through having greater funds available for research and development, electronics firms might have been expected to perform well in the computer industry. They had the resources and the technical background. Yet the market became dominated by specialist computer companies. This thesis will consider how these specialist companies differed from the electronics firms, their different strategies and, above all, the internal reasons why the electronics firms failed to marshall their resources for this industry.

The core question which is addressed in this thesis is whether the diversified electronics firms were capable of supporting all their areas of activity. It addresses the question of whether firms suffer from 'capital-rationing'[37] and, if this existed, did it lead to operational weaknesses and abandonment of new activities? All the factors mentioned above affected how the electronics firms dealt with the process of

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[35]J.A. Schumpeter, Capitalism, Socialism, and Democracy, 1961.

[36]J.K. Galbraith, American Capitalism: The concept of countervailing power, Boston, 1952.

[37]C. Tomkins, Corporate Resource Allocation: financial, strategic and organizational perspectives, Oxford, 1991, pp179-180.

'internal venturing', how they weighed new opportunities and which ones they opted to back the most. Given this point, no overall framework is used for each case study, as the processes could be different in each, but the results are the same. The conclusion examines whether the many lessons from each chapter add up to a criticism of the ability of concentrically diversified firms to expand in commercial and competitive markets.

This is a comparison of one set of firms that entered the computer industry as a new opportunity for exploiting technical knowledge with to a set of companies which built computers when they started to take the place of their old products. It assesses technical giants versus market knowledgable specialists.

The development of the British and American computer industries.

Early computers.

It is common at this stage in a thesis or book about the computer industry to have an outline of how technology has developed and of the scientists that brought the concepts to fruition. However, here there will only be the briefest of outlines. There are a number of comprehensive works on early developments in computing, both in Britain[38] and the USA[39]. They show that Britain was on a par with the United States in what could be termed the pre-competitive phase of the industry: the period when computer technology was confined to small groups of pioneering scientists and entrepreneurs. Developments at the universities of Manchester and Cambridge and at the National Physical Laboratories were extremely important to the progress of early computer technology. This period lasted from about the end of the war to the early 1950s. Instead this section will concentrate on the development of the market for computers.

Only a few laboratories had the financial resources or the skills to develop these complex and intricate machines for their own use. Yet many other laboratories had a requirement for increased calculating speed,

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[38]S.H. Lavington, Early British Computers, Manchester, 1980. This is the most comprehensive British study. See also: N. Metropolis, J. Howlett, and G-C Rota, eds., A History of Computing in the Twentieth Century, New York, 1980; A. Hodges, Alan Turing: The Enigma, 1983; M.V. Wilkes Memoirs of a Computer Pioneer, Cambridge, Mass., 1985; and F.C. Williams "Early computers at Manchester University", The Radio and Electrical Engineer **45** 1975, pp327-31.

[39]N. Metropolis et al, A history of Computing in the Twentieth Century; P.E. Ceruzzi, Reckoners: The Pre-history of the Digital Computer from Relays to the Stored Program, Westport, Conn., 1983; K. Flamm, Creating the Computer: Government, Industry and High Technology, Washington 1988. There are many other histories of the development of computer technology in the USA, many of which will be mentioned in case studies.

created by the growing complexity of science and technology, especially in the nuclear and aeronautical fields. It was this science community which produced the first demand for computers.

By 1950, the Ferranti company claimed to be the first firm to offer fully functional computers for commercial sale[40]. English Electric, using technology from the National Physical Laboratories, was able to follow suit sometime later[41], as did the firm Elliott Brothers.

In the USA the initial technical interest in computers resided in similar institutions, universities and government laboratories. However, the organisations which fulfilled early scientific demand for computers were significantly different from the UK. The two most important early producers were small entrepreneurial organisations, Eckert and Mauchly with the UNIVAC machines[42] and Engineering Research Associates with the ERA 1101[43]. Both of these firms were to become part of the UNIVAC Division of the business machines firm Remington Rand, which in turn became a part of Sperry-Rand. The third significant commercial computer development, though lagging behind Remington Rand's stable, was in IBM[44]. A handful of other small entrepreneurial firms developed computers. Many will be mentioned in this thesis, including ElectroData which was taken over by the business machines firm Burroughs, and the Computer Research Corp. which was absorbed into National Cash Registers[45]. The role of the electronics companies at this early stage in the US industry was on the whole limited to components and technical assistance; their major push into the market came somewhat later.

This very brief outline of the genesis of the computer industry shows that, in Britain, multi-product electronics firms were involved from the very earliest stage. In the USA small enterprises and business machines firms showed a strong early interest; a significant difference between the industries.

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[40]See below, chapter 2 on Ferranti's Mark 1 computer, pp50-57.

[41]See below, chapter 4 on English Electric, pp138-140.

[42]N. Stern, From ENIAC to UNIVAC: An Appraisal of the Eckert-Mauchly Computers, Bedford, Mass., 1981. See also Sperry Rand section in chapter 8, pp350-358.

[43]A.A. Cohen and E. Tomash, "The Birth of an ERA: Engineering Research Associates Inc.", Annals of the History of Computing, 1, 1979, pp.83-100.

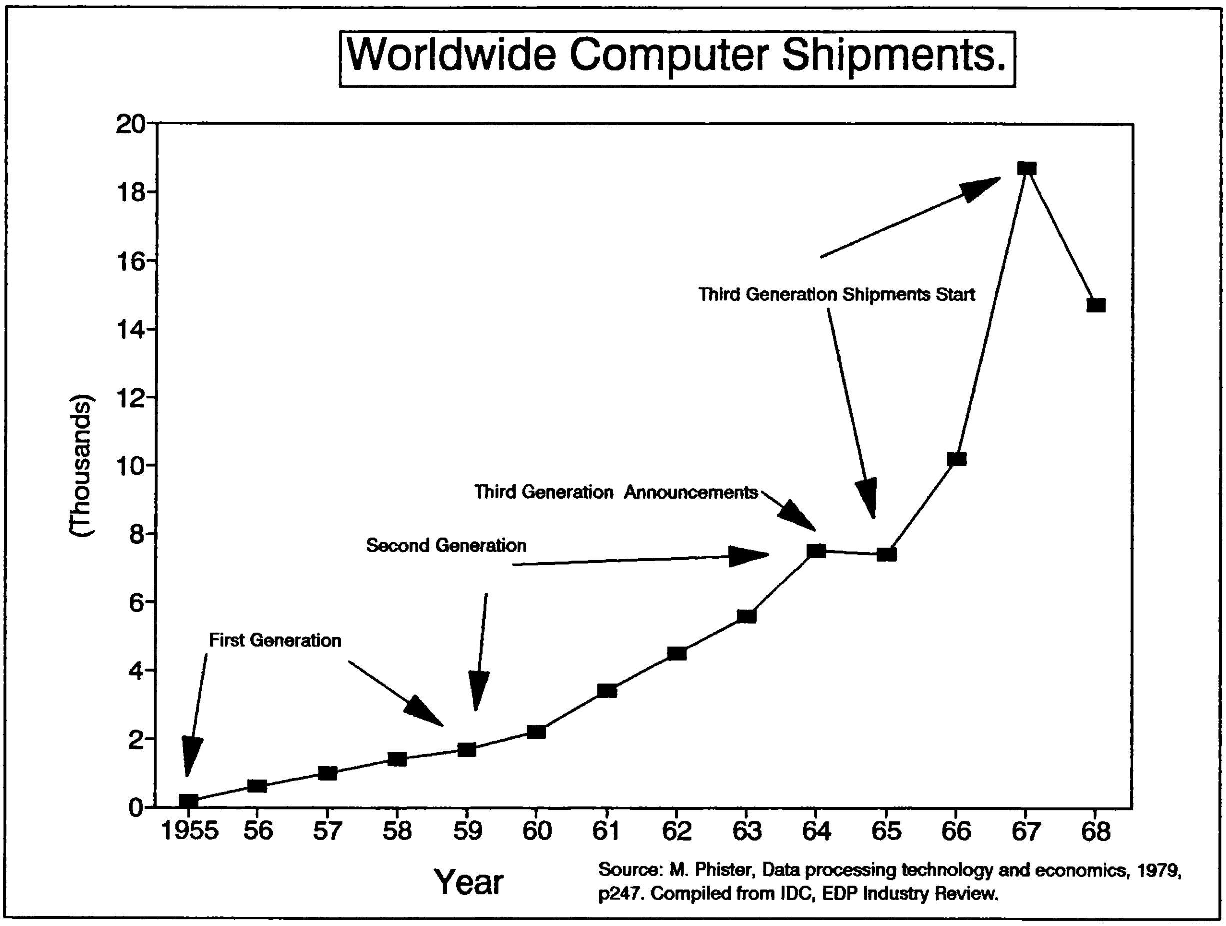
[44]C.J. Bashe et al, IBM's Early Computers, Cambridge, Mass., 1986. This book gives a good description of IBM's early computer developments.

[45]See below, chapter 8, pp330-350.

Development of the mass market.

The world's stock of computers grew rapidly from the mid-1950s onwards. From production of a handful of computers for scientists, machines that were viewed almost as science fiction mysteries and which looked somewhat Heath-Robinson due to their complexity, the mainframe computer became commonplace and the micro computer later became all-pervasive. Figure 1.3, shows how the number of computers multiplied:

Figure 1.3


Worldwide Computer Shipments.
(Thousands)
0
2
4
6
8
10
12
14
16
18
20
1955
56
57
58
59
60
61
62
63
64
65
66
67
68
Year
First Generation
Second Generation
Third Generation Announcements
Third Generation Shipments Start
Source: M. Phister, Data processing technology and economics, 1979, p247. Compiled from IDC, EDP Industry Review.

The history of this growth is usually divided into generations of computers. Each new generation added functions and abilities which enhanced their appeal to users. These generations are framed in terms of the type of component used to build the computer. This is a simple dividing line between machines, but one which masks the evolutionary and conceptual changes which led to the new functional abilities.

First generation computing: early 1950s-late 1950s.

The early computer industry used the vacuum tube as the underlying technology: tubes were used for all logical functions. This made the machines large, power hungry and initially very unreliable. Memory was simple, based on cathode ray tubes or delay lines, systems capable of storing only limited amounts of data, or on slow magnetic drums, akin to the modern disk drive, but with tiny capacity.

The first generation can be divided into two periods. The previous section discussed the first of these when computers were a scientific curiosity with only a small community of developers and users. A number of incremental improvements gave some of the later first generation machines widespread acceptance, with reasonably large production runs. Innovations included the more reliable, lower power, mini-valve; magnetic core memory instead of drum and cathode ray storage; and the introduction of magnetic tape and magnetic disk storage. Magnetic cores became the most important computer memory until the 1970s and were first found in large scale IBM and UNIVAC computers[46]. As these improvements were incorporated, and as prices were reduced through better manufacturing techniques, new functions for computers were developed, leading to computers becoming more than just scientific calculators. IBM's small 650 computer was used for tasks that had previously been carried out by tabulating and punched card equipment[47]; over one thousand of these were produced. IBM's 305, which incorporated early disk drive technology, also approached one thousand sales. These machines were primarily used for commercial data processing, a source of demand that rapidly outstripped the scientific market.

In the UK, first generation computers were not built on such a large scale: only a few systems sold more than 20.

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[46] See below, chapter 8, pp312-314.

[47] Ibid.

Second generation, late 1950s-mid 1960s.

Following the dissemination of the new transistor technology within the electronics world, a number of solid-state computers started to emerge in the late 1950s. Such machines offered great advantages over their predecessors. Transistors greatly reduced size and power consumption, were reliable and easy to package, and made much greater calculation speeds possible.

Second generation computers also had better peripherals, incremental improvements which greatly enhanced the throughput of the computer. Tape drives improved, as did printers, allowing greater speeds at both ends of the computational process. However, it was in the area of random access storage that second generation machines were much better than the first machines. Disk drive technology was greatly enhanced, with IBM producing ever faster and larger disk storage systems[48]. Secondly, the magnetic core main memory came down in price. This made large capacity memory on computers possible, greatly increasing the complexity of the tasks that they could handle.

Improved technology and the falling price meant that computers could be applied to many new tasks. Computer languages such as Fortran, written by IBM for engineering and COBOL a common language for business applications, greatly improved programming productivity. Computers were given the ability to perform multiple tasks, such as printing out the results from one program while calculating another. This ability, together with the availability of large random access stores, led to a number of new real-time applications, where computers performed tasks as required, rather than processing tasks in strict batch order. Above all, the large user base that was being built up was leading to new application ideas, which were developed for one user then attracted others.

At the end of the first generation of computing and during the second generation, there was great momentum behind the computer. By the end of the second generation of computing all the business machines firms had turned their attention to building small systems to complement their old tabulating machines. Figures 8.4 and 8.5[49] show how the computer started to become a significant product for American business machines firms, rapidly becoming their main product line. Likewise ICT in the UK was having to acquire computer technology[50]. For these firms there was little

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[48]See below, chapter 8, pp314-320.

[49]p304 and p305.

[50]See below chapter 5, pp170-176.

choice: the computer was replacing the old electro-mechanical punched card technology.

It was in the cusp between the first generation of computers and the introduction of the second that many of the electronics companies entered the new industry. While Ferranti and English Electric were already involved, others had waited. By 1956-7 it was becoming clear that the computer market was going to be significant. Three the major case studies, EMI, RCA and GE, entered at this time, as did the more successful Honeywell company, while English Electric also greatly increased its effort in the computer industry at this time. A number of other electronics firms also made short lived forays into the early second generation computer market, including British GEC and AEI and American Philco and Bendix. In the case studies it will be seen that electronics companies hoped to use their knowledge of electronics, especially their early experience of the transistor, to lever their way into the forming market. It was Philco in the USA and EMI in Europe which managed to market the first large scale solid state computers. Most of these companies targeted the commercial, rather than the scientific, computer market for their forays: this had become the largest part of the market with the most potential for growth.

Notably, it was during this generation of computing that the most significant start-up computer companies were founded: Control Data Corp. and Digital Equipment Corp., both of which became major players in the world market.

However, the most notable second generation machines once again came from IBM. The 1401 was the first computer to exceed 10,000 installations, an order of magnitude larger than the machines it replaced. The 1401 became the workhorse of the commercial computing world. The second notable series of machines were the various IBM 70** series computers. These were large commercial and scientific machines. The various IBM 70** computers were again the workhorses of their fields, the 7070/2/4 in large scale commercial computing and the 7090/94 in scientific computing. Both of these lines sold many hundreds[51].

Chapter eight shows that it was IBM's ability to control the second generation of computers that was the key to its continued dominance of the market. It was at this stage that the electronics companies, a number of which were much larger than IBM, had a potentially significant competitive advantage by applying their electronic technology to the computer market. IBM's better market knowledge and marketing techniques saw off this

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[51]See below, chapter 8, pp315-319.

potential threat.

Third generation, mid-1960s onwards.

This represents the period in which computer technology became more formalised. The core change in technology was the move from the discrete transistor as the logic component, to the integrated circuit which combined a number of transistors, together with other solid state components such as diodes and silicon resistors, onto a single piece of silicon or germanium. Since this time much effort has gone into striving for an ever greater density of circuits on the chip.

However, the third generation of computing was heralded by the IBM 360 family: a system which did not use IC components[52]. IBM instead used a hybrid technology, silicon with resistors and other passive components built in, with transistors soldered on. Nor did the most successful British third generation computer use ICs. The ICT 1900 family used transistors. What really distinguished the third generation of machines was the adoption of a more advanced architecture, more advanced operating programs, and, most important, compatibility between whole families of computers. Before this computers were optimised for the scale of calculation they were meant to undertake and they varied greatly because rapid technical change meant that models entering the market at just one or two year intervals were very different. These changes to the organisation of computer ranges were additional to the usual cycle of using faster components and lowering manufacturing costs, producing better price:performance ratios and greater functionality.

The IBM 360 was a range of computers which offered all these features. Users of the range could opt for a small system with punched card input-output, or a very large computer capable of the most complex tasks and controlling banks of disk and tape drives. These systems were compatible throughout. For a large company this meant computer and software standards would be the same throughout the company. For smaller firms, expansion to larger systems would not create headaches of reprogramming applications and arranging complex data swapping, a common problem before this concept.

Almost every firm followed this example, though a number of novel tactics were adopted to take advantage of the change to the new generation. Honeywell, and to some degree GE[53], made their new machines backward

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[52]See below, chapter 8, pp320-325.

[53]See below, chapter 7, pp270-273.

compatible with old IBM computers in the hope that users would upgrade to their systems rather than the new IBM range. RCA's Spectra 70 series[54] was made compatible with the new IBM 360 range, a tactic which was aimed at making RCA the standard second source for IBM architecture machines. RCA also hoped that it would benefit from its more advanced component technology; it was the first major range to exploit IC components techniques.

The 360 was a worthy successor to IBM's second generation of computers. Figure 1.3[55] showed a stall in computer sales in 1964 following the announcement of the IBM 360. This was followed by a boom in installations, due, in the main, to the thousands of 360 family machines produced. By this time computer technology was becoming commonplace, employing hundreds of thousands in both building the machines and operating them.

This was the dynamic market in which the electronics firms were trying to establish a presence. What follows is a study of the strategies adopted by firms wishing to exploit technical knowledge and market power, derived from a broad base of other electronics activities, to win a share of this new industry.

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[54]See below, chapter 6, pp230-233.

[55]See above, p38.

Chapter 2
The Ferranti Company and the early computer industry.

Development of the Company.

As a family owned firm Ferranti is unique among the companies studied in this thesis. RCA, IBM and English Electric all had powerful autocrats leading them at one time who passed control of the firm to their sons. However, the actions of these father-son dynasties were tempered by the need to satisfy external sources of capital, and by the non-family board members. There were no such restrictions in Ferranti. Because of this ownership structure, Ferranti was a firm carrying an unusually large historical legacy. It is important to understand the history of Ferranti so that later strategies can be seen in proper context.

The company was formed by Sebastian Ziani de Ferranti and two backers, Alfred Thompson and Francis Ince, in 1882[1]. Sebastian worked at the forefront of technology in the rapidly expanding electrical industry. His achievements included the first alternating current power plant, high voltage distribution cables, electric current meters, and advances in electrical transformer technology[2]. The company suffered a number of set-backs before the 1914-18 war, due to growing competition from larger electrical firms, and to the costs associated with Sebastian's many innovations. For a period the firm was placed in administration[3].

After the war, the firm grew as the importance of electricity in society grew. However, the company still had problems. The switch-gear department was closed down after the war, because it required more investment than the private funds of the firm could provide[4]. Ferranti was unable to raise new capital due to its status as a private company, and, unwilling to take on substantial long-term debt, opted to sell this department despite its potentially strong trading position. In later years the company disposed of a number of departments for the same reason,

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[1]W.L. Randell, S.Z. de Ferranti-his influence upon electrical development, 2nd edition, 1946.

[2]Ferranti International Signal, Ferranti down the years. March 1989, Pamphlet prepared for Ferranti's public relations. Ferranti Archive.

[3]J.F. Wilson, Ferranti and the British electrical industry 1864-1930, Manchester, 1988. This book is the best account of the early history of the company.

[4]Vincent de Ferranti, 'The growth and development of Ferranti Limited', London School of Economics, Seminar on the problems in industrial adminstration, 22/11/55.

including the computer department.

Ferranti was a company that relished technology. However, many of the new products that it became involved with were only of passing interest to the company: it was a willing developer of new technology but was innately conservative when faced with a competitive market. One example of this was in the consumer market. Sebastian developed the domestic electric fire with reflective metal behind it to radiate heat. The firm also produced domestic electronics such as early radio kits, and, in the late 1930s, television sets. Domestic electrical and electronics goods were only a short lived activity, both abandoned by the end of the 1950s as competition increased.

The firm's most important pre-war electronics activity was radio components. It produced a range of components including the AF3 transformer which greatly improved the quality of radio reception[5]. In 1935 the Moston Radio works was opened which contained all the lighter side of the business, the Radio, Valve and Domestic Appliance Departments. As mentioned above, neither the Radio nor Appliances organisations would last long.

The valve and component operations led to Ferranti's large electronic components business after the war. The second major element in Ferranti's electronic development was the Instruments Department. This was Ferranti's capital electronics engineering operation. Some of its first products were electro-mechanical aircraft instruments, which proved useful in the war:

> 'Out of this, it [the Instruments Department] eventually became almost a development laboratory for govrnment contracts.'[6]

Ferranti's first war-related contract came as early as 1934: it was for mechanical fuses[7], a product it had also made in the First World War. This was followed by contracts for radar and navigation equipment, work initially carried out at its Moston plant. To cope with increasing military demand a new operation was set up in Edinburgh. Initially it produced navigation equipment, and later radar and fire-control systems. The Scottish business kept responsibility for these areas after the war, with the rest of the electronics operation concentrated in Manchester.

Therefore Ferranti was unique among electrical and electronic manufacturers in that it was a private concern. It was run by a family that put great store on technology and engineering. However, the private status affected its freedom of action and instilled a conservatism on its

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[5]J.F.Wilson, <u>Ferranti 1964-1930</u>, pp137-8.

[6]'Ferranti-the family and the organisation'. <u>The Electrical Manufacturer</u>, July 1958, pp22-25.

[7]Ibid.

operational activities.

War work and the post-war impetus to build computers.

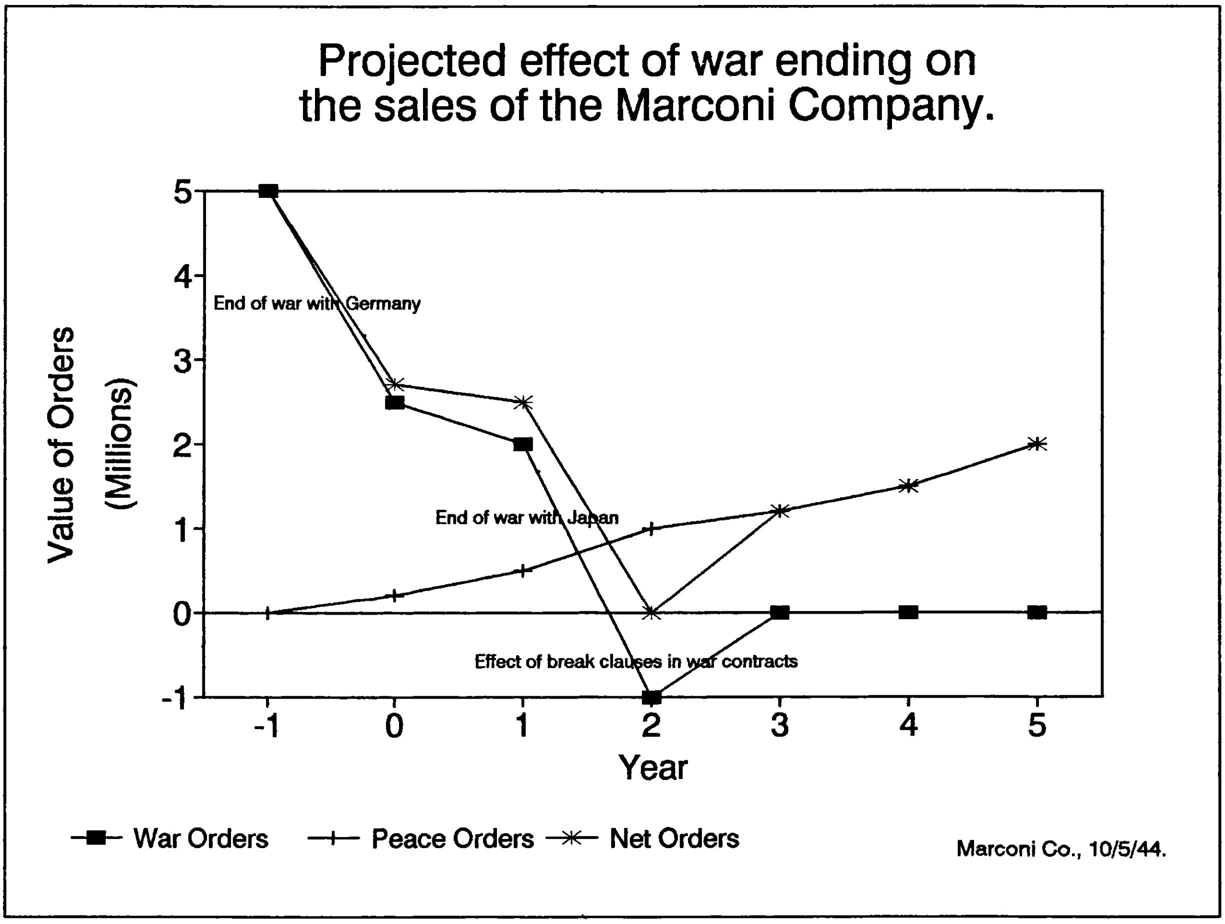
The Second World War had a great effect on the Ferranti company. The fundamental change was the growth of the high technology capital electronics markets. To deal with military work, Ferranti built up a significant electronics capability, with large development and manufacturing facilities being dedicated to capital electronic equipment.

The transformation to peace time manufacture was not an easy one for the company to make. Ferranti was not a recognised force in capital electronics before the war[8], but it now had a very large commitment to this market. After the war, it was faced with a collapse in its order books. This was not unique to Ferranti, the end of war meant a collapse in the order book for all electronics companies: most companies expected there to be a delay between the end of war related orders and a commensurate rise in commercial work . This is illustrated in Figure 2.1 which shows what the leading company in the electronics market, Marconi, expected to happen to its sales after the war[9]:

[8]Marconi Archive, 'Post War Policy-Factual Review of Pre-war and Current Positions', 1944.

[9]Marconi Archive, 'Report on post-war problems in relation to sales policy', prepared by R.D. Bangay, 10/5/44.

Figure 2.1


Projected effect of war ending on the sales of the Marconi Company.
Value of Orders (Millions)
5
4
3
2
1
0
-1
End of war with Germany
End of war with Japan
Effect of break clauses in war contracts
-1
0
1
2
3
4
5
Year
War Orders
Peace Orders
Net Orders
Marconi Co., 10/5/44.

This was the situation faced by Ferranti's Instruments Department, but other parts of the company benefitted from peace. Those sections involved in the electrical side of the company gained from post-war re-equipment and expansion of the nationalised electricity industry.

On the face of it, this temporary downturn in the demand for capital electronics would not seem to have been much of a problem. Ferranti wanted to maintain an interest in the new electronic technologies, and it had profits from the electrical side of the business to tide it through the period in which civil products were being developed. However, the firm rejected the idea of cross subsidisation.

The head of Ferranti's Instrument Department, Eric Grundy, became interested in the possibilities of using computers in industrial control systems[10], as a method of using the department's capabilities. One key seminar paper interested him. At the Institution of Electrical Engineers in 1947, Professor Arthur Porter, who had worked for Ferranti during the war[11], outlined three advantages electronic equipment could offer industry:

> 'First, electronic equipment is extremely flexible. The controlled member can be remote and the same controller may be used for more than one purpose;
>
> Second, a vast amount of experience in electronic techniques had been developed during the past six years; and
>
> Third, the non-technical point that in the United States the design and application of automatic controller equipment was ahead of the U.K., but with the coming of modern electronic techniques there was no reason why we should not achieve parity.'

On the recommendation of Porter, Grundy employed a servo-mechanism expert, Dr Dietrich Prinz[12]. After being interned as a German national, Prinz was released and served under Porter on the Ministry of Supply's Servo Panel. Grundy planned to use Prinz, and his assistant, to develop electronic control systems:

> 'Grundy asked Sir Vincent de Ferranti to sponsor a study of automatic control from general company funds, but this was refused, and Prinz was employed on a study of radar display for the Ministry

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[10]National Archive for the History of Computing, Bernard Swann, sales manager of the Ferranti Computer Department, 'The Ferranti Computer Department', 1975. This paper was prepared for the Computer Science Department of Manchester University, Ferranti's close collaborators in computer design.

[11]Ibid.

[12]Ibid.

of War.'[13]

Sir Vincent had a number of reasons for this decision. Firstly the Berlin blockade increased the urgency of radar developments. However, there was another reason for Vincent's lack of interest. During the post-war period, Ferranti was adopting a policy of operating autonomous departments[14]. Throughout the history of the Ferranti Computer Department, but especially in the early days, the Ferranti family expressed the view that it was unwilling to use central company funds to develop the computer business. Grundy had to find the finance to carry out his plans from elsewhere. Two options existed. Firstly, he could utilise internal department resources, though this was not enough given the drop in military sales. Secondly, he could try to find some external sponsorship for this development.

It is interesting that a family company was operating in this decentralised way. This was ahead of the big three electrical manufacturers in the UK - GEC, EE and AEI - who would not adopt this method until the later 1950s and 1960s, in the meantime continuing to use a functional organisation[15]. The organisation structure and Sir Vincent's level of control over the firm is discussed below[16].

In the summer of 1948 Prinz was again available to Grundy, the radar display having been completed. Grundy dispatched Prinz to study computer developments in the USA[17]. With the aid of Porter, Prinz managed to look at a number of the key developments in America[18]. Grundy's instructions to Prinz still exist in a telegram sent to him in 1948[19]:

> 'Will you please consider the preparation of a complete report on digital computing as you have seen it Stop I would like to submit

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[13]Ibid.

[14]P.Drath, 'The relationship between science and technology: University research and the computer industry, 1945-1962', PhD Thesis, Manchester University, 1973, p4-12. This comes from a Drath interview with Grundy.

[15]R.Jones and O.Marriott, Anatomy of a Merger: a History of GEC, AEI and English Electric, 1970. This is the most comprehensive study of the three major British electrical companies.

[16]pp58-62.

[17]P.L. Young, public relations employee of Ferranti Computer Department, 'The growth of a computer department', part I, The Electrical Manufacturer, March 1958, pp18-20.

[18]Swann 'Ferranti Computer Department'.

[19]NAHC, Fer/bl.

this to Hitch's superiors as a lever to persuade them to finance our developments for their use Stop'

The Mark 1 Computer

It appears that one of Prinz's main conclusions from his trip, was that the UK had as good a position in the new technology as the USA. One of Britain's centres of excellence was developing at Manchester University[20], the company's home town. The University's computer activity was centred in the Electrical Engineering Department and was led by Professor F.C. Williams. Williams, and his assistant Tom Kilburn, had been working at the Telecommunications Research Establishment during the war years. In 1946 they moved to Manchester and continued their work on electronic storage techniques[21]. Williams' most famous contribution to computer hardware development was the Williams Tube. This was a cathode-ray-tube that was used to store digital information. It was one of the few early methods of storing data for use by a computer. This device was not only used in early Ferranti machines, but was also used by IBM in its first electronic computers[22].

In June 1948 Williams had completed the 'baby Mark 1' which was claimed to be the world's first stored-program computer[23]. Most of the funding for the early Manchester work came from the Royal Society, but this was a finite source. Grundy saw this early machine, but the Instrument Department did not have the financial resources to develop the test bed into a full scale computer. In any case, the whole field was completely unknown to the company, and there was little idea of who would be the customers for such machines. In fact, it was the Ferranti Radio Department that was first involved with Williams' work. Williams was an advisor to the Radio Department and in return it provided some hardware to the University project[24]. Later there was a certain amount of conflict between the Radio and Instruments departments as to which should have responsibility for

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[20]P.L. Young, 'Ferranti Computer Dept. Pt I'.

[21]S.H. Lavington, 'Computer development at Manchester University' in: A history of computing in the twentieth century-a collection of essays, ed. N. Metropolis, J. Howlett and Gian-Carlo Rota, New York, 1980. The National Archive for the History of Computing has a large collection covering the computers developed in Manchester University.

[22]C.J. Bashe et al, IBM's Early Computers, Cambridge, Mass., 1986.

[23]Lavington 'Computer Development at Manchester University'.

[24]John Hendry, Innovating for failure: Government policy and the early British computer industry, Cambridge, Massachusetts, 1989, p42.

developing Williams' design. The Instruments Department won the battle but the team that worked on computers was drawn from both operations[25]. The Radio Department developed the circuits, while the Instruments Department provided the precision engineering side, especially the magnetic drum which acted as a large backing store to the faster Williams Tubes[26].

While the Instruments Department had no resources to develop Williams' computer, there had been some movement in government circles regarding further development of a domestic computer capability. Professor P.M.S. Blackett, of Manchester University's Physics Department, discussed the situation with the government's Chief Scientist at the Ministry of Supply, Sir Ben Lockspeiser[27]. After he had seen the prototype he immediately sent Ferranti a letter of intent to purchase a Mark 1 computer to be installed in the University[28], a machine known as MADAM. The contract was not placed through the appropriate contracts department of the MoS, and was not open to tender. This seems appropriate as Ferranti had already contributed to the project and was close to the development team. However, Hendry relates that Williams himself would have preferred to work with EMI which he saw as the premier electronics company in the country[29]. As will be seen below, EMI was fully occupied with television at this time.

Lockspeiser's decision just to get on with the job and to authorise the building of a system was driven by the need for computers in defence work. As in the USA, the concern of the authorities was not so much with computers themselves, but with providing computational facilities powerful enough to ensure that the UK could keep up in areas such as nuclear engineering and aircraft and missile dynamics; the main new technologies of interest to the US and British military services. The Ministry of Supply was reflecting a demand derived from military technological advance.

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[25]Ibid.

[26]Young, 'Ferranti Computer Dept pt I'.

[27]Drath 'Relationship between science and technology' 4-12.

[28]Swann, 'Ferranti Computer Department'.

[29]Hendry, Innovating for failure, pp55-6.

Producing and selling Mark 1 computers; the role of the National Research and Development Corporation.

i) The MADAM and FERUT computers.

From 1949 to July 1951 the Instruments Department was constructing MADAM. To do this the Ministry of Supply had given it a budget of £120,000 to develop and produce one machine. The question that occupied the minds of a number of interested bodies was what would happen next. Lockspeiser tried to keep the momentum going. He initiated the Brunt Committee which was chaired by the eminent meteorologist Sir David Brunt[30]. This committee brought together leading academics and the relevant government departments and was intended to advise government on computers. He also tried to persuade Sir Henry Tizard of the Advisory Council on Scientific Policy to authorise the purchase of three Mark 1 machines[31]. This was refused with Tizard suggesting that the appropriate sponsoring body was the Department of Scientific and Industrial Research. Late in 1951 Lockspeiser took charge of the DSIR.

By 1951 the MADAM was being delivered. A meeting was held in January 1951 between Lockspeiser, Brunt, Williams and the head of the Ministry of Supply, Brigadier G.H. Hinds, it was agreed that the MoS contract needed to be renewed to keep the Manchester and Ferranti team together[32]. This was only for continued research and was a DSIR contract administered through MoS[33]. Of a more substantial nature, Brigadier Hinds let it be known that MoS wanted a Mark 1 computer for atomic weapons research at the Fort Halstead research establishment[34]. However, this would exceed his expenditure authorization and also be out of step with competitive tender policies. He therefore had to wait to place a formal contract.

At this time a new body, the National Research and Development Corporation, stepped in. It was not mandated to employ inventions for military work but to ensure that they were exploited for the benefit of the British economy[35]. The NRDC's main assets were the patent rights it took

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[30]Swann, 'Ferranti Computer Department'.

[31]Ibid.

[32]NRDC 86/7/5 Concluding minutes of a meeting held 22/1/51.

[33]NRDC 86/7/5. Halsbury, Managing Director of the NRDC, to W.G. Bass, Ferranti Director with responsibility for the computer operation. 21/6/51.

[34]Swann, 'Ferranti Computer department'.

[35]Hendry, Innovating for Failure, pp7-22.

over from other government departments. It was these patents it was meant to exploit: these included the rights to the Williams' computer inventions. Negotiations between the NRDC and Ferranti started in 1950/1.

However, the next machine to be sold was not supported by the UK government. Ferranti managed to sell a Mark 1 to the University of Toronto[36], and was known as the FERUT. This sale owed much to the personal contacts of Professor Porter and the efforts of Ferranti's first computer sales representative, Vivian (later Lord) Bowden. The FERUT and MADAM contracts seem to have formed Ferranti's contention that it had produced the first commercially available computer, and it was certainly first to export a computer.

FERUT was purchased to help in the construction of the joint US/Canadian St Lawrence Seaway. Canada wanted to ensure that it matched the contribution of the USA in the construction of this canal. One way it did this was to provide the design calculations: this was where the computer came in[37].

Ferranti found that FERUT was an ambitious project. Problems were caused by a number of factors. Firstly it was one of the world's first computers, and the first to be exported three thousand miles. Another cause of the problems was the fact that Ferranti was not willing to bear the total cost of building the machine, neither was the Canadian government willing to pay for it ahead of delivery. The result was that as each sub-assembly of the machine was manufactured it was exported to Toronto and paid for by the Canadian government. The computer was not first assembled and tested in Manchester[38]. Another problem was the inexperience of the Canadian operators. Ferranti, greatly helped by the chief FERUT maintenance engineer, and the NRDC programming expert Christopher Strachey, managed to get the machine working for the 1952 Toronto Computer Conference. The Seaway calculations were also finished in record time. However, Swann believed that the machine's renowned reliability problems crippled the firms chances of making another sale in North America[39]. Ferranti was continually handicapped by a reputation for unreliability. On the other hand, FERUT did launch Ferranti's Canadian company, Ferranti Packard, into a short but influential computer foray, as it was Ferranti-Packard which

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[36]Swann, 'Ferranti Computer Department'.

[37]Ibid.

[38]Ibid.

[39]Ibid.

maintained the machine once the British engineers went home. After this experience, the NRDC's Christopher Strachey prepared plans for detailed testing of future machines[40]. It also led to an upgrading of future machines to the Mark 1* standard.

ii) The NRDC's attempt to merge the computer and tabulator industries.

Discussions between Ferranti and the NRDC can be divided into two categories. One set of plans concerned the direct support of the computer operations at Ferranti. Another, less successful and less formal, set of talks related to the efforts of the NRDC to bring the UK industry together.

The latter talks revolved around Halsbury's desire to ensure that the UK had a competitor to IBM[41]. In 1950 IBM was not making computers, but had already taken out a license from the NRDC for the Williams Tube, indeed this proved to be a good source of funds for the Corporation. Halsbury saw a major threat in the form of IBM building computers as an extension to its tabulator business. He believed there was a major threat of IBM cornering the world market for computers. His initial efforts in arranging round table talks between the electronics and the business machine companies, to develop a strategy for computer production, came to nought. Halsbury's second effort to produce a British competitor to the perceived threat from IBM, was trying to form a link between British Tabulator Machines's[42] business machines knowledge, and Ferranti's electronic technology capability. However, BTM was fully occupied trying to compete with IBM in the field of tabulators[43] and had little time for an unproven technology. BTM was also concerned that IBM might get hold of any technology that it might develop under contract with the NRDC. IBM was already an established licensee of the NRDC, and BTM was concerned that the vesting of patent rights to the NRDC could benefit its rival. Some plans were made for Ferranti and BTM to work together but they came to nothing. A later attempt to develop a link between Ferranti and the other British business machines firm, Powers-Samas, also came to little, as is explained later.

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[40]NRDC 86/7/5, Internal Memo from C. Strachey to J. Crawley then the NRDC's secretary.

[41]Hendry, Innovating for failure, pp60-73.

[42]Up to this time BTM had been IBM's British licensee, see below, chapter 5, pp161-163.

[43]Ibid.

iii) **Building and selling the Mark 1*.**

Having failed to influence the structure of the embryonic industry, the NRDC was left with little choice but to support and encourage Ferranti in the exploitation of the Mark 1 computer. This proved difficult to arrange, and at least ten months were wasted in pursuing a plan that would be unacceptable to the senior Ferranti management. In February 1951, W.G.Bass, director in charge of Ferranti's computer operations, wrote to Halsbury with a plan of action[44]. It consisted of four points:

a] Fundamental research.
b] Commercial sale of fully engineered Mark 1 computers.
c] Production of specialist business versions of the Mark 1, to be produced in conjunction with users.
d] Development of a business-orientated computer to replace the existing types of business machines.

Bass wanted the NRDC to support sections c] and d] of this scheme. Ferranti estimated that expenditure on these areas would amount to £100,000, spent over three years. Bass suggested that the NRDC contribute fifty percent of this. This was not the basis that the NRDC wanted to start from. Ferranti wanted the NRDC to participate in the longer term aspects of the programme. The NRDC, however, was more interested in Mark 1 sales; it was these patents that the NRDC was administering[45].

The NRDC suggested making a loan against some form of development and production agreement for the Mark 1. Bass and Grundy made a counter proposal, suggesting the NRDC make a direct investment in Ferranti's computer operation[46]. The NRDC chairman, Sir Percy Mills, was cool to the idea, as he believed that it would show too much bias in favour of Ferranti[47]Also, given Vincent de Ferranti's later attitude, it is difficult to believe that he would have agreed to this plan.

Negotiations were long and laborious, but, until the second half of 1951, MADAM and FERUT kept Ferranti busy. One problem was in demarcating the roles of the NRDC and the Ministry of Supply. The FERUT price included royalties for both organisations. It was not until late 1951 that the NRDC

[44]NRDC 86/7/5, 20/2/51.

[45]NRDC 86/7/5, Hennessey, NRDC Patent Manager, comments on Ferranti proposals, 21/2/51.

[46]NRDC 86/7/5, minutes of meeting between NRDC and Ferranti 25/4/51.

[47]Ibid.

seems to have taken full responsibility. There was also some disagreement over patent arrangements, as the NRDC wanted to act as a patents pool to enable British firms to get access to all possible technology.

On the 9th November 1951, Halsbury wrote to Bass with a firm proposal based on Bass's earlier idea[48]. The NRDC was prepared to loan the company £50,000 at an interest rate of 5%. It was to be repaid by a simple 5% levy on sales of all computer equipment made by Ferranti. The exact licence situation was still to be negotiated. It was going to be based on the NRDC receiving the rights to any Ferranti invention made under the arrangement until 50% of the loan had been repaid, and thereafter, Ferranti would retain UK rights and the NRDC overseas rights, or vice versa.

It seems that up to this stage the Instruments Department management had been negotiating on its own behalf, without much input from the rest of the firm, as these plans flew in the face of the firm's attitude to outside funding. Bass' reply to the NRDC proposal showed that Vincent Ferranti was not well disposed to such schemes:

> 'My chairman has given some thought to your kind letter of November 9, but has come to the conclusion that he does not want to borrow money from anyone except the bank, particularly as there are no conditions with regard to licences attached to money lent us by the bank, and they have no charge on our business.'[49]

However, Vincent had a counter proposal which Bass quotes at length:

> 'I understand that the function of the NRDC is to encourage the rapid application of inventions to industry.
>
> The only way I can see that the NRDC could help us to do this in the case of computers, would be to order computers from us which we would keep in stock for sale against firm orders. As a sale took place, we would pay them [the NRDC] the cost of the machine, plus an agreed profit, say 10%, and get what price we could for it. This, in fact, would be similar in its action to a rocket launching apparatus - once in the air we can fly - and I suggest is the most appropriate use of their venture capital.'[50]

Halsbury, contacted the Brunt Committee and S.A. Dakin of the Board of Trade[51], to see if they would be in agreement with this plan. At the 27th NRDC board meeting it was reported that the BoT would approve of NRDC funds being spent in such an arrangement[52]. However, the NRDC wanted to turn the plan around so that it was Ferranti that received a fixed

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[48]NRDC 86/7/5.

[49]NRDC 86/7/5, Bass to Halsbury, 22/11/51.

[50]Ibid.

[51]NRDC 86/7/5, dated 26/11/51.

[52]NRDC 86/7/5, Minutes of the 27th board meeting 27/11/51.

percentage profit and the NRDC any profit above this. It was proposed that the NRDC should buy four machines and then act as the sole stockist of Ferranti computers. Ferranti would then be appointed as selling agents, and would receive a fixed percentage reward for each sale that it made.

Despite Vincent's reticence towards the NRDC having some rights over Ferranti's developments, the Corporation insisted that it have licence rights during the period of the support. It argued that the NRDC had spent £40,000 in patenting Williams' work, and that other NRDC sponsored organisations were just as likely to generate computer inventions as Ferranti[53], and therefore Ferranti was just as likely to benefit from NRDC licence rights. The Corporation also had to ensure that over time it would break even, and licences were seen as essential to this goal. With the new structure of support, it appears that the company relented on this.

After the drawn out negotiations on a loan, the talks on the purchase agreement seem to have gone very smoothly. This was probably due to a combination of factors. Ferranti was getting to the stage where more contracts were needed, while the NRDC was suffering from the frustration of not being able to create the combined computer industry that it desired.

Halsbury met Vincent de Ferranti on the 18th December, and reported to the next board meeting that the proposed arrangement was substantially agreed on[54]. Ferranti was to receive cost +7.5% to build machines and another 5% for a sale. The machines were to be called the Mark 1*, following improvements suggested after experience with the MADAM and FERUT Mark 1 computers. The notional cost of stocking four machines was £220,000 based on manufacturing costs of £55,000:

Table 2.1 Cost and price break-down of the Mark 1*

	£	
manufacturing cost	50,550	
Ferranti 7.5% profit	3,787	
	54,337	
Computer ex works cost roughly		55,000
installation at site		10,000
6% royalty on NRDC patents		4,925
notional 20% NRDC profit		11,000
selling commission to Ferranti		2,075
Customer price		83,000

Source: NRDC 86/10/2, Managing Directors report to the 33rd NRDC board meeting, 28/5/52.

[53]NRDC 86/7/5, Halsbury to Bass 4/12/51.

[54]NRDC 86/7/5, Minutes of the 28th NRDC board meeting 19/12/51.

This price was to increase to £103,000 abroad, to cover the extra cost of export. If the customer wanted the provision of high-speed input-output devices, then the home price would be £100,000 and £115,000 abroad.

Eventually 7 Mark 1*'s were produced, 6 were stocked by the NRDC plus one for the MoS, it is uncertain whether this machine was stocked by the NRDC or bought directly by MoS. The customers and sponsors for all the Mark1 and 1*'s follows:

Table 2.2 Mark 1 Sales.

Code No.	Type	Sponsor	Customer/User	Installed
DC1	Mark1	MoS/DSIR	Manchester University and MoS	1951
DC2	Mark1	National Development Council of Canada	University of Toronto	1952
DC3	Mark1*	MoS or NRDC	MoS	1953
DC4	Mark1*	NRDC	Shell Labs. Holland	1954
DC5	Mark1*	NRDC	National Inst. for the Application of Mathematics, Rome.	1955
DC6	Mark1*	NRDC	AWRE, Aldermaston	1954
DC7	Mark1*	NRDC	MoS	1955
DC8	Mark1*	NRDC	A.V. Roe & Co.	1954
DC9	Mark1*	NRDC	Armstrong Siddley Motors	1957

Source: B.B. Swann, 'The Ferranti Computer Department', 1975.

The final machines were commissioned despite some resistance from the Board of Trade, who were worried that the on-going contract was ultra vires. However, by this stage the machine was becoming increasingly outdated[55] and was receiving little new interest.

Vincent de Ferranti's attitude to these early computer developments.

Earlier it was seen that the company refused to cross subsidise the Instrument Department so that it could start developing computers[56]. This implies that Ferranti was operating a strict decentralised structure, which was undoubtedly the intention. However, it was a family business of limited size, and it seems that Vincent would have been involved in a number of the strategic decisions that operating divisions made.

Nevertheless, it seems that the Instruments Department did have a large measure of freedom. The Department went ahead with detailed talks with the NRDC without feeling it necessary to discuss possible arrangements with the company management. This was testified to by the way Vincent ruled out the possibility of the Instrument Department accepting a loan from the

[55]NRDC 86/9/1, Minutes of the NRDC's Electronic Computer Sub-Committee, 1/12/53.

[56]See above pp48-50.

NRDC, after the Department had spent some time on the negotiations. Bass' idea of the NRDC taking a stake in the Department would undoubtedly have been abhorrent to Vincent. It will be seen that this degree of autonomy led to major control and cost problems in the Computer Department during the mid-1950s.

Vincent's overall attitude to the computer venture seems to have been negative from its inception. This is seen not only by the initial reticence to fund the expansion into computing, but also by continued displays of doubts about the advisability of being in this market. The NRDC made this clear to the Board of Trade when it requested permission to fund the Mark 1* project:

> 'I would be grateful for your earliest indication that the BoT will approve this transaction in principle. You are sufficiently acquainted with the history of this matter to be aware that we have gone to endless trouble to persuade Ferranti to show some initiative in the development of computers. They are, however, extremely reluctant to invest any financial stake in their development notwithstanding the fact that the project has been, so far, financed from the public purse. In these circumstances it seems to me that we are fully justified in trading in these machines as a means of securing their development and exploitation at a faster rate than will take place if the matter is left in Ferranti's hands. If the latter were the case then in my opinion our computer inventions would be currently "insufficiently developed and exploited" within the meaning of section 1 of the <u>Development of Inventions Act</u>....'[57].

Of the next two computer systems developed by Ferranti, the NRDC would sponsor one and was in active discussion about supporting the second. Despite the success of the Mark 1* and the fact that the next machines were expected to sell in greater numbers, the company continued to show reticence about taking the responsibility, and the potential profit, itself. Though it must be said that financing both projects might have proved difficult for the firm.

In March 1953, Halsbury discussed with Sir Vincent how the NRDC could speed up the development of the UK computer industry[58]. Halsbury suggested that the NRDC take over the responsibility for marketing the machines that it was sponsoring. Vincent was against this idea as he expected that this would lead to duplication of effort, and that, in any case, marketing was the natural forte of the private enterprise. He argued that Ferranti was progressing at a sustainable rate, and that the slow expansion of the computer operation was the prudent course. Contrary to this statement it will, in fact, be seen that Vincent had little faith in

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[57]NRDC 86/7/5, Unsigned letter to S.A. Dakin, 27/12/51.

[58]NRDC 86/9/1, internal NRDC file note on the meeting, 11/3/53.

the abilities of his company to sell into a harshly competitive market[59]. Nevertheless, he did not want to become tied to a long-term commitment to the NRDC. The efforts of the firm to overcome its perceived lack of selling skills will be considered later when looking its abortive attempt to work with the Powers-Samas company.

Halsbury believed that much of Ferranti's conservatism was due to a longer than average company memory, not surprising given its family nature:

> 'A contributory factor towards this state of affairs may be that his [Sir Vincent's] father pretty well broke the firm through indebtedness to the banks in the early days, and Sir Vincent's one determination is never again to get into a mess. As his outlook is dominated by the twin factors of a desire for complete independence and a super-cautious attitude to risk taking, he has avoided the worst forms of hubris and the firm is merely overdrawn £4 million.'[60]

Given this conservatism, Sir Vincent was against Ferranti bearing the risk of assuming the role of a computer manufacturer:

> 'If Sir Vincent were looking for a new enterprise to invest Ferranti money in, he would not himself pick computers. He has, however, no objection to a Government agency picking computers for him provided that he is fully compensated for the use of Ferranti facilities. He expects 100% compensation in the first instance and the right to be the sole ultimately interested party in whatever comes of the project.'[61]

Sir Vincent offered a graphical representation of how he expected costs and profit to develop as the Computer Department matured. He only expected profits after an initially large outlay of money for R&D. If the government was willing to pay for him to reach the break even point (E) he was willing to build computers, otherwise not:

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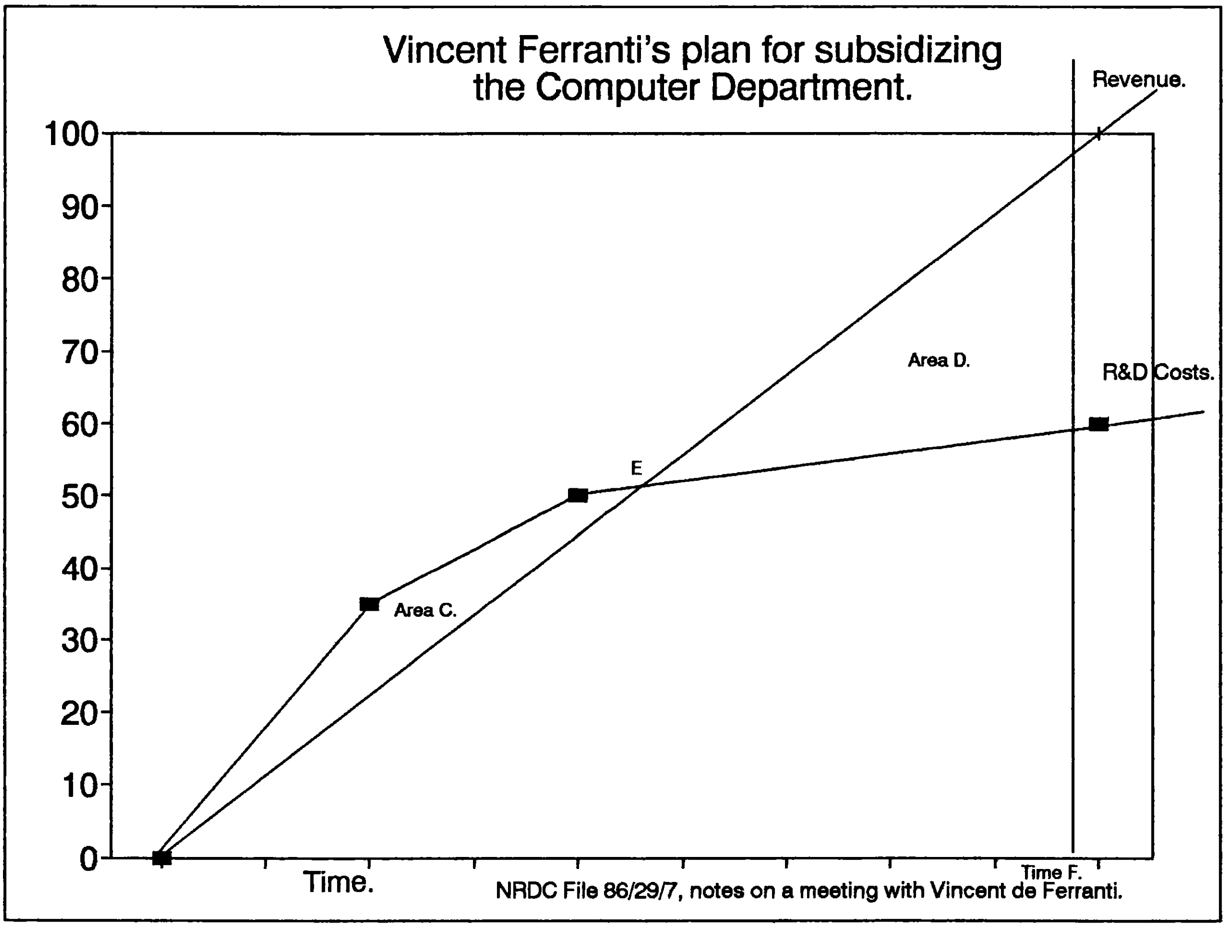
[59]Swann, 'Ferranti Computer Department'.

[60]NRDC 86/30/2, Lord Halsbury 'Some thoughts on Ferranti' 15/2/57. This appears to have been a paper written for the benefit of the new NRDC Chairman Sir William Black.

[61]NRDC 86/29/7, Halsbury's note on a meeting with Ferranti 16/3/54.

Figure 2.2



Vincent Ferranti's plan for subsidizing the Computer Department.
Revenue.
R&D Costs.
100
90
80
70
60
50
40
30
20
10
0
Area C.
Area D.
E
Time.
Time F.
NRDC File 86/29/7, notes on a meeting with Vincent de Ferranti.

Vincent proposed that whoever sponsored the Computer Department would receive all the profit up to time F, covering repayment and some profit. From this point the whole operation would be Ferranti's responsibility. He described this as the 'launching' point for the new department.

This plan was outlined during negotiations over the Mark II Mercury computer, the Mark 1* successor[62]. It is worth noting that even when Sir Vincent decided that Ferranti should develop the Mercury without NRDC support, it was made clear that this decision was made with considerable unease. One of Ferranti's staff put Vincent's agreement to this in terms of his own sky rocket analogy:

> 'Sir Vincent has accepted our view that you [the NRDC] have in fact launched us and that we can now fly. He did not come round to this without a lot of heart-searching, as he seems to think you are a better business man than we are. His view is that so long as the control of selling policy is in your hands you will see to it that everything is sold at a profit because you have nothing else out of which to recover your expenses. We on our side are under the suspicion of wanting to run the computer business at no profit or a loss by subsidising it out of the rest of the Ferranti enterprises.'[63]

If the Computer Department had a degree of operational independence, and later seems to have been riven with discord, it may have been because the senior management were not committed to it.

Formation of the Computer Department.

At the same meeting of March 1953 in which Vincent had rejected the idea of the NRDC taking over the marketing of computers, the question of organisation was raised. Halsbury was concerned that the building of computers was a marginal activity for the company. He suggested that Ferranti's managerial commitment drew unfavourable comparison to the situation at IBM, where computers were receiving the highest attention[64]. Halsbury accepted that Sir Vincent himself had a wide range of company affairs to deal with, covering the world-wide dealings of the company. Sir Vincent stated that he believed his operational managers were completely capable. He stated that the top team in the Instruments Department, Grundy, Toothill and Carter, were quite capable of running wholly independent companies and were, therefore, capable of running a single department. However, Halsbury pointed out that these three men were all involved in the running of the whole of the instruments operation. In fact the first people

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[62]See below, p53.

[63]NRDC 86/29/7, Halsbury's notes on Ferranti meeting.

[64]Ibid.

who were solely involved in computers were Bowden and Swann in sales and marketing and Pollard in design and manufacturing. They did not report to a single person with complete responsibility for computers, but to the previously mentioned senior staff.

Quite clearly Halsbury had hit on a sore point. In a July visit to the company, Halsbury learnt of a major shake up in the organisation[65]. According to the Ferranti representatives at the meeting, the shake up had been precipitated by a revolt by Pollard. He was apparently tired of 'government by committee'[66], and had demanded a better structure. The company therefore made the computer operation into a full department: it was given the same organisation and status as the other departments in the company. Pollard became the overall manager[67], though Grundy remained the director in charge. At the time this satisfied Halsbury. However, it soon became clear that there were huge rifts within the department, which eventually proved costly for the NRDC.

As was implied earlier, the Ferranti company was less than vigorous in its strict adherence to nominal managerial structures. Lord Halsbury experienced a number of problems arising from Sir Vincent's attitude:

> [Sir Vincent] is in the French sense of the word 'le patron' and, whatever managerial structure may be adopted on a paper chart, everybody in the organisation is in reality working for Sir Vincent. One of his concerns of course is to know what is going on everywhere, and from this point of view I do not think he has any great objection to members of his team being at sixes and sevens among themselves. It means that in the end they come to him with their stories and this enables him to keep his ear to the ground. The elder members of the Ferranti family frequently quarrel among themselves, and one of Sir Vincent's main preoccupations seems to be to keep anyone else out of his personal family enclosure, now reserved for himself and his sons Sebastian and Basil.'[68]

Pegasus and Mercury, the ranges for the late 1950's.

The Mark1* made Ferranti the leading European computer company. It was adopting a new organisational format and it had the backing of the British government, in the form of the NRDC. Ferranti had a solid technical base, and the market was starting to develop rapidly in the US and was

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[65]NRDC 86/9/1, file note on meeting between Halsbury and Messers. Grundy, Bowden, Swann and Welchman. 24/7/53.

[66]Ibid.

[67]P.L. Young, 'The Ferranti Computer Department, pt I', Electrical Manufacturer, March 1958.

[68]NRDC 86/30/2, Lord Halsbury, 'Some thoughts on Ferranti'.

likely to do the same in Europe. The firm introduced two new, first generation, machines in the mid 1950s, the medium scale, general purpose, Pegasus and the large scale scientific Mercury. This was the most advanced range in Europe, yet it failed to establish a strong enough base to secure its future.

Ferranti Package Computer 1, Pegasus.

Development and NRDC sponsorship.

As early as 1952 some NRDC board members were enthusiastic to see Ferranti working on a smaller and cheaper system, which they hoped would find a larger user base than the complex Mark1*[69]. Prof. Blackett, suggested that such a computer would be useful both to smaller scientific users and in some commercial roles, especially in PAYE calculations. Two smaller systems were already being developed in the UK[70]. Firstly, there was the English Electric version of the National Physical Laboratories Pilot ACE machine. The NRDC had little knowledge of the Pilot Ace project, and was not particularly interested in a machine geared to scientific research. The second system was actually being supported by the NRDC. It was a design project within the military and instruments firm, Elliott Brothers[71]. Halsbury commented to Blackett that the NRDC would not be able simultaneously to launch a project for a smaller Ferranti machine, while also supporting a replacement for the Mark1* and Elliott's development work. However, this turned out not to be a dilemma.

The relationship between the NRDC and Elliott Brothers was not a great success, at least on the part of the NRDC, though it did benefit Ferranti. Two NRDC representatives, John Crawley and Dennis Hennessey, visited Elliott Brothers in 1950 to look at its computer developments. They saw a computer system which had been developed for a Royal Navy fire control system[72]. The NRDC was impressed by the packaging of the machine, which used interchangeable printed circuit boards, greatly easing the maintenance problem associated with earlier machines. It was also impressed

[69]NRDC 86/9/1, notes on a meeting between the NRDC and Ferranti, Prof. P.M.S. Blackett asked the Ferranti representatives whether they had any plans for such a system, 16/6/52.

[70]Ibid, comment by the NRDC's Hennessey.

[71]Ibid.

[72]NRDC 86/13/1, NRDC Board meeting 23/8/50.

by the computer development group, especially its head W.S. Elliott[73], who was an ex-employee of MoS and an important figure in wartime radar developments. Finally the head of Elliotts, Sir Leon Bagrit, had a general plan that appealed to Lord Halsbury. He talked about building a small machine at a cost of £20-25,000, for sale in the vast US market[74]. He also spoke of linking the computer to a small French accounting machine firm, Logabax[75], in which Bagrit had a holding. Halsbury had always wanted a link between an electronics operation and a business machine company.

However, the NRDC sponsored machine, the Elliott 401, was not a great success. The prototype was completed by early 1953[76], and was eventually installed at Cambridge University[77]. Cambridge was given use of the machine, in return for fine tuning it. However, they discovered that it was a flawed system that needed a good deal of work done on it[78]. In the mean-time the main members of Elliotts' computer team, including W.S. Elliott and H.G. Carpenter, handed in their notice to Elliott Brothers[79]. It took a number of months for the problems to be sorted out, and rather than go to Elliott's for the redesign work, the NRDC employed the ex-Elliott team to work with the University. Elliott's only supplied hardware to the specification of this team. W.S. Elliott then left NRDC employment and started work at Ferranti[80].

Grundy had already put in a bid to replace Elliott Brothers as the main contractor for the 401 project[81]. Initially the NRDC could see no

[73]Not related to the company name which dated back to the previous century.

[74]NRDC 86/13/1, discussion between Halsbury and Bagrit in Chicago, reported by the NRDC's W.E.P Johnson in a letter to the NRDC Chairman Sir Percy Mills, 24/11/50.

[75]NRDC box 86/13, Halsbury to Bagrit 10/4/53.

[76]NRDC 86/13, Internal memo by Hennessey, summarizing the state of the 401 contract. 31/3/53.

[77]NRDC 86/13, Crawley to Elliott Brothers 17/7/53.

[78]NRDC box 86/13, Halsbury to Bagrit 16/10/53.

[79]Ibid.

[80]NRDC 86/13, minutes of the 13th meeting of the electronic computer sub-committee of the NRDC. 24/11/53.

[81]NRDC 86/30/1, Letter replying to Ferranti's Grundy from Halsbury. 29/9/53.

reason for this change of allegiance[82]. A mere two months later, the NRDC and Ferranti were actively negotiating around this proposal[83].

There seems to have been a number of reasons for this. Firstly there was the perceived need for a medium scale computer with more advanced components than the Mark1*. While the technical problems of the 401 had disillusioned the NRDC as to Elliott Brothers' capability to produce useful commercial computers, the faith in the ex-Elliott design team still existed. Ferranti won more patronage from the NRDC now that it employed W.S. Elliott to head a new design department. The NRDC told Ferranti that it did not want a 'Chinese copy of the 401'. The Corporation wanted a machine based on the design, but differing in a number of its weak areas[84].

Swann, the Ferranti sales manager, wrote to the NRDC requesting not only the right to use all the '401 techniques' and a draft specification for the machine, but also gave them the results of a market appraisal for such a computer[85]. The initial markets targeted for this medium scale processor were industries that required advanced scientific calculations, of these the aerospace industry was the largest. It was planned later to add magnetic tape drives to the system, which would make the machine suitable for more input-output intensive tasks, like commercial and administrative duties. He concluded that commercial applications would prove to be a much larger market. The computer was expected to sell for £16,000-22,000, putting it within reach of a few commercial users.

In early 1954 Halsbury wrote to Ferranti ordering 10 Ferranti Packaged Computer 1 computers, in a similar arrangement to the Mark1* contract[86]. The Corporation expected this to cost £220,000. Of this the development costs were to amount to £70,000, to be recovered at a rate of £7000 on each machine. However, it should be noted that the contract was cost plus: Ferranti was to receive a fixed percentage profit for producing the machines and then a commission for selling them. For the NRDC this was a major error.

Most of the problems surrounding the FPC 1, later marketed as the

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[82]Ibid.

[83]NRDC 86/30/1, NRDC's Manager Computer Project, presumably Hennessey, to Grundy. 26/11/53.

[84]Ibid.

[85]NRDC 86/30/1, Ferranti's Swann to the NRDC 17/12/53.

[86]NRDC 86/30/1, Halsbury to Ferranti 2/2/54.

Pegasus, were created by the decision to split development and production. Pegasus was designed by W.S. Elliott in a new centre in London. The new operation in Portland Place, consisted of the London Computer Laboratory, a number of personnel from the Computing Research Group plus the Computer Sales Department[87]. However, production was to be at the Moston plant in Manchester, under the control of Pollard. Simultaneously the Moston operation was developing a new scientific computer, the Mercury, while the London centre marketed all the computers made by Ferranti[88].

This arrangement created much infighting within the company, with the Moston and London operations in competition for supremacy. In early 1953[89], Swann had suggested to Grundy that a 401 type machine would be a very saleable item, and it was the sales staff that drove the Pegasus project on. Grundy hired Elliott to design the type of system wanted by the sales people. This is where the first problem arose. According to both Swann[90] and Halsbury[91], Elliott had once turned Pollard down for a job and now found himself Pollard's subordinate. Pollard was not pleased that Grundy had hired Elliott, nor that he was being given his own operation in London[92]. Swann, and presumably the whole of his sales team in London, saw the Pegasus as a machine that they could sell, but saw the large Mercury computer being developed in Manchester as offering limited potential. Therefore, Swann seems to have sided with W.S. Elliott in this conflict, and his recollections tend to support the views held by the London half of the Computer Department. He suggests that the competition between the two men led to empire building. Elliott wanted to build the first two or three Pegasus computers in London: it was argued that building the first machines near the development team would be beneficial. Once all the problems had been ironed out full production could be moved to Moston. Swann, however, claims that Pollard decided to rush into the production of Pegasus, in order to secure the pre-eminent position in the project. Swann claimed that this was one of a number of ways in which Pollard tried to frustrate the London operation. The outcome was huge cost over-runs and

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[87]P.L. Young, 'The growth of a computer department, part II', Electrical Manufacturer, April 1958, pp30-33.

[88]Ibid.

[89]Swann, 'Ferranti Computer Department'.

[90]Ibid.

[91]NRDC 86/30/2, Halsbury, 'Some thought on Ferranti' 15/2/57.

[92]Swann, 'Ferranti Computer Department'.

delays in deliveries, caused by going into production to quickly.

The NRDC seemed have to apportioned blame more widely, but less on Pollard and more on Elliott. It also levelled blame at the Sales Department and the lax accounting procedures of Ferranti's Costing Department, which failed to inform Pollard that costs were getting out of hand.

The cost calculations used for planning the project, were based on direct labour and materials costing 20% of the total production costs, overheads were to be 60%, and a 20% margin was allowed. Overheads were, therefore, charged at 300% on the direct costs[93]. Presumably the overheads were indirect labour, depreciation of plant, indeed the whole gamut of costs that are incurred indirectly.

On top of the manufacturing costs there was the cost of development. This was budgeted at £70,000. This seemed more than fair as the machine was to be an improved version of the 401, to which Ferranti had access to the design personnel and patents. The cost of the 401, design and prototype, had been £60,000[94].

However, costs were already out of control when the contract was agreed. The NRDC later estimated that the overhead costs were 750% on direct costs in 1954 and eventually rose to 900%[95]. By autumn 1956 the NRDC had bills amounting to £444,500 with the likelihood of the total being over £500,000, over twice the original estimate[96]. It is certain that the management of the operation did not know this was the case, indeed, Pollard was originally thinking in terms of a fixed price contract[97]. Pollard believed that Ferranti would make at least as much profit from a fixed price contract, with the possibility of coming in well under cost. Evidently he did not know that costs were already out of control.

The NRDC believed that some of the blame came from the splitting of responsibilities, and the geographical separation of design and manufacture. This was compounded by the decision to go straight into production without a prototype[98]. This conclusion was similar to Swann's

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[93]NRDC 86/30/2, Halsbury, 'Some thoughts on Ferranti'.

[94]Ibid.

[95]NRDC 86/30/1, Meeting between the NRDC's Hennessey and Crawley and Ferranti's Grundy and Pollard. Hennessey's notes 12/9/56.

[96]Ibid.

[97]NRDC 86/30/1, this detail comes in an internal NRDC report, which unfortunately is not dated, but appears to have been in the autumn 1956 period.

[98]Ibid.

argument that prototypes should have been produced in London. The lack of prototypes led to long delays in delivery, and continued modification of machines as they were being produced. There was no standard to copy. This was made worse by arguments about who should design the drum memory that was used as back-up memory for the faster nickel delay line memory. They squabbled about this endlessly, but ended up with neither the Moston nor the London operations having a drum ready to incorporate into the system when it was finished, leading to further delay and cost[99].

However, in the eyes of the NRDC, it was the London centre where costs were running riot. In February 1956, Pollard assured the NRDC that he had £9000 in hand on the development account[100]. The truth was that he was already well over budget and later had to apologise to the NRDC for this, telling them that he had been misinformed by the accounts department. One problem was that the Portland Place operation had decided to set up an extremely expensive sales promotion centre, and to increase its sales activities. This was on top of the increasingly over-spent design operation. They were not keeping any account of work in progress in London, and rather than route bills via Moston they sent them directly to the NRDC, as Moston were doing on their own behalf. The NRDC seem to have agreed that Pollard was, in fact, being misled. Eventually the design cost of the machine was £170,000 and all other costs had also rocketed[101].

If the doubling in the cost of the machines was not bad enough, the lack of information was worse for the NRDC. Ferranti continued to search for orders for the ten machines that the NRDC had ordered. It had no internal information that the costs had risen, though this did not matter to Ferranti as it was a cost plus contract. Portland Place continued to sell machines at the original asking price of £35,000, despite costs having doubled. Ferranti stuck to this price to the bitter end[102]: the NRDC was left with a massive loss on the machines.

Eventually, after a good deal of arm-twisting by Halsbury and the new NRDC chairman W.R. Black, the company agreed to pay back £75,000[103], but not until early 1958. The Corporation eventually suffered a loss of

[99]NRDC 86/30/2, Halsbury, 'Some thought on Ferranti'.

[100]NRDC 86/30/1, undated internal memo.

[101]Ibid.

[102]ibid.

[103]NRDC 86/30/3, correspondent from Sebastian de Ferranti to Black, 20/2/58.

£140,145[104].

This was not the end of the Pegasus. Indeed, Ferranti must have benefited greatly from the NRDC's misfortune. Pollard later told Halsbury that the original cost projections were calculated at the rate Ferranti expected them to be once production had progressed sufficiently[105]. It was planning to sell the machines at the price it expected to achieve after it had progressed some way down the learning curve. Later machines were therefore expected to be cheaper, but this was too late for the NRDC, which, in effect, paid for the loss leader stage of the project.

After the first ten machines had been produced, Sir Vincent finally decided that the Computer Department was now 'launched', and it continued to build and sell the Pegasus. The company installed 26 Pegasus 1s between 1956 and 1960, and 12 updated Pegasus 2s between 1959 and 1962[106]. Ferranti had not paid anything for the development of the original series, nor for its initial production or even for establishing a sales operation. The latter, though criticised as an unexpected cost by the NRDC, was essential to selling a smaller, more general application system. The sale of early scientific systems was very much an exercise in selling to a closed community of advanced scientists, but the Pegasus was aimed at a much broader audience. The only cost Ferranti had on its first ten sales was the £75,000 settlement with the NRDC, a fairly small development cost.

Selling the Pegasus: the relationship with Power-Samas.

Vincent de Ferranti was unconvinced, firstly about the prudence of the computer manufacturing scheme, and secondly about the ability of Ferranti to sell computers. It was becoming obvious that computers were going to be increasingly used in commercial environments. Potential applications included: calculating payroll, preparing accounts, and calculating statistical data. According to Swann, the Ferranti company had a different attitude to this market compared to the business machine firms[107]. Ferranti was interested in doing calculations that, in the past, had been too large to tackle. Business machines companies looked on office equipment simultaneously to improve the office's function, and to cut staff; business machines were efficiency tools. The tabulating machines

[104]NRDC 86/30/3, 'Estimates of Final Position on F.P.C. Contract', 97th NRDC board meeting, 26/2/58.

[105]NRDC 86/30/2, Halsbury, 'Some thoughts on Ferranti'.

[106]Swann, 'Ferranti Computer Department'.

[107]Ibid.

firms had experience of selling machines in this commercial market.

Ferranti talked to both the major British tabulator producers about this problem. Encouraged by the NRDC, Ferranti first talked to the British Tabulating Machine company. All that came from this arrangement was BTM's help in attaching its punched card equipment to Ferranti machines. The main sticking point was the fact that BTM wanted the sole right to market any machines to come out of a joint venture[108]. However, Swann saw another reason for the failure of the BTM negotiations: Pollard favoured a link up with its rival Powers-Samas.

There were a number of pressures on Ferranti to come to some arrangement with a business machines firm. Firstly, there was pressure from Blackett and the NRDC to get involved in commercial machines, leading in part to Pegasus. If this was going to be sold in the commercial data processing field there were a number of problems that had to be tackled. To sell to this group of users better peripherals were needed; BTM punched cards were the most common data storage medium at that time, but a long term arrangement with this firm seemed unlikely. Even more importantly, the selling of small machines to the commercial market needed a national sales force, and a large service organisation. This would be very expensive to build up:

> '...selling of small computers would [require] many customers to get a reasonable turnover and these would be widely scattered. This would mean a large sales and service organisation, which we were sure the Chairman would not agree to'[109].

Ferranti had no national sales network: all selling was done at its London office. While this was adequate for selling to engineers (advanced users were more willing to travel to find the best equipment), it was not a good enough method for selling to commercial users.

Discussions with Powers-Samas started in July 1952[110], and centred on two areas:

1) The two companies were jointly to design a small commercial computer.

2) Power-Samas was to take over the selling of Ferranti computers in the commercial market.

However, neither the manufacturing nor the sales operations of the companies worked well together. The manufacturing operation of Powers and Ferranti formed a brief liaison to design a computer. However, they failed to come up with a machine: both design teams had their own projects which

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[108]Ibid.

[109]Ibid.

[110]Ibid.

took priority over the joint venture. Likewise the Powers sales operation and the Ferranti Computer Sales Department proved completely incompatible.

In March 1954 the sales staffs of the two companies presented a joint paper, proposing close collaboration leading to an 'integrated data processing system'[111]. Despite these talks, the first 10 Pegasuses were going to use BTM, rather than Powers, punched card peripherals. The reason for this was straightforward. The IBM/BTM standard punched card was the one usually used by engineering customers[112]. This was because they used an electronic device to read the cards rather than the pin mechanism used by the Remington/Powers standard cards. The IBM/BTM machines also had a plug board 'reprogramming' system, which made them more flexible, especially useful in scientific calculations where parameters change frequently. Therefore, a special version of the Pegasus, Pluto, was to be made using the Powers card, which Powers staff were to sell.

The outcome was that Ferranti was trying to sell the Pegasus primarily to technical users, while the Powers staff were meant to sell Pluto to commercial customers. However, the Powers staff were not, in reality, selling it. By 1955, Powers was selling its own smaller PCC calculating device, which, while not a fully functional computer, got preferential treatment from the Powers' staff. A further problem was that Ferranti would only offer a 15% discount on the price of the machines it sold to Powers; Powers wanted 25%. This further discouraged Powers from actively selling the system.

By the time BTM and Power-Samas merged to form ICT[113], Powers had not created a single order for Ferranti. All the arrangement achieved was to reduce the market to which Ferranti could sell systems on its own behalf. The Pegasus sold well enough to technical users, but many of these machines were used in a secondary administration role, proving that it could well have sold in the commercial market.

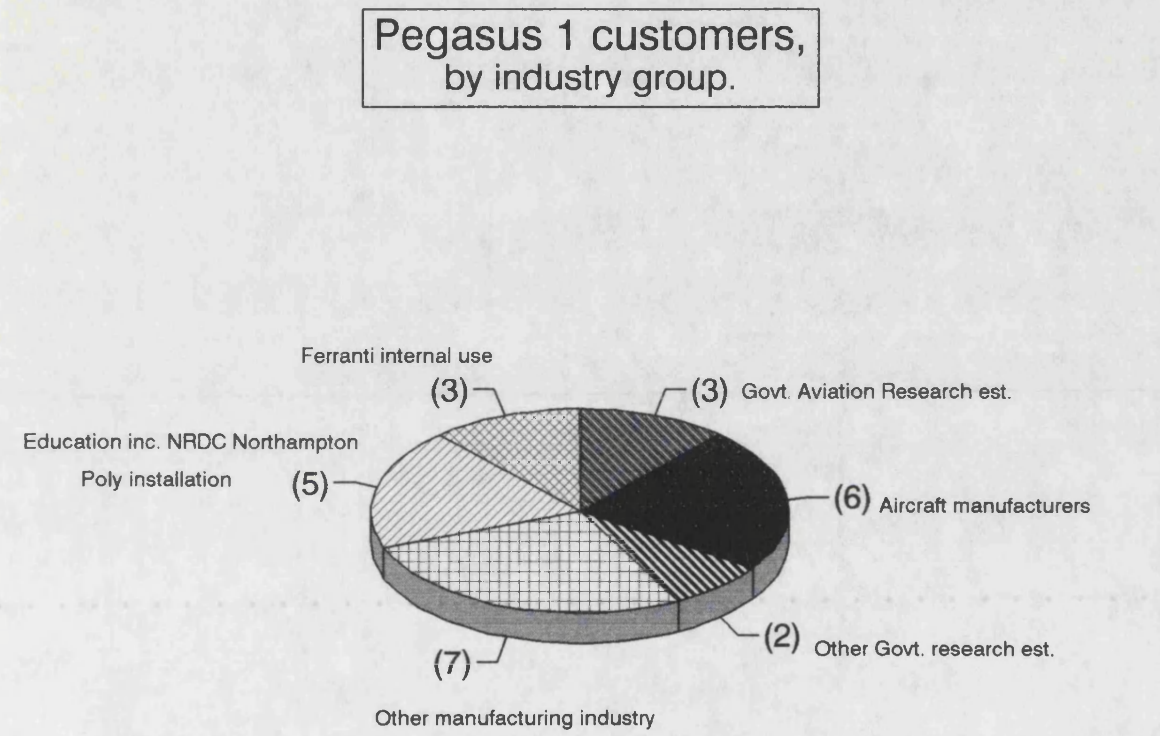
In the early 1960s Ferranti produced the updated Pegasus 2. Free from the Powers arrangement, many were sold into the commercial market. But by this stage it was too late; this first generation computer was outdated. Figures 2.3 and 2.4 show a breakdown of the users of Pegasus computers:

[111]Ibid.

[112]See below, chapter 8 on IBM, pp302-310.

[113]See below, chapter 5 on ICT.

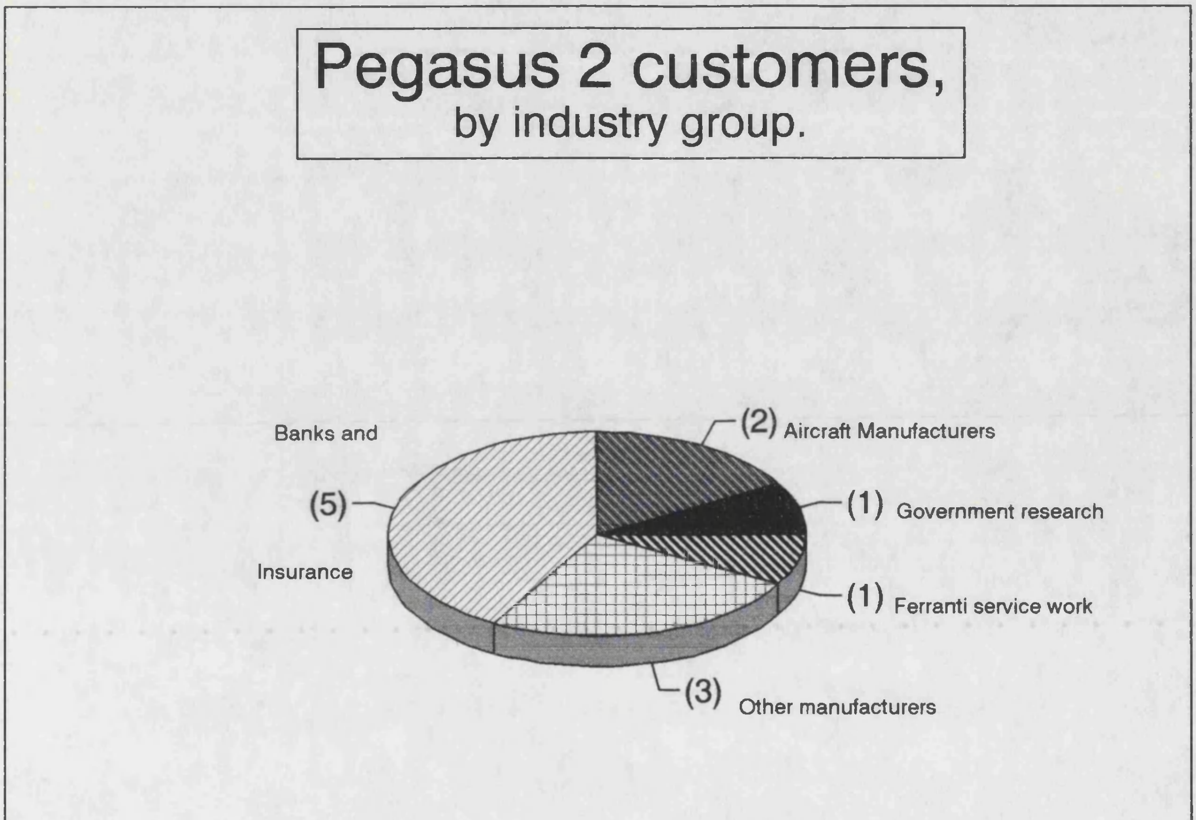
Figure 2.3



3 of the systems used in "other manufacturing industry "and 2 of the Ferranti machines were used for designing heavy electrical plant. Another 3 were used in the steel industry.

B.Swann "The Ferranti Computer Department" 1975.

Figure 2.4



B.Swann "The Ferranti Computer Department" 1975.

Perseus.

In addition to the Pegasus, Ferranti produced one purely commercial system, the Perseus, designed for the insurance industry. This was a scheme devised by the first Ferranti sales manager, Bowden, after he had visited the USA to study advances in commercial computing. After this trip he had discussed user needs with the Royal Insurance Company[114]. The project consisted of a small number of Ferranti engineers and an actuary from Royal Insurance. Unfortunately for this project, it too became a victim of the agreement with Powers.

Perseus was a large machine constructed out of the same packages that made up the Pegasus. However, its development was held up for a number of years because there was some concern that it overlapped with Powers' interests too much. Powers was the leading supplier of punched card equipment to the insurance industry, and it was concerned that Perseus could damage this market. Perseus used magnetic tape memory and Powers' punched cards. Magnetic tapes were particularly useful to the insurance companies as they had huge data bases to access. Two models were finally built at Ferranti's Bracknell Laboratories, showing the flexibility of the Pegasus package system[115]. The first was produced for South African Mutual Life, and the second for a Swedish insurance company. Both were completed in the second half of 1959, way too late for a first generation machine to become popular.

Mark II Mercury.

With the sales department pursuing the future of the Pegasus, the Moston operation was busying itself with the larger Mercury computer. The Mercury was based on the Meg computer developed by Dr Tom Kilburn at Manchester University[116]. It was a machine designed to take up the mantle of the Mark 1 as a fast computer for scientific calculation.

Kilburn had the basic machine working from October 1952 and in its final floating point version[117] by May 1954[118]. The first production

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[114]Swann, 'Ferranti Computer Development'.

[115]Ibid.

[116]S.H. Lavington A history of Manchester computers, Manchester, 1975 p25.

[117]Floating point arithmetic eases the programming task for mathematical calculations. In the Meg it was a hardware feature, whereas previously it had to be done slowly with software.

machine was not installed until August 1957. Kilburn was critical of this delay in getting the system into the market, and blamed it on the lengthy negotiations taking place between the NRDC, the DSIR and Ferranti on the future of the system.

Swann states that Ferranti requested a sum of £25,000 from the DSIR to develop a saleable version of Meg[119]. However, minutes of a meeting held in 1954 show that, in fact, Ferranti had requested £400,000 from the DSIR to fund general computer developments not associated with a single project[120]. Sir Vincent proposed the scheme to 'launch' the Ferranti Computer Department, and the graph he used to explain this has been shown above[121]. The DSIR turned this plan down on the advice of the Brunt committee, which did not see industrial support as a DSIR responsibility[122]. On the other hand, Halsbury was interested in supporting the floating point technology. However, to make another cash advance of this nature the NRDC needed certain concessions. The NRDC wanted the period for recovering the loan to last ten years, and be levied as a flat rate on all Ferranti's computer and computer sub-system sales[123]. Secondly it wanted the right to vet any sub-contracts that Ferranti wanted to make. This was apparently a reference to the negotiations going on between Ferranti and Powers.

Such long term arrangements were onerous to the company. However, this was not the only reason the company rejected the scheme. Pollard was trying to persuade Sir Vincent that the system would be comparatively cheap to produce, having been partially developed by the University. He also tried to persuade him that it would be a profitable offering[124]. Therefore, Ferranti decided to produce the system with its own resources, and hoped to keep the full profit to itself.

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[118]NRDC 86/29/4, note of a conversation with Tom Kilburn in the minutes of the 27th computer sub-committee meeting 15/3/55.

[119]Swann, 'Ferranti Computer Department'.

[120]NRDC 86/29/7, Halsbury's notes on a meeting between himself, the NRDC Chairman, Lockwood, and Ferranti's Sir Vincent, Grundy, Pollard, Robson, Sions, Swann and Welchman, 23/3/54.

[121]Figure 2.2, p68.

[122]NRDC 86/29/7, Halsbury's notes on a meeting with Ferranti 23/3/54.

[123]Ibid.

[124]Swann, 'Ferranti Computer Department'.

Selling the Mercury.

Swann, as manager of sales, did not share Pollard's view of the machine:

> 'After a meeting in the office of [the] NRDC I wrote that I could not see sales of more than four of the projected big computers - though this was of course early days.'[125]

In fact 19 were installed between 1957 and 1961. In a way Swann dismisses most of these sales as chance:

> 'Some years later one of my programmers, John Davidson, told me he had come across this memorandum [see above]; we had by then sold about a dozen Mercurys. I said it only showed how difficult market prophecies could be, but John said that apart from the sales to nuclear establishments we had in fact sold four.'[126]

Swann believed that there was an anti-sales atmosphere in Manchester, with the engineers more interested in the finesse of their technology. They liked the powerful, academically inspired Mercury, but did not like the popular, Elliott-designed, Pegasus. Equally, it appears that there was little enthusiasm in London for selling the big machines, which sold at an average price of £120,000[127].

Nevertheless, the Mercury was a larger seller than the sales department predicted. If the Pegasus had become the work horse of the British aerospace industry, then the Mercury did the same for the atomic research establishments, not just in Britain but across Europe. This is not surprising; it was described as the first computer designed especially for large scale scientific work, outside of the USA[128]. Of the 19 sold, 10 were used for atomic energy and power research, 6 of these abroad, 5 in Europe and 1 in Brazil. The other 9 went to a wide number of other scientific applications.

This period must be counted as the peak of Ferranti's computer operations. The Pegasus was selling well for medium scale technical applications and the Mercury as one of the standard systems used for nuclear calculations. While its link with Powers had proved fruitless in producing commercial sales, it was with this very sort of product range that the US scientific computer manufacturer CDC based its spectacular growth. Notably CDC's 6600 super-computer drew on developments made in Ferranti's last stand-alone computer, the ATLAS.

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[125] Ibid.

[126] Ibid.

[127] Hendry, Innovating for failure, p183, at 1963 prices.

[128] Datamation, Nov/Dec 1958, p17.

According to Swann the company did consider specialising in the scientific market, a policy which would have preempted CDC. One problem with this idea was Ferranti's failure to secure any orders in the US, by far the largest market of scientific computers. In some respects this is not surprising. There were a number of US firms supplying such systems, including IBM. There was also a strong tendency for buyers of such machines to look for domestic supply. This was due to the fact that many of the scientific computers installed in the US were either owned by the government, or used by civil contractors on government contracts. This led to the civil buyers wanting the same systems as the government, and this meant domestic producers.

One extra difficulty for potential competitors was IBM's policy of offering large discounts to scientific users, especially universities. IBM offered discounts of up to 60% to educational buyers, and a lesser amount to some other purchasers. This was offered as a combination of tax write-off, as the US government encouraged such use, and IBM's own enthusiasm to tie up this market, so future users would be trained on IBM systems. Ferranti found it completely impossible to compete on these terms.

In any case, if Ferranti had tried to establish itself in the US market, it would have been faced with very large costs. Establishing comprehensive sales and service facilities throughout the USA would have been expensive. It has already been seen that the company was averse to such risks.

On the other hand, Ferranti was selling machines to the European community of scientists. In Europe, and especially in the UK, Ferranti was able to compete against IBM's 650 computer with the Pegasus; and the Mercury could compete with some of IBM's 700 series machines.

<u>The Orion and the Sirius: The failure to produce appropriate replacements for the old range.</u>

By 1957 the Pegasus and Mercury systems were being delivered to customers. However, the sales department was concerned that, come the November 1958 Computer Exhibition, Ferranti would have no new system to talk about[129]. It was clear that the company needed to start work on solid state computers; firms such as EMI had already progressed a long way with this kind of work. A second factor taxing the mind of the company was that it was becoming apparent that commercial and scientific computing were starting to merge. In the first generation of computers it was assumed that

[129] Swann, 'Ferranti Computer Department'.

scientific machines needed a fast processor, but that peripherals were less important. In commercial machines, processors were cheap and slow, but input-output peripherals were given high priority. However, such scientific applications as statistical analysis and meteorology required high speed input-output. Equally, with the introduction of random access disk drives, throughput of commercial data could benefit from faster central processor units. It was also realised that most of a machine's time, in both classes of work, was spent moving data around the system[130]. It became increasingly apparent that the same machine should be applicable to both tasks, it was equally apparent that the Powers collaboration was not going to produce such a computer.

It was decided to build a machine called the Orion to fulfil these needs. Orion was based on a logical unit contained on a single circuit board, which made use of transistors, magnetic cores and transformers; it was called the Neuron circuit[131]. The concept for this type of circuit started in 1953. By 1955 Ferranti's Manchester operation[132] had started Neuron development[133]. In May 1958 the small, test-bed, NEWT machine was completed[134].

At this stage the Ferranti sales team in London, and the West Gorton design and manufacturing operation, once again started arguing about the direction the company should go. The Neuron circuit was designed at a time when the cost of transistors was very high. The Neuron design was aimed at getting the maximum out of each circuit. This was done at the expense of making timing extremely critical, requiring the circuits to achieve very tight tolerances. Pegasus engineers told Swann that the Pegasus circuit packages had had a good margin of safety built in to them. Orion did not: the Neuron circuit was highly reliant on near perfect operation[135]. The sales operation then argued that a small device, like the transistor, would either always be difficult to make, and therefore would have of only limited market potential, or that it would fall in price. It has already been seen that the cost of the Pegasus had been expected to fall as the

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[130]Ibid.

[131]NAHC, Ferranti brochure 'Orion' 1960.

[132]Now moved to a special plant at West Gorton.

[133]Ferranti Archive, A.R. Wilde, 'The Sirius Computer', Ferranti Journal, vol 18, no. 1, spring 1960.

[134]Ibid.

[135]Swann, 'Ferranti computer Department'.

company progressed along the manufacturing learning curve. Swann expected the same for the transistor or it would hardly be worth using, especially for commercial applications.

While the Newt allayed some of the fears that the system would not work, there was also some concern as to the appropriateness of the machine for the market. Pollard was thinking in terms of an expandable machine. It was expected to start at £120,000 and be configured to a system costing hundreds of thousands. It fulfilled the need for a machine that could be sold for commercial data processing: it had very advanced input-output handling routines, as will be discussed later. However, it was not a great advance in speed; it was only 3-4 times faster than the Mercury, which was less than the ten-fold increase that the sales department would have liked.

The sales department argued that a transistorised Pegasus would be the better route to go down for replacing the Pegasus. Nevertheless Orion was advanced and more suitable for commercial use than the Pegasus had been. In any case Pollard argued that a transistorised Pegasus would have been too expensive to produce. As for a replacement for the Mercury, he argued that a large Orion configuration would be useful for such work. The Orion was expected to be suitable for both commercial and scientific computing.

The first saleable machine to come out of the Neuron work was the small Sirius computer, based on the original NEWT[136]. This was very much a stripped-down system, designed for the very small end of the engineering market. It was easy to program, small, had a fast paper tape input-output device and offered some punched card peripherals[137]. One extra feature was a simple digital display which showed a representation of the program as it ran; associated with it was a keyboard for direct input. Unfortunately the market for small engineering computers had been cornered by Elliott's with the 803 system, and the Sirius offered no significant advantages over it; later DEC would dominate this market. However, the display feature made it singularly suitable for teaching. Between 1960 and 1963 16 were installed. Of these 4 were used for Ferranti's own computer service, while 8 went to manufacturing companies, 2 were used for teaching at universities, 1 was used by the Admiralty and another was exported to Czechoslovakia for unspecified uses. However, according to Swann most of these systems ended up being sold on to colleges for teaching use.

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[136]Wilde, op cit, Ferranti Journal, 1960.

[137]Ferranti Archive, 'Advantage of the Ferranti Sirius Computer', sales brochure, January 1961.

Therefore, by the late 1950s Ferranti was selling a number of different machines. In order of size they were: Sirius, Pegasus, Mercury and Perseus[138]. However, the latter machines were all first generation, valve systems. Ferranti needed the new solid state Orion system to replace them.

Ferranti provided a number of features on the Orion which were very advanced. To increase throughput of data the Orion adopted a technique referred to, by Swann, as time-sharing, though it was of a more limited nature than the later concept of time-shared computers. The design team realised that there was a lot of wasted time when using a computer. For example, even the fastest contemporary paper tape system could only input 1000 characters per second. The machine was running much faster than this, so was always waiting for input and output devices to catch up. Therefore, they devised the computer so it could perform a number of tasks simultaneously, and this was supported by one of the first comprehensive control programs [operating system], the OMP. The Orion could control a number of peripherals simultaneously and could handle a number of programs at the same time. Therefore, if the machine was working on a large and time consuming problem using data from the magnetic tape drive, it could input smaller programs and data from the other devices and process the smaller program during the input-output cycles of the large job. This better utilised the expensive peripherals, and increased throughput[139].

The second great advantage offered by the Orion was the Nebula high level programming language. This was a method by which the machine could be programmed using plain English, which was then translated into machine code[140], like the computer languages used today. This reduced the need to employ mathematically trained programmers and allowed more users to design programs for their specific needs.

However problems with the Orion mounted. One of the problems that the machine had was timing, as predicted by the people in London. The problem was caused by the increased size of the Orion over the simpler Sirius. Engineers found that the wave form of an electrical pulse at one end of a wire was different at the other end: this was known as the Ferranti Effect after its discoverer[141]. This difficulty was less obvious in the smaller

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[138]Wilde, op cit, Ferranti Journal, 1960.

[139]NAHC,'Ferranti System-Orion' sales brochure 1960.

[140]Swann, 'Ferranti Computer Department'.

[141]Ibid.

Newt and Sirius. The problems were so great that Ferranti eventually replaced the Neuron circuits with an alternative, the Gripple technique, and re-launched the system as the Orion 2. It is uncertain how many of the machines sold used the Gripple. Swann only refers to one in his sales figures, the rest being the original Orion 1 design.

The way in which Ferranti overcame the problems of the Orion 1 and the Neuron circuit itself led to problems. It had been intended that the machine be expandable, allowing extra processing equipment to be added to handle more programs at once, and extra peripherals to increase input-output capacity. However, to overcome the timing problem each computer was constructed to meet the exact specification ordered, making future expansion of the machines very difficult. According to Swann neither the management nor the sales staff were informed of this important change.

The Orion had also grown to be a larger system than originally intended and was by no means a Pegasus replacement. In 1963 prices, the average Orion sold for £300,000[142]. 12 systems were installed. 2 were used for Ferranti's own computer service, and 2 were used by government research establishments; the other 8 were all used for commercial data processing in industry and commerce.

Attempts to rectify the problems.

The Sirius was small and cheap, the Orion was large but had costly technical problems and was being severely delayed. The sales department therefore resurrected the transistor Pegasus idea. A set of specifications was created by a study group led by Harry Johnson. The scheme was, however, dropped by the Computer Department. After Swann returned from a holiday in the Autumn of 1961, he found that engineering manager, Peter Hall, had cancelled the idea in favour of the Orion 2 scheme.

However, Ferranti's Canadian organisation, Ferranti-Packard, took up the proposal, together with some techniques learnt from the Orion and the real-time computers Ferranti-Packard had developed for on-line ticket operations and other work, and created the FP 6000. This machine was developed as a medium-size computer that Ferranti-Packard was going to use for its specialist on-line computer activities. However, when ICT took over Ferranti's Computer Department, this design was also included. It became the base of the ICT 1900 computers which have been developed all the way through to the current ICL machines[143].

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[142]Hendry, Innovating for Failure, p183, in 1963 prices.

[143]See below, chapter 5, on ICT, pp199-204.

Nevertheless, in the early 1960s Ferranti had only two second generation machines on offer in the UK, the Sirius and the Orion, a dead end technology.

ATLAS, the final chance.

In the same period that the Orion and Sirius were being marketed, Ferranti had been working on a government contract for a super scale computer. John Hendry has fully described the national project of the late 1950s and early 1960s to produce a British super computer[144].

As with so many government initiatives to improve the country's technological base, the ATLAS project started after a group of experts from Cambridge University, Harwell and the National Physical Laboratories[145] visited the USA in the summer of 1956. Their report concentrated on the potential of the IBM STRETCH project. STRETCH was being constructed by IBM to fulfil the mathematical needs of the largest US scientific laboratories. It was backing this project with a team of 300 graduate level staff, and overall, it was reported to be spending $28 million a year on computer research[146]. This was probably an underestimate.

The French had already started a to develop their own super computer project, in the form of the failed Bull 60. Supercomputers were becoming items of national pride in Europe, based on the assumption that it was strategically important to be able to produce the computers needed to carry out advanced nuclear calculations. It was also thought that such a project was important in ensuring the technological competitiveness of any domestic computer industry, a view supported by the Royal Radar Establishment:

> 'RRE adhered to the opinion expressed by NRDC that it was broadly in the national interest to engage in a high-speed computer project and that the financing of such a project would have to be regarded as, in large part, support for the computer industry....'[147]

Hendry describes the complicated negotiations that went on throughout the late 1950s to start such a programme. The situation was confused by the different visions held by the NRDC and the United Kingdom Atomic Energy Authority, who were expected to be the largest customer for such machines.

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[144]John Hendry, 'Prolonged negotiation: The British fast computer project and the early history of the British computer industry'. Business History 26 1984, pp280-306; and Innovating for failure, chapter 10.

[145]Ibid.

[146]Swann, 'Ferranti Computer Department'.

[147]NRDC 86/40/6, John Crawley's file note on a meeting with RRE representatives, 30/8/57.

Within the latter there was some enthusiasm for becoming directly involved in the development of the computer, or for using the resources of the RRE in the design of the machine. On the NRDC side, £1m was made available for a fast computer project[148]. The Corporation wanted to set up a subsidiary department which would place orders for the overall system with outside contractors. It did not believe that such a development was within the abilities a single firm.

Eventually it was decided to split the roles of the interested parties. The NRDC was to commence a project to produce a super computer within a relatively short period[149]. This short term undertaking was to be based on a machine being developed by the Kilburn team at Manchester University, called the MUSE. It was reckoned that such a machine would be two to three times slower than Stretch, but still fast (about 50 times faster than the Mercury[150]). The second project was to be a long term development programme based at the RRE, which was to leap-frog current technology. Nothing came of the latter idea.

Another factor which was becoming apparent was that Ferranti had a growing interest in the MUSE project. Ferranti was concerned that the Atomic Weapons Research Establishment had bought an IBM 704 in preference to the Mercury. It was becoming increasingly obvious that Ferranti needed to do something to safeguard its place in the university and scientific market. The coincidence of Ferranti and NRDC interests in the MUSE project brought the two parties into negotiation. However, there was some reluctance on the side of the NRDC to commit itself to supporting Ferranti, who, in the past, had created some problems. A second cause for reticence on the NRDC's part, was its feeling that Ferranti was too small to carry out such a large project. It was the NRDC's original contention that the national fast computer project was so large that no single organisation could take it on[151], but eventually it had to accept this situation.

In late 1958, the NRDC and Ferranti could not agree a form of collaboration that was acceptable[152]. As an alternative, the NRDC started talking to EMI and English Electric about whether they could

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[148]Ibid.

[149]NRDC 86/40/6, Sir Owen Wansbrough-Jones, draft report of the Harwell Working Party, presented to the 100th NRDC board meeting, 28/5/58.

[150]Swann, 'Ferranti Computer Department'.

[151]NRDC 86/40/6, internal memo from Halsbury to NRDC chairman W.R. Black, 17/7/58.

[152]Hendry, 'Prolonged Negotiations', Business History, 1984.

produce a fast computer. In 1959 the situation became easier when the atomic energy people at Harwell decided that they no longer wanted to diversify into computer design. The RRE project, supported by the NPL, was taken over by the DSIR. This cleared the decks for the NRDC, who no longer had to consider developments within other parts of government. The Corporation asked for simple proposals from the three companies for projects to build a fast computer. EMI and Ferranti both applied for support. Ferranti had finally decided to accept the same contract conditions as EMI (this had been the sticking point in 1958). EMI had been working on a large commercial data processing system, the 2400, with the backing of the NRDC[153]. The proposed loan was to be paid back based on a flat levy on all EMI's computer sales, not just 2400 sales. Halsbury believed that Ferranti accepted this form of contract because it desperately needed a large contract to keep its design team busy[154].

The NRDC board meeting of 22nd April 1959[155] had two potential projects to support, the first - supporting the Ferranti ATLAS project - was expected to cost £850,000. Ferranti wanted the NRDC to fund 60% of this, £510,000. EMI's plan was to cost £375,000. EMI was asking for 75% of this sum, £280,000[156]. Halsbury and the Electronic Computer Sub-Committee recommended the EMI proposal[157]. EMI planned to produce a scientific version of the 2400, called the 3400[158]. Though this was not expected to be as powerful as the ATLAS, it would be available quicker, and, up to this stage, it was thought that EMI had worked well with the NRDC.

Hennessey, the deputy managing director of the NRDC, made a counter proposal. He suggested that both projects be supported, but to a lesser degree than was being asked for. He won approval for this plan, allowing £240,000 for the 3400 and £300,000 for the ATLAS. The 3400 petered out, but at least ATLAS got going, though with a reduced NRDC commitment. Hendry suggests that the 3400 project may have been a bargaining counter created by Halsbury to get a better deal from Ferranti.

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[153]See below, chapter 3 on EMI, pp134-140

[154]NRDC 86/40/6, Halsbury to Black, 17/7/58.

[155]NRDC 86/40/6, minutes of the 110th NRDC board meeting, 22/4/59.

[156]NRDC 86/42/5, Halsbury, 'Swan Song'. Halsbury wrote this internal report on his retirement summing up the NRDC's role to date.

[157]NRDC 86/40/6, 110th board meeting 22/4/59.

[158]See below, chapter 3, pp141-142.

Building and Selling ATLAS 1.

Neither making nor selling the ATLAS was to prove easy, though it was no less successful than some other super-computer projects.

It was at about this time that Pollard, the Ferranti Computer Department manager, left Ferranti to join the American business machines company, Burroughs. Just after he joined Burroughs he wrote an article in the leading US computer industry journal Datamation, contrasting the UK and US industries[159]. This gives us some insight into the problems Ferranti had at this time, and the weaknesses it had when developing such a system.

He saw computers as being a side line for companies in the UK: UK firms were more interested in other businesses. This was different in the US business machines firms where the commitment to computers was whole-hearted. In chapter eight of this thesis it is seen that the computer was a much more important product to the US business machines firms than it was to the electronics companies. Despite this lower commitment to computers, Pollard noted that British firms still wanted to produce the whole system; American firms, such as Burroughs, were much more willing to sub-contract to specialists. Finally he noted a massive skills shortage. UK computer systems were often being developed by teams of as few as twelve, in the USA the R&D and engineering operations were an order of magnitude larger. Notably, however, these large development teams were no more successful in developing super-computers than the Ferranti team. Pollard saw lack of commitment and an unwillingness to sub-contract, as fundamental British weaknesses.

Some of these weaknesses surfaced in the ATLAS. Despite the sheer scale of the project, most of the machine was constructed by Ferranti. Only some sub-systems were bought in, such as magnetic core stores bought from Plessey and Mullard, and the magnetic tape units bought from Ampex[160]. Ferranti therefore had the cost of developing almost the whole system.

The ATLAS was a very advanced machine. If it did not quite match the break-neck speed of the STRETCH (which in any case never came up to expectation), it made up for this by having very advanced operational concepts built into it. Like the Orion, ATLAS allowed for the running of multiple programs, and could handle a large number of very fast input-output devices, making up for one of Mercury's shortcomings[161]. ATLAS

[159]Brian Pollard 'A comparison of computer industries in the U.S. and the U.K.', Datamation, May/June 1960 p51-52.

[160]NRDC 86/32/2, Atlas progress report, 30/9/60.

[161]Swann, 'Ferranti Computer Department'.

also introduced the concept of virtual memory. This is a technique where active data can be transferred into a secondary store. The user does not know that this has occurred and the system acts as if it has an unlimited fast store, though access is slower when it has to access the virtual memory.

These advanced features were the responsibility of 10 programmers writing the operating system, 15 programmers working on user languages, and a similar number of engineers working on the hardware[162]. As has been noted, STRETCH had a team of 300 developing it, and Bull was using 200 programmers alone on the Bull 60. This was symptomatic of the lack of funds. The original University MUSE project had been partly paid for from the small amount of money accruing to the Department of Electrical Engineering from Mark 1 sales[163]; the NRDC had only put up £300,000; and by mid 1960, Ferranti had spent £1m of its own money on the project[164]. By comparison to the effort in other countries, this was all very modest.

While Ferranti developed a very advanced computer, it was just too much work for such a small group. Swann highlighted a four year lag between the installation of the first computer and the software to run it being available. Delays to the ATLAS became very long, leading to lost sales and increasing the cost to Ferranti. While the company could install ATLASes by 1963, the reality was that a full system could not be working for some time after that.

Another, more immediate, problem was that Ferranti had a great deal of difficulty getting orders. During the 1950s, the Mercury was the only large scientific machine being made in Europe. In the early 1960s, ATLAS was the only 'giant-scale computer' available for commercial sale in the whole world[165]. The reason for this was that the STRETCH had gone awry: it had cost much more than intended to develop and had not proved as fast. IBM had offered them for sale at $10m each, but this was at a huge loss, so it had withdrawn the machine from the market. Likewise the Bull 60 was a failure and that company was buckling under great financial strain[166].

Perversely this actually damaged Ferranti. Many potential ATLAS users, especially in the US, became sceptical that Ferranti could actually

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[162] ibid.

[163] Lavington A History of Manchester Computers p32.

[164] Hendry, 'Prolonged negotiations'.

[165] Datamation, April 1962, p19.

[166] See below, chapter 7 on General Electric, pp315-317.

deliver. Sebastian Ferranti, Vincent's successor, became directly involved in the UK sales effort as the lack of sales started to become a crisis. For a firm like Ferranti, a lot of money was at risk, and yet by 1961 there were no firm orders. The United Kingdom Atomic Energy Authority had ordered a STRETCH in 1960 for the Atomic Weapons Research Establishment. The AWRE opted for the STRETCH because it would be delivered earlier than ATLAS. STRETCH was also expected to be faster than ATLAS, and could use software developed for nuclear scientists in America. However, as it became clear that STRETCH was not living up to expectations, it became evident that the civil side of the UKAEA would need a giant computer for itself, STRETCH not being fast enough to handle both work loads[167]. Harwell, the UKAEA's civil establishment, was sympathetic to Ferranti's plight and the AEA bought a system in 1961 for delivery in 1964. In Hendry's eyes this order was too late to encourage other potential users in the field of nuclear research to follow suit. Sebastian wanted a prestigious order like this to give other users faith in the system, but this order was too late: by this time other developments were on the horizon. Other potential users were willing to wait and see if the system could do the job. By the time it could prove itself, the CDC 6600 was near production in the USA. As the ATLAS was delivered, CDC was mopping up with its machine[168].

The largest single market for this type of computer was in the USA. However Ferranti did not sell any ATLAS machines in the USA. It seems that Ferranti was in informal discussions about the sale of something like 6-12 computers in the USA, despite American preference for domestic machines. Of these, the closest to a firm order was from Westinghouse, a firm with large nuclear interests[169]. However, each order ran into millions of pounds, and each contract would have had to have large penalty clauses written into them in case of late installation. Ferranti decided that this was too great a risk to take. With half a dozen orders taken in the USA, any hold-up in delivery would have put very large sums at risk, larger sums than Ferranti was willing to lose on computers.

The ATLAS was a commercial failure: by 1963 the machine was already looking obsolete. In 1964 IBM announced its third generation systems and CDC was winning the scientific market with the CDC 6600[170], designed by

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[167]Hendry, Innovating for Failure, chapter 10.

[168]See below, chapter 8, pp397-400, on CDC.

[169]Swann, 'Ferranti Computer Department'.

[170]See below, chapter 8, pp397-400.

Seymor Cray who, it is claimed, used the academic papers on the ATLAS system to help design the 6600.

ATLAS 2.

This project started when Ferranti offered Professor Wilkes of Cambridge University some of the ATLAS sub-units. This was in exchange for Wilkes working on an updated and cheaper machine. By 1963 this work was well in hand. In 1963 Ferranti was negotiating the sale of the Computer Department to ICT, and it seems that it talked up the prospects for the Atlas 2, so as to be in a stronger negotiating position. In this respect Ferranti benefited from the failure of STRETCH; the AWRE was concerned that it would be left with the only one in Europe, making it very expensive to get support. Ferranti offered to sell it a replacement ATLAS 2, at an extremely low price with severe penalty clauses, an offer that was accepted.

Once ICT had acquired the Ferranti Computer Department, it was left with an order, at an uneconomical price, for a one-off machine. Despite the help of AEA computer experts, the ATLAS 2 was delivered in 1966, 14 months late.

The following table shows the few ATLAS users:

Table 2.3 ATLAS sales:

Customer	Delivery	Uses
ATLAS 1:		
Manchester University	1963	Research/service University registration
London University	1963	Computer service
UKAEA	1964	Nuclear energy Research
ATLAS 2		
AWRE	1966	Nuclear Weapons Research.

Ferranti's other activities.

Before considering the reasons why Ferranti abandoned its computer operations it is worthwhile outlining the other activities that the firm was developing at this time. The priority which the company accorded each activity sheds a good deal of light on Ferranti's strengths and weaknesses.

Bloodhound missiles and military and industrial control computers.

So far, only one side of Ferranti's computer business has been discussed: commercial and scientific data processing systems. However, Ferranti was producing a number of other computer systems, both military and civilian. By the early 1960s there were two other departments producing computer equipment. The first of these was the Industrial Control Systems Department[171], later known as the Wythenshawe Division.

It will be recalled that Ferranti's Instruments Department had a great deal of difficulty finding work after the Second World War. One solution for this was to build the government sponsored Mark 1 computer. A second important project was the development contract for the Bloodhound anti-aircraft missile, a contract awarded in the same year as the Mark 1 work started, 1948[172]. Ferranti was responsible for the electronic systems of the missile. Bristol Siddeley produced the engines and the Bristol Aircraft Company made the fuselage. The whole system was controlled by a Ferranti digital computer, the Argus[173], developed under the contract.

By 1961 Ferranti had started to install this computer for industrial control purposes. An Argus was used to control chemical production at ICI's Fleetwood plant, and a second was used by Babcock and Wilcox to control the start-up and shut-down of boilers in a power station[174]. This kind of work was closer to Grundy's original plans for computers, as the brains of industrial processes.

Since the 1950s, the Argus has been through many generations, and by 1979, 1263 had been sold, excluding the many used in weapons systems:

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[171]Ferranti Archive, Ferranti Computer World, No.17 Sept/Oct' 63.

[172]J.f. Wilson and Cliff Wimpenney, Ferranti down the years, Manchester, 1989, Ferranti publicity brochure.

[173] Ferranti archive, Ferranti contributions to the Bloodhound guided weapon system, publicity article, 1963.

[174]Ferranti archive, Sebastian Ferranti's managing director's 'Review of Activities', 1961.

Table 2.4 Combined sales of Argus computers.

Industry	Total
Chemical	30
Oil	43
Process industries	12
Manufacturing industries	216
Metal	96
Public utilities	142
Extractive	4
Paper printing	5
Distribution	7
Commerce	60
Transport	145
Communication	61
Public services	73
University research	85
Software houses and OEM[175]	28
Printing and publishing	16
	1023
Military	141
Ferranti internal use	93
Service	6 on loan
	1263

Source: National Archive for the History of Computing Fer/c/31, 'List of principal Argus computer installations, excluding military sales', Ferranti Ltd, 1979.

Apart from the spin-off Argus computers, Bloodhound also provided cash. In fact it provided too much cash. Originally the development contract for the system was to be £1-1.5m[176]. It turned out to be £32m, of which £8m was for the Ferranti control system. The production contract for the missile was worth £44.5m. Of this £13.5m was a fixed price contract for Ferranti's contribution. However, it seems that Ferranti managed to produce the system much cheaper than expected. The House of Commons established a committee to examine allegations of excess profit. The outcome of this was the Lang Report which estimated that Ferranti made a profit of £5.77m from Bloodhound, a 82% margin on costs[177]. Eventually the firm was forced to pay back £4.25m[178].

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[175]Original Equipment Manufacture is the term to describe a substantial self-contained product that is used in the make up of another product.

[176]Times,30/4/64 p6, 7 and 14, statement by Mr Amery, Minister of Aviation, in reaction to the 2nd report on the Bloodhound missile from the Committee of Public Accounts.

[177]Times 24/7/64, p12.

[178]Times, 29/7/64, p10.

Naval and specialist computers.

The third computer operation was a spin-off from the Computer Department itself. When the London operation, which had designed the Pegasus, moved to Bracknell, work commenced on military and civil command and control systems. Originally this was done in the Military Applications Group, but just before the Computer Department was sold to ICT, this group was spun out as the Digital Systems Department[179] and was kept by the firm. It produced a number of specialist military and civil systems. Civil computers included machines for on-line seat reservations for airlines and air traffic control systems.

However, DSD's two core products were the F1600 military computer and the Action Data Automation (ADA) systems, that used the F1600 computer. The first ADA was installed on the aircraft carrier HMS Eagle which led to the highly automated control rooms of the modern navy. Ferranti became one of the largest suppliers of computer systems to western navies.

Automatic machine tools.

Another application for digital technology was numerically controlled machine tools; again this was primarily driven by military needs. The Scottish Group, which was formed after the second war, developed these systems in support of its radar work[180].

The USA was leading the way in this type of technology. During the Korean War, the US Air Force encouraged the development of numerical control systems for machine tools to produce the highly intricate engineering work that was becoming essential to modern aircraft[181]. However, Ferranti was ahead of all competition in one specific area: systems to make radar wave guides. The company had started work on these systems in 1951. By 1954 it had secured a contract that would demand the use of numeric control systems, indeed there seems to have been a symbiosis between this contract and the interest in machine tool numeric control. The contract was for the Airpass Radar that was used in the English Electric P1 Lightning fighter. Radars have a large block of aluminium in them, within this block grooves have to be carved: these are the wave guides which shape the radar pulses. Achieving this needs extremely accurate

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[179]Ferranti Archive, Sebastian Ferranti's Review of Activities, 1963.

[180]Wilson and Wimpenney, Ferranti down the years.

[181]C. Leyton et al, Ten Innovations: an international study on technological development and the use of qualified scientists and engineers in ten industries, 1972, chapter 12.

carving, and the automatic machine tool was the best way to do this. Ferranti made a number of control systems, but it was in this field that it led the market.

However, Ferranti did not manage to make the production of machine tool control systems into a commercial success. Ferranti needed to sell a number of systems to spread the high cost of developing them, just using them to make its own radar systems was too expensive. In the late 1950s, the machine tool control market was becoming large. By 1960 Ferranti had spent £2.4m on numeric control systems, but by 1963 it had sold only 150 units, at a value of £3m[182]. In 1969, under the guidance of the Industrial Reorganisation Corporation, Plessey, which was much more successful in the commercial market, bought the Ferranti operation for £2.5m. This was yet another military spin-off that Ferranti failed to develop into a major business.

Radar and Guided Weapons.

As the above sections show, Ferranti was very active in the areas of radar and missiles. The Bloodhound was a relatively successful weapon and was sold to Britain, Sweden, Switzerland, Singapore and Australia; indeed it is still in limited use. By the late 1950s, together with the Bristol company, Ferranti claimed to have the largest guided weapons team in Europe[183]. In radar, Ferranti was competing against GEC/EE's amalgam of Marconi and Elliott and the smaller EMI operation, and was probably number two in the market.

Consumer Products.

Ferranti left the consumer electronics and electrical market after the war. The final section disposed of was the Television and Radio department to E.K. Cole Ltd[184]. At the time the company explained that this would free working capital for other commitments.

Electrical equipment.

Likewise the company abandoned this most traditional of its activities in the face of heavy competition from larger electrical producers.

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[182] Ibid.

[183] Times 26/7/57 p16, report of Vincent de Ferranti's chairman's statement.

[184] Ibid.

Semiconductors.

Ferranti's history in the electronic components business is a long story which will only be summarised here[185]. The company seems to have displayed a similar attitude to this business as it did to its computer ventures, abandoning harsh commercial markets for a more specialised approach.

In 1953 the Valve Department set up a team of three researchers to work on semiconductors. The wise decision was made to investigate the use of silicon devices, rather than the more expensive germanium devices (germanium research was more common at this stage[186]). Ferranti produced a number of advanced devices, mostly for the military. In 1962 its advanced techniques led it to be the first source of commercial integrated circuits outside of the USA[187]. Initially it developed its own architecture using Diode-Transistor Logic. Its first devices were multi-chip packages called Microlin, then it produced the Micronor chip and then the Micronor II, the latter being developed from RCA technology. The last two families of chips were licensed to Marconi, which used them in the military Myriad and Priam computers and in the English Electric System 4 computers[188]. However, Ferranti did not have the financial resources to develop a broad enough range of Micronor chips[189]. ICs have to be made available in large compatible families so that they can be used for all possible purposes. Ferranti had difficulty fulfilling this criteria. This meant that the Micronor failed to become widely used. A major blow was the failure of ICT to adopt Ferranti chips in the 1900 series, despite a large Ferranti representation on the ICT board after it had taken over the Computer Department.

Ferranti switched from its own designs to producing standard Transistor-Transistor Logic (TTL) devices; Texas Instruments had made this the standard technology worldwide. ICT/L bought large quantities of TTL chips from Ferranti, which cushioned the blow from the commercial failure

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[185] E. Sciberras Multinational electronic companies and national economic policy, Greenwich, Conn., 1977, gives a good outline of Ferranti's history in this market

[186] Leyton, Ten Innovations, chapter 7.

[187] Sciberras, Multinational Electronic Companies, p175.

[188] See below, chapter 4, pp167-171.

[189] A. Golding, 'The semiconductor industry in Britain and the United States: a case study in innovation, growth and the diffusion of technology. PhD. University of Sussex 1971.

of English Electric's System 4 and the failure to establish the Micronor elsewhere. Texas Instruments was, apparently, too busy supplying the burgeoning US market to compete for these orders[190]. This changed in the early 1970s when a general downturn in the world economy, and the first ever slowdown in computer sales, led to the 'TTL war'[191]. Texas Instruments slashed its prices in an effort to increase volume on these commodity devices, and Ferranti, not willing to do the same, lost the ICL deal and became marginalised in the market.

Sciberras characterised Ferranti's strategy as following the same pattern as other 'little league' firms: that is, it specialised in continuously developing new, high value devices, often for the military. As demand for the new device picked up and large mass production companies started to produce it, Ferranti would leave that market before the price came down. This culminated in Ferranti leading the world in the production of semi-custom devices, where it could produce special devices to order, but with a very fast turnaround.

Ferranti sold this successful, technologically advanced, business to Plessey in the late 1980s, as a part of its scheme to pay for the disastrous acquisition of the specialist U.S. defence business, International Signal.

Ferranti's decision to leave the computer industry and some conclusions.

The conclusion that can be drawn from the last section is that Ferranti was, from the late 1950s, concentrating more and more on its advanced military electronics and computer technologies and related civilian spin-off businesses. If one of these areas became too competitive the company would abandon it, as it had with all its purely commercial operations. This stage often seems to have been reached when it became necessary to produce civilian spin-off products to remain competitive.

Given this pattern, it is not surprising that the Computer Department was disposed of. However, the company was not disposing of activities unless there was an underlying economic reason. There were plenty of these reasons surrounding this department.

The Computer Department's ability to compete was hampered by the limited resources of Ferranti. The company was family owned, was unwilling to make long term cooperative arrangements, was worried about past

[190] F. Malerba The Semiconductor Industry: the economics of rapid growth and decline, Madison, Wisconsin, 1985, p116.

[191] Ibid.

indebtedness, and yet it still had a policy of continued high technology expansion. Such a combination was always going to make cash flow a problem. Producing computers is a cash-hungry business. The high demands of R&D mean a continued drain on capital resources, and yet Ferranti was not selling enough machines to cover this outlay without government subsidy.

Ferranti took a number of steps which were designed to restrict the capital drain of establishing its computer enterprise. However, these restrictions ensured that it would not achieve a large enough market share to justify even the limited expenditure. The first way in which the firm mitigated the capital costs of entering the computer industry was by drawing on government sponsorship. It also made extensive use of systems developed outside the firm, mainly from the University of Manchester.

Secondly it tried to come to an agreement with Powers-Samas to reduce the high cost of selling mass-produced commercial computers. There were two factors behind this attempted joint venture. Vincent de Ferranti always believed that the Department's great weakness (and this was probably his view of the whole company) was that it did not have the ability to sell in the commercial environment[192]. The second advantage was that Ferranti would not have to build up a large national sales and support staff. The company could concentrate on its engineering market, while Powers could market commercial systems.

However, this sales policy was not given practical support within either Ferranti or Powers-Samas. All it did was to preclude Ferranti from finding orders from purely commercial customers. Even though much of the cost of the Pegasus was borne by the NRDC, the failure to sell more systems meant that Ferranti lost the opportunity of building a substantial non-scientific user base.

A further problem was that the Ferranti-Powers strategy was not backed with the development of appropriate machines. The engineering teams of the two companies did not produce the general purpose computer that was called for. Because of this failure, Ferranti had no medium-scale computer for the mid-1960s to offer the merging scientific and commercial markets.

Another cash-saving decision was to have a policy of only selling computers, rather than renting systems. As is seen elsewhere, IBM had a policy of leasing its punched card and computer systems: it wanted to be the provider of complete packages of hardware, software and service[193]. This policy meant that computer suppliers had to fund the production of

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[192]Swann, 'Ferranti Computer Department'.

[193]See below, chapter 8.

computers, while having to wait a number of years to recoup this outlay. Without offering this service it would be impossible for Ferranti to establish itself in the commercial market, as leasing was over 60% of the market at the time. Swann seems to have regretted this: he points out that a large number of the Pegasus, Mercury and Sirius computers were used for a number of years, and, therefore, would have generated a good rental income. However, it is worth noting that firms specialising in the scientific market, such as CDC, benefitted greatly by selling rather than leasing; they avoided higher than necessary start up costs, and could use their cash for further R&D.

Another way in which the firm tried to keep selling costs under control was to avoid setting up a sales operation in the USA. Again while this controlled costs and cut the Computer Department's capital requirements, it limited Ferranti's chances of achieving a large enough user base to cover the development of new computer systems.

When it came to replacing Mercury and Pegasus, West Gorton engineers produced the Orion. While the firm may have rejected the idea of concentrating on the science market, the fact that the Orion was not really suitable for that market must have wasted Ferranti's position. Ferranti did not have the sales network nor the expertise to sell Orion in the commercial market. Things were made worse by its technical failures. These failures not only created extra cost, but meant that engineers were tied up dealing with these shortcomings.

ATLAS did build on the firm's past experience. It was in many ways a successor to Mercury, appealing as it did to atomic research agencies. However, again it tied down engineers for longer than expected, and cost substantial amounts of company money. It was eventually a machine that would cost at least £2m per system. This implied a small market place, and very quickly any hopes of securing much of this market evaporated.

By 1963 Ferranti was perceived as having the most advanced computer team in Europe, yet it had no product that was likely to be successful in bringing in a short term profit. The Sirius and Orion had not matched the sales of Mercury and Pegasus: this was despite of the fact that the total market had grown ten-fold. The ATLAS machine had been marginalised. Engineers who could have worked on successor machines had been pinned down sorting out problems on the old systems. All this was at a time when it was becoming obvious that IBM would be delivering third generation equipment by 1964. This meant Ferranti had to start planning to cope with another leap forward in technology.

Therefore, it is not surprising that Ferranti decided to negotiate the sale of the department to ICT. In fact the NRDC had been suggesting that this should happen for a number of years[194], though it was not involved in the negotiations. In preparation for the sale to ICT, Ferranti repaid the £300,000 ATLAS loan to the NRDC in April 1963[195], and the sale was announced on the 7th of August 1963[196].

ICT was doubtful about the saleability of Ferranti machines, especially ATLAS, but the Ferranti Packard 6000 was just the computer it needed on which to base its next generation of systems. The firm also needed to improve its internal design ability, something Ferranti's Computer Department could offer. The department was paid for in cash and shares which valued it at £5.3m[197]. Grundy became Ferranti's representative on the ICT board, Basil de Ferranti became deputy managing director for R&D (though his only prior experience had been as a Conservative M.P.) and by the end of 1964 he was the managing director of the whole company. Finally the last manager of the Ferranti Computer Department, Peter Hall, became a deputy director at ICT. The FP6000 and ICT story is taken up in chapter six.

Computers were a complex and ever changing technology: there was a continual battle to keep up. This leads to continuing R&D expenses, which have to be written off rapidly. Ferranti suffered from this problem. It also faced the prospect of eventually building up an expensive sales and service network, both domestically and internationally. All these initial and on-going costs had to be paid for out of the company's resources; but Ferranti only had a limited capital base.

Ferranti never made a complete corporate commitment to computers: the company never made them central to its survival. While this protected the firm from the rigours of a tough market, it also meant it failed to capitalise on its position as a leading firm in the fastest growing market in the world. This study also shows that there were a number of disadvantages to the concentrically diversified structure. Ferranti was put under pressure from having to support so many different technologies. The following case studies also reveal the same things about the other

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[194]NRDC 86/42/1, 138th NRDC Board meeting 22/11/61, Duckworth, the new MD of the NRDC, suggested that it would be wise for EMI, ICT and Ferranti to consider a rationalisation of the industry.

[195]NRDC 86/42/2, 151st Board meeting.

[196]Ferranti Computer World, Issue 7 September/October 1963.

[197]Martin Campbell-Kelly, ICL: a business and technical history, 1989, p223.

electronics firms. While Ferranti is an unusual case, due to its ownership, it still seems to have suffered from the same problems faced by the other electronics firms that tried to enter the computer industry. Supporting multiple high technology diversifications led to capital rationing, leading in turn to the firm limiting its commitment to a number of its operations, even where those commitments were in strong markets in which it had some technological leadership.

Chapter 3.

Electrical and Musical Industries.

EMI was a more conventional firm than Ferranti, in that it was a publicly quoted company. Despite this major difference, it succumbed to essentially the same pressures that forced Ferranti out of the industry. The main themes are the same, revolving around the ability to exploit technology in a new business opportunity, the success or failure of decentralised control in a concentrically diversified firm, and the problems of supporting multiple growth paths.

EMI's formation.

EMI was formed in the late 1920s and early 1930s by the American company RCA[1]. It was modeled from the merger of a number of the companies that RCA had acquired, as it developed into the world's leading supplier of consumer electronics and entertainment software[2]. The major RCA asset that formed EMI was the large record company, Columbia, which was merged with another large record firm, the Gramophone Company. To this was added the RCA-owned Marconiphone consumer electronics operation, and its holding in the electronic components company M.O. Valve[3]. RCA, itself, was formed from American Marconi Company, and had purchased Marconiphone and Marconi's holding in M.O. RCA initially had a 29% stake in EMI, but disposed of this four years later[4]. At this time RCA was disposing of all its overseas assets to free funds for its domestic operations[5].

The four operations made EMI the world's largest record and music publisher and gave it the rights to RCA's HMV label, and the names Marconiphone and G. Marconi[6]. The largest operation was the record business; records would always remain EMI's largest division. However, it also produced the phonograms and radio sets on which the music was heard,

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[1]J.E. Wall, 'The development and organisation of EMI Ltd', in the Edwards and Townsend seminar series, 'Seminar on the problems in industrial administration', 19/5/64, Wall was the managing director of EMI.

[2]See below, chapter 6 on RCA.

[3]The other partner was GEC.

[4]Robert Sobel, RCA, New York, 1986.

[5]See below, chapter 6, p200.

[6]Wall, 'Development of EMI'.

and made some of the components that were used in these sets.

Development of television and military electronics.

EMI's most important pre-war electronics development was its leading role in the commercialisation of television. This led to EMI being perceived as the most capable electronics firm in the UK. In the mid-1930s a team of thirty EMI engineers, led by Isaac Shoenberg, produced the worlds first all electronic television system[7]. This was a development on the work of RCA's Dr Zworykin, whose Iconoscope was the first practical camera tube. EMI improved on this and produced the EMITRON tube[8], on which it based its TV system. The Marconi company provided transmitter technology, and the two companies formed a joint company to market television equipment, Marconi-EMI Television Co[9]. The BBC encouraged this development by opening the world's first full television station at the Alexandra Palace in 1936[10]. Following a period of dual broadcasting, EMI's system was selected to be the BBC standard, beating the inferior Baird system. However, the existence of the BBC meant that EMI could not copy RCA and exploit this invention by setting up its own television network. The National Broadcasting Company would be an important cash generator for RCA.

EMI's knowledge of building complex electronic systems meant it had a leading role in developing electronic systems for the war effort. One of the most important products was the high powered Klystron tube which was vital to radar. EMI would stay a leader in this technology after the war. Its list of military products was very long, and defence electronics stayed a core activity even after 1945. By 1965 defence sales represented 52% of electronics sales[11].

However, Layton argues that British firms, such as EMI, did not benefit from the Second World War as much as US companies such as RCA[12].

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[7]Baird's system was mechanical.

[8]P.Leggatt, 'The evolution of television technology' Electronic Engineer Vol.60, No.735, March 1988, p14-24.

[9]W.J. Baker A history of the Marconi Company, 1970, p324; S.G. Sturmey, The economics development of television, 1958, p203.

[10]C. Layton et al, Ten Innovations: an international study on technological development and the use of qualified scientists and engineers in ten industries, 1972, Chapter 8.

[11]P.N. Kemp-Gee and Co. 'EMI Ltd' January 1971, private investment circular on EMI, held in the London Business School library.

[12]Layton, Ten Innovations., chapter 8.

He argues that in the UK a company's self interest was secondary to the national effort. In the USA most of the development associated with electronic equipment was the responsibility of private corporations. In the UK a close relationship between companies, government and universities was formed. This led to much of the military development work being undertaken outside the company. After the war the divisions between government laboratories, universities and industry reappeared and broke up this relationship. Companies had to reconstruct their R&D effort to catch up with technological growth after the war. It has been seen that maintaining this link between industry, government and academia was critical to Ferranti's computer interests, a link other companies did not maintain. Layton notes that in the 1930s, EMI's £2-3m research expenditure on television was a match for RCA's $9m spend. However, after the war the RCA Sarnoff Laboratory had become a huge and powerful centre of technical innovation, an order of magnitude larger than EMI's R&D operation. EMI would become dominated by music and film interests: capital electronics counted for only 20-25% of EMI's post-war activities; at RCA electronics was the main activity.

The immediate post war years: rejecting an opportunity to become a computer pioneer.

After the war EMI started a policy of electronic diversification to reduce reliance on records[13]. Marconi, the leading British capital electronics firm, expected EMI to be one of its main competitors[14]. It expected EMI to broaden its broadcasting activities, a particular concern for Marconi as this represented 25% of its pre-war business. The Marconi-EMI Television agreement was to end in 1949. With the experience EMI had picked up in the areas of radar, telemetry and special valves, Marconi feared that EMI would start competing with its transmitter business[15].

Before this happened, EMI made an attempt to take Marconi over. This bid was made possible by the Labour Government's decision to follow the recommendation of the 1945 Commonwealth Telecommunications Conference and

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[13]Times, 19/12/50, p9, report of Sir Alexander Aikeman's 1950 chairman's statement.

[14]Marconi Archive, Marconi Wireless Telegraph Co. Ltd. 'Post-War Policy', internal planning document, 1944.

[15]Ibid.

nationalise Cable and Wireless[16]. However, the manufacturing arm, Marconi, was not wanted. EMI was one of the companies that bid for it. There certainly seems to have been a good case for arguing that the two firms were complementary: Marconi-EMI Television had already shown the possibilities. However, English Electric was the winner; these companies were also reasonably compatible. EE wanted Marconi to start producing television studio equipment as quickly as possible, putting it in direct competition with EMI. This lead to EMI and Marconi agreeing to the end of Marconi-EMI Television in 1948[17] as they both wanted to move on to each others' patch; the two companies were now in open competition. Initially EMI turned to STC and AEI for transmission equipment before producing its own transmitters. Likewise, Marconi started to produce RCA cameras and other RCA studio equipment.

However, the potential of television equipment was slower to be realised than had been expected. Layton sees the BBC as slow to expand its television activities due to post-war austerity. The second TV broadcasting station, Sutton Coldfield[18], was not installed until 1949, and others only followed slowly. In the meantime EMI had invested large amounts of capital to become a turn-key[19] supplier of television equipment. This created a dual problem for the company. Firstly it was continuously increasing its broadcast equipment facilities, yet home orders were slow. Secondly, the company had decided to increase its capacity to produce domestic television sets, in preparation for the opening of the Sutton Coldfield transmitter. However, in the year of its opening, the Chancellor's budget increased purchase tax on television sets from 66 2/3% to 100%. The company decided to keep to its production targets, though this led to a significant squeeze on margins as it had to cut its factory prices to keep sales going.

In 1949/50 trading profits fell substantially, all of which was due to poor results from the UK electronics operations. Until the mid-1950s the company failed to come up to expectations, mainly because of a lower return from television, with the consumer electronics operation remaining a

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[16]Baker, Marconi, p233.

[17]Marconi Archive, A.E. Phillips 'The Grove as Research and Development Laboratories' 1981. Phillips was an ex-employee of Marconi Space and Defence; this was a draft chapter for a book.

[18]Sturmey, The Economic Development of Radio, p208. Sutton Coldfield was an EMI-AEI station.

[19]A provider of complete studio and transmitter stations.

continuing problem.

Later managements blamed this period of failure on the leadership of chairman Sir Alexander Aikeman, and managing director Sir Ernest Fisk. Aikeman and Fisk introduced a new managerial structure, a strict functional structure[20], the exact opposite of the 'M' form structure adopted by Ferranti. The functional operations consisted of:

EMI ENGINEERING DEVELOPMENT LTD
EMI FACTORIES LTD
EMI INSTITUTES LTD
EMI RESEARCH LABS LTD
EMI SALES AND SERVICE LTD
EMI SUPPLIES LTD
EMI STUDIOS LTD
EMI RELAYS (Hayes) LTD
EMI RELAYS (Uxbridge) LTD
EMITRON TELEVISION LTD
ELECTRONIC TUBES LTD
ALPHA ACCESSORIES LTD

Source: EMI Annual Reports.

A device would be invented in the research labs, developed by the engineering operation, made in the factories and sold by the sales and service division. Wall, when he became managing director of EMI, commented that this system had been being inefficient, especially in the consumer products field, as it adversely affected the policy making process:

> 'The fragmentation of the process of making and selling a product reacted against the formulation of an effective and coherent policy to the market position.'[21]

EMI experienced poor returns from a number of its overseas operations, reflecting the difficulties some countries had after the war[22]. This further reduced trading profits, as EMI's overseas businesses (mostly record and TV manufacture) and export business (mostly electronics), accounted for over half of all sales. Fisk, the architect of this structure, was later unceremoniously sacked.

In the late 1940s, EMI was approached for the first time about the possibility of producing computers. When the NRDC was first looking for an

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[20]J.E.Wall, 'Development of EMI'.

[21]Ibid.

[22]Times, 14/12/53, p13, report of the Chairman's annual statement.

electronics firm to join a partnership to produce computers with a business machine firm, the first electronics company it approached was EMI[23]. The reason for this was that F.C. Williams, designer of the Mark 1, recommended EMI as the technically most competent electronics company. EMI attended the NRDC's one and only meeting of the Advisory Panel on Digital Computers in 1949[24]. Like the other electronics firms, EMI rejected the idea of joining a partnership. In any case, EMI's capital electronics operation, EMI Engineering Development, already had its hands full with other capital electronics projects. At this early stage the only active connection it had with computers was an agreement to provide engineering support to the Telecommunications Research Establishment in some of its internal computer developments.

<u>1955 onwards, new management structure, and the background for the computer diversification.</u>

In the early 1950s EMI was in an unsatisfactory position. The following graphs show how profits had fallen, and that the ratios of profit to capital employed and to turnover were at a low point. Another thing to note in these graphs, which is significant later in this story, is the fall in profits and the profit ratios in the period 1957-61, the period in which EMI was actively involved with the marketing of computers:

[23] John Hendry, <u>Innovating for failure: Government policy and the early British computer industry.</u> Cambridge, Massachusetts, 1989, p55.

[24] NAHC, outline minutes of Advisory Panel meeting, 14/12/49.

Figure 3.1

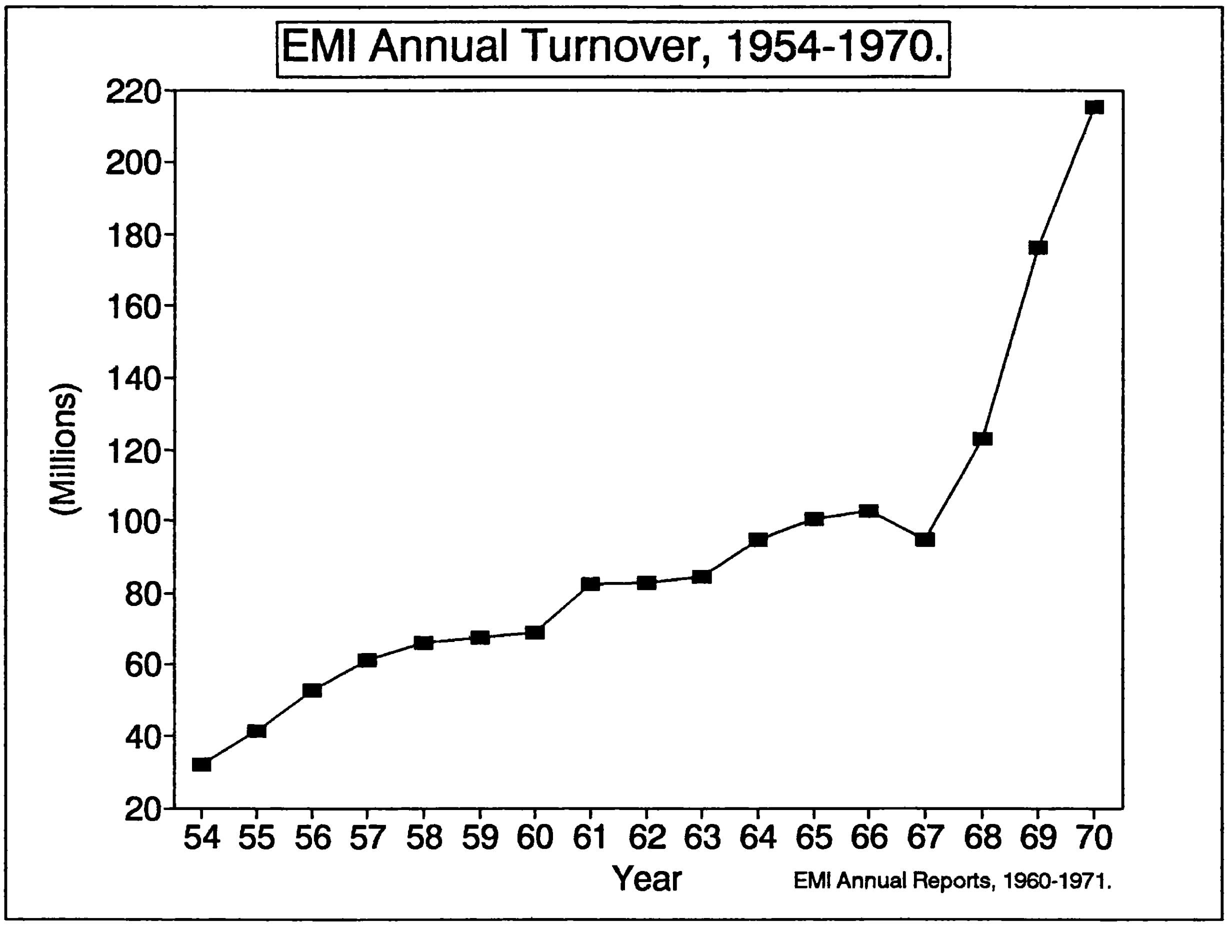
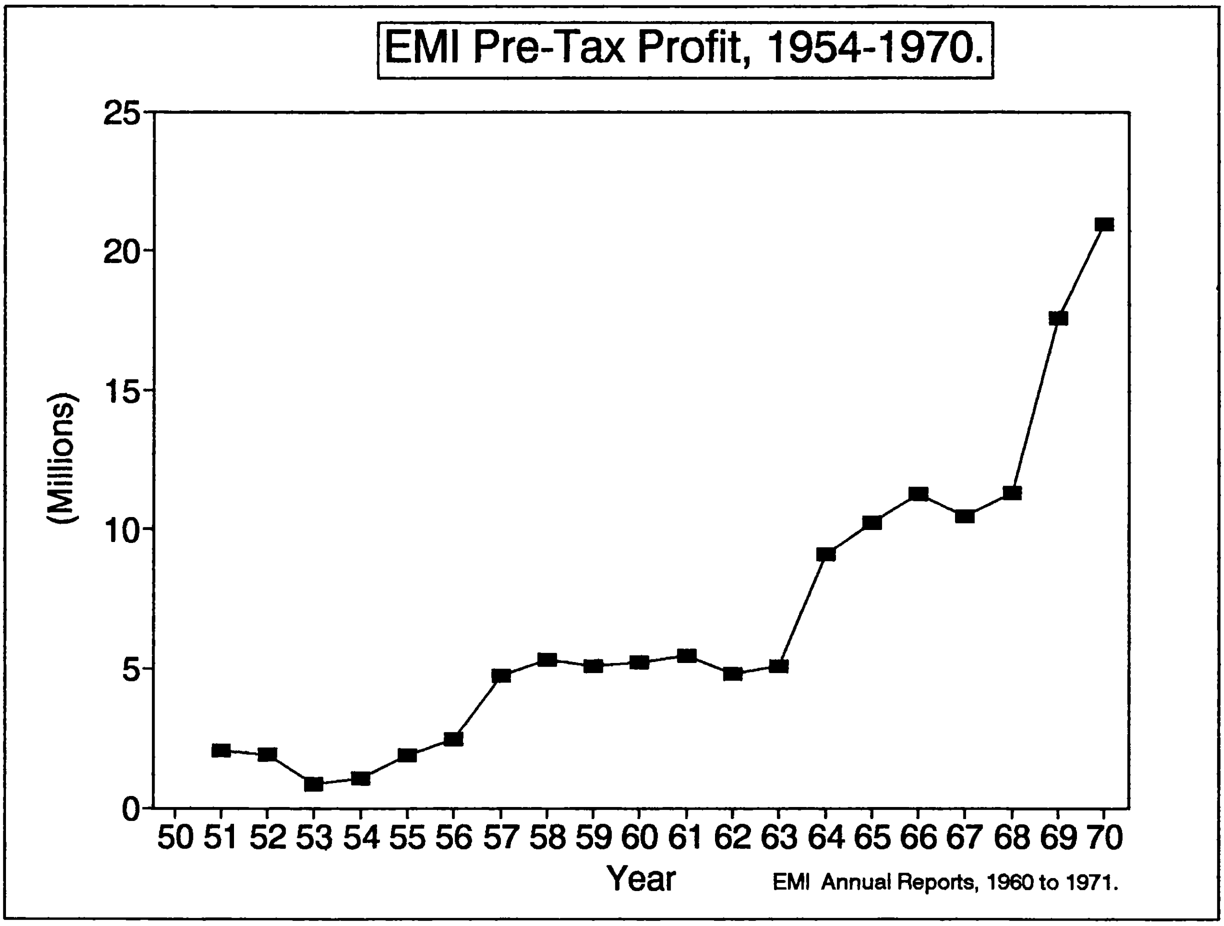
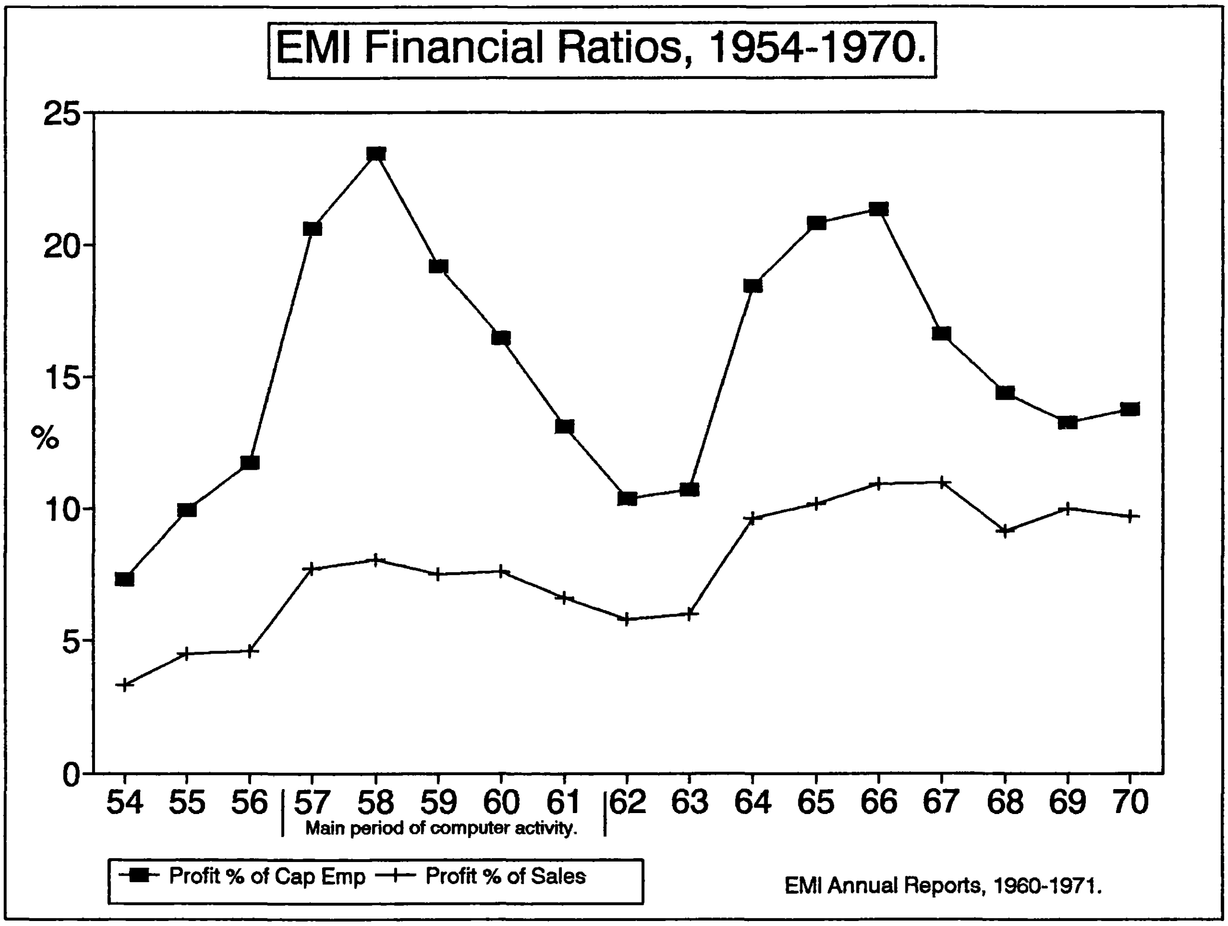

EMI Annual Turnover, 1954-1970.
220
200
180
160
140
120
100
80
60
40
20
(Millions)
54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70
Year
EMI Annual Reports, 1960-1971.

Figure 3.2



EMI Pre-Tax Profit, 1954-1970.
25
20
15
10
5
0
(Millions)
50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70
Year
EMI Annual Reports, 1960 to 1971.

Figure 3.3


EMI Financial Ratios, 1954-1970.
25
20
15
%
10
5
0
54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70
Main period of computer activity.
Profit % of Cap Emp
Profit % of Sales
EMI Annual Reports, 1960-1971.

It is interesting to reflect that Layton claimed that before the war EMI was able to invest as much in television as RCA. However, after the war RCA was an order of magnitude larger than EMI: by 1955 RCA's turnover was $1055m[25]. RCA's rapid expansion was based on its electronics activities: NBC television and record sales were secondary. EMI was still dominated by its music publishing and record business. Though it was the world's largest record producer, this industry had not expanded as rapidly as the electronics market.

The company got back on track in the mid-1950s. A number of steps were taken to sustain this improvement. A new managing director was appointed in 1952, L.J. Brown, and a new chairman, J.F. Lockwood, in 1955[26]. They set about restructuring the company. This time it was based on product divisions[27]. This allowed clearer lines of communication and better accountability and control. The Electronics activities were combined into EMI Electronics. The structure of the board gives an outline of how activities were divided:

Table 3.1 Board structure of EMI Electronics.

Managing Director--controlled the Military Division.
Deputy Managing Director--controlled the Commercial Division.
Director A--Sales of Military Product.
B--Valve Division.
C--Technical.
D--Financial.
E--Works.

Source: J.E. Wall 'The development and organisation of EMI Ltd'.

Wall said that the new structure was arranged so that:

> 'operating subsidiary companies have authority, as well as responsibility, to an extent that enables them to run their own day-to-day affairs.'[28]

The amount of responsibility that each division had was continually assessed and altered. However, it appears that the company's central organisation remained large. In 1964 EMI employed 30,000 worldwide, 18,500 in the UK. The head office staff, employed in the central functional

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[25]See below, chapter 6, fig 6.1, p202.

[26]Times, 12/12/55, p15, report of the Chairman's annual statement.

[27]J.E. Wall, 'Development of EMI'.

[28]Ibid.

divisions, numbered 1,500, of which as many as 1,000 were employed in controlling the UK company and only 500 the large international operation[29]. The only functions that seem to have been under the control of the divisions were selling and producing. Even purchasing, which should operate as a close partner to production, was under head office control.

The new management decided that the company should concentrate on the manufacture of: records, military electronics, civil capital electronics, magnetic tape, and domestic appliances. This allowed the company to dispose of the troublesome consumer electronics operation. In 1950/51 EMI was producing 2000 television sets per week[30]. In 1951 and 1952, total sales of sets in the UK was 500,000 per year. Therefore, EMI had a 20% stake of the British market. However, it had not managed to turn this strong position into a profitable operation. In 1953, despite a rocketing TV set market, EMI sales actually fell[31]. EMI's HMV and Marconiphone sets were high-priced, up-market items. Firms that had much smaller television production facilities in the early 1950s, and which lacked the international television manufacturing operations of EMI (firms like Thorn Electrical Industries), had managed to produce sets more in tune with the growing market for mass-produced, cheap TVs.

In 1957 EMI and Thorn announced that they were to merge their consumer electronics operations[32]. The stated objective was to concentrate both companies' production of television and audio products at Thorn's two 'flow-line' production plants. It was, in reality, a take over of the trade names by Thorn. EMI did continue to produce televisions overseas, but these assets were disposed of later in the decade.

Another step taken to improve EMI's profit ratios was further consolidation of its leading position in the record business. In the 1950s it established EMI (US), which distributed classical records in the USA, and later it purchased the US company Capitol Records[33]. This increased record sales to over 50% of group sales[34], and further underlined its position as the industry leader. EMI also strengthened its electrical

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[29]Ibid.

[30]Times, 19/12/50, p9, report of the Chairman's annual statement 1950.

[31]Times, 14/12/53, p13, report of the Chairman's annual statement.

[32]Times, 29/3/57, p17.

[33]Times, 12/12/55, p15, report of the Chairman's annual statement.

[34]Ibid.

appliances operations with the purchase of Morphy-Richards[35]. Within a few years EMI would have great problems with this low technology, high output business, and would have to enter into various joint ventures with other electrical companies to rationalise the British industry.

Another purchase was the Ardente company[36]. This firm made hearing aids, and associated micro components, a technology EMI also wanted to use in other areas of electronics. It also foreshadowed EMI's major expansion in the area of medical electronics, which caused it such great problems in the 1970s.

In the 1960 annual report, Lockwood reported that the firm was concerned that all these changes had adversely affected the company's product mix. The reliance on the record market was not seen as ideal. EMI saw itself as being too reliant on consumer's entertainment expenditure. One solution was to make purchases such as Morphy Richards and Ardente. The other solution was to increase production in other markets; for EMI this meant civil and military capital electronics. In the late 1950s and early 1960s EMI started a major programme of extending its electronics activities. In civilian electronics it had growing interests in electronic instruments, industrial control systems (especially the Robotug, an automatic wheeled vehicle used in warehouses and factories), medical electronics, and closed circuit television. Military equipment included sub-systems for missile systems and specialist radar, such as mortar and sea search radars. A Canadian electronics company was purchased to form the subsidiary EMI-Cossor which became a world leader in sonar, and EMI's Australian operation produced a number of missile sub-systems. In general EMI was not successful in many of the most competitive areas of capital electronics. Later it abandoned many of the commercial electronics markets.

[35]EMI annual report 1960.

[36]Ibid.

EMI and Data Processing.

One of the major planks in the reorientation of the company towards non-consumer electronics activities was the diversification into commercial data processing. It appeared that EMI Electronics was making a bid to become a major force in the rapidly expanding computer market. However, the little that is known about the internal workings of the computer operation point to a somewhat confused situation, and a limited commitment by the corporate centre to this new opportunity, a common situation in electronics firms.

EMI already had an interest in the field of analogue computing, indeed it was the UK's largest producer of these highly specialist machines. Its main product was the modular EMIAC I and II. Analogue computing took a different approach from digital computing: it was a common method of studying the physical attributes of engineering problems. Analogue computers were an electrical model of the subject of study. Analogue solutions to technical problems became less economic as the power of digital machines increased, and prices came down. However, the commercial digital computer operation had little relationship to this analogue activity.

EMI already had connections with individuals that were involved in developing the computer market, chief among these links being the one to the NRDC. Sir Edward de Stein was on the board of both EMI and the NRDC in the early 1950s. Lockwood was already on the NRDC board before he joined EMI as chairman, and chaired the NRDC's Computer Sub-Committee during the 1950s. Finally, Sir Percy Mills, who had been the NRDC chairman, 1949-1955, joined the EMI board when he retired from the Corporation. Few other companies had connections like this.

It has already been seen that in the late 1940s EMI had rejected the original opportunity to join an NRDC-sponsored, first generation, computer project. EMI had little enthusiasm for removing its technical staff from projects which were directed at less uncertain markets. It is not surprising that EMI decided it had better, and more immediate, opportunities to exploit: after all in the late 1940s there was no computer market.

However, by the mid-1950s there were initiatives within EMI to start developing a commercial computer. Two independent projects got under way, one was a completely internal effort to diversify into a growing part of the electronics market, the second was a joint project with the NRDC to do much the same thing. Both developments started in different parts of EMI Engineering Development Ltd, just before the restructuring of the company along profit centre lines.

In the mid-to-late 1950s, EMI developed two major computer systems, the medium scale 1100 and large scale 2400, both of which were marketed in the late 1950s and early 1960s. They were Europe's first solid state, second generation computers. Both were targeted specifically at the office data processing role[37]. EMI chose the transition from the first to the second generation of computing to enter the market, just as many other electronics companies did, most notably RCA and GE. At this stage the computer market was becoming more developed, attracting the attention of large firms that wanted to develop a major new product line. The shift to solid state electronics gave the multi-product electronics companies a window of opportunity to enter the market. They could gain competitive advantage by applying their knowledge of large solid state electronic systems to this field. This knowledge came from their role as major suppliers of military systems. This was the model that EMI followed.

The BMC and EMIDEC 1100 computers.

Much of the initiative for this project - which became the main thrust of EMI's computer diversification - came from Clifford Metcalfe. Metcalfe took over from C.S. Agate as managing director of EMI Engineering Development, and became the first managing director of EMI Electronics when the 'm' form structure was adopted. One of Metcalfe's first acts was to commission a report from EMI employee R.E.Spencer on the future of electronic business machines[38]. In this report Spencer foresaw a system which would consist of many small computers and workstations, linked to a large central computer storage unit. Spencer's vision was years ahead of its time. EMI was not about to make this scheme a reality; it would be another ten years before relatively cheap minicomputers were produced, let alone microcomputers. Nevertheless, it did confirm Metcalfe's belief that there was a growing market for computers in the commercial office environment. Spencer was described as the technical guru to Metcalfe and

[37]Most of the following detail on the two projects comes from notes made by John Hendry on interviews conducted with some of the key EMI computer staff, and some brief papers written for him by ex-EMI staff, both during the 1980s. He has kindly allowed me to use these, as yet unused, sources.

[38]R.J.Froggatt, one of the managers on the 1100 project, 'Some notes on the EMI computers', 13/1/87, paper written for John Hendry.

Houndsfield (who later led the 1100 project)[39].

At a more practical level, Metcalfe had a potential customer for a machine. ICI Fertilizers was interested in acquiring a computer for invoicing customers. Metcalfe seems to have had a close relationship with ICI: they sent him a bag of fertilizer each Christmas[40]. A project was started to develop a machine that could fulfil this requirement. To lead this group R.T.Clayden was recruited from English Electric[41]. He had previously worked on English Electric's Pilot ACE and DEUCE computers, and before this had worked for EMI Central Research Laboratories. Clayden's group produced a Pilot Machine which was a skeleton of a larger system which could perform the task ICI wanted. According to Froggatt, it was decided that this machine would be too expensive to produce as a stand-alone computer, and would need a number of additions to it to make it a worthwhile system.

The decision not to produce a system based on the Pilot Machine was not the end. Metcalfe personally won a contract to build a computer for the British Motor Corporation. In the mid-1950s Metcalfe had initiated a project to 'look at Rootes'[42]. Kramskoy, as head of the Special Products Unit, joined in this 'look'. Kramskoy lost interest in the idea: he believed that the problems that needed to be addressed at the Longbridge plant were the province of dedicated machine control systems rather than computers. Later Kramskoy developed the EMIDEC 2400 computer. Kramskoy's view of the BMC project shows just how separate his group was from the rest of EMI's computer developments, a factor that later became very important.

In fact, Metcalfe had persuaded BMC's Sir Leonard Lord that a computerised payroll system was needed for the Longbridge factory[43]. According to Froggatt, Metcalfe's efforts were so successful that BMC was telling EMI why it was the best firm for the job. Froggatt believed that BMC was influenced by the fact that EMI was large enough to absorb a loss on a fixed priced contract.

It was hoped that the machine developed for BMC could be sold to

[39]Charles Kramskoy, leader of EMI's 2400 computer team, paper written for John Hendry 18/11/85, Kramskoy was a critic of the 1100 project.

[40]Froggatt 'Some notes on the EMI computers'.

[41]Ibid.

[42]Kramskoy paper.

[43]Froggatt, 'Some notes on the EMI computers'.

other customers[44]. Clayden and his team set to work on producing the central processor unit, which followed similar lines to the Pilot Machine, and was a first generation valve computer. The peripherals were sub-contracted to EMI's Scophony Baird factory at Wells, which EMI had purchased as a pre-production factory, mostly for government contracts. Over the years much of EMI's magnetic tape and specialist recording work was transferred to this site[45]. Wells provided the magnetic drum fast store and the magnetic tape system for the BMC machine. It was decided that the tape drive should be tailored to the BMC machine and no more; it therefore produced a modified domestic tape deck, which was a useless item for any other application. This greatly reduced the likelihood of selling the computer for more general application.

There was a third sub-assembly that Clayden wanted to sub-contract within the company. This was the peripheral control equipment, the means by which the CPU communicated with the outside world. According to Froggatt, two groups were initially interested: Kramskoy's and a small engineering group led by Godfrey Houndsfield. Kramskoy lost interest in this work, in fact Kramskoy makes no mention of this system in his paper for Hendry. Kramskoy claimed that he was surprised when he discovered the existence of the 1100 development team. This is surprising as one of his senior engineers, Norman Brown, was seconded to the BMC development team for six months[46]. Brown was the only member of Kramskoy's team to have any experience of computers before they started to build the 2400.

Kramskoy's lack of interest in producing the peripheral control side of the BMC machine left Houndsfield to develop this equipment. He took a different approach to Clayden and designed a solid state controller. Transistors were still expensive in 1955/6, and production in Europe was very limited. Houndsfield therefore used magnetic core logic. Magnetic cores are tiny ferrite loops which are threaded together on wire matrices and can act as on-off switches, and could therefore be used as computer logic and memory. Magnetic cores were just becoming the favoured type of computer memory. They were small, reliable and could provide large amounts of fast memory. A few companies, such as EMI, also started to use them as logic devices.

Further help was recruited by employing Derek Hemy from LEO Computers, who took charge of programming the BMC machine. LEO was the most

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[44]Ibid.

[45]Ibid.

[46]Norman Brown, interviewed by John Hendry.

experienced company in the application of computers to commercial problems: it had already been doing Ford's payroll on its LEO I service. Hemy and another LEO programmer, John Grover, would become the core of EMI's sales team[47]. The BMC computer was delivered in early 1956. Financially it was not a success: 18 months of debugging was needed at Longbridge before it was acceptable for customer use.

As the engineering teams worked on the BMC machine in 1956, the logic designers (Froggatt, David Robinson and their subordinates) started to work on a machine that could be sold on a commercial basis[48]. Rather than building on Clayden's work, they started to develop an architecture based on Houndsfield's magnetic core technology. Kramskoy says that when he found out about the 1100 computer in 1958[49], he was surprised that this technology had been implemented. Magnetic core logic is inherently slow, especially compared to transistors. Froggatt admits that, if they had foreseen the massive fall in transistor prices from 1957-1959, they would not have used cores. However, the target market was the commercial sector, where speed was only one consideration, though it ruled the machine out of playing any useful secondary role as a scientific machine.

The code name for the system was the OXO 4 (no-one knows why). In October 1956 Metcalfe expressed support for the system, and in early 1957 EMI set up a formal Computer Division within EMI Electronics Ltd. Norman Hill was appointed as its head. He immediately 'firmed up' the OXO 4's specification[50] and appointed Houndsfield as the project leader. Houndsfield received the full support of the Electronics Group senior management, the Managing Director Metcalfe, his Deputy (head of the commercial side) Alloway and Spencer[51]. The computer was given a 1,000-word magnetic core fast memory, and had a magnetic drum backing this, an extension of the peripheral developed in Wells. However, they decided to buy Ampex magnetic tape decks from the USA. They rejected the idea of going back to EMI's Wells operation for tapes, even though it was developing the tape drives for the other EMI computer, the 2400. When the 1100 was upgraded to the 1101 in the early 1960s, they again went to the USA, this

[47]William Talbot interviewed by Hendry.

[48]Froggatt, 'Some notes on the EMI computers'.

[49]Kramskoy paper.

[50]Froggatt 'some notes on the EMI computers'.

[51]Norman Brown and William Talbot interviewed by John Hendry.

time buying the Potter 906 II drive[52]. Other peripherals included the Samastronic printer from Power-Samas (later ICT). While this was the fastest printer in the UK, its reliance on bicycle chains was a source of some concern to the EMI engineers[53]. This printer was never as successful as the excellent machines made by IBM. One of the advantages of IBM systems was the good rate of output that they had. When dealing with commercial problems it is the overall ability of the machine that is important, not just the technical specification of the central processor itself. Electronics firms seem to have had difficulty in appreciating that computers were not just an exercise in circuit board design. Business machines firms took a much broader view of what was needed.

The 1100's market performance.

The 1100 was configured as a medium scale computer: its average price was £180,000[54]. It was the first of the second generation computers built in Europe, and apart from some small BTM/ICT models, the Ferranti Perseus, and the LEO II, it was the first machine to be targeted at the commercial user. In 1960, the analysts Computer Consultants saw the UK computer market as in a 'wait and see' mode[55]. Users were looking at, and sizing up, the new generation of machines. However, two firms were taking substantial orders in 1960, EMI and IBM. The IBM orders were for the 1401, at an average price of £120,000: it was in the same medium scale category as EMI. However, outside of the USA the 1401 was not delivered in quantity until 1962. EMI was installing the 1100 from 1959:

Table 3.2

Annual installations of 1100 and 1101 computers:

1959	1960	1961	1962	1963	1964
1	5	7	6	2	3

Average system price £180,000

Source: Computer Consultants British Commercial Computer Digest 1965.

This represented less than 10% of machines installed in the UK in any one

[52]William Talbot, notes written for John Hendry.

[53]Froggatt, 'Some notes on the EMI computers'.

[54] Computer Consultant Ltd, British Commercial Computer Digest, 1963, 1963 prices.

[55]CBI Archive, Computer Consultants Ltd, Commentary 1/6/60.

year, but it represented 12% of the value of new UK installations in 1960, and in 1961, with EMI also installing 2 2400s, EMI had a 27% share[56].

Table 3.3 shows some of the end users of the systems:

Table 3.3 End users of 1100 and 1101 computers[57].

1100 Users:	
1959	EMI
1960	Air Ministry Central Pay and Record Office Austin Motor Company Boots Pure Drug Co. Glaxo ICI Ministry of Labour
1961	Barclays Bank, London B.E.A. EMI Computer Centre, London Royal Navy, stores. Sainsbury Ltd.
1962	Barclays Bank Kodak
1963	EMI, Hayes
Known users of 1101 computers:	
1962	EMI Computer Centre, London
1963	S.Smith & Son Ltd.
No dates available:	Domestic Electric Rentals National Coal Board London Transport Executive

Source: Computer Consultants British Commercial Computer Digest, 1963 and 1965.

While in 1960-61 the 1100 computer seemed fairly successful (at least in British terms), when the IBM 1401 started to be delivered it soon overtook EMI. IBM installed almost 300 1401's in the UK alone, and around

[56]P. Drath, 'The relationship between science and technology: university research and the computer industry, 1945-1962', Ph.D. thesis, Manchester University, 1973, pp22-24, figures derived from Computer Consultants, British Commercial Computer Digest.

[57]These figures do not exactly concur with the last figures for the annual installations of EMI computers. It seems that Computer Consultants had incomplete knowledge of who was buying the machines.

10,000 worldwide[58]. EMI's sales pale compared to this performance. Nor did it manage to keep up with its major British competitor. The GEC-designed ICT 1301 medium scale computer, selling at an average of £120,000, sold over 150, greatly outstripping 1100 sales despite the fact that it was not delivered in quantity until 1962, quite late for this generation of machine. The momentum behind the 1100 seems to have ceased once the second generation machines from the business machine firms became available. It will be shown that EMI had less comprehensive customer support than many competitors and only had a limited enthusiasm for marketing these machines.

EMIDEC 2400.

The addition of the large scale EMIDEC 2400 machine to the medium sized 1100 gave EMI the sort of comprehensive range some other firms would not be able to offer until the mid-1960s. However, the 2400 did not enjoy the confidence of the divisional or group managements and proved to be an unsuccessful offering.

The decision to build this machine was the result of two factors: one emanated from the Special Products Unit of EMI, and the other came from the NRDC. Charles Kramskoy joined EMI in 1949 and headed the team designing the Blue Boar television guided 'smart' bomb[59]. In 1952 he was put in charge of a small engineering group, the Special Products Unit. This group had an across-the-board engineering capability, designing large military electronics systems. It will be seen that RCA had a similar (though much larger) team, called the Advanced Development Group. It seems that Kramskoy decided in 1954/5 that his team had to broaden its scope and to take on some large civilian projects in order to secure its position[60].

At the same time, the NRDC was going through one of its stages of anxiety about the slow development of the computer industry. Halsbury had visited the USA in the autumn of 1954[61]. He returned concerned that the UK was behind on magnetic tape storage techniques, magnetic core storage, and in planning for the use of transistorised circuits. What worried him most was the potential entry of IBM into the UK market.

Halsbury wanted to see the UK industry respond. However, most of the companies which were already producing computers were fully occupied.

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[58]See below, chapter 8, pp314-315.

[59]Kramskoy's paper for Hendry.

[60]Norman Brown, interviewed by John Hendry.

[61]Hendry, Innovating for Failure, p105-110.

Ferranti was already fully absorbed with its own developments, BTM and GEC had just agreed to build a machine of the nature Halsbury wanted, but the project was a very long term one with no machine likely until the early 1960s[62]. No other company had the ability, or will, to bring a commercial computer to the market quicker. On the other hand, the NRDC and EMI were becoming increasingly close, Lockwood now being the EMI chairman. Halsbury agreed that EMI Electronics Ltd should put forward a proposal to produce a fully transistorised computer.

Two groups in EMI were interested in this contract: the Clayden/Houndsfield team and Kramskoy. The first group was fully occupied on the BMC computer and decided against making a bid for the contract. Kramskoy's team, however, was free, and this offered Kramskoy the opportunity to break out of the military work he had been doing.

There were two initial phases to the project. Kramskoy's group needed to get some computer experience. He therefore packed one of his engineers, Norman Brown, off to the BMC team to get some experience[63]. Brown worked in this group for a period of 5-6 months in 1954/5. However, the Special Products Unit decided the best approach was to follow the design philosophy of Christopher Strachey, the NRDC's own logic expert.

The second phase in preparing the ground for the 2400, was to establish what users wanted. To this end, EMI and Strachey studied the needs of the mail order company Freeman's, which was considering how to automate its large clerical operations[64]. Though it was decided that this was not a suitable business in which to utilise the type of computer EMI was planning[65], it did lead to the notional specification for the 2400.

It was decided to construct a large system, utilising transistors, magnetic cores and magnetic tape. It was to fulfil the needs of the largest commercial office. Kramskoy put forward a proposal for a three-year project, divided into two eighteen-month stages[66]. Phase A was for the design and prototype production of components. Phase B was to produce a machine and perform commercial demonstrations on it. Total cost was estimated at £320,000. One unknown factor was the likely progress that the Mullard company would make in bringing its new transistors and diodes to

[62]Ibid.

[63]Brown, interview.

[64]Ibid.

[65]Ibid.

[66]NRDC 86/37/8, C. Kramskoy, proposal for the 2400 project, 1/12/55.

the market. Mullard was the leading component supplier in the UK and EMI was expecting to purchase new solid state components from it[67].

Kramskoy was very impressed with the way Metcalfe won substantial NRDC backing at such reasonable interest rates[68]. Even before Kramskoy had sorted out the specifications, the NRDC had agreed to finance three quarters of an EMI project costing £300,000[69]. In October 1956 this was extended to three-quarters of Kramskoy's £320,000 plan. EMI accepted the NRDC's view that the best way to recover this finance was a small levy on all EMI's computer output. This safeguarded the NRDC from the risk that the machine it supported would not make it to the market, and that EMI would instead utilise the developments made under the NRDC contract in another computer. It is interesting that this form of arrangement was unacceptable to Ferranti until the Atlas super computer contract[70].

In 1959 the contract was renegotiated to take into account an extension to the project to cover the 3400 computer - which will be detailed later. Together these two contracts would reach over £600,000, with a repayment rate of 2% on all EMI's computer equipment sales and a simple interest rate of 5% on the loan[71]. Theffect of various turnover levels for EMI's computer operations were calculated:

<u>Table 3.4</u>

			Profit to the NRDC
If turnover stabilised at	£2m	after 3 years	-£550,000
" "	£3m	"	-£245,000
	£4m	4	£ 60,000
	£5m	5	£190,000*

*The account would be cleared after 12 years.
Source: NRDC 86/7/8, 118th NRDC Board Meeting.

The contract offered EMI large amounts of cheap cash flow with which to establish the 2400 computer.

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[67] Ibid.

[68] Kramskoy paper for Hendry.

[69] NRDC 86/37/8, 32nd meeting of the Electronics Computer Sub-Committee, 20/9/55.

[70] See above, chapter 2.

[71] NRDC 86/7/8, Notes on a December 1959 meeting between EMI and the NRDC, appearing in the minutes of the 118th NRDC Board Meeting.

Organisation of EMI's computer operations and the outcome of the 2400 Project.

The 2400 was a completely separate operation from the 1100 team. In 1957 Metcalfe appointed Norman Hill from Elliott Brothers to bring its computer operations together. He backed the 1100 as the right-sized machine for the market. The 2400 was treated as a simple cost-plus contract[72]. Although EMI formed a Computer Division in 1958[73], the 2400 and 1100 projects were not integrated in any practical way. The machines used different technologies and the two teams had a different attitude to the procurement of peripherals: the 2400 group preferring internal sources, and the 1100 team buying externally.

The 2400 project was marginalised in a world of its own. It was a forgotten project[74]. It was treated very much like any other government contract, with EMI seemingly unwilling to back it beyond what was necessary to fulfil the contract. EMI made little effort actively to market such a large machine without some proof that it would be successful. This isolation also led to a lack of cost control, and a lacklustre attitude to providing any customer programming support for the system.

Costs on the project rose rapidly. By 1962 the NRDC had invested £593,528 in EMI computer projects, of which £500,000 was for the 2400[75], which had thus proved more expensive to develop and took longer to produce than had been originally planned. The peripherals also presented a major problem. Initially Kramskoy asked the Domestic Electronics Division to consider developing a magnetic tape storage system[76]. However, it was eventually decided to contract EMI's Wells factory to produce a follow on to the systems it had developed for the Pilot Machine[77]. Froggatt criticised this 'battleship' type construction as being completely

[72]Hendry, Innovating for Failure, p116.

[73]Brown interview.

[74]Talbot interview.

[75]NRDC 86/37/8, progress report on the 2400 programme, 14/5/62.

[76]Froggatt, 'Some notes on the EMI computers'.

[77]Paper written for John Hendry by Talbot, 16/12/86.

uneconomic to produce[78]. When Talbot was transferred from the 2400 to head the development of the 1100 follow up (ICT eventually marketed it as the 1101) he saw a Potter tape drive advertised in a US journal[79]. He ordered one having read that it was one-third of the cost of the machines used on the 2400, with only a 20% performance shortfall. When it arrived it worked straight away after unpacking: this greatly impressed him. The Potter tape deck was adopted, and EMI stopped making tape drives. At one time EMI had considered using Decca tape drives on the 2400[80], but dropped this when the Decca project did not go ahead.

The isolation of the 2400 project, and the divisional management's lack of interest in it, is not only revealed in retrospective commentaries. In 1960 the NRDC commissioned reports from two computer experts to examine the 2400 development, with emphasis placed on the programming, customer service and sales activities[81]. Both seemed to have concurred that the computer itself was well designed. However, both had reservations about the software work that was going on, the morale in the operation, and an apparent lack of sales activity.

One of the consultants, J.G.F. Francis, noted in an earlier report that there was a lack of programmers employed. By the time of his second report the situation had improved[82]. However, he found that the majority of the staff were very junior; he was told that experienced programmers were too expensive to employ. With orders imminent at this time, both experts found that a number of sub-routines[83] had not been written. Further, EMI had not considered the need for some form of language compiler for the machine and seemed to be expecting the user to rely on laborious machine code. There was a lack of discipline in programming. Staff were allowed to work on anything that interested them. They did not carry out any formal writing up of their software projects. The result was that some items were lost and others were duplicated, resulting in delays and increasing costs.

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[78]Froggatt, 'Some notes on the EMI computers'.

[79]Talbot paper.

[80]NRDC 86/26/6&7; 'Draft proposal for support for a computer type magnetic tape equipment' submitted by Decca Radar to the NRDC late 1960.

[81]NRDC 86/37/8, J.G.F.Francis, 30/11/60; and C.R.Morton, 25/11/60.

[82]Ibid.

[83]Sub programs were written to allow programmers to rapidly construct their own programs.

At the time of these reports, there were two orders for the 2400, one from the Royal Army Ordnance Corps and one from the Ministry of Pensions and National Insurance[84]. The other consultant, Merton, noted that there was a completely unrealistic attitude to the amount of work that was involved in programming these huge applications. One of EMI's programming lecturers told Merton that he and one colleague could program the whole of the RAOC system in four months, and that the team working on it was over-large. Merton had the opposite point of view, and believed that the programming operation was not large enough. Francis summed up the problems:

> '[there was] little sales effort and some feeling of management neglect...There seems to be little direction and I feel a lot of time is wasted.'[85]

The system was put on the market in 1959/60 at a price of £.5 million per system. Three were sold in the UK and one to the USSR. All the UK contracts were with the government, one for pensions, two for the RAOC[86]. However, it appears that EMI had not even wanted to bid for the first contract with the Ministry of Pensions[87]: the NRDC had to force EMI to tender for this contract. EMI had no wish to tie down working capital and cash-flow on selling an expensive computer it had no interest in. EMI seems to have only been interested in the NRDC money provided for the project. It is interesting to note that the few systems that were sold were to government departments, who may have been sympathetic to the NRDC's plight. Both the RAOC and the Ministry of Pensions computers failed their initial acceptance tests when installed and took a long time to debug[88].

The one bright spot was the sale of a system to the USSR, where the business orientation of the machine meant that it could get around export restrictions[89]. The importance of this contract was that the price included £100,000 for a service contingency. However, the Russian authorities did not require EMI servicing. This £100,000 windfall paid for much of EMI's project costs[90]. This was the only export order for an EMI

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[84]NRDC 86/37/8, C.R.Merton, 25/11/60.

[85]NRDC, 86/37/8, J.G.F.Francis, 30/11/60.

[86]Computer consultants, British Commercial Computer Digest, 1965.

[87]Hendry, Innovating for Failure, p116.

[88]NRDC 86/37/8, progress report 14/5/62.

[89]Froggatt, 'Some notes on the EMI computers'; and Brown interview.

[90]Brown interview.

computer, reflecting the unwillingness to back the Computer Department with adequate marketing resources.

EMIDEC 3400.

This represented EMI's bid to win the NRDC's contract for a British super-computer. The motivation behind this project has been described in the section on the development of the Ferranti Atlas computer.

The 3400 was an extension of the 2400 project and was looked on favourably by the NRDC because of this. The NRDC was actively exploring the possibilities of such a computer from the mid-1950s, with little success. By 1958/59 only two companies were proposing projects for a super-scale scientific computer. One of these was the Manchester University/Ferranti MUSE/ATLAS machine, the other was EMI's 3400. Kramskoy and Metcalfe proposed a project costing £374,000 of which the NRDC was expected to contribute 75% - £280,000[91]. It would build on the experience gained with the 2400, and would continue to be guided by the Strachey team of logisticians. Halsbury supported this project wholeheartedly. He took credit for the commencement of the 2400 project and believed this extension, which again he initiated, would exploit the close relationship between the 2400 team and the NRDC[92]. He also believed that EMI's greater experience with transistorised computers would be of benefit in producing such a large computer system. This was before EMI's evident lack of interest in the 2400 had shown through.

Given these factors, Halsbury and the Computer Sub-Committee recommended the 3400 proposal[93]. However, a counter-proposal by the NRDC's deputy managing director, Hennessey, suggested backing both projects, but to a lesser degree than either had asked for. The Board agreed to this idea, spreading the risk associated with building such complex systems. Initially £240,000 was provided for the 3400.

According to Kramskoy, Metcalfe got cold feet over the project[94]. This is not surprising given the decision to side-line the 2400. EMI Electronics proposed that the contract be altered to a joint 2400/3400[95]

[91]NRDC 86/42/5, Lord Halsbury, 'Swan Song' a final paper he wrote on his retirement for the NRDC in 1959.

[92]Ibid, up to this point no sign of EMI's lack of enthusiasm for selling the 2400 had shown through.

[93]NRDC 86/37/8, 110th NRDC Board meeting 22/4/59.

[94]Kramskoy interview.

[95]NRDC 86/37/8, 118th NRDC Board Meeting December 1959.

one. The new plan was to increase the 2400 funding by £63,000 to allow for the extra costs that were being incurred. In return the 3400 funding was to be decreased: to £190,000 with a request for £142,500 of NRDC funds[96]. It was also proposed that the project be downgraded to a general study of new computer techniques for a future computer system. Instead of being a short term project leading to a scientific fast computer, it became a long term one, and the 3400 development was drastically slowed[97].

However, the 3400 team did remain in existence, slowly carrying out the NRDC sponsored development work. When ICT took over EMI's computer development operation in 1961, the 3400 team and the rest of EMI's design engineers transferred to ICT's Stevenage centre[98]. The development continued as Project PF172. It was thought that it could provide ICT with a top-of-the-range, scientific system. However, the decision by ICT to drop all its previous computer projects in favour of the FP6000/ICT1900 architecture, to counter the IBM 360 family, meant the end of the PF172. ICT needed every engineer to work on the new line. Brown's 3400/PF172 engineers were redeployed to develop the small scale members of the ICT 1900 range[99].

Exit from the computer industry.

In 1961, EMI sold its computer operation to ICT. The NRDC was pleased to see further concentration of the industry[100]. However, there were a number of contractual problems to be sorted out between EMI, ICT and the NRDC. The new head of EMI Electronics, P.A. Alloway, wrote to the NRDC's managing director, Duckworth, to inform him of the details of the merger[101]. ICT had purchased EMI's development and sales operations. ICT were to continue to sell the EMIDEC range of computers and to this extent EMI Electronics had reserved production capacity for 20x1100 and 4x2400 computers per annum. The deal was paid for by the transfer of 275,000 ICT shares to EMI[102], worth £1,250,000[103].

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[96]ibid.

[97]Norman Brown interviewed by Hendry. Brown headed the 3400 development team.

[98]Talbot paper.

[99]Brown interview.

[100]NRDC 86/37/8, 146th Board meeting 25/7/61.

[101]NRDC 86/37/8, Alloway to Duckworth, 16/8/61.

[102]EMI, 'Annual Report', 1962.

This deal gave ICT a larger market share, and the right to sell the fairly successful 1100, as well as the 2400. More importantly it gave ICT the opportunity to capture some of the engineering skills that it desperately needed if it was going to develop future machines in-house. Up to this point, most of ICT's design work had been done by RCA and GEC[104].

EMI had more defensive reasons for this partial disposal. Overall the company's profit ratios had become stagnant, in terms of profit both as a percentage of turnover and of capital employed[105]. In 1961 the company was reporting lower liquidity ratios because of increased working capital and the purchase of Morphy-Richards. Faced with a lacklustre performance, EMI set about cutting some costs. Chief among these moves was the sale of the computer operation. While it would continue to make already designed machines in the short-run, it was freed from the burden of developing and selling these computers.

Apart from these short term considerations, there were also some long term problems to be faced if it was to stay in the computer business. With the increasing scale of the computer market and falling costs, EMI had to achieve significant sales to write-off the spiralling development costs associated with computers. However, EMI was trying to minimise its commitment to the market. It limited its marketing effort to cut costs, especially on the 2400. This meant that it could not reach the scale that was necessary to achieve a long term, self-sustaining size. One example of minimising costs was its lack of overseas marketing. It also seems likely that EMI computers were being sold rather than leased to users. This is definitely true of the 2400 computer, which would have been sold outright to government users. This was not a good approach to securing a large market share for the 2400. Many commercial users were used to leasing data processing equipment, such as tabulators, from the business machines firms. This was particularly good for computer users, as the rapidly advancing technology made outright purchase a risky decision to make. However, it meant the manufacturer was faced with the initial capital costs of the leased computers. It would not be able to fully recoup the cost of these machines for a number of years. ICT was more used to this situation, having had a long history in the business machines industry. EMI was trying to

[103]NRDC 86/37/8, legal opinion prepared for the NRDC by barrister J.E. Donaldson, 22/11/62.

[104]See below, chapter 5, pp171-174.

[105]See above figure 3.3, p108

minimise such costs, even at the expense of not producing enough machines to recoup development expenditures.

Another problem was that the increasing scale of the industry meant that marketing costs were rising. It has already been seen that, in at least the 2400 project, customer support, in terms of software preparation and sales effort, was not comprehensive. EMI was trying to limit the amount spent on the non-NRDC financed aspects of this project.

These efforts to minimise costs sat uneasily with the fact that EMI's range of computers was targeted at the most competitive sectors of the industry: medium to large scale commercial data processing. The dominant companies in the UK, ICT and IBM, were committing their full corporate weight to these types of machine, while EMI had many other activities that demanded company cash. The 1100 was pitched directly at IBM's and ICT's main data processing machines. The 2400 was larger than anything that ICT had to offer and larger than anything that IBM was then offering in the UK. However, because of the great risk associated with producing such large machines, and because of the large support commitment that they would require, EMI failed to market the system actively. Therefore the 1100 was seen as the main product, despite the fact it was up against the stiffest competition.

It should be noted that the sale to ICT was not the first time that a merger had been considered. In 1958 Kramskoy suggested to Metcalfe that he should consider a merger with Ferranti's Computer Department[106]. This would have been reasonably logical as work on the two super-computer projects could have been rationalised. On top of this, Ferranti could have added a range of scientific computers to EMI's business orientated systems. At this time the problems with the division had not shown through and the idea was not taken up. Metcalfe had also rejected an opportunity to set up a joint company with a computer consultancy company[107]. Kramskoy also remarks on the good relationship that EMI had had with Honeywell and Olivetti, which again led to nothing.

The ultimate problem was that, by 1963-4, firms such as IBM and ICT were working on their third generation machines. These would be large families of mass produced machines, requiring very large teams of engineers to design them, and significant marketing commitments to sell the various members of the range across the whole scope of the computer market. This was not the kind of commitment EMI was looking for.

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[106]Kramskoy's paper for Hendry.

[107]Ibid.

When the sale to ICT occurred, a long period of discussion started with the NRDC about how the Corporation could continue to recoup its investment. ICT had refused to accept the NRDC debt in the deal[108]. EMI tried to persuade the NRDC that the sales of the 1100 and 2400 computers that it was to make for ICT would cover the pay back. However, the NRDC believed that, as EMI was unlikely to produce further machines after the 1100 and 2400, the likely money generated would not cover the loan. In any case, although it was pleased by the merger, the loan had been made to establish EMI in the computer market, and in the belief that EMI had an on-going commitment to the market. A number of solutions were considered. The final agreement led to EMI repaying the NRDC money over 15 years and signing over 10% of the dividend earned on its ICT shares to the NRDC, in lieu of interest payments.

EMI's activities in the 1960s

EMI was more interested in pursuing other opportunities in the 1960s. According to Froggatt, Metcalfe was the main force behind the company's efforts to establish a larger commercial electronics activity[109]. Froggatt believed that Lockwood, the chairman, preferred investment in the record business, though this contradicts Lockwood's statement in 1960 that the group was over-reliant on records[110]. Froggatt also believed that the electronics group was too caught up in the military cost-plus mentality. It preferred this safe haven to more competitive scenarios.

The latter statement may well have been close to the truth. In many highly competitive electronic markets, EMI slowly disposed of its activities or operated joint companies so as to mitigate the risk. It has been seen that by 1965 this culminated in 52% of electronics sales being in defence products[111]. However, it should be noted that electronics only counted for about 20% of company sales, worth £36m in 1967/8[112].

Outside the capital electronics arena, EMI took a number of initiatives. In the early 1960s EMI reduced its exposure in the magnetic tape market by merging its tape manufacturing operation with Philips. EMI

[108]NRDC 86/37/8, note by the NRDC's Duckworth on a meeting with EMI's Lockwood, 22/6/62.

[109]Froggatt 'Some notes on the EMI papers'.

[110]EMI, Annual Report, 1960.

[111]Kemp-Gee, 'EMI' circular.

[112]Ibid; EMI reports do not break down the percentage of sales accruing from the divisions.

held 51% of the operation and Philips 49%; together they invested in a new manufacturing plant. To further reduce its exposure to the commercial market, EMI merged its French TV manufacturing operation into a joint company with Thomson-Houston[113]. Later EMI sold its stake to the French partner. EMI also merged Morphy-Richards into a joint company with AEI to rationalise the British appliance market and reduce competition.

More positively, EMI diversified into other areas of industrial control and electronics. One method was to purchase licences from Cincinnati Milling Machines, Canadian General Electric, Fairbanks Whitney, Saab, and others[114]; most of these licences were for industrial control systems. EMI also partially entered the market for semiconductors by purchasing a 49% stake in the Hughes Corporation's Scottish operation[115]. However, in 1974/5 EMI sold its stake in this highly competitive sector back to Hughes.

EMI also bought a number of firms in the USA to add to its specialist US television broadcast equipment and electron tube operations. In the UK an important purchase, in 1966, was the medical electronics company, S.E. Labs, which would prove a major source of problems to EMI in the late 1970s, when it failed to secure a large market for its very expensive medical scanners. EMI had earmarked this as a rapidly growing market, but saw the investment going idle as demand grew slowly.

Capital equipment for television continued to be an important source of revenue throughout the 1960s. In 1961 EMI was able to report that it was supplying large amounts of equipment to a number of the new ITV companies, and had supplied the BBC with 30 FM radio transmitters and 5 satellite stations[116], as well as winning a number of overseas contracts. Later it was to become the UK custodian of the Telefunken PAL licence, further boosting its profit from this area[117]. PAL was the colour television standard chosen for use in Britain. Kemp-Gee estimated that EMI received £1 for every PAL colour set sold in Britain - £650,000 per annum in the early 1970s[118].

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[113]EMI, Annual Report, 1960.

[114]Various annual reports.

[115]E. Sciberras, Multinational electronic companies and national economic policy, Greenwich, Conn, 1977.

[116]EMI, Annual Report, 1961.

[117]Layton, Ten Innovations, chapter 8.

[118]Kemp-Gee 'EMI'.

Overall, EMI Electronics was able to decrease its reliance on MOD contracts, but it was showing a degree of conservatism in choosing areas that were less competitive and in which it already had experience.

However, outside electronics, EMI was more dynamic. The success of the 45 and 33 1/3 r.p.m. records, combined with the worldwide clamour for Beatles records, saw the record operation becoming highly profitable. Much of the large profits of the 1960s went into diversifying the company's activities. Apart from the new electronics operations, much of the company's expansion was in a new division: Leisure and Entertainment. For this division it purchased the Blackpool Tower Company, the Grade Organisation and various theatres. The main purchase was Warner Brother's 25% stake in the television and film company ABPC, which it fully acquired in 1969[119]. This gave EMI a chain of cinemas, a film studio, a production company and a controlling stake in Thames Television.

Conclusion.

Overall there seems to have been a dual problem for the EMI Computer Division. Firstly there was a lack of corporate commitment to developing a large stake in this growing market. Secondly, given the conservative attitude EMI was taking to the operation, it was a mistake to try to take the market head on in the medium-to-large-scale commercial arena, IBM's and ICT's favoured territory.

Taking on this sector of the market needed the full support of a long term programme. As will be seen in the chapters on ICT and the US business machines firms, these companies were totally orientated to achieving a significant market share, so as to cover the high development costs of computers. EMI wanted to make the operation self financing at a very early stage[120]. Operating in the small UK market, with a large number of competitors, such a policy was impossible. It would take more than one generation of machines to establish a large enough base to cover future development costs. If EMI was not willing to sink funds into developing a big market presence with the 1100 and 2400, and at the same time invest heavily in the next generation of machines, it could not hope to maintain its place in the heart of the computer market.

The company was not committed to any such long-term market development project. It was not only diversified at the corporate level (with large record, domestic appliance and entertainment activities), but

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[119]Ibid.

[120]Froggatt 'Some notes on the EMI computers'.

it was also diversified at group level. EMI Electronics had, itself, a wide portfolio of activities. After its development of black and white television, EMI would never produce a similar burst of effort to establish a long-term, market-founding, technology.

EMI's main strategy seems to have been one of diversification. The purpose was to give it protection from the vagaries of the market: it sought protection from failure by ensuring it was not over exposed in any single market place. It seems to have been one of a number of firms that adopted diversification as an inherently defensive strategy and could not tolerate any division needing a large financial commitment for an extended period of time.

In many ways its weaknesses were similar to Ferranti's: lack of corporate commitment, combined with a preference for less risky and shorter term diversifications than computers. To add to this, both companies seemed over-reliant on the divisional structure. They used it to protect the parent company from failure of any single product, as much as a method of improving day to day running of the company.

Given this negative view of the company, the adoption of the most ambitious product plan, building medium scale business machines, was completely inappropriate to the level of corporate commitment. It is seen later that firms like Burroughs, NCR, CDC and DEC had niche market strategies to control costs, plus full commitment to computer technology. EMI had neither of these: an inherently bad strategy for a diversification into computers.

This chapter unveils a story of poor organisation and poor decision making, seemingly caused by an inability to coordinate operational activities, especially with the divide between the 1100 and 2400 teams, a mismatch between tactical and strategic planning. At the higher level the problem was the low corporate commitment to computers, and the product plan chosen. It also shows that EMI was being forced to choose between its various expansion paths, which in itself is not a surprising position for a firm to be in. Even when profits were good, in the late 1950s, the Electronics Division had to make the choice between whole hearted support for the 1100 or the 2400. When profits stagnated in the early 1960s, and its capital resources came under more pressure, it was forced to abandon projects. It opted to leave one of the fastest growing industries in the world, computers. The reasons for this choice goes back to the huge amounts of investment needed to make a success of this market, especially as it was concentrating on the commercial sector, and on the fact that the firm tended to see diversity as a form of risk limitation rather than as a method for changing the corporate direction.

The most revealing information uncovered in the US case studies on RCA and GE, is the detail on how concentrically diversified firms made the decision to abandon computers when faced with capital rationing. Reading these chapters can throw light on what was probably happening within EMI, thanks to the abundant archive information on RCA and GE.

Chapter 4.

English Electric.

With the exits of EMI and Ferranti, English Electric was left as Britain's second major, domestically owned, commercial computer manufacturer. Initially EE specialised in machines for scientific calculation, then added a number of industrial computer control systems to its range and then made a major bid to become a leading computer maker by offering a sophisticated range of commercial computers. EE was the British company that came closest to matching RCA and GE. Indeed the operations of EE and the strategies it adopted seemed to mirror these American giants.

However, this chapter only represents a partial study of the company. Unlike the studies of RCA and GE the decision making process that went on within English Electric is not known. Therefore this partial case study only shows that EE was trying to emulate, consciously or unconsciously, the activities of these US firms. The sections on EE's computer activities, and on its decision to leave the computer industry, draw heavily on the process revealed in the US case studies. The story starts with the firm being analogous to Ferranti in the market, but then becoming increasingly involved in commercial data processing, emulating the 'big push' strategies of US firms. Finally it opted out of the market for essentially the same reasons as the American firms. This study shows that the pressures on electronics firms to leave the computer industry were generally consistent across both Britain and America. EE may have outlasted Ferranti and EMI, but the pressure of supporting multiple high technology activities still forced it out of this rapidly growing, yet very competitive, market.

There are two major reasons why information on this firm is lacking. Firstly, as in other electronics companies, the computer activity was performed down the chain of command, in one of the smaller operating divisions. Information from sub-divisions is even rarer than the archives of corporate headquarters. Secondly English Electric is now a part of the General Electric Company, which is not a good source for archival material.

The Company.

English Electric was formed in 1918 with the merger of five established electrical companies[1]. After a period of financial pressure in the 1920s, the First Lord Nelson became chairman of the company and in the 1930s the American firm Westinghouse became the major shareholder, though control stayed in the UK. Lord Nelson was a powerful figure and tackled the company's problems with a highly centralised decision-making process. It consisted of functional departments, such as accounts, development, home sales and exports, coupled to a geographically based manufacturing organisation, based on the original pre-EE companies. However, the most important aspect of the company's organisation was the routing of decision-making up to Lord Nelson. He was the only executive board member until 1948[2], when an executive committee was formed and his son was appointed to the post of deputy managing director, which made his son the only natural successor.

The organisation of the company only started to change during the Second World War, by which time it was independent of Westinghouse. However the structure was only fully reformed in the 1960s with the formation of a complete product group system. Before this only new acquisitions and new product diversifications had profit centre status[3]. In 1965, following the advice of management consultants McKinsey and Company[4], the second Lord Nelson adopted a product line organisation across the whole company. He introduced this reorganisation to senior management very professionally with lectures and pamphlets[5]. The remaining functional and central staffs were meant to take on a consultancy and planning role, acting as an

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[1]Marconi Archive, Second Lord Nelson of Stafford, Chairman and Chief Executive of EE, 'Address to the meeting of executives and managers of the English Electric Company', 2/11/65. This address summed up the past performance of the company and outlined a major shift in the company's organisation. This paper will be referred to as the 'reorganisation presentation'. The Second Lord Nelson succeeded his father in 1956.

[2]R.Jones and O.Marriott, The Anatomy of a Merger: a History of GEC, AEI and English Electric, 1970, p175: Dictionary of Business Biography: a biographical dictionary of business leaders active in Britain in the period 1860-1980, ed D.J. Jeremy, 1984, pp417-426, biographies of the 1st and 2nd Lord Nelsons of Stafford.

[3]Marconi archive, Lord Nelson, reorganisation presentation, 1965.

[4]D.F.Channon, The Strategy and Structure of British Enterprise, 1973, pp135-6.

[5]Ibid.

internal management consultancy service[6]. This is similar to the GE system of control which will be studied later.

Immediately after the war, EE underwent a period of growth and profit, fuelled by high demand for its core heavy electrical products. It extended these heavy electrical activities by starting to produce diesel-electric locomotive engines and joined in the development of nuclear power. It also expanded into three major new markets: aerospace, electronics (led by Marconi) and computers. However of the three major electrical companies, EE remained the most rooted in the heavy side of the industry.

In the non-traditional end of its operations one of its most important new commitments was to aircraft and aero engines. During the Second World War EE acquired the aircraft engine maker Napiers[7]. It also operated a shadow factory producing bombers under licence. After the war Lord Nelson decided EE should exploit these assets to establish the firm as a major aircraft company. EE developed a number of civil and military aircraft and missile systems. The most successful of these was the Canberra bomber which was produced in large numbers and used worldwide; indeed, many hundreds were produced in the USA under licence for the US forces. This was the product that enabled the company to stay in this international industry into the 1960s.

However, in the early 1960s EE was faced with a number of financial problems and was forced to reshape itself and reassess its financial health. At this time a number of its new operations were disposed of. Napiers was sold to Rolls-Royce following a failed attempt to develop a market for a new turbo-prop engine[8]. The aircraft operation was merged with Bristol to form the British Aircraft Company in the mid-1960s[9]. Eventually EE disposed of its EDP division. The reason for its poor performance was in part caused by the cost of supporting so many high cost technologies.

The second major diversification after the war was into electronics. EE acquired Marconi following the nationalisation of Cable & Wireless in

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[6]Marconi archive, Lord Nelson, reorganisation presentation, 1965.

[7]LSE archival collection, Lord Nelson, 'The development and organisation of the English Electric Company Ltd.', paper given at the London School of Economics in the series, 'Seminars on the problems in industrial adminstration', 5/5/64, hereafter referred to as 'Development and organisation of EE'; see also, C. Wilson & W. Reader, Men and Machines: a history of D.Napier & Son Engineers Ltd., 1958.

[8]Ibid.

[9]Jones and Marriott, Anatomy of a merger, p190.

1946[10]. It won the bid for Marconi in the face of competition from EMI. Both put forward arguments that they would dovetail well with Marconi's product mix[11]. For EE, it meant acquiring the most advanced capital electronics organisation in the country. EE absorbed an organisation strong in military systems, communication equipment and broadcast transmitters. EE also expanded its scope by ending Marconi's collaboration with EMI on television, and moved Marconi into the production of a full line of television studio equipment as well as transmitters, in competition with EMI. This was done by utilising Marconi's technical links with its one time subsidiary, RCA[12], though this was at the expense of EE falling out with its traditional US partner, Westinghouse[13]. That is not to say that EE was reliant on US technology. By 1951 it had a research and development work force of 6000, spending £6.25m per annum, most employed at the Nelson and Marconi Laboratories. For a British firm this was a very large commitment. Jones and Marriott argued that this figure, and the fact that the company had 2000 trainees at any one time, was due to the first Lord Nelson's willingness to think in the long term[14]. He was prepared to forego short-term profits for long-term projects.

EE seems to have picked up Marconi at a very good price. It paid £3.75m, but £1.6m of government stock owned by Marconi was disposed of, making the net price £2.1m[15]. EE added to these Marconi assets. Chief among these additions was the acquisition in the mid 1960s of Elliott Automation. This added to the military command, control and communication activities that Marconi already operated, as well as increasing market share in electronic instruments and adding to the EE's industrial automation business. It was the addition of the industrial automation and small computer activities of Elliotts that mostly affected the computer operation.

After the war, EE also entered the production of domestic appliances and consumer electronics. However, like the aircraft operation these products were sidelined or dropped as the financial statistics failed to

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[10]W.J.Baker, <u>A history of the Marconi Company</u>, 1970.

[11]See also above, chapter 3, where the relationship of Marconi and EMI is discussed, pp101-118.

[12]Lord Nelson, 'Development and organisation of EE', 1964.

[13]Jones and Marriott, <u>Anatomy of a merger</u>, p183.

[14]Ibid, p186.

[15]Ibid p180.

improve. EE did not want to bear the cost of developing the marketing network that goes with such products, and was up against stiff competition from Jules Thorn and Arnold Weinstock.

English Electric and computers.

The third major non-heavy electrical diversification was in computers and automation. EE was one of the first British companies to become involved in computer technology and, after an incubation period which was longer than Ferranti, it offered an early marketable computer to the scientific market. The company's computer scope increased steadily until the mid-1960s, when it attempted to offer a significant new range of machines to compete head on with both ICT and IBM.

DEUCE Computer

EE first became involved in computing when the National Physical Laboratories at Teddington started a project to build a computer. In 1944 the Treasury had given permission to the NPL to set up a centralised Mathematical Division[16], to provide calculation services both within the NPL and to other research laboratories. One of its staff was the leading mathematician and computer theorist, Alan M. Turing[17], who designed the Automatic Computing Engine (ACE) for high-speed mathematical calculation. However, none of Turing's Division had an electronics background, so outside support was needed to construct the system.

In 1949 Turing's development was transferred to the new Electronics Section of the NPL's Radio Division, a section with more appropriate skills[18]. The Electronics Section decided not to continue with Turing's efforts to build the very large and complex ACE and instead to concentrate efforts on a cut-down model, the Pilot ACE, to prove the technology. The ACE would be constructed once the Pilot had been made to work. This was not to Turing's liking: disillusioned with the NPL's lack of commitment to his original idea to build a machine for immense mathematical experimentation, Turing left the NPL and pursued his own developments, first at King's

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[16]M.G. Croarken, "The centralisation of scientific computation in Britain 1925-1955", PhD University of Warwick, 1985. pp129-131.

[17]J.H. Wilkinson, 'Turing's work at the National Physical Laboratory and construction of the Pilot ACE, DEUCE, and ACE', A history of computing in the twentieth century: A collection of essays, ed N. Metropolis et al, New York, 1980, pp 101-114. Wilkinson was one of the ACE project leaders.

[18]Ibid.

College and then at Manchester University[19].

Nevertheless, in 1948 English Electric started working with the NPL Electronics Section to develop a fully engineered version of the Pilot ACE[20]. This was to be known as the DEUCE. The Pilot Ace was fully operational in 1952, roughly two years behind the first Manchester/Ferranti Mark I computer.

The first DEUCE was delivered to the NPL in 1955. EE then installed two for its own use. EE had a large demand for scientific calculation as it had a big interest in science based industries, such as aerospace, conventional power generation, and, later, nuclear power. The average price of the DEUCE was £50,000. Production ended in 1961, with 30 being delivered[21]. This seems impressive compared to the first Ferranti systems, the Mark I and I*'s, of which eight were installed. However, this success was to some degree a symptom of the DEUCE being later and longer in the market. By 1955 production of the Mark 1* was ending, DEUCE was only just being delivered. By 1961 Ferranti had produced the Mercury, Pegasus, Perseus and the second generation Sirius machines, with Orion and Atlas machines nearing production, all of which, added together, greatly outstripped EE's performance with the DEUCE.

The major users of the DEUCE were the aircraft industry, and atomic research laboratories, activities closely related to EE's own businesses:

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[19]Wilkinson, 'Turing's work at the NPL', A history of computing in the twentieth century, ed Metropolis et al.

[20]Croarken, 'The centralisation of scientific computation', pp.160-161.

[21]Computer Consultants Ltd, British Commercial Computer Digest, 1965, in 1963 prices.

Table 4.1 Sales of DEUCE computers.

DEUCE I	
Customers	Number of systems
AWRE	1
British Aircraft Corp.	6
Other Aircraft Designers inc. Royal Aircraft Establishment	4
Other Govt. Research	2
University	3
Other commercial	2
EE internal	2
DEUCE II	
EE Atomic Power Div	1
EE Nelson Laboratory	1
Marconi	1
RAE	1
United Kingdom Atomic Energy Authority	1
DEUCE IIA	
EE internal	2
Ministry of Agriculture	3

Source: Computer Consultants Ltd, British commercial computer digest. 1965.

Second Generation Machines.

During the second generation of computing, English Electric extended the scope of its computer range, especially after it acquired LEO computers. EE started to become a major force in the UK computer market. The NRDC estimated that joint EE and LEO computer turnover at the turn of the decade was £.5m-£1m per annum; by the mid-1960s this had reached £12m, though this was only one quarter of ICT's turnover[22].

Of the second generation machines produced, the KDF9 was the natural successor to the DEUCE. This machine was orientated towards the scientific market, and was of an advanced architecture. It was marketed in the early 1960s and first installed in 1963. It was more expensive than the DEUCE, at an average price of £120,000. However, the research users had a growing demand for larger scale computing. The US Office of Naval Research (ONR) noted that the machine became available at the same time that British universities were about to purchase a large number of computer systems[23]. The major UK universities were in the process of replacing the first generation Ferranti machines, that were then common, with new second

[22]NRDC 86/35/5, 'Commercial prospects for English-Electric-Marconi', undated internal NRDC report prepared in 1965.

[23]CBI Archive, United States Office of Naval Research, London, 'The British Computer Scene; Part II, The British Computer Industry', 1967.

generation systems.

However, the university installations tended to be fairly bare. Limited funds meant that they purchased the central processor unit but with only limited memory and peripheral options. The universities were hoping to add extra facilities as funds became available[24]. With such a chunk of the KDF9's users only wanting limited options, EE seems to have given a low priority to peripherals for the machine. Eventually EE did provide CDC disc packs for the system to add to its own tape drives, manufactured under licence from RCA[25]. Despite this the ONR characterised EE as being weak in peripherals. EE also only offered limited software support, hoping that the advanced users that bought the machine could do their own programming, a tactic also adopted by DEC and CDC[26]. The only language provided by EE, ALGOL, was very inefficient[27].

The NRDC saw the KDF9 as a flawed machine when it was first introduced[28], though it did see it as a useful addition to the UK's stock of scientific systems, with the potential of being improved on over time. It sold about 30 units in the 5 years of production. Aerospace proved to be a second good source of sales:

<u>Table 4.2</u> <u>KDF9 Sales:</u>

User	Number
Universities	7
Aerospace	5
Govt Lab.	3
Internal use	2
ICI	1
Other customers unknown.	

Source: Computer Consultants Ltd, <u>British commercial computer digest.</u> 1965.

EE was also producing small computers to rival Elliotts and Ferranti in the area of process control computer systems. The KDN2/KDF7 sold for about £20,000[29]. However, most of the value of such a system was in the

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[24]Ibid.

[25]NRDC 86/35/5, 'Commercial prospects for EELM'.

[26]See below, chapter 8, pp350-353.

[27]CBI Archive, ONR, 'The British computer scene; part IV, the universities', 1967.

[28]NRDC 86/35/5, 'Commercial prospects for EELM'.

[29]ibid.

area of system integration and plant integration, so how much EE earned from such a computer is not really known. By 1965 12 had been installed:

Table 4.3 KDN2/KDF7 Sales.

Steel producers	8
Electrical utilities	4

Source: Computer Consultants Ltd, British commercial computer digest. 1965.

The steel producers using the KDF7 (the later name for the machine) included the Czechoslovakian state producer, which purchased a large package of computers from EE in the mid-1960s, including two large EE/LEO machines[30].

The expansion into the commercial market.

The most significant second generation computer produced by EE was the KDP10/KDF8. This machine showed the technical and commercial direction that EE planned to go. The crux of English Electric's plan to develop its stake in the computer market was to utilise Marconi's traditional licensing and technological links with RCA. EE made the decision to broaden its coverage of the computer market by adopting the RCA 501 data processing computer and selling it to the office based commercial data processing market. It took this design and 'Anglicised' it[31]. The 501 computer was one of the earliest US second generation data processing machines[32] and was sold from the late 1950s to the early 1960s; in total about 99 were installed. The EE KDP10/KDF8 was available for installation from 1961 to 1965 but only 13 were sold at an average price of £400,000[33]. It was therefore somewhat behind the sales period of the RCA 501, not only a function of it first being designed by RCA and then transferred to EE, but also because of the redesign work done by EE, a mistake the company would make again.

The customers for the KDP10/KDF8 are not completely known, the following represents 9 of the 13:

[30]CBI Archive, ONR, 'The British computer scenes; part II, The British computer industry'.

[31]NRDC 86/35/5, 'Commercial prospects for EELM'.

[32]See below, chapter 6, pp210-213.

[33]Computer Consultants Ltd, British commercial computer digest, 1965.

Table 4.4 KDP10/KDF8 Sales.

Customer Type	Number
Banks and other financial inst.	6
Other commercial	2
Internal use	1

Source: Computer Consultants Ltd, British commercial computer digest. 1965.

At this time EE was also selling the smaller KDF6. This sold for £60,000, and appears to have been sold to both commercial and industrial users, 12 being sold. Unfortunately little is known of this machine, though it may have been related to the KDP10/KDF8.

EE also used its technical links with RCA to get hold of peripheral equipment, building such things as RCA tape drives. However, like RCA it had to look elsewhere for certain other devices, for example buying discs drives from CDC[34], though EE probably would have bought discs from RCA if they had been available. Therefore, to some degree, EE did not suffer from a common weakness of the electronics companies by shunning equipment not built by itself, a weakness pointed out by the manager of Ferranti's Computer Department when he joined Burroughs[35]. This was also noted by the NRDC[36]. However, it also noted that EE planned to produce more equipment in-house as the computer operation grew[37].

Acquiring more commercial skills and real-time computer techniques.

An interesting feature of the relationship with RCA was that no less than one year after the KDP10/KDF8 was first installed, ICT was installing a later RCA machine, the ICT1500/RCA301. During this period there were some vague discussions about the three firms working together on a new system, but nothing came of it[38]. EE was not taking up options on the newer RCA machines because it was already fully occupied with the various KDF ranges. A second factor was that EE had secured a second route into commercial computing by acquiring LEO Computers.

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[34]NRDC 86/35/5, 'Commercial prospects for EELM'.

[35]Brian Pollard, 'A comparison of computer industries in the U.S. and the U.K.', Datamation, May/June 1960, pp51-52.

[36]NRDC 86/35/5, 'Commercial prospects for EELM'.

[37]Ibid.

[38]CBI oral history collection, interview with Colonel A.T. Maxwell, ICT chairman, carried out by A.L.C. Humphreys, former managing director and deputy chairman of ICL, 9/1/80.

By 1963 EE was having to cope with some of the problems that forced it to re-orientate its structure. Compared to a number of its international competitors, its performance looked distinctly weak. Lord Nelson noted that the very high R&D and capital outlays involved in the computer industry made consolidation a natural course of action[39]. This was very much in line with what was happening in the rest of the UK industry, with ICT acquiring EMI and Ferranti, and abroad, with Philco leaving the industry, Bendix's computer operation being sold to CDC, and GE absorbing Bull of France. However, while ICT was actively looking to acquire technical electronics skills from the electronics companies, EE was going in the opposite direction. EE had a sound base in electronic technology, what it wanted was greater access to the skills needed to market computer systems in the commercial environment.

Unfortunately the train of decision making within EE is not known, but from what is seen in other case studies it seems reasonable to speculate about the reasons for its expansion into the commercial environment. The separate arts of scientific and business computing had rapidly merged during the second generation of computing. Scientific tasks required better input-output facilities for such things as statistical work, while improved peripherals meant that the commercial user could benefit from greater processor speed. With the scientific and commercial markets for mainframe computers rapidly coming together, EE needed greater exposure to sell future machines into both markets. It needed to do this so it could get the largest possible return from its R&D investment, and ensure that it could achieve high enough scale economies to compete with other general purpose computer producers.

EE tried to achieve this greater coverage by forming a joint computer operation with the LEO subsidiary of J.Lyons Ltd. In 1963 EE and Lyons formed English Electric-LEO Computer Ltd[40]. A year later Lyons sold its shares in the business to EE and EE thus acquired one of the UK's most progressive, and commercially orientated, computer operations.

An excellent short history of Leo already exists[41], so only a brief outline of it will be given here. Lyons had prided itself on having one of the most advanced office systems, organised by mathematicians from

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[39]Lord Nelson, 'The organisation and development of EE'.

[40]Ibid.

[41]J. Hendry, "The tea-room computer manufacturer: J. Lyons, LEO and the potential and limits of high-tech diversification", Business History 29 (1987) pp 73-102.

Cambridge who worked on early operational research techniques. In the late 1940s and early 1950s it was decided to further improve its systems by developing the LEO I computer, based on Maurice Wilkes' Cambridge EDSAC project. The LEO I was used for a number of roles in Lyons, but was also used to offer services to other firms, doing such things as Ford's Dagenham payroll. In 1954 Lyons started to market the LEO II and set up a subsidiary to produce it. From 1957 to 1961, 11 of these first generation systems were delivered, at an average price of £95,000[42].

In the early 1960s, the LEO III was announced, LEO's second generation system. However, computer systems were becoming increasingly expensive to develop, and were being produced in ever larger numbers. It appears that Lyons decided that its small operation was not large enough to justify the expense of developing a third generation family. In 1965 the NRDC believed that EE's computer division and LEO had each been operating on a financial shoe-string: development costs were very high compared to turnover in both companies[43]. It was hoped that combining the computer interests of the two firms into one range of machines for the third generation of computers would reduce this problem.

The LEO III and its upgrades, the 326 and the 360, sold reasonably well for EE. from 1962 to 1967 43 of the systems were sold at an average price of £200,000.

After the takeover of LEO, it was decided that Marconi's real-time computer activities should be merged into the EEL operation to form English Electric-Leo-Marconi Computers. The main Marconi computer product was the Myriad computer. Marconi's computer activities started with a contract to design and produce an air traffic control/air defence environment for Sweden, called Fur Hat[44]. Marconi had developed the Transistorised Automatic Computer, TAC (meaning 'thank you' in Swedish), to control the system. This was followed by the Myriad computer, which Marconi claimed was the world's first third generation system. Myriad was sold widely for processing radar information and communication switching[45].

Marconi's integrated circuit capability was based on a licence to

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[42]Computer Consultants Ltd, British commercial computer digest, 1965.

[43]NRDC 86/35/5, 'Commercial prospects for EELM'. This report was compiled as a part of an NRDC survey of the UK computer industry.

[44]Marconi Archive, Sir Robert Trafford, 'From Wireless to Chips-All in a Lifetime', The Third Mountbatten Lecture 16/10/80. Trafford was in charge of Marconi's computer activities, and subsequently GEC Computers Ltd.

[45]Ibid

produce the Ferranti Microlin and Micronor chips[46]. The ability to produce third generation components proved an important feature of EELM's bid to become a major player in the rapidly growing industry. The Myriad used Ferranti's Microlin chips, a kind of multi-chip integration, which was later superseded by higher density Ferranti chips, the Micronor I and II circuits, the latter itself based on RCA technology[47].

The final addition to EE's computer operations was the computer activities of Elliott Automation, a firm taken-over by EE in 1967. After this the division became known as English Electric Computers (EEC). Elliotts had particular strengths in military, control and small scale scientific computers. However, with the other developments within EEC, and later ICL, in the area of general purpose machines, Elliotts' main machine, the 4100, was not further developed and production ended in 1970[48].

The purchase of Elliotts gave EE a much stronger presence in the field of process and military control computers, expanding the share given it by the KDN2. Elliotts had over 200 installations in process control, with its leading product being the ARCH system[49]. This gave EE an estimated 50% share of the UK market. Additionally Elliott and Marconi systems gave EE an estimated 80% of the UK dedicated military computer market[50]. In both markets Ferranti was the main rival, and indeed it is difficult to see that EE could have had 80% of the military market for long in the face of the range of military computers made by Ferranti and other producers.

These control and military assets of EE, Marconi and Elliotts, remained with EE after it merged the computer division with ICT, and eventually became GEC Computers.

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[46]E. Scibberas, Multinational electronic companies and national economic policy, Greenwich, Conn., 1977; and E. Leyton, Ten Innovations Chapter 7.

[47]Ibid.

[48]M. Campbell-Kelly, ICL: a business and technical history, Oxford, 1989, p269.

[49]International Data Corporation EDP Europa Report 21/11/69, p3.

[50]Ibid.

Attempt to become a major systems supplier: the third generation System 4.

In 1965 EELM informed the Treasury Support Unit that it intended to compete head on with IBM and ICT[51]. EELM was given a high status within the company. It became one of the eleven trading groups within the new company structure[52]. With this higher station in the company, EELM was expected to grow to become a significant part of the company, and large enough to survive in the competitive computer industry. To do this it took radical steps to produce a range of machines which could exploit LEO's commercial connections, EE's scientific market, Marconi's integrated circuit technology, and the link to RCA.

In the mid-1960s it was clear that the second generation of computers needed to be replaced. IBM was making great strides with the announcement of the 360 family of compatible computers, offering a completely integrated range of machines with massive support and marketing organisations and the best peripheral collection on the market.

EELM took advantage of the fact that ICT was not interested in making use of RCA's 360 rival, the RCA SPECTRA 70. EELM dropped plans to produce its own system and decided to licence the RCA system. RCA had adopted a strategy of trying to be the second source for IBM equipment. The Spectra series was made program-compatible with the IBM 360, though it was architecturally different. Initially the Spectra 70 series consisted of four machines, pitched between members of the IBM family. One of the advantages of RCA being an IBM follower was that it could offer the competitive advantage of using third generation components, integrated circuits (ICs). IBM had to use a hybrid technology as ICs were not readily available at the time the 360 was developed[53]. It was more important within IBM to have the product released at the right time and to capture the market first; the finesse of the component used was not so important. At RCA the two largest Spectra machines used ICs while the two smaller ones used transistors, as found in second generation machines[54].

In 1965 EELM announced its third generation machines, the System 4

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[51]NRDC 86/35/5, 'Commercial prospects for EELM'. The TSU was the Treasury committee in charge of government purchasing and general computer matters.

[52]Marconi archive, Lord Nelson, reorganisation presentation, 1965.

[53]See below, chapter 8, pp320-325

[54]See below, chapter 6, pp230-233.

family[55], the members being the 4/10, 4/30, 4/50 and 4/70. The basic 4/10 cost $185,000, the 4/70 could be configured to cost over $2,800,000[56]. As at RCA, the largest pair of machines used monolithic chips to make them complete third generation systems. However, unlike RCA machines, the smaller members of the family used the same multi-chip integration as the Marconi Myriad used[57]. Marconi was put in charge of developing the two smaller systems[58]. There was also a 4/75 which was a time-sharing system sponsored by MinTech and developed at Edinburgh University[59]. The 4/75 was meant to allow up to 200 users to access the computer at the same time. This called for delivery of a prototype 4/70 to the University in July 1968, conversion to the 4/75 by October 1968 and acceptance for use in December 1968. It was significant that EELM beat ICT and IBM for this contract, showing its relative strength in real time systems.

Neither ICT's 1900 nor IBM's 360 series would adopt such advanced components. They used simpler components so they could get their third generation families quickly into the market. RCA and EELM seemed to be trying to achieve competitive advantage by the beauty of their technology.

There were a number of disadvantages with such a policy. EE was undertaking a major reworking of the RCA Spectra 70 system, as it had with the RCA501-KDP10/KDF8. However, this meant EE was lagging behind not only IBM but also RCA in the production of third generation computers. RCA's strategy meant that it inevitably lagged behind IBM in the introduction of new technologies as it had to wait to copy IBM protocols when they were published. The decision to use transistors for the logic of the smaller members of the Spectra 70 series was an attempt to mitigate this problem; using second generation components meant the smaller machines could be produced quickly, and at a lower cost. EELM had opted to follow RCA, another step removed from the originators of the concept, IBM. Not only did it follow RCA, but it decided to redesign the system, another extension to the time period needed to get the System 4 into the field. It also meant that the System 4 was being released comparatively close to the announcement of the next family of IBM systems, the 370s. Therefore EELM

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[55]CBI Archive, ONR, 'The British computer scene, part II'.

[56]Ibid.

[57]Ibid.

[58]Marconi Archive, The Marconi Company, January 1967. A pamphlet introducing the workings of the Marconi company.

[59]CBI Archive, ONR, 'The British computer scene, part II'.

could only expect to maintain its one advantage - more advanced components - for a very short time.

Another problem with this strategy was that it was putting EELM into direct competition with IBM, even more directly than ICT. ICT, with its 1900 family available for installation from 1964, locked customers into its unique architecture. To change from an ICT to an IBM system was relatively expensive and disruptive because of the change in software required. EELM's System 4 and IBM's 360 series were relatively easy for customers to swap between, and price:performance comparisons were easy to make. RCA intended to tackle the market by offering machines set, on average, 15% above IBM's machines in terms of performance, but set at a price of 15% below IBM. RCA wanted to achieve this by using more integrated components to reduce the cost of building machines, and presumably by foregoing some of the very high profit margin that IBM was operating with[60]. To achieve this goal, RCA was working in the very large US industry and it was also getting some income from licensing its systems abroad, to EELM, Siemens and Hitachi[61]. EELM had a much smaller market in which to achieve the scale economies needed to match this plan.

A further problem was that ICs were comparatively expensive in the 1960s, the second reason for RCA using older technology in its smaller Spectra computers. However, EELM was trying to use the components that Marconi had used to produce the Myriad, a system that had only been used in a few government contracts. Adopting the same technology for small commercial systems proved expensive and the smallest computer in the range, the 4/10, was never delivered due to its impractical costs.

Potentially the main cost advantage of copying RCA's strategy was in not doing its own design work. Yet EE did not exploit this saving as it redesigned the RCA system so much. RCA never managed to make a profit from its policy of building IBM-compatible machines that were more powerful yet cheaper than IBM's own machines. In the limited UK market EE had little chance.

EELM announced the System 4 some twelve months later than ICT announced its 1900 series. The delivery times were to be even longer: ICT delivered the 1905 in January 1965, but the first System 4 was not

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[60]See below, chapter 6, pp230-239.

[61]US v IBM, px 2482; IBM 'World Trade Corporation: Competitive Manufacturer New Sales, Rentals Installed', Sept 1969. This was a summary paper showing the main competition to IBM's overseas operation.

delivered until March 1967[62]. While EELM redesigned RCA machines, ICT simply produced a range based on existing Ferranti technology[63]. At EE delivery dates became longer and costs rose. By 1967 only 60 systems were on order, and as the problems increased a number of these were lost.

Leaving computers; the merger with ICT.

In 1966 only 2 KDF9's, 8 Myriads and 6 LEO machines were delivered, the other EELM systems were obsolete, while the first ten System 4's were not delivered until 1967. It is of some interest, indeed surprise, that, even as late as September 1969, IBM rated no System 4 machine in its top 10 of international competition, and surprisingly the LEO 326 was the only representative from the English Electric Computers (EEC) half of ICL to be rated in the top ten competitive machines. This was due to the installation of a large number of LEO 326's by the General Post Office. The following table lists the computers that IBM's World Trade Corporation rated in the top ten outside the USA:

Table 4.5

Manufacturer and system	1st Half 1969 rank	1968 rank
RCA 70/45	1	2
RCA 70/35	2	7
Univac 1109	3	1
ICL LEO 326	4	0
ICL 1902	5	0
GE 115	6	3
CDC 6500	7	0
Univac 9300	8	4
ICL 1901	9	8
Burroughs 3500	10	6

Source: US vs IBM, px2482, IBM World Trade Corporation: 'Competitive Manufacturer New Sales, Rentals Installed', Sept 1969.

ICL was the leading international competitor, but the System 4 was not leading this effort. Yet sales of the RCA 70/45 and 70/35, by Siemens, Hitachi, and RCA in Canada, had made them the biggest individual system competitors in this list. Overall WTC rated the 1900 series as the most competitive full range[64]. System 4 had not met the challenge of the market, especially compared to other licensees of RCA technology. Sales

[62]International Data Corporation, EDP Europa Report, 21/11/69, p10.

[63]See below, chapter 5, pp175-180.

[64]US V IBM, IBM 'Competitive manufacturer sales', September 1969.

were poor compared to the ICT 1900. A year after the merger of English Electric Computers and ICT, the machines from the EEC part of ICL represented only a small proportion of ICL's installed base and negligible numbers of new orders:

Table 4.6 Installation Census July 1969.

	First Installed.	Installations by July 1969	On Order
ICT Systems			
1900 Series	1/65	1033	1
1900A/E/F Series	9/67	116	473
EEC Systems.			
System 4	3/67	111	20

Source: International Data Corporation, EDP Europa Report, 21/11/69, p8-11.

These figures show just how successful was ICT's policy of getting a family of machines that at least looked like a third generation system into the market rapidly. As time went by the 1900 series was upgraded. The 1900A Series used IC components and the later S series used monolithic chips. The System 4 was marginalised into a system sold only to large users who especially wanted IBM compatibility and good real-time capabilities.

ICT and EEC had a number of false starts in trying to cooperate. These included tri-lateral discussions in the early 1960s between RCA, ICT and EELM to produce a new line of small systems, which came to nothing[65], and a brief plan for a joint EELM-ICT-CITEC[66] super-computer[67]. This latter plan was akin to the Concorde project and was aimed at underpinning British and French computer technology, but, given the difficulty of developing super-computers, the Government did not support it. However, a later ICT proposal for a super-computer, called the 1908, did attract

[65]CBI oral history collection, Colonel A.T. Maxwell, interviewed by A.L.C. Humphreys.

[66]CITEC was a state supported French computer company.

[67]NRDC 86/35/5, ICT and EELM: 'Large computer project: presentation to the Government', September 1965.

government support; but it was never built[68].

The first major move towards merger was taken in 1965. At this time ICT was in the depths of a financial crisis caused by the launch of the 1900 series[69]. Cash flow and profits were in a critical situation, not only due to development and marketing costs, but also because of the success of the 1900 series. The cost of placing large numbers of systems into lease arrangements was very high. Frank Cousin's Ministry of Technology believed that ICT should merge with EE, with effective control going to EELM, which was elated with the announcement of the System 4[70]. Cecil Mead, ICT's chairman, and Arthur Humphreys', ICT's managing director, were told by a government official that:

> '...the Government has made up its mind that ICT should be merged and should be apart of English Electric, because the Government feels that English Electric management is far superior.'[71]

This was not acceptable to ICT, which recognised its stronger long term position and the potential weakness of EELM's strategy. It also showed a lack of understanding in the MinTech. While it may have been possible to argue that a merger of EE, ICT and Elliotts might produce a single British firm which could achieve economies of scale in the limited British market, it is obvious that MinTech had little concept of the long term repercussions of introducing new computer ranges. It was obvious, that, at least on a product and marketing basis, ICT was the leading UK company, not English Electric. It seems that the government was making a decision based on shorter term criteria than even the capital markets were making: it saw the cash flow problems at ICT and judged it to have failed, while EE, which had not yet even begun to build System 4 machines, was considered successful.

By 1966 ICT had recovered, with the 1900 being delivered in large numbers. MinTech still supported merger, but now with ICT as the leading partner, though there was concern that the two companies' strategies were incompatible[72].

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[68]Campbell-Kelly, ICL, pp.248-249.

[69]See below, chapter 5, pp180-190.

[70]Campbell-Kelly, ICL, pp.255-257.

[71]CBI oral history collection, Arthur L.C. Humphreys interview.

[72]Ibid.

In 1967 the mood changed, mainly because English Electric Computers' strategy was becoming a significant burden on the parent corporation. EE was posting poor results in the mid and late 1960s. The company had done well in the early 1950s due to large demand for heavy electrical products. Lord Nelson characterised it as a period when there was no shortage of orders, only limited capacity to fulfil them[73]. However, by the late 1950s and early 1960s, the heavy end of the industry had slowed down. At the same time, EE's major investments in new fields, aerospace, nuclear power, and computers, had not shown through in profits.

Lord Nelson's put these points forward when explaining the major restructuring of the company in the mid-1960s. Figures 4.1 and 4.2, show EE's growth in the 1950s and 1960s. However, figure 4.3 shows that in the key ratio of profit to funds employed, EE lagged all its rivals bar AEI, and was far from achieving its target of 17.5% return on funds employed:

[73]Lord Nelson, 'Organisation and development of EE'.

Figure 4.1

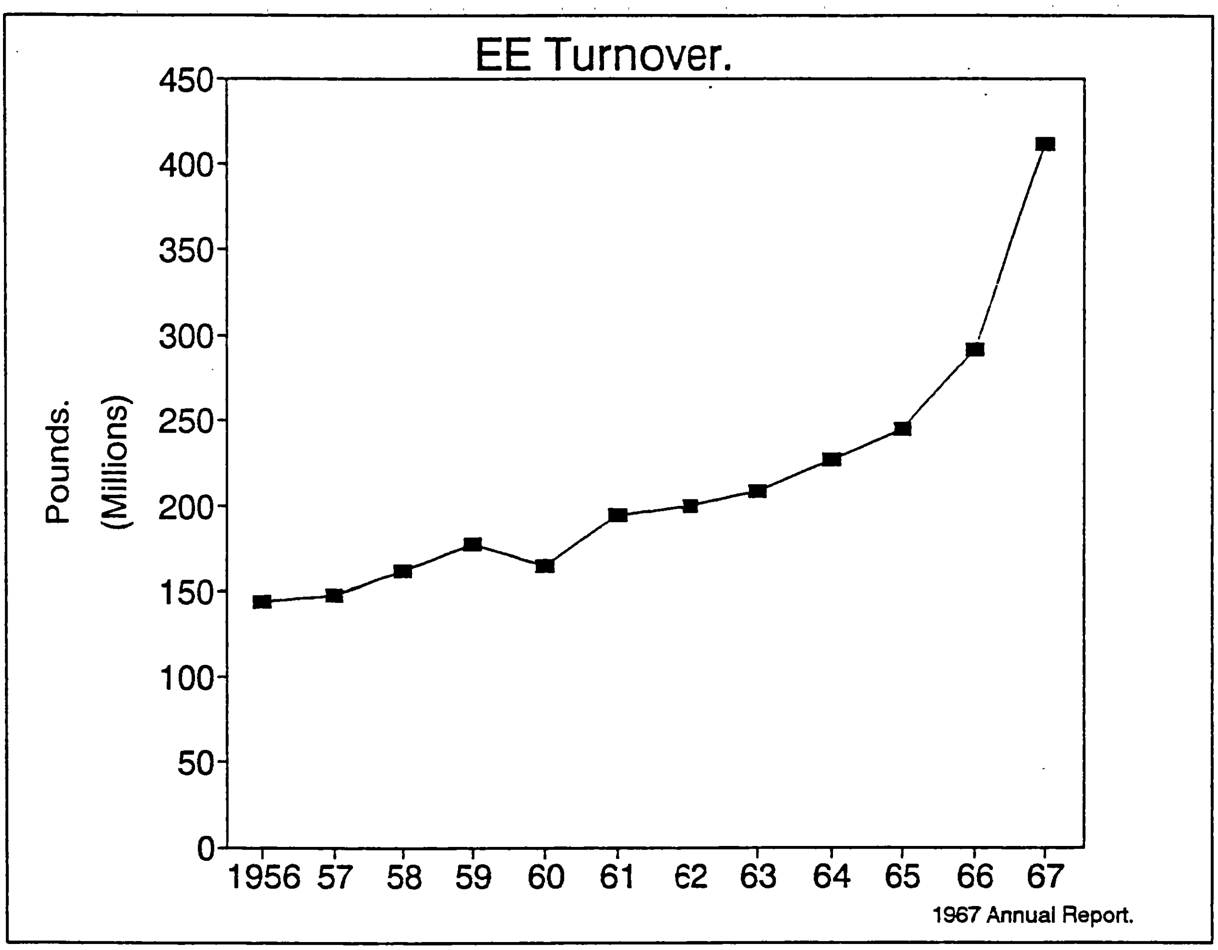

EE Turnover.
Pounds. (Millions)
450
400
350
300
250
200
150
100
50
0
1956 57 58 59 60 61 62 63 64 65 66 67
1967 Annual Report.

Figure 4.2

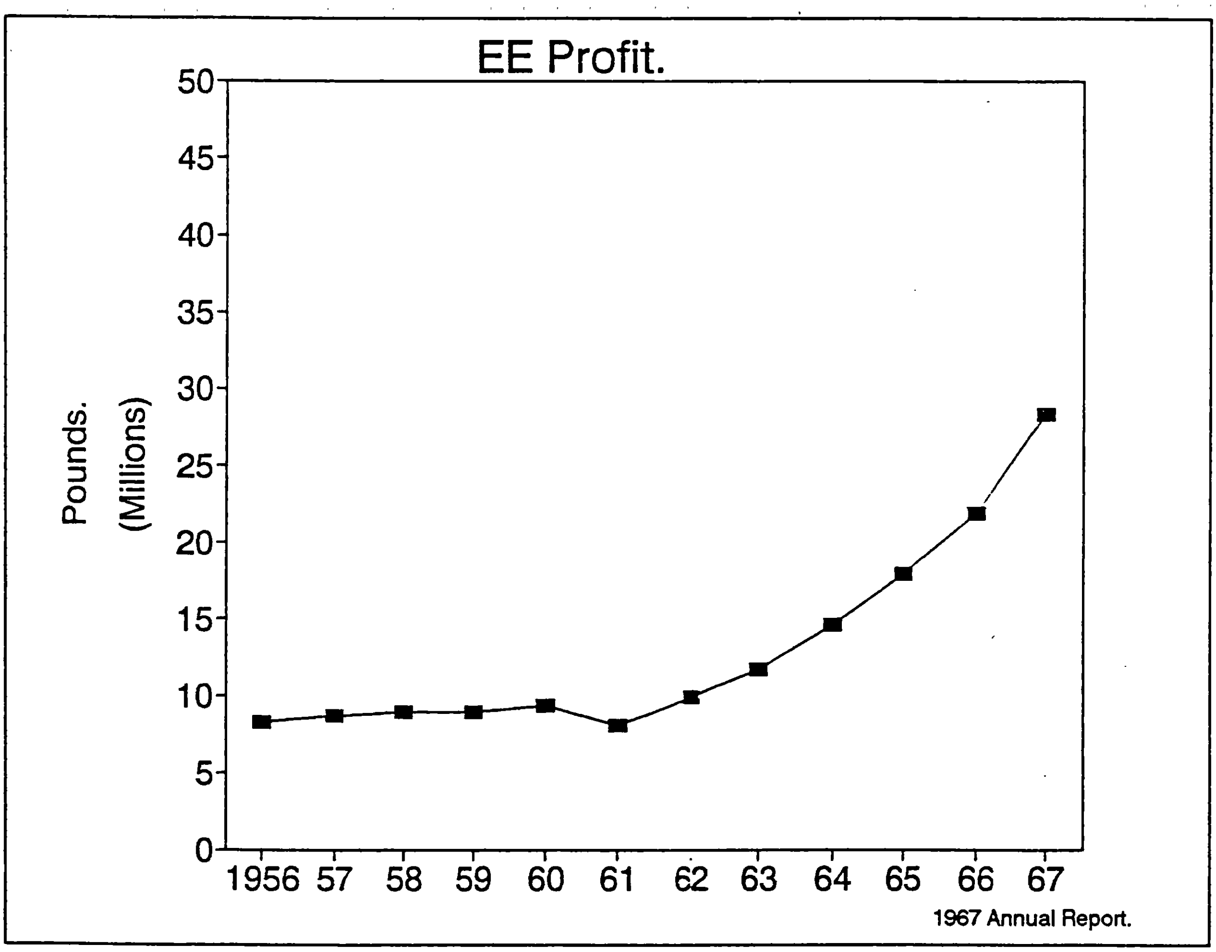
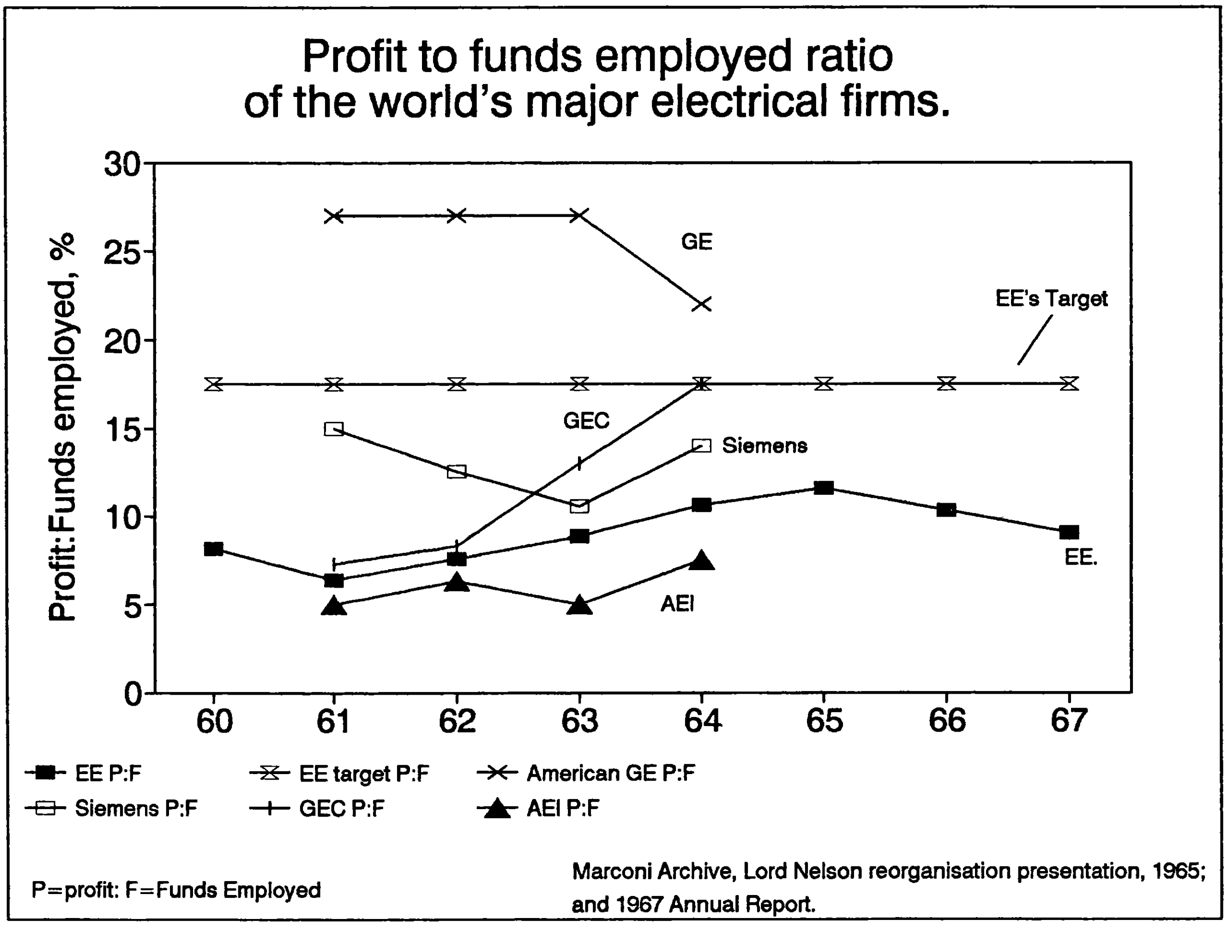

EE Profit.
50
45
40
35
30
25
20
15
10
5
0
Pounds.
(Millions)
1956
57
58
59
60
61
62
63
64
65
66
67
1967 Annual Report.

Figure 4.3


Profit to funds employed ratio
of the world's major electrical firms.
Profit:Funds employed, %
30
25
20
15
10
5
0
60
61
62
63
64
65
66
67
GE
EE's Target
GEC
Siemens
EE.
AEI
EE P:F
EE target P:F
American GE P:F
Siemens P:F
GEC P:F
AEI P:F
P=profit: F=Funds Employed
Marconi Archive, Lord Nelson reorganisation presentation, 1965; and 1967 Annual Report.

Interestingly both GE and RCA made similar calculations before they abandoned the expensive computer market. Both were concerned that their profit to capital ratio was too low to attract the capital needed to fund all their operations[74]. During the mid-1960s EE abandoned the expensive and risky field of aerospace. However, this did not greatly improve EE's profitability ratios and further action was needed.

Meanwhile ICT was starting to accept that, if it wanted to receive greater government support, it would have to go along with the merger. It might not have believed that EE was in a strong position, but it had to take over its computer operation if it wanted further subsidies.

In 1967 the two companies formed a joint committee to plan a single successor to the 1900 and System 4. The hope was to produce a machine which both sets of users could upgrade to. The initiative for this committee came from MinTech, now under the control of Tony Benn[75]. Eventually it turned out no such joint machine was possible. The only arrangement that it was possible to provide was some software to aid conversion from System 4 to ICT 1900 systems.

It was apparent that merger was inevitable. There was a clear mutuality of interests: ICT wanted Government support for a replacement of the 1900 series, and EE wanted to get out of a cash draining business. Efforts towards merger were finally galvanised by the Plessey Company, which let it be known that it wanted to take over ICT. These approaches were as unwelcome as the 1965 plans for EE to take control of ICT[76]. However, it meant that there were two sources of finance on the table for the merged ICT/EEC company: the Government and cash-rich Plessey. Negotiations started to revolve around how much capital the Government and Plessey were willing to commit to a merged company, and for what stake.

EE suffered in these negotiations as the weakness of the System 4 became apparent. EE had certain strengths. It could offer expertise in real-time computer operations. The IBM-type architecture was seen as more advanced than the 1900's design as it used 32-character word length as compared to ICT's 24 character architecture. However, ICT was already updating its range to give it the longer word length. Another advantage EE could offer was a fairly strong presence in the Eastern European

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[74]See below, chapter 6 on RCA, pp248-252; chapter 7 on GE, pp284-295.

[75]CBI oral history collection, Colonel Maxwell interview.

[76]ibid.

market[77]. These countries were unable to deal with IBM, but were interested in having the technology: EE could provide this.

However, EE could not offer capital for further investment: ICT's management saw the availability of finance as the key to making a merged company more successful than the separate firms. Ensuring that the firm obtained a large market share meant it had to be able to finance an increased number of leased and rented computers. ICT saw this as crucial to achieving a minimum efficient scale[78]. Plessey and MinTech were willing to supply finance to a merged company. The outcome was that EE, with its lack of market success with the System 4, was only given equal status to Plessey in the merged firm:

Table 4.7 Initial ownership of ICL:

Shareholder	Percentage of of ordinary shares	Form of Commitment
ICT shareholders inc. Vickers and Ferranti	53.5	ICT operations and assets
English Electric	18.0	EEC business computer operations and assets.
Plessey	18.0	£18 million
MinTech	10.5	£ 3.5 million +£13.5 million grant for development of large computers and a new computer range.

Source: T.Kelly The British computer industry: crises and development, p45; CBI oral history collection, Maxwell and Humphreys interviews.

ICL continued to support the System 4 into the early 1970s, but dropped the smaller members of the family, because of their uncompetitiveness with IBM. It mainly sold the System 4 to large users who required IBM compatibility or strong real-time capability. Eventually the 1900 was replaced by the 2900 and the System 4 ended, though in the mid-1980s ICL did sell a few large Fujitsu, IBM-compatible, systems as part of

[77]CBI archive, ONR, 'The British computer scene, part II', 1967.

[78]CBI oral history collection, Maxwell interview.

a technology and production agreement. However, the management, dominated as it was by ICT personnel, rejected EE's policy of IBM-compatibility.

Concluding remarks on English Electric.

It is clear that in the period 1965-1967 EE was attempting to become a major player in the UK computer market. It attempted this by following RCA's strategy. By doing so it might have expected to cut the high R&D cost of developing computers. Yet by trying to re-invent the range it pushed back the time when it could put machines on the market, by which time IBM had sold hundreds of 360 systems in the UK, and thousands worldwide.

It is also apparent that such a grandiose scheme was out of kilter with English Electric's overall financial position. Later it will be seen that RCA and GE both came to the conclusion that they were under-performing in the market because they were trying to support too many high cost projects at the same time, but this reality was not reflected in their computer product strategies. Like RCA and GE, EE was supporting a number of high cost expansion paths, such as electronics through the acquisition of Marconi and Elliotts, and the expansion into aircraft, locomotion engines, and nuclear power. All these cost a lot to develop.

Given lacklustre financial returns the computer product strategy in the 1960s was not appropriate to the company's situation. EE wanted to develop a major new group within the company, producing computers. However, this meant that it had to spend large amounts of money on building up its production and marketing capacity, and had to reach a scale large enough to compete with IBM. The company was not able to fund such a programme because it had too many other projects. EE might have done better, and put the resources of the company under less strain, if it had adopted a niche strategy similar to that of the smaller US business machines firms or the US producers of scientific computers[79]. An alternative was to drop other development programmes and concentrate more resources on the computer diversification.

It seems that EE opted to support its other activities before the new computer operation. English Electric concentrated on areas which were less risky and more familiar to the firm, not surprising given its poor performance compared to rivals. While it was willing to continue to build computers for industrial and military control systems it would not further support the commercial computer operation. Commercial computers were too far away from its traditional areas of activity and had too great an impact

[79]See below, chapter 8.

on the company's cash balances.

Unfortunately there are few management records available for EE, making it difficult to establish how the firm weighed up its various investment opportunities. However, it has been possible to establish that its grandiose product plan was wrong, and that its systems were late on to the market and poorly implemented. These same problems occurred in the American firms of RCA and GE, where internal records are available. It seems likely that the process of failure in the computer industry was similar across all three firms.

Chapter 5.

British business machine firms and the EDP market.

The main focus of this thesis is the decline of the electronics firm in the British and American computer markets. However, to understand this decline it is necessary to look at the firms which managed to survive in the mainframe computer industry. This chapter shows how the British tabulator companies managed to acquire the skills needed to move into computers as their old products died and how they came to dominate the flagship of the British computer industry, International Computers Limited.

On its formation, ICL was the largest computer company in Europe, as large as a number of US computer companies, but it was not able to mould this into a winning combination. Dominant in ICL was ICT, the combination British business machine industry. A detailed account of ICL and its predecessor tabulating machine companies has recently appeared[1], and this is used to supplement the archival and oral history records used in this chapter.

The roots of British Tabulating Machines and Powers-Samas: reliance on U.S. technology.

The pre-World War Two tabulating machine market was effectively a duopoly. Two British companies, both heavily reliant on US technology, supplied the accounting equipment for the British Empire. These two firms were British Tabulating Machines and Powers-Samas. It is important to establish how these two firms were subservient to US technology and how this handicapped them in the post-war years.

BTM was formed in 1907[2] as an independent company to market and then to manufacture the tabulating products designed by Herman Hollerith of the USA[3]. Hollerith's US operation, the Tabulating Machine Company, evolved

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[1]Martin Campbell-Kelly, ICL: a business and technical history, Oxford, 1989.

[2]Tim Kelly, The British Computer Industry Crisis and Development, Beckenham, Kent, 1987, p41.

[3]National Archive for the History of Computing ICL/A1M, 'Induction Course, some notes on ICL history', circa 1968. This document was used in the induction of new employees.

into IBM[4], and BTM remained IBM's licensee until after the Second World War. The second, smaller, British supplier of tabulating equipment was Powers-Samas. This company produced punched card machines designed by James Powers, whose American company became a part of Remington Rand, the second largest US business machines firm. In the UK, Powers was set up as a British source of tabulating equipment by the Prudential Assurance company[5], a major user of this equipment. It later took over the French distributor of Powers machines, Samas, forming Powers-Samas[6].

During the war both companies were allowed to keep a large percentage of their output in the form of tabulators; tabulators were necessary for the administration of the war effort[7]. The major effect of the war on these firms was to engender an increasing independence. Before the war, Powers had had a limited R&D operation, but BTM was completely under the wing of IBM. For both, these links were cut during the war, both firms having to undertake more development work themselves. BTM also became involved with the ENIGMA code-breaking operation at Bletchley Park[8]. This offered BTM a chance to get involved in innovative work, demanding advanced tabulating techniques.

After the war the Prudential sold Powers-Samas to the Vickers company, which was looking for opportunities to diversify from its military engineering activities:

> 'The problem which for the second time in this century had been placed before the Vickers Board, was to turn swords into ploughshares after the Second World War. The large armament factories and plants had almost at once to stop production and we were faced with the major tasks of finding new products, techniques and new employment for the thousands of people who were then in the plants. One of those opportunities for going into refined engineering appeared to be the punch card systems.....'[9].

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[4]W. Rodgers, Think: A biography of the Watsons and IBM, New York, 1969.

[5]NAHC ICL/A1M, 'Some notes on ICL history'.

[6]CBI Oral History Collection, Col A.T. Maxwell interviewed by A.C.L.Humphreys 9/1/80. Both men were ICT then ICL directors, Maxwell was also chair of Power-Samas before the ICT merger.

[7]Campbell-Kelly, ICL, p106.

[8]Campbell-Kelly ICL, chapter 5. There are a number of sources on Blechley Park including: A. Hodges, Alan Turing: The Enigma 1983; B. Randell, 'The Colossus' in A History of Computing in the Twentieth Century, ed N.Metropolis et al, New York, 1980.

[9]CBI Oral History Collection, Maxwell interview.

Relations between the British firms and the US licensors would not return to normal. Firstly, Powers became a part of the more self-reliant Vickers organization and left Remington's umbrella. Secondly, problems between BTM and IBM, which had been brewing for a number of years[10], led to BTM parting company with IBM[11]. BTM claimed that IBM's 25% royalty on equipment sold in the UK was too great a burden for BTM to bear[12]. A less favourable interpretation suggests that IBM was happy to end the arrangement as it was frustrated by BTM's inability to match its own growth rate[13]. By 'mutual agreement' BTM and IBM terminated their contract.

The British business machines industry faced many challenges, the main one being to supply the rapidly growing office automation market. To do this it had to find the capital resources both to build plant and to finance leasing arrangements. At an early stage leasing became the norm in the business machines market. BTM's Puckey explained that Herman Hollerith started this practice because he believed his systems were too complicated for the users to cope with: it was better for the manufacturer to retain control. However it did create a problem:

> 'It requires us to obtain and use enough capital to maintain production for some years ahead of the time when an adequate return on the investment can be realized and the capital regained.'[14]

Not only were the two UK firms faced with the happy situation of coping with growing demand, but they also had to deal with their new independence (which meant establishing R&D facilities) and they had to compete with US enterprises, which they had previously relied on. Therefore, after the war, BTM and Powers Samas were fully occupied in increasing their capability to deal with the demand for tabulating machines. In the US, IBM, which already had the most advanced knowledge of tabulators, was developing electronics to be used in its traditional products, and soon became interested in computers. Remington Rand was also quick to acquire computer skills, indeed quicker than IBM[15]. British firms were occupied with the old technology and lagged in the development

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[10]Campbell-Kelly, ICL, chapter 4.

[11]Times, 11/1/50, p11, chairman's annual statement, R.Phillpott.

[12]Sir Walter Puckey, BTM Director, 'Design, Development and Marketing of Hollerith and Allied Machinery', London School of Economics, Seminar on the problems in industrial adminstration, 22/11/55

[13]Campbell-Kelly, ICL, pp90-94.

[14]Puckey 'Design, development and marketing.....'.

[15]See below, chapter 8, pp358-361.

of computers.

Early computer work.

During the first generation of computing, the electronics companies dominated the British industry. The British business machines firms (already concerned with building up tabulator capacity and R&D facilities) seemed to view the move towards computers as an unwelcome extra burden. In 1955 Puckey identified one major problem facing BTM:

> 'the extent to which a pure computer, specifically designed for office use, is likely to be of widespread commercial appeal.'[16]

This line of thought was also found at Powers with the same questions being asked:

> '...the big problem facing the punch card industry [was] when and how they were expected to get into some form of electric or electronic data processing and computing.'[17]

BTM approached Prof. A.D. Booth of Birkbeck College to develop its first computers[18]. His early computer work led to the Hollerith Electronic Computer, later called the BTM 1200 (HEC II), and a second machine the BTM 1201 (HEC IV)[19]. The HEC II was a simple drum memory accounting machine, the HEC IV was a full computer.

Unlike the electronics firms, BTM had a user base in commercial data processing, through its punched card customers. It was these on which it concentrated sales of HEC machines[20]. The sales organization had a computer department added to it. This was a stop-gap while information on computers was being disseminated to the district sales organization[21]. This comprehensive sales organisation, and the established market links, were something that the electronics firms needed to develop to be serious competitors in the commercial market:

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[16]Puckey 'Design, development and marketing.....'.

[17]CBI Oral History Collection, Maxwell interview.

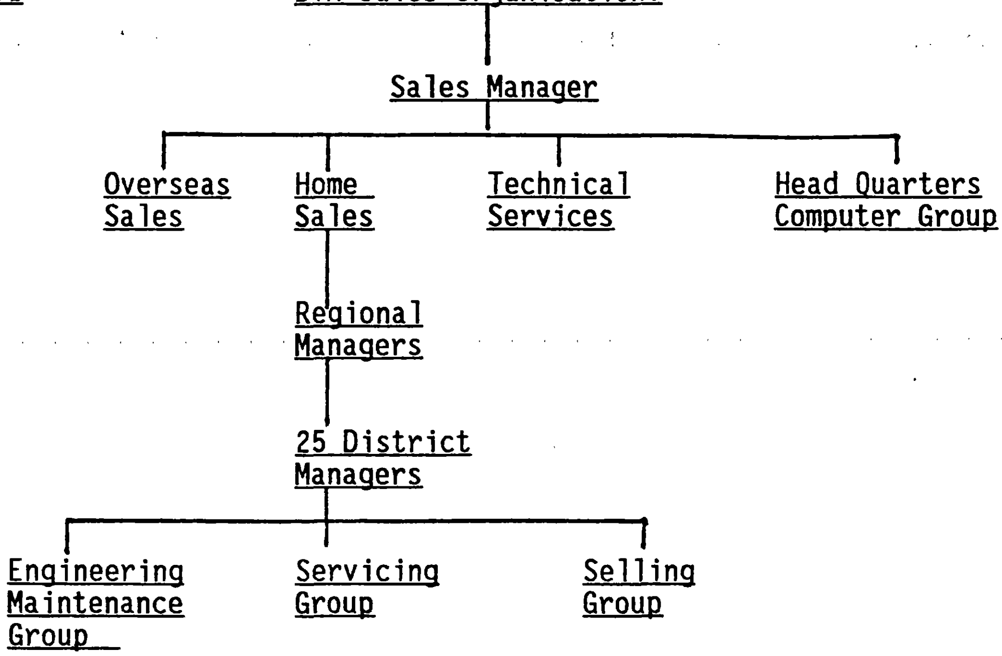
[18]A.D. Booth, 'Computers in the University of London, 1945-1962' in; A History of Computing in the Twentieth Century, Ed. N. Metropolis et al, New York, 1980.

[19]NRDC 86/44/3, 'Summary of digital computer production and development in the UK' 11/7/55; K. Flamm, Creating the Computer, Washington 1988, p147.

[20]NRDC 86/44/3, 'Notes on sales promotion and application of computers', appendix to NRDC paper no 106, 11/7/55, 'Survey of computer availability, application studies and training'.

[21]ibid.

Fig 5.1 BTM Sales Organisation.



Source: NRDC archive 86/44/3, 'Notes on sales promotion and application of computers'.

The overall structure of the company was equally functional: sales production and development were separate units. The functionality of the company structure was very different from the multi-product multi-divisional structures that the electronics companies were adopting. It was a function of the single corporate purpose, to make and sell data processing equipment.

By 1955 there were 20 HEC IVs and 7 HEC IIs on order, with another 3 earmarked for internal use[22]. 50% of orders were for payroll, with the balance to be used for a number of accounting, production, and administrative functions. By this time Powers was also able to offer electronic systems. Firstly there was the Electronic Multiplying Punch, which was an electronic calculating device sold by the 250-strong general sales force. However, the second machine, the Powers Card Programme Calculator, PCC, was much closer to a computer, offering drum storage and a memory of 160 words. To sell these, the sales force would call in members of the Computer Department[23]. Table 5.1 shows the order situation of EMP and PCC machines in 1956:

[22]NRDC 86/44/3, 'Notes on sales promotion and application of computers'.

[23]Ibid.

Table 5.1	Power-Samas computer sales.
Overseas	30 EMPs delivered, 70 ordered.
	30 PCCs ordered.
Home	80 EMPs delivered.
	70 PCCs ordered.

Source: NRDC archive 86/44/3, 'Notes on sales promotion and application of computers'.

These machines were small and they could only fulfil the smallest computer needs. Only BTM's HEC IV was a fully functional computer. Neither could offer to their customers anything to cover larger problems. Both companies would make efforts to overcome these weaknesses by negotiating with other firms for the use of bigger designs.

Early Relations with Ferranti.

The first recorded contact between the business machine companies and the electronics industry was under the auspices of the NRDC. On December 14th 1949, the Corporation hosted the first and only meeting of its Advisory Panel on Digital Computers[24] at which representatives from all interested firms were present. The NRDC wanted the two sets of companies to come to some arrangement to safeguard the UK's leading position in computers, a position given it by the work at Manchester University and the NPL. However, the NRDC was concerned that IBM was going to use its huge sales network and market knowledge to bring the computer in to its own, and establish itself as the dominant company. The NRDC posed three opening questions:

> '1) Is there in the UK any firm with the manufacturing, selling and servicing facilities of the International Business Machine Corporation, with particular reference to the manufacture of electronic equipment.
>
> 2) If not:
> a) Would it be an economic proposition for Powers-Samas or the British Tabulating Machine Co., or both, [to] build up a large-scale electronic manufacturing organization, and could they in effect do so other than by taking staff away from the electronic manufacturers?
> b) Would it be economic for any of the electronic manufacturers to set up a separate selling, servicing and advisory organization in competition with the Powers-Samas and British Tabulating Machine organizations?
>
> 3) If the answer to the above two questions are negative, does the Panel consider that there is no practicable alternative to a joint effort between Powers-Samas and the British Tabulating Machine Co. on the one hand and one or more of the electronic firms on the

[24]NRDC 86/35/1, Advisory Panel file.

other.'[25]

The NRDC proposed that an alliance be formed between the technically competent electronics firms and the business machine firms who had knowledge of the commercial data processing market.

Lord Halsbury, chairman of the NRDC, failed to get a broad alliance of electronics and business machine firms, therefore he started to concentrate on Ferranti and BTM[26]. Halsbury emphasized these two as BTM was, in his view, more go-ahead than Powers. By 1952 it was obvious that little was coming out of these negotiations. BTM was primarily interested in protecting its tabulator market and Ferranti was not developing the type of computer needed for commercial work.

In 1953 attention switched to a link between Powers and Ferranti[27]. Apart from the NRDC's efforts to urge them to cooperate, the leaders of both companies had identified weaknesses which they believed the other firm could help overcome. Vincent de Ferranti blamed much of the company's lack of commercial success with computers on the inability of the Computer Department's small sales force to compete for sales[28]. At Powers, the Chairman, A.T. Maxwell, was becoming aware that the company was not well positioned to enter the computer market[29]. One of his acquaintances, Sir Thomas Merton, placed him in contact with the Hungarian emigre, Professor Gabor, a leader in advanced Physics:

> 'Professor Gabor convinced me that we were not developing technologically fast enough or on a wide enough field to make Powers-Samas into a computer company. The suggestion was made that we should get in touch with the Ferranti company which at that stage was, as it subsequently has continued to do, working on the ...advanced fringes of technology. I was introduced to Sir Vincent Ferranti, who at the time was Chairman and Managing Director of the company which was not quoted on the stock exchange. We had a number of meetings and we agreed that short of any sort of actual merger of interests, the best plan was to see if we could divide up the problem of research and development between the two companies. At this stage, if I remember, we brought in our Managing Directors etc. and the research men. After a considerable study of the problem, fourteen projects were identified and of these eight were to be worked on by the Ferranti research team and six by the Powers. These

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[25]ibid.

[26]John Hendry, Innovating for Failure: Government Policy and the Early British Computer Industry, 1990, chapter 6.

[27]Ibid.

[28]B.B. Swann, 'The Ferranti Computer Department', unpublished, 1973.

[29]CBI Oral History Collection, Maxwell interview.

fourteen took many months to develop, and when the results started to come in, they were realized to be rather disappointing. With the best will in the world, the research teams had reservations about handing over their own know-how and thoughts to the other side, and Sir Vincent and I decided regretfully that this was not the ideal way to carry out a wide-ranging development project into the computer age.'[30]

The arrangement stipulated that sales of computer equipment made by the two companies, mainly Ferranti Pegasus computers, would be divided, Powers selling to commercial markets and Ferranti to scientific and engineering users. Swann blamed this arrangement for undercutting the successful Pegasus range and preventing Ferranti from developing a base in commercial computing. Powers failed to sell a single machine. It was more interested in protecting its traditional equipment and, while Maxwell may have recognised weakness, most effort went into a new range of punched card equipment. This was to be the Samastronic range of tabulators that proved to be a technical and commercial failure.

The ICT Merger, 1959.

Demand for BTM's and Powers' traditional products remained high through to the end of the 1950s. However, there were underlying weaknesses, especially at Powers. Firstly, Powers managed to get itself into severe financial difficulties. It had placed large numbers of machines into lease arrangements and was undertaking a very major development, the costly Samastronic range of equipment:

> 'The consolidated profit and loss account shows a figure of trading profit at £1,180,615, which is substantially better than the corresponding figure in 1956, although the increase is absorbed in heavier financing costs, and in the provision against increased Research and Development expenditure on future projects.'[31]

Increasing interest rates and new credit restrictions exacerbated Powers' problems. The credit restrictions made leasing even more attractive to customers, while the high interest rates made it more expensive for the company to finance[32]. On top of this, the growing use of computers was finally having an effect. The company was being forced to reassess its depreciation policy and had to increase reserves, as the probability of the old punched card equipment being replaced increased. Powers achieved poor

[30] ibid.

[31] Times, 13/5/58, p17, report of A.T.Maxwell's chairman's address to the Powers' annual general meeting.

[32] ibid.

returns on shareholders' funds, at 3% in 1956 and 4% in 1957[33]. It was also in a poor position when it came to exploiting the growth in computers.

Meanwhile BTM had managed to extend its ad hoc computer development. In 1956 it had formed a joint subsidiary, International Computers Corporation Inc, with the small Boston company, Laboratory For Electronics, which was to develop a machine for the Chase Manhattan Bank[34]. The programme was also meant to include the transfer of computer skills to BTM[35]. While the contract with the bank fell through, ICC did produce a very advanced magnetic drum store only equalled by the IBM RAMAC disc system[36].

A few days before the announcement of the International Computers Corporation deal another, more important, deal was struck with GEC[37]. This was the formation of a joint company called Computer Developments Limited. More will be said of this in the next section. In 1957 BTM also acquired a 51% holding in the small British company, Data Recording Instruments, to give it access to magnetic tape technology[38].

With the shift of the market away from traditional business machines, the two firms decided to consolidate the market and merge their activities to take on the big US players. According to Maxwell, negotiations between BTM and Powers-Samas were difficult[39]. Eventually they were merged on a 62/38 basis in favour of BTM[40]. Vickers, as the main Powers shareholder, was willing to take a subordinate role if that meant the mounting problems at Powers were shared with other equity holders.

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[33]Campbell-Kelly, ICL, p173.

[34]Times, 31/5/56, p19.

[35]ibid.

[36]Campbell-Kelly, ICL, pp180-186.

[37]Times, 25/5/56, p19.

[38]Campbell-Kelly, ICL, p187.

[39]CBI Oral History Collection, Maxwell interview.

[40]Ibid, comment by A.L.C. Humphreys, one time ICL managing director, during his interview of Maxwell.

ICT in the late 1950s and early 1960s.

1) Tabulators.

The merged company was faced with the likelihood that rapid technological advance would make obsolete its traditional product line. However, the product plan announced at the time of the merger was rather conservative, with equal emphasis on old systems. The aims were:

> '1. To become a large-scale vertically-integrated data-processing equipment manufacturer.
>
> 2. To supply products for the traditional punched card machine market, and to diversify into small and medium EDP computers.
>
> 3. To become a peripheral manufacturer and OEM supplier.'[41].

There was still faith in the old tabulator products. ICT believed that there was no lack of demand for punched card products and during 1961-2 it increased capacity to produce punched card equipment by 50%[42]. However, this was the period when second generation computer systems were becoming available. Systems such as the hugely successful IBM 1401, and even ICT's own 1301 tore into tabulator sales. In 1961-2 tabulator sales missed their target by one third[43], finally forcing ICT to recognise the end of electro-mechanical business machines.

2) Obtaining second generation computer capabilities - creating the computer company.

This situation put the company into something of a crisis, its main challenge was now rapidly to increase its computer activities.

Internal developments: the 1202 and the abandoned 1400/LFE venture.

At the time of the merger, ICT had inherited a number of computer developments, all from BTM. Firstly there was the established HEC line of small computers. Up to 1959 something like 6 HEC 1200s had been installed in Britain and 11 exported, with another 30 HEC 1201s in the UK and 19 abroad[44]. However, this system was becoming dated. In 1959 ICT started

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[41]Campbell-Kelly, ICL, p195.

[42]Campbell-Kelly, ICL, p204.

[43]ibid.

[44]Computer Consultants Ltd, British Commercial Computer Digest, 1963 and 1965.

to install an improved model with larger drum memory, the 1202[45]. This kept the first generation technology alive and another 28 units were installed in Britain and nearly 30 abroad[46]. However, it was only a stop gap until a second generation machine was ready[47].

ICT was also planning a medium-sized, first generation computer, called the 1400. Development of this machine had been delayed in the hope that it could be based on the system being developed in the joint operation with LFE for Chase Manhattan[48]. Chase scrapped the contract and only a prototype was produced. Development of the 1400 accelerated in 1958 when it was realized that the joint venture had achieved little. In 1958/9 the company publicized the machine heavily, but it was withdrawn following the advice of US consultants[49] - it could not hope to win orders in the face of the new transistorised competition.

Cooperation with GEC and the 1301 computer.

The more successful project was a joint venture with British GEC[50]. The two firms worked together to produce a second generation replacement for the 1200 HEC series. Like the 1400, the 1300 was intended to be available in a magnetic tape and a random access configuration. The project went well:

> 'In November 1959 International Computers and Tabulators Limited and the General Electric Company Ltd. formed Computer Developments Ltd. as a jointly owned design and coordinating group. The 1301 computer, the first outgrowth of this united effort, is a file processor for medium size companies. ICT will manufacture the peripheral equipment and market it through its world-wide channels. General Electric [Company] will manufacture the electronics. At present there are two production prototypes of the 1301 in construction, with a backlog of 17 orders.'[51]

The one problem was that the random access version was dropped, and only

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[45]<u>Times</u>, 7/1/59, p16, Sir Cecil Weir's statement at the 1959 BTM annual meeting; CBI Archive, Nelson M. Blachman, Office of Naval Research, US Embassy, London, 'Commercial Digital Computers In Britain', 8/1/59.

[46]Computer Consultants, <u>British commercial computer digest</u>, 1965.

[47]Campbell-Kelly, <u>ICL</u>, p184.

[48]Campbell-Kelly, <u>ICL</u>, p186.

[49]ibid.

[50]<u>Times</u>, 1/11/60, ICT advert for the 1301 computer.

[51]CBI Archive, Auerbach Electronics Corporation, 'European Information Technology, a report on the industry and the state of the art', 15/1/61, this was one of a number of industry reports by the Auerbach Corp.

magnetic tape was available for mass storage. This was because the BTM drum system, which it had got from the LFE joint development, was not competitive with newer IBM disk systems[52]. It appears that ICT decided not to offer this facility to avoid unfavourable comparison. This meant data could only be accessed from magnetic tape or punched card peripherals, greatly limiting its flexibility. GEC constructed the computers at its Coventry telecommunications plant[53]. ICT provided the peripherals and sold it.

The 1300 was up against stiff competition. ICT was forced to announce the system in May 1960, because of the large sales IBM was achieving with its second generation IBM 1401[54]. This was two years ahead of delivery, which undermined confidence in delivery somewhat. There were also a number of other competitive machines, such as the EMI 1100 and the successful NCR 315.

Despite the competition, and the lack of random access stores, the system was a success, at least in the context of the UK market which was smaller than that of the US. By 1965, 102 1301s had been installed, with another 27 on order; there were also 24 smaller 1300s delivered and orders for 51, plus 1 larger 1302 on the order books. £13,320,000 worth had been delivered and £5,685,000 worth were on order[55]. In the same price category only the IBM 1401 out-sold it in the UK. None of the other British manufacturers' machines approached it: Ferranti and EE were concentrating on scientific or large scale systems, both much smaller markets, while EMI had problems coping with its chosen commercial market.

In 1961 ICT absorbed the joint venture company, CDL, to take control of the team that developed the 1301[56]. GEC continued to manufacture the system[57], but this represented the end of GEC's interest in commercial computing.

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[52]Campbell-Kelly, ICL, p200.

[53]London School of Economics, archival collection, 'Seminar on the problems in industrial administration', A.L.G. Lindley, Chair and M.D. of GEC, 'The Development and Organization of the General Electric Co. Ltd.' 13/3/62.

[54]Campbell-Kelly, ICL, p201.

[55]Computer Consultants, British Commercial Computer Digest, 1965.

[56]NAHC, ICL/A1M, ICL 1968 induction course.

[57]Lindley, 'Development and organisation of GEC'.

The need for more systems: arrangements with RCA.

There were still a number of weaknesses in ICT's computer strategy. The 1301 had a sale price of £120,000[58] which covered only the smaller part of the medium scale market. There was also a feeling among board members that the company still needed 'additional technical skills'[59]. To try to get the extra skills it needed, it started to negotiate with two American companies, General Electric and RCA.

Negotiations with GE came to nothing: GE was simultaneously talking to Bull of France and some arrangement between all three companies was being considered. Representatives of GE came to Britain and discussed the possibility of purchasing a 25% stake in ICT. However, these negotiations petered out. GE was already about to acquire large stakes in Bull and Olivetti so may well have completed its European ambitions[60].

In 1961 Arthur Humphreys[61] was placed in charge of the planning role at ICT, and took charge of negotiations with RCA[62]. RCA already had English Electric as a licensee of the medium scale RCA 501/EE KDP10 computer. Briefly all three firms considered some joint arrangement, but again this came to nothing.

Talks between RCA and ICT were more successful. ICT and Bull (before it came under GE's wing) were given the rights to sell the new RCA 301 computer in Europe[63]. This seems to have been a good arrangement for both ICT and RCA. RCA was able to make a large number of cash sales to its European partners, increasing its cash flow and helping to increase its economies of scale. ICT marketed the system under the name of the ICT 1500 and in British terms it sold well. By 1965, 89 of the machines were installed, at a value of £6,408,000, and another 52, worth £3,744,000 were on order (though many of the latter may not have been delivered as newer systems were developed); about 40 of the orders were abroad[64]. ICT had coupled itself to the success of RCA's most successful product. Indeed

[58]Computer Consultants, British commercial computer digest, 1965.

[59]CBI Oral History Collection, Maxwell interview.

[60]See below, chapter 7, pp276-278.

[61]A long time ICT/L employee who became an executive director in 1963 and eventually rose to managing director.

[62]CBI Oral History Archive, A.C.L.Humphreys interviewed by Erwin Tomash, 28/2/81.

[63]Datamation, December 1961, p53.

[64]Computer Consultants, British commercial computer digest, 1965.

RCA's European links went so well that it started to design a follow up system, the Poplar, to fulfil the needs of the small tabulator users that ICT and Bull had. The fate of this machine (it was overtaken by the rapidly developing market) is discussed in the RCA chapter[65]. While the RCA link only provided a computer for ICT to resell, and gave it few new technical skills, the ICT 1500 enabled ICT to gain a larger market share than would otherwise have been the case and must be counted as a successful short-term project.

ICT also agreed to resell UNIVAC's successful small calculating tabulator, the UNIVAC 1004. Between 1963 and 1966 ICT sold nearly 500 of these units, enabling ICT to cancel an internal project for such a machine. The 1004 was vital in generating enough cash to enable ICT to survive its mid-1960s crisis. These systems were easy for users of traditional punched-card equipment to switch to, and did well in the old tabulator market.

The takeover of EMI's computer operations.

The absorption of GEC's computer capability and the deal with RCA gave ICT two reasonably successful second generation machines, but they covered only the small and medium scale computer markets, though this represented the largest part of the European market. ICT wanted to decrease reliance on outside technology and improve its market coverage. In the early 1960s Humphreys started talking to EMI[66], whose medium scale 1100 and large scale 2400 were both aimed at the commercial data processing market. EMI's range was advanced, but it had many problems[67]. Firstly the two systems were incompatible, and, while EMI's computer department supported the 1100, the 2400 was marginalised. EMI was a small player in the game, with a long way to go if it was to command a large enough user base to finance further R&D.

Given the fragile nature of EMI's position, and the fact that it at least had technology that ICT could use, a merger seemed reasonable. This was achieved with an exchange of shares from ICT to EMI, 10% of the dividend from these shares was then to be transferred to the NRDC in payment for its investment in the 2400. Like GEC with the 1301, EMI continued to manufacture the 1100 and 2400 systems under licence at its Hayes factory, but this was the end of EMI's role as a computer builder.

While the transfer of EMI's computer activities gave ICT extra market

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[65]See below, chapter 6, pp228-230.

[66]CBI Oral History Collection, Humphreys interview.

[67]See above, chapter 3.

share, the most important thing it gave ICT was EMI's design team. They were experienced in the use of solid state electronics in computers. This team proved important when ICT was faced with the task of designing a whole family of third generation computers, and it was the ex-EMI team that developed the smaller members of the range.

The 1963 takeover of the Ferranti computer operation.

The EMI deal did not give ICT technological independence: the systems that came with it were not going to survive into the third generation of computers and the design team was of limited size. The technological dependence of ICT was recognised within RCA. RCA had an overt policy in the early 1960s of staying technologically ahead of ICT and Bull, so that these companies would always come back to it for up-to-date computers. To this end RCA considered, and started designing, a very small computer which would appeal to ICT's tabulator customers[68]. However, in 1963 RCA found that its dominance over its British selling agent had been diminished:

> 'During the past year, ICT and Ferranti reached an agreement under which the Ferranti Computer Division was merged with ICT. This merger has increased ICT's total computer design capability and has also increased their desire to design and manufacture to a greater extent the equipment which they sell. This means that more than ever before RCA must manage to 'keep ahead' of ICT's capabilities.'[69]

It could be argued that ICT was the country's premier computer seller[70]; however, Ferranti was Britain's technological leader. As has already been seen, there had been earlier efforts to bring about some coordination of these skills. These plans had floundered due to the two companies' conservative attitude to the market, and Ferranti's unwillingness to see BTM have complete control of sales. In the early 1960s no such problem occurred, as Ferranti was more than willing to give up its stake in computers.

Ferranti had a number of major problems[71]. While it was true to say it probably had the best design operation, in the early 1960s it only had a limited number of machines to offer to the market. It had achieved its best success with scientific machines, but the only major machine that it had available for mass production, the Orion, while dual-purpose, was not

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[68]US vs IBM, px114, RCA EDP Division, 'Business Review' 1/12/59.

[69]US vs IBM, px243, RCA EDP Division, 'Five year plan 1963'.

[70]A.S. Douglas, CEIR (UK) Ltd, a London based computer research and service bureaux company, 'The European Computer Scene: 1963', Datamation, Aug 1963, pp24-26.

[71]See above, chapter 2, pp78-82 and pp95-99.

really fast enough for scientific operations, and had a number of technical problems. Even if Ferranti had decided to continue in the computer market it had to compete with the marketing and leasing capabilities of US and UK business machine firms. Apart from the Orion and the small scientific Sirius computers, all efforts had been directed towards the super-scale ATLAS development. ATLAS had two negative effects, firstly it worsened the profit and loss situation of the Computer Departments, secondly it had distracted the department from other work.

Ferranti did, however, have one commercial EDP design on the 'back-burner': this was the FP6000 developed by its Canadian operation, Ferranti-Packard[72]. The availability of the FP6000 was vital to ICT: it was to form the base of its third generation computer family. The real problem for Ferranti was that the third generation of computers would be families of mass-produced and mass-marketed systems, not a scale of financing that the private Ferranti company was willing to consider. Therefore, Ferranti was willing to cut its losses and merge its commercial computer activities into ICT. ICT obtained a strong design team with expertise in the area of scientific computing. This team, together with the FP6000 design, was vital to ICT. The alternative was to go in with another supplier and become subservient to that supplier's technology, an option English Electric-LEO-Marconi chose by following RCA[73]. ICT did not favour this stance.

ICT and the third generation of computers.

After all the mergers a member of the NRDC staff wrote that ICT:

> 'represents the major component of the UK industry as far as computers and data processing are concerned.'[74]

This left ICT with a mixed bag of incompatible machines, some of which were competitive with each other. ICT had to take some action to unify its product line. Arthur Humphreys recognised the situation that had been created:

> 'One of the things that pleased me very much is that after having acquired the Ferranti Computer Division and EMI's computer activities and because of the arrangement with RCA [ICT] had a large mixed bag of computers to offer to the market place, we were able to put all the expertise and techniques together and come out with an

[72]NAHC product literature, 'Born in Canada, the ICL-1900 series comes home to roost', ICL publicity leaflet reprinting an article from Canadian Datasystems, November 1969.

[73]See above, chapter 4, pp146-150.

[74]NRDC 86/35/4, J.Crawley,'The UK Computer Industry with particular Reference to ICT', 22/7/64.

entirely new range of computers which was the 1900 series.'[75]

By the time of the 1963 merger with Ferranti the computer industry was starting to turn its attention to developing the next generation of machines. These were the third generation systems which emphasised compatibility, improved peripherals, comprehensive operating systems, and the move toward integrated circuits as the core component. During the third generation the many different computers made by a company were replaced by members of a common family. The difference between scientific computers and those for commercial data processing, a distinction which was already being blurred, became insignificant in all but the realm of super-computing and the new small engineering machines appearing from such firms as DEC and Elliotts. IBM's reaction to these changes in the market was to replace its whole product line with the 360 family of computers[76]: this allowed IBM to achieve significant scale economies on common sub-systems, and gave users greater flexibility.

Every computer company found that it had to make some sort of strategic decision on how to react to the 360. Most decided to follow IBM's example of having a compatible family architecture. RCA went as far as to produce its own version of the 360, with EE following in its wake. ICT made a decision to produce its own compatible family, based on the Ferranti FP6000. Ferranti's Canadian subsidiary had taken on this development as the British operation had its hands full with the Orion and Atlas. The specification was devised by a Ferranti salesman, Harry Johnson, for a system based loosely on the Pegasus computer and as a follow up to it[77]. It used component technology from the Ferranti-Packard airline reservation system, Gemini, and some of the systems philosophy of the Orion. It was a very flexible design and could be configured to cover a large spectrum of the market.

All this closely fitted ICT's needs. It was a much more advanced system than ICT's own developments, and it was possible to produce it quickly as the circuitry had already been proved by Ferranti-Packard. In April 1963 ICT dropped two internal projects for medium sized computers in favour of developing the FP6000, while other projects, such as the 'Poplar' being designed with RCA and a project inherited from EMI, were slowed down

[75]CBI Oral History Collection, Humphreys interview.

[76]US vs IBM, Dx1404, 'Final report of SPREAD Task Group', 28/12/61. This was the report that recommended the 360 strategy.

[77]Campbell-Kelly, ICL, pp221.

and later abandoned[78]. Officially Ferranti did not sell its operation to ICT until September 1963, but it is obvious that the merger was accepted well before this. Even so, before the announcement of the 360 in April 1964[79], ICT's product plan was still complex[80]:

Small:	Enhanced UNIVAC 1004.
Small/Medium:	PF182[81] to replace the EMI 1100 and ICT 1300.
	2201 being designed with RCA.
Medium/Large:	FP6000 sold as ICT 1900.
	RCA 3301 to be sold as the ICT 1600.
Large:	Orion replacement.
Giant:	Atlas replacement.

However, following the announcement of the IBM 360, ICT dropped all the aforementioned projects in favour of an expanded FP6000/ICT1900 programme to cover almost the whole range of the computer market. The initial announcements were made in September 1964 and by 1967 the range, including announcements, consisted of the 1901, 1902, 1903, 1904-5, 1906-7 and 1909. There was also a proposal for a large scale scientific system, the 1908[82]. The 5 and 7 were scientific versions of their commercial siblings.

The smallest member of the family, the 1901, was launched in 1965[83]. Its launch was delayed for two reasons: firstly to spread out R&D costs, secondly to protect the 'cash cow' 1004 sales. The 1901 seems to have been singled out for special attention and was especially successful. It was a small system, with a starting price of only £60,000[84]. In its larger configuration (costing around £120,000) it came with magnetic tape drives. It was also provided with the NICOL[85] programming language which was designed to emulate tabulator techniques, so it was easy for punched card users to switch to, and was fully compatible with the rest of the line. These kinds of facilities were unusual in the smallest member of a

[78]Ibid, pp232-240.

[79]F.M. Fisher et al, IBM and the US data processing industry: an economic history, New York, 1983, p105.

[80]Campbell-Kelly, ICL, pp223-224.

[81]A project being developed by the ex-EMI team.

[82]CBI archive, ONR, 'The British Computer Scene', 17/5/67.

[83]ibid.

[84]Ibid.

[85]CBI Archive, ONR, The British Computer Scene; part II.

computer family: even IBM could not offer such a cheap magnetic tape machine. In its first year its orders ran to 228, a third from overseas[86].

The US Office of Naval Research, ONR, saw the whole 1900 family as a successful product, and an updated series with eight bit data paths promised more success:

> 'The other machines have also sold successfully with over $200 million in value and over 650 total sales. More than a third are for export, notably to Australia, New Zealand, Africa, France (over 30 sales), Germany (to scientific universities among others), and Eastern Europe. About 300 have been delivered. Lower cost 1900s have been promised before the end of 1967 by direct updating with microcircuits. It is also intended to make the 6-bit character structure of the series (24 bit words) compatible with the 8-bit extended BCD set adopted by IBM and English Electric.'[87]

IBM also recognised the range as a major competitor in the overseas market. IBM was conscious that it did not offer magnetic tape facilities on its smallest system, the 360-20. IBM rated ICL and the 1900 as its largest overseas competitor[88].

There were a number of reasons for the success of the 1900. It was, in some ways, not as advanced as other systems announced at that time. It did not use the integrated circuit components of RCA and EE, or hybrid technology as used by IBM, instead relying on the tried and tested transistor. However this gave one great advantage: by using the same components as the FP6000 it meant that the medium sized 1900s (closest in size to the original FP6000) could be delivered four months after announcement. The ICT 1900 family was available in Europe before the IBM 360, mainly due to production delays in IBM's SLT components[89], and way ahead of EE's IC based System 4. The 1900 was available and it had the philosophy of the third generation machines: it was a family of compatible moderately advanced machines, with some good commercial software. In the late 1960s the 1900s were given a new lease of life when the integrated circuit versions were released using 8 bit characters and 32 byte words.

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[86]Ibid.

[87]Ibid.

[88]US vs IBM px2482, IBM World Trade Corporation, 'Competitive Manufacturer New Sales, and Rentals Installed'.

[89]IBM had to cope with massive demand for SLT components due to the great success of the 360 family.

The cost of the 1900 family.

However, things were far from smooth for ICT. As noted by the ONR:

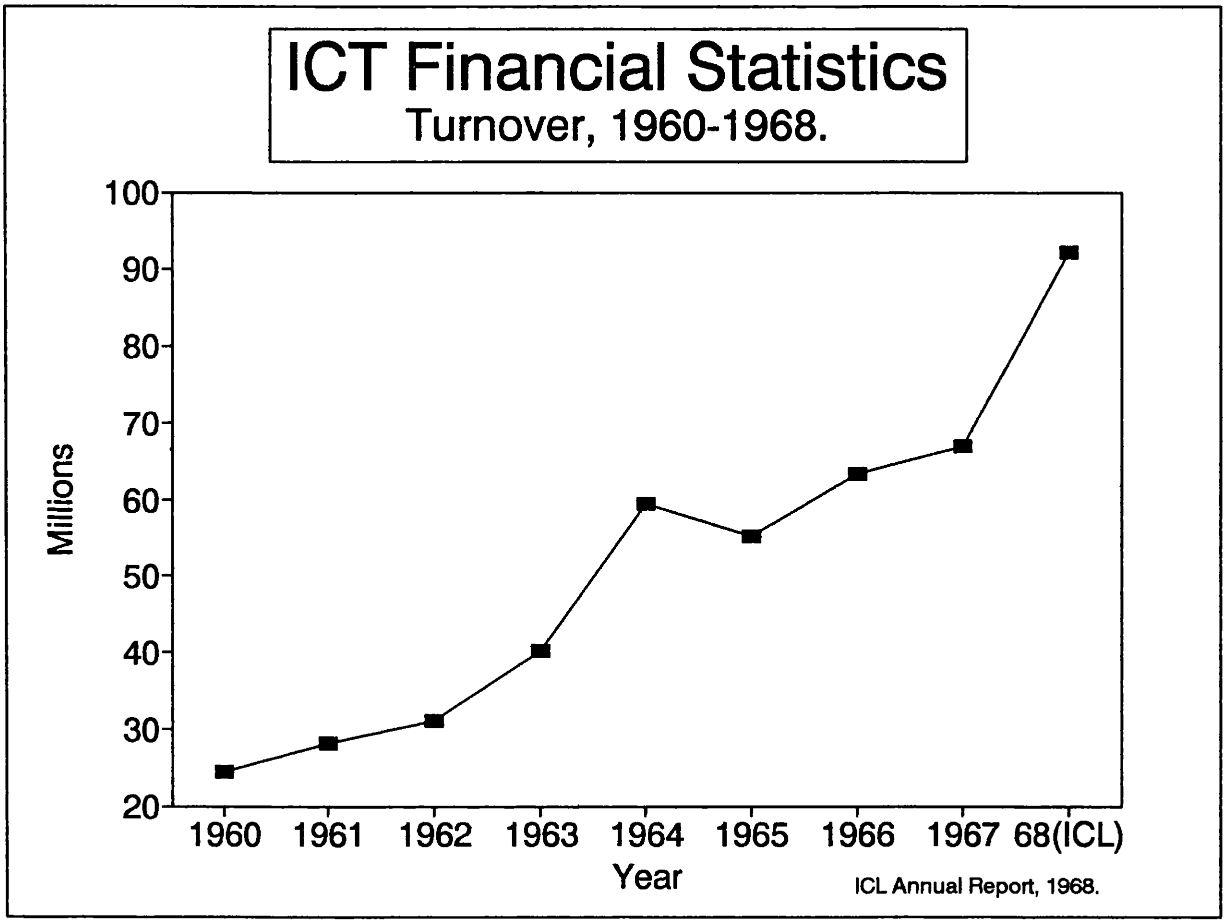
> 'The company is undergoing dramatic transition as it phases out its punch card installations in favour of the low end of its 1900 series of compatible computers.'[90]

Before the success of the 1900 could show through in profits, the company had some bad financial results. In 1965 the trading profit collapsed and did not cover ICT's increasing interest burden: pre-tax loss was £509,000 on a reduced turnover of £55,250,000[91]. Figures 5.2 to 5.4 give the financial statistics for the short life of ICT:

[90]CBI Archive, ONR, 'The British Computer Scene, ptII'.

[91]ICL annual report, 'Review by the chairman', 1968.

Figure 5.2



ICT Financial Statistics
Turnover, 1960-1968.
Millions
100
90
80
70
60
50
40
30
20
1960
1961
1962
1963
1964
1965
1966
1967
68(ICL)
Year
ICL Annual Report, 1968.

Figure 5.3

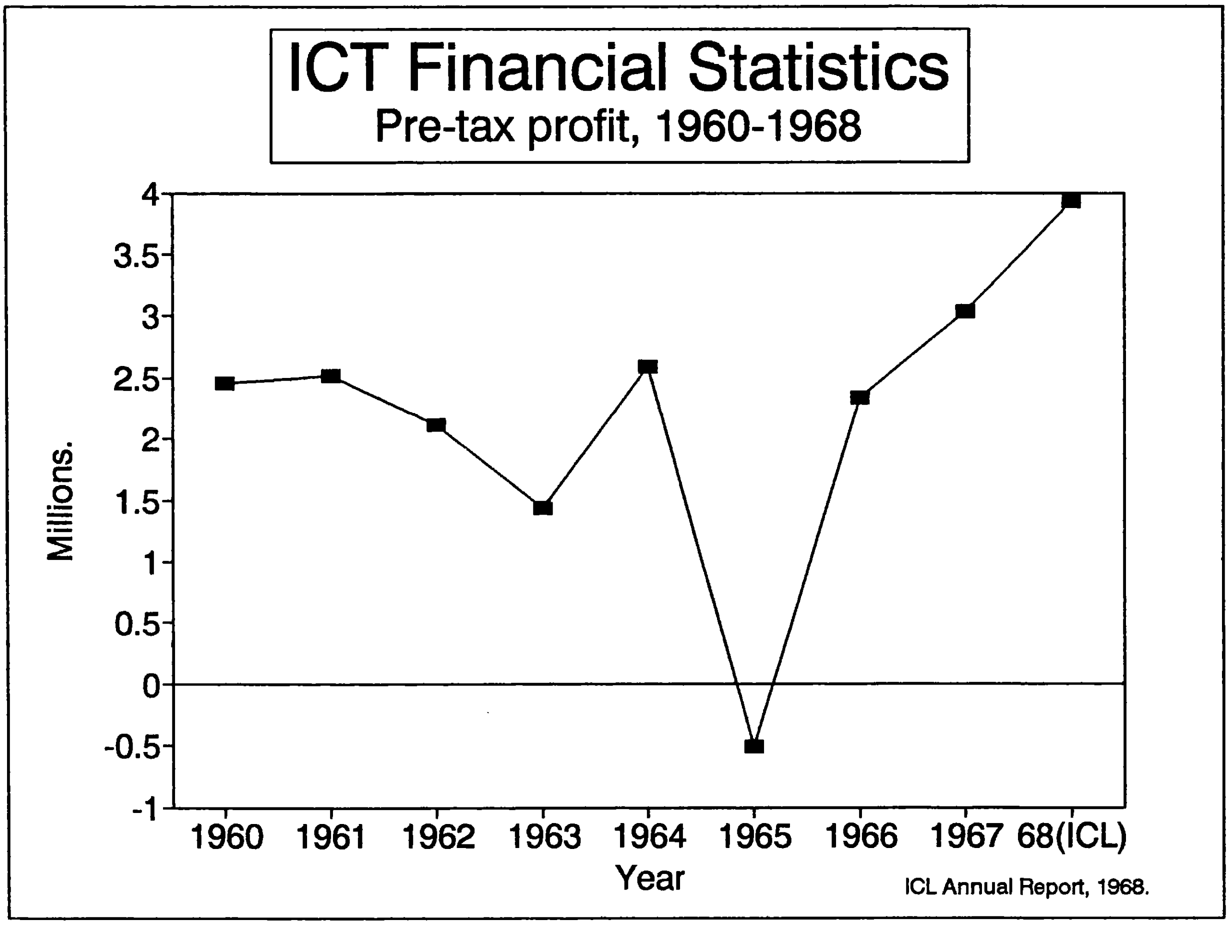
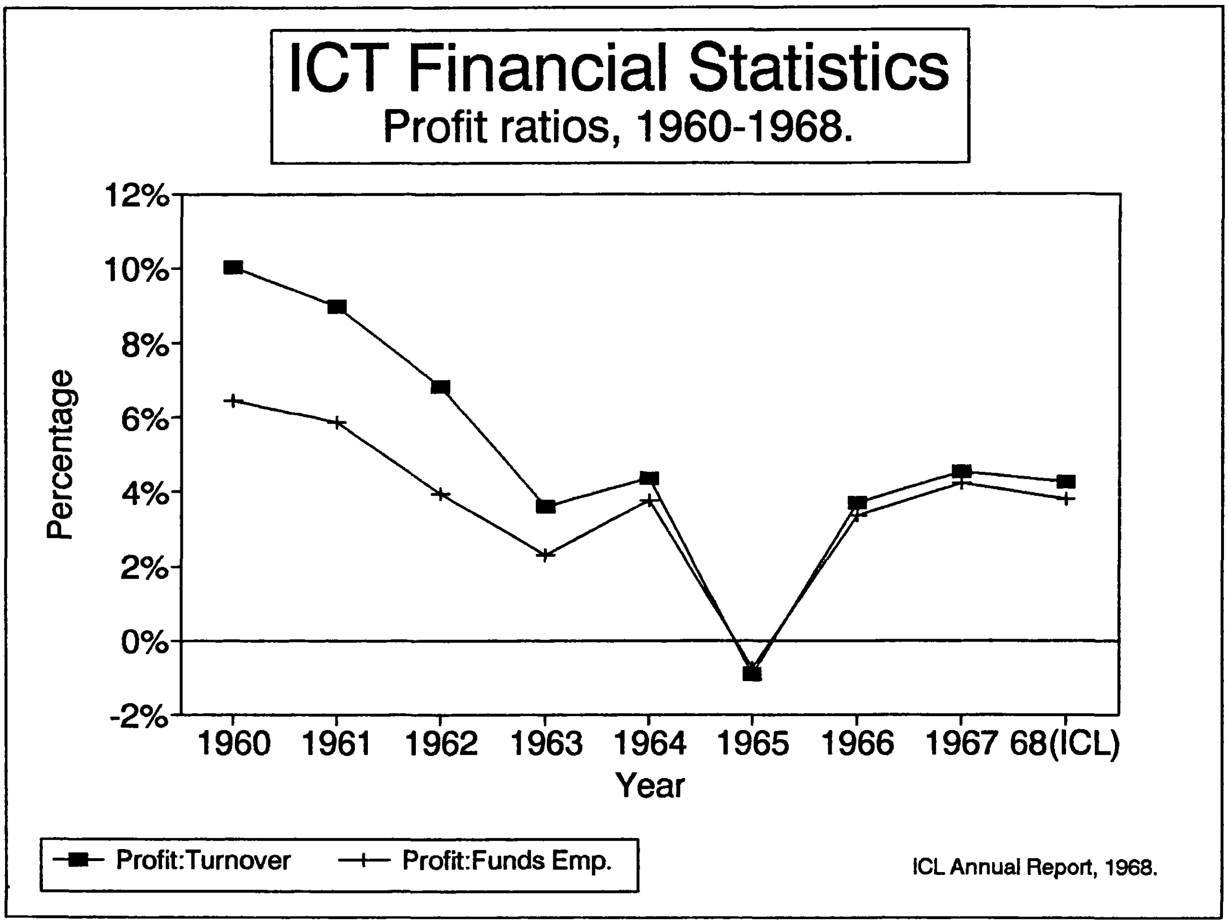

ICT Financial Statistics
Pre-tax profit, 1960-1968
Millions.
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
1960 1961 1962 1963 1964 1965 1966 1967 68(ICL)
Year
ICL Annual Report, 1968.

Figure 5.4


ICT Financial Statistics
Profit ratios, 1960-1968.
12%
10%
8%
6%
4%
2%
0%
-2%
Percentage
1960
1961
1962
1963
1964
1965
1966
1967
68(ICL)
Year
Profit:Turnover
Profit:Funds Emp.
ICL Annual Report, 1968.

Much of the reason for the profit down-turn was the cost of growth, as outlined by the chairman, Sir Cecil Mead:

> 'firstly, the expensive preparation needed for the successful marketing of the company's new 1900 Series computer; secondly a significant loss in the planned output of punch card and ancillary equipment, due to difficulties encountered in the change-over of production facilities to computer manufacture; and thirdly, the considerable fall in revenue (the UK total was down from £43.9m to £36.7m) that resulted both from the falling away of deliveries of earlier types of computers, and from the inevitable lag in getting started an adequate flow of deliveries of the 1900 Series.'[92]

However, ICT also suffered from a familiar problem in the industry - tabulators were being sent back. Customers were ordering computers to replace punched cards. Leased tabulators, which had been giving a steady stream of income, came back to the factory to be replaced by leased computers, with all the initial capital costs of the computer being borne by the supplier. It then took a number of years for the income from the leases to match the capital outlay for the growing number of machines. It was this problem that led to the formation of Computer Leasing Ltd, a leasing finance company backed by city financial interests. This company bought ICT computers, leased them out, and repaid investors at a few percent above base rate; ICT received the remainder[93]. The aim was to reduce the financial strain of leasing computers on ICT itself.

Another problem was that in the early 1960s ICT had built up facilities to produce punched card equipment. However, demand for tabulators collapsed as the computer boomed: the smaller market for these machines could be covered by simply overhauling returned punched card systems[94]. These facilities had to be converted to computer production.

Coping with crisis - government support for R&D.

The 1900 was being accepted well in the market place. The real problem was coping with the cost of this success and ensuring that future growth was not curtailed by the expense of introducing the 1900 series. ICT took a number of steps to improve cash flow, such as raising rental prices, selling assets and cutting staff and other costs[95], but the government stepped in to help ICT maintain its R&D programme when cost cutting

[92] Investors Review, 8/1/66, p11, report of Cecil Mead's chairman's statement.

[93] Campbell-Kelly, ICL, pp220-221.

[94] Campbell-Kelly, ICL, pp249-252.

[95] Campbell-Kelly, ICL, pp252-255.

threatened it.

In the period 1963-1965 there was considerable debate within the NRDC as to how to support the industry. This debate was sparked by the announcement of the IBM 360. One of the first items to be filed in the NRDC folder marked 'the UK computer debate' was an article from the Financial Times[96]. This noted that while ICT had previously been neck and neck with IBM terms of in new orders, in the 7-8 weeks following the launch of the 360 IBM orders had rocketed, with over 100 on the books[97].

The NRDC viewed ICT as the most important part of the UK industry, but was concerned about whether it could compete with IBM[98]. There were three main factors in ICT's situation:

1) The £10m tabulator business had grown in the 1950s but was expected to decline, becoming insignificant by 1970.
2) The Electronic Data Processing market had been zero in 1950, but was growing rapidly.
3) The data capture/peripheral sector, while not well defined at the time, was expected to grow to replace the tabulator business in size.

Crucial to ICT's future was the expected growth in the computer business. This market was expected to grow at between 15% to 20% per annum[99]. This was the crux of the problem; ICT estimated that, at most, it could hope for only 10% growth. It was predicting that its market share would fall from 40% in 1964 to 28% in 1974, allowing IBM and other US companies to become even more powerful.

The reason ICT could not grow faster than 10% per annum, in normal circumstances an admirable achievement, has already been alluded to: ICT was having problems in giving an adequate return to its investors. The argument was that, as ICT was earning only 6% on capital[100], this was not high enough to attract new investors. Therefore, it had to grow using only the £65m of capital it already had. All new finance would have to be generated internally. This limited how fast it could place new machines on

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[96]NRDC 86/35/4.

[97]Financial Times, 3/6/64, Michael Shanks, industrial editor,'Can IBM's rivals stay the pace' p14.

[98]NRDC 86/35/4, Crawley 'The UK Computer Industry with particular Reference to ICT', internal report, 22/7/64.

[99]ibid.

[100]Ibid.

to the market. ICT was telling the NRDC that it could not grow faster than 10% per annum due to its low profitability. However, the NRDC was framing an argument that ICT had to achieve growth rates of over 15% to ensure that it could reach a minimum efficient scale to maintain long term R&D without affecting its financial position. The NRDC was coming to the view that ICT was too small to match IBM's R&D expenditures. ICT's cost cutting was an attempt to compete with the lower IBM cost base, but this was at the expense of abandoning future developments. The reality of the situation was that ICT was not operating at the same cost level as IBM and was only just capable of fulfilling all the functions it had to perform to survive.

To increase the projected growth rate, the NRDC believed that ICT needed to have a larger R&D budget. ICT's spending on R&D was roughly £3m per annum[101], about £2m at Stevenage and the remaining £1m in Manchester, where the old Ferranti operation was based. However, in 1965 ICT proposed cutting long-term research to save £300,000 a year. It abandoned long range development of systems for the early 1970s, although projects to update the 1900 remained. This included the 1900 Series A with a 'modern' 8-bit data path and IC components[102]. The NRDC believed that it was critical to maintain long term research, as well as continuing work on the 1900 Series A. If this was not done then the company would not have a product for the 1970s[103].

Following discussions between Basil de Ferranti, from ICT, and NRDC representatives[104], the organizations came up with a scheme for the NRDC to support ICT's R&D work[105]. The scheme envisaged R&D expenditure of £20m, spread over four years, the NRDC was to provide one quarter of this:

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[101]Ibid.

[102]US vs IBM px2482, IBM 'Competitive Manufacturers', Sept 1969; Campbell-Kelly, ICL, p253.

[103]NRDC 86/35/4, 'The UK computer market with particular reference to ICT'.

[104]NRDC 86/35/4, internal undated memo probably by Crawley, 'UK Computer Industry-Possible arrangements between NRDC and ICT'.

[105]NRDC 86/35/4 'NRDC Support' a paper submitted to the ICT Executive Committee 16/2/65, and submitted to the NRDC as a proposal for support.

Table 5.2 NRDC support for ICT's R&D.

£m	64/5	65/6	66/7	67/8	total
NRDC Funds	1	1.5	1.5	1	5
Total R&D	3.5	4.5	5.0	5.0-5.5	

The final scheme specified that the total should in fact be £20m.

Source: NRDC 86/35/5, 'NRDC/ICT draft agreement, 13/4/65.

ICT had a list of projects it was carrying out, some of which were expected to use NRDC money:

1) Future 1900 plans:

a)A system below the 1902 to compete with the IBM 360/20 and 360/10. This became the very successful 1901. NRDC money was not earmarked for this.

b)A small scientific machine was planned, with no NRDC money.

c)The development of a prototype 1908 super computer was being considered. It was to have with four times the speed of the 1907, but full development was dependent on other Government support and specific orders.

d)The development of 'compatible and competitive peripherals' was to be sponsored by the NRDC. ICT needed to improve its peripherals, both to improve the competitiveness of the 1900 family and for sale to third parties. Sales of peripherals had been a reasonably successful part of ICT's business[106].

2) Future systems:

NRDC support was earmarked for developing a range to replace the 1900 in the 1970s.

Repayment of the £5 million loan was to start in 1969/70 and was to be linked to ICT's profit on funds employed ratio. If ICT maintained a 10% profit on funds employed for four years, the NRDC would receive £5.1m[107]. Therefore, to give the NRDC a reasonable return it was looking for a substantial improvement in ICT's profit ratios.

The NRDC money was essentially a method of supplying cheap long-term debt to ICT. The company also received help from other government

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[106]CBI Archive, ONR, The British Computer Scene, ptII.

[107]NRDC 86/35/5, 'NRDC/ICT Draft Agreement' 13/4/65.

departments. Some £700,000 was provided for long term work from the Ministry of Technology's Advanced Computer Technology Project[108]. This money was used to fund the Basic Language Machine (BLM) concept developed by ICT's J.K Iliffe. The BLM concept, combined with Professor Tom Kilburn's Manchester University MU5 development, was to form the basis of ICL's 1970s and 1980s systems, the ICL 2900[109]. In the 1970s ICL received £40m from the government to develop the 2900[110].

MinTech initiatives also helped in other ways. It sponsored the Flowers Report into higher education computing which was a major catalyst in the argument for increased support for computers. Professor Flowers was the chair of the University Grants Committee's computer sub-committee, which was usually responsible for the purchase of medium scale computers[111]. Flowers came to two major conclusions. He concluded that a number of universities needed new large scale computer facilities: the current KDF9s in service were out of date. He believed the ICT 1907 might be able to fill the need[112]. His second conclusion was that a number of regional super-computer centres were needed. As there was no British super-computer available, he recommended buying a number of CDC 6600s, which was seen as a slight to British abilities.

EELM and ICT used this report to justify proposals for a joint super computer development project between themselves and the French firm CITEC. It also led to increased spending on university computer facilities, and later was used in ICT's arguments that sponsorship should be provided for its 1908 large computer project. However, the report also underlined how far the UK had fallen behind in super-computers.

None of the various super-computer projects came to anything, but the proposal for a National Computer Centre (together with a number of regional centres) outside traditional higher educational facilities was accepted. The National Computer Centre was established in 1965[113], providing a service for scientific computer users and helping to disseminate computer

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[108]CBI Archive, ONR, The British Computer Scene, ptII.

[109]Campbell-Kelly, ICL, p247.

[110]CBI Oral History Collection, Humphreys interview.

[111]NRDC 86/35/5, Kevin Willis internal NRDC memo concerning a meeting with Prof B.H. Flowers and Sir Wilis Jackson of the UGC, 22/3/65.

[112]ibid.

[113]CBI Archive, ONR, 'The British Computer Scene, Part III, The Regional and National Computing Centres'.

knowledge.

Flowers was not the only person to raise concern on the use and availability of computers in the UK. Professor Blackett, an NRDC board member, prepared a report on the use of computers by various governments[114]. He found that by 1964, 1565 computers were being used by the US government[115], and the French state used 111. The UK lagged behind: in a House of Lords debate on 8th April 1963, Lord Blakenham stated that the British authorities used 88 computers, 81 of which were domestically produced[116]. However, the list of machines included some very limited systems such as the Powers PCC calculator.

One of the NRDC's advisors, Professor Gill, came to the conclusion that a 'National Computer Authority' was needed. It would have a dual role, firstly to direct and supply R&D support, and secondly to act as an information source and purchasing agency for government departments. While this did not come about, a Computer Advisory Unit was set up to help Government departments to adopt computer techniques. It also provided information and evaluations of computers, with a strong emphasis on British machines. The agency in charge of purchasing computers, the Treasury Support Unit, also started to favour British systems[117]. This became an overt policy of preferential treatment for ICL computers. IBM estimated that under Civil Service Department rules, IBM tenders for computer contracts had to be 25% better than ICL bids to stand a chance of winning[118].

The final piecemeal method of supporting the data processing industry was the provision of tax breaks on the purchase of equipment. This amounted to an extra 20% tax rebate on computer equipment. Purchasers of computers

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[114]NRDC 86/35/4, Prof. Patrick Blackett, 19/5/64. Blackett prepared this report after receiving a memo on the subject from Prof. Gill, a long time advisor to the NRDC.

[115]More statistics on the use of computers by the US government appear in chapter 9.

[116]NRDC 86/35/5, Prof. Patrick Blackett memo, 19/5/64.

[117]NRDC 86/35/5, internal memo by Crawley on a meeting at the Ministry of Technology, 29/1/65.

[118]E.R. Nixon, M.D. IBM UK, Select Committee on Science and Technology (sub-committee A), Session 1970-71, <u>The prospects for the United Kingdom Computer Industry in the 1970's</u> Vol 2; Minutes of Evidence [HC621-II] Q.349.

received a 40% grant, rather than the normal investment grant of 20%[119]. This was something that the industry had wanted for a number of years[120].

ICT fully utilised all the support it could get from government while it was establishing the large 1900 user base. The costs of supporting a growing user base were, on occasion, fatal for a computer operation[121], ICT ensured that it cushioned the extra expense by employing any government grants that it could find.

Changes in organisation and controlling costs.

Not surprisingly ICT's organisation differed from that of the multi-product electronics companies that are the main focus of this study. ICT's structure reflected the single market place in which it operated, with an organisation based on functional divisions. It did however toy with the IBM formula of partial decentralisation by splitting the product line in half, according to system sizes, and using this to create separate profit centres. This was a short lived exercise. Of all the companies and divisions that went into the formation of ICL, BTM seems to have been the dominant one. BTM had been organised into functional divisions and with a geographically arranged sales operation. There was, however, some division between the tabulator and computer operations[122].

With the takeover of the Ferranti, GEC and EMI operations, and with the growing importance of computers, ICT made a move to decentralise, forming two design and production groups. Based in Stevenage was the Data Processing Equipment Group[123]. This division:

> 'deals with the development and production of the smaller computers, of tabulators and all punch card ancillary equipment, and of peripheral equipment for all computers'.[124]

The second new unit was the Computer Equipment Group:

> 'Our Computer Equipment Group, at West Gorton, Manchester, and also at Bracknell, Berkshire, deals with the development and production of the larger computer systems, such as Atlas, Orion and

[119]Eric Moonman, British Computers and Industrial Innovation; The implications of the Parliamentary Select Committee. 1971, p1.

[120]Campbell-Kelly, ICL, p247.

[121]See below, chapter 6 on RCA.

[122]NRDC 86/44/3, 'Notes on sales promotion and applications of computers', 11/7/55.

[123]ICT Annual Report, 1964.

[124]ibid.

the bigger systems in the 1900 Series.'[125]

The latter was basically the old Ferranti division. Though this represented a major decentralization, it was done with the 1900 architecture as the chosen design for both operations. This resembled IBM's structure with the General Processing Division producing smaller 360s and peripherals, and Computer Systems Division producing larger scale computers. The marketing operation was maintained as a separate functional unit:

Fig 5.5

Managing Director
B.Z. Ferranti

Data Processing Equipment Group	Computer Equipment Group	Marketing
E.C.H. Organ	P.D. Hall	A.L.C. Humphreys

Source: ICT annual report 1964.

Ferranti's influence was large, with both B.Z. Ferranti and P.D. Hall having come from Ferranti. Hall had been the last general manager of Ferranti's computer department, so was a natural choice as the head of CEG. Ferranti was also the second largest shareholder with 10.3% of ordinary shares. Basil was Ferranti's representative on the board of ICT. The largest shareholder was Vickers with 23.6%.

However, decentralization was not a success for the company. During the financial crisis of the mid-1960s, one of the non-executive directors, Sir Anthony Burney, was asked to make recommendations[126]. He recommended the cutting of R&D and selling assets. He also criticized Basil Ferranti for allowing decentralization to go so far as to lose control of expenditure. This led to the re-establishment of a single control over the R&D and production operations. Basil was forced out and long time company employee Echo Organ was placed in charge[127].

The experiment with reorganisation was a failure. While it aped the successful IBM structure it was incongruous given ICT's smaller scale. IBM's partially decentralised divisions were huge compared to the whole of

[125] ibid

[126] Campbell-Kelly, ICL, pp251-252. Burney was a partner in the accountants Binder Hamlyn.

[127] ICL annual report, 1967.

ICT, and in any case they were strictly controlled[128]. Rather like the situation at Ferranti when there were computer operations in both Manchester and London, coordination seems to have been incomplete and costs were not kept under control.

ICT compared to the electronics companies.

The main focus of this case study is to show the reasons why ICT, rather than an electronics firm, came to dominate the British industry (the ICL merger is covered in the EE chapter).

The business machines firms clearly started from a different point from any of the British or American electronics companies. The drive into computers was led by changing demand within its usual market place: it was a matter of survival rather than diversification. In some respects the ICT history is similar to the experience of US business machines companies, especially at the point of entering the manufacture of computers. Like its US counterparts, acquiring the right skills was all important; ICT did this by taking-over the computer departments of the electronics companies. In the US, business machines companies acquired the small entrepreneurial firms that started building computers in the 1950s[129]. The only exception to this was IBM, which grew internally by building on its experience of incorporating electronics into its tabulating machines.

What is different is the higher level of direct government intervention surrounding the ICT history. In the US the government's role was limited to purchasing systems[130], though on a vast scale. In the UK it was deemed necessary to intervene in the fastest growing industry in the world to ensure that Britain maintained a foothold in this strategically important technology. ICT received an important contribution from the state.

ICT's R&D figures seem small compared to the figures that are bandied about for IBM. Thomas Watson Jnr, who inherited control of IBM from his father, estimated that it spent $750 million on the engineering of the 360 Series and up to $4.5bn was spent on all the costs of introducing the family[131]. However, when comparing ICT's spending on the 1900 with say RCA's expenditure on the Spectra 70, it does not seem to have been so far

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[128]See below, chapter 8, pp320-325.

[129]See below, chapter 8, sections on NCR, and Burroughs pp330-350.

[130]See below chapter 9, pp349-401.

[131]Thomas J. Watson Jnr and Perter Petre, Father Son and Co-my life at IBM and beyond, 1990, p347.

out of line[132]. During the development of the Spectra, in the mid-1960s, RCA was spending around $15m per annum on engineering[133]; in some years it was much less than this[134]. ICT, supported by the government, could at least match these kind of expenditures. ICT had also taken steps to reduce the number of areas in which it had to spend development money[135], so it did not have to spread its development funds as thinly as the electronics companies did.

Government support was vital in allowing ICT to continue long range development while maintaining a reasonable earnings to-equity-ratio. It must also be said that the support was targeted at long term projects which did actually lead to commercial products. MinTech backing for the Advanced Computer Technology Project (ACTP) led to ICT's BLM development, and this, together with Manchester University's MU 5, was used as the base for the ICL 2900 series. After the merger, ICL continued to need government assistance: at the time it received £17m of government funds for further development work. The government's involvement in the merger also enabled ICL to get £18m from the Plessey company. These funds were essential to ICL[136]. To maintain growth the firm needed funds to place more leased machines onto the market and to pay for further developments. Eventually another £40m of government funding was found for the launch of the 2900 series of computers in the 1970s.

ICT's problems were financial rather than technical; indeed it has been seen that ICT was willing to buy technology elsewhere if it considered itself not up to the task. The time of crisis was the period when a new generation of systems was introduced. ICT/L seems to have always needed financial assistance to cope with the financial strain of introducing new ranges. The government deemed it necessary to step in as it thought that ICT was unable to find enough funds to cope with the cash flow problems of carrying out R&D and marketing a new system, as well as funding leases. Likewise, in the US it was this problem that forced the electronics firms out of the market.

One great advantage ICT/L had was that it was seen as the UK's

[132]At the 1967 pre-devaluation rate of $2.80.

[133]US vs IBM, McCollister tr9634, McCollister was RCA's Computer Systems Division's vice president of marketing.

[134]See below, chapter 6, table 6.5, p234.

[135]See below, pp180-191.

[136]CBI oral history collection, Humphreys interview.

premier computer company. As such it was to some degree protected. For many buyers, especially in government, ICT/L received sympathetic treatment when buying machines. It is seen below that firms such as Burroughs and NCR exploited their established user bases in niche markets to build their computer businesses[137]. For ICT the UK was its niche, since around 40% of the UK market would stay loyal to the British producer, a base from which ICL could compete with American producers.

ICT had to make the transition from punched card technology to computers as the latter superseded the former. ICT was more capable of dealing with the vagaries of the commercial computer market than the electronics companies. ICT had long dealt with the needs of commercial data processing customers. ICT also had an established user base, a group of clients which it was able to upgrade to computers. It also meant that ICT had an established sales force, an expensive organisation for the electronics firms to build up, and an area they had little experience of.

The concentration of the firm on a single market was the major difference from the electronics corporations. Apart from some partial attempts at decentralisation, the company was focused from top to bottom on a single function. ICT was not tempted to go too far down the path of vertical integration, even when it was directly relevant to manufacturing computers. All funds were focused on producing systems and their software. Components were bought from outside: Ferranti and later others supplied ICT's basic components, Plessey provided memory in the 1960s and early 70s and CDC made ICT's disc drives. ICT thus did not have the expense of developing the full paraphernalia of electronic systems and could concentrate resources on developing computers. Electronics firms had the opposite attitude. They would develop new components, such as ICs, and then exploit them in end products. Electronics firms tried to develop and supply as much as possible from internal sources, bearing multiple costs at once. The conflict this could cause within the electronics company is best described in the RCA and GE chapters[138]. ICT recognised that technology was only part of the competitive mix in the computer industry. Unlike EE, when it came to the third generation of computing, ICT recognised that component technology was much less important than having a well thought out product that it could produce rapidly. ICT did not hold back its third generation systems to wait for ICs to become available, it wanted to offer an intra-compatible range of systems as soon as it could. EE, and its

[137] Chapter 8, pp330-350.

[138] See below, chapters 6 and 7.

American counterpart RCA, put a great emphasis on the core component technology and less on the system and software design.

The different approaches of the electronics and business machines firms had, we have seen, been noted by the manager of Ferranti's Computer Department soon after he left Ferranti and joined Burroughs. Writing in Datamation[139], he noted the focus of business machines firms on computers, as compared to the side line that they were in Ferranti and other electronics firms. He also noted that the US business machines firms were not over-worried about producing every nut and bolt of the machine. They supplied a system, but many components and sub-systems were supplied from outside, if they were better and cheaper. It appears that these lessons had been learnt by ICT, and it benefited from the focus of effort in a similar way to the US firms. ICT/L certainly seemed more market-aware, and had a greater desire to remain in the industry, than the British electronics firms. Looking at both the UK and the US case studies in this thesis, it is far from surprising that it was the business machine firm that ended up dominating the one British mainframe computer manufacturer to survive in the 1970s market.

Yet ICT/L failed to survive without government support. It may have suffered from a certain burden imposed on it by its role as the state-supported computer flagship. There seems to have been an expectation that the UK's flagship should cover the whole market for computers. While it has been said that ICT was concentrating on computers, this was still a broader market than many of the smaller American companies tackled. Similar sized US firms concentrated on even smaller niches than just the computer industry. NCR concentrated on the retail and banking industries, Burroughs' main market was its traditional banking clientele.

Having portrayed the British business machines industry as more in-tune with, and better able to cope with, the complex EDP market, it could be argued that Lord Halsbury was correct in the early 1950s to try to get business machines firms to take a leading role in the computer industry. However, this would have been at the expense of Britain foregoing, even more than was the case, one of the great advantages the USA had: the innovation engendered by having a number of competitive domestic companies feeding from each others' ideas[140]. In any case, BTM and Powers-Samas were both somewhat lacklustre compared to their old American licensors, and

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[139]Brian Pollard, 'A comparison of computer industries in the US and the UK', Datamation, May/June 1960, pp51-52.

[140]M. Porter, The competitive advantage of nations, 1989. Porter has pointed to such issues in the make up of a country's competitive advantage.

were not much of a base on which to build a successful computer industry. The alternative of building an industry based on the electronics firms, was equally unlikely given the lack of success that these firms had. Taking this point of view, it seems that the industrial assets that the UK entered the computer industry with were considerably less suited to exploiting the computer innovation than the US industrial base.

The following chapters on the American industry further explore the weaknesses of the electronics firms in the computer industry and the greater focus and market awareness of the business machines firms.

Part II.

Electronics firms in the United States computer market.

The British electronics firms failed to maintain a presence in the computer industry. It could be speculated that this was because the British industry as a whole was small and weak compared to the huge US market, leaving room for just one domestic producer. While there maybe a case for this, we also have to consider whether the weakness was instead with the electronics companies themselves. When comparing what happened in Britain with the course of events in America, it is striking that, here too, the electronics industry showed little ability to compete successfully with the business machines industry.

The following case studies of the Radio Corporation of America and General Electric show that, as in the UK, the computer activities of the electronics firms did not perform well and were marginalised. Using the evidence and transcripts of the anti-trust case US vs IBM, it can be seen just how difficult it was for such a firm to orientate itself to the commercial data processing market.

RCA and GE survived longer in the larger US market than did the British firms, but they still could not establish themselves as successful competitors and both abandoned their computer divisions. This was despite the fact that they were two of the largest companies in the world, dwarfing the business machines firms. The huge technical and financial resources available to these firms did not enable them to secure a significant market position.

As in Britain, the American industry became dominated by business machines firms. However, they were more successful than their British counterpart, ICT. In the US there were also a number start-up companies that also performed well in the computer market, and it will also be seen that one electronics firm, Honeywell, also managed to survive. All these firms were focused and committed to this new technology, a major contrast to the diversification policies of the multi-product electronics corporations. Chapter 8 shows the distinct contrast of style exhibited by the American business machines firms.

The much greater depth of internal information available on the US electronics companies allows fuller study of the problems of resource allocation within firms that were concentrically diversified. It also shows just how difficult it was for these firms to capture the non-technical skills needed to be successful in the business machines market. While they had many advantages on the technology side, it will be seen that these became less important as the industry developed, it is also clear that they were less able to tailor product and market strategies that were both in-tune with the market and with the state of finances of the company.

The US studies are able to expand on the weaknesses found in the British chapters, which showed problems of funding multiple growth paths and difficulties with producing appropriate strategies for success within the business machines market.

Chapter 6.

RCA and the Electronic Data Processing Business.

Early RCA.

RCA's roots were back in the early telecommunications market. It started life as the American Marconi Company[1], the US subsidiary of the world's leading telecommunications company, Marconi. During and after the First World War the US government, especially the US Navy, started to put pressure on Marconi to sell its American operations[2]. Marconi was seen as having a monopolistic hold over radio communications, a situation made worse by its foreign ownership. Under this government pressure Marconi was forced to sell its American subsidiary to a US consortium led by General Electric. The US government encouraged further consolidation of the radio industry, leading to the assets of GE, Westinghouse and AT&T being pooled to form RCA. This meant that the USA had a firm that had control over all the patents needed to produce every aspect of radio equipment.

Initially the firm was little more than the embodiment of a cartel. Much of the capital equipment it used, and all the consumer sets it sold, were produced by GE and the other shareholders. The National Broadcasting Company and the marine communications network were the main operations that it controlled. However, during the 1920s and 1930s RCA became more independent. There were two reasons for this. Firstly the 'radio ring' risked coming under anti-trust scrutiny. Secondly RCA became annoyed with the sluggishness of the producer companies to make consumer sets that were in line with market demand, as well as having to give its suppliers a 20% margin on all the sets it sold[3]. In 1929 it acquired the consumer electronics company, Victor[4], to which it added the vacuum tube operations of GE and Westinghouse to form the RCA Victor Company and RCA Radiotron. At this stage the company became independent. It was the supplier of the

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[1]M. Graham, RCA and the Video Disc; the business of research, Cambridge, Mass. 1986, p33; R. Sobel, RCA, New York, 1986, p21; J.C. Warner (Vice President, Radiotron Division, RCA Manufacturing Company Inc., 1934-1938), 'A history of Radio Corporation of America-the years to 1938', RCA Engineer, August/September 1957, pp3-9.

[2]General J.G. Harbord, 'Radio in the World War and the organisation of an American-owned transoceanic radio service', The Radio Industry; the story of its development as told by leaders of the industry to the students of the graduate school of Business Administration, George F. Baker Foundation, Harvard University, 1928, pp67-96.

[3]Graham, RCA and the video disc, p39.

[4]Ibid, p43.

largest public broadcasting system, NBC, had an international telecommunications business, and was now a vertically integrated electronics company: within a few years electronics was to account for the majority of its activities.

There are three aspects of RCA's early history that are particularly important, all of which are linked. Firstly the company's growth was guided by one central character, General[5] David Sarnoff. As in so many companies, this central autocrat reinforced the formal organisation of the firm with the strength of his authority. Sarnoff ensured that research had a central role in the company:

> 'We have patents granted by the United States Government for engineering and electrical developments in radio development; we exercise the property rights inherent in these patents; we are soundly financed. These are grievances enough for those who come to reap and not to sow, who cry monopoly but fear competition.'
>
> 'More than 1000 engineers engaged in radio research express the efforts of the Radio Corporation and its associates to develop this art and industry. Millions of dollars are spent annually by the Corporation and its associated interests in these efforts. We are, therefore, inevitably in possession of many valuable patent rights, the fruits of intensive, continuous and costly research. But we doubt whether any other corporation in the industrial history of the country, possessing patented inventions, has ever licensed so many of its competitors and at so early a stage in the development of a new art.'[6]

Later the firm's research assets were pooled into one of the world's largest laboratories, the Sarnoff Research Centre.

RCA had a crucial role as a provider of technology to the world. In the mid-1930s the company was faced with a squeeze in its domestic electronics markets, caused on the one hand by the depression, on the other by a surfeit of suppliers. It reacted by cutting back overseas operations, the idea being to sell off these operations, such as EMI and JVC, and used the monies raised to bolster the domestic operations. After this RCA no longer operated directly overseas, it was not a large exporter nor did it own many overseas operations; instead it sold technology. It used its patent ownership to earn overseas income from licences. It also sold some of its output to overseas firms to re-market. In the British case studies,

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[5]During the war Sarnoff was given the title of general in the Signal Corp.

[6]D.Sarnoff, 'The development of the radio art and radio industry since 1920', The Radio Industry; the story of its development as told by leaders of the industry to the students of the graduate school of Business Administration, George F.Baker Foundation Harvard University, Mass, 1928, p97-113.

it has already been seen that ICT resold RCA computers[7], while EE built them under licence[8]. These arrangements were not limited to the UK or to computers; this was a large trade for RCA.

Given RCA's strong technical base and the attitude of Sarnoff to public service, it is not surprising that RCA fared well out of the 1939-45 war:

> 'From a $100 million corporation in 1938, RCA soared to the billion dollar corporate rank in 1955....'[9]

<u>RCA's post-war expansion</u>.

Demand for all the company's products grew greatly after the war. NBC led the expansion of broadcast radio and television. This in turn led to big demand for the company's consumer electronics equipment. RCA and EMI had developed broadcast quality television, and it was RCA which after the war started to drive towards colour transmission. In response to a mechanical colour system under development at CBS, RCA initiated a huge development project to produce an electronic colour system[10]. This development had a major impact on RCA and on its computer operation, pulling cash away from the computer programme.

Not only were the broadcast and consumer operations in rapid growth, but so also were RCA's component and capital electronics businesses. After the war, RCA had the opportunity to sell these new developments into both the military market, especially when revived by the Korean and Cold Wars, and in the civil market.

The following graphs show RCA's growing sales (fig 6.1) and profit (fig 6.2). What is notable is that profits were less stable. Figure 6.3, which shows profit as a percentage of sales, shows two distinct troughs: both of these were associated with high development costs of some major RCA projects. The first trough, in the 1960s, caused in part by the cost of putting colour television on the market, greatly damaged the computer operation. The second, during 1969-72, led to the termination of the computer business and its sale to Sperry Rand:

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[7]See above, chapter 5., pp173-174.

[8]See above, chapter 4, pp142-143 and pp147-150.

[9]Dr Elmer W. Engstrom (senior executive VP RCA), 'A history of Radio Corporation of America; the years 1938 to 1958', <u>RCA Engineer</u>, June-July 1958, pp29-34.

[10]C. Leyton et al, <u>Ten Innovations: an international study on technological development and the use of qualified scientists and engineers in ten industries</u>, 1972, p119.

Figure 6.1

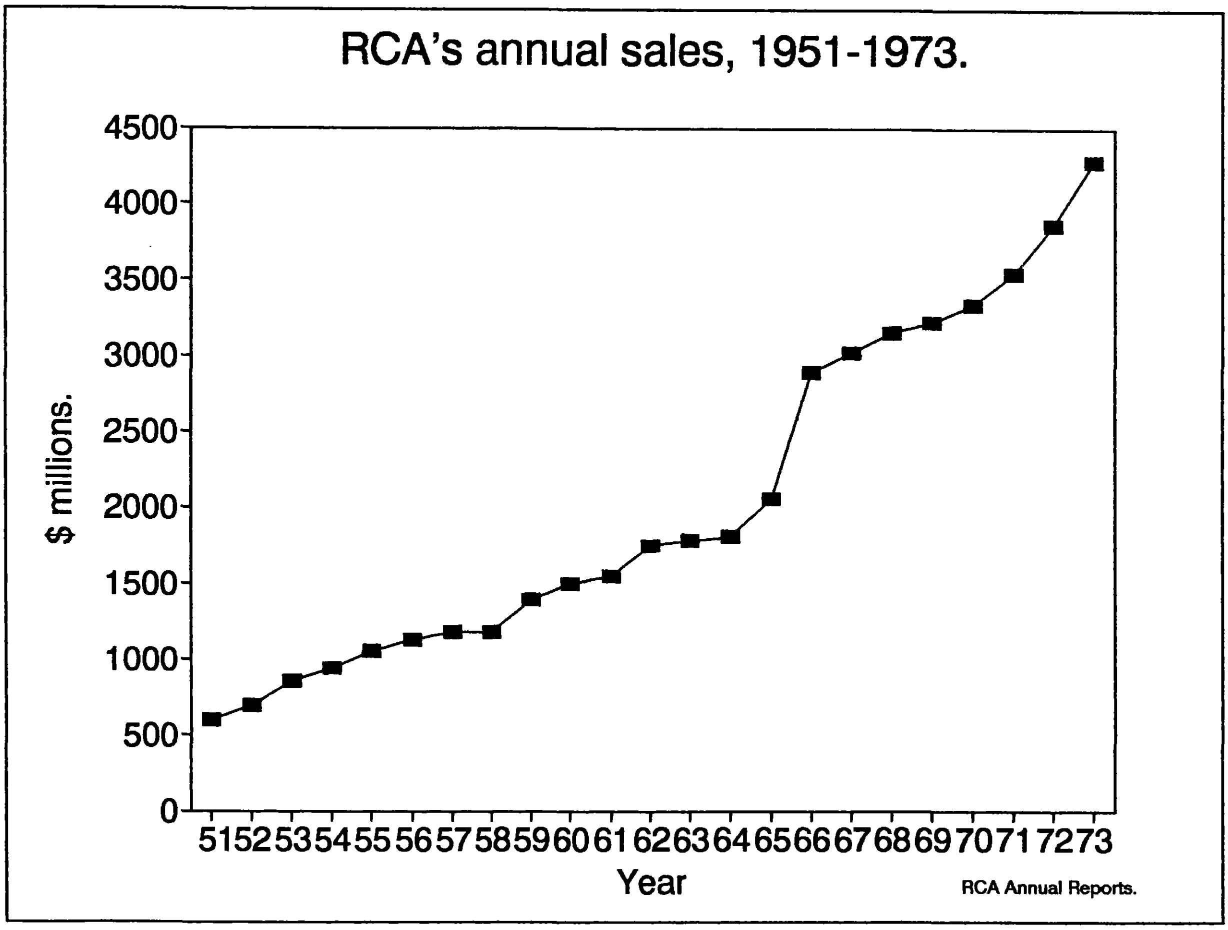

RCA's annual sales, 1951-1973.
$ millions.
4500
4000
3500
3000
2500
2000
1500
1000
500
0
51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73
Year
RCA Annual Reports.

Figure 6.2

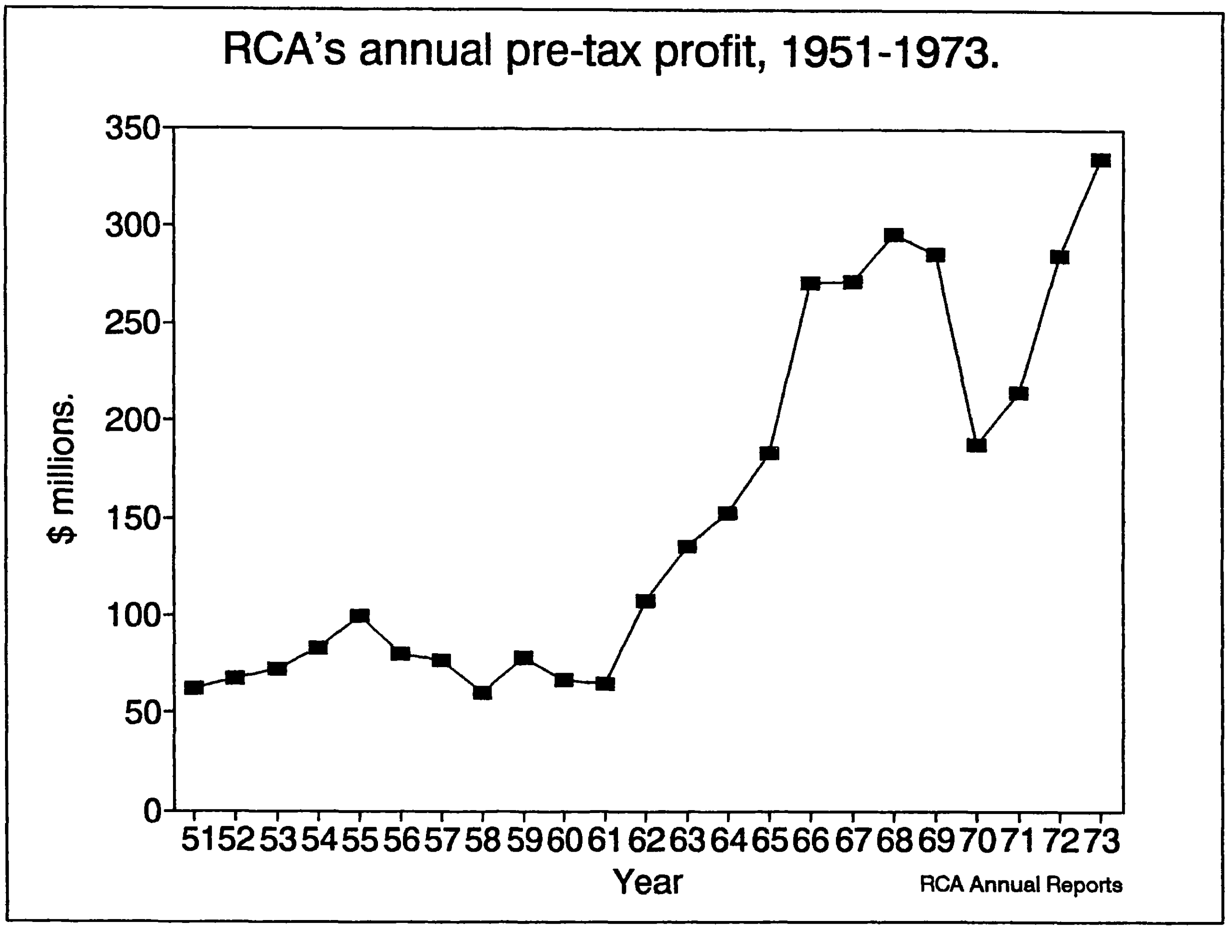
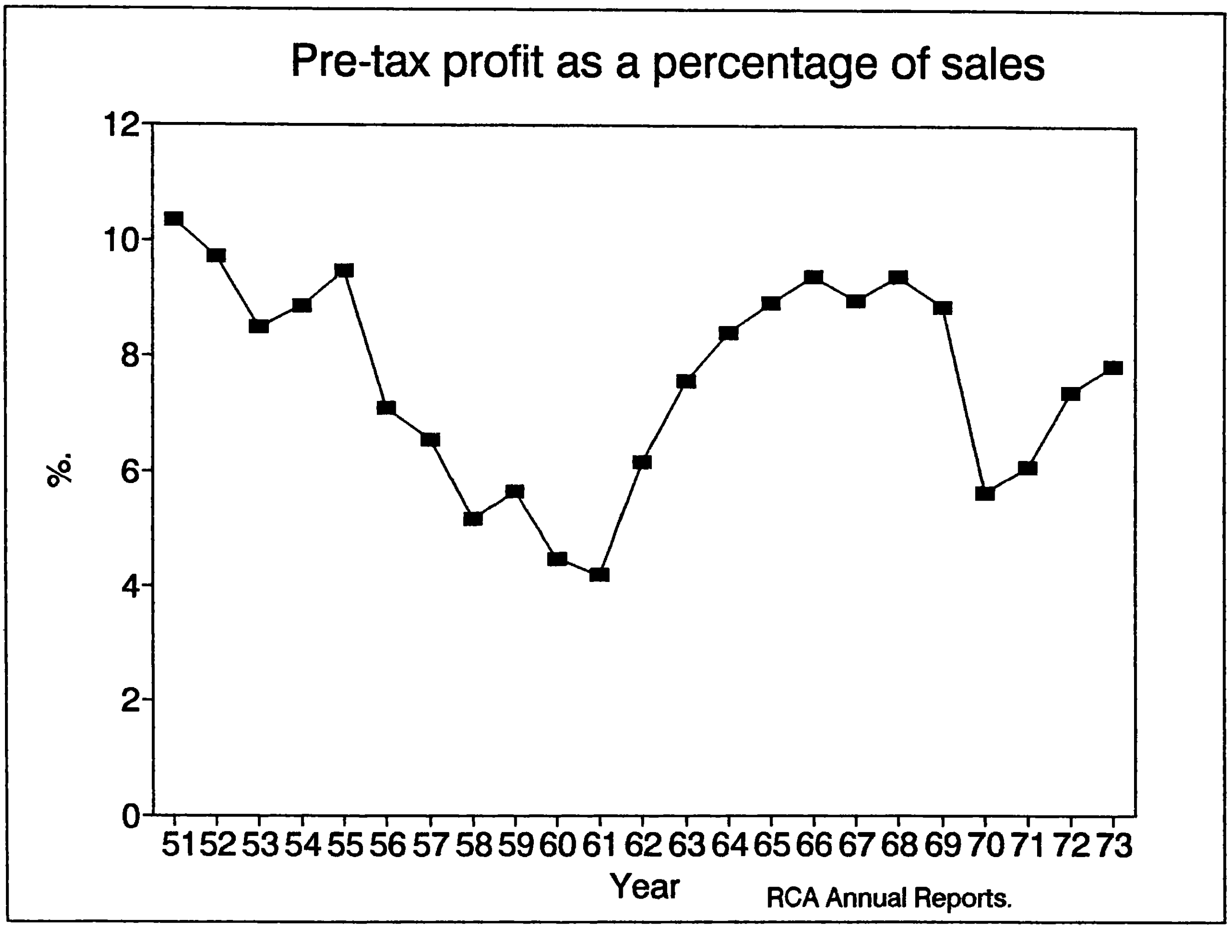

RCA's annual pre-tax profit, 1951-1973.
350
300
250
200
150
100
50
0
$ millions.
51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73
Year
RCA Annual Reports

Figure 6.3



Pre-tax profit as a percentage of sales
12
10
8
6
4
2
0
%.
51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73
Year
RCA Annual Reports.

After the war, RCA was producing an ever expanding range of electronics. In common with most companies, before the war RCA had been functionally controlled, but the pressures of growth and an ever-widening technology led to change. As outlined by RCA's own head of organisation, there were a number of problems to be coped with:

Product leadership was divided.
Coordinating a product was proving difficult.
There was a high administrative load.
Profit responsibility was difficult to delegate.
The outlook was for further growth and diversification[11].

Therefore, RCA adopted a multi-divisional, decentralised profit centre organisation:

> "Basically, the organisation changes taking place are the outcome of RCA's adoption of the philosophy of decentralizing the responsibility for operations. This philosophy may be further defined as the delegation of responsibility and authority to individuals for the profitable conduct of the business operations of integrated units within the Corporation. By integrated unit is meant one having all of its own functions, such as engineering, purchasing, manufacturing, marketing, and any others necessary to manage a particular product line or lines. Such a unit becomes the responsibility of one person"[12].

After a temporary arrangement where the whole of the electronics operation was under one organisation the company was divided into four operational groups:

Defence Electronic Products,

Commercial (later Industrial) Electronic Products,

Radio Marine Communications,

National Broadcast Company.

DEP and CEP are the most important groups in this study, it was the CEP group which controlled the Computer Systems Division.

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[11]J.L. Mastran, Administrator Organizational Planning, "How RCA Organization is Planned to Meet Changing Needs", RCA Engineer, Feb-March 1956, pp32-35.

[12]Ibid.

RCA's early computer work.

In the late 1940s and early 1950s RCA was busy, fulfilling the demand for consumer electronics, developing colour television and supplying advanced electronics for the US armed forces. RCA had only a limited involvement in the genesis of the computer. At the firm's Princeton laboratories a small team built a large analogue computer, the Typhoon[13], for US Navy aeronautical research[14], but this did not lead to further developments.

Of more importance was RCA's early work with computer storage techniques. As the leading electronics firm, RCA was consulted on potential memory techniques for a number of early computer developments, such as the Institute of Advanced Studies computer, the US Army sponsored ENIAC, and the JOHNNIAC built by the Rand Corporation[15]. For these projects, RCA developed the SELECTRON tube. This was an advanced and highly complex electron tube memory device. However, the Williams Tube from Manchester proved much simpler, cheaper, and became available much earlier. Eventually all the machines adopted other techniques, except the JOHNNIAC, a copy of the earlier IAS machine, which did use the Selectron tube. RCA produced 2000 of the tubes for various projects[16].

In the early 1950s RCA developed a second, and much more important, memory technique. This was the magnetic ferrite core which could store information in a matrix of magnetised magnetic rings. This became the standard computer memory system through to the mid-1970s[17]. There was a lot of controversy about who developed this technique as it was simultaneously developed by Jay Forrester of the Massachusetts Institute of Technology. Forrester's device was used in the SAGE air-defence project which proved to be a crucial stepping stone for IBM in its development of

[13]US v IBM, Px344A, RCA press release, 'Quarter-Century of Research is behind RCA's EDP systems', 13/4/60.

[14]US v IBM, transcript (tr) 8652. Arthur D. Beard, Chief Engineer RCA Computer Systems Division.

[15]Saul Rosen 'Electronic Computers: A historical survey' Association of Computer Manufacturers Computing Survey March 1969, p17; F.C. Gruenberger, 'The History of the JOHNNIAC', Annuals of the History of Computing, July 1979, p49

[16]Jan Rajchman (RCA Engineer), 'Early Research on Computers at RCA', A History of Computing in the Twentieth Century, N. Metropolis, J. Howlett, and G-C Rota, eds., New York, 1980, pp465-469.

[17]Ibid.

computer skills[18].

The Advanced Development Group.

In 1950 the company formed a special team of engineers, the ADG[19]. During its eight years of existence it was charged with the task of spreading the use of new digital and computer techniques to all parts of the company:

> 'At that time, in the development of RCA's Camden organization, we were the only advanced development group and we had been supporting in that activity both military and commercial type endeavours. So it was quite natural for this group to be given the responsibility of looking at digital technology for both commercial and military [uses].'[20]

During its first four years much of the ADG's effort was focused on commercial applications. From 1954 onwards it became increasingly involved in military work, eventually becoming a part of the West Coast Missile and Surface Radar Division in 1958[21].

1) ADG and the BIZMAC commercial computer.

The ADG's first project was the foundation of RCA's Computer Systems Division. In 1950 ADG started the development of the BIZMAC. This was a computer designed especially for sorting through large databases. It used the new magnetic core storage plus a random access drum memory. However, its main function was to access data held on hundreds of low cost magnetic tape drives which held the database. Photographs of the machine show that it was truly impressive. It weighed 250 tons and took up 18,000 sq.ft., almost every part of it made by RCA itself[22].

It was built under contract to the US Army's Ordnance Corps, and used for keeping control of the tank spares stores in Detroit:

> 'A contract was negotiated in 1951 with the Army Ordnance Corps for equipping one of their large supply depots (Letterkenney, Pa.) with the RCA BIZMAC electronic processing system. In 1952, the Ordnance Corps requested enlargement of the contract to cover the inventory control at one of their largest stock control points, the Ordnance Tank-Automotive Command. Delivery of the complete system

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[18]See below, chapter 8, pp313-314.

[19]US v IBM, tr8446, Beard.

[20]Ibid, tr8655.

[21]Ibid, tr8653.

[22]CBI Archive; Martin H. Weik, Second Survey of Domestic Electronic Digital Computing Systems; report No. 1010, Ballistic Research Labs, Aberdeen Proving Ground Dept of Army, June 1957.

was set for 1955.'[23]

The contract was worth $4.5m. RCA remained a major supplier of computers to the US armed forces for logistic control purposes.

In 1954 the Commercial Electronic Products Group took over responsibility for the BIZMAC and decided to sell the system on a commercial basis[24]. However the machine did not sell in great numbers: somewhere in the region of 6 were made. Users included a large mail order firm and two large personal insurance companies in New York, users with big database problems. It was dogged by problems of unreliability, not really a great surprise for such a complex first generation system. The low level of sales has led some to the conclusion that the product was a failure[25]. However, it was a large and expensive system and generated revenue of between $10-20 million during 1955-1958. It also allowed RCA to develop a working knowledge of the commercial market place.

The ADG had a staff of only 30, which was too small to cope with such a large system. The Commercial Electronic Products group formed the BIZMAC Engineering Group, consisting of 100 engineers, which took over responsibility for the system[26]. From this new group grew the Electronic Data Processing Division, later becoming the Computer Systems Division (CSD), and eventually becoming the Information Systems Group.

With the BIZMAC group continuing work on that machine the ADG was freed for other projects. It went on to develop a number of defence systems, and the follow-up to the BIZMAC, the second generation 501 system.

<u>2) ADG and military computer projects.</u>

Before looking at the rest of RCA's commercial computer operations, it is worthwhile outlining its activities in defence computers, as these directly affected the economics and organisation of the early commercial products. ADG worked on a number of minor military developments. These included a magnetic logic computer, bomb-aiming systems and encryption

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[23]J. Wesley Leas, Chief Product Engineer, Computer Engineering, Engineering Products Division, Camden N.J. 'Engineering the RCA BIZMAC System' <u>RCA Engineer</u>, Dec/Jan 1955/6, p10-21.

[24]<u>US vs IBM</u>, tr8652, Beard.

[25]<u>US v IBM</u>, tr56507-8, F.G. Withington. Withington was an industry analyst and author of A.D.Little Consultants' reports on the computer industry.

[26]J. Wesley Leas, 'Engineering the RCA BIZMAC System' <u>RCA Engineer</u>, Dec/Jan 1955/6, pp10-21.

techniques[27]. However, the most notable early work of the ADG was in the use of solid state transistorised electronics in large military systems: this ability was used by the ADG to design the 501 transistorised computer for the Commercial Electronic Products Group. In 1958 ADG abandoned its dual commercial and defence role and became solely involved in the military side of the company, the Defence Electronic Products group (DEP):

> 'There were two events which I think bore on this [the absorbtion into DEP]. One was that the Commercial Computer Group had grown considerably and was capable of doing [its] own advanced development work as well as product design. And, secondly, the Missile Group had recently won an award for the BMEWS system, which entailed a considerable amount of digital technology.'[28]

The Ballistic Missile Early Warning System (BMEWS) was one of the major strategic control mechanisms developed in the 1950s. It was probably second only to the huge Semi-Automatic Ground Environment, SAGE system[29]. BMEWS was a computer-controlled warning system covering the USA, Canada and Great Britain. As prime contractor, RCA was not only in charge of the sub-contractor's efforts, but also had to integrate all the systems into one. IBM was chosen as the supplier of the major central computer, but RCA was able to supply three computer types of its own[30]; the CDP, RADCON and DIP. They all used a common architecture and packaging. They had various roles in processing radar data, transmitting the data and then displaying the end result at the NORAD command bunker in Colorado. The IBM system used was the top of the range 7090 transistorised computer, a good opportunity for RCA to look at this machine.

Following BMEWS, RCA received another large contract, this time for a communications network for the US Air Force. This was ComLogNet[31], which was to transmit logistics information around the world. Computers for logistics work proved a staple for RCA after BIZMAC. This system used the Communication Data Processor (CDP) computer to buffer and switch high speed data transfers through microwave and high capacity cable links[32]. The

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[27]US vs IBM, tr8653-4, Beard.

[28]Ibid, tr8661.

[29]See below, chapter 8, pp313-314. SAGE had a profound effect on computer technology and on IBM in particular.

[30]US V IBM, tr8677, Beard.

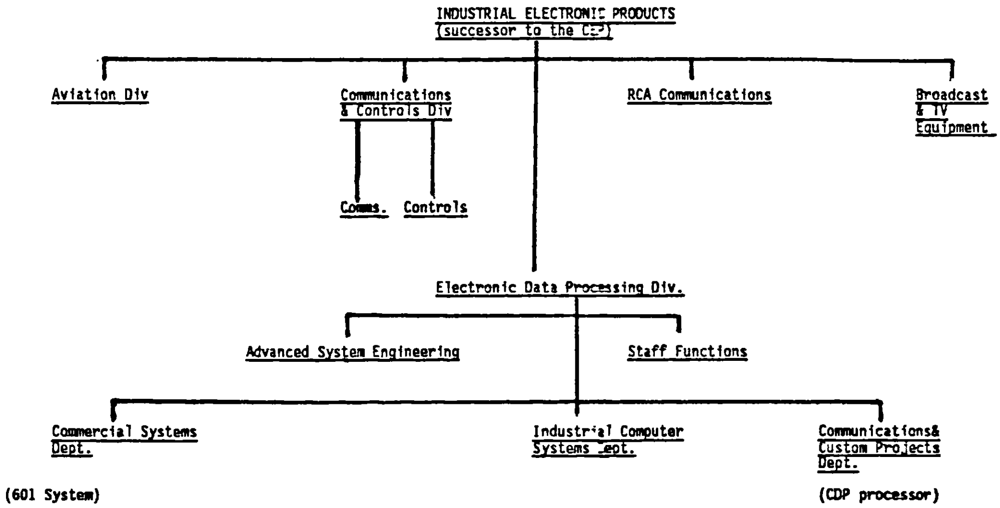
[31]Later known as Autodin 1.

[32]Robert J. Segal and Howard P. Guerber (RCA engineers), 'COmLogNet Automatic Store-and-Forward Message-Switching Centres', RCA Engineer, Feb/March 1962, pp30-33.

prime contractor was Western Union, a firm well used to such communications systems.

Initially, this project was not handled by the Defence Electronic Products Group. It was closely related to normal computer activity and was based in the commercial operation. It was expected that the CDP would be built in conjunction with the large scale 601 commercial computer being constructed by the EDP Division. However, in 1960 a separate Communications and Controls Division was formed to take over this work, see figure 6.4 below.

Fig 6.4



Source: 'IEP Effects Major Reorganization', RCA Engineer, August/Sept 1960, p38.

In 1962 the communications operation was transferred to DEP[33] and the links between the CDP and 601 systems were completely severed. It will be seen that this had a serious effect on the 601 project.

[33] US vs IBM, tr8723, Beard.

RCA and the second generation of computers.

BIZMAC was only a partial entry into the market. However, it gave RCA a chance to build up a team of engineers, and gave it a base for future work. In the second generation of computers, like its off-spring EMI, RCA made a drive to become an important player in the market.

The 501 computer.

With the BIZMAC engineering team taking over responsibility for that system, ADG was not only freed to do its defence work, but also to prepare the logical design for RCA's, first, second generation system, the 501. Design of this system was quickly assimilated into the EDP Division. There were three significant factors in the market positioning of this machine:

1) It used fully transistorized logic, building on the developments of the Semiconductor and Materials Division, which had worked on transistors for military products[34].

2) It was a purely commercial system, with little provision for scientific application. The system was one of the first to offer the business language COBOL, but it was not initially provided with the IBM FORTRAN language which was the staple language for engineering[35].

3) The system was targeted at a perceived gap in the market for medium capacity machines[36].

Figure 6.5 shows how the 501, and its derivations, was meant to fit into the market and exploit weaknesses in the IBM range. RCA hoped to exploit a gap that it perceived in the market for middle size computers:

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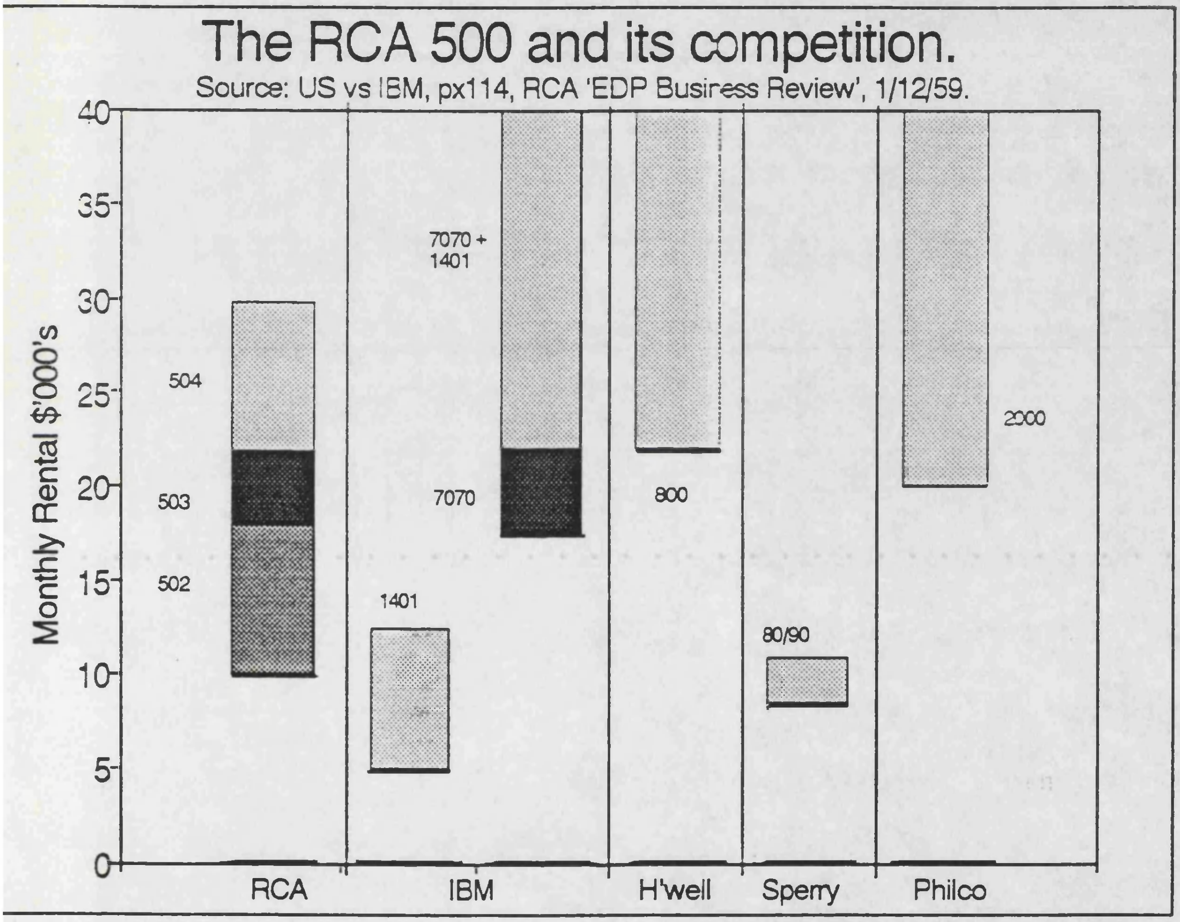
[34] H.M.Elliott, 'The RCA 501 System', RCA Engineer, Feb-March 1959, p39.

[35] US v IBM, tr9404, E.S. McCollister. McCollister was the Marketing Vice President of the Computer Systems Division.

[36] US v IBM, Px114, 'Business Review of the Electronic Data Processing Division', 1/12/59,

Figure 6.5


The RCA 500 and its competition.
Source: US vs IBM, px114, RCA 'EDP Business Review', 1/12/59.
Monthly Rental $'000's
0
5
10
15
20
25
30
35
40
504
503
502
7070 +
1401
7070
1401
800
80/90
2000
RCA
IBM
H'well
Sperry
Philco

By the time the above graph was drawn the original 501 had been renamed the 503, and had been extended upwards with the 504 and down with the 502. The 501 was RCA's real market entry, based not only on the BIZMAC experience, but also the design work of the semi-military ADG and the developments of the Semiconductor Division, again based on its military work.

The addition of the upper and lower machines announced to the trade journal Datamation, that RCA:

> 'formerly a somewhat silent member of the Solid State Computer Manufacturers' Association...have defiantly started an aggressive marketing campaign[37].

The machine was delivered quickly: one was installed internally in April 1959, and the first customer delivery was in June, to the Bureau of Weapons[38]. By November 1959 three had been delivered, twenty one were on order and fourteen letters of intent had been received. Eventually about 100 were installed[39]. Of these the military used 29[40]. Most of the military sales were used by the US Army for logistics work. Overall the marketing staff concluded that the system was competitive apart from some minor flaws in peripherals:

> 'It is my understanding that the 501 was a competitive system; that it was well designed by the standards of the time. It had architectural features which were considered to be excellent.
>
> It was somewhat weak in some of its peripheral equipment...such as the card reader and punching equipment...and the line printer, with which we had considerable trouble, but, as a central system, the 501 was considered a good design and competitive with other equipment in the market place.'[41]

The 301 success and the 601 failure.

However, the 501 could only cover the medium scale market. The firm was concerned that this would mean it would miss out on large sales elsewhere. The division estimated that both the large scale and small scale markets would grow in size:

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[37]Datamation Sept/Oct 1959 p31.

[38]US v IBM, px114, 'EDP Business Review', Dec 1959.

[39]US v IBM, px244, RCA, Computer Systems Division 'Five Year Plan', March 1965.

[40]CBI Archive, Inventory of automatic data processing equipment in the Federal Government, Bureau of the Budget, Executive Office of the President, July 1966.

[41]US v IBM, tr9543, McCollister.

Table 6.1 Future demand for computers, and RCA's projected market share.

	Large Scale Systems	Small Scale Systems
6000 firms with 100+ clerical employees	2000	4000
8000 firms with 50-99 clerical employees	-	4000
total market	2000	8000
RCA's planned share	416 (20%)	615 (8%)

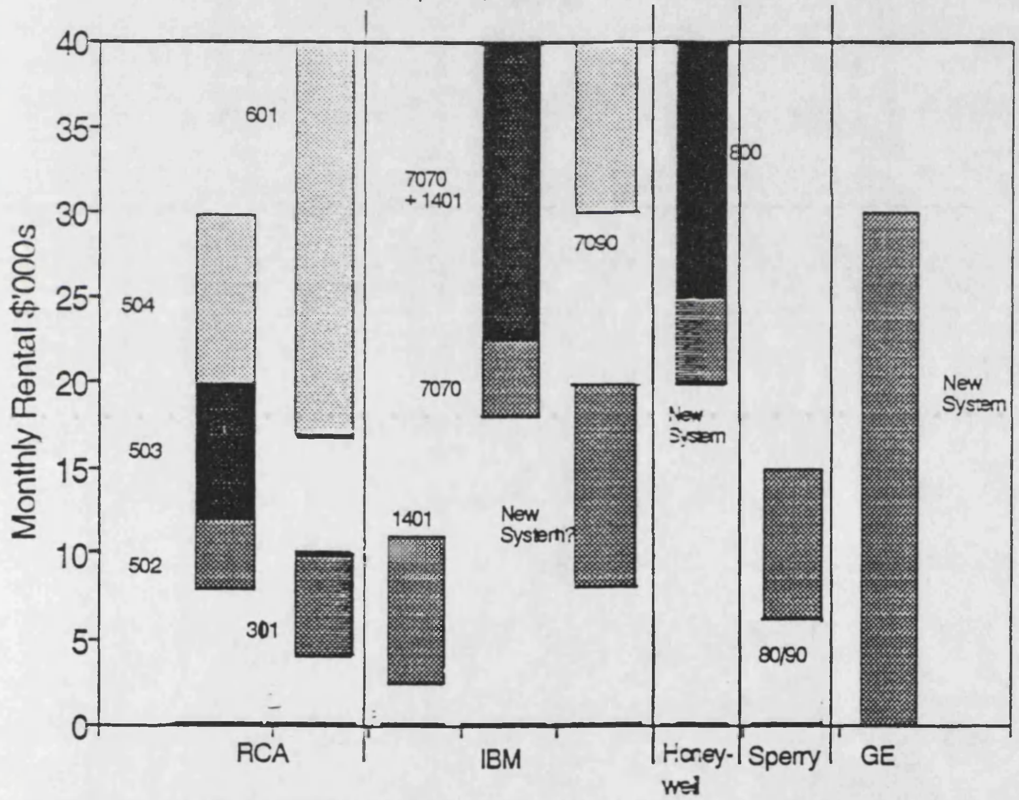
Source: US v IBM, px114, Dec 1 1959 Business Review, pp 55-56.

The division planned to cover the smaller scale market with the 301 and also to introduce the large scale 601. Figure 6.6 shows that this was expected to give RCA a very broad market coverage. It was now planning to offer computer across the broad, greatly expanding the market that the 501 series of computers had covered:

Figure 6.6

RCA systems and predicted competition.

Source: US vs IBM, px114, RCA 'EDP Business Review', 1/12/59.



Thus RCA was offering one of the most comprehensive ranges on the market, second only to IBM. The following table shows the engineering resources and marketing expenditures that were planned to support the second generation systems:

Table 6.2. Forecast Engineering and Marketing costs.

$Million	'60	'61	'62	'63	'64	'65	Total
General Engineering	9.3	9.1	8.3	8.4	8.7	9.1	52.9
Marketing	9.2	12.5	16.0	18.6	20.9	22.8	100.0

Source: US v IBM, px114, Dec 1 1959 Business Review, p53.

With these resources, RCA expected to start shipping machines quickly. However, it expected that income would lag behind expenditures. The reason for this was that, like all the other firms in the industry, RCA had to follow IBM's example and place most of its machines onto the market under leasing arrangements, so it expected to take a number of years for receipts to match the value of the systems shipped out; a profit was not expected until 1964:

Table 6.3

Financial Forecast for the Computer Division 1960-65.

$Million	'60	'61	'62	'63	'64	'65	Total
Net Value Shipped	37.8	73.9	109.3	132.2	165.7	351.2	870.1
Net Sales	12.6	47.7	55.8	78.5	114.2	196.5	505.3
Profit or Loss	-10.2	-8.2	-5.4	-1.1	8.8	24.1	8.0

Source: US v IBM, px114, Dec 1 1959 Business Review, p53.

The 301.

The 301 and 601 were announced together in April 1960[42]. The 301 was the less ambitious machine, primarily aimed at the commercial market. It was pitched in a much more price-sensitive part of the market than the larger scale 501 and 601: RCA did its best to tightly 'value engineer' the system to keep the price down. It was also in a higher volume part of the market. The firm built a new plant in Palm Beach, Florida, to produce the 301[43]. Of the $9.3m spent on engineering in 1960, the largest single item

[42] Arthur S. Kranzley, RCA Product Planning and EDP Methods Department manager, 'Planning the RCA 601 System', Datamation, Sept/Oct 1960, p30.

[43] H.M. Elliott, manager of engineering, 'RCA and Commercial Computer Systems', RCA Engineer, Dec60-Jan61, pp5-7.

was the development of the 301. As tables 6.2 and 6.3 showed, RCA committed itself to a large marketing campaign and a policy of accepting large losses on its computer operations, so as to establish the 301's market share. By doing this it was hoped that the installed 301s would bring in good rental revenues in the future.

Nevertheless, the company took steps to ensure that it did not spend too much on the 301 project. It learnt from the problems that it had encountered with the peripherals on the 501 system and contracted third party companies to supply peripherals, especially punched card equipment and printers. There was a secondary reason for this. RCA was competing for an order in excess of 30 machines to be used at USAF bases for logistics work, probably connected to the ComLogNet programme. To use the existing USAF data, IBM compatible punched card peripherals were needed[44]. Initially these were obtained from IBM; later ICT and Bull provided punched card equipment. Printers came from Anelex and optical character readers, for cheque processing etc, from Farrington. Most importantly random access disk drives, the most important peripheral of all, came from Bryant.

Unfortunately the Bryant disk drives proved unreliable and difficult to service[45]. They also proved unsuitable for real-time, on-line data processing. These problems later forced RCA to restart its peripheral work, and to try to provide itself with better disks. However:

> '...when RCA decided to redevelop its products, it had lost the continuity of the engineering effort that had been going on in such things as printers and essentially had to reestablish its engineering skills and manufacturing skills in those areas. So in a sense time was lost by the early decision to abandon these peripheral developments.'[46]

One peripheral project did remain a key part of RCA's strategy, this was RCA's alternative to the disk drive, the RACE. RACE was meant to leapfrog the current disk drive technology, but proved to be a major product failure, and put RCA further behind in storage techniques. The inadequacies of RACE are studied below.

Another problem with the 301 was that, like the 501, it was not initially offered with a FORTRAN compiler for scientific work[47]. The problem was that during the 1960s most firms wanted to use their computers for both commercial and scientific work. Therefore RCA transferred Arthur

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[44] US v IBM, tr9599, McCollister.

[45] US v IBM, tr9009-9010, Beard.

[46] Ibid, tr9004.

[47] US v IBM, tr9404, McCollister.

Beard from the DEP group to the EDP Division: he was briefed with developing arithmetic co-processors for the 501 and 301 computers, to improve their usefulness as scientific machines[48]. At the same time a FORTRAN compiler was provided for both machines.

However, overall the 301 was a success. IBM credited it as such:

> 'RCA, in the past, had been one of the most successful of the IBM competitors with the RCA 301 selling some 620 systems.'[49]

The first 301 was delivered in February 1961, with the last being delivered in 1967. In 1965 the US government was using 95 of them, most for logistics work, some for civil administration[50]. The rest of the sales were spread widely throughout the rest of the EDP industry. It seems to have been the right scale system for the rapidly growing market, though its sales were only some 1-2% of the equivalent IBM system, the 1401.

The 601.

This was the largest machine in RCA's range and was marketed as the flagship system. Unfortunately it sank. It was a large scale computer designed to handle large amounts of data. It came in two versions: the basic 603 for general purpose data processing, and the 604 which was enhanced for scientific work[51], using a similar co-processor unit to the 301. The basic price was around $1.5m or rental of $31-34,000 per month. It was designed to run a number of programs at once, and used the so-called Omni-channel input-output system to control up to 64 peripherals simultaneously[52]. It was also meant to offer 'unprecedented compatibility with RCA data processing and communications equipment and other processors'[53]. It used so called modular packaging to enable it to be easily enhanced. However, the system eventually offered neither of these advanced features. The packaging technique used led to great difficulty, and it was completely incompatible with any RCA or other system.

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[48]US v IBM, tr8945, Beard.

[49]US v IBM, px4462, IBM ,'Competitive Environment', 4/2/66.

[50]CBI Archive, Inventory of automatic data processing equipment in the federal government, Bureau of the Budget, Executive Office of the President, July 1966.

[51]Arthur S. Kranzley, Manager, Product Planning and EDP Methods, RCA EDP Division, 'Planning the RCA 601 System', Datamation, Sept/Oct 1960, p31.

[52]Datamation, RCA 301 and 601 announcement advert, May/June 1960, p14.

[53]Ibid.

A number of further problems came from the broken relationship of the 601 and the military CDP computer. With the EDP Division fully occupied with producing the 501 and 301, it was decided that the 601 would be built at the military operation in Camden[54]. This was logical as it was envisaged that the 601 and the CDP computer, to be used in ComLogNet, would be close relatives. RCA hoped that the 601 would benefit from this link, and planned to sell the 601 to the telecommunications industry. It was estimated that the New Jersey Bell Telephone Company alone would have a requirement for 100-150 of these systems[55]. A number of difficulties arose. Firstly, it has already been seen that the computer communications operation became a separate unit of the Industrial Electronic Products Group, and then joined the Defence Electronic Products Group. This meant that the CDP and 601 design teams became separated and the designs diverged massively. Secondly there was a lack of communications between the EDP Division and the Camden manufacturing site.

The 601 had been costed in the expectation that it would benefit from sharing many components with the CDP. McCollister saw this as the root of the project's cost problems:

> 'from what I learned of it, I would say it [the cost errors of the 601 project] was probably errors in judgement as to what costs were likely to be to accomplish the functions that had been specified, but there was also one organizational action that may have contributed to this.
>
> There was a parallel machine called the CDP or Communication Data Processor, which was the processor in the ComLogNet, later called Autodin Communication System, for the federal government, and originally it had been expected that the 601 and the CDP would be one and the same machine, but for perhaps several reasons, this turned out not to be so.
>
> For one reason because what had been in one organization was subsequently put into two organizations and to a certain extent each pursued its own independent way.[56]

However, the divorce from the CDP was only one of its problems. RCA also failed to deliver the performance and functions promised. It suffered from massively higher production costs than had been expected, mainly because of a unique packaging problem:

> 'Also, there was difficulty in providing some of the functional capabilities that had originally been announced...for one thing, the 601 system was intended to be an on-line type of system and a multi-programming type of system, and the cost of some of the

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[54] Arthur S. Kranzley, Datamation, Sept/Oct 1960, p31.

[55] Us v IBM, px114, 1959 Business Review.

[56] US v IBM, tr9546, McCollister.

controllers to put these capabilities on line, so to speak, with the central processor, were so far out of line that this was economically just a totally impractical thing to do...

...Finally...to achieve the performance that had been specified in the central processor, they had to go to the extensive use of coaxial cable in the back frame of the system, and there were so many of these wires, and they were so bulky...that it was virtually a physical impossibility to interconnect all of the points on the back side of the machine that had to be interconnected.

So, just in summary, there were severe technical problems, both in a functional and in a manufacturing sense, and there were also severe financial problems, so much so that the company began to look for a way out of the programme.'[57].

In early 1962, the company stopped offering the 601 for sale[58]. It was only sold for just over a year: RCA accepted about five orders for the system.

Managerial changes and financial restrictions.

By 1962 the EDP Division had a number of difficulties. Its top-of-the-range 601 had become a very public failure and the resources that could have been used to build another system had been wasted. The 501 was getting old and needed replacing, its sales were slowing up dramatically, and the firm needed to improve its peripheral equipment. By 1962 RCA had invested $100m in the department[59], but had not seen any profit from this investment, and there was little expectation of an imminent return. Considering the market success of the 501 and 301 it can be concluded that the division was not as successful as could have been expected.

A number of new personnel were brought in to deal with the cost and technical problems. Beard was bought in to head engineering in 1961 and McCollister was poached from Burroughs and took over marketing. In 1962 a new vice president, Art Malcarney[60], took control of the operation, and he appointed Arnold Weber, another long term RCA employee, as General Manager of the EDP Division. Malcarney had previously been in charge of the Camden plant which had produced the 601 and had been very critical of the running of the EDP Division[61].

At the corporate level, Dr Elmer W. Engstrom became president of RCA.

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[57]Ibid, tr9544.

[58]US v IBM, tr8457/8, Beard.

[59]Harold Bergstein, 'RCA and EDP' Datamation, Oct 1962 p57, an article based on interviews with McCollister.

[60]US v IBM, tr8722, Beard.

[61]Ibid, tr8723-8.

He ordered the computer operation to cut its losses and to break-even:

> '...instructions from the corporation, from the Chairman and the President, were to reduce our losses [by] half [each] year from the end of 1961...and to achieve a break-even by the end of 1964.'[62].

The reason for this was that RCA was undergoing a profits squeeze in the early 1960s, as was seen in figures 6.2 and 6.3. This was because the firm was undertaking a number of expensive development projects, apart from computers. The largest of these, and the one that drew heavily on the company treasury, was the cost of bringing colour television to the market. This meant not only preparing facilities for the mass production of domestic sets, but also the building of capital equipment to give NBC and third party television stations the ability to transmit in colour. Television was seen as central to RCA's operations and many hundreds of millions were sunk into it. Beard believed that the effort in television was larger than the company's efforts in computers:

> '...I believe that there was some greater total effort in television from the engineering point of view than there was in the computer.'[63]

To pay for these developments the company had to rein back on losses elsewhere, so the computer operation was ordered to cut losses.

While the development of colour television was undoubtedly the main reason for RCA suspending its efforts to increase market share in the computer industry, there were other RCA developments that impacted on the computer operation. For example Beard mentions that, from 1959, the DEP was expanded substantially[64]. Its main area of growth was the Astro Electronics Division. This was RCA's space and ballistic missiles operation which became involved in many aspects of the space and nuclear weapons programme. Its most public role was as the prime contractor for the electronics for the lunar lander. In 1965 the Astro Division employed 3202 qualified engineers and scientists[65]; the EDP division employed only 217. Many other military projects needed the skills of computer engineers, a further draw on RCA's limited pool of experts.

Overall RCA had a policy of expanding its defence operations:

> 'Defense electronics is a consistently broadening field and it is manifestly impossible to have a representation in all areas. It

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[62]<u>US v IBM</u>, tr9619, McCollister.

[63]<u>US v IBM</u>, tr8717, Beard.

[64]Ibid, tr8715.

[65]<u>Impact of Federal Research and Development Programs</u>, House of Representatives Select Committee on Government Research, 88th Congress, 2nd session, report number 1938, December 28, 1964.

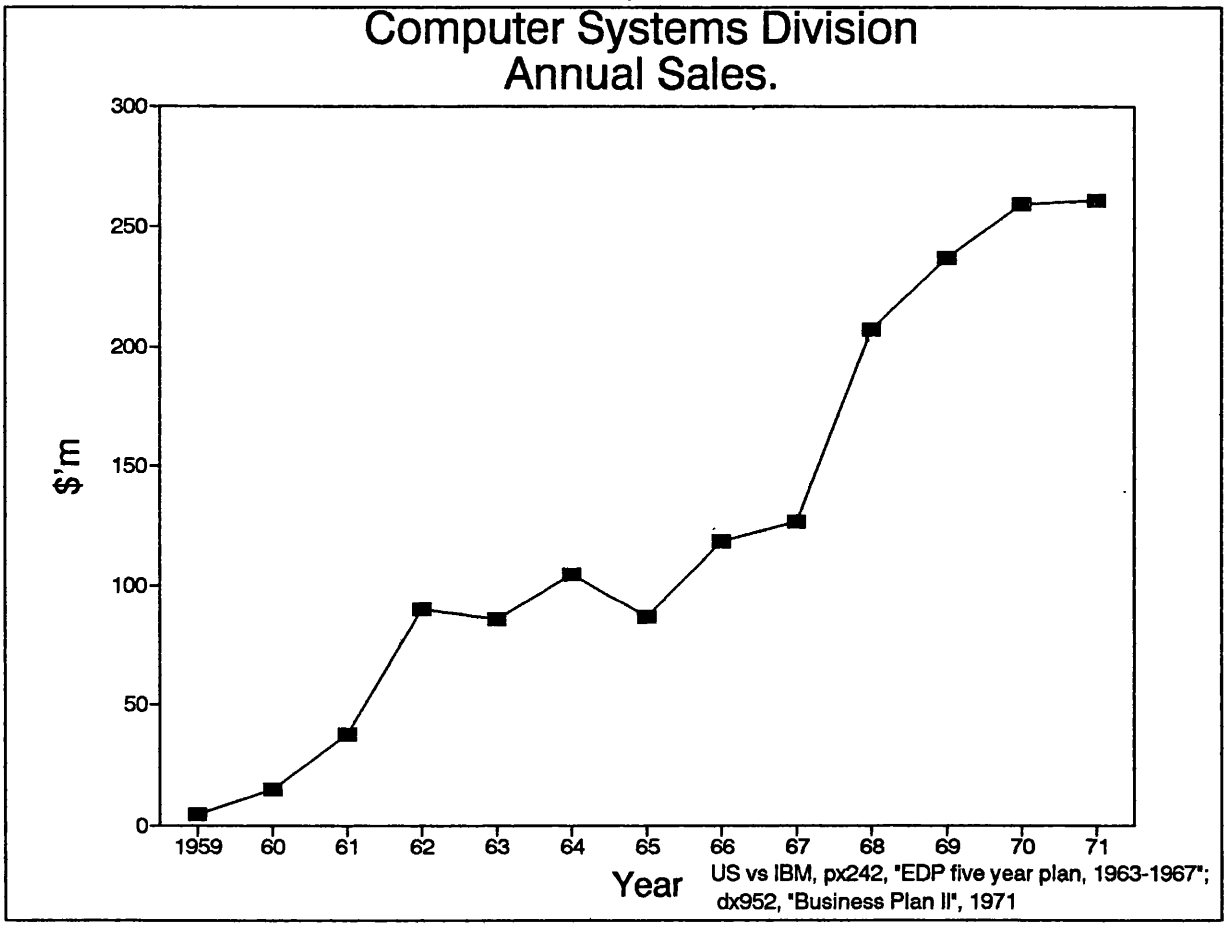
is our policy to develop pre-eminence in selected technical areas.'[66]

While most of these developments were paid for by government contracts, and therefore did not drain the firm of funds (indeed rather the opposite), it did mean that RCA's skills had to be spread thinly.

Table 6.5 (page 234) shows that during the early and mid-1960s, RCA cut the amount of money it spent on developing computer systems. It is argued later that these cuts undermined RCA's third generation computers, as it was during this period that they were being designed. Figure 6.7 shows that EDP sales stagnated from 1962-66. Cutting expansion meant reduced losses. As figure 6.8 shows, this allowed the Computer Systems Division to crawl towards break-even. However, from 1966-7, when profits from colour television started to flow in, the computer operation was again allowed to expand and build up large losses in its efforts to gain market share:

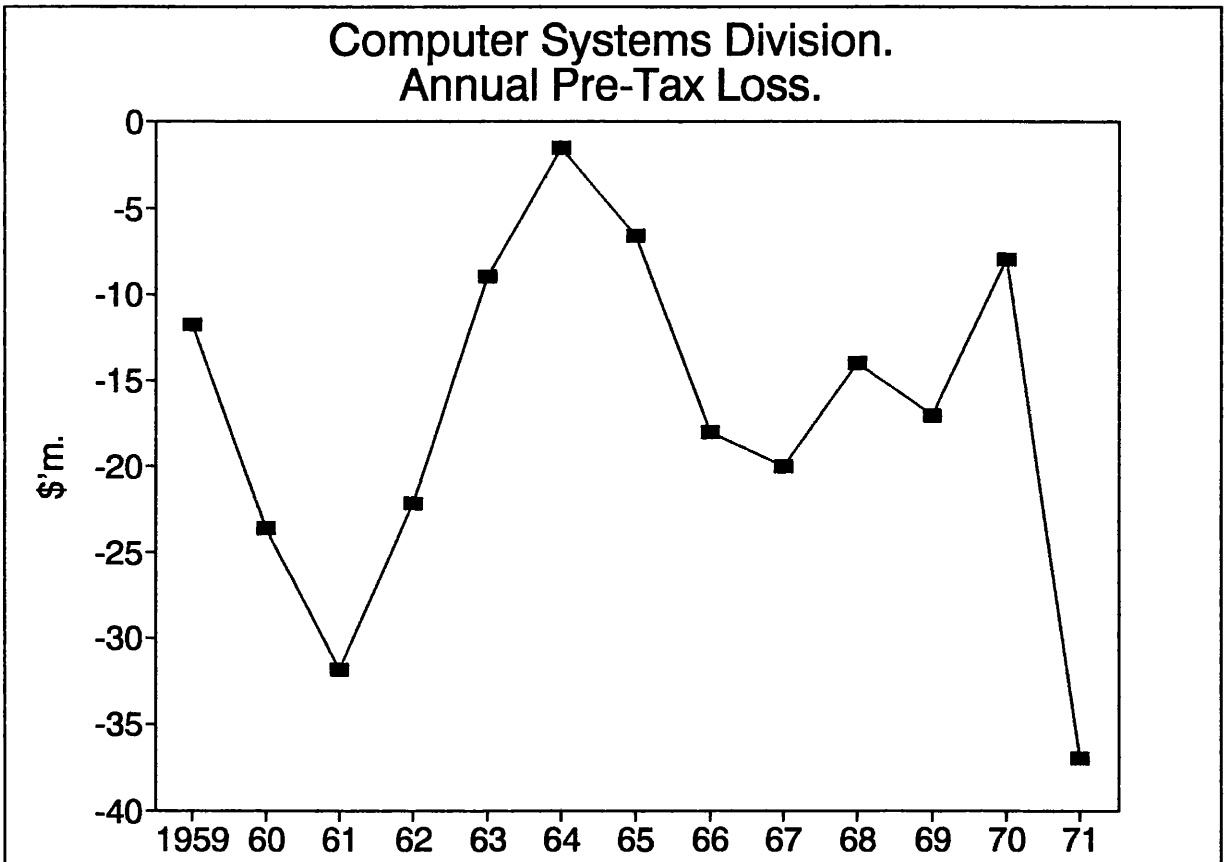
[66]Arthur L. Malcarney, then Executive Vice President DEP, 'The Outlook for DEP.' RCA Engineer, August/Sept 1961, pp6-9.

Figure 6.7



Computer Systems Division
Annual Sales.
$'m
300
250
200
150
100
50
0
1959
60
61
62
63
64
65
66
67
68
69
70
71
Year
US vs IBM, px242, "EDP five year plan, 1963-1967"; dx952, "Business Plan II", 1971

Figure 6.8



US vs IBM, px242, "EDP five year plan, 1963-1967";
dx952, "Business Plan II", 1971

Policies of restriction, keeping the second generation product line alive.

The new edict to move towards break-even was not to be carried out at all costs. It was aimed at cutting losses by 50% per annum while the colour television expansion ran its course, and was to be carried out without damaging RCA's market position. This boiled down to a three point strategy for the computer operation:

> 'a) Protect its current revenue and present customer position, both domestic and foreign.
>
> b) Become a profit contributor to RCA.
>
> c) Maintain a growth which is at least comparable to that of the industry as a whole.'[67]

The plan was to reduce the number of new systems placed on the market. This would allow rental income to catch-up with capital expenditure on new leases.

At this time RCA believed it was number two in the market, at least in terms of systems being shipped if not in terms of established users base:

Table 6.4 Market share by value of new computers shipped.

Company	% of total $ volume
IBM	78.7
RCA	4.0
RemRand UNIVAC	3.5
NCR	3.2
GE	3.2
Honeywell	2.4
CDC	2.1
Burroughs	1.1
Others	1.8

Source: US v IBM, px242, 'RCA EDP Five Year Plan 1963-1967'.

To ensure that its systems stayed competitive enough to maintain its position in the market, it had to undertake a programme of improvements to its product line, while not draining company funds. This led to a number of small enhancement projects.

[67] US v IBM, px242, RCA 'EDP Five Year Plan 1963-1967'.

a) The enhanced 501 and 301.

Beard's first task on officially joining the Computer Systems Division (CSD) was to design a 'speed pack' for the 501[68]. This unit improved the speed of the 501 by 30%, helping to keep the system alive for a few years. However, this was seen as only a temporary measure. Similar packs were provided for other RCA machines to allow them to carry out a secondary scientific role.

b) The 3301.

The 501 was inherently old and needed replacement, RCA decided to introduce an improved and larger scale cousin to the 301, the 3301, to do this. It was designed to utilise disk drives, and had the now usual RCA arithmetic co-processor, now referred to as the PINE unit. However, it was marketed heavily with the RACE storage system (see below), and it was this that it hoped would give it a competitive edge. It was intended that the 3301 would give 301 users a way of increasing their computer power without having to swap their data to a new architecture, but the firm had relatively low expectations of the system:

> 'It was not a new design. It wasn't intended to be the foundation of a future line of products; rather, it was a product that we could develop relatively quickly, at relatively low engineering expense, that would give us an additional offering to take the place of the 601, and that in a sense would give us time to get on with a complete new product program[me] in the long range future.'[69]

However, rather than being in the 601 scale it was in the same price region as the 501. McCollister estimated it cost $2m to develop the 3301[70]. One significant improvement over the 301 was its ability to operate as an on-line real-time computer and as a communications machine. It was given the marketing title of the 3301 REALCOM, to underline its communications abilities. It benefited from some of the 601 research, using the same very fast memory.

Using all these cost saving tactics, it was estimated that only 50 3301s needed to be sold to break-even: Beard estimated that, from its time of announcement in August 1963, 80 were sold[71]. It has been argued that these relatively low sales, and the fact that it was quickly eclipsed by

[68]US v IBM, tr8456, Beard.

[69]US v IBM, tr9623, McCollister.

[70]Ibid, tr9623.

[71]US v IBM, tr8990, Beard.

the third generation SPECTRA series, meant that the machine was a failure[72]. However, given the stop-gap nature of the machine and that Beard testified that so few needed to be sold to recover costs, it must be counted as one of RCA's successful products.

Peripheral failure; the RACE system.

RCA's peripheral problems continued. As has been mentioned, the inadequacies of RCA's own printers and punched card units on the 501 led to it purchasing these devices from elsewhere. It had to do the same with disk drives. It has been seen that the Bryant disk drive proved unreliable and was not a match for IBM systems. It was not really until the late 1960s, and the establishment of a number of so called 'plug compatible' manufacturers who produced copies of IBM kit, that an adequate source of IBM type disk drives became available for purchase. Beard outlined the perceived strengths and weaknesses of the firm:

> 'we felt that the electronic capability of RCA was very strong...
>
> We realized that RCA was not particularly strong in the mechanical or electro-mechanical areas, but this capability could be achieved either inside the company or obtained outside the company as was necessary.
>
> So, in the earlier years, I believe we looked on it primarily as a technological challenge which we felt very optimistic about.'[73]

With the failure to secure adequate devices from third parties, RCA concentrated its efforts on producing a peripheral system that would leap-frog the current technology. This was the RACE which was heavily marketed with the 3301 and, for a while, with the third generation SPECTRA 70 series. Like NCR's CRAM, RACE used magnetic cards[74]. The cards were held in a robotic magazine, which, when selected, mechanically transported the cards to a rotating drum. The card was attached to the spinning drum and read by magnetic heads and would then be returned to the magazine. RACE could hold a massive 250 million bits of information. RCA hoped to deliver the system by 1965.

It was a failure for a number of reasons. Firstly such a complex mechanism proved expensive and unreliable. The cards wore out quickly, and had to be regularly copied to protect the data; there was no way of telling which cards were wearing out so they all had to be copied. It also took a

[72]Fisher et al, IBM and the US data processing industry: an economic history, New York, 1983, pp202-203.

[73]US v IBM, 8487-a, Beard.

[74]Ibid, tr9046.

long time to access the data. Worse still was the fact that in 1964 and 1965 IBM introduced the 2311 and 2314 disk drives. These offered massive improvements over old disk systems[75]. The 2311 was cheap, while the 2314 could be daisy chained together to give nearly as much storage as the RACE, while allowing much faster access times. RACE could not compete with these systems. It also further delayed RCA's efforts to develop better disk drives for its computers.

RCA was more successful in supplying communications peripherals for its computers. Linked to this was a project to provide its computers with the ability to control industrial processes remotely, but this development was abandoned in an attempt to save money.

RCA's overseas partners, and plans for third generation systems.

RCA had some success in selling its second generation designs abroad, a business which had some impact on RCA's plans for third generation computers.

RCA's first overseas computer collaboration was with English Electric[76]. As has been seen, EE took the 501 design and produced the 'anglicized' KDP 10[77] which it sold in small numbers. However, as EE became fully occupied with its own and LEO's systems, it decided not to licence the 301. This proved a boon for ICT. ICT had been sluggish in computers, and it needed an up-to-date small-medium scale computer that could fill the needs of larger tabulator users who wanted to trade up to the new technology. Machines Bull of France had a similar requirement. Both companies ordered a number of 301s to resell, generating cash sales for RCA, which meant it avoided the need to fund leases on these machines. ICT sold over 80 301s as the ICT 1500 and Bull sold more than 95. A few were also shipped to Hitachi. RCA also bought some punched card peripherals from ICT and Bull.

This was big business for the RCA EDP Division with $15 million of overseas sales in 1962 and an expected $25 million in 1963[78]. RCA actively strove to preserve its position. It believed that it had to develop machines that were technically ahead of the systems that its

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[75]Ibid, tr9048.

[76]See above, chapter 4, p142-146.

[77]CBI Archive, J. Cowie, J.W. Hemann, P.D. Maycock, Office of Naval Research, London Branch, 'The British computer scene, PT 2, The British computer industry' 17 May 1967.

[78]US v IBM, px242, RCA 'EDP Five Year Plan 1963-1967'.

customers could create themselves, while also ensuring that they fitted into the marketing plans of these customers. In the early 1960s RCA was considering how to replace its second generation systems. It decided that it should offer a compatible range of computers from the small scale to very large computers. Initially it was planning a series called the ULTRA, though this was replaced by the Vanguard series[79]. Vanguard was planned to be RCA's main computer family, but it decided to start developing an even smaller system called the POPLAR. This system was targeted at helping the tabulator companies to upgrade their users to computers, but it was very cautious about using the system in its domestic American market:

> 'At the present time, we are actively at work with ICT in the logical design of this system, and expect to produce the unit, with the first deliveries beginning in early 1965. While the machine may prove to be attractive in the domestic market, it must be sold on a carefully conceived marketing plan if we are to avoid the unusually high marketing costs which would be attendant with a machine of such small average dollar rental. Nevertheless, we expect POPLAR to make a contribution toward future domestic revenue.'[80]

By 1963 the EDP division employed 926 personnel in marketing, nearly 40% of its total staff of 2471[81]. Given the policy of reducing losses, a machine that would add disproportionately to this staff was not seen as a good prospect. As it was, while the marketing team was growing continually, the engineering staff had been cut back from 755 to 579 to save costs.

The POPLAR plan fell to pieces. Firstly ICT acquired Ferranti's computer operation, giving it the engineering skills necessary to develop its own third generation system. Secondly, Bull's continual crisis had become too much for the French government, who sold it to General Electric[82]. GE did not want to continue to buy RCA equipment. Finally IBM's announcement of the 360 family scuppered all RCA's third generation plans, as the 360 was introduced earlier than had been expected.

This meant that for its third generation systems, RCA had to return to old allies to sell its computers abroad. English Electric decided to follow RCA's radical third generation strategy, and produced another anglicised RCA system, the System 4[83]. Siemens and Hitachi produced parts

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[79]Ibid.

[80]ibid

[81]ibid

[82]See below, chapter 7, pp276-278.

[83]See above, chapter 4, pp146-150.

of the RCA range and imported the rest. All three tied themselves into RCA's third generation strategy, which is outlined below.

RCA and the third generation SPECTRA.

IBM's announcement of the 360 family of computers radically changed the market, though technically the system was only a culmination of a number of trends[84]. It introduced a unified line of commercial and scientific computers and made obsolete most second generation systems. The 360 was announced much earlier than other firms expected and was backed by IBM on a scale that took the industry by storm. Every other firm had to offer something to compete with the new IBM range. RCA dropped its plans for the Vanguard and Poplar systems, to concentrate on a new range. While RCA had been working on the small scale Poplar, the main family, Vanguard, was a long way from production. RCA had to take quick action to announce a new range that was competitive with the 360.

In April 1964, within two or three weeks of the 360 announcement, RCA's planning staff received Art Malcarney's permission to cease the Vanguard programme and to start work on a radical new strategy[85]. The Five Year Plan of June 1964[86] outlined a new range, called at the time the New Product Line, and which became known as the SPECTRA 70. There were two main elements behind the design of the Spectra, the first of these was the choice of advanced components:

> 'The new RCA product line.....will have total capabilities which will be at least a match for those offered by IBM System 360. Furthermore, several, if not all, of the systems in the product line will be built with truly integrated circuits rather than the semi-integrated circuits which IBM plans to use in its system. This should represent a significant 'first' for RCA. We expect the new product line to provide us with the future product capability to enable us to meet the goals which are shown in the plan.'[87]

For IBM it was more important to get a third generation family on the market, rather than wait a year or two for third generation components to be made available. RCA, using its knowledge as a builder of military systems and component maker, hoped that its technical prowess could overcome being behind IBM's conceptual leap forward. Eventually, the upper half of the Spectra range introduced real third generation components to

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[84]See below, chapter 8, pp320-325.

[85]US v IBM, tr9626, McCollister.

[86]US v IBM, px243, Computer Systems Division 'Five Year Plan', June 1964.

[87]Ibid.

the commercial computer world. The lower half of the range used second generation components. This was due to the fact that integrated circuits were still expensive, and would have made the smaller machines too expensive, as semiconductors make up a larger proportion of the cost of smaller systems.

However, this was only half of the plan and the market strategy for the machine was very radical for the time. The product planners decided that the new family should be made program compatible with the new IBM 360[88]. One problem with this idea was that there were no 360 machines available to copy at that time. Beard's team of engineers 'reverse engineered' the systems using the 'privileged instruction set' of the 360[89]. In effect they produced a completely different machine, but one which could run 360 programs. RCA's architecture was unique, based in part on the Vanguard, but to the user it was similar to the 360.

There were some difficulties. IBM delayed giving RCA details of the 360's input-output protocols[90]. This meant that the Spectra had to have its own operating system, and that its peripherals were not completely plug compatible with IBM's. However, users had a real choice: they could run the same software, and use the same data, on either the new RCA or IBM ranges.

RCA perceived a number of advantages in being compatible with the new IBM range. RCA wanted to become the natural second source of computers to large corporations[91]. A large firm could decide to adopt the IBM 360 but would have the safety of having a second source of compatible equipment. It also meant that RCA could benefit from the huge amount of software that was expected to be written for the 360.

This latter point was one of the reasons for rejecting some of the other strategies that were put forward. Beard believed that a natural tactic would have been to produce a third generation family compatible with the old 301 and 3301[92]. This would have allowed RCA to keep its old users locked into its unique architecture and exploit the software that had been written for these machines. However, the 301 architecture was not as advanced as the 360 and would not have offered RCA the chance to exploit new hardware and software ideas. Other firms tried to exploit IBM's

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[88]US v IBM, tr9056, Beard; tr9626, McCollister.

[89]US v IBM, tr8475, Beard.

[90]Ibid.

[91]US v IBM, tr8518, Beard; px244, 'Five year plan', March 1965.

[92]US v IBM, tr8525, Beard.

decision to produce a new system not based on the old IBM machines. The most successful of these was Honeywell's 200 family of computers, which were based on the IBM 1401, which had a user base of over 10,000. It was Honeywell's hope that users of these machines would upgrade to its new and more advanced, but still compatible, machines[93]. GE also hoped to benefit from IBM's move to the 360. Its large 600 series was close to compatible with the scientific IBM 7090/94 computers and it hoped to upgrade this market[94].

However, RCA saw greater potential in leaving behind second generation architectures, and adopting the new policy of making a technically advanced 360 lookalike. RCA expected the market for the Spectra to fall into two phases. The first phase was envisioned to consist of RCA competing to install the first, third generation machine in a customer's computer room. In the second phase, during the late 1960s, it was expected that the main trade would be in replacement systems[95]. RCA expected there to be a move to large systems: users who started of with a medium sized 360/40 would require a larger system. This was not just because data processing needs always increase, but also because RCA expected there to be a change in the way computers were used. It believed that computers would become part of 'large integrated management systems'[96]. They would become increasingly a part of information providing networks. To this end RCA hoped that the RACE would provide the huge data store that would be needed in such a role, and that terminals being developed as part of military programmes could be attached to these systems, to provide managers with access to this information system[97]. A number of companies had this vision of a centralised interactive computer information system. However, it seems that RCA was not that committed to it. RCA was not in the forefront of developments in the field of time-sharing, the method by which many people can use a computer at once, which was a core feature of such a system.

Whether this scheme would actually take place was somewhat academic; the computer market was expanding rapidly anyway. Established users always required new systems, and all the time more businesses were finding that

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[93]See below, chapter 8, pp354-358.

[94]See below, chapter 7, pp270-272.

[95]<u>US v IBM</u>, px244, 'Five year plan', March 1965.

[96]Ibid.

[97]Ibid.

computers were essential. Within the scheme of IBM compatibility, RCA had to ensure that users would be willing to look to RCA as the second supplier of data processing equipment. RCA hoped that its newer technology would offer certain advantages:

> 'We felt that we could not underprice IBM product for product because it is very difficult to take out cost in a computer system, but it is not so difficult to put in added performance. So, therefore, the philosophy that we adopted was to provide equipment, a processor in this case, at about the same price as IBM, in fact almost exactly on it, plus or minus a few percent...but to be able to have anywhere from 35 to 45 percent greater performance or greater computational ability than the corresponding IBM system. So we were holding at the same price but emphasizing performance.'[98]

IBM had very high profits built into its prices: it was by far the most profitable computer company[99]. RCA could compete with IBM's scale by foregoing a large amount of this profit. It also planned to avoid parts of the market that required disproportionately high marketing and support expenses. Reflecting its earlier lack of enthusiasm for the small Poplar machine, RCA planned:

> 'To become the primary second supplier to major U.S. corporations.
>
> To concentrate marketing effort on multiple systems sales or $10,000 monthly rental systems.'[100]

> '...We were interested primarily in customers who were ready for large data processing systems...someone just getting started in the data processing system would start in a some small way...such users require a lot of support and help and education.'[101]

RCA hoped that the Spectra, and the targeting of large scale users, would make RCA the number two computer company by the end of the 1960s. RCA wanted to achieve a 10% market share, a target which it believed was the level at which the division would become self-sufficient[102].

SPECTRA and the edict to stop losses.

This direct assault on IBM's new family had to be done within the terms of the edict that the Computer Systems Division (CSD) had to halve its losses each year. This was reflected in the engineering budget available to the division during the years 1964-1966, the years of peak

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[98]US v IBM, tr9269-70, McCollister.

[99]See below, chapter 8, table 8.2 p323; table 8.3 p324.

[100]US v IBM, px245, '1966 five year plan'.

[101]US v IBM, tr9938, Beard.

[102]US v IBM, px244, 'Five year plan', March 1965.

Spectra 70 development. The following table shows what was available. It should be noted that this includes engineering support for the older machines that still were in the field:

Table 6.5

EDP Engineering Expenditures, $'m.

	59	60	61	62	63	64	65	66*	67**	68**
Advanced Development		1.62	1.80	1.57	0.99	0.47	0.3	0.3	0.5	0.75
Design and Development	5.29	7.82	9.29	5.87	7.57	9.35	16.76	12.75	15.11	16.31
Net Engineering Cost	5.29	9.44	11.10	7.44	8.56	10.43	17.06	13.05	15.61	17.06
% of sales	115	64.8	29.3	8.3	9.9	10.6	21.1	15.5	13.7	11.5

**planned.
Source: US v IBM, px245, 'Five Year Plan 1966'.

There are various estimates of what IBM spent on the 360, ranging up to $4.5bn, including monies spent on new plant and marketing[103]. What is sure is that IBM was operating at an order of magnitude higher than RCA's Computer Systems Division. This did show through in the end product. The Spectra was less well engineered: Spectras were larger, power hungry, needed massive air-conditioning and were less reliable:

> '1)RCA equipment apparently requires larger amounts of dedicated preventive maintenance time than that of our main competitor, IBM. Customers that have both our equipment and IBM equipment are aware of this, and this works to our detriment in the market place.
>
> 2)RCA equipment is apparently more sensitive to environmental fluctuations than that of competition, particularly IBM. This makes our customers somewhat sensitive to the difference [between] our maintenance policy and theirs. I am told, for example, that 360/30's can be left without any maintenance whatsoever for weeks on end. Yet, most of our systems require that we take the system from the customer for periods of time every day.'[104]

On top of this, RCA's decision to stop development of electro-

[103]See below, chapter 8, pp320-325.

[104]US v IBM, dx621, J.W. Rooney, 'Administrator Field Engineering', internal memo, 26/6/69.

mechanical peripherals led to continuing problems, problems which persisted even after the loss cutting order ended. While Spectra was initially marketed with RACE and bought in disk drives, RCA eventually decided to restart peripheral design. At the end of 1967, 18 months after the first Spectra deliveries, RCA could supply an equivalent to IBM's 2311 disk drive[105]. Before this RCA had lost patience with Bryant and had bought these devices from CDC, and even from IBM[106]. What concerned RCA was that peripherals, especially storage devices, were becoming a very significant part of a machine's rental income.

However, by the time RCA could offer its own 2311 equivalent, IBM had added the 2314 to its range, a system which offered massive storage capacity for large users, the type of users RCA wanted to sell to. RCA wanted to produce an equivalent of this system quickly, but again its peripheral plans were thrown into confusion. Firstly Jim Linnel, who had headed the development of the 2311 clone, left the company with his engineers to form his own company, Linnel Electronics. He developed and sold IBM plug compatible peripherals[107]. Secondly the whole peripheral operation was moved, which seems to have caused a lot of problems. This disruption meant that RCA could not supply its own 2314 equipment until 1970, five years after IBM. During 1968/9 RCA accepted that RACE would never be competitive and decided to buy 2314 type equipment from Memorex[108]. When RCA eventually managed to produce these disk drives itself, IBM instantly released the revolutionary 3330 Merlin drive, once again putting RCA at a disadvantage. RCA was always a generation behind in the market for random access storage systems.

Given RCA's small R&D budget, it is not surprising that its software development was inadequate. While the policy of being 360 compatible limited the amount of software work RCA had to do, it was still faced with one of the greatest 1960s problems, that of providing a comprehensive operating system. The standard operating system, TDOS, was adequate to start with, but rapidly aged and needed updating by the end of the decade[109]. A second problem was that the two smallest Spectras, the 70/15 and the 70/25, only offered sub-sets of the instruction set and were

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[105]US v IBM, tr9913, Beard.

[106]Ibid tr9935.

[107]Ibid, tr9914.

[108]Ibid, tr9936.

[109]Us v IBM, tr12135, Rooney.

not offered with COBOL compilers. COBOL was the main business language so this damaged sales, and the small machines were not particulary successful.

The reason TDOS was not updated was that RCA was working on a new time-sharing, virtual memory operating system, the TSOS-VMOS. This was RCA's largest software project. Two machines, the 70/46 and 70/61, were specially developed in the late 1960s to offer large scale interactive computing. However, TSOS-VMOS took much longer to develop than was expected, not only affecting these two machines, but also greatly damaging RCA's next family of machines which was designed to use TSOS-VMOS as its mani operating system[110].

Finally there was one very surprising weakness. Despite the fact that RCA's Memory Products Division was a reasonably large supplier of memories to the computer and capital electronics industries, it consistently failed to provide memory of good enough reliability and functional advantage to the Computer Systems Division. In 1968 this came to a head when the then Information Systems Division informed the corporate management that it had to place an order for $35m worth of memory for a proposed addition to the Spectra series, the 70/49, with an outside company. ISD wrote to Bob Sarnoff[111], informing him that the division of the two operations was illogical and that they should be merged:

> 'Development processes must involve more than theoretical analysis and its immediate physical embodiment. A thorough understanding and consideration of mechanical design, reliability, manufacturability, and maintainability of a complete memory system is required. Nothing less can meet competition today. Economical and functional trade-offs between hardware and software must be optimized.
>
> The present structure within RCA is not conducive to efficient operation or to meet these requirements.......
>
> This is essentially what was pointed out in the Booz, Allen & Hamilton Report of March 7, 1967. It is what has been demonstrated by the inordinate difficulties encountered in trying to provide reliable memory stacks for our computer shipments in 1967 and 1968. Poor stacks may have cost us as much as $10,000,000 in those two years. Additionally, our problem is portrayed by what has been inadequate provisioning in the engineering budgets of Memory Products....
>
> Under a structure providing for a memory group separate from the groups requiring the memories as one of their basic design components, the greatest efficiency cannot result. The objectives of the two groups are not always in parallel. Doing the job properly is made much more difficult. Meeting competition today requires

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[110]See below, pp241-247.

[111]Gen. Sarnoff's son, Robert, had taken over the company on his fathers retirement.

organizing in the most straightforward manner in authority and responsibility[112].

Whether the merger actually occurred is unknown. Once RCA had sold its computer operation, it then sold its memory manufacturing facilities to DEC. What is clear is that, in the eyes of the computer division, the decentralised structure was disjointing the companies development work.

SPECTRA 70 in the market and the end of cash restrictions.

Despite the restricted resources available to develop the Spectra, it fared moderately well in the market. By the end of 1965 there were over 100 orders[113]. While not a great number, this was in line with the slow growth RCA wanted for CSD at the time.

The most successful machine was the 70/45, the smallest of the full scale machines. With the success of this system, RCA introduced a smaller, but fully functional system, below the 70/45, called the 70/35. Unlike the other small machines it used IC components and had the full instruction set. It was in effect a value engineered 70/45, and became the real base level machine. It also offered an emulator for the old IBM 1401 machine, the largest user base in the world[114]. IBM noted that the Spectra range had a number of advantages:

'-Higher internal speed in comparison with comparable IBM System/360 models.
--One-third higher speed magnetic tape drives at equivalent rentals compared to IBM.
--High speed printing is provided at $300 to $600 below our prices.
--Availability of magnetic tapes on the Model 15 gives them a magnetic tape system in a price range where we have no current entry.'[115]

Nevertheless IBM was not worried, noting that RCA's marketing was very conservative[116]. Though IBM did not know it, this was because of the order to reduce losses to pay for colour television development. However, conditions at RCA were changing rapidly. IBM market watchers noted that in 1966 two of RCA's major investments were starting to generate a return:

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[112]US v IBM, px840, Memo from J.R.Bradburn to R.W.Sarnoff, 18/12/68, Bradburn was CSD's general manager.

[113]US v IBM, px245, 'Five year plan', 1965.

[114]US v IBM, dx960, C.E. Fizzell, IBM General Data Processing HQ, Memo to T.J.Watson Jr, IBM CEO, 11/12/64.

[115]Ibid.

[116]Ibid.

'RCA is performing very well as a corporation. Its colour television program[me] is highly successful and it has been doing very well in government and defense business. The data processing portion of RCA has not been doing very well for the last two years.

This is significant on the basis that in the early '60s RCA undertook two major program[mes]---colour television and data processing.'[117]

IBM staff were not sure how this new profitability would affect the computer operations. IBM thought RCA would take one of two courses of action: using the television profits to reinvest in the computer department, or abandoning general purpose computers and concentrating on communications systems. The capital released by this, together with the television profits, could be used for other areas of expansion. As it turned out RCA decided to back the computer operation further, while also expanding in other directions.

In 1966 the computer division proposed to the corporation that it be allowed to run up large new losses, in an attempt to achieve a higher market share:

'..this was fully accepted, by the corporation, and the reason is that they felt we were making good progress and they felt that this was a worthwhile investment in the future of the business.'

'..I think they felt, as they had felt earlier, that it was an industry that had significant growth potential for the RCA Corporation and that at some point in the future had a significant profit potential.'

'..Actually, the profitability of the television business had become quite strong a year or two prior to that.'

'I think the overall profit position of the corporation made it possible for them to support the Division at the level recommended by Division management, but obviously they would not have done this if they did not feel that the Division had a potential in the future for becoming an important part of the total overall RCA operation.'[118]

From 1966 CSD was given permission to place machines on the market, without the need to balance the books. At the same time the company took on a number of new staff to support its expansion. Of these new staff, the key player seems to have been Chase Morsey, who took over the corporate vice-presidency for marketing. In the late 1960s he bought in a number of IBM marketing staff and made market share the key goal[119], and RCA again tried to become the number two in the industry[120]. McCollister, who

[117]US v IBM, px4459, IBM Data Processing Group '1967-1968 Operating Plan' 7/11/66 p184.

[118]US v IBM, tr9620-9622, McCollister.

[119]Sobel RCA, p195.

[120]US v IBM, px340, RCA 1970 Annual Report.

admittedly had been side-lined by these changes, believed this was a function of Chase Morsey's past role in Ford:

> '...he was very conscious of market share statistics and he was also influential, and this caused the division to give increasing recognition to share of the market..'
>
> 'I think it was a legacy from his experience in the automobile industry..'[121]

McCollister did not think that this was a good influence:

> 'because it tended to place the emphasis upon increasing market share and relatively deemphasized control of expenses and achieving profit, and the end result is that the expenses in the RCA Computer Division mounted to the point where they contributed significantly to RCA's withdrawal from the business.'[122]

Given freedom to lose money, RCA was able to increase its market share. RCA's own estimates of its share seem high but they do show the kind of growth aimed at, and especially a big increase in 1970:

Table 6.6 RCA market share, 1968-71.

Year	1968	1969	1970	1971plan
Domestic Market Share	4.1%	3.7%	7.5%	5.8%

Source: US v IBM, dx952, RCA '1971 Business Plan II'.

This was achieved by offering large discounts. A much favoured tactic was to offer a potential customer a larger machine for the same rental as a smaller one[123]. However, the most important method the firm used to attract new users was the Accrued Equity Contract. Users were offered machines on a six year lease basis. At the end of the six years, the user owned the machine and no more payments were required[124]. However, so that the user could still benefit from the advantages of leasing, they had the option of swapping to a lease contract at any time in the six years and upgrade to a new machine. This proved a disaster for RCA. RCA was in the habit of depreciating its leased computers over six years, which was reflected in the accrued equity contract. However, IBM, with its much lower cost base, could afford to depreciate over four years and could write-off leased machines quicker, meaning that they could afford to replace a generation of leased machines must faster[125]. In other words, to keep

[121] US v IBM, tr11156-57, McCollister.

[122] Ibid, tr11158.

[123] US v IBM, tr12217, Rooney, divisional VP for Marketing.

[124] US v IBM, tr9803, McCollister.

[125] US v IBM, tr12219, Rooney.

period.

The effect of this was two-fold. Firstly RCA's drive to expand Spectra's market base happened a long time into the third generation of computing, most being delivered in 1970. By this time a significant percentage of IBM 360s had been fully depreciated and it was preparing to introduce the next range, the 370. Secondly, the division's accountants had counted the accrued contracts as firm sales which made its balance sheet much stronger. However, when the IBM 370 was released, and RCA was forced to react by introducing the
RCA-Series of computers, users swapped accrued equity contracts for leases so as to get the new, more powerful systems. Financial disaster ensued, as is described below.

Other uses for RCA's new-found profits.

Before considering this, it is worth while highlighting the fact that RCA was also using its profits to fund other diversifications as well. In the late 1960s it was not just the CSD management that changed, so did the corporate leadership. Bob Sarnoff gradually took over from his father as head of RCA, eventually becoming Chairman, President, and CEO. IBM lawyers in the anti-trust case made great play of RCA's change of emphasis at this time. Early 1960s Annual Reports talked of RCA's full commitment to 'computers, control and communications' the '3 Cs'. This changed to a policy of diversification; RCA started to spread its risk. The following table shows its major acquisitions:

Table 6.7 RCA acquisitions, 1966-71.

Date	Company	Method of payment	Value
05/19/66	Random House (publishing)	Common stock	$40.1m
05/11/67	Hertz Corp. (car rental)	Preferred and common Stock	$248.4m
03/31/70	Banquet Foods	common stock	$116.5m
10/14/70	Cushman & Wakefield Inc.	Common Stock	$30.0m
02/24/71	Coronet Inds.	Common Stock	$183.9m
			$618.9m

Source: US v IBM, Dx965 and 966, IBM attorneys compiled this list from RCA annual reports.

IBM made the point that RCA's commitment to its electronics activities was less at this time, and this was one of the reasons it abandoned computers in the early 1970s. Some of these purchases caused major problems, especially Hertz. In the early 1970s recession, it proved impossible for Hertz to sell its ex-lease cars, a disaster for its finances. This directly affected the computer operation. In 1971 A.L.Conrad took over the Presidency and CEO roles in the company, reflecting the failure of Bob Sarnoff's dual policy of diversification and computer expansion.

The RCA Series and the collapse of the SPECTRA.

RCA knew that IBM's next series was going to be announced in 1970 and installed in 1971. This was something of a problem. RCA's long term project for new systems had started in 1966. The ground rules were:-

> 'Compatibility with Spectra 70 and where possible, with IBM is a ground rule. This policy will permit maximum growth in a replacement market and retention of our own customers.'[126]

However, Bread's system'X', which was meant to fulfil the above criteria, was cancelled in 1969[127]. This was because it was expected to take too long to get to the market, and had a number of architectural problems. However, its replacement, the New Technology Series, faced the same problem. F. Withington, of the consultants A.D. Little, informed RCA's staff that, in his opinion, the advanced concepts of the NTS could not be brought to the market until 1973. This forced the firm to put the NTS on the back burner as a long term project for a future concept of computing:

> 'I think that in looking at the next family or generation of equipment beyond Spectra, there was a lengthy debate between people responsible for programming systems, that is, the so called software organization, and the people responsible for hardware or equipment specifications, and perhaps the engineering organization as well, as to exactly what the nature of this product should be.'[128]

However, A.D. Little told the company that it needed a new system earlier than 1973 to maintain its broad line strategy, which A.D. Little considered the only way of achieving the company's goal of being the industry's number two:

> 'When I first got to RCA Arthur D. Little had been hired to review the marketing strategies of the RCA Corporation and product

[126] US v IBM, px245, 'EDP Five Year Plan', March 1966.

[127] US v IBM, 12225/6, Rooney.

[128] US v IBM, tr9809, McCollister.

strategy. At a meeting I attended they presented the concept that you had to have a broad product line because you could not possibly sell enough share of any particular product category to achieve this goal [of being number 2 to IBM] and that strategy was accepted as being valid.'[129]

To cover its short term needs, RCA resorted to relaunching what was essentially the same product:

'The RCA Series was an attempt to bring out what was seemingly a new product line for whatever psychological influence it might have on the marketplace.

But it was a restyled product line. There was a new set of covers, the frames were the same, and it was essentially a cosmetic treatment of the existing Spectra 70 Series with new model numbers and new pricing.'[130]

'They were not precisely the same processors. Architecturally they were the same.'[131]

The main difference was that new manufacturing techniques and components made the hardware cheaper to produce, and the memory was speeded up[132]. Half the new RCA Series was to use the old TDOS systems, these were the RCA 2 and 6. The other half, the RCA 3 and 7, were to be offered with the time-sharing VMOS 4 operating system. It was on VMOS that RCA focused its main marketing effort. However, the development of VMOS remained a significant problem. In late 1970 it was 6-9 months behind schedule[133]. It was estimated that this would lead to a loss of 17-20 RCA3 orders and 20-22 RCA7 orders[134]. This represented $2.14m of monthly rental income, and was described as being close to a disaster[135].

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[129]US v IBM, tr11814, Rooney.

[130]US v IBM, tr9817, McCollister.

[131]US v IBM, tr12240, Rooney.

[132]Ibid, tr12241.

[133]US v IBM, dx872, Memo from A.L.Fazio (head of VMOS4 development) to J.W.Rooney, 'Impact of VMOS4 Slippage', 24/12/70.

[134]Ibid.

[135]Ibid.

The RCA Series and the market environment.

The RCA Series was launched at a difficult time for the computer industry. The divisional Vice President for Marketing, J.W. Rooney, noted that:

> 'The economic situation for the computer business in 1970 was quite bad. As I recall, the shipments that year were down some 20% from the previous year.
>
> In 1971 that situation persisted, at least as long as we were in business.'[136]

At the time Datamation predicted that IBM would only reach one third of its 1970 delivery quota[137]. This was a difficult environment for the new machine.

A second problem was the competitive stance IBM was taking. The IBM 370/155 and 165 were announced in June 1970 and the smaller 135 and 145 in September 1970[138]. The 135 and 145 offered virtual memory and time-sharing operating systems, and the larger machines were quickly replaced by the 158 and 168 which offered the same functions. They used IC components and semiconductor memory, rather than magnetic core memory. The combination was faster, more powerful, and produced cheaper machines. Within the IBM range the system that most concerned RCA was the 370/145, which fell right into RCA's most successful class of machine.

Due to the staging of IBM's announcements the smaller 370s were announced after the RCA Series. This was the cause of the argument:

> 'Well, the 370/45 was announced within days after we had announced the RCA 6...it was our opinion that IBM had priced the 145 out of its normal relationship to [the] other...systems that they had announced. We felt that there was a good probability that an alteration had been made in pricing the system as a direct response to the announcement of the RCA 6.
>
> In addition to that, we felt that their delivery pattern, as it would relate to the larger memories in the 145, was not consistent with the other patterns of deliveries on the other newly announced machines, and we felt that it was, in effect, a retaliation [against] the announcement of the RCA 6[139].

RCA made some representations to IBM that the 145 was 'priced selectively' to attack RCA[140]. RCA believed that the 145 was announced specifically

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[136]US v IBM, tr12264, Rooney.

[137]Datamation, 15th October 1970, p17.

[138]Fisher et al IBM and the US DP Industry, p367.

[139]US v IBM, V. O. Wright tr13114. Wright had joined RCA from IBM as head of government marketing.

[140]US v IBM, dx868, internal RCA memo, J.Johnson to the head sales E.Donegan, 3/2/71.

to hit RCA, as it had a delivery time of 18 months rather than IBM's usual 12 months. RCA argued that it was announced ahead of schedule in order to hit RCA 6 sales. It was also argued that the pricing of the semiconductor memory was artificially low. IBM responded that the delay in delivery was due to the time it took to build up yields of memory chips, and that the price was set to reflect the cost that was expected to be achieved as IBM advanced down the learning curve of producing these devices. These are standard practices in the semiconductor industry[141] and RCA did not pursue these complaints. In any case the 145 offered the great advantage of time-sharing, which required large amounts of fast memory. If nothing else, RCA believed that its representations to IBM kept it conscious of the fact that it was under anti-trust scrutiny.

A second problem IBM created for RCA concerned peripherals. Not only did IBM introduce the new 370 computers, but at more or less the same time it introduced the very advanced 3330 Merlin disk drive, and the ASPEN tape drive:

> 'Their announcement of the 3330 disk with the 370 family we felt was very significant, very profound, and would have a great impact on RCA if we were to compete against IBM in this market place.'[142]

At this time RCA had only just managed to produce the 2314 drive that IBM had introduced in the mid-1960s. RCA wrote to IBM asking for details of the new systems just after they were announced[143]. However, the material IBM sent RCA did not contain enough information to enable it to start copying the systems[144]. In August 1971 RCA eventually received a reference manual on the Merlin, the same month it was delivered. Memorex and ISS, the two leading plug compatible manufactures, had managed to get this information much earlier, but RCA wanted to develop this vital equipment itself[145].

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[141]E. Scibberas, <u>Multinational electronic companies and national economic policy,</u> Greenwich, Conn., 1977.

[142]<u>US v IBM</u>, tr11939, Rooney.

[143]<u>US v IBM</u>, dx936, IBM vice president, J.W.Birkenstock, replying to RCA's request, 22/7/70.

[144]<u>US v IBM</u>, dx937, RCA correspondence to Birkenstock.

[145]<u>US v IBM</u>, tr12262, Rooney.

The RCA Series marketing strategy and the collapse of the SPECTRA.

In reality the RCA Series was a marketing ploy, an attempt to re-launch the old range with some evolutionary improvements. In support of this, RCA came up with a strategy to 'intercept' the IBM range:

> 'There was a very elaborate strategy at the time as to where these units of the RCA series would fall against the IBM [range], either as it was announced or was expected to be announced....in this elaborate strategy the RCA series would fall at certain point[s] within the IBM product line spectrum and that IBM would be unwilling to disturb the equilibrium of that product spectrum and, therefore, negate the rationale of the RCA product concept.'[146]

The RCA Series machines were planned to be positioned at the mid-point between IBM machines in terms of scale. The hope was that as a user decided that he wanted to trade up to a larger machine, he would be attracted to the RCA system rather than the IBM, which would often be too big a jump. This plan fell to pieces as it was realised that the part of the range that was to use VMOS would be late. A second problem was that the potentially largest selling of RCA's normal machines, the RCA 6, was pitched directly against the IBM 370/145, which was not only keenly priced, but also offered full time-sharing facilities.

While the RCA failed to intercept the 370, it did manage to affect the old Spectra range. McCollister described the RCA Series as 'blowing the SPECTRA out of the water'[147]. In the late 1960s, up to and including 1970, the Spectra had gone through a veritable boom despite the computer recession:

> 'This investment has already resulted in a more rapid growth rate for RCA than for the domestic industry as a whole. In 1970, the value of RCA's net domestic shipments rose by more than 50 per cent while that of the industry fell by more than 20 per cent.'[148]

However, the RCA Series offered much improved price/performance ratios, so users of the Spectra sent back both leased and accrued equity machines in exchange for the new machines. In the first seven months of 1971 78 old computers had been returned, and another 137 were already booked in for return[149]. The following table breaks down the causes of these returns, and upgrading to new systems accounts for the great majority:

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[146] US v IBM, tr9838, McCollister.

[147] Ibid, tr9839.

[148] RCA Annual Report, 1970.

[149] US v IBM, dx872, RCA 'Returns Presentation', 4/8/71.

Table 6.8 Reasons for users returning RCA computers

System	Losses to Competition	Losses other than Competition	Upgraded
301	2	7	9
501	-	1	-
3301	5	1	-
70/15	2	1	-
70/25	-	1	-
70/35	10	5	30
70/45	20	8	81
70/46	1	2	18
70/55	-	-	5
70/60	-	-	4
RCA 2		2	
	40	26	149

Source: US v IBM, dx872, RCA 'Returns Presentation', 4/8/71.

A second problem was that the computer recession affected which machine upgraders went to. In the past users traded up from second to third generation, spending the same money to get a more advanced and powerful machine. This time Spectra 70/45s were traded up to 'low yield' RCA2s, the same computer power for less dollars[150].

RCA's investment in computers via leases and equity contracts was being wasted. Machines were being returned much earlier than the depreciation policy had allowed. This forced the Information Systems Group to up date its December 1970 plan, and in April 1971 the 'Business Plan II' was produced which cut the expectations for the Information Systems Division[151]. Revenue for 1971 was expected to fall from \$323m to \$261m. This was because, while gross shipments were increasing, net shipments were falling:

[150] Ibid.

[151] US v IBM, dx952, '1971 Business Plan II'.

Table 6.9

Business Plan II: effect of returned computers on RCA's net computer shipments.

($m sales value)	Business Plan 2	Business Plan 1
Gross Shipments:		
RCA	171	118
Spectra	170	202
	341	320
Minus value of returned Spectra computers	155	90
Net Shipments:		
RCA	171	118
Spectra	15	112
	186	230

Source: US v IBM, dx952, 'Business Plan II', 1971.

The outcome was an expected loss of $37m in 1970: worse still was a large increase in the 'cash run-off'. This was the cash outflow to pay for the new RCA machines being built and put out on lease:

Table 6.10 RCA Investment Summary 1968-1971.

$m	1968	1969	1970	1971 BP2
Current Assets	116	140	163	193
Long Term Receivables	27	55	103	146
Net Fixed Assets	126	127	144	188
Total Assets	269	322	410	527
Net Assets	242	286	372	481
Asset Turnover	.8	.8	.6	.5
Cash Run-off	75	45	89	126

Source: US v IBM, dx952, 'Business Plan II', 1971.

RCA's reassessment of its costs and financial position.

The real situation was even worse. Chase Morsey started to take a dim view of the situation in the computer division, and its effects on the rest of the company. He became concerned that even the new plan, predicting a loss of $37m for 1970, was way off target, as the division's accounting procedures were so irregular[152]. This was later backed up by the criticisms of the Accounting Principles Board[153]. The division had been counting 70% of the expected revenue from an accrued equity plan in year one. It was treating these as certain sales, and writing 70% of their value into the books immediately[154]. It became evident that the reality was that these machines were being transferred to leases and then being returned to the firm: Accrued Equity Contracts were far from certain sales.

The problems at the computer division came at the same time that both Hertz and NBC were suffering from a downturn in consumer demand. Figure 6.2 (page 197) showed that RCA's profits collapsed in 1970. Morsey pointed out to Sarnoff that the increased trading loss at the computer division, and the large increase in the division's net assets, had accounted for $181m of the $247m fall in profits[155]. It also accounted for $140m of the company's negative cash flow of $315m that year. For the coming decade Morsey believed that the company's cash requirement had risen from $700m to $1bn; in the first half of the decade he expected that it would be the computer operation which would be the main drain on cash. He illustrated this with the following table, showing that the single biggest drain on cash was expected to be the computer operation:

[152]US v IBM, px347a, Memo from D.A. Peterie (whose role is unknown) to Morsey 26/5/71, which criticised accounting procedures; px955, Morsey to Donegan 29/6/71, concerning a report by Arthur Young concerning major accounting problems, especially regarding inventories and depreciation.

[153]US v IBM, tr14058, Conrad, RCA's new CEO.

[154]US v IBM, tr13580-13600, Wright.

[155]US v IBM, px201, report from Chase Morsey to Sarnoff and Conrad, 27/8/71.

Table 6.11 Cash Flow of Domestic Operations.

$m	1971-1976 total	
Services	208	
Government Systems	27	
Commercial Systems	(51)	
Consumer Electronics	44	
Electronic Components	132	
Solid State	(36)	
NBC/Records	269	
Coronet Industries	3	
Cushman & Wakefield	5	
sub-total		601
Computer Systems	(703)	
Industry Systems	(155)	
sub-total		(858)
Management Reserve		(170)
Total		(427)
Average cash out flow per year		(71)

Source: US v IBM, px201, report from Chase Morsey to Sarnoff and Conrad, 27/8/71.

'As a result of these changes, it is clearly necessary to reassess RCA's cash requirements and new funding capability over the next six years.'[156]

Morsey then went on to make a telling point by comparing RCA's financial status with that of other electrical/electronic and computer companies. Firstly he showed that RCA's ratio of earnings to fixed charges was lower than the average for the electrical and computer industries, and was falling the quickest:

[156] ibid

Table 6.12 — Ratio of Earnings to Fixed Charges.

	'67	'68	'69	'70	total change in cover %.
RCA	10.3	9.1	7.8	3.5	(66)
G.E.	11.9	10.5	7.5	6.4	(46)
ITT	3.4	4.5	4.6	4.5	31
Westinghouse	15.9	11.8	10.6	5.5	(64)
Average	10.4	8.9	7.6	5.5	(47)
Burroughs	7.2	6.8	5.5	3.9	(46)
Honeywell	6.2	6.9	6.0	3.2	(48)
IBM	35.7	46.7	57.8	41.6	17
NCR	4.7	4.2	4.1	2.5	(48)
Sperry Rand	9.9	10.6	6.3	4.7	(52)
Average	12.7	15.0	15.9	11.1	(12)

Source: US v IBM, px201, Chase Morsey report to Sarnoff and Conrad 27/8/71.

Morsey believed that this was the ratio on which investment bankers made their decisions. RCA's low and falling status severely limited the amount of new borrowing RCA could raise.

As it was, RCA already had a very poor debt/equity position compared to a number of the other companies listed. Morsey was very concerned about the high gearing of the firm:

Table 6.13 — Debt/Equity Ratio.

	'67	'68	'69	'70
RCA	.79	.79	.77	.88
GE	.32	.30	.27	.22
ITT	.69	.56	.55	.52
Westinghouse	.36	.32	.28	.44
Average	.46	.39	.37	.39
Burroughs	.48	.74	.57	.60
Honeywell	.59	.61	.56	.87
IBM	.14	.12	.11	.10
NCR	.69	.42	.61	.82
Average	.44	.44	.44	.51

Source: US v IBM, px201, Chase Morsey report to Sarnoff and Conrad 27/8/71.

Morsey guessed that the ratio would have to rise to between 1.25-1.80 by 1976, believing that RCA would not be able to raise finance after it passed a ratio of 1.23. Even plans to sell the radio network and stop development of the highly expensive videodisc[157] would not cover the firm's cash needs[158].

When the revised 1971 computer business plan arrived on Sarnoff's desk it was accompanied by a note from the Finance Department's H.L.Letts[159]. He concluded that:

> 'Unless the substantial cash requirements of Computer Systems can be improved it may prevent us from making investments in other areas of RCA with better and more immediate returns on capital.'[160]

His main concern was that costs at CSD had got out of hand. The head of government marketing, V.O.Wright, who had joined RCA from IBM, believed that this had been a major problem. This was because RCA machines were so easily comparable to IBM systems that any cost disadvantage would show through to customers immediately. There were a number of factors undermining RCA's cost base:

> 'It stemmed from several sources. One was the fact that the manufacturing process in RCA was not as fully automated as I had seen it automated in IBM manufacturing.
>
> RCA was not devoting sufficient attention in engineering a product to the matter of cost. They tended to engineer the product to get it built, but ignore what it might cost to build it after it was engineered.
>
> There was no value engineering work going on after the product was developed to reduce cost within the manufacturing organization...
>
> The cost, as I recall it, when I first got involved...early in 1971,... was running at...about 42% of revenue. That is, the cost of the product was about 42% of revenue...'
>
> '...I was aware of IBM's manufacturing cost, as I had remembered from my days with IBM, would have run something on the order of 14 to 15% of revenue.'[161]

Wright went on to estimate that Sperry Rand's manufacturing cost was 24% of revenue and at Burroughs it was 21%.

Morsey's arguments won the day. In July 1971 Conrad recorded a video

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[157]M. Graham, RCA and the Video Disc: the business of research, Cambridge, Mass. 1986.

[158]ibid.

[159]US v IBM, dx952, '1971 Business Plan II', and Letts' accompanying letter, 16/4/71.

[160]ibid.

[161]US v IBM, tr13559-61, Wright.

taped message for the workers of the computer operation to scotch rumours that RCA was about to sell out[162]. However, in August 1971 such a plan was under consideration. On the 16th of September the senior management came to the decision that the commercial computer division had to be sold off to protect developments in the rest of the company[163]. On the 17th Conrad invited Morsey to present the proposal to the Board:

> 'As a result of the factors outlined in the forgoing analysis of CSD and its impact on RCA, the conclusion has been reached that the additional investment required in CSD no longer appears to be a prudent financial risk. The major reasons for this conclusion are as follows:
>
> *The further delay in the achievement of sustained profitability at CSD to the middle or late 70s, as opposed to the early 70s, could jeopardize the ability of the Corporation to finance its capital requirements.
>
> *The many healthy and vital parts of the rest of RCA could be hindered in the event of a down turn in the economy in the mid-1970's because of the high level of outside financing required to support the growth of CSD (as well as the other parts of RCA).....
>
> *It should be recognized that RCA does have strengths in certain special and more narrowly defined computer-related businesses and these opportunities can be pursued on a prudent basis without risking large amounts of capital.
>
> Beyond these factors, the dominant presence of IBM in the computer industry contributes to the difficulty of achieving a viable computer business for RCA. The manpower and financial resources of IBM, including the size and strength of the marketing, research and development organizations, are such that achieving market share growth as well as acceptable profitability, is extremely [unlikely].'[164]

After negotiations with a number of companies Sperry bought RCA's commercial computer operation for $137m[165]. In September of 1971 RCA set up a reserve of $490m to cover the losses it had sustained on the operations of the computer division[166]. Later the company was able to reduce this reserve by $78m as the disposal was less financially damaging than had been expected because Sperry managed to get a better than expected

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[162] US v IBM, tr13939-42, Conrad.

[163] Ibid, tr13943-4.

[164] US v IBM, Px208.

[165] Initially Sperry paid RCA $70.5m with the rest paid over five years according to the revenue generated by the RCA systems in the field. RCA estimated in 1971 that total payments would be from $100.5m to $130.5m. As Sperry did relatively well at keeping the RCA installed base the payments were at the top of the range.

[166] RCA 1971 annual report.

return from the RCA operation. Under the sales arrangement, a part of the price was linked to the Computer Systems Division's performance under Sperry management in their first few years of control. The RCA computers fitted in well with Sperry's range, a range which included some partially IBM compatible machines[167]. RCA's systems improved this ability and Sperry maintained a reasonably large business in pseudo-IBM compatible systems.

There were a number of reactions to RCA's abandonment of computers. Datamation led with a headline 'In Breach of Ten Thousand promises'[168]. A number of 'autopsy' articles ensued[169]. In general RCA was seen as letting down its customers. On the other hand, financial, rather than industry, journals saw the RCA move as very acceptable:

> 'RCA's recent announcement to leave the computer mainframe business, even though it has resulted in a $250 million[170] non-recurring write-off, eliminates an area of continuing earnings loss, one which has demanded a great amount of management time and attention, and also returns the company to being predominantly a consumer goods company.'[171]

The same article went on to predict an upswing in consumer demand, and that with a 14.4 price:earnings ratio the company was well under the price of similar organizations. The recommendation was to buy; RCA's main concern was the financial market's view not the computer market's view of it.

Conclusion.

The above case study shows just some of the detail that is available on RCA's computer venture. Like EE and GE[172], RCA went through a period of self appraisal at the time it decided to leave the market, the concern being that remaining in the competitive computer market would unduly affect the firm's other operations. In an earlier period, colour television and defence work had received a higher priority when investment funds were squeezed by the number of hi-tech opportunities the firm was pursuing. This seems to have been where the real damage to the computer operation was

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[167]See below, chapter 8, pp364-366.

[168]Datamation, 15/10/71, p7.

[169]Datamation, 'RCA Computer Systems "I suppose you could call that beginners luck", 1/11/71, p42-45; 'RCA Autopsy: The cause was within' 1/12/71, p42.

[170]After tax.

[171]Wall Street Transcript, 8/11/71, p26103.

[172]See next chapter.

done. If RCA had attempted its big market push at an earlier stage, it would have been in a position where a much larger proportion of Spectra 70 machines would have been fully depreciated and have earned a bottom line profit when the IBM 370 was launched.

One of the computer division's great weaknesses was that it was forced to work out of sequence with the market. Having funds denied in the early 1960s, but being able to grow substantially in the late 1960s, meant that it was selling the wrong computers at the wrong time. It exacerbated the whole sequence by its reclothing of the Spectra as the RCA Series. However, this was unavoidable. RCA was in a 'catch 22' position: it had to introduce a new range to prevent IBM's new series replacing a substantial number of the IBM compatible Spectras. Compatibility was not an advantage at this time. At this stage it was concern about IBM poaching RCA customers which drove RCA to launch its new range, despite the fact that it destroyed its old installed base.

Above all, RCA's computer division had to cope with a higher cost base than IBM. When the emphasis changed from cutting losses to buying market share, it seems that controlling costs took second place. This was a fatal error given its direct competition with the low cost, high output IBM.

Even the company's role as a broad based electronic firm was of ambiguous advantage. Certainly the Advanced Development Group greatly aided market entry. The division was also helped by RCA's expertise in integrated circuits, allowing it to lead the market with this kind of technology. However, the decentralised organisation led to problems. The divorce of the CDP and the 601 helped to scupper the flagship of the RCA range. Equally the Computer Systems Division received little help from the Memory Systems Division, indeed it proved something of a handicap.

RCA was not forced out of the market by specific anti-competitive actions by IBM. Indeed, at the beginning of the story, RCA was much larger than IBM and could wield a lot of market power. However, IBM's day to day strategies, its low cost base, high absolute level of R&D, and its established position in the business machines market, all overwhelmed RCA's half-hearted efforts which were subject to the needs of the rest of the company. RCA missed its opportunity to succeed in the computer market when it decided to support colour television development to the hilt, though this proved a profitable option. When it did decide to back its computer diversification again the timing was out of step with the stage of product cycle that the Spectra 70 range was at, and the drive for market share at the end of this product's life was an expensive mistake.

Therefore, like the other electronics companies, RCA was not in a position to support all its diversifications simultaneously, and at least in the short run, it was faced with periods of capital rationing. This forced it to choose between its opportunities in a number of potentially very profitable markets. By the end of the period studied, RCA was under some pressure and preferred to support diversifications away from the risky, though potentially profitable, electronic engineering sector. The purchase of car rental firms and food companies was an attempt to stabilise its income, and was diversification for the sake of defence. It had used more of its high profits from colour television for this purpose than for developing its computer division. The fact that some of these purchases also caused the firm problems increased the pressure on it to rein back on its computer operations where its lack of understanding of the market cycle had caused such large losses.

General Electric and the Commercial Data Processing Market.

Competition for funds and the availability of capital within the corporation played an important role throughout the life of RCA's Computer Systems Division. Another important issue was that there was little advantage accruing to the computer operation from being part of a diversified electronics firm after the stage when digital computer skills were being collected together. General Electric's history in the industry is similar, though it is a more complex story. GE suffered from numerous poor management decisions which exacerbated its problems, and stopped it from taking advantage of the strengths that the firm undoubtedly had. It was forced out of the industry in similar circumstances to RCA, having to cope with the same kind of internal pressures on its finances.

The post war General Electric Corporation.

Like English Electric and Ferranti, GE was born in the heavy electrical industry[1]. It produced everything electrical and electronic and became one of the largest corporations in the world, and easily the largest in the electrical/electronic industry. By 1955 it was the fourth largest company in the U.S.A and had the third largest work force[2]. By 1960 it had sales of $4.4 billion and 250,000 employees[3].

Until the Second World War GE, as with so many successful companies, was run by a tight central autocracy. The leading figures were the Chief Executive Officers: Charles A. Coffin; Edwin Rice; and Gerard Swope[4]. These men made GE highly successful: GE was in the fastest growing industry in the world and was twice the size of its nearest rival, Westinghouse.

During the war the company expanded very rapidly and in many new directions. In 1939 sales were $300 million, during the war it broke the

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[1]Alfred Chandler, Scale and Scope, 1990, pp212-221.

[2]W.B.Harris, 'The overhaul of General Electric'. Fortune, December 1955, p110. This article was based on an interview with GE's CEO, Ralph J. Cordiner.

[3]CBI Archive, Auerbach Electronics Corporation, 'A corporate business strategy for information processing, 1960-1970, Industry Analysis.' June 1960, chapter IV. This industry survey was prepared by the computer industry consultancy Auerbach Corporation for RCA's Advanced Military Systems Division.

[4]Harris, 'The overhaul of GE', Fortune, 1955.

$1 billion mark. The new CEO, R.J. Cordiner, was concerned that centralised decision-making was a handicap for the rapidly diversifying company:

> 'The basic problem, he [Cordiner] had discovered was not GE's gigantic size but its fantastic diversity. He had to figure out how to make decision-making flexible at the operational level where minutes count.'[5]

Therefore, GE started a process of decentralisation[6]. The aim was to fragment the company into operating departments which would have day to day management responsibility. The centre was to be reduced to corporate planning and coordinating inter-divisional activities; all central functional control was to end. During 1948-9 these plans were tested out in a number of affiliated firms, such as the white goods company, Hotpoint[7]. During the early 1950s Cordiner extended decentralisation to the rest of the company. The reorganisation caused a great deal of disruption and for a while led to a downturn in profit ratios. However, Cordiner hoped that in the long term these changes would lead to better control over the company[8]. The results of this case study cast doubt on whether this was achieved.

The company's basic operating unit became the department. By 1955 there were one hundred independent operating departments, organised into 22 Divisions, which in turn made up the 4 Operating Groups. The breakdown of GE's activities was:

Table 7.1 GE group sales.

Apparatus (mostly electrical capital goods)	30%
Industrial Products and Lamps (capital goods and consumer non-durables)	28%
Appliances and Electronics (durables and capital goods)	27%
Atomic Energy and Defence Products	15%

Source: Auerbach Corp, 'A corporate business strategy for information processing', chapter IV, 1960.

This structure was quickly changed with the formation of an Electronic and Flight Systems Group. This new group contained the Defence Electronics

[5]Ibid.

[6]Ibid.

[7]Ibid.

[8]Ibid.

Division[9], which in turn controlled the Heavy and Light Military Electronics Departments, which both had interests in computer technology. However, when the Computer Department was formed it was a part of the Industrial Electronics Division of the Industrial Group. Nevertheless, the group structure was less important than the department level, where day-to-day control lay.

The company tried to develop organisational structures intended ensure that the operating units worked in the same direction, and that there was an adequate flow of information within the company. The earlier experiments with the decentralised structure showed that there was one major problem; the interests of the decentralised affiliates were not always the same as GE's overall corporate interests. Cordiner wanted to allow a degree of operational responsibility yet also to have central control over long-term planning. To do this GE set up the Office of the President, supported by the Services Division[10]. There were 4,000 staff in the Services Division. Of these 3,300 were in the central research laboratories, but many of the rest were involved in the Management Consultation Service. This operation was involved in managerial research, advising departments on management matters, and coordinating inter-department activities. The Management Consultation Service supplemented the ten functional Vice Presidents whose ensured that new methods of management were disseminated to the operational departments and that standards were maintained. The ultimate level of control was the President's Office. This consisted of Cordiner and six other Vice Presidents. The main role of the President's Office was to continually 'needle' operational units, not just with regard to immediate profitability, but also to ensure that planning was adequately carried out and that departmental plans fitted into the overall corporate scheme.

General Electric's entry into the market for commercial computers.

Like RCA, GE entered the computer industry on the back of a single large contract. It also joined at the same time as RCA, EMI, Philco, and a number of other electronics firms, who, following the Korean war, extended their range of electronics activities into computers. At this stage it was becoming obvious that the computer was going to be the basis of a big industry and offered an opportunity for electronics firms to utilise their know-how. These firms all made their bids to enter the

[9]Auerbach, 'A corporate strategy for information processing', chap IV.

[10]Harris 'the overhaul of GE', Fortune, 1955.

industry at the cusp of the transition from valve-based computers to solid state systems.

The general manager of the Electronics Division's Commercial and Government Equipment Department, George Metcalf, wrote a report in 1954 on the computer industry; he believed it was a market on the brink of a boom[11]. GE's early computer work was somewhat undirected, being undertaken at the time that the firm was reorganising itself into decentralised profit centres. There was a lack of direction at this time, and indeed it will be argued that this was the perennial problem for GE's computer operations.

Before the company started commercial computer work it became involved in some early computer development projects. Its first computer work started in 1948 with a research programme on computer guidance for the anti-missile missile Thumper, but this was cancelled in 1950. In 1951 the firm started to develop a mid-course guidance computer for the Hermes missile[12]. However, the most important pre-commercial development GE undertook was the one-off ORAC computer which it produced for the United States Air Force's Wright Field Development Centre[13]. This was developed by GE's Electronic Laboratory and was completed in 1954 for R&D work at the USAF research centre. The successful production of ORAC led to a number of business plans recommending that GE enter the production of computers. These were all rejected by Cordiner who explained in March 1956 to Clair Lasher, an author of one of these proposals and who later became head of the Computer Division, that:

> 'Under no circumstances will the General Electric Company go into the business machine business. However, sometime in the future, in support of our historic businesses it may be necessary for us to go into the process computer business.'[14]

It was ironic that it was at about the same time that GE became the first company in the world to install a computer for commercial work. In

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[11]George Snively, 'General Electric Enters the Computer Business', Annals of the History of Computing, Volume 10, Number 1, 1988, pp74-78. Snively joined G.E. in 1952 as the supervisor of Accounting at G.E. Electronics Laboratories and at the time of writing this article was president of the Technical Equipment Rental Corporation, by way of GE's Computer Division.

[12]Auerbach, 'A corporate business strategy for information processing', chapter IV.

[13]Snively, 'GE enters the computer business', Annals of the History of Computing, 1988.

[14]Ibid.

1954 a UNIVAC 1 was installed at GE's newly constructed Appliance Park[15]. Indeed GE's internal market for computers was large, not surprising given that it produced so many high technology products. Later GE's own Computer Department established the Internal Sales Section to market computers within the firm[16]. By the late 1960s GE represented 0.3% of US computer demand[17].

ERMA.

Apart from his rejected business plan for computers, Lasher had also asked the head of the Microwave Laboratory in Palo Alto, H.R. (Barney) Oldfield, to investigate a computer being designed for the Bank of America[18]. This system was the Electronic Recording Machine, Accounting, 'ERMA', designed by the Stanford Research Institute under contract to the Bank of America[19]. The design of this computer started in 1951, a remarkably early stage for a purely commercial design[20]. ERMA was to be used to automate the record keeping on current accounts. Oldfield's small laboratory started an assessment of the machine in April 1956[21]. According to Snively, Oldfield was a great believer in computers, and unilaterally started negotiations with the Bank of America to produce the design for the bank. Armed with a $30m letter of intent for 40 machines, Oldfield flew to the East Coast and met Dr Walter Baker the general manager of the Electronics Division. Baker had been planning to start a computer laboratory at Syracuse, based on the ORAC staff, but he gave the ERMA project permission to go ahead. Cordiner's diktat that the firm would not produce commercial computers was ignored as they argued that ERMA was a form of process automation, and process automation was a core activity for

[15]F.M. Fisher, et al, IBM and the U.S. data processing industry: an economic history, New York, 1983. p9.

[16]Auerbach, A corporate business strategy for information processing, chapter IV.

[17]US vs IBM, px3222, IBM, 'A corporate study of the General Electric Corporation', 1968. One of a series of IBM reports on competitors.

[18]Snively, 'GE enters the computer business', Annals of the history of computers.

[19]Ibid; Keith Flamm, Creating the Computer: Government, Industry and High-Technology, Washington D.C., 1988 p125.

[20]CBI Archive, 'The story of the G.E. Electronic Data Processor for bank automation', ERMA Systems Laboratory, Menlo Park, California, May 15, 1957. A preliminary document for internal circulation.

[21]Ibid.

GE[22]. The contract, however, went further: it had a number of clauses built into it to deal with royalty payments to the bank if GE sold the system to other users[23].

ERMA was fairly advanced: it used transistors and core memories wherever possible. By luck, or judgement, GE was using the same window of opportunity to enter the computer market as other electronics companies: the cusp between the first and second generations of computers. Significantly a number of the ERMA personnel had worked on semiconductors elsewhere in GE[24]. The system included magnetic tape drives from Ampex and peripherals for the magnetic encoding and reading of cheques. The first ERMA was delivered in late 1958 and, after debugging, was in service by late 1959.

However, the grand unveiling of the first machine was not a happy moment for Barney Oldfield. Cordiner, invited to the ceremony as CEO of GE, saw that it was a cover operation for business computers and fired Oldfield[25]. Lasher was placed in charge of reorienting the operation to the area of industrial control computers once the ERMA deal was over. By this stage the contract was worth $40m, and two other banks had ordered ERMA systems[26].

NCR/GE 304.

The second vital contract that GE won came from the National Cash Register company. By the 1950s, NCR was in a difficult position. Second generation computers were starting to replace traditional business machines, but NCR had little background in this area. NCR reacted to this, like other business machine firms, by setting out to purchase the skills needed to produce computers[27]. NCR's first move was to acquire a small

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[22]Snively, 'GE enters the computer business', annuals of the history of computers.

[23]CBI Archive, 'Proposal ICB 1100101 ERMA', February 3 1956, this was the original GE bid for the ERMA contract. This document was contributed by the head of GE's ERMA Laboratory, G.T. Jacobi.

[24]CBI Jacobi collection, GE booklet introducing the ERMA team prepared by Barney Oldfield, undated.

[25]Snively, 'GE enters the computer business', Annals of the history of computers.

[26]Auerbach, 'A corporate business strategy for information processing', chapter IV.

[27]See below, chapter 8, section on NCR, pp330-339.

start up company, the Computer Research Corporation, to do its design work[28]. However, progress on a first generation machine was slow and it was dropped as it became clear that it could not compete with solid state computers[29]. NCR had to offer a second generation machine to its clients, so it contracted GE to design and produce the electronic sections of a new machine, the NCR304, including the central processor itself[30]. This work commenced early in 1957[31].

GE estimated that, if this order led to GE building 40 systems, it would be worth $15m[32], but NCR was hoping to sell 100 of these machines[33]. GE was given the right to market the system as the GE304 within the company, and it built four for internal use[34]NCR missed its target substantially and only sold 33. Nevertheless, this still helped GE establish its computer operation[35].

<u>Other early computer developments.</u>

Most of GE's computer engineering activity in 1957 was devoted to the two main contracts. At its disposal were 220 engineers and, ironically, an IBM 704 for design work[36]. One other development was the 'paper processor', a small drum memory computer, designed in conjunction with the ERMA[37]. It was for processing accounts in smaller bank branches and GE

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[28]<u>US vs IBM</u>, tr6115, R.S. Oelman, NCR Chairman and CEO.

[29]'The New NCR Data Processing System', <u>Datamation</u>, May/June 1958, pp12-14.

[30]Ibid.

[31]<u>US vs IBM</u>, px320, 'Computer Department presentation to the GE Executive Office', 1964. This was a presentation to the Presidents Office as a part of its role of 'needling' operational departments.

[32]CBI Jacobi collection; Clair Lasher, 'marketing presentation - Product Scope Review Meeting', 1957. The Product Scope Review was an important stage in the formation of the computer division and is discussed in detail below, pp298.

[33]Ibid.

[34]CBI Jacobi collection, GE Computer Department, '304 Electronic Business Data Processor' undated brochure.

[35]Fisher et al, <u>IBM and the data processing industry</u>, p87.

[36]CBI Jacobi collection, Geiser 'engineering presentation' to the Product Scope Review Meeting, 1957.

[37]CBI Jacobi collection, Lasher, 'marketing presentation' to the Product Scope Review meeting.

hoped to sell them to ERMA users. It was not offered to a wider market.

Nevertheless, some of the Department's work was more in keeping with the Presidential edict to avoid business computers. A control computer called the Tin Processor was designed to control the tin making process. There were similar contracts to make computers to control electricity generation plants[38]. A monitoring computer was also produced for the testing of jet engines at the Aircraft Gas Turbine Division. Lasher expected these types of systems to be worth $10-20m to GE over the first five years of operations.

Lasher also noted that the Department of Defence was very important to the computer industry. It was estimated that the government computer market was worth $250m in 1957, including nearly $100m spent on research and development[39]. GE wanted to break into this.

The Product Scope Review Meeting.

From an early stage, the computer operation was using stationery marked 'Computer Department'. According to Snively this was mostly due to Oldfield's efforts to get the ERMA contract[40]. This may have been premature, as in 1956, when control was in the hands of the Industrial Electronics Division, the divisional general manager, Harold Strickland, insisted it be called the Industrial Computer Department[41]. Formally the organisation was set up in 1956 as a section of the Technical Products Department, but in January 1957 it received departmental status[42]. At this stage the Computer Department became involved in a new planning mechanism.

Oldfield had established the computer operation in Phoenix, Arizona. He thought it was a good location to attract the skilled staff needed, but it also had the added advantage of being a long way from GE's main centres in the North East. This reflected the back door method by which he had started to produce commercial machines.

In 1957, once it had become a full department, it became the subject of a Product Scope Review meeting. This was the first new department to

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[38]Ibid.

[39]Ibid.

[40]Snively, 'GE enters the computer business', Annals of the history of computing.

[41]Ibid.

[42]CBI Jacobi collection, 'Summary - Product Scope Review meeting', 1957.

undergo this process, which was intended to ensure that the new organisation fitted into the overall company scheme and did not impinge on another department's authority[43]. Most of this process was carried out by simply sending out a statement outlining the department's role to 161 various bodies in the company. Most departments had no product conflict with the new department. However, three operating departments felt they overlapped significantly with the new operation. This led to a review meeting held over a three day period in October 1957[44].

The conflict of interests was with the following departments: Heavy Military Electronics, Light Military Electronics, and Industrial Controls. Also present at the review meeting were representatives from: Aircraft Nuclear Propulsion, Aircraft Accessory Turbines, Missile and Ordnance Systems, and Apparatus Sales. These probably attended as large users of computers. These operational departments were joined by the head of the Industrial Electronics Division, Strickland, together with a number of consultants from the Management Consultation Service[45].

The conclusion of the conference was that the two military electronics departments had an interest in the computer-like elements of their tactical systems. It was concluded, however, that the Computer Department should be in charge of sales of industrial, business and scientific computers to the military. It was recognized that a number of slow data logging and small control systems were the responsibility of Industrial Controls, but that larger scale control systems were the responsibility of the computer operation. By the mid-1960s almost all industrial systems were the responsibility of the Industrial Controls Division.

The most interesting aspect of the meeting was the presentations made by these departments, especially the plans presented by the Computer Department. It amounted to a formal business plan and a justification of the need for a separate computer operation; the department still felt it needed to justify itself. Its business plan emphasized industrial systems, and while it was willing to build systems of all types for industrial companies, it downplayed commercial computers, even though almost all the computers it was selling were going to banks. The official product plan was to take part in four fields:

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[43]Ibid.

[44]ibid.

[45]Ibid.

'Industrial, and here we recognize two categories of product-computing for control and business and scientific computing. Because of the technological similarities, manufacturing economies, and ultimate system integration, we claim that these products are within the product scope of the Computer Department.

Business, and here we definitely restrict ourselves to definite markets where we can demonstrate to Company management that such participation will be profitable[46].

Military, not as contractors for complete tactical systems employing data processing, but only as contractors for computers and advanced computer developments purchased separately by the military, and

Applications of computers to the solution of industrial, business and military problems which fall within our scope of interest.[47]

Oldfield then presented a number of tables and graphs showing how the business machines, ERMA and 304, were laying the foundation for work more in line with Cordiner's views. Firstly he outlined a belief that general purpose computers were the core of the computer market and that while control systems were going to grow in importance this market would not be as large:

Table 7.2 Computer market size: estimates for 1957 & 1967.

	1957 $m	1967 $m
Industry		
General Purpose (business & scientific)	166.6	530.0
Special Purpose (control, data logging etc)	10.5	150.0
Business	85.5	245.0
Government	291.0	475.0
Total	553.6	1400.0

Source: CBI Jacobi collection, Oldfield's 'opening presentation', slide 5, Product Scope Review Meeting, October 1957.

This was a conservative estimate. Oldfield had already noted that in the previous three years the computer market had tripled. Lasher, then in

[46]Because of ERMA and 304 computers banking was one of these areas.

[47]CBI Jacobi collection, Barney Oldfield, 'Opening presentation' Product Scope Review Meeting, 1957.

charge of marketing, stated that the industry's backlog of orders represented two full years' worth of production. He estimated that the backlog would last until 1960[48]. The plan also predicted that the divide between control and general purpose computers would diminish. Having identified the importance of the general purpose computer, Oldfield then outlined the kind of economies of scale that could be achieved from producing all types of computers. To show this he listed the common components, and the numbers used, in each of the machines that the department planned to make:

Table 7.3 'Digital Computer Building Blocks'

	Flip Flops	Registers	Memories Cores	Drums	Tape Unit	Predicted Sales
ERMA	875	7	130		8	95
Paper Processor	200	5		1	1	47
NCR 304	660	27	132		10	52
Machine Tool Director	600	3		1		8
Tin Line Data Processor	1500	3			1	15
Total	154145	2928	19214	55	1335	

Source: CBI Jacobi collection, Oldfield 'opening presentation', slide 6, Product Scope Review, October 1957.

To reduce the cost of producing process control computers, the manufacture and sale of general purpose machines would allow increased scale economies. Therefore, the Computer Department argued that it should continue to produce commercial computers to reduce the cost of making industrial control systems. To placate senior management the department's sales plan emphasised increasingly large non-commercial activities. Figure 7.1 shows the department's predictions for future sales, which clearly shows an increasing emphasis on non-commercial computers, a plan which was not kept to:

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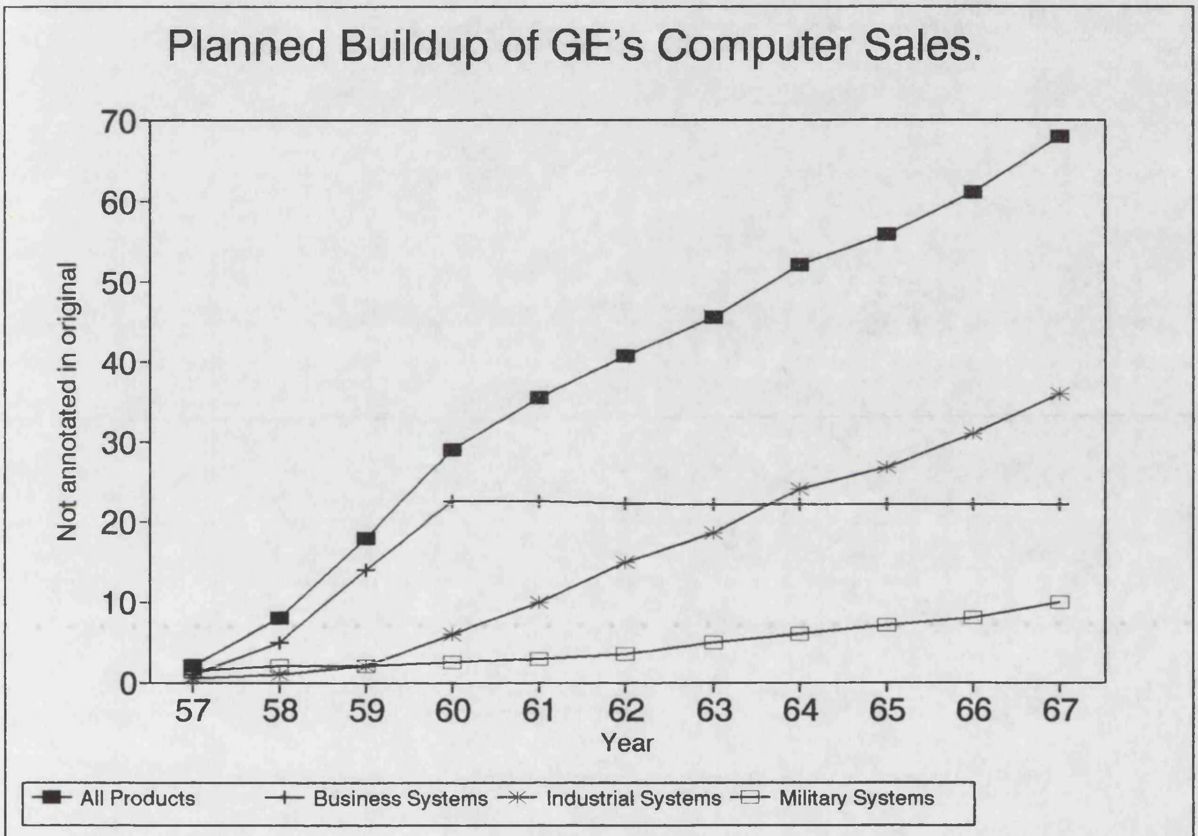
[48]CBI Jacobi collection, Clair Lasher 'marketing presentation', Product Scope Review, October 1957.

Figure 7.1



CBI Jacobi collection, Barney Olfield, "opening presentation" to the Product Scope Review Meeting, October 1957, slide 10.

The Computer Department told GE management that its main development projects were for industrial computers[49]. However, Oldfield had a plan to replace the electro-mechanical memory of the industrial control machine under development, with a magnetic core memory, a change which would make it suitable for commercial use[50]. When he succeeded Oldfield, Lasher prepared another product plan and persuaded the company that, given GE's work on the ERMA and 304 computers and the boom expected in the market, business machines were a worthwhile activity for GE. The process machine was given its core memory and became the 200 series of computers[51]. This was the first range of commercial systems to be all GE's own work and which it could market freely[52]. Lasher managed to get the uncertainty surrounding the department stopped. He was more of a company man and got permission to market the 200 series to commercial users, belatedly allowing the department to exploit the start made with the ERMA and 304.

Taking on IBM 1960-1965.

1)Hardware.

By the mid 1960s GE had four computer engineering groups at work. These covered the four main hardware products that the computer department was selling, the 200 series of computers, the 400 range, the 600 range and peripherals. This decentralised approach to engineering led to a number of problems, not least of which was lack of compatibility between systems.

The 200 series.

Following the banking systems, GE turned to general purpose systems applicable to both scientific calculation and business use. The first computer which GE had sole responsibility for was the GE225[53]. The 225 was based on a process control computer, the 312, which, with a magnetic core memory instead of a magnetic drum, proved suitable for commercial

[49]CBI Jacobi collection, K.H. Geiser, Manager of Engineering, 'engineering presentation', Product Scope Review Meeting, 1957.

[50]Snively, 'GE enters the computer business', Annals of the history of computing.

[51]Ibid.

[52]Ibid.

[53]Snively, 'GE enters the computer business', Annals of the history of computing'.

application[54].

The 225 was seen by Datamation as GE's long awaited entry into the general computer market[55]. No longer was it just making special purpose machines or sub-contracted systems. It was expected that GE would use the unveiling of the 225 to reduce the $12m rental bill it paid IBM each year for its leased computers[56]. In fact GE used its experience as a computer user as an advertising gimmick. The 225 was initially sold for scientific duty, which was of most use to GE internally[57]. However the development of the commercial application programming language, GECOM, led to it being used in many commercial environments. Weil believed this language was a timely product, which was a predecessor of the standard business language COBOL[58].

The 225 was the most successful of GE's early machines. It was announced in June 1960 and first delivered in April 1961[59]. It was a small to medium scale system. By 1966 the system had been extended to include a number of smaller and larger variations:

Table 7.4 Sales of the GE 200 series up to 1966

	Installed	On Order
205	42	10
215	53	3
225	139	2
235	60	8

Source: US vs IBM, px4462, IBM 'competitive environment', 1966.

The 215 and 235 were updated machines introducing better components, an improved arithmetic unit for scientific use and better peripherals for the business user[60].

The engineering group that was in charge of the 200 machines was also

[54]Datamation, March/April 1959, p18.

[55]Datamation, July/August 1960, 'Datamation in business and Science', pp11-12.

[56]Ibid.

[57]US vs IBM, tr7007, Weil.

[58]Ibid, tr7262.

[59]US vs IBM, px4462, IBM, 'Competitive Environment', 4/2/66. This was a survey of IBM's competitors.

[60]US vs IBM, tr7172, Weil.

placed in charge of supporting ERMA, and its follow up, the 210[61], of which 53 were sold from 1959 to the mid-1960s[62]. It also looked after development of the Datanet 30 communications processor, which will be discussed later. By 1963 the 200 range had given GE 2% of the computer market[63]. It was to remain important to GE for the rest of the Computer Department's life, as it was one of the key machines in GE's time-sharing and service operations.

The 400 series.

At the same time as the small and medium scale 200s were being updated, another GE engineering group was bringing the medium scale 400 series to the market. The range was announced as the 425, 435, 455 and 465[64], and in advertising the range was nick-named the 'compatibles'[65]. During this period IBM believed GE was making a direct assault on its market[66]. From 1963-66 IBM judged that GE was trying to establish a strong position in the computer market. IBM saw this as a major threat because of GE's huge financial resources. The 400 led this drive, being the most comparable range to IBM's 360 family[67], though its design predated the 360. However, the range never fulfilled its expectations, a number of the machines were never delivered and, while the 400s were compatible within the family, they were not compatible with any other GE range.

The larger members of the family were not delivered. They were discontinued due to competition from other developments within the department. While IBM decided to cover as much of the computer market as possible with the 360, GE dropped the larger 400 series machines for a wholly unconnected series:

> 'The machine reached the point where a prototype existed on the manufacturing floor, I believe that continued business examination, plus continued competition for resources in the Computer Department by the other computer lines--specifically the

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[61]Ibid tr7176.

[62]US vs IBM, px4462, IBM, 'Competitive environment', 1966.

[63]US vs IBM, px321, GE, 'Computer Department Presentation to Executive Office', April 20 1965, chart 12.

[64]US vs IBM, tr7178, Weil.

[65]US vs IBM, dx490, GE press release 3/12/63.

[66]US vs IBM, px3222, IBM Market Evaluation Department, 'A company study of General Electric' December 1968.

[67]US vs IBM, px4462, IBM, 'Competitive Environment', 1966.

600--eventually came to the point where the development of this second [larger] member of the 400 family was abandoned.'[68]

Instead of extending the range up, this second generation system was given a smaller cousin, the 415[69]. The 400s were general purpose machines, though they were seen as particularly relevant to the business user. Despite IBM's concern that the 400 range and GE's resources represented a major competitive combination, the initial marketing of the 400 was not a great success. By 1966 only 255 were installed and 137 were on order, not a large base for the time[70]. GE had reacted to this lack of sales and the announcement of the IBM 360 family by cutting prices, but sales were still limited. Much of the problem was that, as already mentioned, the GE range of computers was far from being 'compatible'. The 400 was not compatible with the older 200 range, nor with the other GE ranges, the larger 600 series, and the smaller 115 range that was delivered later in the decade[71]. This was completely out of step with the growing compatibility within other firms' ranges and also affected the level of economies of scale that GE could achieve.

The 400 did contribute to a slow rise in GE's market share and it did outsell previous products. Nevertheless, sales were not high enough to achieve GE's goal of capturing 10% of the computer market (the 400 had been the main hope of achieving this target)[72].

The 600 series and peripherals.

The third of the four engineering groups within the Computer Department was headed by J.W.Weil. Its role was to develop a system that was a larger, multi-processor computer designed for scientific work. Again, it had the title 'Compatible' yet it was not compatible with any other GE system. Like the 400 series, it was largely designed before the IBM 360 and was basically a second generation system[73]. It had, however, an advanced architecture with a number of features that made it uniquely attractive in a number of applications.

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[68] US vs IBM, tr7182, Weil.

[69] US vs IBM, px4462, IBM, 'Competitive Environment', 1966.

[70] Ibid.

[71] Ibid.

[72] US vs IBM, px321, GE, 'Computer Department Presentation to the Executive Office', 20/4/65.

[73] US vs IBM, tr7192, Weil.

The 600 range had two lineages. The first line of development was the M-236, a computer developed by the Heavy Military Electronics Department[74]. The M-236 was produced for the control of large strategic radar systems using 'wired logic' and had facilities for the real-time control of such a system. Responsibility for the project was transferred from Syracuse to Phoenix and Weil's engineering group. The 600 series reflected the architecture and component design of the M-236. One area of overlap was the memory organisation, which not only allowed for real-time applications but also helped in developing so called time-shared computers[75]. The 600s were to become the corner stone of GE's time-sharing[76] and service bureau developments, which is discussed below.

The second branch of its ancestry came from its being targeted to replace the large number of IBM 7090/7094 scientific computers:

> '...the machine was basically a scientific machine derived from the 7090/7094.'[77]
>
> '... what we were doing was trying to displace equipment of the 7090 family that was already installed.'[78]

GE had targeted a market for which it was a major customer itself; it had a large internal demand for scientific computing power. The design of the GECOS operating system was 'based heavily on the knowledge we had as users of IBM 7090 and 7094 scale equipment'[79]. The 600 was nearly program compatible with the 7090 machines, and was given something of a boost when it became clear that the 360 was not backwardly compatible with old IBM systems. It was not as easy to transfer from a 7090/94 to a 360 as it was to move to the GE 600. GE's plan was to offer 7090 users a better price:performance ratio than their current machines, while avoiding the large reprogramming task needed to upgrade to the IBM 360 family. A GE635 offered 4-5 times the performance of the IBM 7090, at 20% less cost[80].

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[74]Ibid, tr7178.

[75]US vs IBM, px1205, internal IBM discussion paper on GE's success in time-sharing.

[76]Time-shared computers allow many, inter-active, users to access a computer at the same time.

[77]US vs IBM, tr7192, Weil.

[78]Ibid, tr7213.

[79]Ibid, tr7217.

[80]CBI Archive, International Data Publishing Co, EDP Industry and Market Report, 15/7/64, pp1-5.

Honeywell received a similar windfall for its 200 range which was compatible with IBM's main second generation business computer, the 1401[81].

This strategy was successful as 'the initial acceptance' of the 600 series was good[82]. The first members of the range, the 625 and 635, were joined by the smaller 605 and 615, but the large scale, time-shared 645 was never sold commercially[83].

Initially sales of the larger IBM 360 machines were comparatively weak, one reason being incompatibility with the 7090/94. IBM reacted to this by announcing 12 hardware emulators for older systems. One of the great advantages of the 360 was that it could use Read Only Memory and could emulate other systems fairly efficiently. This mitigated some of the 600 series' advantage.

Apart from the failure to market the 645 there were other less successful aspects of the 600 project. Despite the fact that GE had its own components division it could not produce the memory sub-systems of the 600. The Oklahoma City based Memory Equipment Department supplied ferrite cores for the 200 and 400 series, but was not able to supply the faster 600 memories. These were bought from Fabritek, Lockheed, and Ampex[84].

The biggest crisis for the 600 series was its suspension from the market during 1966/7[85]. There were two reasons for this. Firstly 600 computers proved very difficult to maintain in the field, with a lot of down-time. Secondly the installed machines were failing to deliver the computing power that had been advertised for them[86]. The 615, 625 and 635 delivery programmes were suspended to sort out the problems. The suspension led to a number of redundancies at the Phoenix factories and undermined morale in the organisation. The 600 series had been very much the flagship of GE's range[87], so its failure was a big blow to the firm. It also had

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[81]See below, chapter 8, pp354-358.

[82]US vs IBM, px4829, Arthur D. Little inc., 'The computer industry-the next five years', October 1964.

[83]See below, pp274-276.

[84]US vs IBM, px3222, IBM 'A company study of GE' 1968.

[85]Ibid; Tr7222-6, John Weil.

[86]IDC, EDP Industry and Market Report, 12/1/67, pp4-5.

[87]US vs IBM, px3222, IBM 'A company study of GE' 1968.

a negative effect on the profitability of the computer operation[88].

The fourth of the Computer Department's engineering groups had responsibility for developing peripheral equipment. Despite the existence of this unit, GE, like RCA, had problems supplying electro-mechanical peripherals. One of the major problems was mass storage disc drives, a critical element in a mainframe system. For a number of years Burroughs, and to a lesser extent CDC, supplied these devices to GE[89]. In 1968 GE finally started to supply its own IBM 2311-compatible disc drives. These drives were used on its own systems and were also sold to the leasing company Greyhound, which marketed them to IBM 360 users[90]. However, by the time these were supplied, IBM was releasing new drives which GE was not able to keep up with.

2)Time-sharing equipment and services.

One of the brightest spots in GE's computer portfolio was the advances it made in interactive, time-shared computer systems. GE became involved in two of the premier conceptual developments in computing in the 1960s. Time-sharing allowed multiple users to use a mainframe computer in real-time, running their own programs and getting results, without ever knowing that other users were simultaneously on the system. This was a great advance over batch processing where programs and data had to be entered sequentially on magnetic tape or punch cards. Batch processing was a particular handicap for engineers and program developers who had to wait a long time to find out whether programs worked, making debugging a slow process. The scientific community wanted an interactive form of computing to overcome these problems. Centralised time-shared computers were seen as the answer. At this time it was not thought that distributed resources in the form of minicomputers were an economic solution; only later in the 1960s did DEC and SDS start to prove that, in fact, the minicomputer was a viable option.

[88]US vs IBM, tr8339, Ingersoll, financial manager of the computer operation 1967-1969.

[89]IDC, EDP Industry and Market Report, 30/4/64, pp3-4.

[90]US vs IBM, px3222, IBM 'A company study of GE', 1968.

Dartmouth System.

The simpler, but commercially most successful, of GE's time-share systems was developed from work done at Dartmouth College[91]. In the early 1960s the college developed a language and operating system called Dartmouth BASIC, probably the most famous computer language ever. It was produced using a GE 225 and was picked up by GE's Valley Forge Missile and Space Division for its own engineering design work[92]. The Missile and Space Division started to offer time on its system to other companies in its area. With the success of this ad-hoc service bureau, the Computer Division started marketing a fully engineered version to outside users and started to develop a computer bureau service itself[93]. The machine it was selling and operating was known as the 265. This was basically a second generation 235 computer, coupled with GE's communications computer, the DataNet 30, which handled all the input-output routines. By 1968 the system could handle 40 simultaneous users and had a library of 400 programs[94]. This development kept the second generation GE200 in operation for a lot longer than would otherwise been the case. Even in 1968 there was still a small demand for these units[95].

The same system was also implemented on the 420 and 635. The main marketing emphasis was placed on the GE635 which could interact with 120 users simultaneously. They offered the same suite of programs as the 265. Indeed both systems were used in the network run by GE; the user did not know which system he was using, except that there was a larger charge for using the faster 635[96].

MULTICS System.

The second time-sharing development was also a windfall from outside. It was a highly prestigious venture, though it led to few commercial sales. In 1964 the Massachusetts Institute of Technology was the USA's leading centre for real-time computing and arguably it was the leading academic computing hub. MIT's labs had developed many important computer systems, especially in the area of air defence systems, including the Whirlwind and

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[91] <u>US vs IBM</u>, tr7107, Weil.

[92] <u>US vs IBM</u>, px3222, IBM 'A company study of GE' 1968.

[93] Ibid.

[94] Ibid.

[95] Ibid.

[96] Ibid.

SAGE systems. SAGE was the huge computerized North American continental air defence environment, by far the largest computer project in the 1950s and 1960s. MIT was interested in improving the efficiency of engineers working on such projects. One method of doing this was to use a time-shared computer. MIT established a programme called Project MAC to develop the MULTICS operating system. This was an effort to produce a highly complex operating system, to give engineers the most sophisticated operating environment to work in. The project was funded by the Defence Advanced Research Projects Agency. DARPA had been formed to coordinate and fund basic research for all the US armed forces, so was also very interested in improving scientific productivity.

A number of companies competed for what was one of the most talked about computer projects in the country[97]. MULTICS called for huge processing power and a number of hardware refinements, especially in the area of memory. To get its 635 and DataNet equipment chosen GE had to fight off strong challenges, notably from IBM, DEC and CDC. GE could offer a more suitable system: the 635 which, thanks to its military lineage and supporting DataNet 30, offered more of the necessary features in terms of communications and memory management[98].

GE announced the combination of the 635 and DataNet 30, together with the many modifications and enhancements required by MIT, as the 645[99]. The first and only sale of the system outside of MIT and GE was to AT&T's Bell Laboratories, which was the world's leading commercial research centre. Bell Labs was also interested in improving efficiency and the way in which computers worked with engineers. IBM was worried that there was a snowball effect behind these prestigious orders and that GE was a threat[100].

However, MULTICS was a research project, the 645 system was not commercially marketed[101]. MULTICS was not delivered until after GE had sold its computer operation to Honeywell, and then it only had a few users. The Bell Laboratories recognised just how large and complex MULTICS was

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[97]US vs IBM, px1246, The Wall Street Journal 18/11/64. A copy of this article on the replacement of IBM computers with GE systems at AT&T's Bell Labs was sent to IBM's top executives with a memo recommending that it be kept on their desks until IBM had captured the lead in time-sharing.

[98]US vs IBM, px1205, IBM internal discussion paper, 18/6/64.

[99]US vs IBM, tr7108, Weil.

[100]US vs IBM, px1205, IBM internal discussions paper 18/9/64.

[101]US vs IBM, tr7234, Weil.

turning out to be, and withdrew its engineers from the project, setting them to work producing a stripped down operating system called UNIX, which is now the dominant scientific and mini computer operating environment. Nonetheless, the 645 gave prestige to GE and added lustre to the time-share computers based on the less sophisticated, but immediately workable, Dartmouth system.

Sales of time-share computers and services.

In 1968 an IBM report noted the rapid growth in time-share systems sales[102]. It was estimated that in 1965 there were only 6 such machines, 12 in 1966 and 100 at the end of 1968, 50 of which were delivered in the first 6 months of 1968. IBM estimated that GE had installed just over half of the total. On top of this, GE was the leader in time-share bureau services. These services offered customers a terminal in their premises which allowed them to communicate with a remote time-shared computer. GE had 3000 terminals in the field, 800 within GE and 2200 with outside clients.

Revenue growth from the bureau service had been spectacular. In 1965 GE was expecting to sell $10m worth of services, and expected this to grow to over $40m by 1970[103]. However, by IBM estimates, the bureau service market had reached $50m by 1967, of which GE was estimated to have $30m. In 1968 IBM expected the market to reach $100m, with GE maintaining its 60% stake. The one problem GE had with this market was the failure to get a return on its work with MIT and MULTICS, but the Dartmouth based 200 and 400 machines were successful and put it ahead of IBM in this one area.

3)International Expansion.

Potentially GE's overseas operations offered even greater reward than its leadership in time-sharing; however, this potential came to nothing. Outside of the USA, IBM identified GE and ICT/L as its main competitors. Unlike RCA, which used licensees to sell its equipment abroad, GE bought foreign computer companies as a way of directly entering overseas markets. The two operations that it controlled were the computer arm of the Italian firm, Olivetti, and a 66% holding in French firm Bull[104]. These two acquisitions greatly decreased GE's reliance on the USA computer market:

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[102]US vs IBM px3222, IBM 'A company study of GE', 1968.

[103]US vs IBM, px321, GE, 'Computer Department Presentation to the Executive Office' 20/4/65.

[104]US vs IBM, px3222, IBM, 'A company study of GE', 1968.

Table 7.5 GE's share of national computer markets, 1968.

Country	Total size of national market in Points[1] '000s	% of world computer market.	GE's share of national market.	% of GE's total computer activity.
U.S.A.	128,166	62.1	6.2	37.2
France	10,977	5.3	45.3	23.4
Italy	3,435	1.7	62.8	10.2
Germany	8,336	4.0	17.2	6.7
Netherlands	1,979	1.0	31.2	2.9
Belgium	1,161	.6	52.1	2.8
Switzerland	2,516	1.2	18.8	2.2
U.K.	18,463	8.9	1.9	1.7
Sweden	1,845	.9	19.0	1.6
Spain	1,061	.5	31.4	1.6
Canada	3,992	1.9	5.9	1.1
Mexico	527	.3	44.2	1.1
Austria	481	.2	42.6	1.0
Japan	13,605	6.6	1.4	.9
Australia	2,192	1.1	8.4	.9
Argentina	414	.2	44.2	.9
Others[2]	7,281	3.5	11.2	3.8
Total	206,431	100.0	10.3	100

1)IBM measured market share in points, 1 point was the equivalent to $1 of monthly income received if all equipment installed was leased.
2)16 countries none over 150,000 points.
3)IBM's estimate that GE had 10.3% of the world market seems too high compared to other evidence, GE's own estimates never put them above 5% of worldwide shipments.

Source: US vs IBM, px3222, IBM 'A company history of the General Electric Corporation' 1968.

Bull and Olivetti brought more than just local market share to GE. Bull had a large range of systems called GAMMA computers, the smaller systems of which had sold reasonably well in Europe[105]. Bull also had expertise in punched card and printer devices which could have strengthened GE's peripheral activities. Later both firms designed computers which were added to GE's worldwide range. These were Olivetti's successful small computer, the GE115[106], and the, even smaller Bull/GE 50.

However, there were also problems, especially at Bull. Bull had completely lost control of costs. It produced a large range of computer and punched card equipment; costs of maintaining such a wide range had got out of hand. Bull had even added to its cost burdens by undertaking an abortive super-computer project. Its range of computers was very old and sales slowing down. Even its new machines were outmoded: for example the GAMMA

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[105] 'Bull's rule in Europe', Datamation, September 1961, pp30-3.

[106] IDC, EDP Industry and Market Report, 18/3/65, pp1-3.

300 system, released in 1961, still relied on drum memory[107]. GE had a great deal of trouble in cutting Bull's high cost base: Bull employed 11,500 compared to GE's own Computer Department which employed 9,500. However, staff were difficult to cut as the French state put pressure on GE not to make cuts; costs at Bull remained a continual problem for the firm[108].

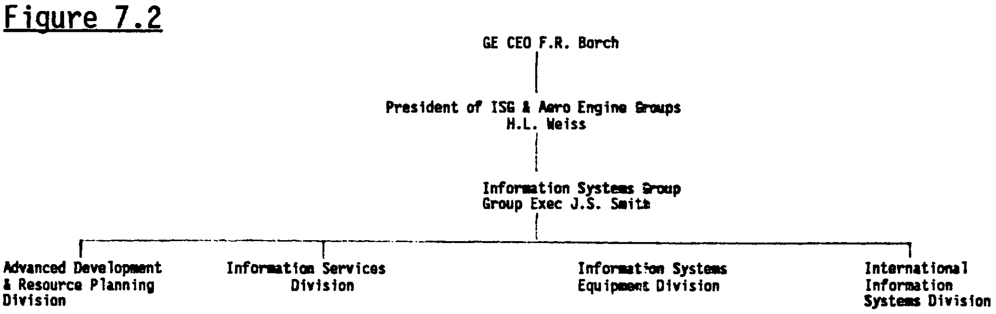
However, an even greater failure was GE's inability to integrate its overseas acquisitions with its four US-based computer engineering groups. This in turn led to lack of control over expenditure. Each part of GE was engaged in its own development and production work, with little coordination. Failure to integrate these activities meant that it was not achieving the economies of scale that were possible. By 1968 IBM estimated that GE had invested $100m in its overseas affiliates, but due to its incompetent management it had failed to achieve a profit from these assets[109].

<u>Product failure and retrenchment.</u>

<u>1)The inability to unify the product range.</u>

Undoubtedly GE had an interesting computer portfolio. Not only did it have the usual hardware and software organisations, but it also had the second largest international presence and the innovative time-sharing and bureau activities. During the mid-1960s GE undertook its first major re-structuring programme since the decentralisation policy of the early 1950s. As a part of these changes it attempted, but failed, to pull its disparate computer activities together. The number of operating groups was increased from five to ten, one of which was the Information Systems Group (ISG), the structure of which is shown below:

<u>Figure 7.2</u>



Source: 1967 Annual Report.

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[107]'Bull's 300 Series', <u>Datamation,</u> November 1961, p47.

[108]<u>US vs IBM</u> px3222, IBM, 'A company study of GE', 1968.

[109]Ibid.

While this structure seems logical, the reality was very different: this was only a paper organisation. GE completely failed to integrate the operations of its various arms. Responsibility for hardware was split between the US Information Systems Equipment Division and the International Information Systems Division, and the reality was that there were many more sub-divisions that were not working together. The main problem this created was that attempts to unify the hardware architecture that GE used, to cut development costs and to achieve scale economies from producing common components, all failed. Table 7.6 shows that GE continued to support a very complex range of incompatible computers:

Table 7.6 GE products; breakdown by nation.

Domestic:	Large Scale	600-sold and manufactured
	Medium Scale	400-sold and manufactured
		200-support for installed machines
	Small Scale	115-marketing only
		50-marketing only
France	Large Scale	600-marketing only
	Medium Scale	400-marketing (and manufacturing?)
	Small Scale	50-sold and manufactured
		Gamma 10-sold and manufactured
		Gamma 55-sold and manufactured
		Unit Record Accounting Machine
		Punched Card machinery
Italy	Large Scale	600-marketing only
	Medium Scale	400-marketing only
	Small Scale	115-sold and manufactured
		130-sold and manufactured

Source: US vs IBM, px3222, IBM, 'A company history of the General Electric Corporation', 1968.

In general large and medium scale systems were the responsibility of the US operations, while Europe looked after the small machines. However Bull had to support its established base of medium scale GAMMA users, and may have manufactured some of the GE400 systems sold in Europe. At one time France was given responsibility for developing medium-sized computers[110].

All of GE's large range of systems were incompatible with each other. ICT had had a similar problem after it had acquired the operations of Ferranti and EMI. ICT tackled it by unifying all its development on the 1900 architecture. GE never managed to achieve this and failed to produce a single unified line, despite wasting resources on a number of false

[110] US vs IBM, tr7241, Weil.

starts.

GE started at least three programmes to replace the whole of its range with a single compatible family. In fact the first plan for a single range of machines to cover the whole of the computer market predated the 400 and 600 lines. In 1962 a team in Phoenix studied a series of machines dubbed the WXYZ range[111]. Of these only the middle ones, the X and Y, were seriously studied. The X machine became the 400 series, but the Y was cancelled in favour of the 600 project, based as it was on military work. GE came up with the term 'The Compatibles' to describe its 200 series and used the same term for the 400 and 600 ranges. This was only lip service to the concept. The concept of the WXYZ series was ahead of the rest of the market, but decentralisation of development into four separate development groups seems to have worked against the idea of a unified range.

After the purchase of the European firms and following the announcement of the IBM 360 family, GE once again turned its attention to producing an integrated range of computers. During 1964-66 Lou Raeder, the general manager of the computer operation, supported a programme to develop a single, worldwide, range of systems[112]. It was christened the 100 Line and was to build on the perceived strengths GE's disparate computer teams:

> 'The 100 line had a series of processors. They were to some extent oriented in the same directions that the IBM 360 had been oriented. It was an eight bit byte machine and consisted primarily of three sets of processors, the smallest of which were to be manufactured in Italy, the medium scale ones were to be manufactured in France, and the larger scale ones were to be designed and manufactured in the US, in Phoenix.'[113]

The Computer Department hoped that such a range could increase its share of the market from 3% to 10%[114].

IBM also developed a system by which design responsibility could be divided internationally. However, this was done within a framework of tight central control over basic architecture and design protocols to ensure complete compatibility. Nothing was said about how this was to be achieved within GE.

The whole concept of the 100 line came into question in 1966 when

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[111] Ibid tr7238.

[112] Ibid, tr7240.

[113] Ibid, tr7240.

[114] <u>US vs IBM</u>, px321, GE, 'Computer Department Presentation to the Executive Office', 20/4/65.

Hershner Cross took over the operation[115]. His first act was to put the 600 series into hibernation until its problems had been sorted out. His second act was to call for an assessment of the 100 plan:

> '..a study was called at Crononville, New York, at GE's installation there, the worldwide marketing and engineering and general management [were] involved.
>
> We broke up into work groups, studied the 100 line versus the then existing 400 lines, and we were asked to recommend should we continue with our existing lines worldwide or should we actually go ahead with the 100 line.
>
> All the study groups recommended we go ahead with the 100 line...Hershner Cross overruled all the study groups and decided that the 100 line would be abandoned, I assume for resource reasons.'[116]

The Italian operation ignored this and went ahead with its small machine, the GE115. Weil believes that this was because the Italian operation had a strong general manager who was willing to take personal responsibility. When the range was cancelled, the French unit had already secured 15 orders for its 140 and 145, but these were cancelled and emphasis in Europe was placed on the old GE400[117]. However, the 115 was marketed worldwide and greatly bolstered GE's otherwise weak low end machines. It was the only GE computer to sell over one thousand systems[118].

Following the failure to establish the 100 line as the worldwide GE architecture another study, Project Charley, was initiated in France. This was the design of a more advanced system than the 100, but with more or less the same role[119]. After a number of meetings in Paris nothing was decided save a few specifications.

Then came the E.R.W. study, named after the project manager Eugene R. White. The project was initiated by John Haanstra who had been appointed as head of development in the US in 1966[120]. Again it was a similar plan to the 100 Line and Project Charley. It also came to a dead end, mainly because Haanstra became to head of the Information Systems Division, with its emphasis on the GE600.

Plans for such a system were then dropped until the Advanced Product

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[115] US vs IBM, tr7240, Weil.

[116] Ibid, tr7241.

[117] IDC, EDP Industry and Market Report, 12/1/67, pp4-5.

[118] IDC, EDP Industry Report, 23/12/68, p10.

[119] US vs IBM, tr7242, Weil.

[120] US vs IBM, tr7243, Weil; px3222, IBM 'A company study of G.E.' 1968, unusually for GE it had imported Haanstra from IBM.

Line scheme[121]. The story of the APL is tied up with the story of GE's departure from the industry and will be considered later.

2) The policy of retrenchment.

From 1966 the disarray in the product line started materially to affect the position of the Information Systems Group, with increasing losses. In 1965 Hershner Cross took over from Lou Raeder as general manager and ended the 100 Line[122]. He also took the 600 off the market until its problems were sorted out. In late 1966 J.S. Smith took over and a policy of cost cutting was started[123]. The industry analysts, IDC, estimated that by 1967 GE lost $400m on its computer operations, $50m of which came from the first 18 months of the ownership of Bull[124]. The dropping of the 140 and 145 and the suspension of 600 series sales, allowed for a programme of cutbacks in France. The dropping of the 100 Line and the hold on the 600 series also allowed for cuts in the USA. Engineering, software development and marketing departments were cut back, leading to the loss of several hundred jobs. In Phoenix, 500 were laid off from manufacturing positions. Additionally, the Computer Research Laboratory, which dealt with fundamental research, was shut down altogether.

Another method of retrenchment was to concentrate on fewer vertical markets. One of the major ones chosen was banking. GE had remained stronger in this sector than others following ERMA, but it trailed IBM and Burroughs by a long way. GE hoped that it could win business from banks upgrading ERMA and 200 series systems[125]. The aim was to concentrate its marketing effort on fewer markets, building up its presence in these areas, while trimming marketing costs.

Despite the lay-offs and other cost cutting measures, IBM thought that GE still had cost problems, especially in France[126]. It believed that GE had not dealt with the duplication of research facilities across the US, French and Italian operations. Another problem was that pressure

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[121]US vs IBM, tr7615, R. Bloch. Bloch was one of the new personnel brought in from outside to break the log-jam in GE's computer operation. He had held a senior position in Honeywell and joined GE after a period with the consultants Auerbach Electronics Corp.

[122]Us vs IBM, tr7224, Weil.

[123]IDC, EDP Industry and Market Report, 12/1/67, pp4-5.

[124]Ibid.

[125]IDC, EDP Industry and Market Report, 23/2/67, pp4-5.

[126]US vs IBM, px3222, IBM 'A company study of the GE' 1968.

from the French government had restricted the number of redundancies that had been made there[127]. In IBM's view, GE had been inept in its handling of its excellent opportunity in the international market[128]. It had old products, which were not selling well enough to utilise the large facilities and personnel that it had. Only the 115 was a modern machine. Costs were a major problem but these problems were being exacerbated by the lack of modern machines; no matter how efficient GE became it would still be unable to sell these old systems.

By 1968 all these problems had further damaged ISG's bottom line performance. Despite the efficiency drive, GE's market share was declining. IBM gauged that in 1967-8 GE's US operation actually saw a fall in sales of 3%, while its international sales grew by only 11%, against an average market growth rate of 25%[129].

Despite all these problems, IBM concluded that in 1968 GE was not going to leave the industry: rather the opposite, it expected GE to try to justify the $400m it had already lost by investing in a new internationally competitive system. With GE's vast resources, IBM expected it to make one final effort to bring the whole operation together. The new head of ISG, J.S. Smith, was seen by IBM as one of GE's most successful managers, having already turned the Outdoor Lighting Department around[130]. He bought in new managers, managers that had expertise in computers, such as Bloch and Haanstra. The oft-quoted GE adage, 'A good manager, no matter what his background, can manage anything'[131], seems to have been wearing thin.

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[127]Ibid.

[128]Ibid.

[129]Ibid.

[130]Ibid.

[131]"GE's Edsel", Forbes, 1/4/67, p280.

Competition for funds and the decision to abandon computers.

During 1968-1971 two reports were written within GE which determined the future of both GE's Information Systems Division and the corporation as a whole. The rest of this chapter will look at the background to these two documents.

1)The Advanced Product Line.

In 1968 Bloch, head of the Advanced Development and Resource Planning Division, started work on the 'APL Master Plan'[132]. The APL was GE's plan to make the one final push in the market that IBM was predicting. The aim was to take the company into a strong number two position in the industry[133]. The plan called for GE to build on its current user base and to attack IBM directly.

Before the APL plan was finalised there was an extensive consultation period. In April 1969 Bloch's Division presented a plan to the Information Systems Strategy Board, calling for GE finally to launch a unified computer range and to try to achieve a 10% market share, seen as the minimum scale needed to compete with IBM[134]. The scale of such a project was immense. Total life time revenue was expected to be \$8.2bn, pre-tax profit was expected to be \$2.3bn[135]. The full APL plan showed that this would require a very big improvement in its market performance, which had been in decline:

Table 7.7 GE's share of the computer market, 1964-69.

% of shipments	1964	65	66	67	68	69
worldwide	2.1	2.5	5.0	4.2	3.6	3.9
U.S.A		4.2	2.5	2.9		

Source: US vs IBM, px353, 'APL Master Plan', 1/1/70.

Although rental income from the installed Current Product Line (CPL) was expected to pay for some of the APL development, the plan still called for a massive injection of funds into the ISG. Profits would take years to flow

[132]US vs IBM, px353, 'APL Master Plan', 1/1/70.

[133]US vs IBM, tr7636, Bloch.

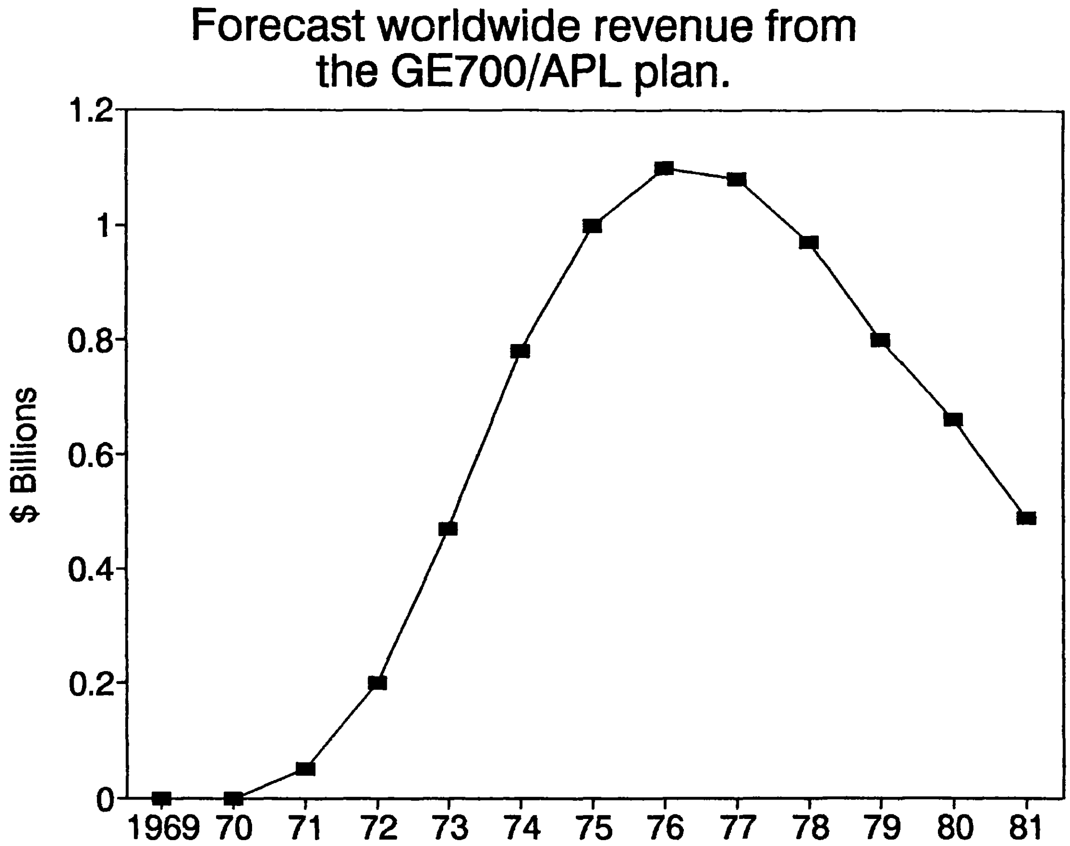
[134]US vs IBM, px322, 'Alternative Business Strategies, Presentation to Information Systems Strategy Board', 15/4/69.

[135]Ibid.

in, and cash flow would be negative until the mid-1970s. The large amount of cash and capital needed was not only to cover developing, building and selling the range, GE also had to fund a big increase in leases if it was to reach a 10% market share. The income from the CPL was not likely to cover much of this cost.

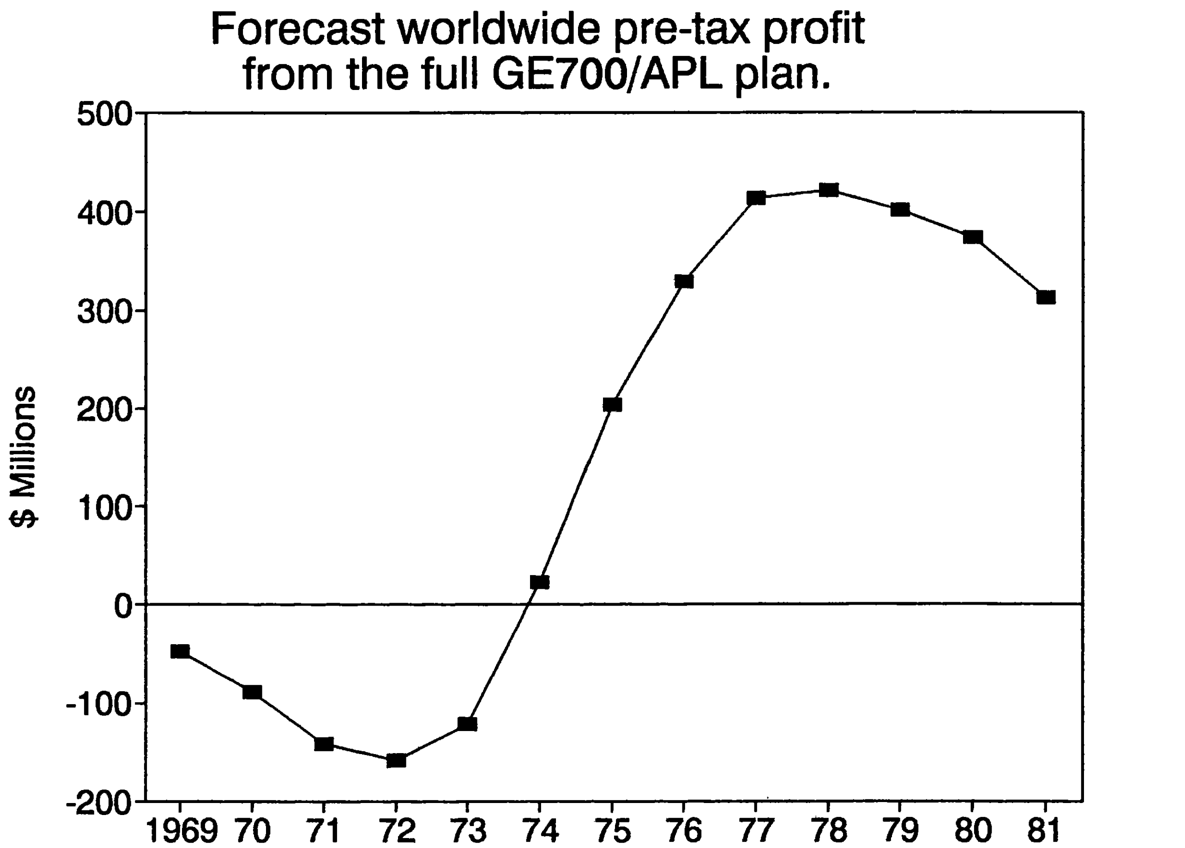
The following graphs show the effect the APL plan was expected to have on the finances of the Information Systems Group. 7.3 shows that the APL was expected to generate very large revenues. However, 7.4 shows that no profit could be expected from the APL until 1974, while 7.5 shows that the cumulative cash flow was expected to be negative until 1978. Finally figure 7.6 shows that the Information Systems Group as a whole was expected to be in loss until 1974:

Figure 7.3



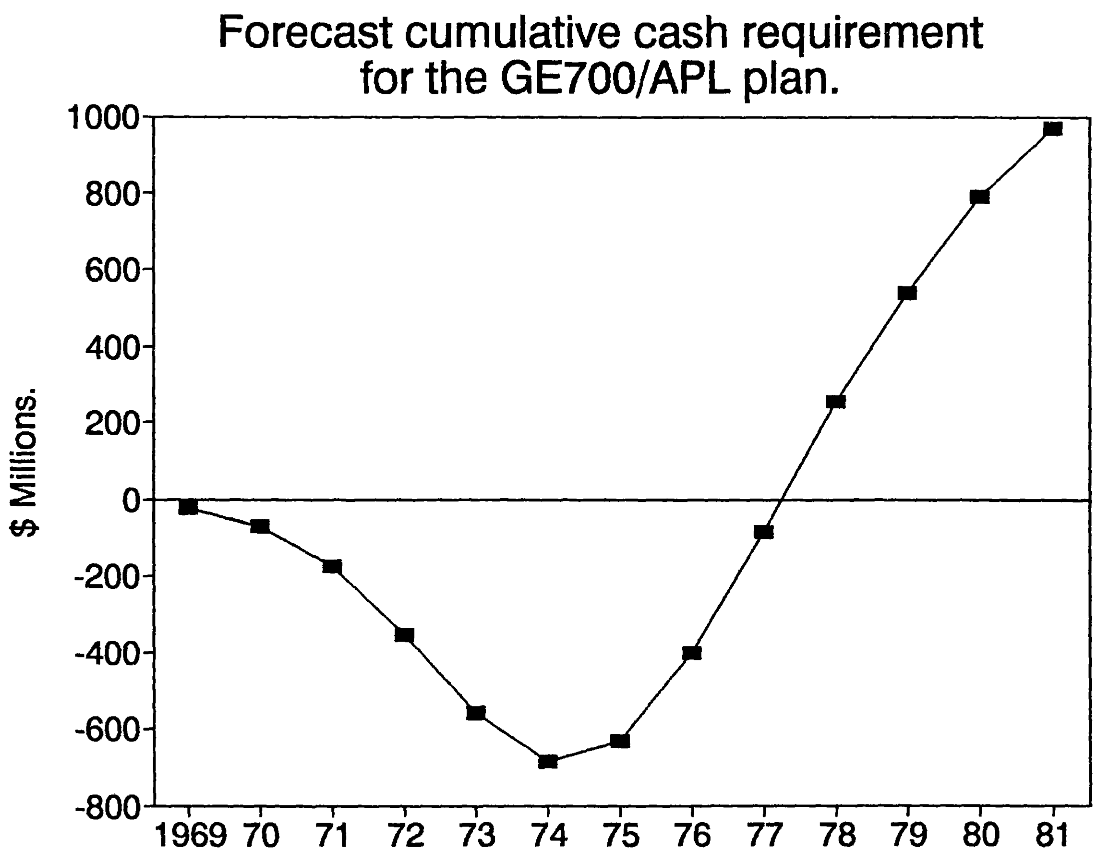
US vs IBM, px322, "Alternative Business Strategies, Presentation to the Board of the Information Systems Group", 15/4/69.

Figure 7.4



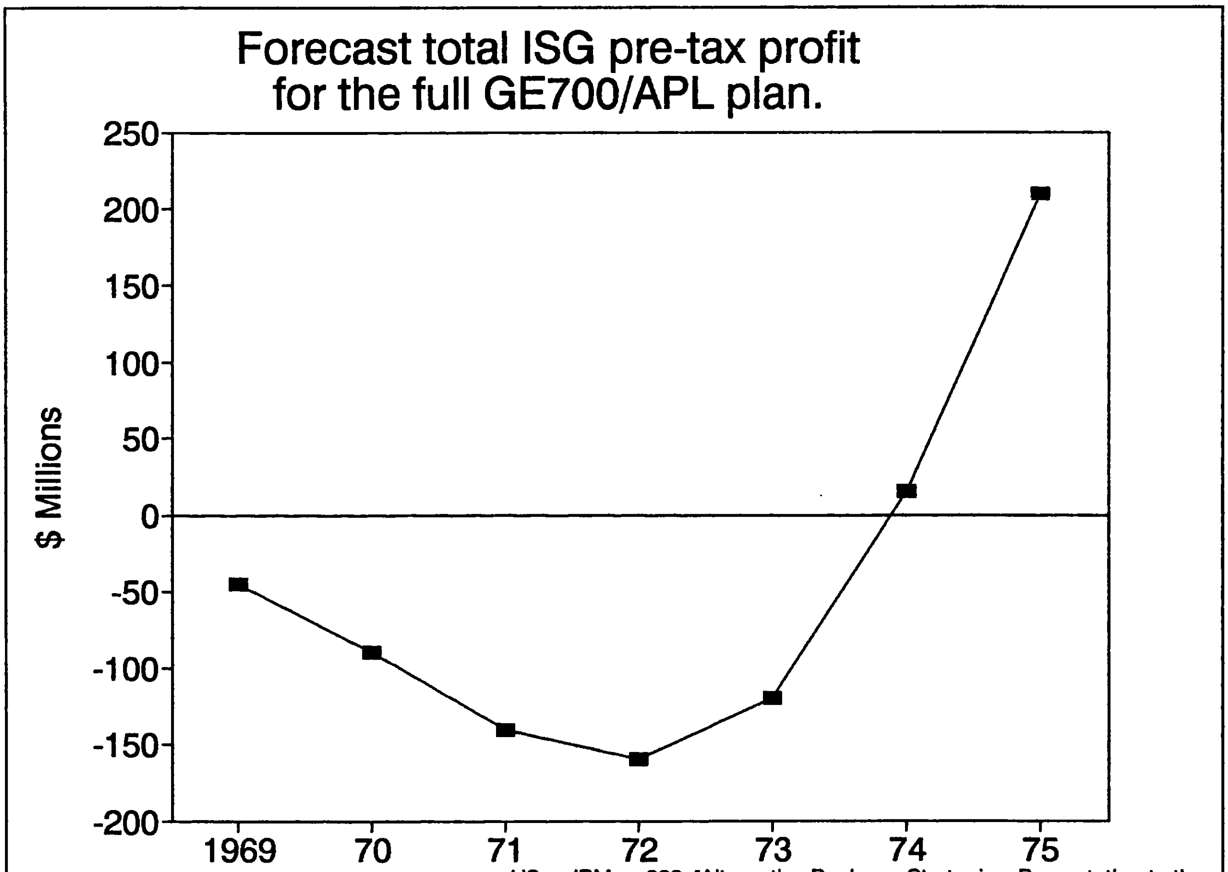
US vs IBM, px322, 'Alternative Business Strategies, Presentation to the Board of the Information Systems Group', 15/4/69.

Figure 7.5



US vs IBM, px322, 'Alternative Business Strategies, Presentation to the Board of the Information Systems Group', 15/4/69.

Figure 7.6



US vs IBM, px322, 'Alternative Business Strategies, Presentation to the Board of the Information Systems Group', 15/4/69.

2)The Ventures Task Force.

ISG had been a continuing drain on the corporation, but it represented only a small fraction of GE's vast electrical/electronics empire. However, the APL plan called for a much larger commitment. ISG was calling for the corporation to earmark computers as one of its 'Venture Activities', alongside GE's activities in civil nuclear power and civil aero-engines. All three were seen as markets that would grow much faster than the general economy, and as such would be allowed massive injections of capital to enable GE to capture significant stakes in these industries. Together the cost of supporting all three venture activities was huge, forcing GE to reassess whether it could support all of them. This reassessment was carried out by the Ventures Task Force. The Task Force was headed by R.H. Jones, a long time employee of GE, who later became CEO and Chairman, undoubtedly helped by his work on these reports[136].

The Task Force presented a number of reports to the board intended to assist them 'in evaluating the business proposition advanced by [the] Information Systems Group'[137]. The aim was to put the APL plan into the context of the whole company. Its work began in November 1969[138]. It started by interviewing a number of ISG staff to establish what the position of the Advanced Product Line was. It also took advice from outside the company, notably the computer industry consultants, A.D.Little and Diebold. Jones wanted to get an idea of where GE stood in the market and where the industry was going[139]. While most discussions centred directly on the likely outcome of the APL plan, this was done against a background of great concern about the ability of GE to fund any further major projects. There was a growing view in the company that GE's financial performance was not good. Over the period 1965-1969 earnings per share had fallen by nearly 25%[140] and as a consequence the company's share price had under-performed the rest of the market:

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[136]US vs IBM, tr8752, R.H.Jones.

[137]US vs IBM, px371A, Venture Task Force 'Preliminary Report on the Computer Business', 2/2/70.

[138]US vs IBM, px371, Ventures Task Force 'preliminary report'.

[139]Ibid.

[140]Ibid.

Table 7.8 GE stock performance.

GE stock price 1965-69	-26%
Dow-Jones Average	-17%
Westinghouse	-7%

Source: US vs IBM, px225, Ventures Task Force 'Preliminary report on [the] computer business' undated.

The policy of cancelling new computer lines, and the cuts in staff, had reduced losses. In the financial statement supplied by Honeywell to shareholders when it acquired GE's computer operation, losses are shown to have been reduced. However, as has been seen, this was done at the cost of new product lines, and the APL would have led to vast new losses:

Table 7.9 ISG sales and profit.

$m	1965	1966	1967	1968	1969
Sales & Rental	179.1	248.2	315.5	357.0	411.6
Pre-Tax Earnings	(74.6)	(101.8)	(58.5)	(29.6)	(.9)
Net Earnings	(39.6)	(55.8)	(42.5)	(11.4)	4.7

Source: US vs IBM, dx554, Honeywell, 'Statement to shareholders', 21/8/70.

Overall the GE Corporation had seen turnover continue to increase, but profit growth had been uninspiring in the late 1960s. Figures 7.7 shows how turnover had grown, while figure 7.8 shows how profits had been much more erratic:

Figure 7.7

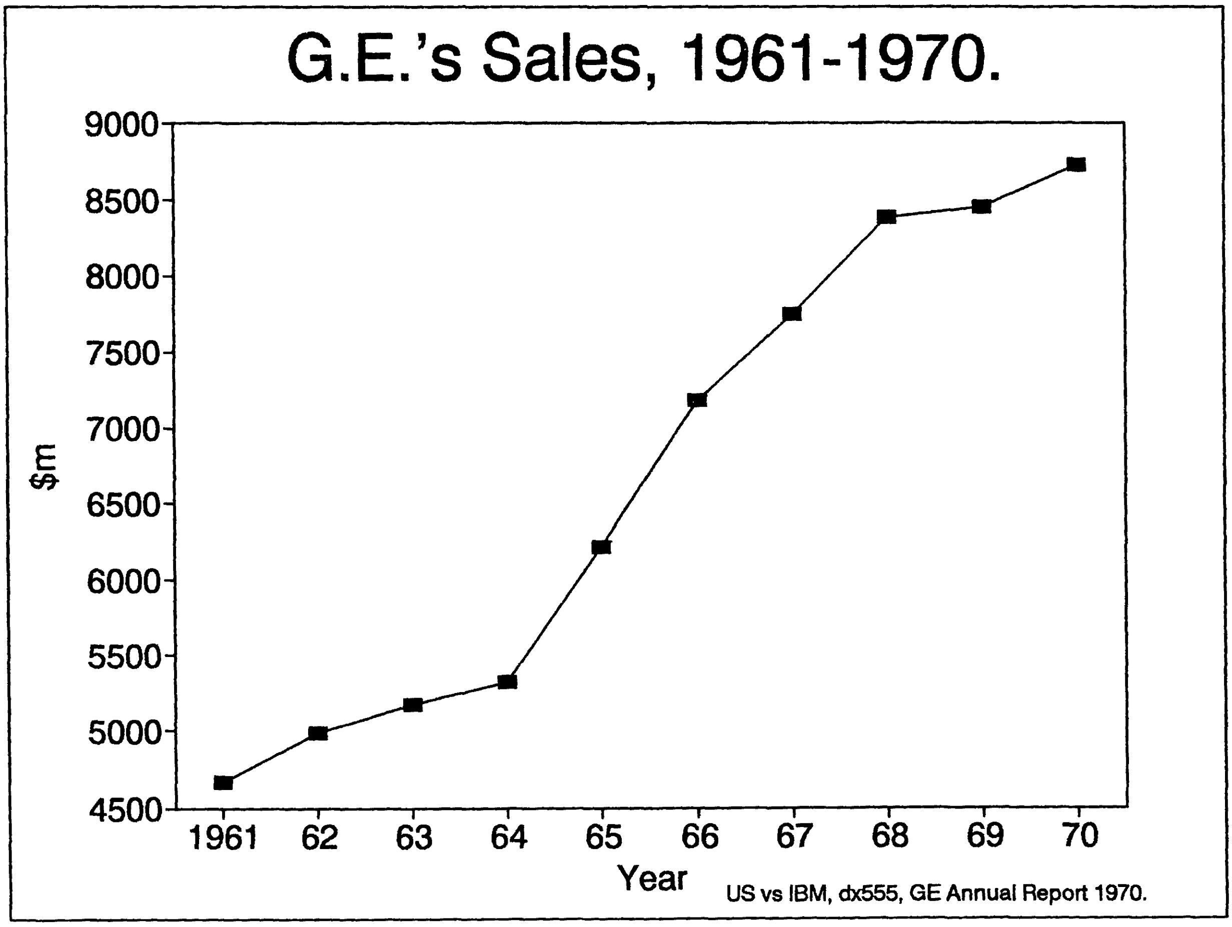
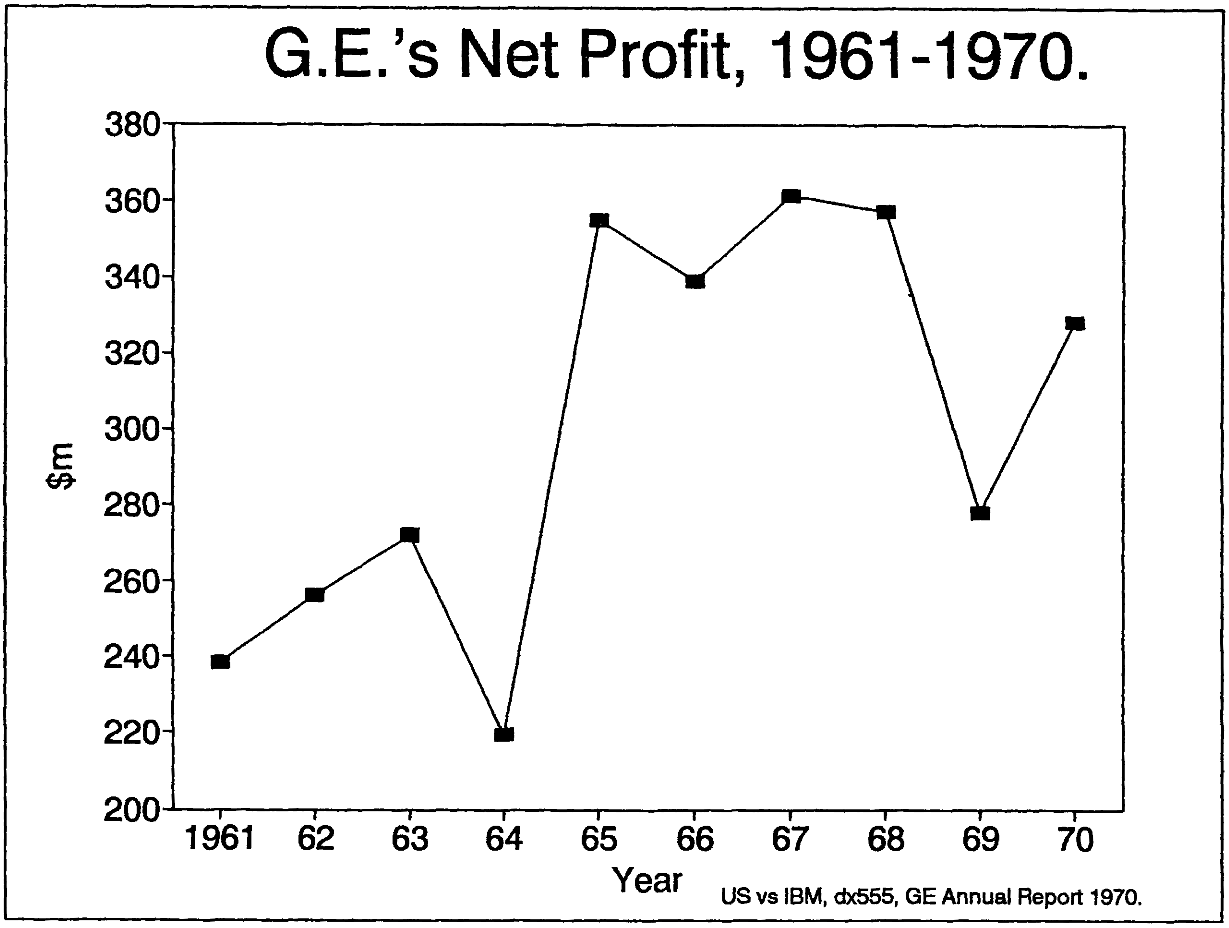

G.E.'s Sales, 1961-1970.
9000
8500
8000
7500
7000
6500
6000
5500
5000
4500
$m
1961
62
63
64
65
66
67
68
69
70
Year
US vs IBM, dx555, GE Annual Report 1970.

Figure 7.8


G.E.'s Net Profit, 1961-1970.
380
360
340
320
300
280
260
240
220
200
$m
1961
62
63
64
65
66
67
68
69
70
Year
US vs IBM, dx555, GE Annual Report 1970.

Against this background of poor profit performance, GE was faced with the prospect of funding three very large developments in the early 1970s. Even without the APL plan, GE was expecting greatly to increase its gearing ratio to pay for the other projects. The critical concern was the negative cash flow that the APL would cause. The other two venture activities were also expected to be cash hungry. In jet engines GE had been fairly successful, especially in supplying the engines for the military C5A Galaxy transporter, but it was finding it very difficult to make a profit from its commercial business, and expected to lose money on this operation for many years[141]. To improve its position in the civil market it was developing two new engines. One was for the new generation of 'airbuses'[142], wide bodied medium haul aircraft. The second development was for an engine to be used in supersonic passenger aircraft. IBM estimated that GE would not show a profit on its substantial engine investment until the mid-1970s.

The second major investment was in nuclear power. GE had a backlog of orders in 1968 worth $2bn[143]. By 1970, GE had completed or had on order 54 nuclear plants[144]. In 1970 alone 7 plants were completed[145]. To cope with this demand GE had invested $250m in the late 1960s[146]. However it was also suffering from large losses in nuclear power due to major cost overruns on 'turnkey' contracts[147]. These contracts were for complete power plants, for which GE was supplying the generating equipment and acting as civil engineer. The construction costs on these plants had been much higher than expected, leading to losses on the contracts and forcing GE to use an outside construction company for future work.

However, both nuclear power and civil jet engines were seen as areas of massive potential, at least matching that of computers. The Task Force concluded that:

> 'Beset with mounting pressures for immediate growth in earnings, carrying an inordinate load of losses from major risk ventures that have not sequentially offset each other's financial impacts as originally planned, and facing increasing financial

[141]<u>US vs IBM</u>, px3222, IBM, 'A company study of GE', 1968.

[142]Not the airbus of Airbus Industries but a generic term for the type of aircraft.

[143]<u>US vs IBM</u>, px3222, IBM 'A company study of GE', 1968.

[144]<u>US vs IBM</u>, dx555, Annual report 1970.

[145]Ibid.

[146]<u>US vs IBM</u>, px3222, IBM 'A company study of GE', 1968.

[147]<u>US vs IBM</u>, dx555, Annual Report 1970.

demands from its core businesses, [the] General Electric Company cannot undertake any half-billion dollar venture that produces substantial immediate net income losses.'[148]

This conclusion was reached before any of the weaknesses of the APL plan were considered.

When it came to the APL plan itself, the Task Force appears to have been more impressed with the niche strategies of other firms. Examples included Burroughs in banking (an area GE had lost), NCR in banking and retail and CDC in the scientific market, which were all carving out their own niches. However, the Task force recognised that ISG could not follow this path as its current user base was already very dispersed. It concluded that the target of 10% of the market could only be achieved by an across-the-board approach, or it risked losing its current user base. GE would have to take on the whole market, not only the general producers like IBM and Honeywell, but also those entrenched niche producers. The Task Force was also concerned that the APL plan did not take into account possible IBM reactions to being challenged by such a huge company across its whole product line.

Another problem was in ensuring that the APL offered significant price/performance advantages over IBM. If it could not do this it would be difficult to get customers to swap suppliers. ISG was looking for a 20% performance/price advantage over IBM. However, this seems to have been an impossible target. It was noted that in 1969 47% of ISG's costs were represented by manufacturing, as compared to 20% at IBM[149]. If IBM reduced its very high profit margins by even a small amount GE would be squeezed out.

The Ventures Task Force also thought that the APL plan was weak in some of its assumptions. The plan envisaged that by 1975 IBM's market share would have fallen from 66% to 59%, but this depended on vigorous anti-trust actions against IBM[150]. The plan also made very optimistic assumptions about the efficiency of the sales force it wanted to build:

'To reach our market position objective in [the] U.S.A. by 1975 [we] must increase [our] sales force 60-70% per year in size and must develop salesmen who are twice as productive [as] those of IBM'[151]

The Task Force did not hesitate to recommend the sale of ISG. It

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[148]US vs IBM, px371A, Ventures Task Force report to the CEO, 2/2/70.

[149]Ibid.

[150]Ibid.

[151]Ibid, quoting ISG executive T. Vanderslice.

recommended that the best potential buyer would be another generalist company, but one which had complementary strengths: Honeywell was recommended[152]. The Honeywell H200 was strong in the market for medium scale systems, while GE's 400 was weak and aging. In the area of large scale systems Honeywell was weak, and while the GE 600 had had its problems, it was back on sale and was a relatively advanced machine. It was argued that they were only competitive in the area of small scale machines. Importantly both firms were in need of a new range of machines: it would be cheaper to develop one system for both companies.

The decision to leave the industry was taken soon after the Task Force's recommendation. Honeywell and GE merged their computer interests into a new company called Honeywell Information Systems, which instantly had a work force of 50,000. Honeywell had a stake of 81.5% and GE 18.5%, which it soon sold to Honeywell. GE did not abandon computers altogether. It had long detached its control and industrial computer operations from the business machines area. It also retained its computer bureau operation and computer communications network, both of which supplied a constant cash flow and were useful for its own operations. GE Information Systems, GEIS, remains a significant business.

Conclusion.

The reasons for General Electric leaving the market were similar to those of RCA. They were a combination of fear that supporting multiple growth paths would drain corporate funds to a critical point, and an inability to match IBM's low costs and successful marketing strategy. RCA's decision was made following the crisis caused by displacement of Spectra computers by newer RCA Series machines before the former had been fully depreciated. However, while GE had already lost money on some aspects of its computer operations, the crucial factor was the large sums that would have been required to complete the APL plan; without the APL product line GE's executives did not see any scope for the company in the computer industry. The corporate staff did not believe that GE could undertake such a large investment, feeling that funds could be better used elsewhere. In these circumstances GE was willing to give up the chance of being a player in a market that it acknowledged would continue to be one of the major growth sectors of the economy. It opted instead to provide funds for other projects - projects which were closer to its traditional fields of excellence. From 1970 to 1974 GE raised $600m in long term debt to fund its

[152] US vs IBM, px331A, Ventures Task Force, 'Presentation to the Board of Directors' 24/4/70.

operations: much of this debt was used to finance the aero engine and nuclear power diversifications[153].

This thesis argues that competition for funds weakened the ability of the electronics firms to invest in their computer operations at crucial stages in the development of the industry. Nevertheless, the fact that it was the computer department which was sacrificed when finances were tight has to be explained. It was, after all, the fastest growing market around. In GE's case the reasons were its inability to compete with IBM, numerous poor management decisions, and a failure to integrate the computer operation into one. The firm did not exploit the market created by the ERMA, and failed to develop a unified family of machines, both of these can be seen as major mistakes. GE's lack of a single product range meant that it was not exploiting the economies of scale that other firms were achieving. It also meant that it was duplicating its engineering activities across its many designs, and duplicating this effort in three countries. GE also managed to waste resources on dead end projects. In both the USA and France programmes to develop a single range of computers were started and dropped, despite the fact that the rest of the industry had developed such families.

Bloch believed that GE's policy of decentralisation was the problem; ISG was not able to operate as a coherent organisation[154]. Even within the operating unit there was little coordination. In his eyes it was this excessive decentralisation which prevented the firm from creating a single product line before the APL plan. Bloch believed that if such a range had been built then a 10% market share could have been achieved in the early 1960s. This was seen as the minimum market size needed to fund new developments, such as the APL.

Decentralisation also limited GE's opportunity to exploit economies of scope flowing from the wider electronic interests of the firm. When the computer operation started, Barney Oldfield argued that the production of control computers went hand in hand with business machines[155]. However, GE's policy of decentralisation meant that this operation was soon moved into a separate profit centre, the Industrial Controls Division. One of the few machines that seems to have benefited from cross fertilisation of ideas within GE was the 600 series which drew on the development of the military M-236 computer built by the Light Military Electronics Division. However,

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[153]US vs IBM, tr8273, Ingersoll.

[154]US vs IBM, tr7646, Bloch.

[155]Table, 7.3, p265.

these systems were not built together, negating any production advantages. One area in which GE did actively try to take advantage of its scope was in the field of basic components. IBM noted that GE had a policy of sourcing components internally. However, IBM went on to note that GE had lost market share in the semiconductor industry, and saw this policy as tying the Information Systems Group to one of the less successful component sources[156]. The Semiconductor Products Department had been a late mover in developing integrated circuits. It did not invest large sums in the design of ICs until 1967. GE never really had a third generation computer system. There seems to be a connection between this and GE's weakness in the area of ICs.

On the other hand, the corporate work on the use of computers was of benefit to ISG. Examples of this included the development of the Dartmouth system and the information services operations. It was in this area that GE had its main successes.

The following chapter shows that the successful firms in the industry ensured that they were focused on the computer industry. To a firm like GE it was a new market which was very different to its old product lines. The concluding chapter looks again at the failure to exploit economies of scale and scope, the disadvantages of supporting multiple growth paths, the potential weaknesses of decentralisation and lack of focus on individual markets. All of these conclusions have a direct relevance to the failure of GE in this market.

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[156] US vs IBM, px3222, IBM, 'A company study of GE', 1968.

Chapter 8

Strategies and organisations of the successful US computer companies.

The case studies of the multi-product electronics firms show that vertically and horizontally integrated companies failed to take full advantage of the economies that they should have been able to exploit. However, to understand why these firms failed it is necessary to understand how other more successful companies operated. In the UK the firm which survived was ICT/L, but this was with considerable state support. In the USA there are many more examples of firms that survived in the computer market. This chapter will look at the operations of the more focused US companies, to see how they were different from Ferranti, EMI, EE, RCA and GE. The companies to be looked at are:

1)IBM.
2)NCR and Burroughs, which focused on the utilisation of a niche strategy built on established market positions.
3)Start up companies, CDC and DEC, which successfully identified new niche sectors.
4) Honeywell and Sperry Rand. While both these companies had a product mix closer to that of the electronics companies so far studied, they differed significantly in that both had a much larger commitment to computers.

Some initial data may help to indicate the overall position of the business machines and start-up companies compared to the electronics firms. Figures 8.1-8.3 show the share of the installed base of computers that the major US companies had. Figure 8.1 illustrates IBM's lead over the rest of the industry, with a consistent 70% share. Figures 8.2 and 8.3 show the market share of the other major companies. These figures show the fall of Sperry-Rand from its position as IBM's major competitor. They also show that in the 1960s, while Sperry and Honeywell tended to have a larger market share than GE and RCA, the electronics firms had a user base as large as such firms as Burroughs and NCR. By this measure RCA and GE were not completely 'out of the ball park'. These figures also show the boost given to Honeywell and Sperry when they purchased the computer divisions of the two major case study firms, they also indicate the success of CDC in the 1960s, and the success of Burroughs and DEC in the 1970s.

Figure 8.1

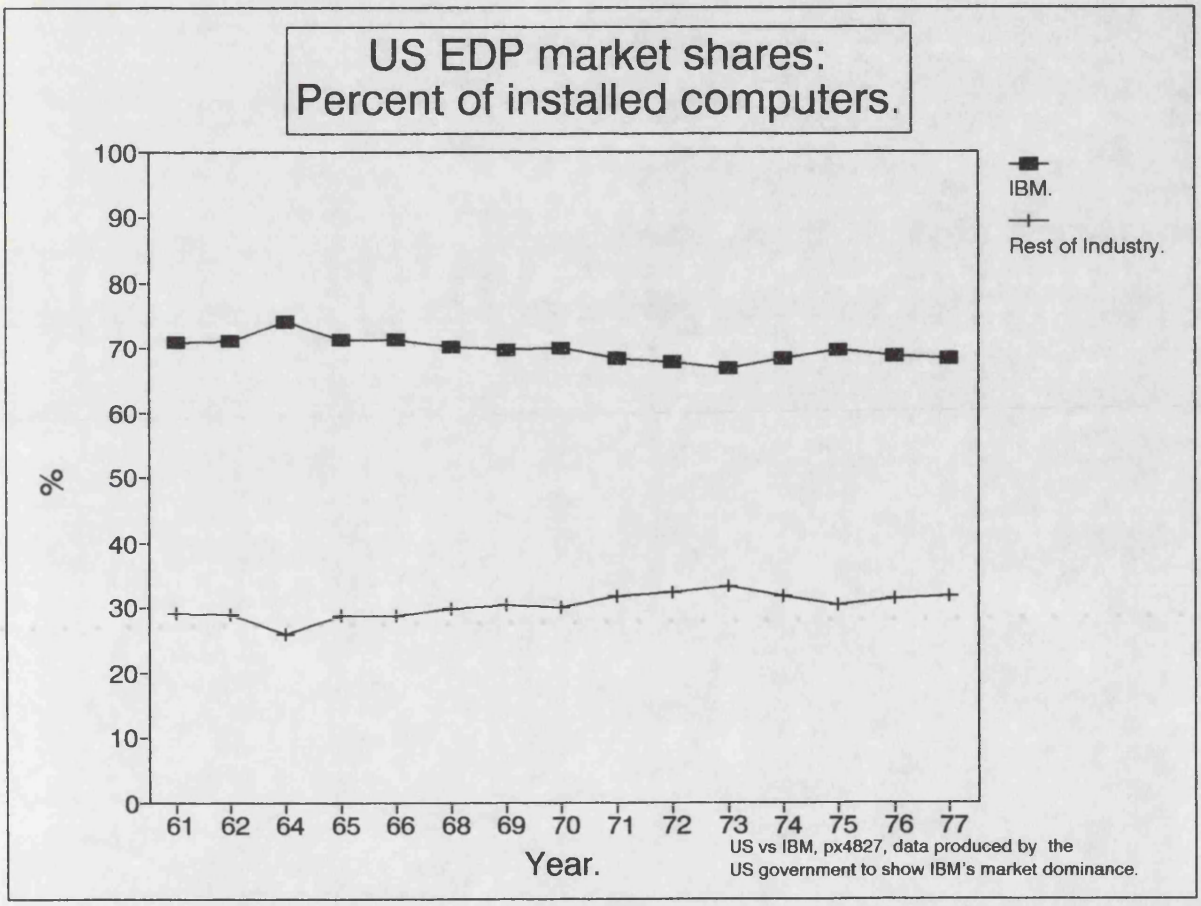
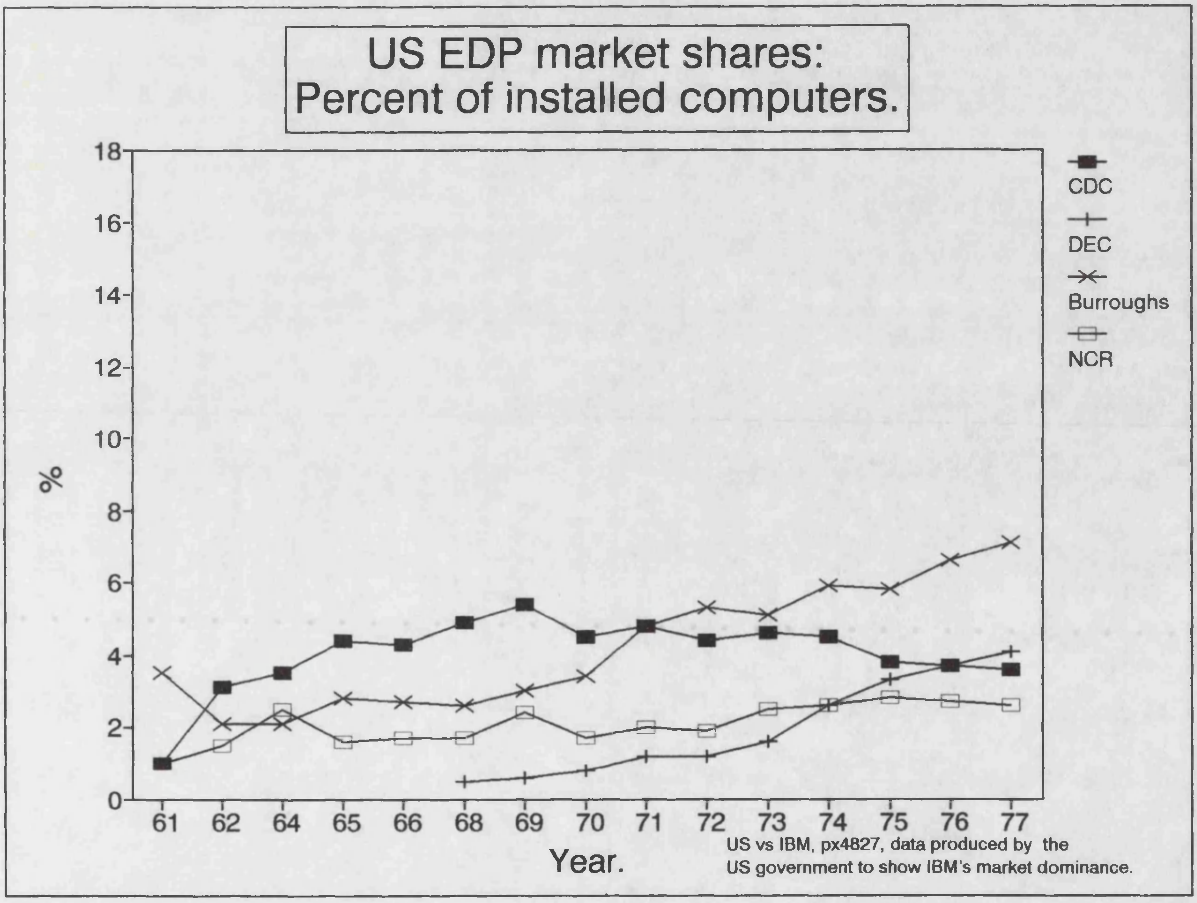
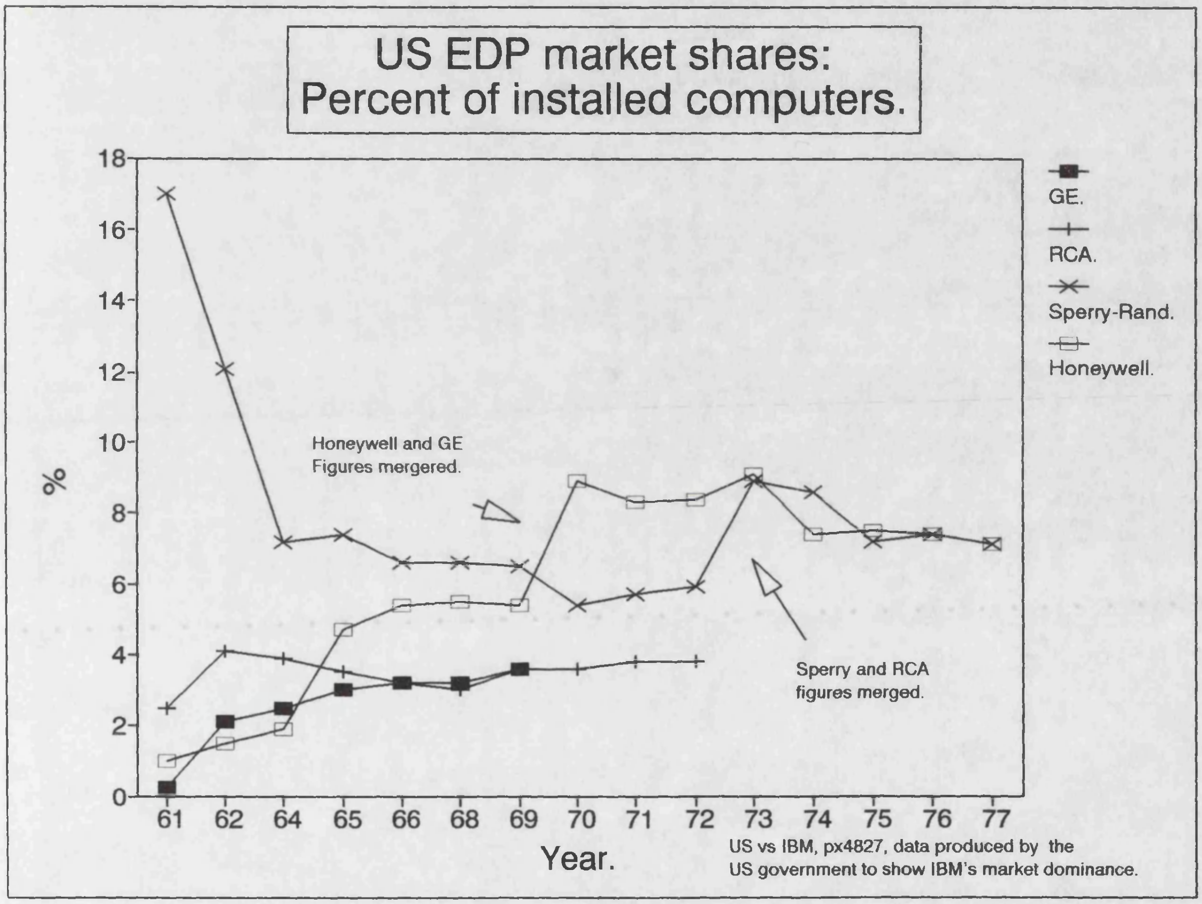

US EDP market shares:
Percent of installed computers.
100
90
80
70
60
50
40
30
20
10
0
%
61 62 64 65 66 68 69 70 71 72 73 74 75 76 77
Year.
IBM.
Rest of Industry.
US vs IBM, px4827, data produced by the
US government to show IBM's market dominance.

Figure 8.2



US EDP market shares:
Percent of installed computers.
%
18
16
14
12
10
8
6
4
2
0
61
62
64
65
66
68
69
70
71
72
73
74
75
76
77
Year.
CDC
DEC
Burroughs
NCR
US vs IBM, px4827, data produced by the
US government to show IBM's market dominance.

Figure 8.3



US EDP market shares:
Percent of installed computers.
18
16
14
12
10
8
6
4
2
0
%
61
62
64
65
66
68
69
70
71
72
73
74
75
76
77
Year.
GE.
RCA.
Sperry-Rand.
Honeywell.
Honeywell and GE
Figures mergered.
Sperry and RCA
figures merged.
US vs IBM, px4827, data produced by the
US government to show IBM's market dominance.

The second set of graphs show a significant difference between GE, RCA and the rest of the industry. By 1969 computers made up at least 20% of corporate revenue in every company bar GE and RCA, which never even saw 10% of their sales coming from computers. While NCR's commitment to EDP seems less in these graphs, it should be noted that computers and information technology were important to its success in its other business activities, supporting its sales of accounting equipment to the banking and retail industries:

Figure 8.4

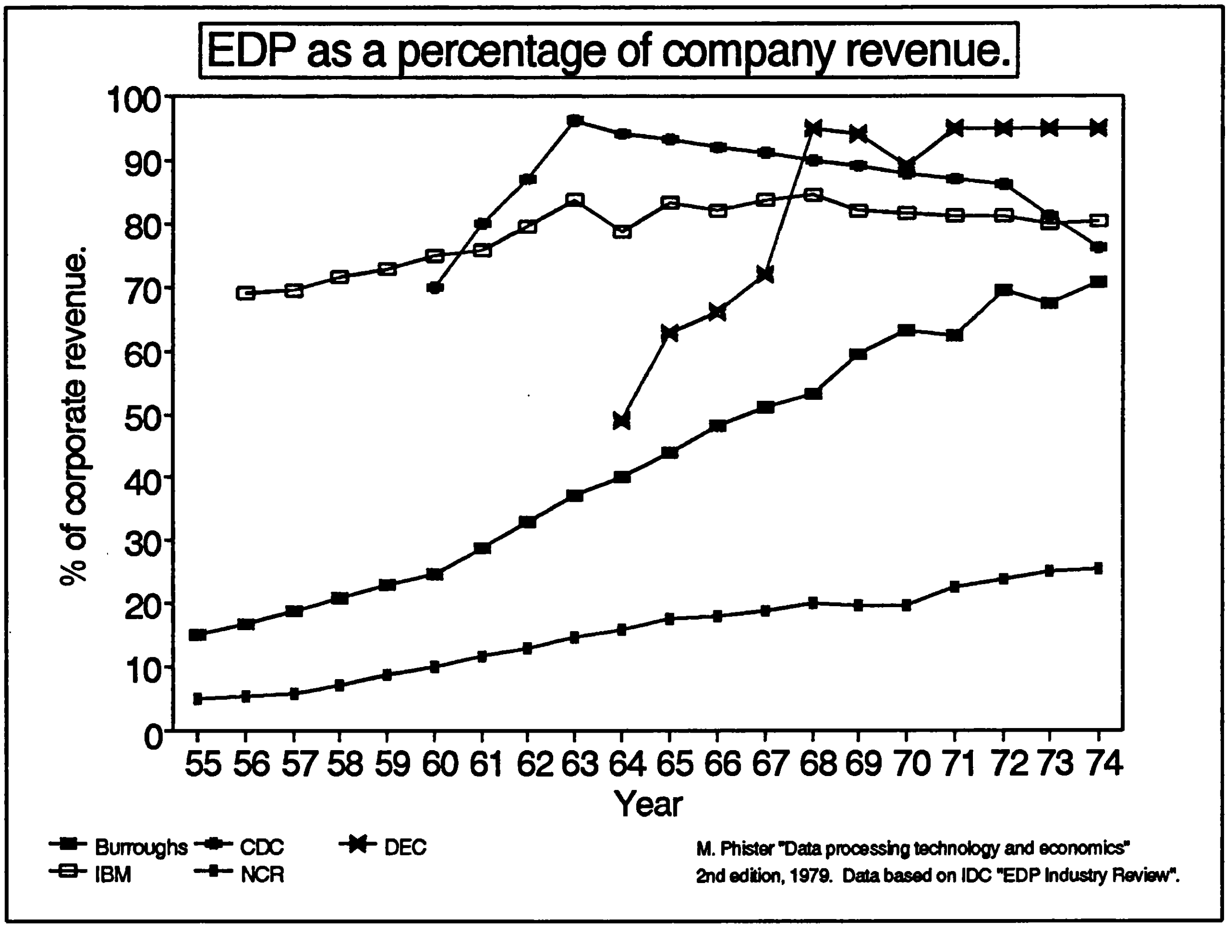
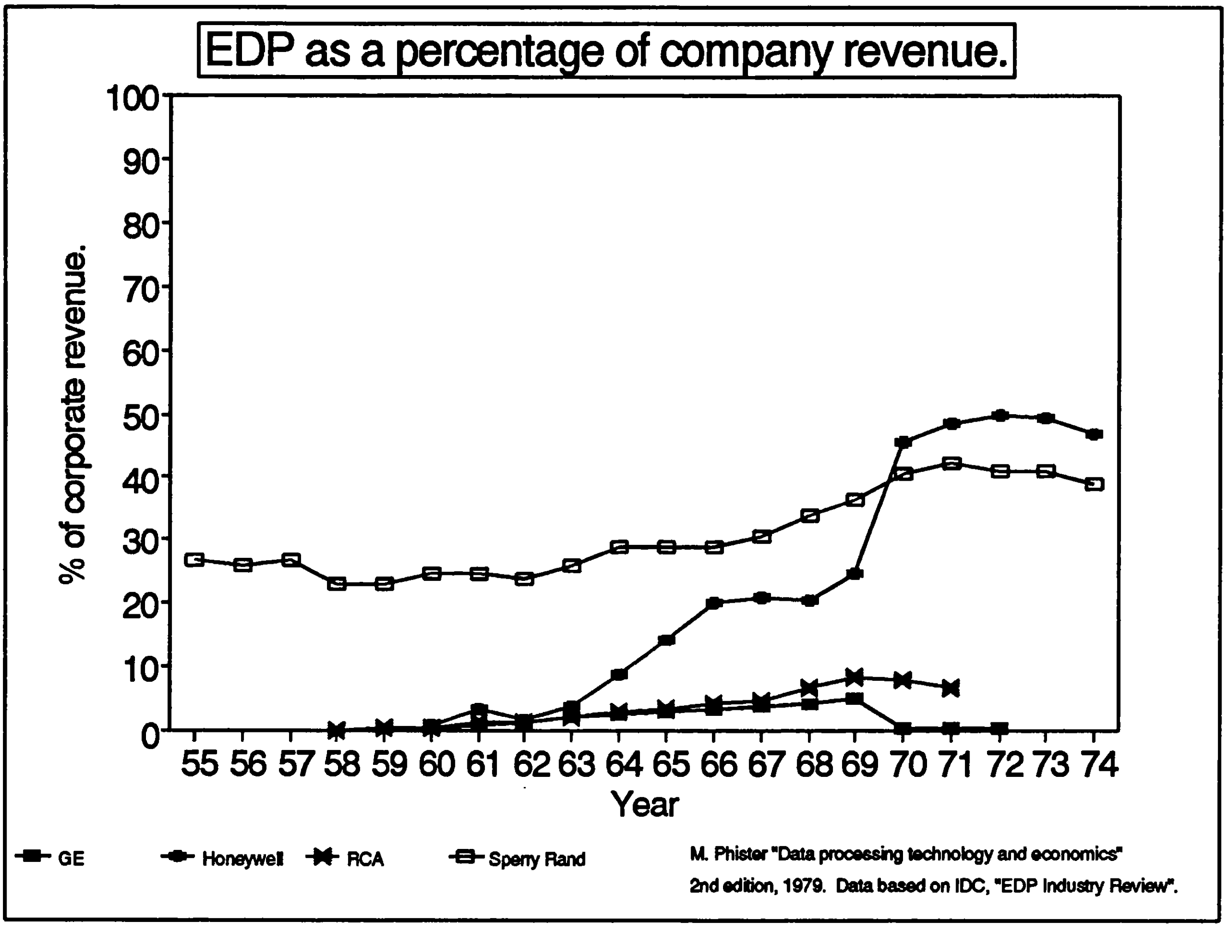

EDP as a percentage of company revenue.
100
90
80
70
60
50
40
30
20
10
0
% of corporate revenue.
55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74
Year
Burroughs
CDC
DEC
IBM
NCR
M. Phister "Data processing technology and economics"
2nd edition, 1979. Data based on IDC "EDP Industry Review".

Figure 8.5


EDP as a percentage of company revenue.
% of corporate revenue.
100
90
80
70
60
50
40
30
20
10
0
55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74
Year
GE
Honeywell
RCA
Sperry Rand
M. Phister "Data processing technology and economics"
2nd edition, 1979. Data based on IDC, "EDP Industry Review".

IBM.

1)Leadership of the pre-War business and scientific machine market.

> 'You never saw another company quite like International Business Machines Corp.- where all men dress well, every office boy is a potential Leader, and the Leader gets $442,500 in one year.... It's marvellous.'[1]

Evidently Fortune magazine was impressed by the corporate success engendered within Thomas J. Watson's company. IBM's prosperity was founded on its dominance of the market for punched card and tabulating systems, based on the technology of Herman Hollerith. The forerunner of IBM, the Computing, Tabulating and Recording Company was an amalgam of a time clock producer, a weighing machine company and the company that produced the statistical tabulating equipment invented by Dr Herman Hollerith[2]. This company was formed in 1911 but initially it did not fare well. In 1914 Thomas J. Watson Snr was appointed to head the company, and made it a success[3]. This success came from the huge demand for tabulating equipment after the war.

During the inter-war years IBM was operating in a rapidly growing market. Private corporations were increasingly turning to tabulating techniques to automate their administration systems. This was reflected in the adoption of a new name to describe IBM's main products, Electric Accounting Machines[4]. The expanding role of government bureaucracy also proved a significant market for IBM[5].

IBM saw itself as a complete service operation: its machines were viewed as too complex for users to purchase and service themselves. Therefore IBM only leased machines to users, providing its own service and maintenance staff. This provided good, steady income. It also meant IBM could force users to buy its own supplies for the machines[6].

In Watson's first year with IBM there were 1400 employees, and the firm had sales of $4m and profits of $1.3M. Employment reached 10,000 in

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[1]'International Business Machines', Fortune, January 1940.

[2]Rex Malik, 'And Tomorrow The World?', 1975, p36.

[3]William Rodgers Think: A biography of the Watsons and IBM, 1969, New York. This book gives an account of the Watson's control over IBM.

[4]Martin Campbell-Kelly, ICL A business and technical history, 1989, p91. Campbell-Kelly's book is one of the few studies that tackles the, pre-computer, tabulator era.

[5]Malik And tomorrow the world? pp36-37.

[6]Ibid.

1930 and by 1945 turnover was over $140m[7].

So growth was impressive, as were profits, but it was not one of the world's largest corporations, not in the league of firms like GE, Ford, and RCA, though Watson ensured IBM received as much publicity as these larger firms. What is notable is that growth was almost solely internally generated, and most of this was based on the tabulating operation rather than any of the other businesses, such as weighing machines and time clocks. The only merger was with a typewriter company. This move was similar to the merger of the tabulator firm Powers and the typewriter firm Remington, forming Remington Rand, IBM's main competitor.

Under Watson Senior's guidance the company managed to achieve an 80% share of the tabulator market. There were many factors behind this success. Watson ploughed back much of the profit[8], he also set up a competitive research and development environment within the corporation[9]. Campbell-Kelly gives one example of how this worked. One weakness in IBM's range during the First World War was lack of a tabulator that printed: under IBM's competitive research environment four were developed, all competing for the right to go into production. Even when this machine was developed, it was held back so that old leased machines were not returned until fully depreciated. This is an early example of IBM being very conscious of how its policy of renting systems meant that certain competitive practices had to be modified. The printing tabulator was not introduced because the model it replaced had not been in service for the minimum time required - five years. An awareness of this problem was not evident within RCA. During the computer period, with the potential damage to market share of not presenting new technology quickly, IBM again modified its behaviour. During this later period it used its lower cost base to depreciate its machines faster than other firms, which allowed it to introduce new generations more quickly.

Vital to the policy of leasing machines, rather than selling them, was the availability of capital to finance the cost of putting new machines on to the market. As has already been mentioned, Watson ploughed back the very large profits the company was making. Shareholders benefited both from the reasonable dividends and the fact that high profits funded further expansion, thereby ensuring future rental income.

Underpinning this strategy was a low cost base. Low costs allowed IBM

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[7]Ibid pp36-39.

[8]Ibid, p36.

[9]Campbell-Kelly, ICL, p63.

to depreciate equipment more quickly than other firms, allowing it to turn-over computer generations faster, while maintaining profitability and therefore generating the capital for leases. Efficiency and strategy were therefore linked: low costs made possible a market strategy which kept competitors off-balance with a rapid advance in computer generations. This strategy was most pronounced during the 1960s, when the 360 series of computers was introduced even while second generation computers were selling well. The 360 was then itself replaced in the early 1970s by the 370, well before firms like GE and RCA could cope with a new generation.

One significant feature of the pre-computer IBM was that it also had a large share of the marketplace for scientific and statistical calculation punched card machinery, though this specialist area was much smaller than the commercial market. Initially Powers machines seemed more appropriate to this market as they could be more rapidly altered to carry out new calculation tasks. However, IBM reacted by introducing a 'plug board' control panel which enabled its system to be rapidly 'reprogrammed'[10]. This ability came with the 600 series of electronic calculators which IBM started to produce in the early 1940s. The flexibility of the plug board was a boon to research establishments that often had a number of different calculations to perform. Therefore IBM had a foothold in the scientific and engineering markets, and this proved an early incentive for the firm to enter the computer industry.

IBM had also introduced a new larger card format of 80 columns: however, the new machines could also read the cards produce by the old 45 column system. Powers' attempt to introduce a 90 line system was not a great success because it failed to be downward compatible with its old cards[11].

Above all, IBM was a marketing organisation, both internally and externally. Within the company slogans were bandied about to encourage activity, such as 'Make things happen' and the single word, that appeared throughout the company and for which Watson was renowned, 'Think'. Watson developed his management technique in NCR. He emphasised marketing: the salesman was king. It seems that feedback and consultation between development teams, manufacturing and marketing staff was strong.

This brief outline of early IBM has highlighted a crucial phase in its history. So many of the factors that were to be important in the

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[10]Ibid, p160.

[11]Ibid, p82.

computer industry were being tackled by IBM in this earlier period: the link between a solid capital base and the ability to grow with a leased product line; ensuring that new technology was compatible with old; ensuring that new technology did not conflict with the financial discipline required to profit from leased products; the importance of marketing; the prominence of information within the organisation; and strong leadership. These policies were made possible by large scale and low costs, its ultimate competitive advantage.

2) Becoming a computer company.

On the entry of the USA into the Second World War, Watson Snr wrote to the President offering the services of IBM to the country[12]. However, in essence IBM's activities did not change greatly. It did build a new plant to produce mechanisms such as gunsights, but the majority of IBM factories were simply told to produce more tabulators. The war necessitated a greatly increased government bureaucracy, and IBM machines were in big demand in Washington; thousands of machines were conscripted into military and government service. Remington Rand, IBM's chief rival, had a number of businesses, including munitions factories; much of Remington's effort was diverted to the latter[13].

However, IBM machines were not just needed for the running of the war, they also formed the backbone of cryptography, the art of code breaking. The flexibility of IBM machines, and their larger card sizes, made them the best suited to this task. IBM also found that one of the developments it was sponsoring in scientific calculators was useful in this role. In 1937 IBM started to fund the development of the Harvard Mark 1/Automatic Sequence Controlled Calculator (ASCC)[14] which was completed in 1944. This was an electro-mechanical calculator system, in the main produced from existing IBM components[15]. However, it was soon overhauled by the very early computers coming from such groups as Eckert and Mauchly at the Moore School[16].

IBM improved on the ASCC, and in 1948 produced the SSEC, Selective

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[12]K.D. Fishman The Computer Establishment, New York, 1981, pp34-5, quoting Thomas Watson Jnr.

[13]Ibid.

[14]Ibid.

[15]T.E. Ivall, Electronic Computers: Principles and Applications. 2nd Ed. 1960, pp9-11.

[16]Fishman, The computer establishment, Chapter 2.

Sequence Electronic Calculator. This was still essentially an electro-mechanical calculator, and it was not in the league of the first real computers then being constructed.

During the war and the immediate post-war period IBM was increasingly reliant on the new electronics technology to improve the speed of its traditional punched card and tabulator systems. The key product was the 600 series of electronic tabulators. In 1948 the 604 calculating punch was introduced, of which 5600[17] were produced and which further increased IBM's stake in the engineering calculator market[18].

Therefore, IBM was moving towards computers along two tracks: through its involvement in one-off scientific systems, and in increasingly sophisticated electronic tabulators. Significantly both trends involved IBM taking on more professional electronics engineers and scientists: after the war IBM had significantly expanded its skill base.

Many of the computer enthusiasts in IBM crowded around Thomas Watson Jnr, who after the war was made president of the company, with his father chairman and CEO. One of the new employees with an academic and research leaning was Ralph Palmer[19]. In response to the concerns of a major IBM customer[20] that it was being swamped by punched cards[21], Palmer proposed the Tape Processing Machine (TPM). This was to be one of the first machines to work with magnetic tape storage mechanisms, connected to a modified 604[22]. Initially the company was cool on this development as the sales staff concluded that such tape based systems would never sell[23]. Their claim was that users preferred the ability to pick-out punched cards in any order rather than the sequential storage of magnetic tape.

On the other hand IBM salesmen were increasingly speaking to customers who had been thoroughly enthralled with the new technology of UNIVAC, the commercial offspring of Eckert and Mauchly's computer developments, which been taken over by rival Remington Rand.

The Korean War intervened to push IBM into computers via its

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[17]Campbell-Kelly, ICL, p160.

[18]Fishman The computer establishment, p38.

[19]Ibid.

[20]Metropolitan Life.

[21]Ibid p39.

[22]Malik, And tomorrow the world?, p55.

[23]Fishman, The computer establishment, p39.

interests in systems for scientific and defence calculations. Watson Snr ordered James Birkenstock, Watson Jnr's executive assistant[24], to support government contracts in the war effort. Birkenstock was a champion of computers. He started talking to a number of different government departments about developing systems for their unique needs. Birkenstock and a colleague, Hurd, approached Watson Jnr and put forward a submission that most of these proposals could be adequately covered by a single type of machine. They asked for $3m to start the production of the 'Defense Calculator'[25]. Before Watson would agree he told them to go out and find specific orders. They came back with around thirty orders for a machine that rented for $8000 per month.

At this stage, the Defense Calculator consisted of only a block diagram drawn by Palmer. It was not the TPM, as this was designed for commercial use and was not fast enough. As development advanced, it became apparent that, to cover costs, a rental of $22,000 per month would be needed. Unwilling to triple the price, a $15,000 tag was chosen as a compromise. 19 were eventually produced[26]. In IBM nomenclature the Defense Calculator became the 701. It was based on the Williams Tube memory system used in the Ferranti Mark 1 computer, indeed IBM was the first licensee of that technology, though it lagged behind Ferranti in the introduction of computers. The first 701 was not delivered until 1953, well behind UNIVAC and Ferranti.

While the cost overrun on the system was of some concern, the machine was built on the basis of 'build it and see': IBM was building it for the national good, and for the benefit of learning about the new technology. The 701 was extremely reliable for its time, an IBM trait which would prove significant in winning other important military contracts[27].

The first generation scientific machines continued to be developed: the 701 was replaced by the 704, and then the last in the line of first generation computers, the 709. The 704 greatly outsold the 701. However, the 709, while being a big advance, was quickly superseded by a transistorised version of its architecture, the highly successful 7090. The 704 introduced magnetic core memory to IBM's range of scientific computers,

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[24] Ibid p39.

[25] Ibid p41.

[26] Ibid.

[27] John F.Jacobs The SAGE Air Defense System: A personal history. Boston, 1986. p47.

some two years after UNIVAC's scientific 1103A[28]. However, the 704 was to dominate the market. The 704 was fast and had a larger memory capacity, allowing it to be the first machine to utilise the IBM scientific computer language, FORTRAN[29]. The combination of the 704's hardware and software, and IBM's presence in the scientific market, allowed it to dominate the sector. It is notable that the 709 was compatible with the older 704, showing IBM's early realisation that it should be careful about making users' software obsolete.

The development of commercial processors went down two separate routes. Confidence in computer technology was increased by the 701 experience, and Palmer was returned to the development of the TPM, which became known as the 702[30]. However, it was immediately outclassed by new UNIVAC technology[31]. The 702 was quickly replaced by the 705 which was a great success. It used buffered input-output, peripherals that were interchangeable with the scientific line of machines, and the new magnetic core memory technique[32]. This was two years before UNIVAC could offer this memory technology to civilian users[33]. This was IBM's development route in large scale commercial systems.

IBM's second route into commercial computing was the production of small, cheap, computers, of a type more easily usable by punched card customers. In 1954, the same year that the 702 was fully developed, the 650 was completed. This was a simple punched card input-output machine that used a drum memory for holding programs and active data. Over a thousand were installed, almost exclusively in the business environment. This was despite the fact that initially it was envisaged as a machine appropriate for small scientific calculations[34]. The fact that it was small, simple, and used punched cards, made it ideal for IBM's established commercial customers.

IBM had rapidly become the biggest computer manufacturer, with the large scale scientific 704 and 709, the large commercial 705, and the small

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[28]Nancy Dorfman Innovation and Market Structure: Lessons from the Computer and Semiconductor industries, Cambridge Massachusetts, 1987, p54.

[29]Ibid.

[30]Malik, And Tomorrow the World?, p55.

[31]Fishman, The Computer Establishment, p45.

[32]See below.

[33]Dorfman, innovation and market structure, p55.

[34]Ibid.

650. The question that needs to be answered is how IBM transfered from the unremarkable sales of the 701 to mass production. This process is fairly obvious for the 650. There was simply no alternative to it. Users in the commercial market were used to leasing from IBM, and IBM was offering a machine with more advanced specifications than the old tabulator systems. IBM had far more experience with electronics than any of the other business machines firms. It also offered a degree of backward compatibility for data, as the main input-output media was the 80 hole punched card.

However, IBM had no special advantage in the area of large scale systems: indeed, initially it was UNIVAC that was the larger producer. It seems that much of IBM's ability in the area of large scale computers came from the winning of a contract to build the computers for the Semi-Automatic Ground Environment (SAGE). SAGE was to be the backbone of North America's air defences, sorting information and helping to control air warfare.

It was developed in the Lincoln Air Defence Laboratory of MIT, with the computer side supplied by Jay Forrester and the Digital Computer Laboratory[35]. The MITRE Corporation was appointed to manage the whole project. To unify the system a number of computers were needed. The main machines were the FSQ-7s. It was one of the first real-time computers, able to process information as soon as it was presented to the computer. In October 1952 IBM was awarded an engineering development sub-contract for FSQ-7[36]. IBM beat off a number of competitors for this contract, including UNIVAC and Raytheon. IBM won on areas such as management commitment to the project, availability of skills within the company, and production and service organisations[37].

The SAGE contract proved to be important to IBM. FSQ-7's were big, 110-250 tons, with 49,000-60,000 vacuum tubes, needing three megawatts of power and massive air-conditioning. It also introduced Jay Forrester's magnetic core memory system. The fast memory on these machines was (for those times) a massive 64K. IBM used similar memory on the 704 scientific and the 705 commercial computers, giving both systems significant advantages over other competitiors. IBM managed to build up mass production of core memory and offer large memory capacities on its machines. The FSQ 7 introduced many other innovations. It also emphasised reliability: FSQ-7

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[35]John F.Jacobs, <u>SAGE</u>, p39-42.

[36]Ibid p xvi.

[37]Ibid p43.

down time was expected to be four hours per year[38].

Of equal importance was the fact that there were around 24 SAGE direction sites constructed, each with two $20m FSQ-7s. The scale of the project enabled IBM to build up its ability to mass produce computers:

> 'A lot had to be done before we could go into electronics in a big way. We did not know how to mass-manufacture circuit boards, for example. We learned by landing a contract to build huge computers for the first North American early-warning system against bomber attacks, known as SAGE. The entire field of computer science was as new to us as it was to everyone else.[39]

The 650 and SAGE gave IBM a scale of production quite beyond that of other firms. The SAGE also gave IBM a number of technical advances with which to underline its lead. It seems from Watson's comment that the SAGE contract was as valuable in terms of moving IBM further along the learning curve, as it was in simple sales and profit terms.

3) The market coverage of IBM's first and second generation systems.

From this solid first generation base, IBM continued to strengthen its hold. Indeed it was the second generation of computing in which IBM became an order of magnitude larger than the opposition:

a) Small-Medium scale commercial processors:

The 650 had put IBM well ahead in transferring tabulator users to computers. One of the first IBM machines to build on this tactic was the 305 RAMAC. This first generation computer was based around a disk memory system, RAMAC, which had first appeared on about 300 so called 650 RAMAC's[40]. This allowed users to access relatively large amounts of information in any order required, at two hundred times the speed of magnetic tape[41]. This was a significant feature for a number of users, and around a thousand 305 RAMAC's were installed. IBM spent $10m on developing the disk system, a technology that it would continue to dominate. The 305 RAMAC's disk and magnetic core storage put it well ahead of the competition, and with these features, it was one of the first computers to be used for commercial on-line applications.

Even greater success was achieved with the second generation 1401, first delivered in 1960. The 1401 was developed using IBM's competitive

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[38]Ibid p74.

[39]Thomas J.Watson Jnr. Fortune, 31/8/87, p27.

[40]Dorfman, Innovation and market structure, p142.

[41]ibid.

research system, with IBM France winning with its proposal[42]. The 1401 was simultaneously built in the USA and West Germany, with printers coming from IBM France. It was designed to be an improvement on the 650 and better able to work with magnetic tape. It was also larger than the 650; it could be configured up to the medium scale of computing.

The 1401, and its cousins the 1410 and 1440, were a great success, out-selling the 650 ten-fold, even to IBM's surprise[43]. One of its great advantages was in peripherals: not only did it offer good magnetic tape drives, but also the best printer on the market, the 1403, developed by IBM in France[44]. It also improved the disc drives that were available for this machine. By 1962 IBM was offering the 1301 disc file, which made obsolete many of the systems other companies were developing to tackle the older RAMAC and 1405 disk files.

With the success of the 305, and the 10,000 sales of the 1401 and the best range of peripherals, IBM had secured its place as market leader. Most established data processor users adopted the new IBM machines as the standard upgrade course.

b) Scientific systems and larger commercial systems.

IBM's first foray into second generation computing was the very ambitious STRETCH/7030[45]. This was IBM's attempt to enter the super-computer market. The lead machine was ordered under a development contract by the Atomic Energy Commission's Los Alamos Laboratory in 1956. The aim was to produce a computer a hundred times faster than the 704 computer, utilising solid state second generation components.

The Los Alamos contract was worth $3.5m, although IBM realised it would cost $15m to develop and $4.5m to deliver the first machine. However, the company expected orders for another 20-30 such systems. This was not to occur, due to the cost problems of developing and building the new components and the new eight-bit architecture. The first STRETCH was not delivered until 1961 and then IBM decided to stop taking orders for the machines as it proved uneconomic to build.

However, there were a number of spin-offs from the project. Eight bit

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[42] C.J. Bashe et al, IBM's Early Computers, Cambridge, Mass., 1986, pp465-474.

[43] Campbell-Kelly, ICL, p201.

[44] Ibid.

[45] F.M. Fisher, J.W. McKie, R.B. Mancke, IBM and the U.S. data processing industry: an economic history, New York, 1983, pp47-50.

architecture was to be found in the third generation 360 range. The packaging techniques were used on other members of the 7000 series of computers, as were many other aspects of the computer. In that respect it helped IBM to advance its technology.

IBM's main approach to introducing large scale second generation computers was fairly straightforward: take the 700 series and bring them into the second generation. The major systems were the 7010, 7040, 7044s, 7070/2/4, 7080, and 7090/94. This policy meant that the various machines were compatible with their old first generation parent, but were not compatible with the other second generation systems. However, a number of peripherals were common between the second generation machines and the adoption of the new FORTRAN language helped with some data transfer. Nearly a thousand of the various 7000 series machines were produced.

Probably the most significant of the machines was the 7090 and the improved 7094 I/II models. These were transistorised 709s and compatible with it, the 709 itself had been compatible with the earlier successful 704. The original 7090 was developed for the ballistic early warning system, DEWLINE, four 7090s being delivered for this purpose in 1959[46]. The civil versions became the work-horses of scientific computing. One of the most significant uses of the 7090 was in the SABRE aircraft seat reservation system for American Airlines. This was one of the first large scale inter-active, on-line commercial applications.

The most notable of the business environment machines was the 7070 series, based on the old 705. The 7070/2/4 was most successful when it was coupled to a 1401, which was used to control peripheral and communications functions, freeing the main processor for calculation tasks. This meant 7070 installations were very large systems indeed, generating large incomes for IBM. The 7040/44 was a new system, designed for scientific work, though the provision of a COBOL business language compiler made it popular in the commercial market.

The final computer of this period was the 1620-1622. This was a small scientific computer, designed to give direct access to a computer for departmental research, 1700 of which were produced[47]. This was a very respectable performance compared to many competitors, though in general IBM was seen as weak in the small scientific market.

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[46]Ibid, p51.

[47]US vs IBM, px1888, internal IBM report, Manager Program Profit Evaluation, 'Program profit evaluation on selected 1400/7000 series systems and component machine types', 27/9/66.

Much of IBM's success in this period was due to its computer peripheral products. The best disk and tape drives and printers all came from IBM. These significantly improved the functionality of the computers, and their rental value. IBM's implementations of its own FORTRAN engineering language, its own business language PL/1, as well as the COBOL business language, also enhanced the IBM reputation.

During this period IBM was functioning with three domestic divisions plus the World Trade Corporation. World Trade's function was to carry out IBM's business on an international basis. However, it was not run along the lines of GE's international venture. World Trade produced computers, initially in Germany and France and then in the UK and Japan. However, the machines produced were standardised with the US ones. As the European operations gained in strength, they contributed to IBM's development cycle. IBM Germany worked on the 1401, while France specialised in printers. When IBM turned its attention to the third generation System 360, a number of the components, peripherals and even some cpu's were designed in Europe. The British Laboratory Systems Support Group even contributed to the logic manual for the System 360[48], helping define the architecture that IBM uses to the current day. IBM ensured that foreign operations were fully integrated with the rest of IBM: compatibility was worldwide.

The other three components of the company were the Data Systems Division (DSD), General Processing Division (GPD) and the Federal Systems Division (FSD). DSD was responsible for the scientific orientated machines, and the larger end of the commercial data processing market. It covered the following first and second generation computers[49]:

<u>Commercial</u>	<u>Scientific</u>
1410, 1410X	7070, 7072, 7074[50]
705, 705 III, 7080	704, 709, 7040/44, 7090/94
	7030, 7034.

[48]<u>US vs IBM</u>, dx1404, IBM,'Final Report of SPREAD Task Group',28/12/61.

[49]Ibid.

[50]Though most 7040/44s and 7070/2/4s were sold as commercial systems.

GPD, as would be expected, covered the smaller end of the market, together with the punched card business, consumables and peripherals operations. The following table shows the main processors[51]:

Commercial	Scientific
14LC, 1401	1620
650	
305	

FSD covered sales to the US government, including applications of IBM technology to military purposes. It is uncertain whether it also covered sales of standard systems to the government for administrative data processing. Notably IBM had a smaller proportion of the government market than other markets, though it was still the largest supplier.

Simple aggregated financial statistics do not give a good indication of the real profitablity of IBM machines. However, IBM's own internal figures reveal just how profitable IBM's core products, the 1400 and 7000 computers and their peripherals, were:

[51]US vs IBM, dx1404 'Final report of SPREAD task group'.

Table 8.1 Profitability of IBM's second generation hardware.

Machine	Revenue $'m	Profit $'m	Profit as a %of revenue
Intermediate Systems			
1401	1613	705	49.3
1440	277	133	48.1
1460	187	81	43.5
1410-7010	328	155	47.2
7070-7074	309	34	10.9
7080	145	57	39.3
Total	2859	1255	43.9
Large Systems			
7040-7044	158	36	23.1
7090/94	540	227	42.12
Total	698	263	37.7[52]
Memory systems			
1406	174.9	107.7	61.6
7301	106.4	56.7	53.2
7302	224.4	107.2	47.8
Total	505.7	271.6	53.7
Storage Products; Disks drives, tape drives etc			
Total	2149.5	913.3	42.5
Card Machine Products; Punch-card input-output.			
Total	387.8	94.9	24.5
Printers			
Total	505.7	271.6	53.7
Communication Products			
Total	51.5	3.8	7.4
Grand Total	7157.2	3073.2	42.93

Source: US vs IBM, px1888, internal IBM report, Manager Program Profit Evaluation, 'Program profit evaluation on selected 1400/7000 series systems and component machine types'. 27/9/66.

[52] In the original IBM report this was inadvertently calculated at 27.7%.

4)The Third Generation, the IBM 360 system.

IBM had the bulk of the computer market sewn up. However, there were weaknesses in the IBM line:

> 'In the low performance end of our present product line, we are strong commercially with the 1401-10, but weak scientifically with a gap between the 1620 and 7040/44. At the high performance end of our present product line, we are strongest scientifically, with the 7090/94, and relatively weak commercially with the 7074, 7080. Throughout the line there is insufficient capability for real-time, multiprogramming systems.'[53]

The conclusion must be that GPD's emphasis was on the commercial sector, while DSD was more interested in the scientific market. However, during the second generation of computers commercial and scientific computing had begun to merge. Only in the areas of very large super-computers and very small mini-type computers had scientific computing maintained a separate identity. It was becoming evident that improved peripherals meant commercial computers could make use of faster processor speed, while new scientific and statistical applications needed much greater input-output support. A good computer should have been able to perform both tasks.

These factors led to radical product reform. The SPREAD Task Group is renowned in the history of IBM. It was a planning group established to consider how IBM should approach the third generation of computing. At the end of 1961 the Task Group recommended establishing a new product line which was an expandable range of compatible machines, from the small scale mainframe to super-computer systems[54]; a plan that was adopted in early 1962 and announced in 1964. The twenty or so engineering groups involved in processor design were to be made subservient to Corporate Processor Control (CPC) which laid down the new logical architecture across GPD, DSD and WTC operations[55]. Not only was architecture to be standardized, but so was programming, testing, and even marketing.

CPC and WTC were to work in tandem to ensure Worldwide standards. A third organisation, the Component Division, was to ensure that the 'Design Automation Procedure' was a standard maintained throughout the company. The Component Division was important to the plan as it was responsible for the supply of Solid Logic Technology, SLT[56]. This was a kind of hybrid technology, transistors being automatically inserted on a silicon film

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[53]US vs IBM, dx1404, 'Final report of SPREAD Task Group', 1961.

[54]ibid.

[55]Ibid.

[56]Ibid.

which had passive components, such as resistors, integrated into the silicon. It was hoped that this technique would not only increase computational speed, but also lower prices. IBM, by standardising the computers in its range, could mass produce huge quantities of standard circuits, and SLT technology allowed component assembly to be fully automated. Though not fully third generation components, SLT was quite fast enough and offered potentially cheaper circuits for a considerable length of time. In the English Electric and RCA chapters it was shown that early ICs proved too expensive for small scale systems. It was estimated that IBM's new range would offer systems costing one half of their old 1400 or 7000 equivalent[57].

However, it was not just improved performance and cost that was to attract new customers; it was the whole system concept which represented a complete up-date of computer standards, though few of the ideas were new. The 360 Series offered the following advantages:

a fully compatible range of computers,
inter-changeable peripherals,
better disk storage,
very large memory,
better communication and peripheral handling facilities,
32 bit data paths (first seen in STRETCH),
facilities for multi-programming (though this proved to be one of the system's major failings),
a full operating system (this too was a problem),
the COBOL business language, and IBM's own PL/1 and FORTRAN languages,

The system was expected to make obsolete all other computer systems. This was the barb in the tail of the plan. Not only would IBM bear the cost of developing the system, tooling up for the production of the new technology, preparing new software, accepting the returns of old leased machines for new 360 machines, but it also ran the risk that users would resist changing to a new system that was incompatible with the old. The Task Group took the attitude that to provide the greater functionality of the 360, backward compatibility with the 1400 and 7000 could not be offered. The preferred view was that users who required new functions, such as the ability to use large random access stores, would in any case have to reprogram their old applications: therefore getting users to up-grade would not present an additional problem[58].

Two companies tried to exploit IBM's lack of backward compatibility, though their strategies were decided before the 360 announcement. It will

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[57]International Data Publishing, EDP Industry and Market Report, Vol 1, No 1, 23/3/64, p1.

[58]Ibid.

be seen that Honeywell's main 1960s strategy was to offer a machine that was program-compatible with the IBM 1401. With IBM abandoning the 1401 for the 360, Honeywell probably picked up extra orders for this machine. IBM responded to this by repackaging returned 1400 machines and offered them as cheap alternatives to the Honeywell systems. It also took steps to produce conversion programs to transfer 1400 data to 360 machines. It also produced software emulators of the 1400, which, due to the increased speed of the 360, performed reasonably well.

GE was in a similar position. Its 600 series was closely program-compatible with the 7090/94. It also hoped to benefit from the 7090/94's incompatibility with the 360, though most of GE's advantages came in the area of multi-programming operations. The 600 was less successful than the H200, mainly due to the system's unreliability.

Both challenges led to some reaction from IBM. Apart from the reworked 1401s, an SLT version of the 7090 was also rumoured[59], but never appeared. IBM's greater scale, and full line concept of compatibility coped adequately with the threat posed by others competing for its old customers. The 360 concept and architecture were well ahead of the opposition: there was no one other family that could offer all the 360's features. Matched to this was a major program to develop the largest possible software library, freeing users from some of the burden of programming.

The 360 programme did have some problems. A major one, and one that became a common feature in the computer industry, was the failure to deliver the operating system on time. The 360 family was to offer a comprehensive control program called OS 360[60], one of the first major operating systems. However, it proved much more expensive and time-consuming than expected. Eventually only the larger machines in the family had this comprehensive operating system, the rest having a simplified system known as the Disk Operating System, an obvious reference to the preferred peripheral. These problems led to some delays in 360 delivery times.

However, the 360 was a great success; indeed it had to be. There are various estimates of how risky and expensive the worldwide implementation of the 360 was. An R&D budget of $750m and a total cost for development, tooling, marketing, etc in the region of $4.5bn is quoted by Thomas J.

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[59]IDC, EDP Industry and Market Report, 15/5/64, p2.

[60]Malik, And tomorrow the world?, p141.

Watson[61]. Whatever the true cost it was a huge risk. However, IBM was very professional in its market analysis, and carefully analysed the likely reactions of the competition. IBM made the considered judgement that by offering this type of family ahead of competitors, even before IC components were an option, IBM was striking well before any competitor could afford to make obsolete their entire ranges. IBM's lower cost base and large user base allowed it to depreciate its machines faster than competitors, so it could tackle such a radical change.

While it is not possible to find out the individual profitability of the various System 360 computers, it is possible to observe just how profitable IBM was compared to its competitors. It managed to maintain the profit ratios it had achieved with the earlier second generation systems.

Table 8.2

IBM profitability compared to major competitors, 1960.

	Gross Income $'000	Net Earnings After Tax $'000	Net Earnings: Gross Income	NE per Employee
IBM	3,572,825	476,902	13.3	2,706
Burroughs	456,667	17,528	3.8	498
CDC	158,651	4,763	3.0	489
GE	6,213,595	355,122	5.7	1,134
Honeywell	700,357	37,500	5.3	686
NCR	736,849	24,725	3.3	339
RCA	2,042,001	101,161	4.9	1,012
SDS	43,999	3,372	7.7	1,421
Sperry	1,243,319	20,055	1.6	219

Source: US vs IBM, px3446, IBM,'Analysis of Major Computer Manufacturers', 19/5/66.

The figures suggest two things. First, only the broad based electric/electronic/conglomerate corporations were in the same league as IBM in terms of size. Second, IBM's high ratios of profit to turnover and employees were unchallenged by its competitors. In pre-tax terms IBM profit to turnover amounted to a massive 26.1%[62]. Return on investment was at 17%[63], nearly 3 times most of the opposition.

[61] Thomas J.Watson Jnr and Peter Petre, Father Son & Co.- my life at IBM and beyond, 1990, p347.

[62] US vs IBM, px3446, IBM, 'Analysis of Major Computer Manufacturers', 19/5/66.

[63] Ibid.

Few figures are available regarding the breakdown of sales within these companies. However, one later estimate shows how revenue and profits were distributed within the computer industry and estimated that IBM was again in a different league of operation:

Table 8.3
Worldwide EDP revenue and profits of U.S. based mainframe manufacturers

$m.	1966	1967	1968	1969	1970	1971
Total Revenue:						
Non-IBM	1479	1874	2329	3032	3280	3547
IBM	2603	3562	4873	4935	5195	5400
Total	4082	5436	7202	7967	8475	8947
IBM %	63.5	65.5	67.5	62.0	61.0	60.5
Pre-tax income:						
Non-IBM	(88)	12	123	168	34	73
IBM	627	843	1343	1389	1412	1403
Total	539	855	1466	1557	1446	1476
IBM %	116	99	92	89	98	95

Source: IDC, EDP Industry Report, 31/12/71, p5.

This ties in well with the RCA and GE case studies which show that, for most years, their computer operations were running at a loss, pulling down the profit for the non-IBM part of the industry. No one turned in profits like IBM's, but given IBM's huge scale in the industry, and its low costs, competitors had to forego IBM's high profit ratios to compete adequately against it.

It was stated earlier that Tom Watson Snr. had a policy of ploughing back as much profit as possible to fund internal expansion. Internal figures show that on average this was still IBM's policy. Very high profits gave the company great scope for investment, including the phenomenal investment in the 360. Even such a large expenditure did not mean IBM had to go into substantial debt. Notably as the 360 investment decreased, IBM increased profits distributed:

Table 8.4 Percent of earnings distributed by US computer producers 1960-1965.

	1960	61	62	63	64	65
IBM	27	25	27	32	38	44
Burroughs	72	63	70	83	73	42
CDC	4	3	1	1	--	1
GE	80	74	69	67	90	61
Honeywell	53	59	55	43	37	43
NCR	48	44	48	50	42	38
RCA	53	56	34	44	42	38
Sperry	63	2	3	2	2	2

Source: US vs IBM, px 3446, IBM, 1966.

Both Sperry and CDC were experiencing unusual circumstances at this time. Sperry had unusually low profits and was in the throes of changing its structure and introducing new products. CDC, being a star of the stock markets, was utilising all its resources in a meteoric rise.

The following table, first shown in the RCA chapter, shows IBM's low debt during the late 1960s:

Table 8.5 Debt/Equity Ratios of electronics and computer companies.

	'67	'68	'69	'70
RCA	.79	.79	.77	.88
GE	.32	.30	.27	.22
ITT	.69	.56	.55	.52
Westinghouse	.36	.32	.28	.44
Average	.46	.39	.37	.39
Burroughs	.48	.74	.57	.60
Honeywell	.59	.61	.56	.87
IBM	.14	.12	.11	.10
NCR	.69	.42	.61	.82
Average	.44	.44	.44	.51

Source: US vs IBM, px201, Chase Morsey, RCA Vice President Finance, memo to Sarnoff and Conrad, 27/8/71.

So the mix with which IBM dominated the market consisted of:

Established market places, both commercial and scientific;
Strong marketing;
Knowledge of the market;
Strong leadership willing to direct the company into radical reform;
Integration of corporate effort and control;
Large scale production;
Strong financial base.

Anti-competitive?

One question remains: was IBM using its market position to compete unfairly with its opponents? During this period IBM has been accused of a number of anti-competitive acts, some against major hardware producers, and others against smaller producers and service companies. In the following section a number of these anti-competitive practices will be mentioned, especially those which were aimed at the major hardware producers, GE, RCA and CDC. However, the evidence on these anti-competitive actions is less than clear. While two cases can be framed in such a way as to appear as exploitation of monopolistic power, equally they can be seen as IBM wishing to maintain competitiveness by establishing themselves in two areas which were widely perceived as the future technologies of computing.

CDC had a big stake in the market for large scientific computers with the 1604 and the later 3000 series, but the major problem for IBM was the dominance of the 1960s super-computer market by the CDC 6600[64]. It has been argued that IBM tried to undermine CDC in two ways. The 360 model 44 has been described as a 360/50 at 360/30 prices. It has been suggested that its role was to undermine the CDC 3000 range of medium scale scientific computers[65]. Unusually it was not fully compatible with the rest of the range, being 'tweaked' for scientific processing. It did not sell in great numbers due to its incompatibility with the rest of the family. To fight off the larger CDC 3600 computers, IBM announced larger members of the 360 range[66], the /75 /85 and the /195, for sale to the scientific market.

To head off the CDC 6600 super computer, IBM had a programme for a family of machines larger than the 360 series, called the Series 90[67]. Malik among others, argues that the Series 90 was a phantom product aimed at undermining CDC sales. It is argued that its main role was to encourage users to wait for an IBM product rather than buy CDC. The Series 90 was to be based on so called Advanced SLT components. IBM worked on the project with the help of the National Security Agency who required large computers for code breaking. According to one study, the Series 90 was announced in August 1964[68]. This was a number of years before machines could be delivered, and it was quickly found that the ASLT was flawed and that the component design had to be reworked. Yet the marketing staff continued to discuss it with users. Its specifications seem to have shifted continuously: Series 90 announcements were cancelled and replaced by new models on a number of occasions. It seems to have been a chaotic project,

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[64]See below, CDC section, pp350-354.

[65]Malik, <u>And tomorrow the world?</u>, p99.

[66]Ibid p104.

[67]Ibid.

[68]Fisher et al, <u>IBM and the US data processing industry</u>, p157.

and finally only 11 machines were produced: far from covering the investment, an overall loss of $114.1m was made[69].

The main problem presented by GE was the dominance it had in the area of multi-access, time-shared computers[70]. GE was perceived as a technology leader due to its involvement in the Project MAC, MULTICS development programme at MIT. This perceived technological leadership had rubbed off on GE's simpler and smaller solution, based on the Dartmouth BASIC time-sharing systems. IBM's reaction was to start offering extensions to the 360 range. The initial announcements were the /64 and /66. Like the Series 90, it was the sales staff's concern that sales were being lost which led to the pressure to announce such a system. This again led to the multiplication of specifications[71]. Eventually the various promises were brought together. The conventional /60 and /62 were replaced by the successful 360/65 in April 1965[72]. This system introduced an optional compatibility with the 7000 series, to compete with the GE 600 machines. Linked to this was the extended time-share version called the /67. While the hardware modification was comparatively easy and the first installation of /67 machines was in August 1966[73], the software proved next to impossible. The problem was the Time-Share System: TSS was the operating system. The sales staff had promised so many users different specifications that the TSS could not hope to fulfil them all[74]. Only a few of the systems were delivered, mostly to universities. Again this phantom product was seen as merely an attempt to undermine the sales of a rival.

Another possibly anti-competitive practice was IBM's policy of giving huge discounts to colleges and government laboratories. The educational market was seen as important, due to the fact that those that learnt on university machines would be the customers of the future, and it was the major market for scientific and time-share systems. Some of the discount was paid for, and justified by, the high level of tax concession available on sales to educational and non-profit research organisations. However, a hidden agenda may have been that IBM was covering up its lacklustre

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[69]Ibid p103.

[70]See above, chapter 7, pp273-274.

[71]Malik, And tomorrow the world? pp101-103.

[72]US vs IBM, px226, IBM, 'System 360/65 Financial Analysis', 4/68.

[73]US vs IBM, px2227, IBM, 'System 360/67 Financial Analysis', 4/68.

[74]Ibid.

performance in areas such as super-computing and time-sharing, by offering low prices for its standard scientific installations to attract noteworthy customers.

Malik estimates that the loss incurred on the phantom and anti-competition machines, the Series 90, 360/44, /67, /75, /85, /195, over 500 machines in total, was nearly $235m[75]. This was comparatively small fry to IBM: less than 10% of a single year's revenue.

However, there are obvious defences for IBM's behaviour. A number of companies in the industry were working on time-shared computers. Time-sharing was seen as the next wave of computing: it was the 'buzz' concept of the 1960s, and IBM needed to get into this area to maintain future capability. It was far from the only organisation to have problems in producing what it promised. IBM's next generation, the 370, was a complete range of time-shared systems, IBM having learnt much from the TSS. Super-computers were also seen as an important technology. IBM may well have viewed super-computers in the same way.

Whether the projects mentioned above simply show that IBM was capable of expensive failure, or had deliberately tried to undermine opponents' sales, it did bring anti-trust scrutiny. On 11 December 1968, CDC filed a damages claim to recover losses caused by IBM's phantom machines[76]. This was one of a number of cases which led to the composite US vs IBM. Whether CDC, as the fastest growing computer company of the 1960s, really expected to win its claim is not known. However, the case did stop IBM from announcing further paper super computers and cleared the way for CDC's 1970s 7000 series.

In another area, peripherals, IBM may well have tried to limit competition. There were two targets, RCA and the so called Plug Compatible Manufacturers. PCMs were small firms that developed in the late 1960s and produced low priced peripherals for attachment to the standard 360 input-output interface. PCMs achieved this by 'reverse engineering' IBM products, often employing ex-IBM engineers to do this[77]. Therefore, development costs were minimised. In IBM's view PCMs were parasites[78].

The problem with RCA was that it was in direct conflict with IBM

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[75]Malik, And tomorrow the world? p103-104.

[76]IDC, EDP Industry Report, 23/12/68, pp1-3.

[77]Dorfman, Innovation and market structure, Chapter 10.

[78]Ibid.

machinery; to compete adequately RCA needed to keep up with IBM in all its nuances. As was seen in the RCA chapter, IBM filibustered about supplying it with details of the new 3330 Merlin disk drives, preventing RCA from making an early start on copying it. The argument IBM offered was that it could not have been expected to release detailed technical data before the system was even on the market. It seems that this was not the first example of IBM hostility towards RCA. It has been recorded that Thomas Watson Jnr. was incensed when RCA entered the commercial computer industry; General Sarnoff had previously assured him that RCA's only interest was the BIZMAC logistics systems and other military computers[79]. With this assurance, IBM continued to use the management consultant, Booz Allen, who were also RCA's advisers. Two years later RCA hired J.L. Burns from Booz Allen as president. He had been the consultant who had advised IBM on management organisation[80]. IBM sales staff were informed that they could undercut RCA by any means.

IBM's reaction to PCMs became apparent in the early 1970s. It offered a new rental deal on its peripherals, called the Fixed Term Lease Plan. It offered a small discount on the first year of rental, which steadily increased over the subsequent years, the idea being that the price would be declining as rival PCM products appeared[81]. IBM saw the peripheral as vital: peripherals were becoming an increasing percentage of hardware value. IBM's Fixed Term Lease Plan was the major cause of the <u>Telex vs IBM</u> anti-trust case.

IBM took similar action against another group of companies that threatened its role as the supplier of complete computer services: these were the leasing companies. These firms bought a manufacturer's machines and then leased them to users on their own terms, often with peripherals from the PCMs. IBM's actions against leasing firms led to <u>Greyhound vs IBM</u>, another case which led to <u>US vs IBM</u>.

However, IBM's underlying competitive advantage was the company's conventional computer ranges and its associated selling tactics, advantages that have already been considered. IBM's ability to progress from one generation to the next, before opposition could adequately recoup expenditure from the last generation, was much more vital to ensuring the IBM lead. Underpinning all its strategies was its large scale, low costs

[79]W. Rodgers <u>Think</u>, p247.

[80]Ibid.

[81]Dorfman, <u>Innovation and market structure</u>, p91.

and high profits.

IBM was an aggressive company, clearly in the strongest position in the market, a position which had been built on its historic strength in the business machines market. No other large firm could match IBM's vision or its focused attention on the sole market of data processing: this was certainly the case with the electronics firms. While other business machines firms and some start up-companies did match IBM's commitment to the computer market, they only had limited resources compared to IBM. Though more successful than the electronics firms, they could not muster enough resources to make a significant impact on the leading company.

IBM was the dominant supplier. This in turn meant that it had the longest production runs, lowest costs, and highest profits, ensuring it remained number one in the mainframe market. Using its market and production advantages, IBM was able maintain a significant competitive advantage over the smaller business machines firms. This forced these firms to adopt strategies aimed at surviving in a market dominated by a single large supplier. Both IBM's traditional competitors and its newer rivals adopted niche tactics to enable them to survive in this environment.

However, it is not so easy to put the failure of the electronics companies down to the problems of small firms taking on a large monopolist. The electronics corporations were larger than IBM and had a much greater technological base to draw skills from. The failure of these firms to establish themselves in the EDP market has been discussed in the other case studies. It is also summarized in the conclusion, which emphasizes their failure to marshall their resources to tackle IBM, the problems they had in supporting so many technologies and the organisational difficulties that they had.

Smaller business machines firms.

NCR.

The National Cash Register company was one of the two niche business machines firms that competed with IBM and Sperry-Rand. While NCR's early success had been built on the cash register business, by the 1950s it had earned more revenue from the production of accounting machines. Despite holding 75-85% of the cash register business[82], competition from the likes of Monroe/Sweda had completely wiped out any monopolistic profits and

[82] US vs IBM, px2050, IBM Market Evaluation Department, Data Processing Group, 'A company study of [the] National Cash Register Company', 1/5/67.

this part of NCR's business was not growing[83]. However, the adding and accounting machine market replaced cash registers as a source of growth. NCR entered the accounting machine business in the 1920s, and enhanced its market share with the purchase of the Allen-Wales Adding Machine Company in 1943[84]. Within ten years of entering this business NCR had managed to match and surpass its main rival, Burroughs. NCR's lead was built on the Postronic accounting machine, which was widely seen as the best on the market[85]. NCR was particulary successful in the retailing and banking markets.

By 1960 NCR employed 49,000, of whom 23,000 were employed outside of the United States[86]. Of this workforce, IBM believed the main strength was the huge marketing force needed to sell cash registers and accounting machines[87]. NCR employed thousands of salesmen and service engineers[88]. IBM's Watson Snr. himself had been a graduate of the NCR marketing system, and it was clear that it was rated highly within IBM.

However, IBM believed the firm had one weakness. The traditional businesses of cash registers and accounting machines did not generate high profit margins. IBM viewed them as basically financially healthy but not generating the resources to develop and lease a complete line of computers. The following graphs show that revenue increased significantly in the 1960s, but that profit fell as a proportion of these earnings, IBM saw this as a weakness, but that it was still basically healthy:

[83]Ibid.

[84]NCR, Celebrating the Future: NCR 1884-1984, Booklet two, '1923-1951, The Accounting Machine Era' Dayton, Ohio, 1984. This is a four booklet history of NCR.

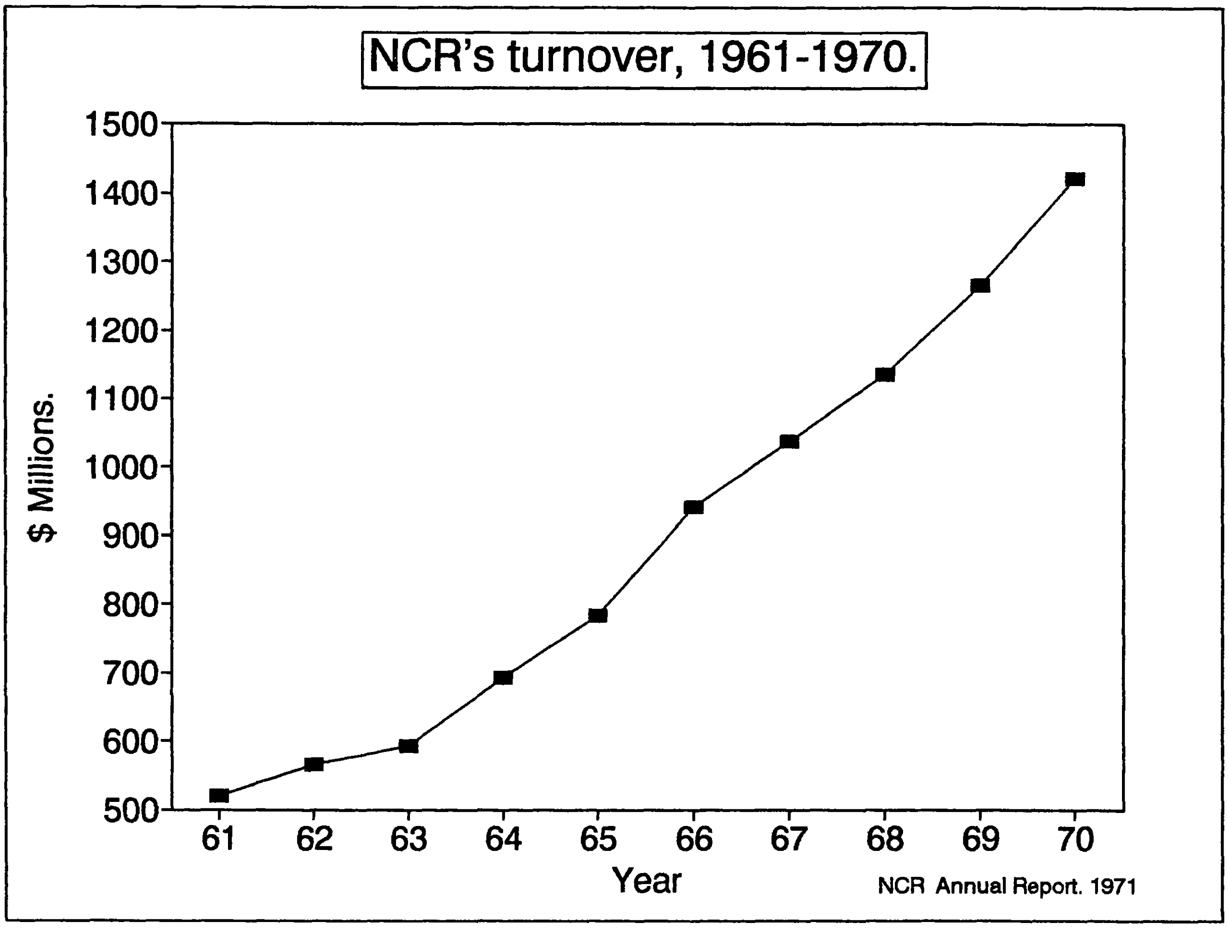
[85]Ibid.

[86]CBI Archive, Auerbach Electronics Corporation, 'A corporate business strategy for information processing, 1960-1970', Chapter IX 'NCR', 1960.

[87]US vs IBM, px2050, IBM 'NCR', 1/5/67.

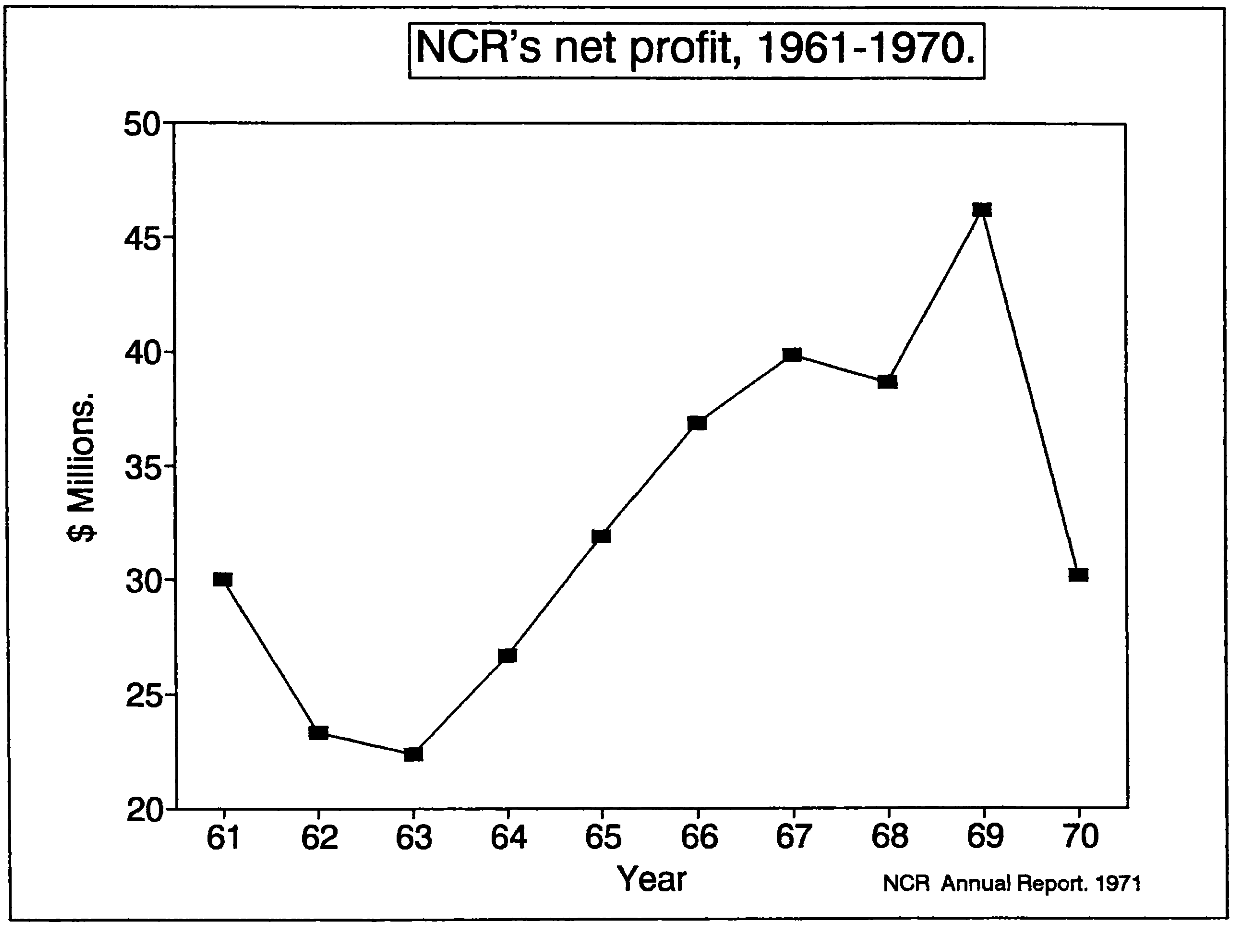
[88]Ibid.

Figure 8.6



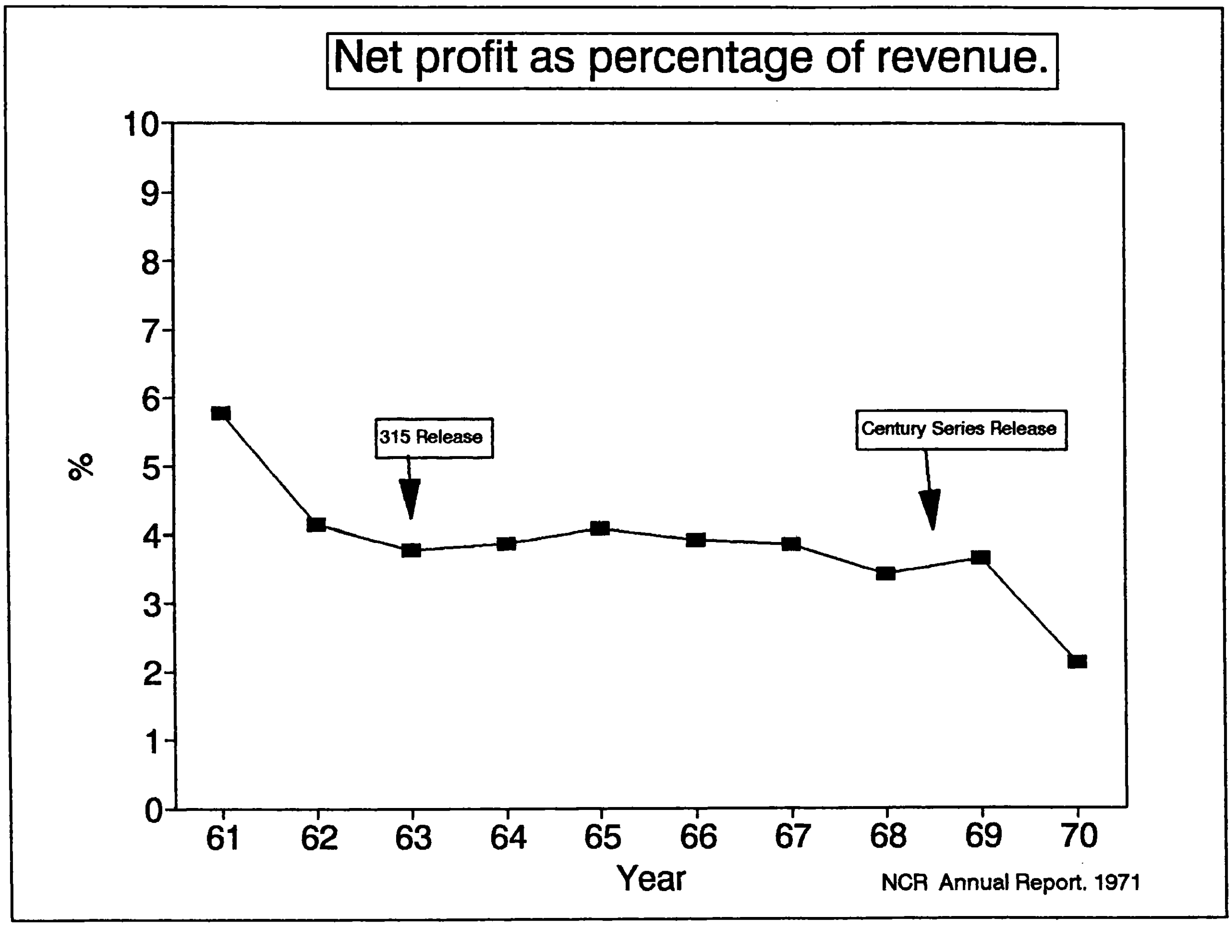
NCR's turnover, 1961-1970.
1500
1400
1300
1200
1100
1000
900
800
700
600
500
$ Millions.
61
62
63
64
65
66
67
68
69
70
Year
NCR Annual Report. 1971

Figure 8.7



NCR's net profit, 1961-1970.
50
45
40
35
30
25
20
$ Millions.
61
62
63
64
65
66
67
68
69
70
Year
NCR Annual Report. 1971

Figure 8.8


Net profit as percentage of revenue.
10
9
8
7
6
5
4
3
2
1
0
%
315 Release
Century Series Release
61
62
63
64
65
66
67
68
69
70
Year
NCR Annual Report. 1971

A second weakness IBM saw in the company was its conservative management, which was unable to make radical decisions to exploit its very large marketing force.

NCR entered the computer industry in the 1950s. Like other business machine firms it had a number of reasons to do so. The company had started electronics research in the 1930s for use in its accounting products. By the 1950s, some of the applications for NCR's traditional systems were being superseded by computer technology. A number of financial institutions were becoming interested in using computers; these were NCR's core clients.

NCR took a slow methodical path in entering the commercial computer business, and took a number of actions to keep down the costs of doing so. The first step it took was to acquire the Computer Research Corporation[89]. This was a small firm making specialist computers. It consisted of engineers who had left the Northrop Aircraft Corporation when it ceased developing its own computer to guide the SNARK long range missile and opted to buy the BINAC computer from the Electronic Control Company (Eckert and Mauchly's UNIVAC firm). NCR set this team to work on developing a commercial computer. However, many of the CRC engineers left when NCR announced that the operation was to move away from California to NCR's home town, Dayton, Ohio. By the time this order was reversed, most of the engineers had gone[90].

For this reason, and to limit the financial impact of producing the computer, NCR commissioned GE to carry out all the engineering and production of a system known as the NCR 304. As has been seen, GE had already made an impact on the banking market with the production of the ERMA computers for the Bank of America[91], and it seems natural that NCR should look to it to produce the 304. It was a fairly substantial computer, costing between $750,000 and $1.25m. It was a transistorised machine, relying on GE's capability in this area. Deliveries began in 1960; 33 were delivered.

By 1960 NCR was developing two more arrangements with other firms to give it further options in the data processing market. In the UK NCR went in to partnership with the Elliott Automation company to form National-Elliott. By 1960, Elliotts was delivering the 405 computer in numbers, which NCR sold to commercial users in Europe. Later National-Elliott sold a number of NCR systems in Europe. However, as it built up its presence,

[89] Auerbach, 'A corporate business strategy', chapter IX.

[90] Ibid.

[91] See above, chapter 7, pp259-261.

NCR started to market its own systems directly, and in the mid-1960s the agreement ended. NCR had come to a similar arrangement with CDC. CDC had been selling the 160 computer into the scientific market very successfully. In July 1960 a team from NCR visited the CDC operation in Bloomington, Minneapolis[92]. It was arranged that NCR would sell the system to the banking and retail industries[93]. The system was sold as the NCR 310. However, it was not a huge succee, 45 being installed by 1964[94].

Eventually NCR started to produce and sell its own computers. The first of these was released in 1960. This was a small scale, second generation system, the NCR 390. It had paper tape input-output and optional punched card peripherals, but most important was the provision for input-output via magnetic ledger cards, which the Postronic and Burroughs banking calculators used for their input-output[95]. Many hundreds of these computers were sold. The United States Air Force purchased 175 of them for payroll calculations at air bases[96].

In 1962 the NCR 315 was released as a replacement for the 304. The 315, together with the small scale 390, was to remain the standard NCR computer throughout most of the 1960s, though it was gradually enhanced, being offered in more sizes and with more peripherals. By March 1968 NCR had 800 315s either installed or on order, and another 120 of the improved 315 RMCs installed or on order[97].

This level of sales was way ahead of the original plan. On its release, NCR had budgeted for the production of 200 315's, of which 90% were to be leased to customers. By May 1961, with the release of the on-line version of the machine, the planned production had been raised to 500 machines[98]. NCR was to double this by the end of the decade.

In 1965 NCR added the NCR 500 to its range. This was another system not compatible with any of the other machines in its range. It was

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[92]US vs IBM, dx330, Correspondents from R.S. Oleman, NCR President, to W.C. Norris, CDC President, 8/7/60.

[93]US vs IBM, dx331, W.C. Norris, 'Address to [the] Twin City Security Analysts', 2/3/61.

[94]IDC, EDP Industry and Market Report, 23/3/64, p11.

[95]Auerbach Corp, 'A corporate business strategy', chapter IX.

[96]US vs IBM, px4829, Arthur D. Little Inc, Services to Investors, 'The Computer Industry-The Next Five Years', October 1964, these were private market analysis papers.

[97]IDC, EDP Industry Report, 29/3/68, p7.

[98]US vs IBM,dx746, NCR,'Financial report on the 315program', 10/6/63.

specifically aimed at handling the type of data generated by its traditional users[99]. Over 1000 of these small machines were installed[100], many being used in a core area of NCR business, payroll calculations. One major failure for NCR was the CRAM memory device. This was a mass storage system similar to the RCA RACE. It used strips of magnetic tape which were stored in a large device which would select a tape and read it. It was NCR's rival to the disk drive for mass random-access storage. While it could store large amounts of data, it was slower and less reliable than the disk drive. Its one advantage of large capacity was matched quickly by new IBM disk drives. NCR stuck to the product for a long time, showing a conservative refusal to accept the failure of the concept.

NCR computers were most successful in its traditional banking and retailing markets. Many of the smaller machines went to smaller banks. The 315 had a program for controlling early on-line banking terminals and automatic tellers, a facility which helped it sell to banks. The 315 RMC was given multi-access capability to improve NCR's position in this same market. NCR was more successful in small and medium sized banks, while the large scale Burroughs equipment found its way into larger banks. This distribution is illustrated in the following table:

Table 8.6 NCR's computer customers.

Industry	% of NCR computer/electronic accounting machine sales, 1966.
Banking	51%
Distribution	14
Manufacturing	9
Federal Government	5
State and local Government	4
Process	3
Insurance	3
Consultants and service bureau	3
Medical	3
Other	6
	100

Source: US vs IBM, px2050, IBM Market Evaluation Department, 'A company study of [the] National Cash Register Company', 1/5/67.

Overall, computers took a long time to become an important revenue generator for NCR:

[99]Fisher et al, IBM and the U.S. Data Processing Industry, p250.

[100]IDC, EDP Industry Report, 29/3/68, p7.

Table 8.7 NCR products as a percentage of revenue.

Product	1965 Amount $m	1965 %	1966 Amount $m	1966 %
Cash Reg.	190	26	200	23
Acc. Machines	246	33	319	37
Service	130	18	157	18
Supplies (inc NCR paper)	113	15	131	15
EDP	58	8	63	7
Total	737	100	871	100

Source: US vs IBM, px2050, IBM Market Evaluation Department, 'A company study of [the] National Cash Register Company', 1/5/67.

This seems remarkably low, and it may have been the case that the 390 was counted as an accounting machine. However, it is clear that from this stage onwards EDP became a more important product for NCR[101].

In 1968 the company released the first members of the Century Series of third generation computers. It is significant that, while computers did not form a large part of NCR sales before this, it had been able to keep selling second generation computing well into the third generation period. NCR had milked as much as possible out of its investment in second generation equipment.

The Century Series changed this, and heralded what IBM had feared in 1966, a more positive attitude towards the computer industry on the part of NCR. NCR continued to emphasise the smaller end of the market, the end where it already had strong customer rapport[102]. However, increasingly NCR was selling the Century 100 and 200 computers to a wider audience outside its traditional markets[103]. There were probably two reasons for this: the desire to increase market share, and the need to spread costs to maintain competitiveness. Sales of NCR computers rocketed by 98% in one year, but earnings fell on the back of the large cost of financing so many new lease agreements[104]. Rapidly, electronic data processing rose to well over 25% of the whole business[105]. In the main however, its main

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[101]See figure 8.4, p304.

[102]US vs IBM, px2050, IBM, Market Evaluation Dept, 'A company study of NCR', 1/5/67. IBM considered NCR's reputation to have been excellent with users.

[103]Fisher et al IBM and the US data processing industry, p252.

[104]US vs IBM, dx340A, NCR annual report 1968.

[105]See figure 8.4, p304.

markets stayed as banking, retail, payroll and accounting.

Computers were only a part of the mix of technology that would maintain NCR's place in the information processing market of the 1970s. The company benefited greatly from on-line applications of technology, such as bank cash machines and automated retail check-out systems and tills. Now a part of AT&T, it is still strong in these sectors.

NCR had a different approach to RCA and GE, and indeed IBM. It took to computers slowly, expanding deliberately on its traditional user base, a base which allowed it to introduce new technology slowly to ensure it maximised returns from the old systems. Yet even by 1964 NCR, despite its slow adoption of computers, its concentration on a few niche markets, and its small size, had already matched GE's market share[106]. By this standard NCR's approach seemed to be successful and allowed NCR to be a profitable player in the new market.

Burroughs

Burroughs was similar to NCR, but in the 1930s and 40s it was losing market share in its traditional market, and therefore adopted computers at an earlier stage. Before NCR moved into accounting machines, the Detroit-based Burroughs company[107] dominated the market. It supplied a wide array of accounting machines, adding machines and office supplies. Like NCR, the main customers were accounts departments and banks. However, by the 1940s NCR had stripped it of its lead in this market.

IBM believed that Burroughs' decline was due to the poor management structure of the company. It described Burroughs' management as having been 'casual'[108]. The company was split between manufacturing and marketing, and this stifled the flow of information between the key operating functions. It also had a weaker field sales force than NCR. Better strategies and tighter control slowly came about in the 1960s. The company seemed to become revitalised with the rise of R.W. Macdonald to the post of Executive Vice President in 1964: eventually he became President and CEO[109]. He cut his teeth as an accounting machine salesman. The new management split the company into four groups:

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[106]US vs IBM, px4829, Arthur D. Little Inc, 'The Computer Industry-The Next Five Years', October 1964.

[107]US vs IBM, px2082, IBM, Market Evaluation Department, 'A Company Study of [the] Burroughs Corporation', 30/6/67.

[108]Ibid.

[109]Ibid.

Business Machines,
International,
Defence Space and Special products,
Business Forms and Supplies.

The following tables show Burroughs' product and market breakdown. Notably, computers became more important to Burroughs at an earlier stage than at NCR, though overall Burroughs was smaller and therefore the computer revenues were little more than those of NCR:

Table 8.8 Burroughs revenue by product, 1966

	Amount $'m	%
Accounting Machines	194	39
Adding Machines	28	6
Data Processing	62	13
Service	73	15
Supplies	76	15
Components/Misc	16	3
Total commercial	449	91
U.S. Govt. contract	45	9
Total	494	100

Source: US vs IBM, px2082, IBM, Market Evaluation Department, 'A Company Study of [the] Burroughs Corporation', 30/6/67.

Table 8.9 Burroughs revenue by customer.

Banks and other financial institutions	37%
Manufacturing and wholesales	27%
Retail trade and general	22%
Government	11%
Public utilities	3%

Source: US vs IBM, px2082, IBM, Market Evaluation Department, 'A Company Study of [the] Burroughs Corporation', 30/6/67.

The firm had 2,200 research personnel and an annual research budget of $22m[110]. As most of these were committed to some form of data processing work, this was a significant R&D force.

Like NCR it was basically a financially sound company, especially after McDonald's shake up. While not in the league of IBM, it was moving in the right direction, and during in the 1960s a number of financial indicators started to look better than NCR's. The following graphs show Burroughs' revenue, profit, and profit to revenue. The latter showed a healthy improvement as McDonald's programme developed:

110 US vs IBM, px2082, IBM, 'A company study of Burroughs', 30/6/67.

Figure 8.9

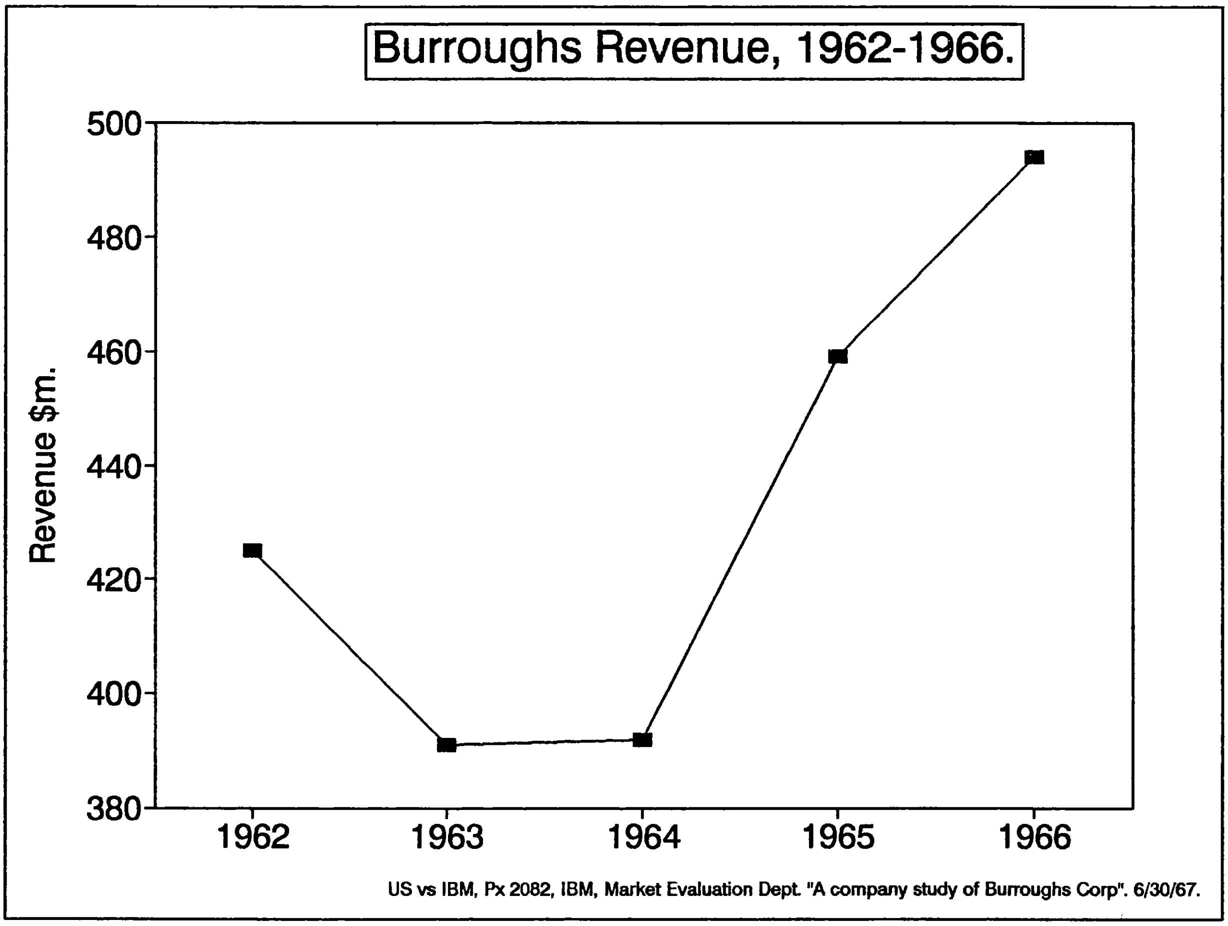
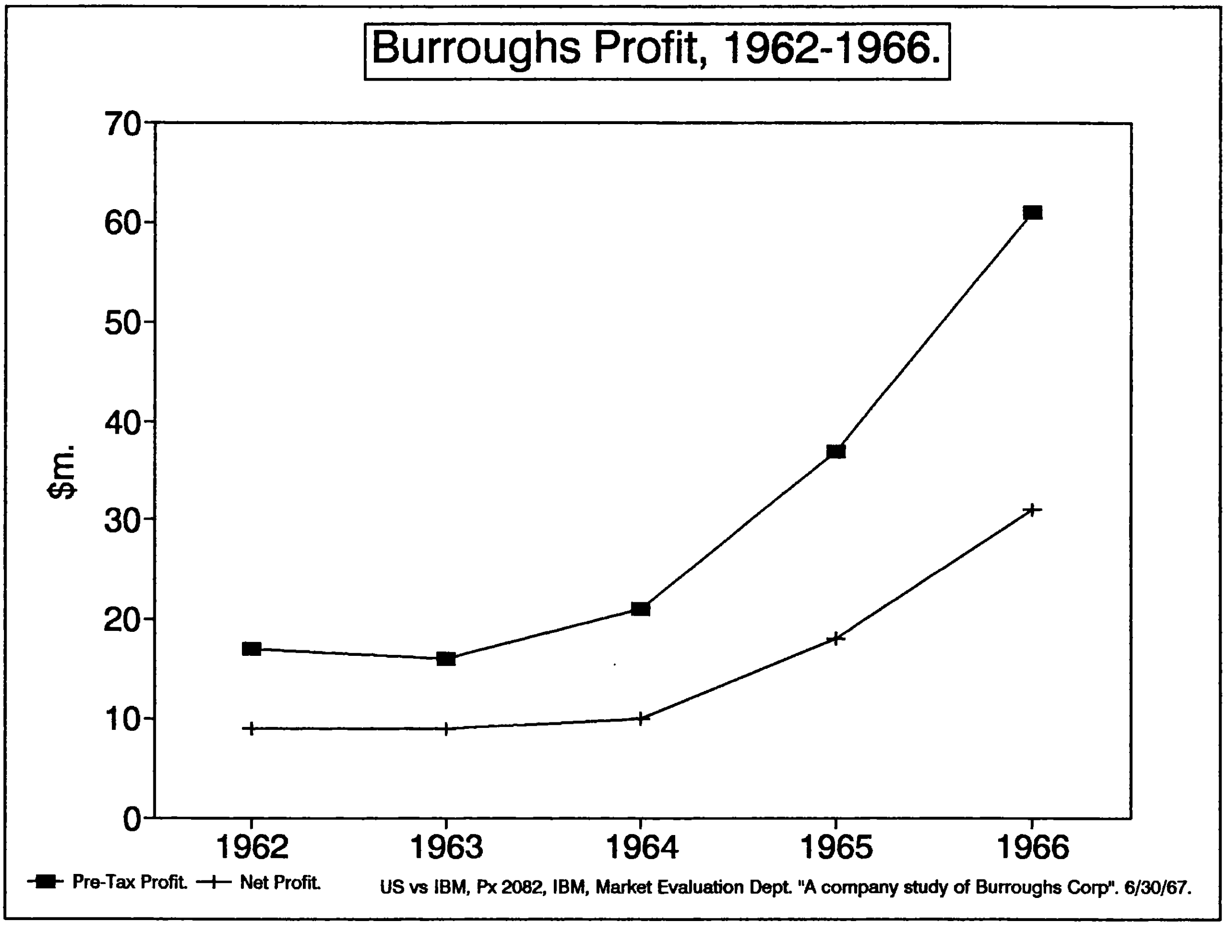
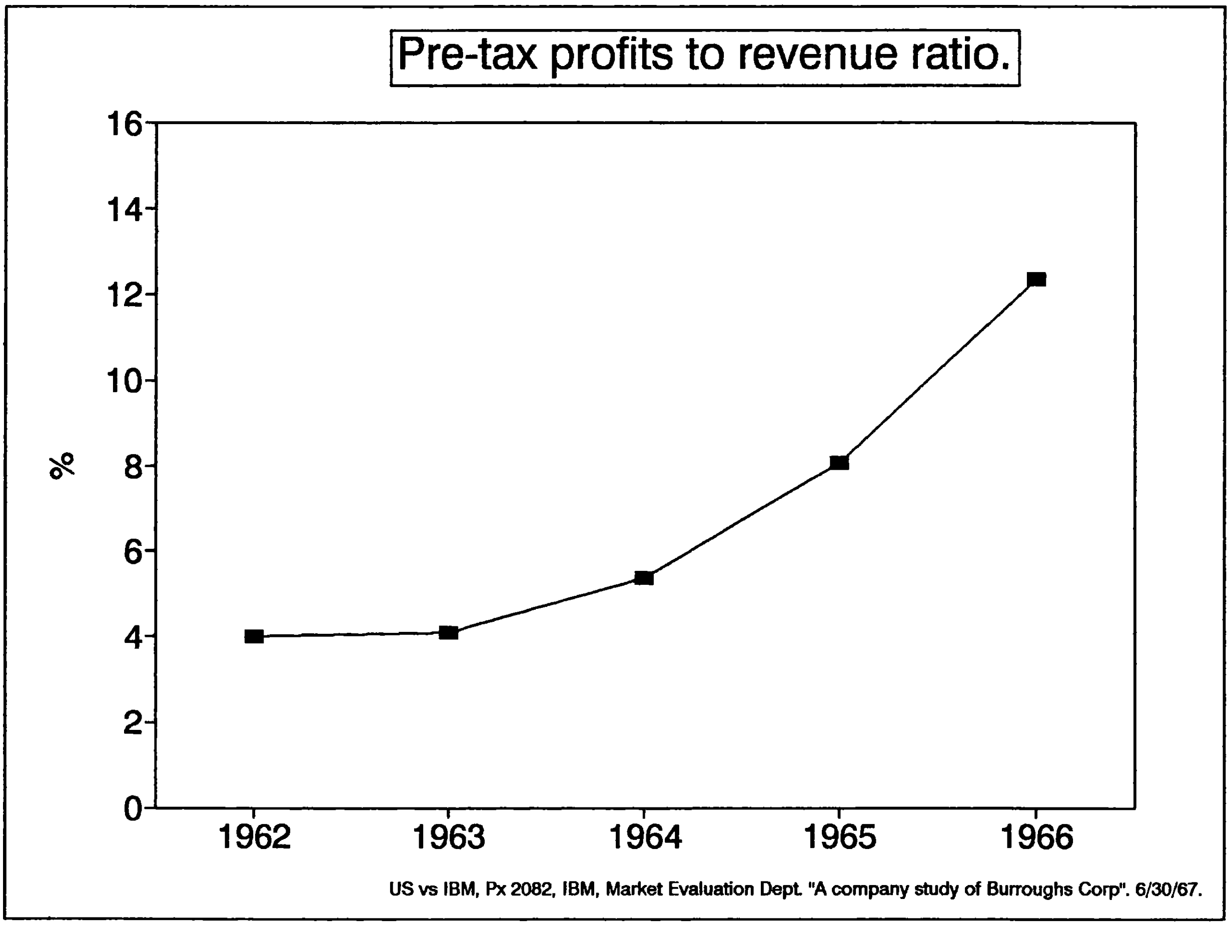

Burroughs Revenue, 1962-1966.
Revenue $m.
500
480
460
440
420
400
380
1962
1963
1964
1965
1966
US vs IBM, Px 2082, IBM, Market Evaluation Dept. "A company study of Burroughs Corp". 6/30/67.

Figure 8.10



Burroughs Profit, 1962-1966.
70
60
50
40
30
20
10
0
$m.
1962
1963
1964
1965
1966
Pre-Tax Profit
Net Profit
US vs IBM, Px 2082, IBM, Market Evaluation Dept. "A company study of Burroughs Corp". 6/30/67.

Figure 8.11


Pre-tax profits to revenue ratio.
%
16
14
12
10
8
6
4
2
0
1962
1963
1964
1965
1966
US vs IBM, Px 2082, IBM, Market Evaluation Dept. "A company study of Burroughs Corp". 6/30/67.

Burroughs approached computers from a different angle to NCR: it tended to manufacture larger and more complex systems. On the whole it produced these systems successfully, though in the late 1960s it did have serious problems with its very large 8500. IBM believed Burroughs was committed to computer technology from an earlier stage than NCR[111], and saw this as an attempt to compensate for its declining fortunes in traditional products. It also developed a large business in small systems, designed to replace accounting machines.

Burroughs had two routes into computing, it took part in a number of high technology military contracts, and, secondly, purchased computer skills from outside. All business machines firms, except IBM, had to acquire electronics and computer technology from outside when it started to impinge on traditional techniques. At the end of June 1956, Burroughs bought a small computer company called ElectroData[112]. This firm was formed in 1954[113] and had developed the Datatron computer, delivering 9 of them in the 1954, and a further 13 in 1955[114]. It also supplied some of the earliest magnetic tape drives. Under Burroughs' control the original machines, the 203 and 204, were replaced by the 205 and later the 220 computer. The latter introduced magnetic core memory instead of the magnetic drum memory used in the earlier systems[115].

The ElectroData Division of Burroughs also absorbed Burroughs' own early computer developments, namely the E-101. The E-101, was aimed at the scientific market[116] and was basically a simple electronic calculator. Burroughs itself had had a growing interest in electronics since the Second World War. It had made a number of specialist components for other firms and had started work on air defence and communications projects[117]. Like IBM, Burroughs benefited from the SAGE contract. Burroughs was responsible for the building of the AN/FST-2, which was the main computer for

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[111]US vs IBM, px2050, IBM, 'A company study of NCR', 1967.

[112]US vs IBM, tr9185, McCollister, ElectroData Marketing vice president.

[113]US vs IBM, dx698, ElectroData annual report 1954.

[114]US vs IBM, dx700, ElectroData annual report 1955.

[115]US vs IBM, tr9181, McCollister.

[116]CBI Archive, Auerbach Electronics Corporation, 'A corporate business strategy for information processing, 1960-1970', Chapter III 'Burroughs Corporation', 1960.

[117]Ibid.

processing radar information[118]. This contract led to the growth of the Paoli electronics laboratory, the establishment of a large electronics facility in Detroit, a large defence service organisation, and the acquisition of computer-literate personnel. By 1959 Burroughs' revenue from SAGE had reached $155m and it had received another $35m thereafter for an airborne version of the AN/FST-2 for the Airborne extension to SAGE, ALRI[119]. Later in the 1950s, Burroughs was awarded a contract to build the navigation computers for the ATLAS ballistic missiles. This led to Burroughs' first solid state military computer; by 1959 this had earned $77m for the company. IBM believed this was the first large scale solid state computer ever built, and gave Burroughs real prestige[120].

The merger of ElectroData and Burroughs' own computer operations made a good deal of sense. ElectroData was trying to sell to both the commercial and science market, taking on both the IBM 650 and 704[121]. This was expensive for a small company, especially given the slow returns from leased machines. Burroughs took the opportunity to integrate Burroughs' own computer developments into the more commercially orientated ElectroData organisation. It is ironic that what was basically a business machines firm needed to buy in commercial computer skills.

The following table shows how many first generation computers Burroughs sold:

<u>Table 8.10 Accumulated installations of Burroughs computers.</u>

	1954	1955	1956	1957	1958	1959
E-101	65	130	165	180	205-production ended	
205	7	20	50	85	100	120
220					2	31

Source: CBI Archive, Auerbach Electronics Corporation, 'A corporate business strategy for information processing, 1960-1970', Chapter 3 'Burroughs Corporation', 1960.

Burroughs took all this and produced a computer operation of small size compared to IBM, only selling around 250 computers per year in the mid-1960s, but with an extremely loyal customer base[122]. By the early

[118]Ibid.

[119]Ibid.

[120]<u>US vs IBM</u>, px2082, IBM, 'A company study of Burroughs', 30/6/67.

[121]<u>US vs IBM</u>, tr9180, McCollister.

[122]<u>US vs IBM</u>, px2082, IBM, 'A company study of Burroughs', 30/6/67.

1970s it was a contender for the number two spot in the US market. By 1977 it had equalled the installed base of Honeywell and Sperry[123].

Yet it was a small company compared to the likes of IBM, RCA, GE, and Sperry. It only had a small computer business in the late 1950s and was not greatly profitable in the early 1960s. As has been stated, this changed with MacDonald taking control and recovery was greatly helped by the success of Burroughs' second and third generation computers.

The machines that gave it its position were on the whole larger than NCR's, and they had significant advanced features over the opposition. One area in which it fared well was in large commercial computers and more importantly the concepts that went with them. The basis of this was military work. In 1962 it received an order to supply the military with the D825 large scale computer to control the Back-up Interception Control, BUIC[124]. This was a smaller scale SAGE-type system. It allowed Burroughs to fund the development of a computer with multiple processors, advanced communications and sophisticated memory. This gave it a very advanced real-time computer, which Burroughs utilised in a number of ways. In 1965, as the D830, it was used to supply TWA with a large-scale flight reservation system. It was up-dated as the B8500 civil computer, announced in 1965, utilising integrated circuit technology and advanced thin-film memory. The B8500 was to be a very large time-shared computer system, the largest of the x500 family though not fully compatible with the rest of the family. B8500s were ordered by the University of Wisconsin and U.S. Steel. However, the most significant order was from Barclays Bank in the UK[125]. A centrally located 8500 was to communicate with Burroughs TC 500 terminals in almost all 2,500 of its branches. This was to be the largest On-Line Transaction Processing (OLTP) banking system in the world, an application firmly based on Burroughs' traditional market. The 8500 never became a standard product, and most were not delivered, as was the case with the Barclays installation. Indeed the Barclays effort became something of an embarrassment. However, it gave Burroughs communication and OLTP knowledge that was to be the strength of the rest of the x500 range.

The x500 series architecture proved to be a successful range of large scale systems. It was based on the B5000 first delivered in 1961 and therefore predating the 8500. The B5000 was updated in 1964 and became the B5500, and then, in 1966, it was brought into the third generation of

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[123] See figure 8.2, p301.

[124] US vs IBM, px2082, IBM, 'A company study of Burroughs', 30/6/67.

[125] Ibid.

computing as the 6500. The 5500's great advantage was that it could communicate with 15 independent terminals, and consequently sold reasonably well. The 6500 offered greater power, equivalent to the IBM 360/65, and again was reasonably successful. Burroughs' peripheral systems were geared to support the advantages that the x500 architecture offered. Burroughs' disk drives had a fixed pick-up head on each groove of the disk. While this meant they could not store as much information as competitor's moving head systems, it did make them very fast. Together with good communications facilities, this feature greatly improved the ability of the x500 range to act in the OLTP role. This was a significant market which other firms had difficulty supplying products for.

Burroughs quickly introduced smaller systems compatible with the 6500, the additions to the range were the medium scale B2500 and B3500, seen by IBM as the best competition to the 360/30 and /40[126]. While this concept meant it was taking on IBM's medium and large scale products, Burroughs ensured it did not over-stretch itself. Components came from outside: it purchased the most advanced chips that Fairchild had to offer and, while it provided its own fixed head disk drives, printers were bought in. The 2500/3500 was very successful[127]. A.D. Little Inc., saw the 2500/3500 as a large system at moderate prices, utilising advanced components and concepts. It had virtual memory derived from the 6500, giving it advanced multi-user abilities. In 1970 the 6500 and 2/3500 machines were replaced by the x700 series, also described by A.D. Little as the most sophisticated on the market.

Below this level, Burroughs offered a separate range of smaller computers. Announced at the same time as the B5000 in 1961, the B200 fared moderately well. By 1967 about 500 had been placed on the market. However, this had been greatly aided by Burroughs winning the contract for the Air Force Base Level Program, Phase 1A[128]. This accounted for 30% of sales, and put a B200 in most large USAF bases. This is another example of how large US military expenditure on conventional computers was helping to increase the economies of scale of the US industry. Another 40% of B200 sales went to the financial industry. The reason the system did well in both sectors, was that the B200 was designed with an operating set that allowed direct access by terminal. In banks, this was used for direct on-

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[126] Ibid.

[127] US vs IBM, px4835, A.D.Little Inc, 'The computer industry 1970-1975', April 1971.

[128] US vs IBM, px2082, IBM, 'A company study of Burroughs', 30/6/67.

line access by bank tellers. Though crude, this was an attractive feature for smaller banks. A smaller compatible version, the B100, was added to the range. The B200 was replaced by the B300 in 1965.

An even smaller machine was the TC500. This was the so-called Terminal Computer for the large scale x500 range. The 8500 installation at Barclays was to have 2,500 of these in branches: they were to act as intelligent terminals. While this contract never came to fruition, many TC500s were sold in similar roles.

Burroughs had two other notable products. First, the traditional accounting machines were superseded by the electronics based E and L ranges of calculators[129]. They were selling at around 20,000 per year by 1970, and A.D.Little saw this as a large potential up-grade market for any small third generation computer that Burroughs could turn its attention to. This was a potential market for the B500, a small scale member of the x500. Second, there was the much vaunted ILLIAC IV. This was Burroughs' super-computer venture. The project was funded by [D]ARPA, the [Defence] Advanced Research Project Agency, and was being constructed at the University of Illinois, for NASA use. It was to provide large scale inter-active super computing, to improve the productivity of NASA engineers: in this respect it was similar to MIT/GE's project MAC, which was also funded by [D]ARPA. This project started in the 1960s and lasted well into the 1970s, but was not successful.

Thus Burroughs was a growing force in the industry and was outstripping giants like RCA and GE. Despite this, it is evident that it was not competing for all aspects of the market: instead it concentrated on such areas as banking and military systems, and ignored some peripherals and components. Yet it seems that Burroughs was somewhat less enthusiastic about its traditional user base than NCR. It was not until the latter half of the 1960s that the firm started offering small scale computers for its accounting machine user base. Burroughs was concentrating on two basic product lines: large scale commercial computing, later joined by a range of small scale computers for accounting purposes.

A breakdown of Burroughs' computer sales in 1967 shows that, indeed, the firm had a finance and government emphasis. Figure 8.11 shows a simple breakdown of Burroughs' customers. It should be noted that the figures for 1967 are not representitive as they over-emphasises the importance of non-government and non-financial customers due to the inclusion of two large orders for the 8500 systems from manufacturing and educational users:

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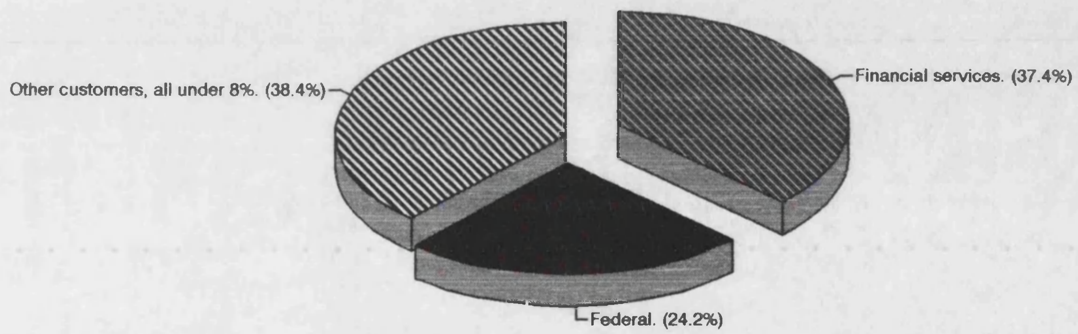
[129]US vs IBM, px4835, A.D.Little, 'The computer industry 1970-75', April 1971.

Figure 8.12

Burroughs EDP Customers.



US vs IBM, Px 2082, IBM, Market Evaluation Dept. "A company study of Burroughs Corp". 6/30/67,.

In the IBM section it was shown that NCR and Burroughs were fairly highly geared compared to IBM. This underlines the financial burden placed on them when they tried to expand their computer user base. They needed long term debt to fund high levels of R&D, expensive sales networks, and to cover leases. This seems to have been one of the factors that prevented either firm from being able to tackle IBM head on. The niche strategy was more successful than the broad attack of the electronics companies, but it also showed the trap they were in which prevented them challenging the market leader.

CDC and DEC.

The start-up firms CDC and DEC, though completely different types of organisation and operating in different areas of computing, also followed niche strategies. Detail on these firms will be limited: they will merely be contrasted to the electronic/electrical corporations to show their more focused approach.

Digital Equipment Corp made its reputation building minicomputers for the scientific community. DEC then reached the number two position in the computer market, having extended its machinery into every aspect of small to medium scale computing. DEC was formed by engineers from the Lincoln Laboratories of MIT, part of the computer team supporting MIT's air defence developments, working on such famous projects as Whirlwind and SAGE. In the late 1950s the future head of DEC, Kenneth Olsen[130], worked on developing MIT's TX0 and TX1 computers. While others were starting to develop large, time-shared computers to satisfy the need for interactive computer access for engineers[131], the TX0 team took the opposite approach. The TX0 provided a small departmental machine for engineers to interact with, decentralised as opposed to centralised computing.

After the formation of DEC in 1957, the firm rapidly expanded from making specialist research equipment to producing the PDP series of computers which were small scale machines for engineers. The first PDP machines did well, selling in large numbers to the scientific and research community. Throughout the 1960s the company grew rapidly, but steadily. There were two notable features of computers of this class: firstly, they were purchased rather than rented, and secondly, they were sold to advanced users, therefore requiring only limited programming and service support.

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[130] G.Rifkin & G.Harrar, The Ultimate Entrepreneur: the story of Ken Olsen and Digital Equipment Corporation, Chicago, Ill.,1988.

[131] Indeed MIT itself was the project manager for the large time-sharing system Project MAC/MULTICS.

The purchasers of these systems were willing to develop their own programs, most of the tasks that the machines were used for were highly specific. DEC did not have to find the capital to fund leases or to develop large software and servicing operations. This meant that the firm avoided the cash-flow problems which forced the first generation of small computer producers to sell out to the business machines firms.

Another advantage that the company had was the fact that many of its machines were sold on an OEM basis[132], as a part of another firm's commercial application. Many firms used an embedded DEC computer as the controller device for industrial and military systems, a good source of cash sales.

From this solid base the company expanded into larger scale systems for the science market, and later it started to support and market its mini-computers for the commercial market. The mini-computer market of the 1970s is where DEC managed to score its major victory, building on the niche base it had developed in the 1960s. The firm's great success was producing a product which tapped a huge pent-up demand from advanced users not satisfied by the larger time-share computers. It did so without encountering crippling cash-flow problems of the type encountered by the more ambitious approach taken by a firm like RCA.

Before the minicomputer boom of the 1970s, Control Data Corp had been the most dramatically successful firm in the industry. CDC worked at both ends of the scientific market, but has since been most renowned for its 1960s range of super-computers, though at the time its insatiable desire for acquisition created as much furore.

CDC was formed by many of the people who had also started Engineering Research Associates[133]. ERA was a small high technology company in Minneapolis formed by a number of ex-US Navy code breakers, who started to act as the USN's captive computer and electronics firm. Remington bought ERA and merged it into UNIVAC[134]; this caused some discontent in Minnesota. In general UNIVAC's Philadelphia operation got the general purpose computer work, UNIVAC/ERA tended to get the specialist military work, though they managed on occasion to pre-empt their colleagues in

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[132]Original Equipment Manufacture, is the term used for describing controllers or other equipment which is embedded in a larger system.

[133]D.E. Lundstrom, <u>A few good men from UNIVAC</u>, Cambridge, Massachusetts, 1987.

[134]See the final section of this chapter.

Philadelphia with well timed commercial machines[135]. William C. Norris, while a senior official with UNIVAC, was one of the most discontented[136]. He led the ERA men into a new firm, CDC, which was backed by local venture capital[137].

The core reason for CDC's meteoric success was its chief designer, Seymour Cray. Discontented with UNIVAC, Cray phoned Norris and told him he would start work at CDC the next morning[138]. Cray's business plan was simple:

'Five-year goal: Build the biggest computer in the world.
One-year goal: Achieve one-fifth of the above.[139]

CDC's first major product, the 1604, was snapped up by the US Navy; the second was bought by the UK Government for code breaking. CDC was producing a large, powerful machine, cheaply. It avoided the costs of developing huge amounts of applications software and targetted the highly advanced science market. Sperry tried to sue CDC for using knowledge acquired from UNIVAC. However, it was the next large machine it built which proved the small company's ability, and the genius of Cray. New circuit techniques, cryogenic cooling, the shortest possible connections between circuit boards, led to the 6600 super-computer, the first really successful super-scale computer. As has been seen, IBM's reaction to this was a mere paper phantom. Before the release of the follow-up 7600 machine in the late 1960s, CDC started anti-trust proceedings against IBM, putting 'Big Blue' off announcing another unbuildable machine. IBM has not seriously ventured into this market since. The 6600 became a range of super-computers, the single processor 6400 and the multi-processor 6500 (basically two 6400s coupled together) and the 6700 (two 6600s together).

CDC was able to offer excellent price/performance ratios[140]. As in the case of DEC, this was because, by offering the machines to expert users who had unusual applications, CDC did not have to provide the vast backup and software services needed elsewhere. At the same time it supplied

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[135]See below pp359-360.

[136]CBI Oral History Collection, W.C. Norris interviewed by A.L. Norberg, 28/7/86.

[137]James C. Worthy, William C. Norris: Portrait of a Maverick, Cambridge Massachusetts, 1987.

[138]Ibid p38.

[139]Ibid p39.

[140]Nancy Dorfman, Innovation and Market Structure: Lessons from the Computer and Semiconductor Industries, Cambridge Massachusetts, 1987, p59.

what were probably the most technically advanced systems then available.

However, CDC did not just build super-computers. The smaller 160, like the larger 1604, was sold into the science market, though NCR sold a few commercially. These machines were replaced by the 3000 series in the mid-1960s. These were comparable to larger 360 machines, but were mainly sold to scientific users. CDC was one of the most aggressive companies in the computer market, acquiring dozens of companies. From 1957 to 1973 IBM lawyers calculated CDC had purchased 60 companies at a value of $951.4m[141]. This included the minicomputer arm of Bendix, the scientific computer bureau, CEIR, and the Commercial Credit Corp worth $.75bn. Bendix gave it a stake in the market for scientific mini-computers, and it was successful in OEM markets.

It moved only slowly into the commercial market: it opened up computer data networks, computer bureaus, and became the largest supplier of OEM peripherals to other producers. While firms like Memorex and Telex are famous for offering plug compatible disk and tape drives to end users, CDC was supplying the producers, including Burroughs, ICL, Honeywell and many others. In the 1970s it continued to supply super-computers, replaced the 3000 range with machines of broader appeal, and even started producing IBM-compatible computers.

CDC's fall from grace, under competition from the likes of Cray Research, was equally dramatic. CDC was built on the back of a star rating in the investment market. The loss of Cray, and the financial failure of the huge interactive education system, PLUTO, undermined this status as early as the mid-1970s, and by the late 1970s this made supporting its debt an extremely difficult prospect. CDC is now a shadow of its former self.

These firms only competed in an oblique way with IBM. DEC proved the most successful in the long run. However, they both displayed an ability to capture a niche and to build on that niche to enter the more mainstream markets. They had solid cash flows from the tendency of scientific and OEM users to purchase systems. R&D was focused on the hardware. Better software and support came as the companies grew and enough funds became available to provide these extra facilities.

This is not dissimilar to NCR and Burroughs. The accounting machine firms did have the expense of leasing systems, but they were able to concentrate on established niches, giving them a solid base to build on, a major contrast to the electronics firms.

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[141] US vs IBM, dx296, IBM attorney's estimates.

Honeywell and Sperry Rand

Until the 1980s there were two other notable survivors in the computer industry which fell somewhere in between the electronics companies and the business machine firms. Sperry-Rand was a major business machine company, but was also heavily involved in military electronics, farm equipment and a number of other areas. Honeywell, by a combination of a shrewd approach to the market, and a slow build up of its computer market coverage, managed to establish a large computer operation.

These were the two firms which benefitted most directly from the demise of RCA and GE. Sperry acquired the RCA user base, making it once more the number two computer company and Honeywell absorbed GE's operation.

Honeywell

Honeywell's entry into the general purpose computer business was via a joint venture with Raytheon[142]. In the late 1940s and early 1950s, Raytheon had undertaken some early computer developments with military sponsorship. However, once these sources dried up it was not interested in continuing with computers on a speculative basis. Raytheon was a completely military orientated company: by the 1980s it was one of the largest military contractors in the USA[143]. Honeywell was also in the military business, but it was equally involved in civil instrumentation and industrial control. In 1955 Honeywell formed DATAmatic with Raytheon[144]. Raytheon supplied 150 engineers, Honeywell supplying just 12 staff, but Honeywell took 60% of the stock and quickly took full control[145].

The first product was the D-1000, a very large business machine. Seven were built, two for use by Honeywell and five were leased out at an annual income of $3m[146]. However, the major effort to enter the market was in 1960, and like so many of the electronics companies, it was based on second generation technology. The H400 and H800 were designed to run multiple programs, therefore being able to perform such things as input-output functions while a main program was running. They were compatible machines, a fairly advanced feature for the time. They had limited success

[142]Auerbach 'A corporate business strategy', Chapter V 'Minneapolis-Honeywell Regulator Company', 1960.

[143]D. Todd, The world electronics industry, 1989, p155.

[144]Auerbach Corp, 'A corporate business strategy', chapter V.

[145]US vs IBM, tr7573, R.M. Bloch, at the time of the merger Bloch had been head of the Raytheon Computer Division.

[146]Ibid.

with over 120 H400's and 12 upgraded H1400 systems installed by late-1966 and 89 H800's and 21 upgraded H1800's[147]. However by this time the upgraded models had been eclipsed by the next Honeywell range, the H200.

Simultaneously, Honeywell produced the industrial control H290 computer, which was used by Honeywell's Brown Instrument Division. In the mid-1960s the industrial process control division, the computer department, the computer bureau operation and some other activities were merged into one: later, with GE and Bull added to it, it become known as Honeywell Information Systems.

Even by 1960 the Auerbach Corporation[148] had noted that Honeywell was building up a very large marketing force. In 1967 IBM estimated that the size of the field force had rocketed to nearly 5,500; the third largest in the industry[149].

In 1962 the company took a radical decision to attack IBM's user base, but in a way which still avoided direct competition with IBM's systems. The H200 was introduced a few weeks before the IBM 360[150]. Honeywell recognised that IBM was likely to merge the commercial 1400 range with the larger 7000 machines, and therefore the new range would not be compatible with the old systems. The H200 was designed so that a 1400 program could be easily run on it, in the hope that this would entice some of the 10,000 1401 users into using Honeywell's implementation of second generation architecture. The hope was that many users would not want to change to IBM's new architecture as it entailed large alterations to software, but they still wanted access to more advanced components to speed the system up. In many respects the H200 was not as advanced as the 400/800 range, but it hoped this would not worry many users.

This worked. A significant number of IBM 1400 users wanting to upgrade to more capable systems opted for the H200. The scope of the range grew with the additions of the smaller H120, and larger H1200 and H2200:

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[147]IDC, EDP Industry and Market Report, 29/12/66, p2

[148]Auerbach, 'A corporate business strategy', chapter V.

[149]US vs IBM, dx? (due to the poor quality of this document the number is not legible), IBM Market Evaluation Department, 'A company study of Honeywell Inc.', 29/12/69.

[150]IDC, EDP Industry and Market Report 29/12/66, pp1-12.

Table 8.11 Honeywell 200 Series Sales, up to December 1966.

Machine	Installed base
H120	350
H200	1014
H1200	65
H2200	20

Source: IDC, EDP Industry and Market Report, 29/12/66, pp1-12.

One source estimated that by 1966 Honeywell had installed $270.1m worth of systems, 7.4% of the market, putting them a distant second to IBM (at 68.3%)[151].

By this stage Honeywell was also offering a large range of industrial and military control computers. It also moved into minicomputers. These computers were used throughout Honeywell's operations, being supplied as imbedded controllers in industrial systems, as well as being sold in their own right.

Honeywell had a good reputation among its users. IDC found that most Honeywell users rated its machines and services as excellent[152]. However, it had cut some corners to ensure costs did not mushroom. Users found that Honeywell's training was limited, and some advanced software was not available. More importantly, like other firms, Honeywell was relying on outside sources for some peripherals; CDC was again the disk supplier. Some peripherals, especially Honeywell's punched card reading equipment, were seen as being weak. Honeywell was also targeting its computers at certain markets. IDC believed that the emphasis was on:

manufacturing, retailing, insurance, state government, transport and finance[153].

In 1966, Honeywell planned to increase its investment in programming and application software for these specific markets by 50%. The emphasis was commercial rather than scientific[154].

Therefore, it seems that Honeywell was much more market-driven than other electronics firms. It had a large marketing organisation, and was willing merely to update second generation architecture and to attack a certain aspect of the market; it was not technology-led. It targeted a certain type of computing and built the scope of the operation steadily, unlike the other electronics firms. Honeywell's EDP and control computer

[151]Ibid.

[152]Ibid.

[153]Ibid.

[154]Ibid.

activities were covered by the same operational group; in other electronics firms they tended to be separate profit centres. As it progressed in the industry, Honeywell improved its peripherals and increased software support for its target groups: techniques more in keeping with the business machine firms.

A final difference between Honeywell and GE and RCA was the greater importance of the computer operation to the company. IDC estimated that by 1967 EDP sales would represent 26% of Honeywell's revenue[155]. IBM estimated that Honeywell's computer group was profitable by the late mid-1960s[156], something few others could achieve. Computers were much more important to Honeywell than to GE and RCA.

However, IBM believed that Honeywell's rapid growth would slow down in the 1970s. The H200 range had been a great marketing success but offered little to users wanting more advanced features. This was probably the underlying impetus behind Honeywell's purchase of GE's computer division. In the late 1960s, Honeywell was considering what type of equipment it needed to compete adequately in the 1970s. It believed that even the H200 success would not give it a large enough user base adequately to spread the R&D costs involved[157]. The Honeywell 200 was basically not advanced, and its efforts to bring the H200 range and H400/800 systems together proved to be impossible. It started developing the very large 8200 computer to do this, but it was eventually cancelled[158]. Thus Honeywell needed a more advanced offering. It also believed that a wider international base was needed to spread R&D burdens.

GE could offer all this. In 1970 the successful marketeer Honeywell acquired GE's computer division for an exchange of shares[159]. This not only gave Honeywell the market share it perceived was needed, but it gave it computers of more advanced concept. The time-shared GE 600 architecture was maintained as a product, despite the problems GE had with it. The H6000 followed it, which in turn led to Honeywell's main 1970s products, the Level 66 and Level 68 machines[160], which offered support for distributed processing. Honeywell's mini-computer technology was a part of the

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[155]Ibid.

[156]<u>US vs IBM</u>, dx?, IBM, 'A company study of Honeywell Inc.', 29/12/69.

[157]<u>US vs IBM</u>, tr4990, C.W. Spangle, a Honeywell manager.

[158]Ibid, tr4989.

[159]Ibid tr4990.

[160]Ibid, tr4961.

distributed processing concept and it strengthened its activities in this field. Honeywell updated the 200 series with the 2000 range, which continued as an important product range. Even the small scale G100 was maintained as a product. The advanced GE 600 operating system, GCOS, became the main Honeywell operating system.

Honeywell was more committed to surviving in this market than GE, which had other burdens such as nuclear power and jet engines. Computers represented a large part of Honeywell's business and were tied into many of its other operations. GE's technology added to Honeywell's operations: the H200/IBM 1400 compatibility being a somewhat stale marketing coup by the 1970s. Much of Honeywell's work in the 1970s was spent in ensuring that the users of the various GE and Honeywell systems upgraded to the GE600/Honeywell L66/68 architecture[161].

Sperry Rand.

In 1955 Sperry-Rand's share of computer market revenue was 30%; however, in the next fifteen years this share fell rapidly. By 1977 the value of its installed base was the same as Honeywell and Burroughs. Before 1955 the company was even more powerful in the fledgling computer market, especially in the field of large scale systems:

Table 8.12

Deliveries of early large scale computers in the USA.

Year	Total Computer Deliveries in the USA	Remington Rand Computers delivered.
1950	1	1
1951	4	4
1952	5	5
1953	7	7
1954	9	8
1955	32	9

Source: CBI Archive, Auerbach Electronics Corporation, 'A corporate business strategy for information processing, 1960-1970', Chapter 2 'Sperry Corporation', 1960.

Sperry Rand was formed in 1956 after the merger of the defence electronics, controls, hydraulics and farm equipment company, Sperry, and the second largest business machine company, Remington Rand[162]. The

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[161]US vs IBM, dx230, internal Honeywell memo from, R.A. Kovak to R.R. Douglas, 20/5/75, This memo discussed methods of ensuring that GE 400 users transferred to the L66, rather than to a rival product.

[162]CBI Archive, Auerbach Electronics Corporation, 'A corporate business strategy for information processing, 1960-1970', Chapter 2 'Sperry Corporation', 1960.

breakdown of the company's 1959 revenue shows the military dominance:

Table 8.13

Revenue source:	
Defence:	52%
Domestic, commercial	30%
International	18%

Total Sperry Rand revenue: $1,173m

Source: Auerbach, 'A corporate business strategy for information processing', Chapter 2 'Sperry Corporation', 1960.

Its dominance of the early large scale computer market was a result of Remington Rand acquisitions in the early 1950s. It purchased two of America's leading computer enterprises. These were the Eckert and Mauchly Computer Corporation, developers of the ENIAC and BINAC military computers and the commercial UNIVAC[163], and Engineering Research Associates, developers of the 1101 system used by the US Navy and the National Security Agency[164]. ERA was partially absorbed into UNIVAC. After Sperry purchased Remington Rand, the position of the computer operation was complex. James Rand was allowed to run Remington as a self-governing operation, so the computer operation was in effect the UNIVAC division of the Remington Rand group of Sperry Rand[165].

The purchase of UNIVAC and ERA gave Remington-Rand control of two of the most significant early computer systems, the UNIVAC I and the ERA 1100 series[166]. The former tended to be used by commercial clients, while the 1100 range was favoured for scientific calculation. The UNIVAC successor was the UNIVAC II, engineered by the ERA team in Minnesota, which had basically the same logic, but added magnetic core storage and improved tape speeds. However, problems seem to have occurred in coordinating the two halves of the UNIVAC division and the UNIVAC II was not released until 1957, when other firms were starting to offer second generation computers. By 1960 only 33 had been sold[167].

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[163]Nancy Stern, From ENIAC to UNIVAC-An appraisal of the Eckert and Mauchley computers, Bedford Mass, 1981.

[164]Hakala Associates Inc., Engineering Research Associates: The wellspring of Minnesota's computer industry, St Paul Minnesota, undated. This pamphlet was commissioned by the Sperry Corp.

[165]Auerbach, 'A corporate business strategy', chapter 2.

[166]Ibid.

[167]Ibid.

On the ERA side, the 1101 was replaced by the 1102 which was widely used for air traffic control. This was then replaced by the 1103-A and the upgraded 1105, which, while similar, were not compatible with the older machines.

The UNIVAC operation was slow to produce a small computer, and was slow to exploit the large Remington Rand tabulator user base. The first offering was the UNIVAC File Computer of 1956. This machine again came from the Minnesota side of the operation. The File Computer had to compete with the IBM 650 and 305 RAMAC, but it was not the success that might have been expected: like the large UNIVAC II, it was released too late. It did not match the sales of IBM machines, and only 130 were made[168].

Its first really successful small-medium scale computer was the UNIVAC Solid-State. This was a semi-second generation machine from the Philadelphia half of UNIVAC, which surprisingly used IBM standard 80 hole punched cards for input-output. It drew on technology developed for a US Air Force sponsored computer for its Cambridge Research Centre[169]. It used magnetic core logic, and presumably had IBM punched cards because these were standard at that research facility. In many respects it was like the EMI Austin machine, using magnetic logic, but with vacuum tubes elsewhere. Initially it was only marketed in Europe; all sales enquiries in the US were refused until 1959[170]. There appear to have been two reasons for this: first, it would have undermined sales of the delayed File Computer, and, second, it would also have undermined the core Remington product line, the 90 hole card punches and tabulators[171]. Eventually somewhere in the region of 600 of these machines, including both the 80 and 90 hole version and the SSII up-date, were installed[172]. However, while the SS range greatly outsold the File Computer, it failed to reach the scale of production IBM was achieving with the 1401.

Other second generation equipment was generally no more successful. One exceptional success was the 1004. This was a small punched card based calculator/computer. It was ideal for the large Remington tabulator user base that wanted to have improved functions, but did not desire a larger computer. Many thousands of these were sold, and it became a vital product

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[168]Ibid.

[169]Ibid.

[170]Ibid.

[171]Fisher et al, <u>IBM and the US data processing industry</u>, p59.

[172]Ibid, p60.

to Sperry-Rand. The 1005 and the medium scale 1050 computers were added to the range, giving an upgrade path for 1004 users. This low end range was the most successful part of the UNIVAC operation.

However, the rest of the second generation computer range was rather confused. The UNIVAC II was replaced by the transistorised III, while the 1107 became the new solid state ERA offering[173]. These were joined by the 490, a large-scale real-time computer used for such things as airline booking and reservation systems[174]. Finally, larger than all these was the LARC, Sperry's turn to fail in the super-computer market.

The LARC was ordered under a development contract by the Livermore Atomic Research Laboratory. Sperry is estimated to have over-spent by $10m on the fixed price contract[175]. If Sperry got anything from this effort, it was only one or two sales and some extra circuit know-how.

Outside general purpose computing, the UNIVAC Division and the rest of Sperry Rand built many specialist computers. Most of these were military systems: this is not surprising given the military connections of both the UNIVAC Division and the rest of Sperry. UNIVAC was the largest producer of specialist military computer systems in the USA. This gave the company both access to military R&D sponsorship and a good market for high-value high-profit systems.

Yet despite its early strength Sperry-Rand had gone from the number one spot in the industry to a poor second. The problems seem to have fallen into two categories: first, early products were not delivered on time and were poorly supported; second, there were serious problems with the organisation of the corporation, problems which mirrored the difficulties found in other electronics companies.

Product failure.

UNIVAC was undermined by the publicised failure of some of its early products. One of the most discussed installations of the UNIVAC I, was at the GE Appliance Park in Louisville, the first commercial electronic data processing system[176]. However, it took much more than installing the

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[173]US vs IBM, dx8, J.P. Eckert, internal memo to H.B. Horton 7/4/61, outlining the chaotic state of the Sperry computer range and the wasted effort this entailed.

[174]Ibid.

[175]Auerbach, 'A corporate business strategy', chapter 2.

[176]R.F. Osborn, GE and UNIVAC: Harnessing the high-speed computer, Harvard Business Review, July-August 1954, pp99-107.

computer to give GE, and the other early users, an operational data processing system. The Auerbach Corporation believed UNIVAC was delivering computers before the customers were ready, and then not offering the service and programming support needed to make the computers useful to their new owners[177]. It was a new technology being used for a new type of application: users needed help in achieving this. A second problem was with the UNIVAC II and the File Computer, which were both promised well before they were delivered. Potential customers lost faith in the ability of the firm to deliver, and when they did finally appear they were too late for the first generation of computing.

IBM was much more successful at offering service and support. Its follow up machines to the 701 and 702, which were inferior to the UNIVAC I, were much better than the slow-to-emerge UNIVAC I replacements.

Organisational confusion.

The major failure seems to have been the inability of Remington to integrate the two computer operations with each other or with its business machines operation. At the time of the Sperry purchase of Remington, the company was described thus:

> 'Washington has a name for it: a 'conglomerate' merger, the union of two non-competitive companies with nothing in common except the desire to face the future together. Sperry-Rand is 1955's biggest conglomerate to date...'[178]

It was headed by Harry F. Vickers, with James Rand staying in charge of the Remington Division, and with Remington's ex-chairman, General Douglas MacArthur, becoming the chairman of Sperry-Rand. The logic for the merger was seen in the combination of UNIVAC and the Sperry military electronics operations.

However, William Norris viewed the real situation differently:

> '..Harry Vickers [Sperry CEO] didn't understand what he bought. He thought he bought into the computer business. What he bought was a chance to get into the computer business by investing a hell of a lot more in R&D. And he wasn't prepared to spend the money.'[179]

Norris was placed in operational charge of the UNIVAC division, but his control seems to have been very limited, with UNIVAC's Eckert acting as the division's president. Despite an earlier statement by Vickers that he

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[177]Auerbach Corp, 'A corporate business strategy', chapter 2.

[178]E.L. Van Deusen, 'The Two-Plus-Two of Sperry Rand', Fortune, August 1955, p88.

[179]CBI Oral History Collection, William Norris.

wanted to build up the EDP operation, Sperry management were not pleased by the heavy R&D costs and the losses incurred in this division.

Coordination between sections of both the company and the units within the UNIVAC division seems to have been limited. When questioned as to how much cooperation there was between ERA, Philadelphia and the punched card operation in Norwalk, Norris gave a long discourse on the bad relationships between different parts of the company:

> 'Very little. President Eckert took the view that what ERA was doing was not state of the art. Therefore, he didn't want to waste his time with us. Norwalk was less involved in electronics. They were still in the tabulator era.'[180]

Eckert seems to have had a similar view, but not surprisingly saw Philadelphia as the hard-done-by organisation. Eckert also blamed the failure to exploit its position on the poor structure of the company. Until his retirement, James Rand was running Remington Rand as a separate entity within Sperry Rand[181]. This meant that the Sperry management did not have direct control over the computer operation and yet they were expected to find the funding necessary to cover the losses. From 1953 to 1958 Sperry Rand sales had increased by 39%, but earnings fell by 19%[182]. The cause was the costs of developing and marketing computers. A further problem was the division of the sales operations from the computer manufacturing units. Sales staff were split between such things as typewriters and office equipment. Initially there were few for computers, and even by 1962 computer salesmen numbered only 500[183].

It is not surprising, given the division between the ERA and Philadelphia operations, that UNIVAC supported a number of incompatible computer architectures within the company. This meant that it lost the economies of scale and scope that should have been made with the merger of UNIVAC and ERA. It also failed to utilise the opportunity that IBM had so well exploited: selling systems to the firm's vast tabulator user base. It was not until the low-technology 1004 that the company had a small machine it could sell to its established customers.

Sperry had made the following major errors:

i) It did not establish central control of architectures,

ii) therefore, it was producing multiple and incompatible systems,

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[180]Ibid.

[181]J.P Eckert interviewed in 'Post-Mortem', <u>Forbes</u> 15/9/61, pp35-6.

[182]Ibid.

[183]Ibid.

multiplying R&D costs.

iii) therefore, the mergers led to no manufacturing economies.

iv) programming, support and service costs were multiplied.

v) and it did not utilise the marketing advantage of having a large and well established tabulator user base.

This internal chaos within the UNIVAC division was perpetuated after Norris had taken his engineers away. Eckert became a director without portfolio and tried on many occasions to persuade the company to coordinate its activities better:

> 'Back when Mr Schnackel was president of Univac, it was proposed that we build a 490, a UNIVAC III and an 1107. I strongly opposed this idea....Unfortunately, the political nature of Univac prevented a resolution of this problem and we went ahead and built three logically unrelated machines. At that time there were several meetings and discussions on the matter but the situation was never resolved. All this occurred over ten years ago.....'[184]

Nevertheless, Sperry remained a competitor for the number two position in the industry, and UNIVAC became the largest single component of the conglomerate. In 1963, after a major conference, Sperry finally ended one of its ranges by deciding not to update the UNIVAC III. The successful 1004 was joined by the updated 1005. A new medium scale machine, the 1050, proved reasonably successful, thanks to its compatibility with the 1004/5. The 490 medium scale real-time systems continued. The 1107 scientific computer was replaced in 1964 by the successful third generation 1108 and time-shared 1108 II. These also had a great deal of real-time capacity, and were used in large scale applications that the 490 was not appropriate for. The 490 survived throughout the 1960s and the 1108 architecture remained Sperry's scientific and real-time system well into the 1970s.

However, the main third generation initiative was the small-medium scale 9000 series, which replaced the 1005, 1050, and Solid State computers and to some degree it also replaced the 490 machine. This system was recommended by the Product Line Task Force of 1964-5[185], four years after IBM's SPREAD committee. It recommended building a machine that was compatible with the IBM 360 and to form the bottom half of the Sperry range; the 490 and 1108 computers would form the upper half of the

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[184] US vs IBM, dx10, Eckert memo to Sperry CEO R.E.Macdonald, 19/7/71.

[185] US vs IBM, dx15, Product Line Task Force, report no. 2., 9/2/65.

range[186]. What it actually came up with was a near IBM compatible machine, which was not compatible with the other Sperry machines[187]. However, it did give Sperry a range of small and medium scale third generation computers for the mass market of the late 1960s.

Another problem for Sperry was its poor peripheral performance, especially in mass storage devices. It persisted with drum memories into the 1960s, when others had adopted the disk drive. Drums did give fast access, and were useful for on-line operations, a Sperry speciality, but were not much use for really large data bases.

What probably made all these disparate and less than awe-inspiring offerings successful enough to keep Sperry in the business were two areas in which it did rather well. These were sales of computers to the US government and the market for on-line reservation systems. Sperry was a leading supplier, indeed the leading supplier of military computer systems, and this seems to have rubbed off on the commercial computers. Sperry had double the share of the government market as it had of the general market. In terms of the numbers of computers installed, Sperry was IBM's only close rival:

Table 8.14

IBM and Sperry shares of US government installations.

%	1966	1967	1968	1969
IBM	34.3	29.9	28.4	28.1
Sperry	19.8	21.6	21.3	20.4

Source: General Services Administration Federal Supply Service. Inventory of automatic data processing equipment in the United States Government. 1969, Washington.

Like many other American companies, it benefited from the sale of big numbers of computers to the US armed forces for uses that what were essentially business type applications. An example of this was the sale of 150 1050s and three 1107s for logistics work at airforce bases. This was about half the 1050s sold. The company also developed, under contract, many special purpose military computers which helped to extend its technological base.

The second strong area was in real-time computers, the 490 and 1108, and their use in ticket reservation systems. This included an order for $39m worth of 1108 computers from United Airlines for its reservation

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[186] US vs IBM, tr2882, Macdonald.

[187] US vs IBM, Eckert memo, 19/7/71.

system. Sperry claimed this was the largest commercial computer contract ever[188]. Sperry extended the 1108 by adding a time-shared version to the range, the 1108 II, and, in 1969, it also released a smaller scale version called the 1106. During 1966-67 the 1108 represented half of the UNIVAC Division's sales.

Despite the limited success of the real-time systems, Sperry had failed to maintain its position in the market. Its failure to integrate its operations was reminiscent of the electronics companies, rather than business machines firms. Eventually Sperry did stabilise its position. In 1971 it bought the computer operation of RCA, which fitted in quite well. The Spectra/RCA series was a much better implementation of IBM compatibility than the 9000, and offered a number of larger machines. Sperry managed to hold on to the RCA user base, ensuring that it kept up with Honeywell and Burroughs in the 1970s.

The Series 9000 was replaced by the Series 90 giving an upgrade path for the RCA users. However, the main focus was the 1100 series. In general, both ranges fared well enough to maintain Sperry's position as one of the leading firms in the so called 'BUNCH', the smaller competitors to IBM. Yet it had failed to make good its early position and had frittered away the opportunity to be the leading player in the world's fastest growing market.

When Burroughs and Sperry merged to form Unisys it was Burroughs that was in the better position. However, it seems obvious that some of the lessons that Sperry should have learnt were ignored. Unisys' current product line includes a vast array of both companies' systems, including the 1100 and 90 architectures, and the A series of Burroughs equipment, as well as a big range of UNIX systems. Unisys has not fared well, and seems to have suffered from many of the problems described in the Sperry and GE histories.

All the firms in this chapter were more committed to the commercial computer market than RCA, GE, English Electric Ferranti and EMI. For Burroughs and NCR it was an essential technology if they were going to survive in their major market, business accounting machines. CDC and DEC were totally orientated to exploiting the new technology and building on the niche markets that they had identified. For Honeywell and Sperry, commercial computers were their major commercial diversification, related to their established electronics and control technologies but a significant new dimension to their companies. The sheer speed with which the computer

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[188] US vs IBM, dx61, Sperry annual report 1966.

market expanded meant that the computer operations became the most important division within all these companies. The electronics firms studied did not have this commitment to the new industry, for them it was only a speculative diversification which had to compete within the firm for funds against other divisions.

Chapter 9

Conclusion: concentric diversification versus market specialisation and the problem of resource allocation.

The case studies provide the raw material for an explanation of the failure of broad-based electronics firms in the new market for commercial computers. We can now analyze more systematically the weaknesses of these firms, bring out their common faults and then contrast these failings with the systems adopted by the more successful firms. The evidence provided by the case studies is varied, pointing to a whole variety of possible causes for failure. There are three possible reasons for this:

Firstly, the sources for such a study, covering so many of the major players in two countries, are varied and are not necessarily uniform in the detail that they provide. This can give a distorted view: information provided by a government sponsor emphasises different aspects from the kind of detail provided by internal management documents. However, it is the aim of this thesis to have drawn on a large enough variety of archival sources to reveal the consistent themes.

Secondly, it could be that the circumstances of firms in the two countries were substantially different. However, it is the contention of this thesis that the exit of British and American electronics firms from the computer industry, while occurring at different times and driven by a number of tactical and strategic reasons, had some common elements. This chapter will emphasise the growing opportunity costs of staying in the computer industry faced by these firms, and the political and organisational structures which encouraged exit from the market.

Thirdly, each company had some freedom of choice: firms could choose between a variety of courses of action. Managements had the flexibility to choose between a number of strategies; some firms used strategies which were successful. The best example of this was Honeywell, which, by emulating some of the techniques of the business machines firms, managed to survive in the industry. There is an infinity of other possible responses, some illustrated by the circumstantial detail in the narrative accounts that have been presented. Selecting a handful of control themes may be imposing an artificial simplicity on the complexity of historical experience.

Yet some key conclusions can be drawn. In the next three sections of this chapter, some of the significant differences between the firms will be noted. The first section will look at the entry of firms into the computer market. Second, the product policies of the various types of firms will be considered. The third section looks at the place of the computer operations within the corporate structure. It also considers the failure of these firms to utilise vertical and horizontal links between divisions.

These points will then be considered in terms of the overall strategic challenges faced by the companies. The alternative investment opportunities open to the companies were a significant feature in the development of the computer operations and played a major role in the eventual decision to leave the market.

Three major conclusions are drawn from the case studies:

a) That, apart from lowering the barriers to entering the computer market, the electronics companies benefitted little from the economies of scope and scale. It is argued that they failed to apply the appropriate organisational structures to fully benefit from their vertical and horizontal diversity.

b) That the electronics firms adopted the wrong product strategy, both in terms of the state of the market and in terms of the overall position of the corporation. Business machines firms adopted strategies that reflected their knowledge of the market place.

c) That the concentrically diversified electronics firms suffered from capital rationing due to trying to support too many high technology growth paths. This problem was exaggerated by the choice of the wrong computer strategy.

<u>1) Market entry; incentives to innovate and the first phase product strategy.</u>

The starting point for this analysis is to consider the incentives that firms had for entering the industry. The main split is between those firms that started building computers as an extension to their activities, exploiting technical knowledge in a concentric diversification, and those that were forced to develop commercial computer technology to maintain their current market position. The former case describes the electronics companies and the latter the business machines firms.

The majority of electronics firms did not join the computer industry at its inception; most either joined the industry or extended their computer activities at the cusp of the first and second generations of computers. This was when computers started to become a significant commercial tool and became a mass produced capital good. It is possible to speculate on why many of them chose to join the market at this time. These firms had in-depth knowledge of electronic components and used digital technology elsewhere within the company, often in military products. Whether by strategic decision, or through tactical expediency, these skills were put together to develop computers for the rapidly growing commercial computer market.

In general the latter, tactical pattern, was dominant: development of the first general purpose computer was usually undertaken to fulfil a specific contract. Examples of this include the GE ERMA, RCA BIZMAC, and the EMI BMC computers. The building of these machines relied on the enthusiasm of a handful of people within an operating division of the company. Later, a second decision was made to continue to build on this base and to add more resources to it to build it up. This decision was followed by the setting up of an operating unit to mass produce second generation computers for the rapidly growing commercial market. These firms were exploiting technological skills in what was becoming a major market for electronics. The decision to build computers was facilitated by the large profits being earned in other areas of electronics which helped fund this diversification. Another factor was that these companies already had the technical resources to build computers and, therefore, had a low initial entry barrier to the market.

This process was not the same for all companies. EE, for example, was involved in the very early development of computer technology in Britain[1]. EE was a major producer of medium scale, first generation, scientific computers in the UK. However, it made no great drive to build commercial machines until the second generation of computers. At this stage it built RCA designed computers and bought the LEO computer organisation, greatly extending its data processing operations. Therefore, while it had a pioneering interest in computers, its major push into the market also came at the time of the second generation machines. An even earlier entrant was Ferranti[2]. This firm entered the industry at the earliest stage, mainly because the head of an operating division wanted to keep together the electronics team built up during the war, but for which there was little work left. Government development funds given to the company to build computers allowed the division to survive. Self preservation led the Instruments Department to become an early computer pioneer, but it too was

[1]See above, chapter 4, pp156-160.

[2]See above, chapter 2, pp55-65.

exploiting its technical skills, and the whole project relied on the enthusiasm of a handful of managers.

The self preservation motive was even clearer in the entry of the business machine firms into the computer industry. For these firms the incentive was the encroachment of digital technology on the punched card market; their main problem in entering the industry was the acquisition of technical knowledge. Two firms, Remington Rand and IBM, entered the industry at a fairly early stage.

IBM was by far the strongest business machines company when it came to the new technology. It had already been working on incorporating electronics into its current punched card product line, it also had a tradition of producing machines for the science market[3]. Production of the Defense Calculator enabled IBM to build up its digital computer ability quickly, despite having lagged Remington in the initial stages of the computer industry. By using its established marketing channels for its range of small computers, such as the 650, it achieved a scale of production well ahead of its competitors[4].

Remington Rand took a different approach, necessitated by its relative lack of technical resources in this field. Remington bought two leading-edge start-up companies, ERA and UNIVAC. Remington seems to have tried to use computers to attack IBM in the market for scientific calculating equipment[5]. Remington was trying to usurp IBM's position in one of the smaller parts of the market for punched card equipment, hoping to establish a lead in the niche science market. This is confirmed by Remington's singular lack of success in integrating its computer operations with its old tabulator market, despite the fact that the UNIVAC people saw their product as being primarily aimed at the commercial market.

The acquisition of skills was also necessary for smaller firms. NCR and Burroughs copied Remington's strategy when it became necessary for them to offer computers to their niche market clients[6]. For NCR and Burroughs the move to the new technology was defensive. It was a matter of self preservation: the market for business machines was shifting from electro-mechanical systems to computers. Both firms had to acquire these skills to survive. In Britain, ICT also adopted computer technology when it became

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[3]pp347-350.

[4]See above, pp357-358.

[5]See above pp407-410.

[6]See above, pp375-396.

necessary to the business machine market. Like the American firms, it also had to buy in the necessary skills to build computers[7]. However, for ICT/L the main source of bought-in technology came from buying the computer divisions sold by the British electronics industry.

Most of the electronics companies entered the computer industry as a concentric diversification. They had established technological skills which could be used in the development of commercial computer hardware, reducing the entry barriers to this new and expanding market. For the electronics firms, developing a commercial computer was a relatively cheap exercise. The business machines companies became increasingly involved in the new computer technology as it started to invade their traditional market place. It is therefore not surprising that the attack of the business machines firms on the market for computers was slow to start with. It took off with IBM's later first generation systems, especially the 650 which was the first computer to reach 1000 installations. From this point all the business machines firms were forced to react.

While the electronics companies had the advantage of having technical resources available, the business machines companies had the advantage of established marketing and service networks. These organisations were large and gave the firms a method of placing equipment on the market, understanding how this process worked. Electronics firms seemed to lack this understanding of how to market commercial data processing equipment, an issue which is taken up in the next section.

2) 'Second Phase' Product and marketing strategies.

The different traditions of the firms, and the time at which the firms entered the new industry, affected their product strategies. The electronics firms had certain advantages in entering the computer market by exploiting their great technological experience, in the 'first phase' of their history in the market. Their 'second phase' product and marketing strategies were not as successful as those adopted by the business machines companies. This section presents the justifications for the adoption of these strategies, but also points to the inherent weaknesses. Section four of this chapter takes the points made in this section and puts them in the context the corporation as a whole. It especially looks at the inappropriateness of the strategies chosen by the electronics firms in the context of the many calls on these companies' capital resources.

Firms in the commercial computer market tended either to offer

[7] See above, chapter 5, pp194-201.

machines for general applications, or to specialize in a niche market. To be in the general applications market a firm needed a range of computers, from the small to the large scale. From the early 1960s onwards, this range had to take the form of a compatible family, with a wide range of peripherals. More importantly, it had to be provided with a massive amount of software; also it had to be marketed to every possible computer user, and on an international scale. The firm had to achieve a large number of sales to recover the very high costs of developing such a range. A firm which coveted a large market share would have to provide such a family, so that it could penetrate a broad spectrum of the market and stand a chance of winning multiple sales from large computer users. The problem with this technique was that it was very expensive. Families of compatible machines were very costly to develop, the provision of a full range of peripherals adding significantly to the costs. Just as important was the cost of supplying the necessary software to carry out all the tasks desired. On top of these costs was the huge expense of marketing and supporting such systems. Field support to cover a large number of machines was expensive, and the sales and marketing staffs had to be large enough to penetrate every niche of the market. Success in selling systems to new types of users meant undertaking more software development, and supporting high cost applications design. A further expense came from the high percentage of commercial machines that were placed on the market under lease agreements. This meant that firms wanting a large and rapidly expanding user base had to find large amounts of capital funds to finance these leases.

A number of firms felt that the general purpose course was the best route to take. IBM, Sperry Rand and later ICT took this course because they had to fulfil the requirements of their many customers who wanted computer technology to replace their punched card systems. They also wanted to compete for the business of new users attracted to data processing by computer technology. RCA and General Electric also adopted such a policy, in their case because they lacked any niche market to build upon. They therefore believed that, to gain large enough production runs for their systems, they needed to sell to the widest possible number of users. EMI and EE also adopted this policy when they made their major pushes into the market, EMI with the second generation 1100[8] and EE with the third generation System 4[9]. The general purpose commercial market was the largest part of the computer market and offered the quickest route to large

[8]See above, chapter 3, pp128-134.

[9]See above, pp167-170.

market share.

The electronics firms not only had to develop computer systems, where undoubtedly their technical skills helped; they also had to develop marketing and support operations that could compete with the vast organisations already operated by the likes of IBM and Sperry Rand.

The alternative was to aim at a niche market. Burroughs and NCR are the best examples of this. Their traditional user bases were already concentrated in specific industries. NCR had an established base in retailing, and, more importantly for computers, in small scale banking systems and accounting machines[10]. Burroughs was the established leader in banking systems, though heavily pressed by NCR[11]. NCR's first systems were small and well suited to the kind of clients that it had. Burroughs' larger systems were provided with early time-share facilities, which was particularly useful for on-line banking applications. It also had a well targeted military computer development which enhanced its other activities. However, these firms still had all the costs of developing full computer lines for their niche clients to use, especially Burroughs which eventually offered the whole range of computer sizes. The big advantage both had was that they had well established marketing operations. This meant they could target their marketing and software development to specific types of client. From this base they could then start to sell the systems they had developed to a wider audience, and therefore spread their costs over a larger market than just their niche groups.

A second group of niche marketeers existed: the second generation start-up firms. Prime examples were CDC and DEC[12]. These firms were greatly influenced by their founding entrepreneurs and by some of their key employees, such as Seymour Cray of CDC. They used a number of methods to cut the costs of both entering and then operating in the computer market. They targeted specialist technical users. One significant feature of these users was that their requirements were so specific that they expected to write their own software. Science users also tended to buy the machines they used. This reduced the capital outlay required by the producer, as they did not have to find finance to cover leasing deals or develop software. An extra dimension was that there were only a few users in this category and they were a tight-knit community, which kept marketing costs down.

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[10]See above pp375-385.

[11]See above, pp835-397.

[12]See above, pp397-401.

Few electronics firms made the decision to use the niche technique. English Electric had an established stake in the medium scale scientific market, but after the purchase of LEO it started to move towards the general market[13]. As it happened, the medium scale science market was superseded by the third generation of general purpose machines, which were quite capable of this kind of scientific processing. However EE did have the option of expanding its stake in the scientific market by producing small scale science machines, akin to DEC, or super-scale systems like CDC. Instead it started to develop the System 4 family.

A firm that was a more clear-cut candidate for this niche route was Ferranti. Ferranti's failure to develop its base in the science market must be counted one of the major strategic failures. However, there were many factors which reduced Ferranti's commitment to the stand-alone computer market which have been discussed in chapter two.

The only really successful product strategy adopted by a broad based firm was Honeywell's tactic of producing machines based on old IBM computers[14]. The strategy for the H200 family was to emulate the IBM 1401, of which 10,000 had been installed. It was hoped that a significant number of these users would not want all the software and data transfer problems that moving to the new IBM 360 family would entail. Honeywell was offering a 1401 compatible system which was newer, faster and larger than the old IBM systems. Not only did it provide Honeywell with a niche, it also meant software expenses were kept down: users merely wanted to run the large 1401 catalogue of programs on better machines. While this ploy was only useful for a few years, it did give Honeywell a user base to build on. However, Honeywell had to have a large enough sales effort to contact the 1401 users and persuade them to exchange their old machines for the Honeywell 200, rather than staying with IBM and transferring to the more advanced IBM 360. The firm recognised this and put large resources into its sales force. IBM noted that by the end of the 1960s Honeywell had built up one of the largest sales teams in the industry[15].

The other broad based firms decided on a wider attack. Most chose to do so by exploiting their technical skills to offer an early second generation commercial system, to which larger and smaller scale ranges were added. RCA took this process furthest by moving from its large range of

[13]See above, pp163-167.

[14]See above, pp402-407.

[15]See above, pp403.

second generation systems to its third generation SPECTRA family[16]. English Electric took the same course. These two firms consciously chose a path of following IBM, imitating its technology to the point of compatibility. Most firms imitated IBM's method of offering inter-compatible families of third generation computers, but it was RCA and EE which opted for full compatibility with the IBM 360 itself. As stated in the relevant chapters, neither RCA nor EE managed to achieve much benefit from this policy. The hope was that they would become the second source for the IBM architecture. They also hoped that development cash would be saved by not having to develop so much software.

These firms were adopting a policy which closely resembled the strategy outlined by Baldwin and Childs called the 'fast second strategy'[17]. This required a fast response to changes made by the market leader. They had quickly to emulate the advances made by IBM so that their customers had a product equal to IBM's. However, RCA and EE, and indeed all the electronics firms, made a number of errors which nullified the advantages such a policy was meant to give them. The RCA/EE architecture was unique; it was not a matter of reverse engineering. RCA and EE were high technology companies: they had advanced techniques that they wanted to build into their computers. Therefore, large sums were needed to develop what, to the user, was a machine essentially the same as IBM's. This meant that RCA had to develop a unique operating system which worked in the same manner as IBM DOS, a large expense. On top of this the two firms wasted large amounts of development funds on dead-end projects. RCA tried to develop the RACE storage system, wasting a lot of money and putting it a long way behind IBM in the area of disk storage[18]. EE spent relatively large sums on trying to use advanced Marconi chips to make the System 4 the first range of computers to use integrated circuits throughout; eventually this was found to be uneconomic[19].

The RCA/EE strategy would only have succeeded if they had made enough savings from being a follower. They had to have a lower cost strategy in order to compete against IBM's greater scale in this market. They were the most vulnerable to IBM's cost and technology advantages, as their machines were the most directly comparable to IBM's computers. RCA and EE hoped to

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[16]See above, pp261-271.

[17]W.L.Baldwin and G.L.Childs, 'The fast second and rivalry in research and development', Southern Economic Journal, 1969, **36**, pp18-24.

[18]See above, pp257-259.

[19]See above pp167-171.

make savings on applications costs, exploiting programs developed for the IBM systems, but they still had to support all the other areas needed to be internationally competitive. They needed to build up large marketing operations, continually to develop new systems and techniques, to build modern plants, and to finance lease contracts on computer installations. They could have achieved some savings through economies of scope, but it seems that this was only a factor when the firms were entering the industry; 'm' form decentralised organisation limited any on-going economies.

The few marginal savings that RCA and EE made were not enough to outweigh IBM's huge scale advantage; especially as both firms were wasting large sums on dead-end projects. At least firms like ICT, Burroughs, NCR, Honeywell and even GE had locked in users, whose costs of moving to another company's architecture would have been high. Another problem was that RCA and EE were accepting a follower's role in a rapidly changing technological environment. They had to mimic the advances made by IBM to ensure that their computers could perform at least as well as IBM's. While all firms faced the problem of keeping up with technological advance, RCA and EE had a compounded problem. The fact that their computers were pitched directly against IBM meant they had to respond to changes at IBM quickly, but their unique architecture meant that, like all the other firms, their machines had to be designed from the ground up; they couldn't just copy new IBM equipment. EE's position was even worse. It followed RCA, which in turn followed IBM. What was more, EE went about redesigning RCA's systems. The consequence was that the System 4 reached the market too late. The later, more successful, 'plug-compatible manufacturers' made sure their equipment could work directly with IBM equipment, so users could mix and match the best machines. The RCA/EE strategy was not well suited to their role as technological innovators: their technology was not right for firms with a follower strategy.

While RCA and EE made the most direct attack on IBM, most of the other electronics firms also had a policy of producing computers for the largest section of the market. Though the others did not become IBM-compatible, their product ranges were mirrors of it. EMI tried to enter the largest section of the market, medium scale commercial systems, abandoning it when it became obvious that the required investment was huge. GE tried to market a diverse range of general purpose systems, though it did develop a time-sharing niche.

As stated earlier the reason that the electronics firms tried to tackle the largest section of the market was that this was the only way to get a significant market share. This was seen as a pre-requisite for generating enough income to fund future developments. The companies were trying to establish significant new operations. The exploitation of their electronics knowledge in the commercial computer market was the strategy adopted for this expansion. The target that RCA and GE had was to reach the number two position in the market. They both aimed at a 10% market share, which was seen as the long run minimum efficient scale. Given the size of the electronics firms and their resources, such a policy seemed attainable. However, to achieve the rapid growth needed, it was necessary to tackle as much of the market as possible, at least this was the view within the electronics firms[20]. A second reason for this strategy was that the niche markets were already occupied by firms such as NCR and Burroughs.

The problem with this strategy was that it meant taking on IBM, the established leader in commercial data processing, with the largest marketing operation in the industry, a very profitable line of products, and a very able management. The tactics adopted by the electronics firms evidently failed to take on this giant. However, at the beginning of the period studied, RCA, GE and even English Electric were much larger than IBM; if they had been able to turn their full resources against IBM, surely they could have achieved the 10% market stake that was the perceived target.

It is the contention of this thesis that the electronics companies adopted the wrong 'second phase' product strategy. In the first stage of the industry, computers built were for one-off orders. As it was realised that the computer market was going to be large, firms wanting a big stake in the industry aimed to capture market share quickly, usually with general application second and third generation computers. This 'second phase' product strategy was inappropriate to the financial commitment that the electronics firms wanted to make.

The strategy described above was very close to what Porter describes as the 'pure spending' method of attacking a market leader[21]. It was inappropriate because of the many other calls on the electronics firms' capital budgets. In section four of this chapter, the pressure of supporting multiple expansion paths is discussed[22]. It is argued that

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[20]See for example pp323-336, above, for GE's Advance Product Line plan. It was argued that only a broad attack on the market could achieve a large enough market share to fund further computer developments.

[21]M.E.Porter, Competitive advantage, creating and sustaining superior advantage, New York, 1985, chapter 15, pp513-536.

[22]pp383-391, below.

this broad attack on such a large market was not the right policy for firms that were also trying to expand in a number of other directions. Secondly, it meant that the electronics firms were following the same tactics as IBM, trying to satisfy most of the market. However, they were bearing all the costs of doing this with production levels that were well below those of IBM. The economies of scope open to the electronics firms were only really utilised when entering the market, when the firms were trying to collect appropriate skills together. Such savings were marginal compared to the economies of scale being achieved by IBM.

The electronics firms were adopting the most expensive product policy possible in the computer market, by producing a broad line of systems. This 'second phase' product strategy thus suffered both from having to compete against the low cost production base of IBM and from having to compete for investment funds with other divisions within the company.

<u>3) The political and structural position of commercial computer technology within the firm.</u>

To understand the choices faced by firms, the place of computers in the corporate structure has to be understood. Most commercial computer developments in the electronics firms started as tactical expedients. This meant that the decision to undertake the development and building of early systems was taken by departmental or divisional level management. GE's ERMA computer was built thanks to the enthusiasm of departmental staff, mainly Barney Oldfield[23]; Ferranti's connection with the Mark 1 was due mostly to the Instruments Department manager, Grundy[24]; and EMI's BMC machine was produced for a one-off contract negotiated by the Electronics Division management[25]. The other developments were equally small compared to the company as a whole, and none appears to have received much attention at corporate level. This includes the BIZMAC[26] and EE's involvement in the Pilot ACE[27]. Given this pattern it seems likely that, for most electronics firms, the initial product champions were from the operational units of the company. One exception was Honeywell. Its entry into the computer market involved the acquisition of Raytheon's computer operation

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[23] See above, chapter 7, pp293-296.

[24] See above, chapter 2, pp51-55.

[25] See above, chapter 3, pp126-131.

[26] See above, chapter, pp235-237.

[27] See above, chapter 4, pp156-160.

and the formation of a new division[28]. Such a decision required a high level of authority, implying a strategic move agreed at a senior level in this company.

As computer technology developed and the market started to blossom, the computer operations also grew. These operations soon won divisional status in their own right, and those that survived into the late 1960s became whole groups within the corporations. Each generation of computers became more expensive to develop and was produced on a greater scale. This entailed an ever-increasing risk and an ever-growing opportunity cost. In turn, the status accorded to the computer operation increased. The computer division was made a decentralised profit making centre and, as the technology became more complicated, it established its own sub-units acting as profit centres. An example of this was RCA's Information Systems Group, which had a number of divisions (by the end of the 1960s five divisions). As the scale of computer activities grew, these divisions started to adopt the m-form structure described by Williamson[29], a process which closely resembles the structural development described by Chandler[30].

However, outside of the internal sub-departments of the computer divisions, there was little coordination of effort within the electronics companies. The m-form structure isolated divisions from each other: this made the achievement of economies of scope very difficult. Even if the firm did achieve some horizontal or vertical linkages, they were just as likely to have been a disadvantage as an advantage.

The evidence for this is anecdotal, but, certainly in the cases mentioned, the links between various departments within the company were sometimes as likely to have been a real handicap as an advantage. The first example of this comes from the comments of Ferranti's ex-computer manager after he joined Burroughs[31]. He criticised the British industry, and here he must have had Ferranti in mind, for trying to make every part of the computer. He pointed to the fact that American business machines firms bought many sub assemblies from specialists, thus benefiting from the skills of these specialists. These suppliers could have high production

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[28]See above, chapter 8, pp402-404.

[29]O.E. Williamson, Markets and hierarchies, analysis and antitrust implications, New York, 1975, pp148-154.

[30]A.D. Chandler jr, Strategy and Structure, New York, 1966.

[31]Brian Pollard, 'A comparison of computer industries in the US and the UK', Datamation, May/June 1960, pp51-52.

runs by producing for a number of firms. In the RCA chapter it is seen that the memory products supplied to the Information Systems Group by the Memory Division of the Components Group were not well suited to the computers being produced[32]. One of the great weaknesses of RCA systems was the poor reliability of memory stacks. Another company faced with the inappropriateness of internally sourced components was English Electric, especially when it decided to use advanced chips from Marconi in its System 4 computers. Not only did this greatly slow the development process, but the chips turned out to be uneconomic to use in smaller computers of the range.

The company that clearly had the most problems with its organisation was General Electric, which ironically had the most developed organisational strategy. Despite its system of decentralised control within a framework of product departments and groups, coupled to a very large internal management consultancy operation, its computer division was chaotically run. Out of its one computer group (which contained three US development teams, one French team and one Italian team) it managed to create a large range of incompatible systems. This led to multiplied development costs and destroyed any chance of gaining economies of scale on shared sub-systems. GE failed to become a success in the computer market, a great relief to IBM, which feared GE above all others due to its size.

Two points can be deduced from this. Firstly there was little advantage for the computer department in being linked to a semiconductor division that itself was not a very successful player in the component industry. In general, the broad-based electronics companies were as unsuccessful in maintaining a long term stake in the components market as they were in the computer industry[33]. The vertical link was a link between one problem area and another; business machines firms could pick and choose suppliers. A second problem for the electronics firms was that, while they were tied into buying internal components, the decentralised structure meant that the requirements of the computer operations were not always synchronized with the developments being made in the component operations. Electronics firms could lose both ways.

The single product business machines company tended to have a different structure from that of the multi-product firm. They had less divisionalisation and a more functional structure, a finding that Channon

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[32]See above, chapter 6, p268.

[33]See below, pp447-448.

confirmed when studying the organisation of British industry[34]. The business machines firms had a central electro-mechanical technology before the digital computer. These firms adopted electronics either to improve the functionality of their systems, like IBM, or as a defensive measure to protect themselves from the encroachment of other computer producers on their territory, an example being Burroughs. These firms were more likely to be functionally organised, with the computer displacing the tabulator as the core of their manufactured output.

Representation of commercial computer interests was likely to be significantly different between the two types of company. Commercial computers were an adjunct to the rest of the diversified company's product line. Commercial computers, while expected to fit in with the company's portfolio and to benefit from economies of scope within the firm, were not very close to the company's traditional product lines. Commercial computers were also not essential to the whole product line. Firms like RCA and EMI had bases in consumer electronics and professional and defence electronics. GE and EE were more familiar with consumer electrical products, electrical power generation, and professional and defence electronics. Computers became important in a number of these activities, especially as they became used in military and industrial control systems. However, commercial computers occupied an unusual position. While the computer market was booming, it was still a very competitive activity. The computer was unlike the consumer products that these firms made; computers were very large, complex and expensive professional products[35]. However, they also differed from the other capital electronics that the electronics firms made; computers had to be mass-produced and supported by vast marketing and development operations in a highly competitive market.

The commercial computer was something of an alien product for the electronics firm. However, for the business machines firms computers became the core technology. This had a knock on effect on the status of the computer within each type of company. As the computer was a new product developed on the initiative of low level people within the electronics firm, computer product champions seem to have been few and far between at the board level. Most board members came from the traditional product divisions. They often favoured investment proposals from these traditional activities, rather than from the new computer diversification. The opposite

[34]D.F. Channon, The strategy and structure of British enterprise, 1973.

[35]Few of these firms survived in the consumer products markets after the 1960s and 1970s.

usually occurred in the business machines firm, where the computer's core place in the business machines market put it at the centre of attention.

The electronics firms opted to take IBM on with a broad attack, a method that implied committing large resources to tackle the established market leader[36]. This was an attempt to develop rapidly a major new product line for the company. Yet the computer operation was not represented at the highest level in the firm, and it seems that most computer divisions suffered from inconsistent support for this 'spending method' of capturing market share. Even in a firm like RCA, in which the Sarnoffs were very enthusiastic about having a large computer operation, the funding for this major diversification fluctuated greatly as the firm targeted other growth options. Again it seems that the second phase policy, of trying rapidly to become a major player in the market, was out of line with the nature of the electronics firm and its other commitments.

4) Options for a firm's capital budget; opportunity costs of staying in the computer industry.

A conclusion of this thesis is that a concentrically diversified, high technology company faces a major problem in dealing with the many calls on its capital resources. The difference between the multi-product electronics firm of the time and most other innovators was that they had adopted a strategy of supporting multiple high-technology growth paths. Having a choice of growth paths can be seen as an advantage. It can lead to internal competition for funds, making operational units more efficient and forcing them to develop good plans to win financial backing. A firm can then chose the option which it anticipates will give the highest long-term return. This is the main decision to be made when comparing the relative advantages of the numerous innovations that high technology firms generate. However, problems do occur when the wrong choices are made. A number of these firms opted to support too many of these innovations in the market place, whereas the efficient course of action would have been to concentrate resources from the beginning on one or two technologies. The pre-war philosophy of many of the electronics firms that they should be in everything electronic or electrical carried over to the post-war period. This led them to support too many products, to the detriment of establishing themselves in any one of the new electronics markets.

Computers were an expensive development and, as the market grew, they became increasingly costly to bring onto the market. The full cost of

[36] Porter, Competitive advantage, pp528-529.

selling mainframe computers is multi-faceted. In the early stages of the industry, when demand was limited to scientific users, most of the cost was in developing and producing the computer hardware. As the computer market advanced, the cost of producing and selling computers grew. The machines had to offer more features and had to be much more refined. One-off designs were superseded by programmes to develop whole series of machines that had to be internally consistent, and which had to relate to the outside world in exactly the same way. Computers had to have an ever wider range of facilities. Improvements included more advanced electronic and electro-mechanical mass storage systems, communications peripherals, logic improvements to allow on-line and real-time processing, and ever faster calculation speeds and memory capacities.

As the market developed other costs grew to out-weigh development expenses. The scale of the industry was increasing all the time[37], requiring the building of specialist plants and an increasing level of mechanisation. The manufacture of one-off or short production run electronic equipment was (and is still) surprisingly unmechanised. With computers becoming mass production items, greater investment in plant was required. An additional cost came from the ever-increasing complexity of software, and the variety of it. One of the most complex, and often most expensive pieces of software to develop, was the operating system. This was the program which enabled the system to communicate with the outside world and which had to allow access to an ever more complex array of features. Many firms had problems with creating operating systems capable of exploiting the advantages of the hardware architecture. Among these were IBM and RCA, which both had problems in delivering time-share systems to the market when promised. Costs also increased as the number of applications programs rose, and as the scale of marketing the machines grew. With the growing scale of production, companies had to look more and more to overseas sales to ensure the production runs that they wanted. That meant replicating all the sales and support facilities overseas.

One significant cost that has been highlighted in some of the case studies was financing leases for rented machines. As the number of installed machines increased, more capital was needed to fund the building of rented computers. Income from these leased systems was spread over a number of years. Some of the electronics firms, especially RCA, had difficulty dealing with this system of operation; for the business machines firms it was already standard practice.

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[37]See above, figure 1.3, p42.

It cost just £220,000 to produce the first four Ferranti Mark 1 computers[38], but the IBM 360 is estimated to have cost up to $4.5 bn to bring to the market[39]. Thus the opportunity cost of staying in the market was growing. Business machines firms required the computer as the core feature of their product mix. They all had large installed bases of business machines, both new computers and old electro-mechanical systems, which provided steady lease incomes. For IBM this was more than enough to enable it to be the greatest producer of general purpose commercial computers. For Burroughs and NCR it was enough for them to continue to build on niche markets.

The situation for the electronics firms was very different. The ever rising costs had a much more profound effect on firms trying to develop a large, across the board, computer capability from scratch. Of the firms studied, the first to leave were EMI and Ferranti. They were the two smallest firms in the study, Ferranti being family owned, and EMI only having an electronics activity equal to roughly 20% of the company. They chose to leave the market before they had to build the third generation of computers. This is not surprising; their financial resources were limited and the product champions of the computer operations were always low in the company hierarchy. Ferranti had problems with its second generation systems, and was probably not making any profit on them. At the time of entering the industry, Vincent Ferranti had shown an extremely negative attitude towards commercial systems[40]. The idea of committing the huge resources needed to develop third generation computers was not contemplated by the firm. Ferranti was a firm that prided itself on being on the edge of technology and its limited resources had to be carefully marshalled to remain in a number of high technology areas.

At EMI the 1100 and 2400 had made only slow in-roads into the computer market, and only one overseas sale was made. The income from these systems was small, nowhere near enough to cover the cost of developing third generation commercial systems. Again senior management, including Lockwood, preferred to invest in other activities rather than in computers, despite the huge potential of this market. EMI appears to have preferred further reinforcement of the records business, and its military and

[38]See above, figure 2.1, p64.

[39]Thomas J.Watson Jr and Peter Petre, Father Son & Co.- my life at IBM and beyond, 1990, p347.

[40]See above, chapter 2, pp65-69.

professional electronics operations[41].

It is not surprising that British firms were forced out first. They were operating in a smaller market than the US firms and were achieving few overseas sales. This small market was not large enough to support many firms bearing the costs of developing third generation systems. Both firms had other options for their capital and could expand in other directions which were less expensive and less risky, at least in the eyes of the senior management.

The picture becomes clearer when looking at the larger firms that did go into the third generation. It is possible to follow the decision-making process and to see the difficulties of supporting a number of high cost diversifications. All the electronics firms involved in this study had multiple growth paths open to them, and this had a profound effect on the computer divisions. RCA's computer department was invariably dependent on the state of play in the firm's television operation for its funds, as well as being affected by the component and military projects that were going on[42]. GE was also heavily involved with a number of 'venture' projects, namely jet engines and nuclear power[43]. Both these firms went through a period of self examination during the late 1960s and early 1970s: the main question was whether enough cash could be generated to fund all the developments that were in hand.

Both RCA and GE studied their borrowing levels and returns to investors and decided they could not support all their developments; there is evidence that English Electric did the same. The concentrically diversified firm, which could have been expected to benefit from economies of scope, instead suffered from having to support multiple, high-cost development options. The case studies of RCA, GE and to a lesser degree EE, describe the financial introspection that was going on at the time that the firms left the computer industry. They also show that, even before this point, investment in computers had been subject to developments elsewhere in the company. This point is made more clearly for the US firms than in the EMI and Ferranti chapters where material on management decision making is more limited. However, it seems likely that the smaller British firms were faced with exactly the same problem, but that they had to face it earlier because both the firms themselves and the market they operated in were smaller.

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[41]See above, chapter 3, pp143-149.

[42]See above, chapter 6, pp250-256 and pp281-286.

[43]See above, chapter 7, pp229-336.

The next question to ask is why, given that finance was limited, was the computer operation dropped and not one of the many other equally expensive developments that these firms had in hand? The explanation lies in the arguments already presented - the product strategies were inappropriate given the low political status of the computer divisions.

The schemes adopted by RCA, GE and EE were grandiose attempts to take on an established market leader. These firms tried to produce a broad range of computers directly pitched against IBM, with little attempt at product differentiation. While the computer industry was one of the fastest growing industries in the world, it was still risky. The failure to adopt a niche strategy meant that further investment had to be sufficient to keep up with the largest firm in the sector, yet up to this point the electronics firms had not made a profit on their computer operations. Given this fact, it was a reasonable decision to drop this division rather than to continue to support it. The corporate staff had little evidence that the computer division could be profitable.

It has already been argued that product champions for computers were not represented at the highest level in the company. Therefore, it may have been politically expedient to drop the one operation in which the senior management had the least personal stake, rather than one of the other major investment schemes that the firms had in hand. This does not really hold true for RCA, where the younger Sarnoff had personally supported the rapid expansion of the computer department at the end of the 1960s, but this was a disastrous policy[44]. After this, he was side-lined and again there were no other computer people on the board.

There were other justifications for the preference for the non-computer investments. The other new activities tended to be either closer to the original core products of the company, or in industries where established market leaders were less dominant. The latter case can be made for GE's interest in commercial jet engines, remembering that it was already an established producer of military jet engines. The core technology argument certainly applies to GE's interest in nuclear power, because of its large stake in the electrical equipment market. In RCA's case, colour television development built on its traditional strength in the field of broadcast equipment.

Disposal of the computer operation was comparatively easy to carry out, because decentralisation kept it separate from the corporation as a whole. The product centre organisation makes it easier to off-load

[44]See above, chapter 6.

difficult sectors without destabilising the rest of the company.

Thus one of the major conclusions of this thesis is that competition for funds within the multi-product electronics firms undoubtedly existed and directly led to their abandoning a potentially profitable product line. Poor management of this internal competition for funds was a great weakness of the firms in question. The main problem was supporting too many projects for too long. When decisions had to be made to solve this problem, the solution reflected the structural and political realities of the company. While computers were potentially the most dynamic of the options they could take, computers were also the most risky and least familiar to the electronics firms. This analysis resembles the risk reduction theory of company strategy outlined by Prais[45].

Prais' work can also throw light on why a concentrically diversified firm suffers from internal cash flow problems. Prais predicted that there would be a higher likelihood of a positive correlation between the rates of return from a firm's various product lines than a negative correlation between the profitability of its products. Therefore, if one part of a firm is undergoing difficulty or success, it is likely that the rest of the firm is in the same situation. In his analysis, Prais sees this as a result of products being exposed to the same general economic conditions, and the same management approach. In the case of the electronics companies this correlation between a firm's various product lines could have been exacerbated by the common core technology. The introduction of a new type of component meant that the components division needed to develop and introduce the new device. Following this it was likely that all the various end product divisions, such as the military electronics, professional electronics and computer divisions, would want to develop products based on the new component. This implied that all the divisions would want an injection of funds at the same time to introduce new products. It is possible to envisage an electronics firm which has a number of divisions which are very nearly at the same stage of the product life-cycle. This would mean that on occasion the firm would have a surplus of cash from 'cash cows', but could also be faced by simultaneous demands for cash to develop and market new products. While this sounds unlikely, this is very much the situation that hit RCA (and in the early 1980s the British firm STC). The case studies show how electronics companies were strained by the internal pressures associated with having to support a number of development paths. Computers added greatly to this strain. Computers were

[45]S.J. Prais, The evolution of giant firms in Britain, Cambridge 1976, p93.

a product with a rapid technological turnover, requiring large research commitments, while simultaneously having high marketing costs.

In essence this argument runs counter to the Schumpeterian thesis of large firm size leading to market power and to the ability to fund innovation[46]. Galbraith has made similar arguments to Schumpeter[47]. The argument is that a large firm can benefit from economies of size and scope, giving it an advantage in the process of innovation. Large firms are better able to fund research and development, can afford to support a number of technologies and, adding the advantages of scope[48], can benefit from the cross fertilisation of developments from one technology/product to another. At the beginning of the computer era the largest firms to enter the market, in both the US and the UK, were the electronics firms. They had the advantages of size, benefited from rapid growth in their other electronic products and benefited from the in-depth technical knowledge they had of electronics technology.

Yet the firm which came to dominate the market was smaller and had less background in electronics: this was IBM. It did, however, have experience of the market for computers. The market for data processing equipment consisted of large commercial and government organisations with big data-keeping requirements; an area in which IBM had well established connections. This is why IBM had the potential to lead the computer market. What is more surprising is that the electronics firms were also beaten in the market by a host of even smaller companies. Business machines firms and the successful start-up companies concentrated all their resources on general purpose computer technology; electronics firms nullified the advantages that Schumpeter and Galbraith might have accorded them, by supporting so many technologies for too long and by adopting a poor product strategy. IBM and the other firms, while having neither the technological background nor the great size of the electronics companies, concentrated resources on a single activity, and brought to bear a greater knowledge of the market.

Rather than using their diversity as a competitive weapon to gain the

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[46]J.A Schumpeter, Capitalism, Socialism and Democracy, 1961.

[47]J.K. Galbraith, American Capitalism: The concept of countervailing power, Boston, 1952, pp91-5; O.E Williamson, Markets and Hierarchies, analysis and antitrust implications, New York, 1975, pp178-179.

[48]E.E. Bailey and A.F. Friedlaender, "Market structure and multi-product industries", Journal of Economic Literature, 1982, 20, pp1024-48. W.J. Baumol, J.C. Panzer, R.D. Willig Contestable Markets and the theory of industrial structure, New York, 1982.

economies of scale and scope it appears that electronics firms were trying to reduce their risks by having a broad spread of products. It has been seen that the electronics firms were less than successful in a number of markets, making them somewhat embattled. In this circumstance diversification became a defensive measure: there was a worry that if they concentrated on one market they could still lose it and therefore die. However, it can be argued that it is not the role of the firm to spread risk: shareholders can do this by adjusting their own portfolio of holdings. Any desire for firms to do so is led by management's own aspirations for survival, rather than as a means of protecting the shareholder.

The one electronics company that did have a 'bet the company' attitude, like IBM, was RCA. It put huge resources into such projects as colour television, video disc players[49], and even for a short while into computers. However, these projects overlapped and it too found itself short of capital and cash to cover all its projects. This was damaging at the beginning of the computer diversification, as well as leading to its final abandonment. This was because the development of colour television drained the computer operation of funds at a critical time in its early development: indeed, this is one of the clearest examples of this problem in the thesis.

Traditional financial theory would dispute the idea that capital-rationing exists. It is argued that for projects that are expected to offer a reasonable return, necessary funds can always be raised from the market. However, recently this view has been questioned and the possibility of capital restrictions within a diversified company has been considered[50]. This thesis supports the view that such firms do in fact suffer from, or at least perceive that they suffer from, a limited ability to fund multiple high technology projects, and that this is a major consideration in abandoning operations. Specialist firms have the problem of raising capital to support their activities in one market; the diversified firm can be faced with a situation where it has to raise capital, either from the market or using past reserves, to fund many projects at the same time.

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[49]M. Graham, RCA and the Video Disc: the business of research, Cambridge, Mass. 1986.

[50]C. Tomkins, Corporate Resource Allocation: financial, strategic and organizational perspectives, Oxford, 1991, pp179-180.

The combined affect of capital rationing and poor management structures on the electronics corporations.

A recent report, commissioned by the NEDC's Electronics Industry Sector Group[51], found that one of the weaknesses of the British electronics industry was its over-diversification. It recommended that British firms concentrate on a few core products, in which they should build up expert knowledge and their scale, so as to be able to compete in the world market for these central activities. These case studies show that, indeed, there were weaknesses in the multi-product electronics firm. Despite the chance they had to exploit the economies of size and scope, too often they suffered the problems of being over-committed to too many products. This applies not just to British firms, but also to their larger US cousins. The multi-product electronics companies were greatly handicapped by their attempts to support so many technological growth paths. Most abandoned computers due to pressures on cash flow caused by supporting all these activities.

Why did this general difficulty almost always lead to the abandonment of the computer department and not other operations? The following lines of thought closely resemble the findings of the SAPPHO project carried out by the Science Policy Research Unit in the early 1970s[52]. This project found that successful product innovation came from such things as close market and user awareness and having powerful product champions. It is the contention of this thesis that the electronics firms, by trying to develop the computer as a technological spin-off from their other electronics activities, were weaker in these areas than the business machines firms. This meant that the computer was the natural target for cutting when the company needed to reduce its commitment to new investment.

The business machines firms started from a position where an in-depth knowledge of the market for commercial computers already existed. The problems of selling mass produced complex professional machines had already been dealt with. IBM used this knowledge and its market presence to move from dominance of the punched card market to dominance of the computer market. Its systems were well engineered, built with the knowledge of business users' needs, and it could feed its computers into the market using its existing huge sales network. IBM was established as the most

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[51]McKinsey & Co., for the NEDC's Electronics Industry Sector Group, Performance and Competitive Success: Strengthening Competitiveness in UK Electronics, 1988.

[52]R. Rothwell et al, 'SAPPHO Updated - Project SAPPHO Phase II', Research Policy, 1974, vol 3, pp258-291.

trusted supplier of business machines: its computers benefited from the purchaser's familiarity with IBM's quality products. All the business machines firms could build on a similar, though smaller, base. It also meant that the smaller business machines firms were used to operating in a world dominated by IBM; NCR and Burroughs could easily switch their niche markets from electro-mechanical systems to computers. ICT had a similar advantage in that it had a geographical niche which afforded it partial protection from domination by IBM.

Nevertheless, these advantages and disadvantages did not automatically mean success for one set of firms and failure for others; there was freedom of action. Honeywell entered the industry by acquiring the computer division of another company, Raytheon, adopted a clever product strategy, put huge resources into a large sales organisation, and saw the computer division become over one third of the company. It achieved success and had little need to reassess the diversification into computers. If Honeywell had had to reassess its investment plans, the computer department might have received more backing due to its central status as a core product.

With this one exception, the other electronics firms adopted inappropriate product strategies by trying to capture market share quickly, while not having the long term commitment to back-up this expensive policy. The pressures of multiple-growth paths, failure to produce quick profits from computers, and lack of central commitment, earmarked the computer for abandonment in times of stress. Despite their m-form organisation, they were not able to take the appropriate decisions or evaluate the choices for internal capital allocation efficiently, which is the goal of such a structure[53]. If the firms were not willing to back the product strategy they had adopted, they should not have entered it at all.

One striking feature of the failure of electronics firms was that the same process occurred in a number of their product areas. One of the most directly comparable industries to the early mainframe industry is the active[54] semiconductor sector. The comparisons are many. The development of the transistor marked a quantum leap in electronic capabilities, just as the computer was a massive leap forward in calculation power. Like the computer (indeed the two things are closely linked), the principal active component technologies have advanced in fairly definable generations. The main generations were:

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[53]Williamson, Markets and hierarchy, p149.

[54]By active we mean circuits which can act as logical circuits.

1) the vacuum tube,
2) single transistor circuits,
3) integrated circuits,
4) Large Scale Integration (LSI),
5) Very Large Scale Integration (VLSI),

Basically this meant that circuit densities have increased, representing ever greater power and a falling price per circuit. There were also a number of new types of circuit developed, such as the TTL, ECL and CMOS chips, each having different properties. This process of changing generations has been outlined by a number of authors[55] and is similar to the development of computers, which themselves were built using the changing generations of semiconductors. The main difference between computers and chips is in terms of scale; semiconductors are produced in their millions and sold for very low prices. Apart from this, the rate of change of the technology and the importance of keeping pace with the technology was similar between computers and semiconductors.

An even more important comparison can be found when looking at the firms that were involved in the two industries. When the main components were vacuum tubes, the market was dominated by the same broad-based electronics firms that have been studied in this thesis. The introduction of the transistor did not greatly damage their position of leadership, though the US industry did pull slightly ahead of the European industry. However, the advent of the integrated circuit heralded the boom of specialist manufacturers such as Texas Instruments, Motorola and Fairchild. By the 1970s most of the broad based firms had been marginalised into specialist markets, mostly for the military, or what Scibberas describes as the little league[56]. Since then the star performers in the semiconductor market have been specialist companies.

This bears a striking resemblance to the development of the computer market. Many of the same pressures were present. The introduction of ranges of components was very expensive. To win market acceptance of a new range of chips, the company had to produce them on a vast scale and sell them at a low price, even though this entailed a short term loss due to the low

[55]F. Malerba The Semiconductor Industry: the economics of rapid growth and decline, Madison, Wisconsin, 1985; A. Golding, 'The semiconductor industry in Britain and the United States: a case study in innovation, growth and the diffusion of technology', PhD, University of Sussex, 1971.

[56]E. Scibberas Multinational electronic companies and national economic policy, Greenwich, Conn., 1977.

yield of usable chips at the beginning of the learning curve. Given the cash flow disadvantages of supporting so many technologies, it is not perhaps surprising to see British firms like Ferranti, GEC, and Plessey opting to become smaller specialist manufacturers[57], and others like GE and RCA having great difficulty in maintaining a credible market share. The specialist chips they made were those most directly relevant to their military and telecommunications markets. The newer firms reacted better to changing market demand. Eventually the specialist firms came to dominate the market, bar the mass production memory market which is controlled by the Japanese electronics industry.

Government policy and the computer industry.

The apparent weakness of the multi-product electronics firms in the EDP and other electronics markets has implications for the analysis of the effect of government policies on the industry: lessons which are still valuable when considering new policy options. The basic difference between the role of the American and British governments was that the US government's main influence was through purchasing huge quantities of technology and funding the development of new computer concepts. The British government tried a more direct method of influencing the industry through intervention in the market place and supporting hardware developments. The US government bought equipment from market leaders to meet its demand for computer equipment, supporting its industry by buying product. The British government tried to help British firms to compete against the large American industry by underpinning companies which were building computers; until the late 1960s this meant supporting the electronics firms that were trying to build a stake in the computer sector.

The US computer industry received substantial support from the government, much of it through sales to the armed forces. The driving force was the need to support a massive military effort during the cold war, rather than as a method of creating a new industry. Arguments have been constructed which suggest that the purchase of military systems is so oblique to the commercial market that it has little effect on the general industry:

> 'Most military (and space) hardware is designed for specific applications under severe environmental conditions. It is usually far more expensive than any comparable civil product. Not only the specification but method of manufacture, testing and selling are

[57]Ibid.

very different from those of the normal civil market.'[58]

However, evidence gathered in this study shows that the US government was indeed very important in the growth of the market for standard computer equipment. A number of examples are given of the American government buying large quantities of computers for military uses which were for essentially commercial applications. These included sales of NCR machines for payroll tasks, Burroughs computers for accounting at military bases and RCA systems for store keeping. These sales were of a large magnitude and helped firms establish series production of standard commercial models:

> 'Another hot government trend--fleet purchases of computers, with the Air Force playing the lead role. Following up the AFLC order for 30 301's, the Air Force has announced plans to install between 160 and 174 NCR 390's for payroll processing at some 105 US and 25 overseas bases. The two orders sandwiched a dinky order for 19 CDC 160A's for an AF Satellite Control Facility tracking network.'[59]

This scale of purchasing was much larger than the output of the whole of the British industry at this time.

This anecdotal evidence of big government purchases of standard machines is supported by statistical data. The following graph (figure 9.1) shows that the US government was the driving force behind early demand. It bought the majority of early computer systems, helping to establish the technology. The US government continued to buy an ever growing number of computers, but, as figure 9.2 shows, its relative importance decreased as computers were taken up by private industry. Private firms could only buy EDP equipment once the computer industry had learnt how to make reliable, cheap equipment. This was achieved by satisfying early government demand:

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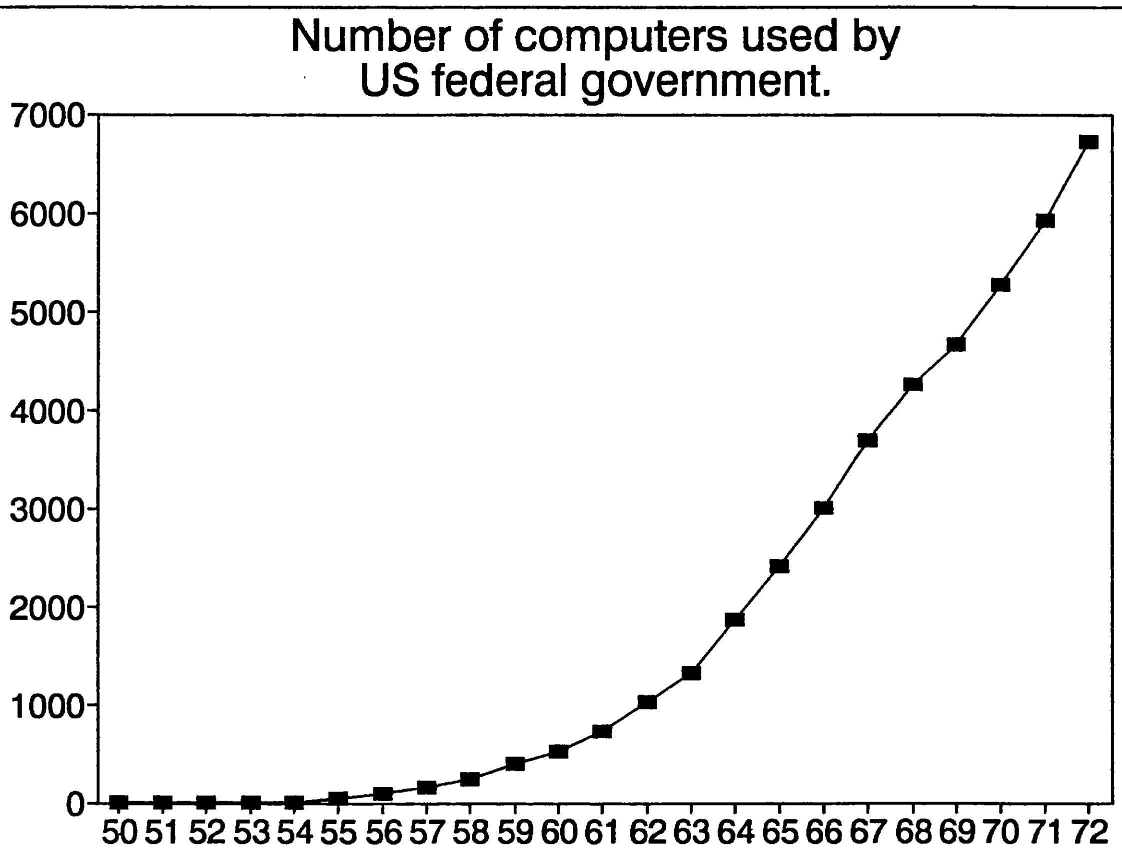
[58] C. Freeman, 'Research and Development in Electronic Capital Goods', National Institute Economic Review, November 1965, pp40-91.

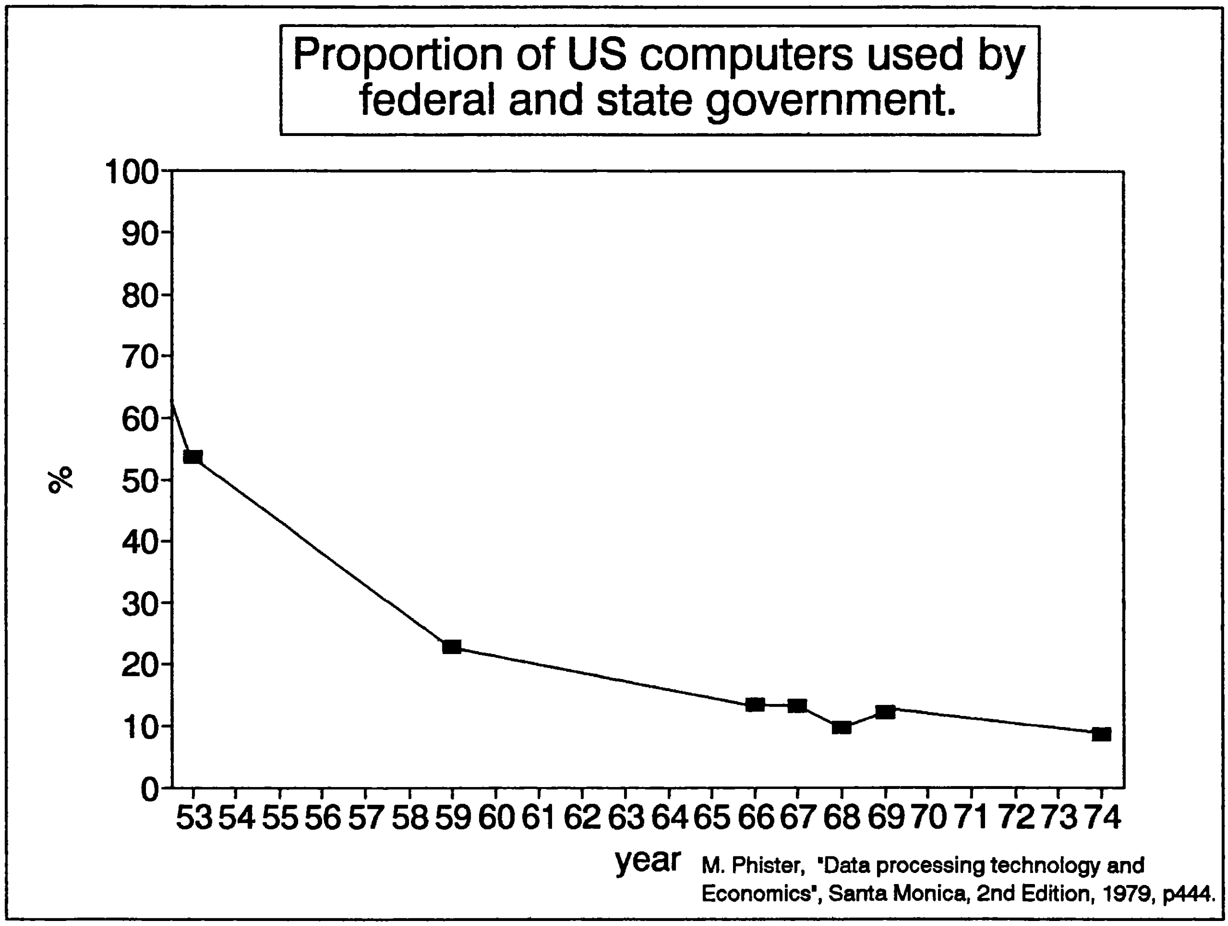
[59] Datamation, July 1963, p19.

Figure 9.1



CBI Archive: Bureau of the Budget, "Inventory of automatic data processing equipment in the Federal Government", 1962-66; "Inventory of automatic data processing equipment of the US Government", 1966-1975.

Figure 9.2


Proportion of US computers used by federal and state government.
%
100
90
80
70
60
50
40
30
20
10
0
53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74
year
M. Phister, "Data processing technology and Economics", Santa Monica, 2nd Edition, 1979, p444.

It has to be emphasised that the US government was not concentrating its spending on specialist computers; most systems that it bought were standard commercial or scientific machines. This is borne out by looking at the weighting of administrative systems to special purpose machines:

Table 9.1 Types of computers in use by the US federal government 1967-72.

Year	General Management Classification	Special Management Class, Control, Classified & Mobile	Total
1967	2754	938	3692
1968	2909	1323	4232
1969	3039	1627	4666
1970	3404	1873	5277
1971	3389	2545	5934
1972	3433	3298	6731

Source: CBI Archive, General Services Administration, Inventory and summary of federal ADP activities for fiscal year 1972.

General management systems were used for standard administrative activities and very similar to the uses made of computers by commercial companies. It also has to be remembered that many of the special classifications systems were standard scientific machines used for such things as real-time strategic control systems.

The importance of standard business applications to the US armed forces also shows through in the type of research that they funded. It is interesting that it was IBM that developed the standard scientific computer language, FORTRAN, while it was the US armed forces that paid for the development of the business language COBOL. Even large military projects like the ComLogNet communications system[60] were, in fact, developed for tasks close to those that business could use. ComLogNet gave the USAF a method of allowing stock control computers to talk to each other to allow the airforce to control its inventories on a worldwide scale; it was one of the first such developments. Not only was the government helping the industry by buying large quantities of hardware, it was also developing commercially useful applications.

The US government also had a similar effect on the basic component market. It was government purchasing of such things as integrated circuits that allowed prices to fall to a level low enough for commercial use:

[60]See above, chapter 6, pp237-239.

Table 9.2 Average price of integrated circuits and the proportion of production purchased by the US military, 1962-1968.

	Average Price $	Percent used by Military
1962	50.00	100
1963	31.60	94
1964	18.50	85
1965	8.33	72
1966	5.05	53
1967	3.32	43
1968	2.33	37

Source: John Tilton, International Diffusion of Technology, the case of semiconductors, 1971, p91.

The analogy between the role of the US government in the semiconductor and computer industries is striking. In neither case did the government favour its traditional suppliers, the defence electronics companies. Instead it bought chips or computers from the best source; increasingly this meant specialist producers.

In contrast the British government's role was often reactive. British policy was based on meeting the challenge of competing with the advancing US industry. British government purchasing was low, while direct intervention was more common. It is notable that much of the British intervention was aimed at keeping up with technology, rather than in developing new applications concepts as in the USA.

Prof. Blackett, an NRDC board member, prepared a report on the use of computers by various governments[61]. Blackett reported that, by 1964, 1565 computers were being used by the US government and the French state used 111. The British authorities used only 88 computers, 81 of which were domestically produced[62]. However, the list of machines included some dubious entries, like the Elliott 153 control computer, and the Powers PCC calculator.

One obvious explanation of the slower British government purchasing of computers was that the UK economy was much smaller than the US economy, and therefore government purchasing was proportionately smaller. However, if the British industry was held back by one general economic problem, it was that the adoption of computers was much slower in Britain than America.

[61]NRDC, 86/35/4, Prof. Patrick Blackett, 19/5/64. Blackett prepared this report after receiving a memo on the subject from Prof. Gill, a long time advisor to the NRDC.

[62]Ibid.

This is seen when comparing the number of computers used per billion US dollars of GNP:

Table 9.3

Computers per $bn of GNP.

Year	1958	1963	1965	1966	1967	1968	1969	1970	1971
USA	5.7	23.4	36.3	43.1	52.4	58.3	66.8	76.0	84.7
UK	1.8	11.4	15.8	19.9	27.0	38.9	46.2	52.7	50.4

Source: M. Phister Jnr., Data Processing, technology and economics, 2nd ed., Santa Monica, 1979, p289.

The UK economy was small compared to the US and it was not taking to the new technology as fast. In these circumstances it would be expected that a government that wanted to encourage a domestic industry would consider purchasing computers or methods of encouraging their use by industry. This would not only benefit the computer sector, but wider use of computers would lead to greater efficiency in both government and industry. However, it was not until the late 1960s that the British government started a programme to increase demand for British computers. At this time it initiated a more active purchasing policy, discriminating in favour of British computers in government purchasing[63] and offering tax rebates to encourage private industry to purchase systems[64].

Before this change, the British government's policy was to intervene directly to underpin the firms making computers. Until the end of the 1960s, the main responsibility for carrying out this policy was with the National Research and Development Council. The main concern of the NRDC was that the UK was falling behind the USA. It was these concerns that led it to support the Ferranti Mark 1 and Atlas computers[65] and the EMI 2400[66]. This same concern also led to the government supporting ICT in the mid-1960s, when there was widespread concern that IBM was starting to dominate the industry[67]. However, rather than trying to beef up demand, most activity was directed at supporting core technology. Policy was orientated to keeping the UK industry's hardware up to date and, until the

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[63]E. Moonman, British computers and industrial innovation: the implications of the Parliamentary Select Committee, 1971, p1.

[64]Martin Campbell-Kelly, ICL: a business and technical history, Oxford, 1989, p247.

[65]See above, chapter 2, pp51-65 and pp93-100.

[66]See above, chapter 3, pp128-133.

[67]See above, chapter 5, pp210-216.

mid-1960s, this meant supporting the computer divisions of the electronics firms. There were two reasons for this. Firstly, the British business machines firms were not as interested in the early computer industry as the equivalent firms in the USA. These firms were already busy establishing themselves as independent punched card manufacturers, following their separation from their US partners after the war. Secondly, electronics firms looked on computers as a way of extending their scope in the electronics market and a way of making use of their expertise. They were used to receiving government funds to develop military equipment and were willing to receive it to support their policy of concentric diversification. The fact that computers had a major military role fitted well into this framework.

The consequences of this were two-fold. Firstly, attention went on developing hardware rather than on production techniques and commercial applications skills. Government support tended to go on the development of new computers; relatively little support went to peripherals and applications, and what support there was in this area tended to be wasted[68]. This seems inappropriate, as the main weakness of these firms was not in developing electronic systems, but rather was their lack of understanding of the market place: this was where they needed help. Secondly, it meant that, in what was already a market that was much slower to develop than the US market, firms that were inherently weak were receiving support to stay in the industry. This was a problem that was recognised early on. Halsbury, the NRDC's managing director, had always seen the importance of getting the business machines firms involved in the computer market and he felt frustrated that they were slow to do so[69]. However, his alternative strategy of supporting the electronics companies on the basis that they were at least willing to take government cash to build computers, only diluted the size of the market open to the business machines firms. When the business machines firms did become involved in computers, this only increased the competition that they had to deal with.

British industrial policies were less successful at developing the UK industry than the simple mass purchasing of the US government. This buying of computers not only supported hardware developments, but also led

[68]Examples of this include the NRDC's support of the abandoned Epsylon and Pye tape drive systems, and the failed stock control experiment at the Siemens Edison Swan factory in Woolwich in the 1950s; see John Hendry, Innovating for failure: Government policy and the early British computer industry, Cambridge, Massachusetts, 1989, chapter 11.

[69]Ibid, chapters 5 and 6.

to economies of scale and to conceptual improvements in the use of computers.

Conclusion

The diversified electronics firms failed to gain the economies of scale and scope that might have been expected. They chose over-ambitious product plans, while at the same time limiting the amounts of capital invested in developing their computer operation, so as to marshal resources for other high technology developments. Capital rationing prevented them from fully exploiting all their opportunities.

This analysis of the computer industry, supported by other studies carried out on the semiconductor industry, points to the weakness of the multi-product, concentrically diversified, electronics company. If this is correct it has an important lesson for some existing high technology firms, as well as for governments.

European firms are becoming increasingly diversified. The number of firms involved in electrical, electronic and computer engineering is again growing, and national states are supporting the formation of large concentrically diversified electrical conglomerates. Consolidation is also occurring in other areas, such as the growing trend of merging car and aerospace interests. The lesson of this study is that firms of this nature cannot be successful, unless the horizontal and vertical structures are correct, and correct information is available to the corporate management. While success seems to have been achieved in the Japanese electrical/electronics industry, the lesson of the Anglo/American computer industry is that specialisation and complete corporate commitment to a market is likely to achieve greater success. Diversified firms are not necessarily successful in maintaining their markets against specialists. The governments that encourage firms to merge to form huge engineering conglomerates are doing so in the hope that strategic technologies will be protected. The opposite could well be true. Every firm faces problems from time to time, and it has been seen that at such times firms are often forced to drop an operation which is straining the finances of the company. Indeed there is a propensity for such concentrically diversified firms to suffer periodic crises: it is an inherently less secure strategy than full conglomeration of unrelated activities. Therefore, it seems that by merging whole segments of a country's industry into one, a government could see a single private enterprise give up a whole market segment in order to protect its investment in other areas. To many governments this would be unacceptable and would lead to direct intervention to underpin these large firms.

Broad-based firms have difficulties in concentrating on individual markets and can suffer from the inability to fund multiple growth paths. Before concentric diversification takes place, the firm has to consider the amount of expertise it can bring to the market and whether it can afford to fund all its developments. Even Japanese electronics firms, often seen as the most successful group of companies in the world, are, in the recession of the early 1990s, having to reassess their strategies. At the end of the day it might be better to reinvest profits into current areas of activity to preserve a market position, or even to distribute profits to shareholders, rather than to pursue inappropriate markets for a firm's skills. This policy could be better than trying to take on specialist producers and trying to overcome the problems of capital rationing that further expansion could lead to.

Biographical notes on some of the personalities mentioned in this thesis.

The following notes outline the role of the main managers, engineers and scientists mentioned in this thesis. These are only one-line notes for guidance, and are not necessarily the formal position that they held, but describe their function.

Sir Alexander Aikeman, post-war EMI chairman.

Sir Leon Bagrit, managing director of Elliott Automation/Brothers.

Dr Walter Baker, general manager of GE's Electronics Division during the mid-1950s.

W.G. Bass, Ferranti Director responsible for the computer department in the early 1950s.

Arthur Beard, Senior engineer at RCA, manager in charge of development in RCA's Computer Systems Division and one of the original Advanced Development Group engineers.

James Birkenstock, Thomas J. Watson Jnr's executive assistant in the late 1940s and early 1950s, proposed the manufacture of the IBM 701 'defence calculator'.

Sir William Black, NRDC chairman from 1957.

Prof. P.M.S.Blackett, Professor at Manchester University and NRDC board member.

R.Bloch, head of the Advanced Development and Resource Planning Division in GE's Computer Division in the late 1960s, produced the Advanced Product Line plan.

J.R.Bradburn, general manager of RCA's Computer Systems Division.

L.J. Brown, appointed as EMI managing director in 1952.

Norman Brown, EMI engineer who worked on the BMC computer and the 2400.

Sir David Brunt, chair of the Brunt committee which advised the government on early computer policy.

(Lord) Vivian Bowden, first sales manager for Ferranti computers.

H.G. Carpenter, member of the early Elliott Brothers' design team, later a NRDC employee.

R.T.Clayden, EE engineer who worked on the Pilot ACE and DEUCE, then worked for EMI and developed the EMI BMC machine.

A.L.Conrad, appointed as RCA's CEO in the early 1970s following the problems the firm encountered under Bob Sarnoff's management.

R.J. Cordiner, GE's post-war CEO.

John Crawley, NRDC employee, heavily involved in the computer activity.

Seymour Cray, designer of CDC's super computers, founder of Cray Research and Cray Computers.

Hershner Cross, GE's fourth general manager of the Computer Division from 1965 to 1966.

S.A. Dakin, head of the Board of Trade in the early 1950s.

John Duckworth, NRDC MD from 1959.

J.P. Eckert, co-inventor of a number of early computers, including the UNIVAC, and co-founder of the Eckert and Mauchly Computer Corporation which became the foundation of Sperry-Rand's UNIVAC Division.

W.S. Elliott, firstly developer of Elliott Brothers' first computers, then leader of Ferranti's London development team, working on the Pegasus.

Dr Elmer W. Engstrom, RCA President during the early-mid 1960s.

Sebastian Ziani de Ferranti, founder of Ferranti.
Vincent de Ferranti, MD and chairman of Ferranti from the 1930s to late 50s
Sebastian de Ferranti, took over from Vincent when he died in the late 1950s.
Basil de Ferranti, Ferranti's representative on the ICT board, and MD 1964-65.

Sir Ernest Fisk, post-war EMI managing director.

Jay Forrester, MIT academic, worked on the Whirlwind, and SAGE computers as well as inventing magnetic core memory.

J.G.F. Francis, consultant employed by the NRDC to inspect EMI's computer operations.

R.J.Froggatt, EMI engineer who worked on the BMC and 1100 projects.

Eric Grundy, manager of the Ferranti Instrument Department after the war.

Lord Halsbury, managing director of the National Research and Development Corporation.

John Haanstra, GE Computer Division's manager of development.

Derek Hemy, software engineer for LEO then EMI.

Dennis Hennessey, NRDC deputy managing director, greatly involved in the computer activities.

Norman Hill, head of EMI's Computer Division.

Brigadier G.H. Hinds, head of the Ministry of Supply during the building of the Ferranti Mark1 computers.

Herman Hollerith, inventor of punch card tabulation and founder of IBM.

Godfrey Houndsfield, developed the peripheral control unit of the EMI BMC computer and then developed the EMI 1100 system using magnetic core logic.

Arthur Humphrys, director of BTM, ICT and managing director of ICL.

George Jacobi, GE Engineer.

Harry Johnson, Ferranti salesman who produced the specification for the Ferranti-Packard FP6000, which later became the core of the ICT1900 range.

R.H. Jones, headed GE's Ventures Task Force and recommended the abandonment of the computer diversification, later became GE's CEO and Chairman.

Dr.Tom Kilburn, Manchester University scientist, worked with Williams on the Mark1 and the Williams Tube, designed the MEG (Mercury), MV950, MUSE (ATLAS) and the MU5 (which in part became the ICL 2900)

Charles Kramskoy, head of EMI's Special Products Unit, and manager of the EMI 2400 and 3400 projects.

Clair Lasher, second general manager of GE's Computer Department, and one of the first to support such a diversification.

Sir Ben Lockspeiser, Chief Scientist of the Ministry of Supply, responsible for the MADAM contract.

Sir Joseph Lockwood, NRDC board member, and one time chair of the computer sub-committee, appointed chairman of EMI in 1955.

Arthur L. Malcarney, RCA vice-president with responsibility for the Computer Systems Division.

Col. T.A. Maxwell, head of Power Samas, then chair of ICT.

Edwin S. McCollister, RCA, Computer Systems Division's director of marketing.

R.W. Macdonald, CEO of Burroughs

John W. Mauchly, co-inventor of a number of early computers, including the UNIVAC, and co-founder of the Eckert and Mauchly Computer Corporation which became the foundation of Sperry-Rand's UNIVAC Division.

George Metcalf, general manager of the General Electric Electronics Division's Commercial and Government Equipment Department.

Clifford Metcalfe, managing director of EMI Engineering and later EMI Electronics, he was in charge when EMI started computer development.

Sir Percy Mills, first chairman of the NRDC and later a member of the EMI board.

Chase Morsey, RCA's corporate vice president for marketing, recruited from Ford in the late 1960s, responsible for the Computer Systems Division's rapid growth in the late 1960s and one of the key players in RCA's exit from the industry.

C.R. Morton, consultant employed by the NRDC to inspect EMI's computer operations.

1st Lord Nelson of Stafford, managing director of English Electric until 1956, and chairman until 1962.

2nd Lord Nelson of Stafford, replaced his father as head of EE, became MD in 1956 and chairman on his father's death in 1962.

William C. Norris, founder of Control Data Corp.

H.R. (Barney) Oldfield, founder and first general manager of GE's Computer Department.

Kenneth Olsen, founder of Digital Equipment Corp.

Ralph Palmer, designer of IBM's early computers.

Brian Pollard, manager of the Ferranti Computer Department, left to work for Burroughs in the USA. Notably wrote an article in Datamation, criticising the efforts of the British electronics industry in the computer market.

Prof. Arthur Porter, electronics academic who influenced Ferranti's decision to start the manufacture of computers.

D.P.Prinz, engineer employed by Ferranti on the recommendation of Prof. Porter to investigate computing techniques.

Lou Raeder, third manager of GE's Computer Division.

James Rand, head of Remington Rand, and then controlled the Remington Division of Sperry-Rand after the merger with Sperry.

J.W. Rooney, RCA Computer Systems Division marketing director in the late 1960s.

General David Sarnoff, Leader and autocrat at RCA.
Robert Sarnoff, replaced Gen. Sarnoff as head of RCA.

Isaac Shoenberg, EMI television designer.

M.E. Sions, director responsible for computers at Ferranti.

J.S. Smith, fifth general manager of GE's Computer Division, from 1966.

George Snively, head of accounting in GE's electronics laboratory during the 1950s.

R.E.Spencer, EMI employee credited with encouraging the development of commercial computers by the company.

Sir Edward de Stein, board member of EMI and the NRDC in the early 1950s.

Christopher Strachey, chief technical advisor in the NRDC, helped design a number of systems, rated as a brilliant logistician.

Bernard Swann, Computer sales manager at Ferranti.

Sir Henry Tizard, Member of the Advisory Council on Scientific Policy, established by the 1945 Labour government.

Harry F. Vickers, head of Sperry-Rand.

Sir John Wall, Managing Director of EMI Electronics and later EMI, joined ICT board after acquisition of EMI's computer division, and became first Chairman of ICL.

Thomas Watson Snr, head of IBM, led it to dominate the business machines industry.
Thomas Watson Jnr, headed IBM throughout most of the computer era.

John William Weil, engineer in GE's Computer Division, head of the GE600 program and the failed WXYZ project.

Eugene R. White, GE engineer.

Prof M.Wilkes, Cambridge computer academic, developer of the EDSAC.

Professor F.C. Williams, developed the MADAM and Ferranti Markl computers, inventor of the Williams Tube electro-static storage technique.

F. Withington, chief computer strategy adviser for A.D. Little Inc.

V.O. Wright, RCA Computer Systems Division's vice president responsible for government marketing.

Dr Zworykin, RCA television designer.

Bibliography

I. Archival sources:

The following list shows the main sources of archival material used in this thesis.

Charles Babbage Institute.

This is the most important collection of archival material on the history of the computer. Within this collection, the partial copy of the proceedings, evidence and testimonies of the US vs IBM, anti-trust case has proved the most valuable source. It also has a copy of the Honeywell vs Sperry-Rand intellectual property case, a good source for those wishing to study very early computer developments. It also holds a large collection of product literature, journals and other ephemera. Its collection of material covering the technical history of the computer is even larger. The Oral History Collection is a growing and important source of information.

National Archive for the History of Computing, Manchester University.

This is the most useful repository of material in the UK. Its most interesting non-technical material is the collection containing the archive of the National Research and Development Corporation. It also contains a number of important reports, which are listed in Part II of the bibliography.

Ferranti Archive.

This has some material which is directly related to the operations of the Ferranti Department. At the moment the continued existence of this archive is in doubt.

Marconi Archive.

This contains some interesting material. It has a number of internal reports written during the war which show the problems that the electronics industry faced during disarmament.

Institution of Electrical Engineers.

Before transfer to the NAHC, the IEE held the NRDC collection. It also holds some technical information on the history of computing.

London School of Economic and Political Science.

The archival department of the British Library of Political and Economic Science holds a collection of papers given in the Edwards and Townsend series: 'Seminar on the problems in industrial administration'. These seminars were given by a number of captains of industry in the 1950s and 1960s on the development of the organisation in their companies, including some covering the electronics and business machines firms.

London Business School Library.

The LBS has a collection of company annual reports starting in the early 1960s. It also holds a number of stockbroker reports on individual companies starting in the early 1970s.

II. Unpublished papers and series.

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