CYBERHISTORY

by

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Cyberhistory: Outline

Cyberhistory: Abstract

Cyberhistory is a thesis presented at The University of Western Australia for the Degree of Master of Science. Computer history is its prime field of focus. **Cyberhistory** pursues four key themes in computer history. These are, gender, the notion of the periphery, access and the role of the proselytiser. **Cyberhistory** argues that, gender issues are significant to computer history, culture ascribes gender to computing, and culture has driven computer development as much as technological progress. **Cyberhistory** identifies significant factors in the progress of computer technology in the 20th century. **Cyberhistory** finds that, innovation can occur on the periphery, access to computers can liberate and lead to progress, key proselytisers have impacted the development of computing and computing has become decentralised due to a need for greater access to the information machine. **Cyberhistory** traces a symbolic journey from the industrial periphery to the centres of computing development during WWII, then out to a marginal computer centre and into the personal space of the room. From the room, **Cyberhistory** connects into cyberspace. **Cyberhistory** finds that, despite its chaos, the Internet can act like a sanctuary for those seeking to bring imagination and creativity to computing.

Cyberhistory: Introduction

The history of computing is currently a small field of research dwelling on the fringe of historical inquiry. **Cyberhistory** is the first thesis to be presented at The University of Western Australia for the Degree of Master of Science with computer history as its prime area of research. **Cyberhistory** seeks to place computer history on the main agenda of modern historical discourse. **Cyberhistory** does this through the pursuit of four themes. These are, gender, the notion of periphery, access and the role of the proselytiser.

If computing is a cultural space then what defines computing is that which occurs on its frontier. **Cyberhistory** considers the periphery in relation to the development of computing. It looks at peripheral cities, individuals and computer centres and identifies the impact they have made on computer history. **Cyberhistory** aims to identify significant factors in the progress of computer technology. **Cyberhistory** seeks to highlight how innovation frequently occurs on the computing periphery. Gender is woven into computer history. **Cyberhistory** argues that computing is inseparable from gendered culture. **Cyberhistory** shows that, in specific cases, proselytisers have accelerated the spread of computers and their use. **Cyberhistory** asserts that access to computing is an imperative if imagination and creativity are to be brought to the information machine.

Cyberhistory traces a symbolic journey from the periphery to the centre. It moves from Manchester, the cradle of the industrial revolution, to the routes of the pedlar and textile mills in the rural hinterlands of NorthEast America [Chapter 1]. **Cyberhistory** then sojourns in the computational centres of World War II [Chapter 2], before tracing the spread of computing into industry [Chapter 3]. **Cyberhistory** shifts to regional computing, focusing on the Computer Centre at The University of Western Australia between 1960 and 1980 [Chapters 4 and 5]. Through microcomputing, **Cyberhistory** arrives in the very personal space of the room. Cyberhistory then hyperlinks to a myriad of other spaces via the metaphor of the communications “super highway”. Gender is examined in relation to computing [Chapter 6]. Cyberhistory seeks to analyse the role of women in computing and notes their contributions to the development of computing. Like the street plan of a medieval city, the Internet is depicted as a distopia [Chapter 6]. Despite this, the voyage of **Cyberhistory** ends in a sanctuary amid the chaos of cyberspace. Here, in an electronic “room of one’s own”, **Cyberhistory** argues that, imagination can be expressed and creativity can flourish, through the instrument of the computer.

1.0

Spread of Mechanical Computing

1.1 Introduction

Before the monolithic electronic contraptions that filled entire laboratories with relays and vacuum tubes, there was a burgeoning mechanical computing industry. The following seeks to explore this pre-history to the electronic computer. It breaks this discovery down into three sections.

In **Manchester: a City on the Periphery** a special consideration is given to the city that was the hub of the industrial revolution. It asserts that Manchester was also closely connected with the growth of computing. Why was Manchester at the forefront of the technology? What is it about this city and the people who worked there that made it innovative? This section examines these questions asserting that in Manchester there was rapid economic growth associated with the application of new technology, that Manchester was a city of applied science, and research there had close links with local industry from Manchester University's inception. It also asserts that Manchester benefited from being a peripheral city, in that out on the periphery innovation is more likely to occur.

With **Changing the Work Culture of Science within Britain** an argument is made that science practice is subject to cultural moderation. It notes that computational devices were slow to be adopted by Scientists in Britain. Key individuals are identified who spread computing culture within research departments in an act of proselytisation. It asserts that computing was accepted within institutions after the perception of computing devices was altered by the efforts of scientists such as Hartree, Comrie and Whittaker. Implicit in this analysis is the assertion that the use of computational devices was as much to do with cultural concerns as with efficiency.

Commercial Calculating Machine Industry in America and Britain seeks to construct a brief history of the industry that would later spur the wide spread use of computing. It looks to America identifying individualism, attachment to property, and application as key cultural tenets that helped the growth of the office machine industry there. It asserts that technological innovation and the marketing of machines were equally important contributing factors to commercial success. It argues that America had a manufacturing base and sales culture that permitted it to excel in the construction and marketing of computing machinery. **Britain** notes the office machine boom was necessitated by the change in the composition of the workforce. It argues that the British office machine industry depended upon its American parent from the outset. Britain, lacking the US sales culture and economic power, could not compete with its larger ally. It asserts that factors were such that the computing machine industry in Britain would not attain the magnitude of its American counterpart. This section aims to emphasise that the calculating machine industry had elements within it that provided the foundation for the later computer industry.

1.2

Manchester: a city on the periphery

Electronic digital computing arose out of the efforts of three great powers. The United States, the United Kingdom and Germany at the outset of World War II (WWII) were three Nation states that would spearhead the development of computing during the course of the war. While Germany's efforts in computing stagnated with their concentration on the development of rocket technology, it was the USA and the UK who were to produce the first series of operable electronic digital computers. These two allies pioneered the field.

Why then devote a section on early computing to a large British city called Manchester? The answer lies in the fact that in the immediate postwar situation conditions were favourable in this city for the construction of the first working stored programme computer. Manchester produced the world's first commercial computer and pioneered storage techniques that allowed computers to have "memory" (This is covered in **3.2 Manchester Computing**). **1.2 Manchester a City on the Periphery** looks at the conditions and people that enabled this city to be at the forefront of computer technology.

The great machines that filled entire rooms with valves, wiring and cathode ray tubes heralded the dawn of a new age. Computers have altered the way we live. It is interesting that one of the cities where electronic computers first began to whirr and process data was also the cradle of the industrial revolution.

From the 1780s Manchester was the first city of the industrial revolution. The town boomed as ‘workshops proliferated and large factories were built along the rivers in the neighbouring countryside’ [1]. Early industrial growth was associated with the application of manufacturing technology to the textile process. Hence with Manchester there was a vibrant culture of economic growth associated with the application of new technologies.

Physical location mattered. Manchester was ideally situated to forge ahead in the area of textile manufacturing and its associated industrial processes. This was due to factors such as the ‘legendary dampness of climate (ideal for spinning cotton), the softness of the Pennine water and the existence of the Lancashire coalfield…Manchester’s long experience in marketing and distribution, and the proximity of Liverpool for imports of raw cotton’ [2].

Cultural factors would also have played a part in Manchester’s success as the first industrial city. Manchester was culturally a peripheral city to the seat of the British Empire – London. Yet this distance may have allowed for the rapid adoption of new ideas. Indeed, local producers utilised the new technology of the machine age earlier than in the other cotton regions such as the East Midlands, North Wales, Ulster and Scotland [2]. Hence in Manchester there was an attitude to technology that set it apart and enabled its denizens to take advantage of a new age in manufacturing.

Did this attitude of the ready acceptance of technology contribute to the development of computers? Bowden in his 1953 symposium on computing machines notes the parallels between the nascent British computer industry and Manchester's innovative past. He wrote comparing the new computing machines to a previous feat of engineering. There 'can have been few more promising investments since the Duke of Bridgewater built his famous canal a hundred and ninety years ago, at the beginning of the first Industrial Revolution. It cost £250,000; it enabled him to halve the cost of transporting coal from the pit head to Manchester, and was finally sold for £750,000' [3].

In 1894 the Manchester transformed itself into an inland port 55 miles from the sea, thereby bypassing Liverpool [4]. It was the ship canal project that enabled this. This was a sizeable feat of engineering appropriate for a region that placed emphasis on the application of science. Bowden's optimism in relation to the success of computers was ahead of its time, yet in his statement he makes a clear connection. Manchester had previously been a city of innovation and was continuing to be so.

Manchester had its own University with an independent newspaper by 1904 [5]. Given that there had been universities in England centuries prior to this and that there had been considerable people of wealth in the North Western region at least since the 1780s, Manchester established a university very late. People of wealth would tend to send their offspring to colleges in other cultural centres. This emphasises the point that Manchester was a peripheral city.

When Manchester University was created it had a distinctly different character to those more illustrious institutions to the South East. Applied Science is the key to understanding the Manchester culture of innovation. When Manchester established a university its character emphasised this. From 1851 Owens College had been seen as the University of the North [6]. Owens College was reborn as Manchester University in 1904. It was the first “red-brick” university of the nation. At Owens College the intellectual tradition existed whereby science was applied to the industry of the region. Manchester University would follow suit. Hence from its inception the University had traditional links with the local industry. This was to be decisive in the development of the first electronic computers.

1.3

Changing the work culture of Science within Britain

Computing began at Manchester University with D.R. Hartree. In 1929 he became Professor of Applied Mathematics at Manchester University where he applied wave mechanics to the study of electron densities in atoms [7].

Hartree was to become the chief link between British and US computing efforts in the immediate post-war period [8]. Yet his influence on computing at the University occurred earlier. It was sparked by a scientist's creation across the Atlantic.

Vannevar Bush was a brilliant and inventive scientist. In 1919 he became an instructor in electrical engineering at the Massachusetts Institute of Technology (MIT) [9]. In 1924 he and a colleague built a simple machine called the "product integraph", which they devised after spending several months performing painstaking arithmetic and graph plotting in order to solve an electrical transmission problem [9]. Such drudgery inspired Bush to create a machine that would ease the mundane aspects of calculations.

Bush's next invention was more sophisticated and caught the imagination of Hartree. Hartree saw it while on a trip to the USA. This was the differential analyser. It was a calculating device that was capable of addressing a wide range of engineering problems that could be specified in terms of ordinary differential equations [9]. Designed to solve differential equations up to the sixth order [10], Bush's invention was something that could be useful in any scientific department around the world.

On his return home, Hartree constructed a model of Bush's machine in 1934 [7]. His materials of choice for the model were interesting in that they were largely Meccano components. Meccano was a children's construction set patented by Frank Hornby of Liverpool in 1901 [11]. Hornby sold the components in sets that consisted of perforated strips and plates. These components could be fastened together with nuts and bolts.

Hartree's model worked and could solve problems. He soon set about obtaining funding for a full sized machine. His efforts paid off. A full sized four integrator differential analyser was installed in the basement of the Physics Department of Manchester University [12]. The machine was formally opened in March 1935 [12].

The significance of the installation of this machine was threefold. First, the analyser was the beginning of a centre of computation that was open to those scientists in academia and industry who approached Hartree. It was the first large-scale centre of its kind in Britain and began the process of computer centres there. Hartree had brought a technology over from the United States and began to implement it for the benefit of British scientists.

Second, Hartree had arranged for the construction of the analyser by the Metropolitan-Vickers Electrical Company [12]. Vickers had a large engineering and production works in Manchester. Hartree's use of the firm is illustrative of the close link between the University and its surrounding industries. This is a continuation of the notion carried down from the original Owens College. Instead of the analyser being both designed and constructed on the campus, industry constructed the device. Hence industry was involved in computational development at Manchester University from the outset.

The third aspect concerning Hartree's analyser relates to the culture of scientists. By culture, it is meant the way scientists went about their work and how it was changing. The analyser was essentially an aid to computation. It facilitated the shortening of time spent on problems by calculating what would otherwise be tedious arithmetic. The analyser was part of a long line of innovations that enabled calculation to occur. It would seem logical that all scientists from the enlightenment onwards would have embraced new tools with open arms. Yet this was not the case.

Science as a pure system of thought exists outside culture. The laws of physics will hold true whether they have been articulated by human culture or not. Yet the practice of science involves human interaction and human habits. In this sense culture can influence science. This was evident in the adoption of computational methods and tools, of which the computer is one.

Calculating machines had been available since the 1890s yet the use of desk calculating machines among British scientists did not become widespread until at least the mid 1920s [13]. This suggests that the culture among scientists was slow to adapt to the introduction of new calculating tools. Indeed, the new machines may have been perceived as below some scientists (mostly male) who would have associated calculation with the rooms full of human computers (mostly female) as used in censuses.

In order to change the culture of science practice it was necessary to encourage researchers to use computational equipment. What was needed was a proselytiser. This is a person who could spread the word regarding new calculating technology. Hartree installing a differential analyser in the Manchester University Physics lab was performing an act of proselytisation. Yet his efforts were not alone.

Hartree was preceded by two scientists in his actions to encourage the use of new calculating tools. The first was E. T. Whittaker. The second was L. J. Comrie. Whittaker was Professor of Mathematics at Edinburgh University. In 1913 he set up a mathematical laboratory at Edinburgh University and began to run courses on numerical mathematics and computation [14]. There were other calculating machinery laboratories in the country yet the emphasis of this centre differed markedly from the others. The Biometrics Laboratory at University College London used the calculating machinery as a tool to carry out statistical research [14]. Whittaker, at Edinburgh, was encouraging mathematicians to use the machinery for their daily work [14]. Hence Whittaker was deliberately setting out to alter the work practice of researchers. He was seeking to incorporate the new technology into academic work.

Comrie (1893-1950) was another proselytiser. In 1925 he joined the National Almanac Office (NAO) where he was quickly appointed Deputy Superintendent and, in 1930, Superintendent [15]. The purpose of the NAO was to calculate and publish accurate ephemerides to aid navigation and to assist astronomers [16]. Hence the type of work engaged in at the NAO was directly suited to the application of computational devices. Comrie realised this and set about procuring tabulating machines to be used in the preparation of charts and tables.

The tabulator Comrie used was an American invention. For the 1890 census the USA Government had commissioned Herman Hollerith (1859-1929) to construct a machine that could be used to sort the voluminous amounts of information that the census would generate. Hollerith's machine was successful and in 1896 he incorporated his business under the title Tabulating Machine Company (TMC) [17]. Hollerith would sell his company in 1911 [18]. It was then named Computing-Tabulating-Recording Company or CTR. Yet in 1924 under the inspired leadership of Thomas J. Watson Sr. CTR was renamed International Business Machines (IBM) [18]. Hollerith had begun the company that would dominate the tabulating machine and later the computer industry.

Hollerith's machine used punched cards to store information. Tabulators would then sort the cards. The tabulator 'could be set up to read selected values from any area of the card, print the values, and/or add them into a combination of the five 9-figure registers' [19]. In terms of the 1890 US census, the tabulating machines were a wonder to behold. The fundamental measure of their success was in time taken and cost. The census was processed in two and a half years instead of the seven years it took to process the previous census [20]. The total cost of the census was $US 11.5 million [20]. Without the tabulating machines it is estimated the census would have cost $US 5 million more [20].

Comrie, at the NAO in Britain, perceived the value of the Hollerith device. With it he could produce accurate tables in less time and avoid the elusive errors that were associated with previous tables. Comrie altered the attitude towards and perception of computational devices in Britain. As Croarken notes, by ‘publishing the results of his work, lecturing widely, and taking on consultancy work Comrie greatly influenced the way in which scientific computation was performed not only at the NAO but throughout Britain’ [21].

As an example of the tasks to which the tabulators were used by the NAO, consider the *Tables of the Moon* project. Information from these tables was punched in the form of 20 million holes in half a million cards [22]. These were then used to compute the position of the moon at every noon and midnight from 1935 to 2000 [22]. Some hundred million digits were added in groups and the results printed in the course of seven months [22]. To attempt such a task performing the calculations by hand would have been laborious, even with a room full of people solving sections of the problem. The advantage of mechanical computation in scientific work was therefore apparent.

Comrie’s use of the Hollerith devices was the first scientific application of the Hollerith system [22]. This is significant in that Hollerith designed the tabulation machine in order to be used in data processing. The need for such a machine in science had not been a consideration. Comrie’s application of the tabulator was perceptive.

The use of tabulating machines at the NAO was effectively science taking an idea from commerce and applying it. Mechanical calculating devices were invented and evolved for use in the office machine industry. When it came to digital electronic computers it was commerce that slowly used a concept generated by the efforts of science. What was the office machine industry? How did it develop?

1.4

Commercial Calculating Machine Industry in America and Britain

1.41 America

"Greed is good", stated Gordon Gecko in the Oliver Stone film 'Wall Street' [1987]. In this fictional character there is the essence of the entrepreneurial dream. Ensnared in the notion of entrepreneurialism is the need for property and capital. Gecko (as played by actor Michael Douglas) was the epitome of capitalist success. When considering the rise of the commercial machine industry in the United States and the later development of the computer industry, Gecko should be held in mind. This is because the essential traits of his character were created in early industrial America and permeate every aspect of the commercial computer industry. These are a ruthless individualism, a strong notion of property, and a desire to outdo others, particularly those who were born into wealth. The previous section has asked why

Manchester? The fictitious character of Gecko helps the historian to understand why the computing machine industry took hold in the United States.

Like Manchester the cities in North America had been peripheral to the British and French Empires. This sense of being on the fringe permitted freedoms that were not to be had in the administrative centres in Europe. In the New World pioneering skills enabled the settlers and immigrants to get by in a new environment full of opportunity. This would have meant the rapid adoption of new ideas, as in the newly industrialising Manchester.

In a sense, the inhabitants of nineteenth century North America inherited a pioneering spirit from their forebears. Years of adapting quickly to change and trading in goods and services had woven itself into the Anglo Saxon North American culture. Along with this went a strong notion of property. From Europe the North American settlers carried with them the work ethic that had been entrenched in Protestantism. Inherent in this way of life was the notion that work as applied to the commons generated wealth. Affluence was thereby the product of merit. Property was earned. This notion of application of effort to commons is a fundamental tenet of the capitalist way of life that pervades in the USA. The United States thus had a highly adaptive, capitalist mindset. This quickly translated into business practice.

Herman Hollerith incorporated the Tabulating Machine Company in 1896. Yet it was not the only business producing calculating equipment. For instance, while a bank clerk in the early 1880s, William S. Burroughs (1857-98) conceived of the idea of a calculator with a numerical keyboard and a built-in printer [23]. He was not the only person to arrive at this idea. Yet Burroughs persisted with his concept. After a few failures he patented a keyboard calculator with a built in printer in 1892 [24]. This machine was a huge success due largely to the inclusion of a printer. By 1913, the Burroughs Adding Machine company had some 2500 employees and $US 8 million in sales [24]. Clearly this new industry was one in which profit could be had.

Early in the new century dozens of other manufacturers entered the market. These included companies such as Dalton (1902), Wales (1903), National (1904), and Madas (1908) [25]. This is indicative of the competitive business environment as fostered by the North American capitalist culture. Innovation was not the only essential ingredient to financial success. Marketing of the office machines played an integral role in spreading their use among businesses. As in the case of scientific research, it was the culture of the office that needed to be changed in order for commerce to adopt the new machines. One company pioneered the marketing of office machinery. Its name was National Cash Register (NCR).

An American restaurateur who was concerned that his staff was defrauding him invented the cash register. His name was James Ritty. “Ritty’s Incorruptible Cashier” was built in 1879, yet he only sold one machine [26]. The man he sold it to had worked in the coal retailing business. His name was John H. Patterson.

Patterson was no inventor, nor was he a technical innovator. Instead he was a marketing genius. Patterson bought Ritty's floundering business and formed the National Cash Register Company (NCR). By 1886 Patterson was selling more than a thousand machines per year [27]. NCR created business practices that would later be taken up by IBM and transferred to the computer industry. It did this in two areas. The first was marketing. The second was research and development.

Although he was no inventor, Patterson recognised the need that NCR's product would only outsell a competitor's machine if it were the best. Innovation was the key to developing a better product. Patterson perceived this. By 1888 NCR had set up an inventions department [27]. This would later be mirrored in research and development sections in businesses throughout the world.

By far the greatest contribution NCR made to the later computer industry was its sales culture. Ritty had come up with an exceptionally useful device yet had failed to sell more than one of his machines. Patterson had learned that storeowners rarely walked off the street to inspect cash registers and make a purchase [28]. As a result of this, Patterson set out to develop a sales force that would take the cash registers to its potential customers. This was a decisive step.

A salesperson was not an unusual sight in the American landscape. With the industrial revolution grew manufacturers who needed to find customers for their wares. Household items spread through the States as a mass consumer market grew through the nineteenth century. The simple shelf clock is one example. It was invented in the second decade of the nineteenth century [29]. Until this innovation, household clocks were huge contraptions that stood in halls. Their expense and rarity were great symbols of household wealth and status. The shelf clock was produced in large numbers. It was affordable, yet still contained connotations of status. As a result many households desired them.

This single invention altered the entire clock industry [29]. More importantly the way in which the householders perceived the clock had changed. It had become a consumer item that every house required in order to legitimise its position as the seat of a family. The expression that “no home is complete without…” may well have been used with great frequency in this period. It would not be a surprise if the individual who coined this phrase were an itinerant pedlar.

Itinerants were at the epicentre of commercialisation in the rural hinterlands of the northern USA [30]. They moved from home to home selling a variety of goods and services including mantle clocks. Tinsmiths had ‘pioneered the use of pedlars to create mass demand; itinerants carried tinware and other goods out from local shops to buyers in surrounding towns’ [29]. In the pedlar there was the early marketeer.

The pedlar was the type of person who NCR were reshaping into a calculating machine sales expert. Notionally, a travelling sales person was not a new concept. NCR were borrowing an old concept and giving it new life. In 1894

Patterson had founded a small sales school [31]. He had taken the pedlar culture and turned it into a profession. One early graduate was T. J. Watson, the individual who would later transform CTR into IBM.

Frustrated by a sedentary job, Watson had taken to the road in his youth. He travelled the countryside selling organs. In this one individual was embodied the transformation from a pedlar to a sales professional then to a corporate leader. Watson joined NCR. While working for Patterson he graduated from the sales school quickly ascending the company ranks. Watson had a gift for sales and absorbed every aspect of NCR that made it successful. Rising to the level of a Sales Manager at NCR, Watson left in 1911 after falling out of favour with Patterson [32].

Watson was offered the position of General Manager at CTR in 1914 [33]. He undertook this task and brought to CTR the sales culture that Patterson had established at NCR. This involved practices such as sales territories, commissions and quotas [33]. In 1924 he renamed the company International Business Machines (IBM) and set about to make it the best office machine manufacturer in the world.

IBM was at this stage a small fish in a big pond. In 1928 the table for the world’s top office suppliers was as follows [34].

Table 1.1 Depicts annual sales of the world's top office suppliers in 1928.

Remington Rand	$60m annual sales
National Cash Register (NCR)	$50m annual sales
Burroughs Adding Machine Company	$32m annual sales
International Business Machines (IBM)	$20m annual sales

Watson realised the value in the Hollerith patents. Every punch card machine required numerous cards. IBM made sure that it was the sole supplier of cards for each of its machines. They cost a fraction to produce of the $US 1 for which they were sold [35]. In a company that manufactured office machinery the card sales counted for 30-40% of the total revenues [36].

The tabulators and punch card devices were leased rather than sold. In fact it was the deliberate policy of IBM to avoid selling machines. This meant that in times when sales were low the company could depend upon the rental payments to keep it afloat. IBM weathered the Great Depression of the early 1930s precisely because of this strategy.

In the dark years of the depression IBM and its CEO were a tower of strength. Watson's personal and business confidence helped him to become one of the most influential businesspeople in America. President of the American Chamber of Commerce, later President of the International Chamber of Commerce [37], Watson was a role model for any American seeking to innovate and succeed through the capitalist model. By the end of the depression, Watson was a friend and adviser to Franklin D. Roosevelt [37].

Roosevelt came to power on the strength of his New Deal platform. Watson's close association with the Presidency proved fortuitous for IBM. With Roosevelt's New Deal legislation there were obligations for employers to comply with federal demands for information [38]. Roosevelt had installed a welfare system and initiated public works projects. Such initiatives required information. IBM's information machines would process it.

Watson had steered the company through the pitfalls of the depression and now had it poised to capitalise on the new pre-war information boom. Between 1936 and 1940 IBM's sales nearly doubled. They went from $US 26.2 million to $46.2 million, and its workforce rose to 12 656 [38]. The information economy took Watson’s company to great heights. By the late 1960s IBM was the third largest corporation in the world, with annual revenues of $US 21 billion and a work force of over 300 000 [34].

During the period discussed above there was not one single electronic digital computer produced. An electronic digital computer is now popularly regarded as a computer. Yet the issues discussed above are of integral importance to the computer industry as it has existed from the 1950s. America had a manufacturing and sales culture that could generate machines shaping the office practices of businesses across the nation and around the world. The early office machine industry paved the way for the growth of computers.

Consider once again the example of the shelf clock. Traditionally only a wealthy home could afford a large clock. These devices would legitimise the seat of a family. Relate this to computing where traditionally large calculating machines and early electronic calculators were the domain of governments and large corporations. Yet more affordable devices became available for business to such an extent that computing devices legitimised serious professional businesses.

This anology extends further to the home environment. By the early 1970s computers were machines that individuals, who were not extremely wealthy, could not afford. Yet this changed with the explosion of microcomputing in the late 1970s. By the mid 1980s television advertisements helped use the home computer as a legitimation of a family residence. Commodore's advertisements asked, "Are you keeping up with the Commodore?" Although the products have changed, the underlying culture that marketed and used them had not. This is why understanding the early calculating machine industry is essential to understanding the later computer industry. Within it are the patterns and traits that would shape the information revolution.

1.42 Britain

Unlike America with its colonial background, Britain in the early twentieth century was the seat of a vast empire. Yet in the period following World War One (WWI) the empire was deeply drained. WWI had been a total war of attrition that consumed the economic resources of the principal participants. Within British society many changes had occurred in business due to the war. These changes would affect the use of office machinery.

What were the changes alluded to above? WWI was a total war that enlisted the efforts of men and women in British society. Many businesses began to employ women in manufacturing and clerical work. They also turned to automation. 1916-17 was the period in which office machinery took off in Britain [39]. This was due to a loss of clerical labour to the front in France [39]. Hence in Britain there was a change in the composition of the work force that necessitated the introduction of new office technology.

Tabulating machinery made its way into British commerce via the American Tabulating Machine Company (TMC). The

British owned Accounting and Tabulating Machine Company (BTM) imported the components of the American designed machines and assembled them under license. Hence from its inception the commercial British industry was linked to the parent company in the US.

The link with TMC was also financial. BTM's license agreement stipulated that BTM had to pay a royalty of 25% on gross revenue [40]. This levy was effectively a millstone that would plague BTM throughout its history. BTM was stuck with assembling an American product and having to pay dearly for the privilege.

Had BTM enjoyed a monopoly within the market, the royalty payments may not have been a serious problem. Yet in the 1920s there was an office machine boom which saw other companies enter the growing arena. In 1922 the *Societe Anonyme de Machines a Statistiques* (SAMAS) began selling its own machines [40]. Although a French company, its products competed in the British sphere particularly when SAMAS merged with Powers accounting machine company in 1929 [41].

Powers Accounting Machine Company was the tabulating machine division of Remington Rand. Rand had begun as Rand Ledger Company with Rand Jnr. forming his own company called Kardex. Kardex was a file sorting system. Both firms merged in 1925 to form Rand Kardex [42]. Then in May 1927 Rand Kardex merged with Remington Typewriter Company to from Remington Rand. With assets on formation of US $ 73 million the new corporation was approximately twice the size of its contemporary IBM [42]. Remington Rand was a further American company that was reaching out globally.

The British tabulating machine market was not a seminal industry. It relied on ideas imported from America. The companies operating in this zone were characterised through regular merger. Yet Britain through the 1920s was still a world power with industrial and scientific resources that could have sustained research and development in this industry. Why did BTM struggle?

The iniquitous royalty rate has been mentioned above. Yet there is another far-reaching factor affecting the growth of the British office machine industry and later the British computer industry. Born of the innovative spirit required in a new frontier, America had a competitive sales culture that Britain lacked. Patterson had turned marketing and sales into a profession with NCR. Watson had perfected Patterson’s ideas with great success at IBM. In Britain there was no equivalent.

As Campbell-Kelly notes [43] creating an ‘aggressive and motivated sales force in British culture was no simple matter. Sales commissions were viewed as ungentlemanly and were never used in BTM.’ This factor points to a distinct cultural difference between the two nations. American business had benefited from a capitalist culture that eluded the more reticent British. For the Americans “greed was good”. Their aggressive sales culture had ensured that their newfound dominance of the commercial office machine industry would continue.

A further factor concerned economics. American banks had largely financed the allied war effort. Initially the USA played a neutral hand when hostilities commenced in 1914. American business took the opportunities that were offered by the vast needs of the allied forces. Raw materials, particularly iron, were consumed feverishly by the war. As a result of this, America expanded an industrial base that had already exceeded the British capacity in the pre war years.

Russia, also a great power, had suffered at the hands of the German forces. The political situation was so precarious and the economic conditions so dire that the country was gripped by revolution then civil war. Germany, fighting a war of attrition on two fronts, had been defeated when the Americans joined the war on the allies' side. Hence, at the end of the Great War America stood as an economic and industrial powerhouse. Such pre-eminence in these spheres was conducive to the success of American business. Burroughs, Remington Rand, NCR and IBM would benefit from America's economic strength.

The rent and refill nature of the commercial office tabulating industry meant that companies such as IBM weathered the worst of the Great Depression relatively unscathed. The British tabulator manufacturers equally weathered the economic crisis from 1929-32. By 1936 all the world's office machine industry had fully recovered and moved into a phase of rapid growth [44].

With the introduction of the IBM 400 series “electric accounting machine” the nature of the equipment was beginning to change. This occurred in 1931 [45]. Tabulators were ceasing to be mechanical and were being manufactured with designs that were beginning to use electrical switches. Note the use of the term electric in the name of the IBM 400 series. It implies a device that is a new concept or innovation leaving behind the terms mechanical and tabulator.

Larger storage space in the machines had been extant as early as 1923 when the Campos book keeping machine offered possibilities for mathematical computation. Its significance was that ‘by specifying an index number, the corresponding register sends the number which it holds to the accumulator or stores the number which was held in the accumulator’ [46]. Other developments in storage techniques would come about in the course of World War Two (WWII). It was in the midst of this conflict that the electronic digital computer was truly born.

1.5 Conclusion

Mechanical computing preceded electronic computing in an engineering sense yet also in a cultural sense. In having a culture that applied science to industrial concerns, Manchester was a fertile bed from which the computer could emerge. Being on the periphery had its advantages in the sense that Manchester was not constrained by intransigence; a tradition of rapid adoption of new ideas and technology served it well into the 20th century. This is why it reached the forefront of computer technology in the postwar period. Manchester University's close link with local industry insured that industry could apply and benefit from any new innovation that developed. This is why Manchester was also one of the birthplaces of the computer revolution.

Human culture as well as the need for expediency shape computing practice and this is why proselytisers such as Comrie, Hartree and Whittaker were integral to the spread of a computing culture. They altered the perception of computing devices establishing centres of computation and furthering the induction of computers into researchers' daily work. This change in culture meant that the scientific community would be more receptive to new computing technology in the future and is why the actions of these proselytisers was of importance.

America, being on the periphery of the Empire, benefited from a pioneering mentality whereby new ideas were rapidly adopted in order to solve problems and forge ahead. Individualism and competition in the market place meant that new computing devices were innovative. American culture was suited to a sales mentality and manufacturing industry. In computing technological advances and marketing superiority are what bring success. This is a central tenet of the early American computing machine industry and remains a cornerstone of the computer industry in the 21st century. It is also why America has been so successful in this sphere.

2.0

World War II and the Birth of the Electronic Digital Computer

2.1 Introduction

World War Two was a pivotal event in the history of computing in that it provided a hitherto unseen demand for calculation. This intensity of computing demand could only be met by electronic computing devices. Research into these devices was a key priority among the allied powers during the war. As such it is this era in which the electronic digital computer was born. World War Two also harnessed the talents of a generation of mathematicians and scientists and applied them to computing. Many of these individuals made their reputation on their war work and continued computer research into the post war period. This chapter examines some of these individuals and the machines that made them famous. It tackles this in five sections.

Turing is a seminal contributor to modern computing. By 1934 he had constructed a theoretical framework for a universal computing machine. **Bletchley Park and the Enigmatic Alan Turing** investigates the role of this shadowy figure during World War Two. It asserts that Turing had taken figurative concepts and related them to the physical world. It argues that Turing’s life and work has existed on the periphery of computing due in large part to its secrecy. It argues that his universal machine was an industrial concept removed from the Platonic world of symbols, and that, in cracking the enigma, Turing proved the potential of his figurative construct.

The **Colossus** was a significant precursor of the electronic computer and as such is examined in this account. Although it was constructed at the secret Bletchley Park facility during the war its influence can be seen in that those who built it went on to pioneer stored programme computers immediately after the war. This section notes that in the construction of the Colossus one of the fundamental problems in building an electronic computer was discovered – that of the need for an operable internal store.

Zuse was a German engineer who worked on computing in relative isolation throughout World War Two. This section attempts to locate him within the history of electronic computer development. It argues that Zuse’s sequence controlled calculator along with the Colossus and Atanasoff projects collectively represented a stepping stone in computer technology from the mechanical to the electronic. It asserts that Zuse was hampered by the lack of perception displayed by the German authorities. It considers that had this not been the case Zuse might well have built the first stored programme electronic computer. In terms of his ideas and application Zuse was ahead, in time, of the team that built the Colossus and ENIAC machines.

The Moore School and the ENIAC analyses the American contribution to electronic computing. It notes the economic superiority of the US and its ability to devote large resources to computing projects. It asserts that the Moore School was a conducive environment for the production of a computer. It asserts that the ENIAC team did work with the awareness of a precedent for an electronic computing device in the Atanasoff computer. The ENIAC's major failing was its lack of memory, and the following shows how this led to the emergence of the stored programme concept.

John von Neumann encountered the ENIAC by chance. **John von Neumann** details how von Neumann's work influenced the Moore school project, asserting that his involvement brought prestige to the ENIAC development. It notes that von Neumann was aware of Turing's universal computer yet argues that it was von Neumann's 'First Draft of a Report on the EDVAC' that brought computing to the rest of the world. The following contrasts the scientific culture of von Neumann with the engineering culture of Eckert and Mauchly, asserting that his status took a peripheral project and turned it into an effort of international importance. By bringing his interest and prestige to the ENIAC project, Von Neumann was also a great proselytiser of computing.

2.2

Bletchley Park and the Enigmatic Alan Turing

Early in the summer of 1935 a young man lay down in a meadow in Grantchester, England after a long afternoon run [1]. In his mind was a mathematical problem conceived by Hilbert. Could there exist a method for solving all mathematical questions? Daydreaming, he used his imagination to create a machine. His name was Alan Turing. His creation was a universal computing machine.

The theoretical problem that confronted Turing had been encountered in a course on the foundations of mathematics taught by Max Newman. This was at Cambridge University. In the course Newman had introduced research on the logical foundations of mathematics. There was Hilbert's formalist programme for providing a foundation for mathematics and Kurt Godel's incompleteness results of 1930 and 1931, which destroyed Hilbert's programme [2].

Newman highlighted to his students that Godel's results had left one important question of the Hilbert programme unanswered. This was what was referred to as the *Entscheidungsproblem*: is there a procedure that, for every formally statable mathematical assertion, will determine the truth-value of that assertion? [2] It was this problem that Turing addressed while lying in the meadow.

Turing’s idea for a solution centred on a machine that could scan a line of tape section by section. It could move along the tape one place at a time to the left or right. It could write or erase new symbols on the tape. Turing reasoned as Godel had done before him that numbers and operations upon them were all symbols and could be represented as such. He reasoned that the numbers that can be calculated by any purely effective or mechanical procedure in mathematics are exactly those that can be calculated by his machine [2]. Hence on the tape that passed through the theoretical machine, any number or operation could be represented.

Due to this quality of symbolic representation, Turing’s device could simulate the work performed by any machine. It could read description numbers, decode them into tables and execute them. Turing had constructed in his mind’s eye the logical framework of the modern computer. He had taken the figurative concepts of mathematics and related them to the physical world.

Turing had shown that mathematics could never be exhausted by any finite set of procedures. ‘The answer to the Hilbert question was ‘no’. There could exist no ‘definitive method for solving all mathematical questions. For an incomputable number would be an example of an unsolvable problem.’ [3] He articulated this discovery in a paper titled ‘Computable Numbers’ in 1937.

This was a pre World War Two (WWII) paper that entered into the Mathematical discourse without a sizeable stir. Indeed this was not uncharacteristic of Turing’s work. His life to a large degree existed on the periphery of society and his work was shrouded in the shadows of the War. Turing's paper was ingenious as it identified the major features of the modern computer.

Having studied at Kings College in Cambridge in 1938 Turing was recruited into a section of Government intelligence that worked on decryption and ciphers. This was the Code and Cipher school that was based in a Victorian mansion in Bletchley. He was one of a number of men and few women of the "professorial" type who would work for the British Government on intercepted German radio transmissions. These messages were encrypted and it was the task of Turing and his colleagues to decrypt the communiques. They were cryptanalysts.

Turing was mentally well suited for the type of work that the Government required. Yet he was an odd character, being shabbily dressed and ill equipped to deal with the regimentation of a semi-military environment. His eccentricities were tolerated by his military superiors, for his work was invaluable. By devising his analytical machine he had already taken the abstract notions of mathematics and applied them to the physical world. The Turing machine, even though a theoretical device, was an industrial concept far removed from the Platonic world of symbols.

Shrouded in a vast cloak of secrecy, Turing worked with others at Bletchley on the number one problem confronting the allies, that of cracking the German enigma transmissions. During WWI the Germans had transmitted something of the order of two million words a month. During WWII it was estimated that the Germans were transmitting two million words per day [4]. Through the enigma device almost all German military traffic was encoded.

Prior to the 1939 invasion of Poland, Polish intelligence had constructed a mechanical device specifically designed to decrypt messages sent by using the enigma encoding machine. These were called *Bombes*. At the outbreak of the war, with Poland being overrun by German forces, the details of this machine were passed onto the British. Turing and Gordon Welchman designed and implemented the British version of the Polish machine calling it the *Bombe* [5]. The British machine resembled its Polish predecessor in that it applied mechanical brute force to cracking the encryption key. Other than that it was an entirely new device.

The bombe was probably the first application of a mechanical device to code breaking. A highly specialist machine, the bombe was no computer. Yet it tackled a mathematical concept mechanically. The precursor of the electronic computer was the device that succeeded the bombe. It was called the Colossus.

German High command exuded confidence in the security of their communications. The enigma was thought by the Germans to be uncrackable. Such was their confidence in the enigma, when the German high command suspected that their communications had been compromised, they placed the blame on traitors rather than doubt their encryption devices.

In appearance each enigma device was box like. It had a number of keys like a typewriter for entering messages. Beyond the keys were a series of rotors or scrambler wheels. Also on the box was a plug board that was used to switch letter settings. The machine was not that sophisticated, yet the mathematical principle behind its encryption produced messages that were nearly impossible to decrypt.

An enigma achieved its purpose very effectively. The key to the encryption process centred on the growing permutations of the combined product of the scrambler orientations, scrambler orders, and plug board settings. Unlike a simple Caesar code, enigma machines allowed the same letter to be encrypted differently. For instance, assume the phrase to be encrypted was “**artillery division**”. The letter **i** recurs four times in the phrase. With a simple Caesar code the letter **i** may be encrypted to **k**. At each instance of the occurrence of **i** a **k** would be put in its place. In this example the code exchanges each letter in “**artillery division**” with a letter two places further along the alphabet, so that “**artillery division**” would read “**ctvknngta fkxkukqp**”. With the enigma code, **i** would be encrypted to different letters with no simple relationship between them. By doing this, it is extremely hard to crack. How did the machine do this?

Table 2.1 Depicts a simple Caesar code where the original letter is replaced by a letter two places to the right along the alphabet from it. The original letters are on top (shaded) with their corresponding encrypted letter below. This type of code is easy to crack.

A	B	C	D	E	F	G	H	I	J	K	L	M
C	D	E	F	G	H	I	J	K	L	M	N	O

N	O	P	Q	R	S	T	U	V	W	X	Y	Z
P	Q	R	S	T	U	V	W	X	Y	Z	A	B

Initially consider the scrambler arrangement. The commercial enigma machine had three rotors or scramblers. Campbell-Kelly has offered a concise description of the scrambling process. He notes that the unit,

> ‘…included a set of three rotors [or scramblers], each of which had 26 input-output terminals on either side. The input-output terminals of the rotors were randomly connected, so that any letter entering a rotor emerged from it as some other letter. The three rotors in the machine were connected in the form of a counter…so that as each letter was keyed in the left-hand rotor stepped on one position. When after 26 letters had been keyed in, the left-hand rotor had made a complete revolution, the middle rotor would be stepped on one position; similarly when the middle rotor had completed a revolution, the right-hand rotor would step on one position. In this way, the rotors would only be restored to their original setting after 17 576 (that is, 26 x 26 x 26) letters had been keyed in.’ [6].

Essentially each of the 3 scramblers can be set in one of 26 orientations. There are therefore 26 x 26 x 26 (17 576) settings.

The second stage of encryption complexity concerns the order of the scramblers. Three scramblers can be placed in any one of six orders: 123, 132, 213, 231, 312, 321 [4]. In 1938 the German military added two extra scramblers to the machine [4]. With this new arrangement any three of the five scramblers were used for encryption. This increased the number of possible scrambler orders to 60 [4].

Complexity further increased with the plug board settings. The plug board enabled letters to be swapped. For example, if letter ***a*** was swapped for letter ***b*** then letter ***b*** would follow the path through the machine that letter ***a*** would have followed before the swap and *vice versa*. The enigma had six cables capable of swapping six letters. The number of ways of connecting, thereby swapping, six pairs of letters out of 26 is 100 391 791 500 [4].

For the military enigma machine the number of possible keys is the multiple of the above factors:
17 576 x 60 x 100 391 791 500
= 105 869 167 644 240 000
(Approximately 10^{17}).

The sender and receiver of the message had only to agree on the scrambler orientation, the scrambler order and the plug board settings. Having done this they could exchange messages with ease. To crack the key the cryptanalyst would have to try every one of the 105 869 167 644 240 000 combinations. Given that the agreed settings could be changed every day with ease, the cryptanalysts at Bletchley were up against an enormous challenge.

Although he dressed untidily, was slightly eccentric and rather odd, Turing devised a way of beating the enigma cipher. What follows is a brief explanation of Turing's strategy. For a detailed description with examples refer to Singh [4]. This explanation relies heavily on the work of Singh [4] and Campbell-Kelly [6].

Pondering the library of intercepted enigma crypts that quickly accumulated at Bletchley, Turing found a weakness. Turing realised that the German military used a certain structure in their communiques. That is certain terms would be repeated at specific junctures in the order of a message. In cryptanalysis this type of break is called a crib. Turing could look at an intercepted message and guess with some accuracy that a series of jumbled letters represented a specific word due to its position in the communique. This would be common with messages such as weather reports where specific jargon was employed.

British intelligence had a replica of an enigma machine and knew how they worked. Turing could see how the complexity of the encryption grew at each of the three stages of the plug board, the scrambler arrangement and the scrambler orientation.

In order to begin tackling the problem Turing simplified it. He set aside the issue of the plug board combinations and pondered the scramblers in isolation. He had the encrypted text and the corresponding plaintext or crib. Turing noted that some of the cribs contained an internal loop in relation to the encrypted text. He then devised a set up where three replica enigma machines were connected in sequence so that they dealt with each element of the loop.

Scramblers on the machines would rotate through their multifarious permutations. Each machine had its scrambler set at a specific number of places forward than the machine next to it. The replica enigmas were connected in a circuit. If all the components of the loop aligned then a light would go on. This would signal that the scrambler positions and the scrambler orientations were correct.

Turing's solution was a stroke of genius and is best explained through an illustration. Consider the term 'vessel' as an example of a crib. Assume in an intercepted transmission Turing guessed that vessel was encrypted as **E S K V P R**. When the plaintext is aligned with the encrypted text there is a loop. The loop flows from the plaintext to the encrypted text and back again. In this case it is through the letter combinations of **v** to **E**, **e** to **S** and **s** to **V**. This is illustrated below in Table 2.

Table 2.2 Plaintext, Cipher alignment and internal loop [4].

s	$s+1$	$s+2$	$s+3$	$s+4$	$s+5$
v	**e**	**s**	**s**	**e**	**l**
E	S	K	V	P	R

When a letter is entered into the keyboard the scrambler wheel clicks round one notch before the next letter is typed.

By a notch, it is meant that the scrambler moves to the next letter on the wheel (there are 26 letters thereby 26 positions or notches on each wheel). In this case, once **v** is entered the scrambler moves one position around before **e** is entered. If ***s*** represents the initial position of the scrambler wheel, then ***s*** + 1 represents the next position. This is shown in the table above.

Turing's solution used three enigmas connected in series. For the above example the initial setting on the first machine's scrambler would be put at ***s***. On the second machine the initial setting would be moved round one notch, ***s***+1. The third machine would be set at three notches in advance, ***s***+3. Note that the space between the settings corresponds to the space between the connecting letters in the loop - it follows the same pattern. This utilises the fact that the scrambler on the enigma rotates one notch for each letter of plaintext that is entered.

The enigma devices then go through each setting mechanically one after the other. When the scramblers align such that when **v** is fed into the first machine it returns **e**, when **e** is fed into the second machine it returns **s**, and when **s** is fed into the third machine it returns **v**, the scramblers on all three machines are properly set. This means they are at the equivalent alignment of the enemy enigma that encrypted the original message.

Turing connected all three machines so that the output of the first would be fed into the second and the second into the third. The output of the third machine was then fed into the first. By placing a light in the circuit, Turing would know that the scramblers had aligned because the light would illuminate [4]. In this way he was able to solve the problem of the scrambler order and orientation.

The next problem was the plug board setting. Once correct scrambler arrangement and orientations had been discovered it was a simple matter to find the plug board connections. To get these Turing used a single enigma machine with the correct scrambler arrangement and order. He then entered the cipher text to get the plain text.

Using the above example, he would have entered the string **E S K V P R**. This time the plug board would be in operation so the results would be imperfect. But Turing would know the crib (in this example the term ‘vessel’). He would also know that whatever the plug board’s combination, the letters for the crib would be the same. They would merely be jumbled.

If the imperfect output were ‘**s s e l v e**’, Turing would just switch the plugs around until the output was **v e s s e l**. This was a simple operation. Turing had theoretically cracked the enigma. Turing and Welchman then designed a device that would use all the principles and mechanics set out above. This device was the British Bombe. And it altered the course of the war [4]. In cracking the enigma Turing had proved the potential of his universal machine in that figurative concepts embodied in a machine could achieve the seemingly impossible.

2.3 The Colossus

Success in WWII relied more so on accurate intelligence than any conflict previous to it. Britain needed constant supply from the USA, which had stayed out of the conflict until December 1941. Ships would travel across the Atlantic in large convoys laden with supplies only to fall victim to German U-boats. In the first years of the war U-boats sunk a staggering tonnage of allied merchant shipping. If unchecked Britain would have run out of supplies and been forced to capitulate.

In the early years of the war radar triangulation had been the only method of locating the U-boats. The *Kriegsmarine* as the German navy was known employed a more complicated enigma encryption than that which had been cracked by Turing. This machine used more scrambler wheels and an adjustable reflector that greatly increased the difficulty of cracking the code. The bombes were not up to this task. Instead the allies relied on a new machine, the Colossus.

The Germans also had what was called a *Geheimschreiber* device [7]. It operated on the same principles as the enigma machine, yet it employed ten rotors instead of three. The *Geheimschreiber* was not as portable as the enigma and was used for only the most sensitive communications. The bombes as devised by Turing could not crack the *Geheimschreiber* or the more involved enigma codes. A new machine was required. Having pioneered the successful application of a mechanical device to solve an encryption, Turing was not involved with the Colossus project.

The Colossus was designed and built by a team directed by Max Newman and including T. H. Flowers, S. W. Broadhurst, W. W. Chandler and A. W. M. Coombs [8]. Like Turing, Newman was a Cambridge mathematician. He was the same mathematician that had first drawn Turing’s attention to the Hilbert question in 1935. Newman outlined the specifications of the Colossus. Flowers, Broadhurst, Chandler and Coombs were the engineers who designed and built the device [8]. They made it work.

From February 1943 construction began. It took eleven months of night and day working to complete [9]. In designing the device Flowers developed some revolutionary methods for solving some of the engineering problems. One example concerned tape synchronisation and the continual need for fresh tapes [9]. Flowers developed an internal store using an electronic medium. Only one tape was therefore required. Yet extensive use of electronic valves were required to facilitate this [9].

Flowers was thereby beginning to deal with one of the fundamental problems of the electronic computer – that of an internal store or memory. The first Colossus used 1500 electronic valves to achieve this. The second, produced by June 1944 used 2400 [10]. With an internal store the Colossus was able to perform simple acts of decision that were conceptually in a different realm to the bombes that had preceded it.

By recognising and counting, the Colossus could produce the best match of a given piece of pattern with text [10]. The newer machine, by automating the process of varying the pattern, was able to work out which was the best solution to try out [10]. It was programmed largely by the means of plug boards and was capable of flexible Boolean operations. It read the tape at 5000 characters per second [8]. The later Collosi were capable of carrying out more than 10^{11} consecutive elementary Boolean (and/or) operations without error [8]. This was impressive and spoke well of the soundness of its design. Although not a general-purpose electronic computer, Colossus was an advanced machine that compared well with the electronic computers of the 1950s.

In terms of the precursors of electronic computers the Colossus was only preceded by work carried out by J. V. Atanasoff and C. Berry at Iowa State College between 1937 and 1941 [7]. They had designed an electronic binary digital 'equation solver' yet never completed a finished product. Atanasoff was later to become embroiled in a long tangled legal suit with Eckert and Mauchly, the creators of the ENIAC, over the patent rights to the electronic digital computer.

2.4 Zuse

The other precursor to the Colossus was a machine devised by a German civil engineer called Konrad Zuse. Zuse had been bored witless laboriously solving calculations associated with his undergraduate studies and began to develop instruments that would ease these tasks. At twenty-six he was a young graduate and began to build his own machines. This was in 1936 [11]. Zuse built four pre WWII machines only one of which survived the war. His first machine was operational in 1941 [7].

Like the Colossi, both the Zuse and Atanasoff projects involved internal stores for numbers. All three can be best described as sequence controlled calculators [7]. This is due to the fact that they all lacked the vital component that was to differentiate the modern computer from all that had preceded it. This was an internal store for the programmes or instructions from which the devices operated. Despite this, they collectively represented a stepping stone in technology from the mechanical to the electronic.

Zuse’s growth as a computer designer and inventor was stunted from the outset of WWII. Nazi Germany took a gifted and innovative engineer and drafted him as a simple soldier. Zuse had filed for patents in the USA and Germany in 1938. American and British intelligence would have been aware that a German had been building computing machines. Yet unlike the allies, who recruited people such as Turing in a conscious effort to win the war of intelligence, the Germans lacked perceptiveness.

Zuse’s employer had been a calculator maker. This was how Zuse had financed his first machines. The employer asked a military superior if Zuse might be spared from soldierly duties in order to develop a computer that could aid the calculations required for aircraft design. The officer replied that he considered the German airforce infallible and in no need of further calculations [11].

Had Zuse been allowed a free hand to develop computers he may well have implemented the first stored programme electronic machine. Even his electronic sequence controlled calculators were the equivalent of the British Colossus in terms of technology. Zuse’s machine was extant in 1938 while the Colossus was not developed until 1943.

Unlike Turing, Zuse had given no thought to decryption technology and was unaware of the potential of his machines in that area. Code breaking and intelligence were clearly not perceived by the Nazis as an application of computer technology. Instead they wanted machines to calculate specific engineering problems in relation to the design of aircraft.

Zuse calculators were used in the engineering of V2 rockets, and in 1945 Zuse himself was installed in the Dora underground factory [12]. In the final months of the war Zuse had first seen the concentration camps around the underground factories near Northeim [13]. He managed to leave with one of his machines, the Z4, intact.

The underground factories were part of the late thrust of the German wartime scientific effort. The Germans did not realise that machines similar to those that Zuse had been building had compromised their encryption. In this sense they lost the intelligence war, a factor that was decisive in WWII.

Persistence was a quality that Zuse had in abundance. In the early 1940s he persevered against his superior’s lack of vision. The Henschel aircraft factory did require purpose built calculators even though they had no interest in computers [14]. Zuse used the excuse of designing a calculator to meet their needs to work on a computer that could perform more than just the specific task. He set up a 15-person firm in 1941 [14]. Zuse then developed the Z3. Although an electro-mechanical device, it was the first fully functioning, programme-controlled general-purpose digital computer [14]. It predated the start of the American ENIAC project by 2 years.

The Z3 used a magnetic relay-based memory. It was built from 2600 relays and consisted of the operator’s console, a tape reader and three cabinets [15]. The memory in the machine was relatively small. It could only store sixty-four 22-bit numbers [15]. It could add, subtract, multiply, divide, and find square roots, yet was largely used to evaluate the determinant of a complex matrix [15]. Although it lacked the ability to store programmes, the Z3 fundamentally had all the attributes of the modern computer.

The Z3 was the equivalent of the ENIAC technology, except that it was slower, smaller, and not fully electronic. Zuse had lacked the freedom and the scale of budget that the Americans and British enjoyed. He had worked in isolation under indifferent superiors yet had managed to solve some complex and challenging problems. As such he was a true pioneer of the modern computer. It is fitting that he survived the war evading capture by the Russians with one machine intact (the Z4). In 1949 he managed to establish a computer company called Zuse KG, which developed into a leading manufacturer of small scientific computers [13].

2.5

The Moore School and the ENIAC

The USA did not enter the war until the Japanese surprise attack on Pearl Harbour in December 1941. Following WWI the US had consolidated its position as the greatest industrial power in the world. Its resources far outstripped those of Britain and Germany. As such it was able to devote considerable amounts of backing to scientific programmes that would enhance the WWII effort. One such programme concerned the construction of an electronic digital computer at the University of Pennsylvania.

With the onset of war looming, the USA military needed to produce accurate firing tables for artillery. Once fired, munitions would travel through different trajectories. Factors that affected the arc of an artillery shell as it sped through the atmosphere were wind, humidity, distance, as well as the elevation of the gun piece from which it was fired. Tables were thereby needed so that gunners could determine what settings were required to hit the designated target.

The production of firing tables involved rooms full of human computers laboriously solving differentiation equations. Ballistics computations took place near the Aberdeen proving ground on the East Coast of the USA. A task specific research division had been established in 1935 called the Ballistics Research Laboratory (BRL) [16].

Significantly this military installation was nearby the University of Pennsylvania in which was located the Moore School of electrical engineering. This was important, for the proximity of the academic institution meant that scientists there were recruited into scientific work for the USA Government. Liaisons operated between the BRL and the Moore school. They provided the link between the armed forces and the scientists and were often academics that had been recruited into the BRL. Due to this there was a responsive method of communication between the military and scientific cultures. As the political situation in Europe worsened, this was to prove valuable as it facilitated the distribution of Government funds into innovative projects.

In the months preceding WWII the Moore School was placed on a war footing. This meant that the ‘undergraduate programmes were accelerated by eliminating vacations…The main training activity was the Engineering, Science, Management, War Training (ESMWT) program, …an intensive course designed to train physicists and mathematicians for technical posts – particularly in electronics’ [16]. John W. Mauchly was one of the outstanding graduates of this course in the summer of 1941 [16]. Mauchly was the co-inventor of the Electronic Numerical Integrator and Calculator (ENIAC) – the world’s first operational electronic digital computer.

By early 1942 the Moore school was humming with computer activity [16]. Differential calculators were used to calculate munitions trajectories. These were the same machines that had been developed in the 1930s by Howard Aitken at Harvard University. There were also a hundred women computers using desk calculating machines [16]. Later this would increase to two hundred [17]. Many of these women had responded to advertisements looking for college and high school graduates with a strong component of mathematics in their training [18]. Indeed by 1943 and for the balance of WWII, essentially all human computers were women as were their direct supervisors [18].

The Moore School was thereby becoming a human and mechanical centre of computation. This drew in people with expertise in mathematics and engineering, placing them in a fast paced work place with an imperative to reduce the time expended on calculations. Together with the rapid ESMWT course in electronics this made the Moore School an environment conducive to the production of a conceptually advanced machine such as the ENIAC.

Even with a vast array of machinery and human computers the firing tables were being produced at a painfully slow rate. Consider that the average firing table contained data for around 3000 trajectories [16]. The integration of an ordinary differential equation in seven variables was needed for each trajectory [16]. Solving a trajectory calculation in ten to twenty minutes, a differential analyser would take 30 days to complete a table [16]. A person using a desk calculator would take one or two days per trajectory [16]. An entire table would tie up a hundred person team for a full month [16]. There had to be a faster way to compute the tables.

Prior to the ESMWT programme Mauchly had been a physics instructor at Ursinus College with an interest in numerical weather prediction [16]. After achieving well in the ESMWT course he stayed at the Moore school as an instructor. While there he became acutely aware of the problem faced by those charged with constructing the firing tables.

Mauchly had met Atanasoff in December 1940 [16]. Atanasoff along with Clifford Berry, had produced the design for an automatic sequence controlled calculator between 1937 and 1941 at Iowa State University [7]. The 1939 Atanasoff-Berry prototype could add and subtract sixteen-digit binary numbers and was the first machine to calculate with vacuum tubes [19].

Their next design was called the Atanasoff-Berry Computer or ABC. It stored binary numbers on capacitors, or condensers as they were then called, in rotating drums [20]. The ABC used vacuum circuits to perform arithmetic, as would the ENIAC, and had a speed operation of 60 pulses per second, which was relatively slow compared to the ENIAC [20].

Although abandoned through the course of the war, the design of the ABC exhibited most of the features of the modern computer. These features were a central processor, the primary memory, the instruction set, and the input/output structure [21]. Yet it was designed solely to solve linear equations [20] and thereby lacked the general-purpose nature of machines like the ENIAC and the later Manchester computers. In this sense the ABC was more akin to the

Colossus, a machine that was also used for one specific purpose. Despite this, Atanasoff had set a precedent which others in the USA could follow.

During their meeting Mauchly had discussed at length with Atanasoff the problems with electronic computational devices. That he garnered information is true, yet the extent to which Mauchly took ideas from the ABC and brought them to the ENIAC project is a moot point and has been the subject of a huge patent dispute. This dispute arose long after the war. The important point to note is that the ENIAC team worked in an environment where there was a precedent for an electronic computational device. Unlike Zuse they were not operating in isolation.

A judge found that the ENIAC team had inherited the broad subject matter from Atanasoff in the Honeywell v. Sperry Rand Case in 1973 [22]. That either the Atanasoff-Berry group or the ENIAC team could claim to have invented the modern computer is far fetched. Such a claim ignores the pioneering work of Babbage, Byron, Zuse, Turing, Aitken, Hollerith, and Von Neumann among others. The disputants did contribute vastly to the field. Yet they built their machines on the shoulders of earlier significant pioneers.

In August 1942 Mauchly penned a memorandum titled *The Use of High Speed Vacuum Tubes for Calculating* [16]. This was in effect a proposal for the construction of a digital electronic computer. Herman Goldstine was Mauchly's superior and was directly responsible for getting a funded project off the ground. Goldstine, a captain in Army Ordnance who held a Ph.D. in mathematics from the University of Chicago, was the army’s liaison to the Moore School [23].

Across the Atlantic, Zuse struggled to get the funds and approval needed for his machine. In America the situation vastly differed. Goldstine was known to the army and was trusted by the BRL [24]. He recognised the potential of Mauchly’s proposal and was able to convince Government officials of its promise. In 1943 the project was approved with an allowance of $US 150 000 for completion [24]. (Zuse had built the Z3 on $ US 6500 [15].) The USA military was keen to fund projects in experienced institutions [24]. Unlike Zuse, the ENIAC team did not have to struggle to prove viability.

Mauchly’s enthusiasm had inspired a young graduate of the Moore School. J. Presper Eckert had forgone a course at MIT in order to respect his parent’s wishes for him to study business. He soon regretted this move and ended up in the Moore School’s engineering course after being unable to get into Physics [25]. Eckert was no slouch and when he met Mauchly had a reputation as the best electronic engineer in the school [16]. The two became the core ENIAC team.

From 1943 the ENIAC project commenced. Herman Lukoff was an engineering student at the time. He noted that a shroud of secrecy had descended over particular work at the Moore School. He wrote:

> ‘During our senior year, The Moore School took on some “secret” government project work. Two of the large laboratories at the rear of the first floor were commandeered and declared off limits to all but

> authorized project workers. The projects were coded PX and PY and that is all we knew about them.' [26].

Lukoff would later be inducted into Project PX and was tasked with designing the "Cycling Unit" portion of ENIAC [26]. This is illustrative that ENIAC was built by a large team of scientists and engineers with Eckert and Mauchly being the ringleaders.

Operational in 1946, the ENIAC was purely electronic and in this sense was the first of its kind. The initial budget of $US 150 000 exploded to $US 400 000 as the number of tubes needed was expanded from 5000 to 18 000 [27]. These tubes were *thermionic valves*, essentially an evacuated glass tube in which some metal electrodes are made to control the flow of electrons, the electrons being produced by heating a 'cathode' electrode [28]. The valves allowed the ENIAC to store digits.

Two tubes were used per stored binary digit [28]. Tube storage was highly expensive as thousands were required for a tiny amount of memory. Numbers formed in the course of a computation and needed in subsequent iterations of the calculation were stored in accumulators [29]. If the accumulators were full the data could be printed off on cards then fed back into the process at a later stage [29]. Due to this the ENIAC was difficult to use. It lacked the convenience of a long-term memory store.

Eckert was an inspired engineer who had a gift for over coming difficult technical hurdles. For instance the valve failure rate on the ENIAC should have been one every ten minutes [27]. With 18 000 valves this would have been a maintenance nightmare. Eckert reasoned that the failure rate would be drastically reduced if they were run at half power. This solution worked. Eckert had seen to it that the ENIAC had an average error-free running period of 5.6 hours [30].

As an example of the huge number of valves required for scant memory consider the storage capacity of the ENIAC. A word is a string of bits (binary digits). The ENIAC had a 10-bit word length plus sign [30]. It could store just 20 words in its vacuum tubes and 100 in its magnetic core [30]. Memory was thereby scarce in the ENIAC.

That the ENIAC lacked a substantial memory store was a measure of expediency. Its 18 000 tubes took up 1800 square feet of floor space [30]. The sheer size of the machine was due to the fact that the whole of the high-speed memory was in valve staticisors and to the relative inefficiency of valve circuits that worked in a decimal scale [31]. In order to create a more effective memory Eckert would have had to use more valves or invent a better method of storage.

A better method was stumbled across in work concerning radar. It was known as the delay principle. The idea centred on slowing down a signal, while in the computer around it the electrons flowed as their normal speed. With the ENIAC well under way it was not implemented until after the war.

2.6 John von Neumann

John von Neumann happened to be standing on a railroad platform in Aberdeen returning home from a Scientific Advisory Committee meeting at the BRL [23]. While waiting for a train, he had a chance meeting with Goldstine, the liaison with the ENIAC project. At the time von Neumann was an eminent intellectual working on a number of consultancies and projects for the USA war effort. It was through this meeting that he learned of the ENIAC.

Born in Budapest on 28th December 1903, von Neumann was a precocious child [32]. He had a near photographic memory. His interests were vast, spreading from a keen enthusiasm for history to a deep fascination with mathematics. At the age of 18 he entered the University of Budapest where he attended at the end of each semester to take exams [32]. The rest of his time he spent in Berlin, where he attended the lectures of the chemist Fritz Haber, heard Einstein lecture on statistical mechanics, and came under the influence of the mathematician Erhard Schmidt [32]. His analytical mind was drawn to the intricacies of mathematics and it was this subject to which he devoted most of his time.

In order to respect the interests of his father, von Neumann took a degree in chemical engineering from the *Eidgenossische Technische Hochschule* (Zurich) in 1925 and a Ph.D in mathematics from the University of Budapest in 1926 [32]. From here he moved to Germany and published a series of papers in the field that seemed to fascinate him the most – mathematics. He offered a rigorous definition of ordinal numbers (1923), developed a new system of axioms for set theory (1925), made a direct contribution to Hilbert's formalist programme (1927), and also conducted research on quantum mechanics [32]. Clearly he was a gifted intellect.

Invited to America, von Neumann took up a professorship at Princeton in 1930 [32]. Mathematics at Princeton had been greatly augmented by the endowment of five million dollars for the foundation, in 1932, of the Institute for Advanced Study [33]. By January 1933 the institute had appointed four mathematicians or mathematically oriented physicists: Veblen and James Alexander from Princeton, Albert Einstein from Berlin, and Weyl from Gottingen [32]. Von Neumann was the fifth appointment in 1933 [32]. Princeton thereby became a centre for elite mathematics and mathematical physics.

J. Robert Oppenheimer, who knew von Neumann from Gottingen, persuaded him to become a mathematical consultant for the secret Manhattan Project late in 1943 [34]. Von Neumann, Edward Teller, and others on the Manhattan project came up with the implosive lens, which generated a strong spherical shock wave that imploded or compressed a ball of plutonium or uranium isotope [34]. Hence von Neumann was involved in developing a technique to detonate the nuclear explosion.

Such research required intensive calculations, not unlike those needed at the BRL for shell trajectory tables. Indeed it was well known from the Los Alamos laboratory's beginning that the equations governing the hydrodynamics of implosions and explosions could not be solved analytically but must be treated either experimentally or numerically [35]. This meant that the computing load increased rapidly. Von Neumann would have been searching for ways in which the equations could have been computed rapidly when he met Goldstine on the railroad platform. At the time von Neumann was aware of computing centres at Bell Telephone Laboratories, the Columbia-Watson Laboratory, and Harvard University. He was unaware of the ENIAC project [35].

Despite the classified nature of the ENIAC project, it would not have been held secret from an individual with von Neumann’s clearance. Rather, the ENIAC was an important project yet with little stature at the time. It was incomplete. Mauchly and Eckert were unproven, and not well known among the intellectual elite. The National Defence Research Committee (NRDC) considered the project naive [36]. Von Neumann’s interest in the ENIAC project brought to it a greater stature than it had previously enjoyed. This may have been why Goldstine choose to confide in him. It may also have been that Goldstine wanted to impress this brilliant scientist.

Von Neumann had read Turing’s paper on computable numbers. After the war he had instructed all those working on the IAS computer project to read Turing’s work [36]. The two had also met and discussed aspects of mathematical research in 1935 [36]. Turing had been offered a position as von Neumann’s assistant in 1938, yet he declined and returned to Cambridge [36]. Von Neumann was therefore aware of the concept of a universal Turing machine and the logical framework that Turing had provided.

On seeing the ENIAC at the Moore School, von Neumann was greatly impressed by its potential. At this stage the hulking monolithic machine which covered a vast floor space was extremely difficult to use. Due to a lack of memory the intense speed of the ENIAC could not fully be taken advantage of. Von Neumann saw this problem and immediately sought to develop a new improved machine.

In 1944 Eckert had realised that the solution to the memory problem lay in the delay line principle. In March he arrived at the idea of using an acoustic mercury delay line as a recirculating memory for pulses representing data or instructions to be stored [37]. Von Neumann picked up on this idea and saw that it was an essential facet that they would need to incorporate into the next computer.

A stored programme computer would alleviate the memory problem. With von Neumann's backing the ENIAC group submitted a new proposal to the BRL [38]. This document concerned the plan to build a second machine utilising the stored programme concept. This machine was the Electronic Discrete Variable Automatic Computer (EDVAC). As mentioned above, Lukoff had noted that there were two secret projects underway at the Moore school. One was PX – the ENIAC, the other being PY – the EDVAC.

The stored programme concept was a fundamental technology in the history of computing. For the first time the computer’s storage device would be used to hold both the instructions of a programme and the numbers on which it operated [38]. It was the last element that the ENIAC required to be a computer, in the modern sense. The logical framework for the modern computer was now complete. The paper that codified this logic and gave it to the world was the ‘First Draft of a Report on the EDVAC’[39]. Its author was von Neumann.

The ‘First Draft of a Report on the EDVAC’ was a paper that von Neumann intended for a small circulation almost like an internal memo. Yet it was written in 1945 at the closure of the war. The paper soon spread through scientific circles to such an extent that the logical architecture of the modern computer was called von Neumann architecture and the computers themselves von Neumann machines.

Success of this paper and its rapid spread constituted publication in a legal sense. This meant that Eckert and Mauchly could not patent the EDVAC’s design. At the closure of the war von Neumann exhibited the attributes of a scientist desiring to further the search for knowledge. He was the son of a prosperous banker and without his well paid appointment and consultancy work would still have been a man of independent means. He had no desire to turn the computer into a marketable product.

Eckert and Mauchly, while gifted scientists, were engineers at heart. They were from a culture that pioneered in order to profit, unlike von Neumann who came from a wealthy European background. They sought to file for patents on their work yet could not succeed due largely to the EDVAC report.

This began a legal wrangle that ended bitterly for Eckert and Mauchly.

This difference between the scientific purist and the engineering mindset reflects a point alluded to above concerning the nature of the American culture. Eckert and Mauchly were unproven and worked outside of the intellectual elite. They existed on the periphery. Prior to von Neumann's involvement, the ENIAC project was unrecognised within those circles of scientists who were already established and respected. They were pioneering to aid the war effort yet at the cessation of hostilities they worked with the aim of starting a business. Von Neumann, with an Old World culture, sought to advance science and mathematics. By bringing his scientific prestige to the ENIAC project, von Neumann was a great proselytiser of computing. The two groups clashed over the issue of patenting the computer, with Eckert and Mauchly leaving the Moore school to form UNIVAC, a company based around the Universal Automatic Computer, and von Neumann centring his efforts on a machine being built for the IAS.

2.7 Conclusion

Turing was an individual who existed on the periphery of society yet his contribution to computing has been extensive. Later, Turing worked at Manchester University with the computer laboratory there. Turing was thus a peripheral figure in a peripheral city. By taking a figurative concept and relating it to the physical world Turing sought to design a universal machine. This was an industrial concept. He proved the potential of his universal machine by cracking the enigma encryption thereby showing the potential of the universal computer. By taking concepts that existed as symbols and embodying them in a machine, Turing made a great contribution to the allied war effort.

Colossus, Zuse’s sequence controlled calculator and the Atanasoff-Berry computer were precursors of the electronic digital computer. All were but a small step from the goal of being a universal computer. Generous resources and sound communication between the military and researchers meant that the ENIAC team reached the goal of a universal computer before other groups. Yet the ENIAC lacked an effective memory and it is due to this that efforts were put into developing a stored programme machine. Zuse operating in isolation had nearly reached this end yet had been hampered by German authorities, who neglected to appreciate the significance of his work, nor the potential of its applications.

Von Neumann brought prestige to the ENIAC project. He was largely responsible for steering the group towards a stored programme machine. His ‘First Draft of a Report on the EDVAC’ fundamentally laid out the logical design of the modern computer. Due to von Neumann’s scientific notion of the pursuit of knowledge the design for the computer was given to other research centres around the world.

3.0

Computing Moves Out from the Laboratory

3.1 Introduction

During WWII computer development had been shrouded by the cloak of the laboratory. As the sun rose over a post war world the hidden machines of monstrous proportions were gradually unveiled to the public. They were displayed on the media and set up at festivals in an attempt to communicate the new technology to societies in which they were built. The stored programme computer was finally operational and industry was beginning to manufacture the first machines. In this sense the period covered by this chapter can be characterised by a movement of computers out of the laboratory and into wider society. This chapter delves into this topic in four sections.

Manchester Computing returns to the cradle of the industrial revolution and examines the centre where the first stored programme computer was operational. This section asserts that principles gathered in the cerebral sciences were actuated at Manchester in machinery. It traces how wartime radar research led to the creation of the cathode ray tube store, a key enabling technology in early computer memory. It points out that while Williams and Kilburn at Manchester may have brought the stored programme computer to life others had also conceived of solutions.

From the laboratory **The Link with Industry** follows the construction of the first manufactured computers in England. It asserts that the rapid move of computing into manufacturing in England was due to the close ties held between centres of research and commercial concerns. Lyons entry into computer manufacture is traced. The following asserts that Lyons' LEO computer could be built due to the ease of information exchange with the researchers at the Cambridge computing laboratory. It argues that the LEO was significant in that its demand originated in the commercial sector and that it was applied to resolving laborious clerical tasks.

In moving the computer out of the laboratory the following asserts that a change in **Computer Perceptions** was experienced. This section investigates how computers came to be located in the waking consciousness of the societies in which they were built. It examines computers as they were portrayed through the media, in fiction and reality. The following asserts that computers were devices of mythical proportions and that a latent fear of technology within society, as embodied in the computer, was played out in fictional films. It argues that such fears were ameliorated somewhat when individuals came into contact with the new machines. In particular it argues that the Nimrod helped cast aside any aspersions that computers were sinister.

Along with the move out of the laboratory came the dissemination of computer ideas. **Computing Goes Global** traces this. This section argues that despite the cold war, the post WWII climate of computer research was one of information exchange. The following offers an illustration of the technological transfer that took place through the spread of von Neumann's 'First Draft of a Report on the EDVAC'. It also briefly considers groups who worked in relative isolation or concurrently with developments in major centres.

3.2

Manchester Computing

WWII saw the birth of the first electronic digital computer, yet it was after the war that the first operational stored programme computer flickered into existence. The machine that, as far as can be ascertained, ran the world's first stored programme did so June 21st 1948 [1]. It was not an American computer, rather it was a device that was crafted in the cradle of the first city of the industrial revolution. It was a Manchester computer.

As noted in **1.0 Spread of Mechanical Computing**, it is no coincidence that the first operational stored programme computer was built in Manchester. Given the city's tradition of innovation and applied science the creation of a computer does not seem an anomaly. In Manchester the principles gathered in the cerebral sciences were actuated in machinery. The theoretical symbols that Turing sought to bring into the physical realm became practice at Manchester.

Peripheral, red brick, yet ready to embrace new concepts, Manchester is a poignant symbol of the birth of the computer revolution. It was the city that in the 1830s was attracting tourists to see the future [2]. They visited the mills and saw the intricacies of the Jaquard looms with their punched cards [2]. In post war Britain those mills had given way to huge industrial works such as Metropolitan Vickers and electronics companies like Ferranti Ltd. Yet the spirit of inventiveness was ever pervasive.

Bletchley Park was the coracle that carried great mathematical minds such as Turing’s through the troubled waters of WWII yet it was not the only concentration of applied intellect. The Telecommunications Research Establishment (TRE), Malvern nurtured two of the key players on the Manchester computer team, T. Kilburn and F. Williams. It would also provide most of the thermionic valves required to produce the prototype Mark 1 machine which ran the first programme.

Kilburn was a Scientific Officer at the TRE from 1942-46 [2]. With a background education in mathematics at Cambridge, Kilburn was recruited into the group and trained intensively in electronics [2]. Others in the group had a strong background in electronics yet Kilburn had a mind which, shaped by mathematical training, allowed him to learn rapidly and excel [2].

Williams headed the group into which Kilburn was placed and soon appreciated the talents of the new recruit. Graduating in engineering at Manchester University in 1932, Williams had worked for Metropolitan-Vickers for a short time before moving to Oxford University in 1934 to work on circuit and valve noise [3]. Near the outset of WWII Williams was recruited into the TRE to work on radar research [3]. It was in this field that he was to come across a method of solving the memory store problem in computers.

Unlike the young Kilburn, Williams had a solid academic reputation before the onset of the war. He had published over 20 papers by the late 1930s. Like Kilburn, his ideas and thoughts were galvanised by the war experience. In a sense the two were part of a war generation. It was as if the war was a crucible through which bright minds were able to gain enough momentum to propel them and their creations into the historical discourse. Eckert and Mauchly are examples of this, as is the more enigmatic Turing whose war work was kept within the shadowed walls of the intelligence community. All benefited by the opportunity provided by war to meet challenging problems head on in a make or break environment.

As the end of the war drew near, Williams visited MIT in connection with a series of works on electrical engineering. While there he learned of the use of cathode ray tubes as storage devices. By October 1946 Williams was engaged in cathode ray tube storage research and was able to demonstrate that a single cathode ray tube (CRT) could regeneratively store a single binary digit [3].

Kilburn was working with Williams on this CRT research. He had attended some lectures by Turing among others at the

National Physics Laboratory (NPL) in 1947 and was aware of the use of mercury delay lines as possible storage devices in computers [2]. He had grasped in his own mind essentially what he felt a computer was. For Kilburn, the computer was a device with a store which was alterable, that goes through a programme in order, and does its computing in an arithmetic unit [2]. Kilburn was determined to build a computer. Despite being trained in mathematics he had the soul of an engineer and was less interested in the theoretical beauty of Turing's universal computer [2].

Williams' work and initial success had generated interest from the NPL. He was offered a job there with the Automatic Computing Engine project [3]. Yet he turned this down preferring instead to head back to his *alma mater* accepting the chair of electro-technics at Manchester University in 1946 [3]. Kilburn went with Williams to Manchester University. On arrival the pair set about perfecting a digital store [1].

The computer project at Manchester University was funded by a Royal Society grant on May 16, 1946 [3]. The grant faced opposition from Royal Society fellow Darwin, yet found support from Hartree [3]. Darwin was, at the time, head of the NPL and felt that Government funds would be misplaced if they were put into a second computer project [3]. Yet Hartree was still the proselytiser who had introduced and promoted mechanical computing within Manchester University. His understanding that more than one computer project would be required was visionary.

The applicant for the grant was none other than Max Newman, the then Fielden Professor of Mathematics at Manchester University. This was the same lecturer who had put Turing onto the *Entscheidungsproblem* at Cambridge. Newman was the designer of the Colossus. During the war he was in charge of the machine decipherment section at Bletchley Park [3]. On gaining the grant, Newman was able to create the Royal Society Computing Machine Laboratory at Manchester with the specific aim of constructing a stored programme electronic computer within 5 years [3].

Manchester would be the third post war computer development to be initiated in Britain. The first was the Automatic Computing Engine (ACE) project at the NPL. The second was a computing device that was being constructed in the Cambridge Mathematical Laboratory from 1946 [3]. This latter was known as the Electronic Delay Storage Automatic Calculator (EDSAC).

By the autumn of 1947, Williams had managed to store 2048 digits for 4 hours [1]. The bits of information were stored as very small areas of electronic charge, put on the phosphor-coated screen of the CRT by a controlled beam of electrons [4]. The charge would leak away in a fifth of a second, hence the pattern of information had to be continually refreshed [4]. The problem was refreshing the information.

Williams had come across a solution to this problem through radar work. Within the CRT a trace was produced. This was a normal CRT trace with a gap in it. Signals occurred at the beginning of the gap, just before the gap and after the gap

[2]. When a trace with a gap in it was scanned twice, a negative signal appeared before the gap in the trace [2]. It was called the anticipation pulse and could be used to put the gap in the second, third and fourth trace [2]. By this method Williams and Kilburn were able to store digits. When in 1946 they had stored one digit they were effectively storing one gap in the trace. Later systems were based on the positive pulse that appeared after the gap in the trace, yet they worked on the same principle. This was that there were pulses within consecutive CRT scans which allowed the original gap (which represented a digit) to be refreshed constantly.

The timing of the anticipation pulse (or the positive pulse as used later) gave an early warning that the scanning electron beam was about to arrive at an area of charged phosphor, and the shape of the pulse determined whether this area was currently storing a binary 1 or binary 0 [5]. The binary information was stored as a pattern of bright or dim dots on the phosphor coated CRT screen. Emission of light was not a necessity for the storage mechanism, but it did mean that the CRT could give a primitive form of visual display [5]. In appearance this resembled a small black and white television screen with small bright dots corresponding to areas of electrostatic charge.

CRT memory stores permitted random access to memory [1]. Mercury delay lines and other methods of digit storage were sequential. In the delay line store the information was held as a train of impulses circulating round a special closed path [5]. Electrical pulses representing digits were applied to one crystal, which converted them into ultrasonic waves [5]. These travelled relatively slowly through a tube filled with mercury to be picked up by a second crystal, which amplified and reshaped them, then recirculated them back to the first crystal.

With the ability to store numbers on the CRT the problem of a memory store for a computer was solved. This allowed the team to proceed with a small prototype machine that became known as the “Baby”. Newman, as head of the computer laboratory, still had a lingering doubt as to whether or not a stored programme computer could be made to work [3]. While Williams had already stored digits proving the technology, the material he was still working with was subject to faults. For instance the CRT was initially made of soda glass, which would allow charges to build up on it, so that the merest breath would cause the whole glass tube to move up and down [2]. They then had to be specially made of lead glass [2]. The intention of the prototype was to therefore dispel any doubts as to the viability of the stored programme computer.

While the delay line technology was used in other early British computers, the Williams–Kilburn CRT stores were the preferred choice in American computers [1]. It wasn’t that Williams and Kilburn had come up with a solution to the store problem on their own. Eckert had envisioned a delay line device at the Moore School. Williams and Kilburn had developed a better solution to the problem and they were the first to get it to work in a prototype machine. This is illustrative that research at Manchester was at the forefront of the technology.

The prototype had just 32 words of 32-bits each for its main memory, no index registers, manual input/output, and a simple seven-function instruction set [6]. In modern terms the “Baby” computer had a specification as follows:

‘32-bit word length
serial binary arithmetic using two’s complement integers
single-address format instruction set (order code)
main store: 32 words (ie. 128 bytes), extendable to 8192 words, random access
computing speed: 1.2 milliseconds per instruction.’ [1].

Temporary storage throughout the main machine was with CRT tubes wherever possible in order to cut down on expensive flip-flops (bistable circuits) [1]. This meant that the contents of the main store, accumulator and control register (ie. Program Counter) could be viewed on a separate monitor CRT during or after a computation [1]. Visually an onlooker could see the lines of binary dots shift as new values were displayed. The stage of the programme at which the computer was operating could also be discerned. It was like watching the workings of a simple intelligence illuminated by electrons beamed at a screen.

The first programme to be run on the “Baby” computer was a factorisation routine. Kilburn penned it. Kilburn is reputed to have written only one computer programme, which was the first ever to run on an operational stored programme computer [3]. As they read the first correct answer off the CRT the team must have felt a sense of relief. The stored programme computer was now a reality and all the previous doubts concerning viability had been quashed.

3.3

The Link with Industry

By 1949 the laboratory at Manchester had a fully operational computer which exceeded the capabilities of the “Baby” prototype. This was the Mark 1. The Mark 1 had two general-purpose index registers, 128 words of primary memory, and 1000 words of drum backing memory [6]. The most important improvement on the prototype was the way in which the magnetic store was brought under the control of instructions from the machine, reference to it being made fully automatic [7]. The design of this facility was influenced by the desire to permit reference, not only to the magnetic store, but also to other possible stores, input and output systems etc. without a re-coding of the machine being necessary [7].

The Mark 1 was part of a new generation of electronic computers, the architecture of which has not altered significantly over the last 50 years. Although the “Baby” prototype was the first machine to run a stored programme, the EDSAC machine at Cambridge University, the EDVAC at the University of Pennsylvania and the UNIVAC machine soon joined it. Developments at Manchester were not in isolation. The research group was at the edge of the technology. Yet other groups were on the same path. The computer as it is today known and used had essentially arrived.

From the user’s perspective, compared with the Cambridge Electronic Delay Storage Automatic Computer, the Mark 1 was much less of a finished product [8]. Yet the Mark 1 was the first design specification of a computer to be manufactured and delivered in the world [9]. This rapid move into industry was indicative of the applied science approach of Manchester and the University’s close links with the surrounding industry. Along with the UNIVAC 1 the Mark 1 was the only computer at the time to be brought to the market place. Manchester was like a gateway between the sphere of academia and the realm of industry.

After WWII, Britain pursued an atomic weapons programme. The British Government was quick to realise the significance of a stored programme computer. Not only would the Mark 1 have a decisive role in atomic weapons calculations, it is likely production Mark 1s were whisked away to Bletchley for cryptographic and cryptanalysis applications [10]. Indeed, as early as July 1948 Sir Henry Tizard, then Chief Scientific Adviser to the Ministry of Defence, had seen the machine and considered it of national importance that the development should proceed as fast as possible [11].

The British National Research and Development Corporation (NRDC) was the instrument via which the Manchester Mark 1 went into production. Sir Ben Lockspeiser of the NRDC saw the Mark 1 running and realised that it would have applications beyond the laboratory [3]. He recommended that an electronics firm, Ferranti Ltd., be brought in to produce a production model. £100 000 was put into the project by the Government in order to get the process under way [11].

Sebastian de Ferranti founded the Manchester based electronics firm in the late nineteenth century [10]. His son Vincent built upon his father's work so that by 1963 the firm was valued at £23 million and employed some 20 000 people [10]. Ferranti had close ties with the University and it was no surprise that a Ferranti computer group was set up in 1949 to manufacture the Mark 1 [10]. It was in this way that British industry was drawn into the world of electronic computing.

As mentioned above, there was not the sales culture in Britain that existed in America. While the giants of the office machine industry such as IBM would later cautiously follow Ferranti and UNIVAC into the computer-manufacturing realm, the marketing of the new stored programme machines was in its infancy. Ferranti appointed Vivian Bowden as its first salesman from 1951 [10]. His task was to get the new computers out of the laboratories and into the commercial world.

Bowden was a visionary. In his 1953 book *Faster than Thought: A Symposium on Digital Computing Machines*, he perceptively put forward the notion that there would be a need for computers in commerce, industry, and even recreational pursuits within the short term. This was a rather radical view on the situation of computing. Hartree, the individual responsible for arguing the case for the Manchester machine, felt that Ferranti was wasting the company's time. He said, 'We have a computer in Cambridge, there is one in Manchester and at the NPL. I suppose there ought to be one in Scotland, but that is about all.'[10] Despite this, Bowden was unfazed and continued to promote computing.

Bowden had caught a glimpse of the future yet he found the role of a salesman,

> 'interesting and often exciting, but unrewarding. Time and again we could only report that, after customer visits, that they were showing a keen interest, but no order.'[10]

Bowden did achieve some sales, particularly in Canada to Toronto University. In the long term his foresight was proved true. By 1963 Ferranti had sold 99 computers generating some twenty five million pounds in revenue [10]. Computing, although not yet ubiquitous, was moving out of the laboratory.

3.31

Lyons and the Cambridge Connection

Ferranti was not the only British company building electronic computers. A further example is a company that initially was involved in the wholesale manufacturing and distributing of bakery products, ice cream, tea, coffee, sugar, confectionary and other lines [12]. It was called Lyons.

Lyons was a public company yet it was directed and closely controlled by the Salmon and Gluckstein families [12]. This meant that there was scope at the highest levels of management for the implementation of radical solutions to the company's challenges. Essentially Lyons was a catering company and on the surface this seemed an unlikely candidate to manufacture computers, yet this it did.

Below the surface was a web of complexity that only computers could revel in. The absence of wholesalers in Lyons supply channels meant that a staggering number of quite small transactions had to be carried out and accounted for in order for Lyons to go about its daily routine [12]. Some of the lines Lyons offered had 30 000 customers, with new orders being taken from every customer every week [12]. Lyons had to deal efficiently with these orders and process them. Hence Lyons’s business was so complex that having a computer was a measure of expediency.

In 1922 and 1928 Lyons recruited Simmons and Thompson respectively [12]. Both were talented Cambridge mathematicians with an eye to applying their knowledge. The complexity of the Lyons catering business was a suitable task. By 1939 the two had put Lyons at the forefront of office management by managing the information flow within the company [12]. Yet in the postwar period masses of boring, error prone operations associated with clerical work pestered the company [12]. Therefore they needed a new solution that would automate as much of this work as possible.

Thompson discovered a promising avenue while on a 1947 study tour in America. It was then that he met with Herman Goldstine and through discussion realised that computers could be applied to the clerical problems Lyons faced. Ironically Thompson, a Cambridge graduate, had to go to America to learn that a computer capable of fulfilling Lyons needs was being constructed at his *alma mater* [12]. On return to England Thompson toured the Cambridge laboratory where the EDSAC was housed to see if he could find a device that could manage the complexity of Lyons. In order to understand how Lyons got a computer it is necessary to consider computing at Cambridge University.

3.32

EDSAC at Cambridge

Cambridge University first established a computer laboratory in 1937 [13]. Directed by Maurice Wilkes, the centre was one of the three groups in post WWII Britain that were building computers. Wilkes was a mathematical physicist who after the war was working at re- establishing the computing centre [14]. In 1946 he received a visit from Comrie, who had just been the first British visitor to the Moore School, and returned with a copy of von Neumann’s EDVAC report [14]. Reading the ‘Draft Report on the EDVAC’ Wilkes instantly knew that this was the future. Hence the Cambridge computer, the EDSAC, would be built following the von Neumann architecture.

Wilkes managed to visit the USA in 1946 and take the Moore School course [14]. While there he met with Howard Aitken and perused the differential analyser. This last convinced Wilkes that electronic analysers were dinosaurs and that computers were the way of the future [14]. He therefore returned to Cambridge. In Wilkes’ mind he was already sketching out the design for a stored programme computer. This machine would be developed along the lines of the EDVAC machine at the University of Pennsylvania.

The EDSAC employed mercury delay line technology as a memory store. Each mercury filled tube was about 1.5m long and stored 576 binary digits [15]. There were 32 such tubes in the main store with additional tubes acting as central registers within the processor [15]. EDSAC stored 512 36-bit words and took 1.4 milliseconds to perform an addition instruction [15]. It contained about 3000 thermionic valves thereby filling a large room [15]. This was compared to the Mark 1's 128 40-bit word storage, 1.8 millisecond add time and 1300 valves [16]. The EDSAC was therefore a larger, faster machine with a greater memory capacity.

While the EDVAC was not operational until 1952 the EDSAC ran a programme on the 6th May 1949. That was just three years after Wilkes had returned inspired from the Moore School. While the Mark 1 prototype had run the first programme the EDSAC was a complete machine. It didn't resemble a laboratory experiment. Instead, it looked and performed like a machine that could be sold to industry as a finished product. In this sense it was the first practical stored programme computer [17]. That the EDSAC was functional before the EDVAC is also an indication of the solid organisation of the Cambridge computer team. EDSAC offered a regular computing service from early 1950 until it was shut down in 1958 [15].

3.33

Lyons' LEO

Lyons' representatives toured the Cambridge laboratory and saw in the EDSAC an answer to their complexity problem. They received a promise from Wilkes that he would provide all necessary technical information [12]. John Pinkerton was hired with the view of constructing the machine in 1948 [12]. An experienced scientist, Pinkerton was also from Cambridge and had spent the war on radar research. Feeling that they had quality advice and expertise on hand, Lyons catering made a formal decision to build their own computer in May 1949 [12].

Unlike Wilkes, Pinkerton was not starting from scratch. He had open access to the design specifications of the EDSAC. Pinkerton also had Wilkes knowledge on tap if there were any difficulty in the construction. He recalled that during the construction phase Lyons very easily obtained all the information they wanted from the Cambridge Laboratory [12]. Hence the Lyons project was more like the Ferranti construction of the Mark 1. It was just unusual that unlike Ferranti, Lyons had no experience in the electronics industry. Also Lyons were building the original machine primarily for Lyons' use. Ferranti was building machines to sell.

The Lyons Electronic Office (LEO) was operational by 1951 [18]. It was a stored programme computer that contained almost 7000 thermionic valves, with 2048 18-bit words of fast storage and two line printers [18]. It was therefore a larger machine than the EDSAC and had a greater storage capacity.

From 1954 the LEO undertook routine office work [12]. Lyons venture into the world of computing had proved a success. In order to capitalise on the LEO’s construction, Lyons founded LEO Computers Ltd. in November 1954 [18]. A newer version of the LEO was this venture’s first product. LEO Computers later went on to sell just over 113 machines until it merged with English Electric Ltd in 1963 [18]. Entry into the nascent computer industry had proved a success for Lyons.

LEO was significant in that it was an application of computing to clerical tasks. Previously this had been the domain of the office machine giants such as IBM and Remington Rand who in the 1950s were beginning to incorporate new computer technology into their product range. Computers were moving into the domain once occupied by electronic tabulators and calculators. The LEO processed data rather than carrying out scientific calculations. It dealt with payrolls instead of artillery shell trajectories. It was therefore a commercial computer.

Commercial computing applications had a growth potential. In Britain the 1951 census indicated that 10 percent of workers in Britain were performing clerical work [19]. This was a 67 percent increase from 1931 [19]. Even within the heart of industry – the factory, the number of people involved in administration had increased by a factor of three since 1920 [19]. Hence white-collar work was thereby a growing factor in the post war period. It was a phenomenon that was occurring in the USA and other industrialised countries. That computing was entering this area signalled that its implementations would increase.

3.4

Computer Perceptions

In a USA laboratory, a military installation, or at Manchester University, early computers were the stuff of myth. Few had seen them, even fewer had touched them, and only a select elite had controlled one by submitting a programme to it. For those outside the world of the scientists and engineers, computers were marvelled at.

Outside the laboratories people were aware that computers existed. Early machines were presented as the future. The thought of a room full of intricate circuitry performing calculations not unlike a human mind must have held in awe the people who were encountering the concept of the computer for the first time.

With the Mark 1, Bowden noted that a random number generator on the machine could be exploited to make it produce a series of musical notes [20]. This feature was not lost on those who were trying to introduce the new machines to the masses of people who had no idea what a computer was. In December 1951 the BBC broadcast the Mark 1's performance of "Jingle Bells on a One Horse Open Sleigh" and "Good King Wenceslas." [20]. The BBC was exposing the Mark 1 to its winter radio audience.

Technically the performance of the carols by the Mark 1 was time consuming and elaborate. The whole computer was used in the operation not to produce successive musical tones, as an ordinary instrument does, but each separate vibration had to be separately programmed [20]. As a publicity device it would have communicated, to a huge audience, what a computer could do.

Symbolically it was the beginning of a move into the virtual. It was a fabrication of reality which has been continued with the machines of today. It is no coincidence that the fictional computer HAL in Stanley Kubrick's '2001: A Space Odyssey' [1968] plays "Daisy" as it is being shut down. "Daisy" was the first tune to be produced by a computer and was the beginning of the road to machines of the future that may have the capabilities of the fictional HAL.

In the USA the UNIVAC 1 went on television to use the preliminary results to calculate the probable winner of the presidential election in 1952. Mauchly, with the help of a statistician from the University of Pennsylvania, devised a programme that would use the early returns from a number of key states to predict the result, based on the corresponding patterns in 1944 and 1948 [21]. The publicity stunt was organised by Remington Rand who had procured Eckert and Mauchly's young company. It was a further example of placing the computer in the consciousness of the media-viewing public.

The computer initially forecasted a landslide for Eisenhower in complete contrast with the Gallup and Roper opinion polls taken the previous day, which had predicted a close race [21]. The Broadcasters thought that the machine had calculated wrong and deliberately moderated its results before they were broadcast. As it turned out the UNIVAC was very close in its prediction, which is a good indicator of the effectiveness of Mauchly’s programme.

Significantly, most of the viewing public may not have attributed the success of the machine to its programmer. In their minds the machine was seen as taking the preliminary results and calculating before giving the operators the prediction. It may have been stressed that the computer was following instructions given by an operator yet in the public imagination the new computers were devices of mythical proportions.

Science fiction had adopted the notion of computer technology. In 1956 Metro Goldwin Meyer released a film called ‘The Forbidden Planet’ [1956]. It featured a desolate planet where a civilisation had created powerful technology and then disappeared due to some unforseen force. The interior of the planet was filled with circuitry that resembled the rooms crammed with the vast electronics of the new computers. Technology was cast in the role of a forbidden fruit. The society on ‘The Forbidden Planet’ had delved too far into science and they had perished.

The theme conveyed in ‘The Forbidden Planet’ recurs in science fiction films. It reflects a fear in society of technological change and progress. Often at the centre of this fear is the computer, which is usually portrayed as vast and monolithic. Consider the 1970 Hollywood film ‘Colossus the Forbin Project’ [1969]. An American super computer became self aware and teamed up with a Soviet machine of equal power to use its control of nuclear weapons to dominate humanity. Kubrick’s ‘2001: A Space Odyssey’ [1968] casts the computer HAL as the villain. Even James Cameron’s ‘Terminator’ films [1985 and 1992] centre on a computer becoming self-aware and then proceeding to destroy the human race. In each case the machine is feared because of its complexity and its potential.

The assertion here is that these depictions in fictional works echo some perceptions of computers in the wider community. Such perceptions were shaped and crafted by the emergence of the new “electronic brains” after the Second World War. Machines such as the Mark1, the ENIAC, and the UNIVAC were associated with government, scientists, atomic weapons research and cryptography. They were therefore every bit as shadowy as organisations such as the National Security Agency (NSA), the Central Intelligence Agency (CIA), and MI6, in the public mind. Science fiction films articulated this perception well.

3.41

Nimrod

Yet the view of early computers was not all sinister. A machine playing “Good King Wenceslas” is hardly scary. In 1951 the British Government decided to end the austerity years following the war with a celebration of British culture and progress. This was the Festival of Britain. The Festival was a showcase of the best that Britain had to offer. Housed in the futurist architecture of the “Dome of Discovery” were science exhibits designed for direct interaction with the public. One such exhibit was the Nimrod. The Nimrod cast aside any aspersions that computers were mysterious.

The Nimrod was a special-purpose computing machine. It was a device where automatic sequence control and digital techniques were employed to favour efficiency in the solution of a restricted range of problems [22]. Put simply, the Nimrod was designed specifically to play one game. Nim is a game where two players must alternatively take one or more objects from one of several heaps and seek either to avoid taking or to take the last remaining object. The Nimrod played this game.

Significantly the Nimrod was not kept hidden in a laboratory where only researchers had access to its interface. Instead it was open for the viewing public to come along and play a game with it. The Festival of Britain was a large event spread out over a series of locations but the showpiece of the event was the pavilions located on the south bank of the Thames in the nation’s capital London. Passers by could enter the “Dome of Discovery” and wander through the science exhibits. The “Dome of Discovery” was the centrepiece of the Southbank Festival site in London. It was a large futuristic dome. In appearance it was similar to the “Millennium Dome” Designed by the Richard Rogers Partnership for the year 2000 celebrations in London. Festival visitors could also play the computer. Hence the Nimrod opened computing to the general public of Britain giving them access to the new technology.

Turing visited the festival. Ferranti had manufactured the Nimrod and the representatives at the pavilion were pleased to see Turing. They said, ‘Oh Dr. Turing, would *you* like to play the machine?’ which of course he did and knowing the rule himself he managed to win [23]. As Hodges notes, ‘The machine dutifully flashed up ‘MACHINE LOSES’ in lights, but then went into a distinctly Turingesque sulk, refusing to come to a stop and flashing ‘MACHINE WINS’ instead’ [23]. Apparently Turing was delighted at having elicited such human behaviour from a machine [23].

Turing’s encounter with the Nimrod illustrates two important facets of the Nimrod exhibit. The first was that he beat the machine, which would not have been unusual given the simplicity of the game. Note that unlike the exactitude of the UNIVAC’s election predictions the Nimrod was openly seen to be fallible. That is, people playing the machine and the onlookers who watched could discern that the machine was not superior to human intelligence, yet that it would win if the human made a mistake or played a sloppy game. The perception generated by this display would have thereby significantly ameliorated the fear of the new technology.

Second, was the way in which the programmers had deliberately included a sulk type performance if the machine lost. As mentioned, this impressed Turing but the significance goes even deeper. By exhibiting human characteristics, that is by sulking and being a playful spoilsport, the Nimrod was operating in a manner to which people could relate. Rather than perform in an exact and logical manner it was instructed to display human qualities. This would have made it easier for people to accept the machine as it was interacting on their terms and not strictly formal premises.

From an engineering perspective, the Nimrod was constructed around the need of a programme. It was not a universal computer. It illustrated that if only one problem type was to be solved then advantages could be obtained by employing a special purpose machine [22]. Yet while solving one particular problem the Nimrod illustrated the principles of automatic computers in general. Hence the machine was aimed as much at scientists and industrialists as it was at the general public.

Nimrod displayed an animated programme and block schematic diagram of a game. Conceptually this was not unlike a series of pocket sized games for children, such as 'Donkey Kong', which flourished in the early 1980s. They were single purpose devices that were built around the needs of a game programme. Their appeal to children introduced many to the world of electronics and computing in much the same way as the Nimrod. By using the technology in the context of a game, children could gain a partial understanding of the machine and its limitations without being intimidated by its inner complexity. Hence the Nimrod was a communicative device. It spoke of the new possibilities of post war computer technology.

3.5

Computing Goes Global

The above has located and focussed on computing in two particular nations, the USA and Great Britain. This is due to the fact that computing mainly grew and developed in these nations then spread to other centres across the globe like a small universe of knowledge rapidly expanding. Many of the centres to which computing spread developed their own machines on a largely independent basis, yet the core ideas of computer architecture and the technology for implementing it was passed on from the USA and Britain through a process of technological transfer.

Informal distribution, in 1945 and 1946, of a 'First Draft of a Report on the EDVAC' by von Neumann brought to the scientific community in America and Britain a general awareness of the stored programme concept [24]. This report worked its way through the scientific community to such an extent that the early computers became known as von Neumann machines. Von Neumann dealt with the structure of '*a very high speed automatic digital computing system*, and in particular with its *logical control*' [25].

The 'First Draft...' was a logical guide built on mathematical logic and symbols. It was not a thorough guide to solving the physical requirements of the machine. Rather it was a concise blue print for what would be described in 2001 as a computer.

Neuron and other terms associated with the biological sciences were introduced with this paper. Von Neumann wrote that ‘simplified neuron functions can be imitated by telegraph relays and by vacuum tubes’ [25]. New terminology would shape how people saw the new computer. The storage mechanism would from this point be likened to memory, suggesting that the computer was a simplistic construct of the human mind.

A further paper from the IAS titled a ‘Report on the Mathematical and Logical Aspects of an Electronic Computing Instrument’ was equally as important as the ‘First Draft of a Report on the EDVAC’ in spreading knowledge on the new computers. It was circulated from 1946-48 [26]. In this paper was outlined the first description of logical design and coding for stored programme computers [26].

Table 3.1
Computers built using the IAS computer design
[Source: Aspray 1992:91]

AVIDAC	Argonne National Laboratory	1953
BESK	Swedish Board for Computing Machinery, Stockholm	1953
BESM	Academy of Sciences, Moscow	1955
DASK	Danish Academy, Institute of Computing Machinery	1957
GEORGE	Argonne National Laboratory	?
IBM 701	IBM Corporation	1952
ILLIAC	University of Illinios	1952
JOHNNIAC	RAND Corporation	1954
MANIAC	Los Alamos Scientific Laboratory	1952
MSUDC	Michigan State University	?
ORACLE	Oak Ridge National Laboratory	1953
ORDVAC	Aberdeen Proving Grounds	1952
PERM	Technische Hochschule, Munich	1954
SILLIAC	University of Sydney	1956
SMIL	Lund University	1956
TC-1	International Telemeter Corporation	1955
WEIZAC	Weizmann Institute, Rehovoth	1955

Notes: AVIDAC: Argonne's Version of the IAS Digital Automatic Computer; BESK: *Binar Electronisk Sekvens Kalkylator*; BESM: *Bystrodeistwujuschtschaja Elektronnajastschethaja Machina*; DASK: Dansk BESK; ILLIAC: Illinios Automatic Computer; MANIAC: Mathematical Analyser, Numerical Integrator, and Computer; MSUDC: Michigan State University Discrete Computer; ORACLE: Oak Ridge Automatic Computer and Logical Engine; ORDVAC: Ordnance Discrete Variable Automatic Computer; PERM: *Programmgestenerte Elektronenrechenmaschine*;

Dates are approximate dates of completion or dedication. The organisations listed are those that operated the machines. In some cases the machines were built by other organisations [27].

Both papers combined with von Neumann's stature as a prominent scientist, and the emerging interest in computers led to a steady stream of visitors to the IAS at Princeton. They came from England, Sweden, Switzerland, the Netherlands, France and Czechoslovakia to see the IAS machine and garner ideas for projects in their own research centres [27]. Indeed in the post war environment these visits contrasted with the spread of ideas through the Moore School lectures in that there was a greater international flavour to the visits. During the war visitors to the Moore School had mostly been from Britain and other close allies.

Within the US scientists and engineers from Raytheon, Harvard and IBM frequented the IAS specifically to learn from the computer project there [27]. The visits were so numerous that von Neumann set strict conditions curtailing the frequency of tours to as much as was politically feasible [27]. Hence the post war climate of computing research was one of exchange. The only limiting factor in international technology transfer was the onset of the cold war.

The extent that dissemination of IAS computer design parameters occurred is best captured by Table 3.1. It conveys that at least 17 projects around the globe constructed computers using the IAS blueprint. Note that the BESM machine in the Soviet Union also followed von Neumann architecture. Despite the rapid stand off between the USA and the USSR following the division of Germany in 1945, the EDVAC report still found its way to Russian researchers.

That there was technical exchange and cross-pollination of ideas with regards to post war computing is not surprising. It has been a characteristic of the developments that led to the electronic computers. For instance, it was Hartree, who first saw the Differential Analyser while on a visit to Harvard, who then instituted a machine at Manchester University. It was the Americans, who had originally discovered the notion of a delay storage system, who took on board Williams and Kilburn’s CRT storage technique.

Research groups learned from each other’s progress, yet there was still a large element of innovation occurring independently. For instance, consider the Zuse computers that were developed in a situation close to isolation. Turing’s notional universal machine was another instance of innovation that was achieved through independent inquiry.

A separate path to development is more noticeable when advances were shrouded by the secrecy surrounding war work such as the Colossus machines at Bletchley Park. No one except those who worked on the Colossi knew of their existence and it is only recently that the broader history of Bletchley Park has been revealed. Hence there may be other projects that still remain hidden in the non-space of national security research.

It is interesting that Newman, who designed the technical specifications for the Colossus, headed the computer facility at Manchester. Newman was a key player in wartime computing. By 1949 Alan Turing had also moved to Manchester after an unhappy stint at the NPL where he designed the pilot Automatic Computing Engine (ACE). The extent to which Newman's perspective on electronic computing devices as gained during the war nourished the Manchester team is unknown and difficult for the historian to determine. Yet it would be clear to note that following the war Newman set a computer project as a priority. The rapid provision of funding to Manchester from the Ministry of Supply when the stored programme concept worked is evidence that the British Government benefited from having a computer developed at Manchester.

Many researchers and centres did have the innovative capacity to build computers with little knowledge of other programmes. Zuse is the best example of this, yet he was constrained by Nazism and the war. Even in the post war world some groups pioneered their own machines in a similar time frame to developments in the key centres. A noticeable example of this is a machine that does not appear in Table 3.1 as it was not developed from the IAS architecture. Its acronym was CSIRAC and it was built in Australia.

3.51

CSIRAC

The Australian Council for Scientific and Industrial Research Automatic Computer (CSIRAC) was developed from 1947-51 [28]. It was designed and built primarily by Maston Beard and Trevor Pearcey. Like Williams in Manchester, Beard was involved in radar work during the war until he joined the CSIRAC project in 1947 [28]. Pearcey also worked on radar and began forming preliminary ideas on computing techniques in 1946 [28].

The two embarked upon the construction of a stored programme computer in the Division of Radiophysics at the Council for Scientific and Industrial Research (CSIR). They had an operational machine before the first Australian Computer Conference in June 1951 [28]. Hence the CSIRAC was developed concurrently with the machines in Manchester, Cambridge and the USA.

Significantly Pearcey worked closely with Hartree in England while performing radar development. He had worked with Comrie between 1940 and 1945. These two great proselytisers of computing influenced Pearcey. He had engaged in discussions with Hartree in early 1945 regarding the possibility of using electronics for fast computation [28].

This link with Hartree and Comrie highlights the spread of computing ideas. Both were keen advocates of machine computation. Both realised that electronic computers were the next step. Having worked with them Pearcey took these notions with him to the Southern Hemisphere.

Pearcey found a need to develop a computer when he took a position in Sydney at the CSIR division of Radiophysics. A massive amount of computation was required for radio astronomy and the theoretical studies in cloud physics associated with rain making [28]. Hence the computer was practical.

Note that, in this case, the need for a computational device was driven by research science. Unlike the machines in the USA and Britain, the Australian machine was not required for atomic weapons projects. The emphasis in this project was on constructing a machine to serve the needs of an academic community.

The independent nature of the CSIRAC's development becomes apparent when it is considered that Beard and Pearcey only became aware of the Pilot ACE, the EDSAC and the Mark 1 work in 1948 [28]. They had learned of the success of the ENIAC in 1947. Pearcey immediately arranged a visit to inspect the British computers and discuss implementation problems with the researchers at those centres. Yet the planning and construction of the Australian computer was already under way. Hence Pearcey and Beard were not following the lead of the larger centres, rather they were on the leading edge of the technology.

CSIRAC was unlike the ENIAC in that it was a stored programme computer. It resembled the Mark 1 and the EDVAC in its capabilities in that it was part of the new wave of computers with memory capabilities. Pearcey through his radar work had encountered the use of mercury delay lines for the enhancement of weak radar echoes [28]. Hence the team had a grasp of technology to construct memory prior to learning of the EDVAC and the Mark 1 machines.

The CSIRAC was a relatively successful machine when commissioned. It stayed at the CSIR from 1951-56 being employed in cloud physics and radio astronomy projects [28].

Programming techniques were studied on the CSIRAC as it provided a computing service to scientists and Government bodies [28]. Design of hydrological and power generation systems for the Snowy Mountains hydrosystem (1950-65) was another contribution of the CSIRAC [28].

The enduring legacy of the CSIRAC machine is that it was the first true computer in Australia. It introduced a number of Government bodies in engineering, design and research science to computing. It also paved the way for the SILLIAC in 1956 that was developed at the University of Sydney. The CSIRAC thereby introduced Australia to the realm of computing.

Other computers around the world, some of which are listed on Table 3.1, would have similarly brought computing into their respective countries. On these foundations centres of computing spread so that the dissemination of ideas and principles continued to feed further waves of innovation. Hence computing had grown from the shadows of WWII to become a global phenomenon.

3.6 Conclusion

In Manchester the principles gathered in the cerebral sciences were actuated in machinery. This is why Manchester found itself at the forefront of computing following the war. Although Manchester University ran the first stored programme computer, the efforts of the team there were part of a global effort to solve the stored programme problem. The

War was a crucible through which bright minds were given momentum and Manchester benefited from this. The rapid move into industry of the stored programme computer at Manchester was due to the city's tradition of applied science and close links between research and the surrounding industry.

Lyons demonstrated that computing was not the sole domain of research laboratories and industrial concerns. The Lyons LEO also proved the foresight of Bowden that computers had applications beyond scientific calculations, that in fact their greatest potential lay in the sphere of commerce and data processing. In this sense computing, while not ubiquitous, was moving out of the laboratory.

The way computers are perceived is an integral factor in their acceptance by a society. Computers have been placed in the consciousness of the media viewing public. Some perceptions of early computers are negative and relate to the associations that the machine has had with secrecy and weapons research. Others are quite positive, as in the case of the Nimrod that demonstrated that people are more likely to accept computers if they can interact with them in a way that individuals can relate to. Fiction can articulate the perceptions of society and this has been the case with computers. Greater access to computers will ameliorate the negativity associated with certain fictional depictions of the information machine.

Computing technology and ideas were disseminated in the post war period. Despite the cold war the climate was one of information exchange. Due to this and the spread of the von Neumann architecture, computing became a global phenomenon after WWII. Yet some centres were able to develop machines with only a loose idea of what was occurring in the major research laboratories of the USA and Britain. The CSIRAC machine exemplifies this, as does the work of Zuse.

4.0

Early Computing at The University of Western Australia

The CSIRAC was the seed of computing in Australia. **Early Computing at The University of Western Australia** focuses on the way in which computing was initiated and fostered at one research centre in Western Australia. This is the University of Western Australia. In this sense the chapter is moving from the general nature of the material preceding it to a specific historical account, one which prior to **Cyberhistory** has remained unwritten.

International Business Machines (IBM) supplied an operational electronic digital computer to The University of Western Australia (UWA) in September 1962. It was the dawn of electronic computing on the Crawley campus and in the State. In 1965 a PDP-6 arrived at UWA. Both machines were significant yet in different ways. This chapter employs material gathered from interviews with people closely connected to early computing on the campus. Dennis Moore, Bruce Kirkby, Professor E. J. Jory, Professor John Ross, Amedeo Sala, and Professor Syd Hall have all been interviewed [1]. It seeks to examine the impact of early computing on UWA and discover what it meant to those closely associated with the machines. This chapter finds that the individual had a large influence on computing at UWA, that the impact of computing went beyond specialist fields, and that open access enabled a progressive environment.

4.1 Introduction

Two machines characterised the early period of electronic computing at UWA. The first was the IBM 1620. The second was the Digital Equipment Corporation (DEC) Programmable Data Processor (PDP-6). This chapter seeks to find why both computers were important and the differing ways in which they were significant and asks a number of key questions. Why was each computer chosen? What kind of access was permitted to the machines? What areas of research benefited from the computers? What innovation did the computers enable? It argues that the individual did have an impact on computing at UWA and examines the early computer culture around the machines. This chapter seeks to uncover the significance of these machines and look at how early computers had an impact on campus.

4.2 Big Blue

By 1960 the nascent computer industry had delivered about 5000 computers in the United States and over a thousand to the rest of the world [2]. Across the industrialised regions of the world computers were seldom seen devices. They hid, shrouded in mystery, like tall wardrobes, in large rooms where the air temperature had to be regulated so as to absorb the heat from the electronics that filled the block-like covers. The IBM 1620 was no exception. The company had earned the nickname ‘Big Blue’ due to the pale blue covers that enveloped its machines. Located in the new Physics building on the west side of the campus, tended by a small group of academics and technicians, the UWA 1620 sat inert yet alive, a mystery waiting to be unfurled.

UWA’s first officer in charge of the 1620 was Dennis Moore. Moore had previous experience on the 1620 machine at the Lucas Heights facility run by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in New South Wales. John Ross interviewed Moore and recommended that he be appointed as director of the UWA Computer Centre (UCC). That the 1620 was a commonly purchased machine in the 1960s was no coincidence. Due to its hold on the business computer market, IBM was able to offer machines at a 60% discount. In 1962 the discounted 1620 cost $88 054 [3]. The corporation was keen to dominate the educational market. Students trained on IBM machines would be more likely to order and use further IBM machines. Such a reduction meant that there was no reasonable competition for the purchase of a scientific machine by the University. In 1999 Moore recalled that the discount was a decisive feature in the purchase of an IBM mainframe. UWA was not the only campus taking this option. For instance, in the United States at the University of Southwestern Louisiana, a computer centre was established in 1961 based around the procurement of an IBM 1620 [4].

The computer and the nascent Computing Centre were the first to populate the new physics building. In contrast to the Mediterranean sandstone of the older campus, this new edifice was a stark modernist block echoing Miesian design. Moore commented that he thought the design was awful, noting that the building was conceived by State Government architects. These architects were used because funding came from the Commonwealth and the State Government. It was the same situation with the computer in that both the Federal and State Governments granted money. This arrangement was to persist with computing on the campus right through the seventies and is a key to understanding why, at a later stage, the State Government was to have a close role in the use of computing facilities at the University.

Townsing, the then Under Treasurer in the Western Australian State Government, was also on the University Senate. He was responsible for getting hold of the funds for the 1620. His dual role was not uncommon in WA. It suggests a reason for the close link between the State Government and the Computer Centre. Having a foot in both camps would make negotiations easier.

Figure 4.1 The UWA Physics building.

Close ties in funding led into joint usage. Both the CSIRO and the State Government were early users of the IBM 1620. The machine ran twenty-four hours per day seven days per week. The involvement of organisations external to the University brought in large amounts of cash. Academics using the computer for teaching or research purposes were not charged. Other bodies from the Government to industry, paid rates for each hour on the machine. As a result of this multiple usage there was rarely a moment in the week when the machine was not being needed. Jobs were ordered in terms of priority and a balance had to be struck between the needs of the various users. The disadvantage of this system was that some jobs took days to be fed through the computer. Yet the advantage was that due to the close co-operation, the University was able to procure a machine that it otherwise could not have purchased.

4.3 Access

A single machine in a physics building is a centralised system. Departments and other users would go to the Centre to submit programmes that would then be fed into the machine by technicians. The programmes would be punched through a typewriter-like device onto thin cards that could then be fed to the 1620 card reader. It was an elaborate process, one which has been commented on in terms of the lack of access those who were programming the machine had to the actual hardware. For instance, consider this account of computing around the same period at Cambridge University:

> ‘Interacting with a batch-processing machine could be a pretty dispiriting affair. It was my first experience of computing in the mid-1960s and it damn nearly put me off it for life. The machine we used was an IBM 1401 which sat in an air-conditioned suite, attended by operators and clerks. No student was ever allowed into the hallowed ‘machine room’. We typed our programs line by laborious line on a machine with a QWERTY keyboard. With every key press came a ‘thunk’ as the machine punched a hole in a card. At the end of each line, it spat out a completed card. A deck of punched cards constituted a program.’[5]

At UWA the situation was not as clinical as described above. In a region that faced a long dry summer, the 1620 was housed in the only airconditioned room on the campus. In the heat of summer, the computer room was a popular place. Yet as Moore stressed, when interviewed, the room was not designed to house a computer. It was located on the second floor of the physics building right above the atrium. It was a teaching or lab space, not a computer enclosure.

Access to the computer was not limited to a select priesthood of technicians. For instance, a couch had been deposited in the machine room alongside a series of alarm clocks. The priority system meant that low status jobs would be computed in the early hours of the morning with the machine room shrouded in shadows. Research students would sleep on the couch waiting for the alarm to wake them, signalling their turn on the machine. Staffing was low and certainly non-existent in the middle of the night. Researchers must have fed the cards in themselves and learnt quickly how to avoid errors and bugs. This suggests that the small scale of the early computing centre at UWA enabled greater access to the machine.

Access is important in relation to computing. Bruce Kirkby (currently head of the University Computing Service) noted that most of the time people taught themselves to use the computer. There was a graduate diploma course from 1963, yet Kirkby commented that learning was something the early users undertook themselves. Levy notes that the computer hacking community at MIT did not take off until the arrival of the TX-0 machine, to which greater access was given [6]. The early IBM machines at MIT were hard to get near. They were effectively removed from the programmers, who would only interact with the technicians, not the machine itself. In contrast, the UWA Computer Centre lacked the stultified atmosphere that kept the MIT hackers away from the IBM machines. From the beginning at UWA, access to computers was attainable. Given that a substantial amount of learning was undertaken through individual interaction with the computer, this freedom of access was then conducive to a progressive environment.

Note that it would be a mistake to assume that UWA had a progressive environment while MIT (as a comparison) endured the IBM machine priesthood. Indeed MIT ran its first computer-programming course in 1959, three years before UWA had a computer. The TX-0 and the PDP-1 were installed and being used by undergraduates at MIT by 1962. Space War, the first ever computer game, was hacked together on the PDP-1 at MIT around 1962-3. When interviewed, Moore commented that the 1620 computer came to the UWA campus five years too late. Purchase approval for an expensive piece of capital was difficult to obtain. Universities are notoriously conservative on the administrative side of their operations. When interviewed, Moore stated that there was a reluctance to buy into the phenomenon of computing. Already the campus was behind other institutions in North America. The step was taken into the computer game, yet the foot was planted slowly and cautiously. With a functioning 1620 UWA was in no way at the forefront of computing. It had however taken the decisive first step. The challenge would be to reduce the gap then begin to pioneer.

4.4 New Research on the 1620

One area of research that benefited directly from the procurement of a digital computer was Crystallography. From the onset the Crystallographers were heavy users of the IBM 1620. Crystallography is a discipline that has grown with the spread and evolution of computing power. This is due to the way in which its ‘most active field, single-crystal structure analysis, involves extensive and repetitive Fourier-transform calculations on data sets of several thousand coefficients, and iterative least squares operations with several hundreds of variables.’[7] Hence the extent to which a Crystallographer can model a structure in a given time frame, is directly proportional to the computing power which that person has available to apply. Professor Hall of Crystallography at UWA stressed the dependence of the modern discipline on processing power.

As a result of Crystallography’s need for computers, members of the Department of Physics were fully versed in the computing technology of the day. The late Professor Ted Maslen, a Crystallographer, arrived in Western Australia from Oxford in 1960. He had direct experience with the machines at that University. Maslen was an advocate of computing. He was convinced of the potential of the machines to further his discipline. Previously, Crystallography work was carried out by hand or by using mechanical calculating machines. Film was used to measure the data, as was the naked eye. The computer crunched through repetitive calculations and provided researchers with results in less time. Yet, as Hall put it, with each increase in computational power the Crystallographers also increased their ambitions. Hence they always wanted more powerful machines and more time to work with them.

As an illustration of the intensive calculations needed for the Crystallographers, consider that jobs would often run for thirty-six hours straight on the 1620. Hall stated that the PDP-6 would perform the same calculations at least ten times faster than the 1620. Research students would sleep in the machine room, alarm clocks ticking away with mechanical precision. Half asleep, they listened for a possible card misread. If it occurred, a misread could jeopardise the whole job. Students would perk up at the familiar sound and wait in the dark listening intently. The IBM card reader would switch off, sort the misread, then switch back on. Ears would be pricked waiting for the confirmation that the machine had switched back on, before relaxing again into a state of half sleep.

Crystallography was not the only area where the 1620 was used extensively. The IBM was used in the Busselton Survey, results of which were published in 1972 [8]. Norman Stenhouse conducted the project. It involved recording the medical statistics of all the people in Busselton. The computer processed the statistical data collected in the survey. The machine was also used as a unit record for the University Administration. Colin Jarvis worked with the 1620 to write a thesis that would now be classed within the area of Computer Science [9]. This was long before computer science formally came to the University in 1976. Moore described Jarvis as the first programmer of the 1620.

4.5 Impact of the Individual

Aspirant historians as undergraduates are warned of the perils of focussing on “great” individuals, particularly “great men”. The corpus of historical writing is full of lengthy tomes detailing the lives of politicians, soldiers, queens, and other influential beings. In delving into the computer literature the young historian encounters even more accounts of pioneers, explorers on the edge of computing. As Rosenzweig notes, ‘narratives of “great men” of science and technology remain popular, deriving their power both from widespread assumptions about new ideas emerging from particular men of genius as well as from the narrative appeal of biography’[10]. It is easy to forget the role of culture, class, gender and other factors beyond the individual, in the shaping of computing. Computing at UWA is no exception. Yet within that exception there is an exceptional case.

Twenty-four in the year 2001 is considered a young age. In the university setting a twenty-four year old would normally be working on a masters or doctorate, perhaps tutoring. Yet at age twenty-four Moore was fully in charge of the UWA Computer Centre. He oversaw the day to day operations on the machine and taught the postgraduate diploma in Numerical Analysis and Automatic Computing from 1963 [11]. This course was instituted to meet the acute shortage of trained computer staff [11]. Moore was in a position of power in relation to computing on the campus. Systemically this was unusual in an institution where decisions were made via committees and meetings. Yet it was Moore who would later be largely responsible for the procurement of the machine that would put UWA at the forefront of computer technology. In this case the individual made a direct difference.

Why was it that a relatively young man came into a position of such influence? In the early 1960s the University was relatively small having approximately 4000 students in 1963 [11]. When it is considered that this figure was to more than double by 1974, it is clear that UWA was a small campus in the 1960s. Yet the student population was expanding. Some 396 full time academic staff were employed in 1963 [12]. Of this number, only a few were familiar with computers and their usage. Hence within a growing pond there was room for promotion.

Kirkby commented that a few people in the University Administration knew that computers were important but it seemed that no one had a clue about any other facet of their use. Despite this, Moore was an expert and along with a few other academics from the Departments of Physics and Engineering formed a solid core of computer knowledge within the University. Moore recalled that there was a view held at the University that the future of computing would be in numerical analysis. That is, academic administrators perceived the computer as a tool for mathematicians and physicists. There was also a tendency for some academics involved in research to see computing as a “technician’s” field. They were therefore reticent to move into it. Yet numerical analysis was not where the computer industry would stay. There was a lack of imagination with regard to seeing the computer as a general-purpose machine that could have a wide number of applications.

How then was the individual influential in the development of computing on campus? The IBM 1620 provided a foundation for computing at UWA. The next computer would take the institution to the forefront of commercially available technology. Moore was able to engage in the negotiating process that would lead to an agreement between the State Government, the University, and local industry. He was also able to convince others at UWA that the next computer to be purchased should be innovative, and ambitious. If it failed Moore’s career was at risk.

4.6 The “Little” DEC

The PDP range of computers were manufactured by DEC. Formed in 1957 by Kenneth Olsen and Harland Anderson, DEC by 1965 was a small firm [2]. Significantly, Olsen aimed his product not at the commercial data-processing user, but at the scientific and engineering community [2]. DEC customers did not need advanced peripherals and they could write their own software [2]. They also could do without a sales expert holding their hand and guiding them through the dark hearted jungle of the new technology. If there was a bug in the machine the DEC customer usually had the expertise to fix it. The PDP-6 was cheaper than a mainframe yet faster than older IBM models like the 1620. It was ideal for a university computing centre.

When interviewed Moore stated that the choice of the PDP-6 was an aesthetic decision. IBM was no longer able to offer a 60% discount for its machines due to anti-trust regulations. The DEC PDP-6 was chosen by Moore due to its promise of time-sharing. Time-sharing was highly innovative. It involved multi-tasking a machine so that more than one user could be working on it at one time. Obviously, there were restrictions. The PDP-6 was by no means powerful when compared to the computers of the year 2001. In 1965 it cost $351 600 [3]. Yet here was the promise of something new and unfolding, something that could put UWA at the forefront of the technology.

Time-sharing on computers grew out of project MAC at MIT [13]. Based on IBM mainframes, the project MAC system became operational in 1963 and eventually built up to a total of 160 typewriter consoles on campus and in the homes of faculty [2]. Olsen was a graduate of MIT and his company retained close links with the institution. DEC made the boards for machines involved with project MAC and they applied the time-sharing technology to their new range of computers. The PDP-6 exhibited this technology.

The choice of the PDP-6 was not straightforward or obvious. Other machines were also under consideration. For example the Ferranti-Packard 6000 of Canada was suitable. Yet the UWA Computer Centre people were sold on the DEC machine by a visit from a sales representative. Moore recalled that this sales person gave a talk on the marvels of multi-programming. The thought of having multiple tasks operating on the same machine was appealing. Table 4.1 [3] illustrates the diversity of tasks that the PDP-6 could manage.

Table 4.1 Depicts the diversity of tasks that the UWA PDP-6 could manage

EXPERIMENT/TERMINAL AND FIELD OF STUDY	YEAR OF CONNECTION
Rat Runway (Psychology)	1965
Spectrometers (2) (Physics)	1965
Physiology Computer	1966
Hybrid Link (Electrical Engineering)	1966
Diffractometer (Physics)	1967
Field Recorder (Electrical Engineering)	1967
Flying Spot Scanner (Pathology)	1968
Perception Laboratory (Psychology)	1968

Enthused at the prospect of obtaining a time-sharing system, Moore and the then Deputy Vice Chancellor, Burkett-Clews trekked across the Pacific to Boston. When Moore and Burkett-Clews arrived at the DEC warehouse they found a company that was just starting out. Dennis noted that there would have been around 100 employees. Moore described the first time he entered Kenneth Olsen's office. There at a large desk was Olsen playing with a small machine housed inside a large glass cylinder. Core memories on the early computers consisted of thousands of wires threaded through coils. In the manufacturing process they would be laboriously threaded by hand. The small machine was designed to thread the cores automatically and failed to work. Olsen sat there tinkering and talking.

Figure 4.4 Moore poses with a broom at DEC in 1965. Dr. R. Smart, then General Manager of DEC Australia, stands to his left (foreground). Deputy Vice-Chancellor Birkett-Clews stands in the background.
Source: The University of Western Australia Computing Service.

UWA had the fourth PDP-6 ever made. There for all to see was the serial number 4. The first PDP-6 did not work. Number two had been kept by DEC. The third machine was in transit to its new home. Riding high, it was destroyed as the truck upon which it was travelling went under a low bridge. Hence, effectively, UWA had the first commercially available time-sharing computer. It meant that the five-year lag in computing technology previously endured at UWA had been overcome.

Installed at UWA in 1965 the PDP-6 took a long time to be fully operational. There were some serious faults with the hardware that made life difficult for those who programmed the machine and those who had to keep it working. One of these bugs concerned the block transfer of instructions. With each transfer of a block to a new register there would be a start address, an instruction length and the new address. While running another piece of work the computer would have a tendency to stop half way through and overwrite the code already transferred into the register with the code yet to be shifted. A further example of a hardware bug was that three successive floating-point operations would fail. Moore said that this was a rare occurrence simply because there would rarely be three operations in a row using floating points. They eventually solved the hardware problems and had the machine running, yet with the mounting pressure Moore at times regretted getting such an experimental machine. Had the PDP-6 failed, it would have cost Moore his job.

4.7 Computer Culture

British Petroleum (BP) in the 1960s ran a refinery just south of Perth in a coastal town called Kwinana. Being a huge industrial concern they had access to some expensive technology, one item of which was a light pen. The computing centre at UWA got wind of this and struck a deal. In exchange for use of the pen the Computing Centre agreed to write the code for the BP maintenance system. A light pen had applications in graphics where it would benefit crystallography and medical research. Procurement of the light pen was a further example of the close network of personal links within the state.

The bulk of the work for the BP maintenance code went to a person nicknamed the “Phantom”, after the “ghost who walks” (a comic book character created by Lee Falk). The “Phantom” was otherwise known as Brian Horan. Ross recalled that Horan was most unlike the Phantom, yet he would come and go in Phantom like ways. Ross supervised Horan through Honours and a Ph.D. Horan had been a Perth tram conductor. At one stage an intelligence quotient test had been given to all the personnel working on the trams. Horan blitzed the test and was slowly convinced to undertake a university degree. As a student he could be difficult, yet he had a sharp mind. Horan would later work at the UWA Computer Centre while studying for a Doctorate. He excelled at programming both the 1620 and the PDP-6. He had a talent for writing code that was used in an extremely efficient manner by the computers. Every last bit of information would be considered so that Horan could get the most out of the limited machine.

Kirkby and Gent had been through the graduate diploma course taught by Moore. The course attracted a diverse group of people. On a Friday evening the programmers would head over to University House (a function centre and tavern) for drinks. Kirkby recalled that they were a distinct group among the other academics and University staff. The Computer Centre group did not use the term hacker, but many of the programmers exhibited hacker traits. As they drank by the bar the small group of programmers were already set apart in the first computer subculture on campus. They understood the workings of the machines. When interviewed in 1999 Kirkby noted that, as more beers were downed and the conversation grew more animated, the rest of the crowd would tend to fade away. Even at this early stage computer people were distinct.

Figure 4.3 The UWA PDP-6 at DEC in Boston (before delivery).
Source: The University of Western Australia Computing Service.

Access to computing was greatly facilitated by the PDP-6. Postgraduates would work on the machine in the early hours of the morning. After hours they could find spaces to run programmes and tinker. The time-sharing facility also provided online interaction. This was the first time in the world that there had been a concept of online (in the computational sense). The PDP-6 was the first commercial computer in the world that exhibited the time-sharing feature. Terry Gent, an early programmer with the Computer Centre, described large, hulking “ergonomic free” teletype machines that were connected up to the computers. They operated at ten characters per second. Initiates would have to learn a subculture of jargon such as ASR – auto sender receiver and KSR – (amusingly neither Moore nor Gent could recall what KSR stood for). Understanding the jargon solidified the group. To an outsider conversations between programmers would have seemed bizarre. Thus through their use of terminology the computer subculture was made more distinct.

4.8 Innovation

Crystallography continued to develop their research in image analysis. They would use the light pen to draw molecules on the PDP-6 vector graphics screen. Ray Jarvis was able to interface an electronic defractometer with the PDP-6. This may have been a world first. From each of the interviewees for this chapter there was the distinct impression that they were tinkering on their own, trying to see what they could get the machine to do. Jarvis’s success is indicative of the freedom that the time-sharing machine provided. There was room to experiment even if it meant getting it wrong.

The following details two projects conducted at UWA using the PDP-6. Both undertakings were highly innovative. The Latin Inscription Concordance Project was a world first. The flight simulator produced for the PDP-6 was also a highly important development. **Innovation** asserts that, on the periphery, greater freedom can lead to original methods and techniques when combined with computer technology.

4.81 Latin Inscription Concordance Project

Perhaps the most innovative use of the PDP-6 came in the area of data processing. Classicist Jory embarked on an epic project in 1965. The Latin Inscription Concordance Project was a world first. It sought to provide a cross-referenced, Key Word in Context (KWIC) index to the entire body of Latin writings of the classical period. This involved sorting references to fragments such as half a single letter, to texts of more than two thousand words. The project was planned in 1963-4 and took until the end of 1970 to complete [14]. A further work, consisting of an index of names was published with the rest of the volumes in 1972 [14].

The Concordance Project was innovative due to the fact that few had perceived that the computational power offered by the 1620 or the PDP-6 could be harnessed for tasks that were more like data processing. Jory noted that the Science Faculty at UWA and, in particular, the Department of Mathematics avoided computing from early on. Jory noted that an important factor in the Concordance Project was that the director of the Computing Centre, Moore, was interested in the Concordance Project from an academic perspective. Moore saw the technical challenge of using the computer for the task yet also appreciated what it would mean for the epigraphic community. From a wider perspective it represented the transition of the computer from a numerical tool to a device that could aspire to more diverse uses within the University.

In 1961 Jory had worked on the Mercury computer at London University. Looking back he held no fond memories for that machine and described it in unfavourable terms. Jory pondered the problem of producing a computer-compiled index by learning the Mercury's Autocode then FORTRAN [14]. Prior to the Concordance Project no researcher had ever dealt with fragmentary text in an index of such a size. Fragmentary text was important to include as it could be used for aspects of textual analysis. A key programming problem was how the team would codify all the possible accidents and breaks. For example, the Roman Emperor Nero was chiselled quite literally out of the recorded Roman memory. Any tablets, inscriptions or sculptures bearing information regarding his rule were scratched out or written over. Hence there are hundreds of fragmentary remains with only the slightest bit of text regarding Nero. There would be a couple of letters then a break or scratch and this would have to be represented in a cohesive manner within the index.

Kirkby and Gent were both involved with technical and programming aspects of the Concordance Project. Sala was assigned the task of finding the reams of paper that were need to print off the index. The core team consisted of Jory and Helen Zaliki. The work was intense and highly stressful. The PDP-6 had remote terminals, one of which was in the Arts Faculty building. Yet Jory and Zaliki would have to venture over to the Physics building three nights per week in order to sort out the paper tape. The epigraphical records were first punched onto paper tape [15]. The paper tape was read onto magnetic tape, and all the data were then checked and corrected [15]. The team was consistently there from one a.m. to four in the morning. Frequently they would find themselves knee deep in a room full of tangled paper tape, the result of the tape spinning off the spool. As an example of the intensity of the work, Helen Zaliki went blind for 12 months following the completion of the project. Jory also felt that the effort took its toll on his own health.

Every day Jory would discover errors on the paper tape. Increasingly, energy would be consumed in a seemingly ceaseless hunt for inaccuracies and error. As time progressed new features of the inscriptions would be brought to light through research. This meant that sections of the text had to be redone. Indeed, every six months there was a complete revision of the unfinished index. Data in the machine was often corrupted due to computer error. The original magnetic tapes either became physically worn, making it impossible to retrieve the information on them, or lost information. The computer, through dropping bits and consequently changing bytes, sometimes altered individual characters [15]. (Jory had a hard time convincing Moore of the truth of this). There were also glitches at the printing stage. Voluminous amounts of paper were used printing off copies until the index was error free. Approximately 250 000 inscriptions were listed. It took two people four years to cover them all. The total output was 7315 pages with 90 lines on each page [15]. The Latin Inscription Concordance Project was a world first.

4.82 Flight Simulation on the PDP-6

For a Master of Engineering Science project in 1971, James Trevelyan developed an operational flight simulator on the PDP-6. Trevelyan proposed that an airborne pictorial contact analogy display, with suitable modifications, could supply all the visual information required by a pilot for manual control of an aircraft during all phases of flight [16]. Trevelyan used the PDP-6 to write and run his simulator software.

The principal device used by the simulator for input and output was a 340 model Precision Vector Display, which was a cathode ray tube (CRT) [17]. Programmes within the PDP-6 could control the display on the tube [17]. Input was via a control box that mimicked the control stick of a passenger aircraft. The control box converted movements of the control column and the throttle lever into linear movements of four independent sensors, which were situated just in front of the display screen [18]. The PDP-6 could detect the position of the four sensors [18]. The PDP-6 could then calculate the movements of the control column and throttle lever and use this information to place a simulated model of an aircraft on the CRT.

The visual section of the software created pictures constantly from information. This information defined aircraft position and orientation. The visual display section was interrupted at regular intervals for the real-time simulation section of the simulator to perform its function of computing the aircraft position and orientation. In terms of its design, the visual display was constantly refreshed. The flight simulator software restarted the visual system where it left off before the interrupt [19]. Ideally, this was at such a frequency where the pilot would not notice the interrupts.

Limitations of the PDP-6 processing capacity meant that the display refresh rate was slower than ideal. Simulation of aircraft dynamics, while the software was running, occupied the PDP-6 processor for between 10 and 25 percent of the time [19]. The rate at which the visual system on the simulator could refresh images was reduced by a corresponding amount [19]. Hence Trevelyan's simulator pushed the PDP-6 to its limit. Ideally it required a faster computer.

Trevelyan used several trained pilots to test the effectiveness of the simulator. Their flying experience ranged from 10 000 hours in multi-engine jet transports to a few hours in light aircraft [19]. Using the PDP-6, Trevelyan was able to graph the performance of the pilots using the simulator. Trevelyan noted pilot comments on the realism of the simulator and concluded that the display, in considerably improved form, could be used for controlling an aircraft during the final approach to landing and touchdown [20].

During WWII, the first flight simulators developed in the USA used cameras and projectors to fill the peripheral areas of human visual range with as much imagery as possible [21]. When the first video cameras became available, they were coupled to the controls of a flight simulator, and the view through the aircraft windshield was provided by a high-quality projection of the video image [22]. Using the kind of miniature sets pioneered by the film industry in Hollywood, it became possible to steer video cameras in tandem with the pilot’s commands over a miniature landscape [22].

In 1968, Evans and Sutherland began to develop the first computer graphic simulations for flight trainers [22]. Dynamism and detail, in early flight simulators, were limited by available computational power. Trevelyan was working in 1970 on his project. Unlike the computer flight simulators for training pilots on the ground, Trevelyan’s system was designed to be implemented within a functioning aircraft as an aircraft landing aid in zero visibility [23].

Trevelyan’s flight simulator prototype was a highly innovative technology. Trevelyan realised that flight instrumentation in 1970 was not adequate. In 1970, most landings made by jet aircraft were made in conjunction with an ILS (Instrument Landing System) instrumentation, which had remained more or less the same since 1946 [24]. The technology with which Trevelyan was working was in a developmental stage. Yet the innovative nature of his project can best be gauged through the fact that researchers are still trying to create technologies that ‘would couple the pilot’s perceptual systems far more effectively with the instrumentation displays from the aircraft.’ [25]

Simulator technology is significant in computing. As Rheingold [1992] writes,

> 'The cognitive scientists who are beginning to tackle the "interior" of cyberspace – the part that resides in our brains and bodies rather than the displays or computing engines – have a rich body of findings to guide their research, thanks to the human factors aspect of flight simulation.' [26]

Simulation is a seed technology of the type of virtual reality science that is depicted in science fiction novels, such as *Neuromancer* [Gibson 1982], and films, such as 'The Matrix' [1999]. Simulation is the technology of the communications future.

In 1982 the first working model of the Visually Coupled Airborne Systems Simulator (VCASS) was operational [25]. VCASS is an eyeless helmet that provides a flight-simulated view of physical flight [26]. VCASS is a technological extension of the principles upon which Trevelyan was working in 1971. VCASS seeks to aid pilot navigation through improving the pilot's interaction with aircraft instrumentation systems. Trevelyan was working towards the same goal with simpler, less capable, computers to run his project.

Trevelyan's implementation of computer simulated instrumentation technology on the PDP-6 was a project on the forefront of research. The Computer Centre at UWA was small by international standards. Based in Perth, Australia, UWA is relatively isolated. Trevelyan managed to be innovative at a relatively small centre, in a remote part of the world. Trevelyan's work shows that, given access to the computer, inventive work is possible on the periphery.

4.9 Conclusion

The impact of early computing went beyond specialist disciplines such as Crystallography. Yet initially it failed to capture the imagination of some University Departments. Joint funding and co-operation enabled the purchase of machines. Access was relatively open when compared with some stultified situations at other institutions. This openness permitted a progressive environment. UWA went from a position of being five years behind to operating at the forefront of technology. This was largely due to the efforts of Dennis Moore. While other factors shape history, the individual can impact situations, particularly in the case of a small campus dealing with a new technology. Early computing attracted a diverse group of people yet they tended to band together into the first computer subculture at UWA. Work on the PDP-6 tended to illustrate the ability of a centre on the periphery to innovate. The Concordance Project was the first move of computing beyond a quantitative field at UWA. It put the University on the map, particularly in Europe. It symbolised the change which computing had brought to the campus and hinted at the changes to come.

5.0 Western Australian Regional Computing Centre

5.1 Introduction

Early Computing at the University of Western Australia was a chapter largely constructed from interviews. For the historian, every subject, event and institution leaves behind traces of its existence. When dealing with a bureaucratic institution such as a University, there are a series of records that are left behind. The information can be used to build a structural picture of an institution like the fragments of a Grecian urn carefully pieced together to reveal a picture story that the potter intended to leave for posterity. In the case of the Western Australian Regional Computing Centre (WARCC) there are a series of archival records that have been stored in the University's archival section. The following is primarily constructed from these records. It attempts to build a depiction of the growth of a successful computational centre and the changes that it underwent through the 1970s. The following makes use of a series of acronyms. A table of the acronyms used in Chapter 5.0 has been provided in Appendix 2 for the convenience of the reader.

The following asserts that there was a need for a Regional Computer Centre in Western Australia (WA) as the State moved into the 1970s. It shows that a Regional Centre was the best solution for the State's computing needs. The **Growth of WARCC** traces consolidation of the Regional

Centre's viability as a commercial entity. Despite this growth, the following asserts that, by the mid 1970s, the concept of central computing was fragmenting. **Mini-computing** illustrates the way in which computing was moving away from large centres as technology became cheaper, smaller and more powerful. **Microcomputing** seeks to assert that computing had, by the end of the 1970s, moved out into the periphery from the laboratories of WWII, through centres such as WARCC, finally reaching the home and the room of the individual.

5.2 Need for a Regional Centre

With the IBM 1620 and the DEC PDP-6, computing at The University of Western Australia (UWA) had been occurring at a central location. Outside of UWA there was a growing need for computing throughout the State. In particular, Government bodies such as the Main Roads Department (MRD), the State Treasury and the Public Works Department (PWD), had a need for computing. As computing at UWA moved into the 1970s this need for computing in the State could not be met by the University Computing Centre (UCC).

There was a commercial Computer Bureau operating in Perth in the early 1970s [1]. It was directed by International Computers Limited (ICL). ICL was a British firm that was the result of the merger of the early companies that had moved into electronic computing after WWII. Computing interests in firms such as BTM, Ferranti, Powers-Samas, Lyons and the English Electric Company were gradually amalgamated into

ICL in the decades after the war. This was due to British industry struggling to compete with American corporations such as IBM and Burroughs.

The ICL commercial Computing Bureau in Perth was limited in the computing capacity that it could offer. For instance, in 1969 the MRD was planning the use of a computer in the Eastern States of Australia for a special project [1]. This was because there was no machine in Western Australia with a sufficient memory capacity to run the computations needed for the project. This included the IBM 1620 and PDP-6 at UWA.

The State Treasury was also running a batched processing facility for computation at the beginning of the 1970s. An NCR Century-200 computer was to be added to the Treasury inventory in the early 1970s. Even with this additional machine, the computer could not provide the time sharing facilities needed by the Treasury to perform its work [1]. Hence the Treasury computing facility was not meeting the needs of its own department. This does not even consider the other Government and commercial bodies that needed computing facilities.

Scientific processing time at the Treasury computer centre had risen from zero to an average of 30 hours per week in the eleven months prior to August 1969 [1]. In a similar way, MRD computer usage had increased from 20 hours in 1967 to 32 hours in 1968 [1]. In 1969 this had increased further to 57 hours [1]. The WA Metropolitan Water Board (MWB) had spent $5112 in 1967 and $11332 in 1968 on computer processing at the UWA Computing Centre [1]. In 1969 it was expected to spend some $16668 on payments for the use of the UWA computing facilities [1]. This was a 47% increase in computer usage in the space of one year. The PWD contracted to the Snowy Mountains Hydro Electric Authority in Eastern Australia for the preparation of contour plans and the calculation of quantities on the Hydro Electric Authority computers. This was due to unavailable local facilities.

Other Government Departments requiring the use of computers included the Forests Department, State Energy Commission (SEC), Lands and Surveys, Agriculture and Fisheries. All these bodies were serviced by the UCC, the Treasury and the MRD computers. There was clearly a demand for more computing capacity within the state.

The increased demand for computing was due to a realisation by Government Departments that the use of computers could radically cut work times. For instance, the MRD was tasked with urban road design. This was becoming a complex problem. Project selection and road width calculations required sophisticated traffic forecasting methods requiring the use of a large scientific computer. The time required for detailed geometric and structural design calculations was dramatically reduced by the use of a computer [1].

The UWA computing facilities where at the time innovative. Yet constant advances in the industry had meant that the equipment was gradually being superseded. The PDP-6 was purchased in 1965 and it was now close to 1970. Newer machines had greater storage capacity and faster processing speeds. Essentially this development let the latest machines perform more processing per day.

While the UWA facility ran programmes for Government Departments it did have greater priorities. The computer was primarily for research and teaching purposes at UWA and was run with this aim [1]. Frequently the hardware on the UWA machines would be modified and new software would be added which meant periods of down time [1]. Government bodies such as the Engineering Department required a steady work flow to be processed on the UWA machines [1]. Interruptions and down time hampered this, a situation that left Government bodies looking for a more viable solution to their needs.

As the 1960s drew to a close, the UWA machines were faced with an increased workload. Departments submitting work to UWA would have to wait some 48 hours on average for the results to be obtained from the computer [1]. This was not the time taken to process the work. Rather it was the length of time taken for a given job to make its way along the queue of tasks until it could be run on the machine. The PDP-6 was a time sharing computer, which meant that it could run multiple tasks. Yet, by 1970, there were great demands on the PDP-6.

5.3 Formation of WARCC

Mainframe computers were expensive. Only large businesses and Government institutions could afford to purchase a machine. Upkeep and servicing of mainframes were also expensive. Hence any solution to the problem of WA computing needs would emanate from the sources of development funds.

The principal source of funding for UWA was the Australian Universities Commission (AUC). This was a federal body that regulated and approved funding allocations for universities around Australia. State Government funding came from federal taxes and locally raised revenues. Significantly, by 1970 the AUC had declared that all future computing funds allocated to Western Australia would be on a regional basis [2]. This meant that the impetus for a regional computing centre came from the Federal Government.

The AUC had sensibly determined that scientific computing resources around the country were under increasing demand. Large scientific machines could only meet such requirements. These mainframe computers represented a high capital outlay. This is evidenced by the way in which the WA Regional Centre’s final computing solution came to approximately $2 million. Hence in order to direct the flow of funds, the AUC declared that it would only offer funds to States that could demonstrate a plan for a regional centre.

This was a difficult proposition for any State. Universities were Federally funded bodies that existed largely independent of State political apparatus. In order for a regional plan to be developed close co-operation between the State Government and the University Administration would be required. Points of difference such as the priority schemes on the proposed Computing Centre would need to be agreed before hand. Issues of administration and control would also need to be resolved. Hence, in order to meet the AUC requirements, there needed to be a process of smooth interaction between the University and the State.

Western Australia was the only State besides South Australia to benefit from the AUC grant in its first triennium of allocation. Why was this? The first point to consider is that WA, and Perth in particular, are on the geographical periphery of Australia. Perth is some 4000km away from the nation’s capital. Perth is closer to cities in South East Asia than it is to its own governing city, Canberra. Perth is one of the most (if not the most) isolated cities in the industrialised world.

Due to its geographical isolation, Perth was also on the computing periphery. Previously, it was shown that Perth was at the technical forefront of computing globally. The PDP-6 that was installed at UWA in 1965 was the first commercially installed time sharing computer in the world. The peripheral nature of Perth came in the sense of not being subservient to more established computing centres. For instance, the University of Sydney was where the SILLIAC machine was developed in the 1950s. Yet this was not the sole source of scientific computing in New South Wales (NSW). There was also a CSIRO facility at Lucas Heights in Sydney’s outskirts. There were therefore at least two competing institutions for computing within NSW.

In Perth the UWA Computing Centre was not the sole source of scientific computing in WA. There were other small Government centres and at least one commercial Computing Bureau, yet these lacked large scientific machines as advanced as the UWA set up. There were also prior links between the State Government and the UWA Computing Centre (UCC). It was the combination of the two bodies that had financed the IBM 1620 and the PDP-6. State Government Departments were already running a large amount of work on the UWA machines. The UCC was also the undisputed hub of expertise within the State. Hence in WA there was already an informal Regional Centre that was waiting in the wings to be formalised if events suited it. WA was therefore ready to capitalise on the AUC policy.

Agreement on regional computing by the Universities in Sydney and Melbourne was not reached before the AUC report was finalised and no funds were allocated for those centres in the 1970-72 triennium [3]. Gaining agreement in WA was no easy task. There were concerns regarding control and access. For instance, the Faculty of Science at UWA was concerned about possible loss of autonomy over all computer facilities [3]. The Faculty of Science did not approve the handing over of a University computer to the State Government's control [4]. Due to this, the Faculty of Science was pushing for the PDP-6 to be left out of the proposed centre in order to ensure priority access for its researchers and students [4].

Moving into a Regional Computing Centre was a measure of expediency. A Regional Centre offered the only chance of staying ahead of demand for computing facilities [5]. UWA's involvement was critical. If UWA failed to participate, the State Government was unlikely to match the federal funds that were recommended by the AUC. The other academic institution in WA at the time, with a technical interest in computing, was the Western Australian Institute of Technology (WAIT, now Curtin University). The State Government was not content to engage in an agreement solely with WAIT [5]. This was probably indicative of the expertise that UWA enjoyed and its informal links with the State Government, as opposed to WAIT.

The other option open to UWA, in 1970, was to upgrade the PDP-6 to a PDP-10 configuration. This was a short-term solution. A PDP-10 machine would have been incapable of meeting the demand outside of UWA for computing time. It was also less suitable as a scientific computer when compared to the purchasing power that a regional group could wield. Other machines, although more expensive, offered more power and memory. The regional plan was ambitious. It would procure a machine that held greater capacity than UWA could afford on its own. A large computer was a long-term proposal that would satisfy both researchers and State Government Departments. To proceed with the PDP-10 alone would be, in terms of the AUC grant conditions, a mistake [6].

In September of 1970 a preliminary report was put together by R. Sipe of the UWA Central Administration [7]. It outlined the aims and needs of a Regional Centre. Sipe's report also gave the proposed body its new name and acronym. It would be called the Western Australian Regional Computing Centre (WARCC).

WARCC's aims were initially twofold. First, it was to provide a reliable computing service to all users at any time, regardless of user job size and file size. The WARCC system was to permit a terminal controller to manage an individual terminal configuration as though it was a separate computer. This meant that an individual terminal could serve localised users according to their own priority arrangements.

This first aim was significant in that it promised access to a high-speed computer capable of matching the challenge of even the most complex of tasks. It was also a system that, through the branching off of terminals, could permit the autonomy and access that the Faculty of Science had feared losing. It is almost certain that concerns regarding access, as expressed by the Faculty of Science, would have been echoed in the MRD and State Treasury. This initial aim was therefore targeted at appeasing these fears.

A second aim was for WARCC to provide a system that simplified operations at consoles, batch terminals, and at the machine centre itself [7]. Terminal operators were to have no direct control over Centre facilities, except direct-access storage [7]. This aim was integral to the smooth operation of a time sharing computer system. As noted previously, time sharing machines could be fed work from remote terminals that were connected to the central computer. This aim provided for remote computing, yet located control over memory allocation within the centre.

In terms of computing specifications, the initial report submitted by UWA Administration to the AUC set out requirements for 550 million bytes of direct-access storage in the first year of operation [7]. Two fast magnetic tape drives were needed in order to supplement such memory. The parties involved knew what kind of machine would satisfy these needs. The specifications for the machine promised a computer that would meet all the requirements. Yet it was an ideal aim. The reality of the new computer would be different. Despite this, a regional proposal was the best option for the beleaguered WA computing operation.

State approval of WARCC was granted on 4th February 1970 [8]. By December 1970, Prime Minister John Gorton had approved, in principle, the formation of WARCC [9]. This gave the initial Board of Management the green light to shop for a suitable computer. The Interim Board of Management for WARCC consisted of representatives from UWA, the CSIRO and Government Departments [10]. It was their task to obtain the funding and purchase a computer for the Centre.

5.4 Computer Shopping

Submissions were invited for a new machine from various computer manufacturers. Six indicated that they would be making presentations. The firms and the computers they offered were Burroughs (6500), IBM (360/67), Control Data Corporation (CDC 6400), DEC (PDP-10), ICL (4/70), and UNIVAC (1106) [2].

DEC proposed the installation of a PDP-10 machine with 32 K of memory and associated peripherals [11]. The advantage with this system was that it would cost $450 000 [11]. This was a sum that could be met by UWA alone with its AUC grant allocation. Yet the AUC felt that the PDP-10 was unwise and a short-term solution only. UWA had a close relationship with DEC, as its previous computer, the PDP-6, was one of the first commercial time sharing machines that DEC managed to install. This relationship had been established in particular by Moore, the head of the University Computing Centre (UCC). Moore was initially keen on the PDP-10 proposal yet noted that it had deficiencies [12]. While $450 000 would obtain a workable computer, an additional $80 000 would be required later in the 1970-72 triennium, in order to have an adequate disk backing store [12].

Control Data Corporation (CDC) initially offered a CDC 6400 model. It had 64 K of core memory at an aggregate cost of $2 050 000 [11]. This package excluded the cost of the remote terminals that were required to meet the initial aims of WARCC. Yet CDC were keen to get the contract. They offered nearly $500 000 discount in order to secure a deal [11].

The expense of the CDC 6400 computer was cause for concern. It was not a modular system and its installation could not be phased over a period of time [11]. With the PDP-10, the purchase could be made in increments until the system was complete. Due to the nature of the CDC proposal, the State Government would have been forced to enter into a contract to purchase to whole installation. This meant that the State could not claim a Commonwealth Government contribution in the 1973-75 grant triennium [11].

UNIVAC, the company founded by Eckert and Mauchly after building the ENIAC, offered a discount 1108 computer. It cost in the vicinity of $1.7 million [11]. Added to this were the on-going maintenance costs of $6041 per month. The 1108 was a capable machine with over 200 instructions and 128 fast registers [13].

Burroughs offered a B 6500 computer. It had a 96 K 600-nanosecond core, being installed with 2 card readers, 2 printers, and 100 million bytes of 60-millisec disk with an optimiser [13]. With this computer, a sum of around $2 million would be needed to secure an installation. On the Burroughs 6500, a LOAD instruction took 1.4 microseconds plus 1.2 microseconds for stack adjustment. Moore concluded that this machine was too slow for the price asked [13].

The IBM 360 was a machine upon which Tom Watson Jr. bet the entire IBM company in the early 1960s. Watson Jr. was the son of the IBM stalwart Watson Snr, who took the company to its position of global dominance. Prior to its release, not one of IBM’s computers could run the programs of another IBM system [15]. Software for IBM computers was model specific. With each new computer, software had to be written specifically to run on that respective machine. IBM had sought to develop a compatible range of computers in secrecy from 1962 [14]. A compatible range of computers could run the same generic software. Direct research costs for this project were $US 500 million [14].

On the 18th March 1964, IBM's System/360 was released with a media-marketing blitz of Windows 95 proportions. IBM staged press conferences in sixty-three cities in the USA and fourteen foreign countries on the same day [14]. In New York a chartered train conveyed two hundred reporters from Grand Central Station to IBM's Poughkeepsie plant, where they were shown six new computers and 44 new peripherals [14]. Watson Jr. in his late 40s took centre stage to make the "most important announcement in company history," IBM's third-generation computer, System/360 [14].

Although the concept of a compatible range of computers was not new, the System/360 dramatically reshaped the industry by setting compatible computing as a standard. Yet the System/360 range of computers was not as innovative as IBM's marketing suggested. For instance, the proprietary electronics technology that IBM had chosen to use, known as Solid Logic Technology (SLT), was halfway between the discrete transistors used in second generation computers and the true integrated circuits of later machines [15]. The operating system (OS) software development for the System/360, was a financial disaster for the company. It cost US$100 million to produce and contained many shortcomings [15]. By 1970 the IBM 370 was announced. It redressed some of the System/360's deficiencies. In particular, the architecture was altered to support time-sharing and communications-based online computing [16].

Yet the damage had been done, in terms of the perceptions of those who were to decide on the purchase of the WARCC computer. These were the people who formed the Technical Committee of the WARCC Interim Board of Management. Moore, the then director of the UCC, headed the Technical Committee. System/360 was flawed and the negative publicity generated by the OS/360 saga would have been borne in the minds of people such as Moore. Time-sharing was a decisive feature required by the initial WARCC report. In 1970, IBM indicated to WARCC that they wished to offer a new 370 range of equipment that was to be announced in June [13].

By 1971, the situation in the computer supermarket had changed somewhat. Moore described it as a time when WARCC ‘can now get more computer cheaper’ [17]. For instance, the IBM 370 series offered time sharing potential with a 100 million character store and 30 microsecond access, compared with 30 million characters memory and 60 microsecond access on the System/360 [17]. UNIVAC also offered a 1110 computer with a heavily discounted price at around $2 million [17]. The UNIVAC 1108 was now costed at $1 million yet, compared with the 1110, it was limited in performance and came with few peripherals [17].

DEC had released a PDP-10-I computer, yet was unable to deliver a machine before the second half of 1972 [17]. Building work had begun on a facility to house the new computer and was due to be completed by May 1972. The prospect of this facility lying dormant for half a year before the installation of a computer was not appealing to the

WARCC Board, who were anxious for a system to be operational as soon as possible.

CDC was part of a group of companies that had weathered the 1960s and stayed solvent into the 1970s by competing with the market dominance of IBM. While the IBM System/360 lacked technical aspects, these were more than compensated by the best sales force in the world. By 1970 IBM was the world's leading computer manufacturer. The rest of the industry competed for the scraps from IBM's table. The computer industry by 1970 was characterised as IBM and the BUNCH. The BUNCH stood for Burroughs, UNIVAC, NCR, CDC and Honeywell [18].

The BUNCH had survived through targeting niche markets and product differentiation. As an example, Honeywell had released a series of computers smaller than those in the System/360 range, and four machines larger than the System/360 computers. They were all compatible with the Sytem/360 architecture, yet were not directly competing with the 360 range. NCR and Burroughs adopted a similar tactic [19].

CDC had realised that there was a specialist market for high performance scientific machines. CDC abandoned the regular mainframe size of the IBM inventory and manufactured giant number crunching computers well suited for government institutions and defence establishments [19]. UNIVAC relied on its existing applications experience and software. It competed directly and successfully with IBM in the sphere of airline reservation systems [18]. In this way, members of the

BUNCH managed to retain a small enough share of the computer market to be economically viable.

1970-1 had seen a downturn in the computer market, which meant only the strongest would survive through the early part of the decade. The BUNCH just made it through while IBM coasted. This was a contributing factor to Moore's comment on WARCC being able to get more computer power for the dollar. After 1971 companies were keen to close any deal possible, mainly because their future viability would depend on it.

CDC offered WARCC one of their new range of CYBER computers. The CDC CYBER 72 was similar to the 6000 series yet had improvements and new peripherals [17]. The CYBER 72 had a speed of 0.9 million operations per second [17]. It featured new instructions in the form of integer multiply, character move (which doubled the speed of compilation and execution of COBOL) [17]. It had a 48 K 60-bit central memory and 10 peripheral processors each with 4 K 12-bit memories [17]. The CYBER 72 had the capacity to run user terminals with 300 lines per minute printers and 300 character per minute readers, with displays and keyboards [17]. It also came with free software.

The time-sharing capacity of the CDC CYBER 72 was of great importance to WARCC. Its terminal capacity facilitated WARCC's needs. Another significant benefit was that Melbourne, Sydney and Adelaide were also using CDC machines. Sydney and Adelaide had CDC 6000 range computers while Melbourne had a CYBER 72 [17]. With the type “200” terminals that came with the CYBER 72, a WARCC terminal could access the computers in the East of Australia in the case of an emergency. This would be via a packet switched network.

Already in 1971 people at terminals on the Melbourne CYBER were calling up the Sydney machine [17]. The CSIRO also ran several CDC computers [17]. If WARCC purchased a CYBER 72 there would be a ready made network of personnel and experience on which it could tap. The success of the CDC computers in these other centres would also guide WARCC’s decision.

All the interested vendors were vying to sell WARCC its computer. Terry Gent and Moore (with a wry smile) in 1999 recalled that Moore had ordered an airconditioning system to be constructed in the new computer building in a way that would suit the UNIVAC machine [20]. The UNIVAC 1110 was designed to be cooled from above. Moore had staff begin to install ducting as if the airconditioning was to be fed from the ceiling. The CDC computer was, by design, cooled from below. The CDC Cyber 72 would sit on a false floor underneath which cool air was circulated up through the interior of the device. Rumour had it that when CDC learned of Moore’s intended airconditioning plan they dropped the CYBER 72 price yet further.

The extent to which the ploy by Moore was a “tall tale” is difficult to discern, yet it is indicative of the competitive nature of the proposals and their respective companies. Although from a relatively small, peripheral computer centre, Moore was not intimidated by dealing with the world’s largest computer companies.

A room to house the two motor generator sets, the transformer, and some switchgear for the computer, was constructed in the South West corner of the Physics tower at UWA in the basement level [21]. A supply of cooling water for the computer equipment was required in the computer centre to come in under the computer’s false floor [21]. Racks needed to be installed in the computing centre to house tapes [21]. As the University Architect noted,

> ‘Some units of the Control Data Corporation [computer] are cooled by using airconditioned air from the room space. However, our installation has been designed exclusively on supplying cooling for computer units in the underfloor plenum. To get over this difficulty some of the underfloor air must be bled by control grills on to the inlet grills of these pieces of equipment’ [21].

The new computer was therefore a vast machine that required ducted airconditioning to maintain fault free operation. It sat as an electronic monolith clattering and buzzing, amid the whirr of a large airconditioning system.

5.5 CDC CYBER 72

CDC operated in the sphere of large scale computing. A CDC mainframe was a powerful scientific machine. CDC clients were generally Government institutions and research corporations in the USA. In 1971-2 McDonnell-Douglas placed an order valued at $US 30 million for a large CYBER System for use in the site defence of the Minuteman Project [22]. The Minuteman project was a series of Intercontinental

Ballistic Missiles (ICBM) that the US Government was developing in the nuclear arms race against the then USSR. The US Air Force placed an order valued at $US 83 million for six interconnected sites each with dual CYBER computers. This whole system was to be dedicated to the Air Force inventory system [22]. Hence the CDC CYBER computers were some of the most powerful and sophisticated machines in the world.

The University of Melbourne was one of CDC's first CYBER 72 customers [23]. A CYBER 72 at UWA would be one of the most powerful computers in Australia. Only the CDC 6600 at CDC's own Data Centre in Sydney was more powerful. The only Australian University machines approaching the CYBER's power were the CYBER 72 as ordered by the University of Melbourne and the University of Adelaide's Control Data 6400 [23]. The purchase of a CYBER 72 would thereby keep UWA at the forefront of computer technology, a position that the UCC had enjoyed since 1965. In August 1971 the WARCC Technical Committee passed a motion at the Interim Board of Management recommending the purchase of a CYBER 72 computer [24].

On the 2nd of December 1971 both the WA Premier's Department and UWA released press statements announcing WARCC [25]. These contained details of the new computer. The WARCC Interim Board had decided to go for the CYBER 72. Documents to finalise the contract for CDC Australia to install the $1.119 million CDC CYBER 72 computer system were signed in Perth on the afternoon of the 2nd of December

[25]. A special ceremony was arranged and the then WA Premier, John Tonkin attended [25].

It was an important moment for computing in Australia and WA. A Regional Centre would firmly keep WA at the cutting edge of computer technology. The choice of the CYBER computer meant that large scale scientific processing and time-sharing were feasible. By co-operating with State Government and taking advantage of the AUC policy, UWA had procured one of the best scientific computing systems in the world.

At the contract signing ceremony, Tonkin stated that the CYBER 72 was like 11 computers in one, as it incorporated multi processor and time sharing technology [25]. It was to be delivered in May 1972 and would be operational before the end of June 1972 [25]. The extension to the Physics building in which the computer would be housed was now due for completion in May 1972 [26]. With the signing of the CDC contract, a formal Regional Centre was born.

The CYBER 72's central processor could execute in the vicinity of 1 million operations per second [25]. While this was occurring, ten peripheral processors were capable of handling ancillary work such as controlling the flow of data in and out of the system [25]. Including extended core storage, the CYBER 72 had a central memory of 3 million characters [25]. Magnetic disk drives would provide on-line data storage for 360 million characters [25]. Like a thoroughbred racehorse, the CYBER 72 was a performance machine.

5.6 Knowledge Transfer

WARCC absorbed the UCC and all of its equipment. While WARCC was mainly to be concerned with scientific and engineering computing, the State Government Computer Centre at the Treasury Department focussed on accounting and statistical services for State Departments [25]. Computing at WARCC was thereby distributed to machines at sites other than the UWA campus. Yet significantly, the main CYBER computer was housed on campus at UWA. The key experts around the machine were, prior to WARCC, UWA staff. Both these factors gave UWA solid access to the new machine. WARCC was formally opened on 13th September 1972 [27].

The chief technical expert at the WARCC facility and its future Director was Moore. From January to February 1972, Moore visited significant CDC computer installations around the globe [28]. These sites included Stanford, Minneapolis, Chicago, London, and Paris [28]. In preparation for the CYBER 72 installation, members of the Computing Centre staff spent periods of familiarisation on the University of Adelaide CDC computer [29]. Once in Adelaide they were given pre-installation training and programme development. This preparation lasted from January to April 1972 [29].

Such visits illustrated the way in which knowledge was spread in the computing community. Computing centres may have operated in isolation yet there were always lines of communication open with other groups. Computing involved hands-on knowledge and communication with others.

Knowledge would be spread through meetings and experience. In this way the transfer of computing knowledge was rapid.

The rapid spread of von Neumann’s EDVAC report had proliferated the design of computer architecture following WWII. Such technology transfer was continued through papers, journals, conferences and visits, such as those made by the WARCC staff. It is not surprising then, that the spread of computing through the world had been rapid. Such practices assisted this dissemination of knowledge and experience. By 1960 there were 5000 computers operating in the USA and some 2000 in the rest of the world [30]. By 1970 there were approximately 130 000 computer installations globally [30]. Computing had therefore grown exponentially. Frequent exchange of information assisted this growth.

5.7 Women at WARCC

Of the 34 WARCC staff as of December 1973, 16 were women [31]. There were no women on the WARCC Board or its Technical Committee. Yet they made up nearly half of the WARCC staff. Further analysis of staff at WARCC in this period reveals that of the 16 women, 2 were Librarians, 1 was a programmer, 1 was a senior operator, 3 were assistant operators, 7 were punch card operators and 2 were involved in secretarial or typist roles [31].

There were no male punch card operators. This position was very low on the WARCC hierarchy. Yet it was an essential task for the smooth operation of the facility. Six of the seven programmers were male. Programming was high on the WARCC career ladder. Of the top four executive positions of Director, Computer Control Manager, Applications Manager and Administrative Officer all were male. This illustrates WARCC was a work environment where roughly fifty percent of the employees were female yet the workplace was controlled and managed by males.

These statistics reflected a general gender bias in the WA community throughout the 1970s. An informative illustration of the community perceptions regarding women in the workplace can be observed in the employment section of the State's strongest daily newspaper, *The West Australian*. In the Saturday edition of *The West Australian*, 17th August 1974, two WARCC positions were advertised. They were for two experienced key-to-tape operators to work with FRIDEN key-to-tape encoders for approximately 9 months at Royal Perth Hospital [32]. Significantly, these positions were advertised in *The West Australian's* 'Women and Girls' section. The paper actually separated its employment categories by gender, thereby helping employers enforce a perception of work that was suitable for men and jobs that women could perform.

When considering the role of women employed in WARCC, such cultural inequity should be borne in mind. In a society that permitted newspapers to segregate their employment sections in this way it is not surprising that women did not feature in the management of its computer systems. As a contrast to the previous advertisement, consider a vacancy for a Computer Training Officer at WARCC. This position was advertised in *The Australian*, a newspaper with national circulation as opposed to the State circulation of *The West Australian*. A Computer Training Officer was required to supervise all aspects of user education and undertake the teaching load [33]. This position noted good opportunities for advancement with tertiary qualifications in Science or Engineering being desirable [33].

5.8 Growth of WARCC

With the CYBER 72 installed and operating, WARCC began to run as a profitable venture. From 1974 to 1979 WARCC operated with a net surplus of revenues [34]. WARCC posted profitability so that by 1979 its net assets were $2.7 million [35]. This was despite the declining value of the computer systems in the Centre, purchase of disk drives, plotters and core memory [35].

WARCC in the 1970s did consolidate as a business venture, yet was no longer a hub of centralised computing. Centralised computing experienced fragmentation from the mid to late 1970s. The following section traces aspects of WARCC’s growth and illustrates the slow breakdown of the central computing concept.

State Government Departments were frequent clients of WARCC as were the CSIRO and other University based researchers. In 1971 alone, the list of private firms in the corporate sector who were running tasks included nineteen companies [36]. This increased as the CYBER facility swung into full operation. WARCC also processed programmes for secondary schools in WA under a “MINITRAN” system [37].

A significant use of WARCC was a three-year Medical Records Linkage project. This involved producing a file of patient records from all West Australian hospitals where all the admissions of a given patient were linked together, regardless of the hospital to which they were related [38]. This was used to produce morbidity tabulations [38]. The aim of this project was to link other data such as births, deaths and mental health records to hospital morbidity records [38]. The CYBER was therefore heavily used from its inception.

Use of WARCC, and in particular the CYBER computer, grew rapidly. As Table 5.1 illustrates, jobs submitted to the CYBER had increased by a factor of two since 1973. By 1975 the Centre was drawing $85 000 per month. As a centre of computing, WARCC had expanded considerably by 1976. The PDP-6 had been upgraded to a PDP-10 and linked to the CYBER by 1973 [40]. In late 1975, a second CDC CYBER was installed at WARCC [41]. This procurement, combined with additional memory to the existing

Table 5.1 WARCC Measures of Growth 1973-75 [39].

	1973	**1974**	**1975**	**Growth Factor 1973-5**
Value of Capital Equipment (AUD$ millions)	1.5	2.2	2.5	1.7
Number of CYBER Jobs Run Daily	700	900	1400	2.0
Total Centre Monthly Income (AUD$ thousands)	42	45	85	2.0
No. Centre Users (as measured by no. of accounts)	500	1000	1400	2.8
No. of Programmers in Programming Services	8	9	8.5	1.06

CYBER, meant that the Centre would move from a $750 000 turnover to something in excess of $1.5 million per annum in 1976 [41].

The two CYBER computers were linked back to back at the facility. With the medical records project it was an imperative that data could be accessed at all times. Down time on one CYBER was covered by the operation of the other and *vice versa*. Two CYBERs ensured that WARCC could keep on processing work even through periods of maintenance.

From 1975 there were three tertiary institutions using WARCC's facilities. These clients were UWA, WAIT and Murdoch University. UWA mostly ran projects on the WARCC computers that were associated with teaching and research. Administration of the University also heavily relied upon the computing facility. This can be observed in the WARCC Income Analysis Table 1 [Appendix 2]. A plot of this information illustrates that UWA was by far the biggest single user of the computers at WARCC [See Figure 1, Appendix 2]. Its average monthly account at WARCC was between $30 000 and $40 000 from 1975-7. This compared to $10 000 for WAIT and $5000 for the Public Works Department (PWD) [34].

Both Murdoch University and WAIT ran a large proportion of their administrative tasks on the WARCC CYBER. From 1975 much of Murdoch's administration work was dependent on the WARCC computers [43]. It wasn't until 1981 that Murdoch was seriously working towards developing its own large computer systems [44]. At this time, the Murdoch computer services unit felt that a proposal to jointly develop computer systems with UWA was not in keeping with its own pursuit of a computer strategy [43]. There were substantial differences in procedures between Murdoch and UWA [44]. When it is considered that UWA dominated the WARCC facility, Murdoch's goal of an individual computer facility was sensible.

This last point illustrates an important factor of computing. This concerns access to computers. By locating the WARCC systems primarily at UWA, the State Government and UWA had ensured vital access to the machinery for UWA. Access led to frequent contact with the computer and this in turn inspired innovation. In 1975 access was a contentious issue at WARCC. Before Christmas 1975, WARCC experienced a difficult run on its resources. The lead up to summer is a difficult time at tertiary institutions. Results had to be correlated and issued to the student populace. This was the case with WAIT, Murdoch, UWA and the Tertiary Information and Services Centre (TISC). At this time they were using the WARCC computers for most of their administration tasks. WARCC could not meet the demand for computing [45]. They went so far as to approach Western Mining, a private company, to take some of the excess demand on the Western Mining CYBER [45]. Access was therefore a very immediate issue with WA computing in the 1970s.

Programming support was also, by 1975, unable to cater for the needs of clients. In August 1975, WARCC could no longer offer the quality and quantity of programming support that users had previously enjoyed [39]. This is not indicative of poor performance on the part of WARCC. The demand for programming support was excessive. The talents of the Centre's staff were pushed. Staff were working over and above the normal working hours clocking some extra 90 hours per week as a group [39].

Programming was a facet of computer use that required close familiarisation with the machine. Effective programming required access. The excessive need for programming support by WARCC clients was probably due to customers not enjoying constant access to the computers. The early UCC had evolved with a culture whereby computer usage and programming was to a large extent self-taught. Yet such education required time with the computer and interaction with it. Those outside of WARCC did not have this access. This would have contributed to clients desiring to procure their own systems.

When demand on the computers exceeded capacity, jobs were prioritised. It was not uncommon for clients to 'buy their way out of such a situation to avoid the political hassles of rationing' [46]. This kind of solution would have left many clients frustrated at the lack of their own computer facilities, especially when their work was urgent and they could not afford to pay the extra cost on their processing time. A better option would be to buy small systems thereby gaining autonomy. Hence there was an impetus for independence from WARCC computers.

Expressions of this goal for independence in computing facilities were evidenced in the purchase of computers by the

Government Sector and others. WAIT was one example. WAIT installed a DEC-10 computer late in 1976 as part of WAIT's own computing facility [47]. There was pressure for processing time on the WARCC PDP-10 in 1975 [47]. By installing a machine, WAIT alleviated some of this pressure. This can be observed in a slight downturn in WAIT's average monthly computing bill in early 1977 [48].

WAIT's share of WARCC revenues actually increased from 1975-7 [49]. It rose from 12 to 17 percent [49]. This was not due to an increased use of WARCC by WAIT. Rather, it was indicative of a slight decline in the use of WARCC facilities by the Government sector. The Health Computing Services (HCS), Main Roads Department (MRD) and the PWD were examples of this trend [50]. This trend was due to decisions to place new large computers at WAIT and MRD in 1975 [51]. MRD, the State Energy Commission (SEC), and HCS had purchased large computers by 1976 [52]. Murdoch University had also invested in a midi-computer by 1976 [52]. The centres that were peripheral to WARCC were therefore gaining greater computer access, through installing their own devices. This would give the centres greater autonomy.

HCS exhibited a sizeable decline in its use of the WARCC facility [51]. Its WARCC bill dropped from a monthly average of $11228 in 1975 to $1814 in early 1977 [34]. HCS had been developing a Medical Records Project with WARCC. With the procurement of another CYBER computer, HCS took over the running of the new machine. This can be observed directly in the WARCC expenditure data [34]. In 1978 WARCC spent an average of $10864 operating the CYBER B machine [34]. In 1979 the running of the CYBER B was off its books [34].

The 1970s were therefore a period of rapid flux for WARCC. It was commercially successful in posting a regular revenue surplus. Yet lack of access to the computers began to see a trend towards clients purchasing their own systems. Improvements in computer technology through the 1970s and the drop in the expense of computers helped this. Hence, the centralised computing concept was beginning to fragment.

5.9 Mini-computing

WARCC was formed on the premise that large computing power could be obtained by the pooling of resources. In 1969 it was generally accepted that a large computer was cheaper per instruction executed than several medium sized machines [12]. Overhead costs such as staffing, maintenance, and housing were considerably less with a central system. Why then, from the mid to late 1970s, were some of WARCC's clients purchasing computers under their own auspices?

The answer to this question lies in a change in the nature of computing in a global sense. Computing was a rapidly evolving industry in the 1970s. The mass-produced integrated circuit, mini-computers and the maturing of the mainframe, were decisive factors in the opening up of centralised computing and the spread of computing autonomy to smaller groups in the commercial and academic spheres.

The numerous vacuum tubes, which had given the early post war computers their memory, were replaced by transistor technology in the late 1950s. Invented in 1947, the transistor exhibited the electronic properties of the vacuum tube [53]. Transistors first appeared in computers in 1957, being introduced by UNIVAC and Philco Corporation [53].

The invention of the transistor was further augmented by the creation of the integrated circuit in 1958 [54]. This is when a transistor's parts were physically embedded into a piece of silicon wafer [55]. The first integrated circuits were produced in 1962 for the USA military [56]. They were initially expensive but slowly they were incorporated into computer memories. For instance, the IBM Sytem/360, that WARCC was considering purchasing, did not make use of integrated circuit technology. The later IBM System/370 did make use of integrated circuits. Integrated circuits reduced the size and cost of computers. They meant that in the early 1970s it was possible to buy a mini-computer with the power of a 1965 mainframe that had cost ten times as much [57].

The tool that enabled the breakdown of central computing was the mini-computer. The UWA PDP-6 was a time sharing system. It worked on the principle that computing resources were best deployed by feeding work to the central processor from remote terminals that could be hooked up to the mainframe by a data cable. This meant that, on the UWA campus, a terminal in the Arts building could submit work to the PDP-6 in the Computer Centre across the campus. The CYBER 72 also worked on this principle. Yet, while the PDP-6 had only one processor, the CYBER had multiple processors so that it could run tasks at the same time. With only one processor, the PDP-6 only appeared to run tasks at the same time.

All this changed when Olsen's DEC released the PDP-8 in 1963 [59]. The PDP-8 was marketed on the premise that a powerful mainframe system was not required to process all computing tasks. For instance, Chapter 4 notes that Crystallography needed the power of a large machine to calculate their structures. On the other hand, the Latin Inscription Project, as pursued by Jory, didn't require the full resources of the mainframe. The Latin Inscription Project could have been performed on a mini-computer. The PDP-8 was a mini-computer.

The PDP-8 was about the size of an ordinary refrigerator [58]. It was made out of transistors and magnetic cores costing only $US18000 [58]. The PDP-8 only ran one programme at a time, processed data in 12 bit words, and contained only 4K words of memory [58]. As a comparison, the PDP-6 at UWA cost $351 600 in 1965, had 16K of core memory, and was a time sharing machine [59]. University departments could, by the mid 1970s, afford to purchase and run a mini-computer.

At UWA through the 1960s, there was not the expertise outside the UCC to effectively operate and run a mini-computer. Yet this changed in the 1970s. The Department of Psychology and the Crystallography Centre were two early examples of University research groups that had the computing expertise to run their own machine.

By 1976, a new breed of mini-computers was being produced with core memories of 64K words and word lengths of up to 32 bits [60]. This kind of power had previously been the domain of the mainframe computer. A typical mini-computer configuration of a central processing unit (CPU), core memory, a console, magnetic tape drive, disc drives, line printer and card reader, cost around $125 000 [60]. This was affordable by Centres and Departments such as Crystallography. As Table 5.2 illustrates, mini-computers compared well with the mainframe IBM 370. Although they could not compute as fast as a mainframe, their lower cost meant that researchers at Crystallography could obtain access to a dedicated machine.

In 1976 the Crystallography Centre put forward a proposal to obtain its own mini-computer [60]. This is significant in that Crystallography tended to be among the largest users of CPU-intensive computing in scientific-based Computer Centres [60]. Crystallography was one client of WARCC that required the performance of the CYBER machine. Yet they also needed access to computers in a direct fashion coupled with fast turn around times on their processing. As previously noted, WARCC, at times, found difficulty in meeting such client needs due to the sheer volume of computer work that would be submitted to it. Due to the variety of tasks submitted to the WARCC CYBER, it was optimised for an average-job profile, which was quite different from the high

Table 5.2 Comparison of Compute Times [60].

	IBM		INTERDATA		HARRIS		DEC		DATA GENERAL	
FUNCTION	370/158		8 32		SLASH 4		PDP 11		ECLIPSE 200	
	INT	FP	INT	FP	INT	FP	INT	FP	INT	FP
SINGLE WORD	32	32	32	32	24	48	16	32	16	32
ADD/SUBTRACT	0.9	2.4	1.2	2.3	1.5	2.3	1.8	8.2	2.5	5.3
MULTIPLY	2	2.3	3.5	3	6	5.2	3.9	11.2	8.8	7.2
DIVIDE	9.9	8.9	5.8	5.3	11.3	12	8.3	12.2	11.2	7.9
REGISTERS	16		128		5		16		4	

Note: The IBM machine is a mainframe computer included for comparison with the remaining mini computers. Single Word refers to bit length of a single word of memory. INT and FP columns list times for processing integers and floating point numbers respectively in microseconds.

CPU/core memory demands of Crystallography. Crystallography was thereby motivated to purchase its own computer through a desire for greater access and autonomy.

In November 1978 the UWA Computer Policy Committee approved the Crystallography proposal for a mini-computer [61]. It was a significant step for computing at the University and at WARCC. A separate entity within the University was obtaining independence from the central authority and plying its own course in computing.

5.10 Western Australian Regional Network

From the mid 1970s, WA was experiencing an influx in computers. Installation of mini-computers within Government Departments, University Centres, and commercial enterprise meant that WARCC was no longer the sole concentration of computing power in WA. Computing was disseminating through the State like a series of pods from a cybernetic organism. Remote terminals fed into the WARCC machines yet the pods of the other computers outside WARCC were not linked. In 1974 the first proposal for a computer network linking most of the WA computer sites was put forward [62].

In 1975 WARCC realised that, ‘even to achieve economy of scale, it is probably not true that the single large computer is appropriate. The demands are not for more and more of the same service but for more and more diverse applications’ [63]. WARCC sought to put forward a proposal asserting that co-ordination and consolidation among a wide group of users could generate more computing resources for the same expenditure [63]. A network promised the potential to share processing loads, economies of specialisation with respect to hardware, systems programming, construction of complex highly tailored applications programmes, and the development of large scale data bases [63]. Essentially, WARCC wanted to link the newly installed computers in the State.

A network operated on a principle of packet switching. Essentially this is where bundles of data are transferred along a communications line from computer to computer. Packet switching resulted from the fusing of two technologies. The first was telegraph store and forward message switching networks [64]. The second was time sharing computers as developed in the 1960s [64].

Message switching technology was computerised in the 1960s [64]. Magnetic disks and tapes stored messages intermediately between the points of communication [64]. Yet long delays were experienced with this technology and it was not until the advent of real-time transaction processing systems, in the early 1960s, that the transmission delays were dramatically reduced [64]. This was the technology that enabled the exchange between the remote terminal and the time sharing computer to work.

Yet time sharing terminals communicated to the mainframe through a direct line, as was the case with the PDP-6 at WARCC, or through a local call. This process experienced little delay. Large centres such as the WARCC could afford to install cables that linked the terminals to the computers. Hence, in the local area, communication with the mainframe was swift.

However, there was not yet the technology to speed communication over a substantial distance. Packet switching was the answer to this problem. The concept of packet switching arrived with two independent research efforts in Britain and the USA. In Britain, D.W. Davies, at the NPL, published a ‘Proposal for the Development of a National Communication Service for On-line Data Processing’ in December 1965. Davies proposed that instead of transmitting each message in its entirety, as was the case with time sharing systems, messages would be split into blocks [64]. These blocks would then be transferred along a communications line on a round robin basis [64].

Paul Baran, working for Rand Corporation in the USA, arrived at the same system independently in 1964. This was while developing a resilient speech technique for military communications [64]. Messages would be disassembled at the starting point, passed over the communication lines, then reassembled when all the pieces had reached the destination computer. This was how packet switching worked.

Different computers used different software. This posed a serious problem for a computer network, in that different computers would have to have their software altered significantly, in order to handle the network traffic. Researchers at the Advanced Research Projects Agency

(ARPA) arrived at the solution through mini-computers. A separate, inexpensive mini-computer, known as an Interface Message Processor (IMP), would be placed at every node in the network to handle all the data communications traffic [65]. Host computers sending the initial communique would only require slight modification in order to send and receive data from the IMPs. ARPA had a four-node network operating by 1970 [65]. It was the ARPAnet that spawned the Internet that hundreds of millions of people now use across the globe.

The Western Australian Regional Network would use this same technology. It was conceived as a communications system to which a number of independent host computers and user terminals would be connected [62]. A network would be able to accept additional host computers. The initial report on the network stressed that these hosts would need to be independent with autonomy [62]. The network would thereby foster decentralisation. In effect, the seeds of decentralisation would reach full bloom with the evolution of a Regional Network.

Although there was discussion and research within WARCC from 1974, the development of a Regional Network was slow. High capital costs were associated with a Regional Network. By 1977, the SEC and Forests Department had started to extend access to their computers to country centres using telephone lines [66]. By September 1977, the WA Government Computer Policy Committee had yet to comment on the WARCC Board’s Network Report [67]. Despite this, WARCC had made some progress in developing an experimental facility. This gave terminal users access to the WARCC CYBER, DEC-10 and to the WAIT DEC-10 [67].

Computer networks would decentralise computing across the developed world and beyond. Mini-computers and packet switching technology had set the scene for greater access to computing. Groups with mini-computers could access large mainframes through a phone connection, or in some cases a direct cable. Powerful computing was therefore potentially on tap to smaller peripheral users. Yet the final blow to the centralised computing concept came in the form of the microcomputer.

5.11 Microcomputing

Microprocessors were the enabling technology of the personal computer [68]. Invented in 1971 they were not widely available until 1973 [69]. By 1979 microprocessor sales had reached 75 million [69]. The microprocessor was essentially a computer on a chip. With a microprocessor, a small, low powered, computer could be built that would fit on a desktop. Mass production had lowered the price of these processors to the extent that the electronics hobbyist could afford to purchase them. In 1975 the first commercially available kit computer, which would fit on a desktop, appeared on the cover of *Popular Electronics*. It was the Altair 8800.

In the early 1970s, the idea of an individual owning a personal computer was no more than a wild dream [70]. The

Altair and similar kit computers changed that dream into a reality. It was not technological innovation alone that brought personal computing to the masses. A hobbyist culture took to the inexpensive microprocessors and kit computers shaping them into home computers. Bill Gates and Paul Allen (co-founders of Microsoft) relied on the hobbyist electronics magazines, such as *Popular Electronics* and *Radio Electronics*, to stay up with the latest technological developments [70]. Many more like them met at the Homebrew Computer Club. This informal group had been meeting in Menlo Park on the edge of Silicon Valley, California since 1975 [71].

Once assembled, the Altair was a rectangular box filled with wires and a chip. On the exterior there were a few light-emitting diodes. That was it. The Altair was not designed for connection with a display monitor. If the owner wanted to make the machine perform a task it was their responsibility to create the hardware. Hence the Altair was not a user-friendly product. Altair sales were huge. In three weeks, Model Instrumentation Telemetry Systems (MITS) went from being in the red to having a cash flow of over
$US 250 000 [72].

The significance of the Altair was that it provided a focus point for enthusiasts across America. They could meet, exchange ideas and help each other get the “darn thing working”. The machine brought people of a like mind together. Gates and Allen worked for MITS writing a version of the BASIC computer language for the Altair.

MITS sales also illustrated that a microcomputer could be a viable business venture. Start-up costs for a business in the microcomputer market were, initially, low. Here was a window whereby entrepreneurs could achieve entry into an embryonic industry. Large companies such as IBM initially waited in the wings without selling microcomputers. There was a space for small start-ups to enter the market before the giants awoke to the market potential.

The people who were willing to take advantage of this opportunity were those willing to risk being on the innovative frontier. It is not surprising that the first successful computer to reach beyond the hobbyists and into the homes of non-experts came from two regulars of the Homebrew Computer Club, Stephen Wozniak and Steve Jobs, co-founders of Apple computers. Their machine was the Apple II. Their company, along with others such as Tandy and Commodore, showed that the peripheral microcomputer industry could be a major business concern. Their vision was confirmed when the then computer industry giant, IBM, released its own personal computer (PC). During 1982-3 the IBM PC became the industry standard [73]. As Table 5.3 illustrates, by 1980 there were well over half a million microcomputers in homes around the developed world [74]. Microcomputing had therefore moved from the periphery of the industry to the centre.

Table 5.3 Desktop Computer Installations Globally 1977-9 [74].

Computer Type	1977	1978	1979 (estimated)
Tandy TRS-80	unknown	70000	180000
Commodore PET	unknown	47000	127000
HP 9825/35/45	unknown	45000	70000
Apple II	unknown	18000	63000
Others	unknown	46000	116000
Total	53000	226000	556000

By April 1980 there were 30 mini-computers on the UWA campus [75]. Large numbers of mini-computers could be found in Crystallography, Mechanical Engineering, Psychology, Electrical Engineering and the Reid Library [75]. There were also a large number of microcomputers, yet the exact figure and distribution is uncertain [75]. Microcomputers were affordable enough to be purchased by individual researchers, yet were low powered when compared to the mini and mainframe computers.

WARCC's equipment inventory from May 1980 lists several PDP-11 mini-computers and no microcomputers [75]. This could indicate the perception that microprocessors were not sufficiently powerful to warrant inclusion on the Centre's inventory. It could also suggest that many of the microcomputers on campus were probably personal possessions.

The first funds allocation request for a microcomputer that is listed in the UWA Archives was on the 7th October 1982 [76]. This was for an Apple II computer for the UWA Department of Education. In 1983 it was forecast that 80 percent of the UWA

Faculties would have microcomputers by 1987 [77]. Hence microcomputers were making their way onto the UWA campus, in an official capacity, through the 1980s.

Where mini-computers had placed machines in small Centres and Departments, the microcomputer would place an information tool in the home. Computers had once been the tools of groups and centres. They were now devices designed for the individual. Regional Centres, and the mainframes that ran in them, were becoming like dinosaurs. In skilled hands, the personal computers of the 1980s could weave through the networks accessing powerful machines, often without permission. Computing had at last reached the hands of the individual. It had ventured from the large spaces of the scientific laboratories, out to the centres of computing such as WARCC, then into the bedrooms of teenage computer wizards.

5.12 Conclusion

WARCC was formed through a need for computing power, an impetus provided from Federal Government funding policy and an existing situation of close co-operation between State Government and UWA interests. Of all the computers available in 1972 the CDC CYBER 72 offered the best solution to WARCC's aims. Exchange of information and technical knowledge assisted with the growth of the Regional Centre. Although they made up approximately half of the WARCC staff, women, on aggregate, did not have influential roles at WARCC. Women's career paths and positions at

WARCC in the 1970s tended to reflect cultural expectations and gender inequities in WA. WARCC grew rapidly to become a successful commercial venture. Yet, the need for clients to have greater access, autonomy and interaction with computers, saw a trend of independent mini-computer purchases from the mid 1970s. The centralised computing concept fragmented in the 1970s. The proposed Regional Network inherently fostered decentralisation. Microcomputing took the information machine out of the centres and into the home. Regional computing would still continue to exist, yet, symbolically, its role as the major access point to computing power had diminished by the end of the 1970s.

6.0 Gender and Computing

6.1 Introduction

One of the tenets of the **Cyberhistory** thesis is that gender is a central issue in respect to computing and its history. The following seeks to explore the concept of gender in relation to computer history. It does this through seven sections, each dealing with one significant aspect of gendered computing.

The Room argues that the computer provides the user with the freedom of a room of one's own. **The Weave** seeks to link computing to the cultural sphere of women. **Ada and the Engine** examines the contribution of the enchantress of numbers to computing. It asserts that she was the first programmer and master of software. **Hard Master – Soft Master** examines two different approaches to computers and suggests that the acceptance of one brings highly imaginative and creative skills to computing. **Women on the Machines** locates women in the early history of computers. In particular it portrays their dominance of software. **The Turing Test** discusses an unperson of computer history, one whose life was ridden by internal gender issues. Turing is included, due to the fact that his gender identity (Turing was homosexual) affected his role in, and approach to, computing. ***Machina*: the Gendered Computer** seeks to argue that gender is ascribed to technology by human culture. **Cyberspace: Gender Online** returns to the notion of the room as a place of expression. It argues that the Internet is not a utopia, that a hacking ethos and critical thinking are methods that can circumvent the pitfalls of the Internet, and that communal online forums can act as a sanctuary.

6.2 The Room

The following section is a journey into the room of the computer. It begins with a place of privilege and moves to spaces where individuals suffer from constraint. It asserts that the room is the reification of personal space. It asks is there a space where the freedom exists to alter personal space and self-image? Then **The Room** proceeds to illustrate that the computer can offer “a room of one’s own”.

Imagine standing in Peckwater quadrangle, Oxford University, 1926, the grooves of Panelled Oak lead to a doorway. After a nervous knock at the door a voice from within bids entry. Daylight is left behind in a single step. Heavy curtains blanket the room in darkness. As young eyes grow used to the dim a decaying form of an orange might be glimpsed on the mantelpiece. All attention gravitates to the seated figure ahead. Eerily by a half hidden lamplight the smooth facial lines are illuminated casting deep shadows over the recesses of the eyes. The line of the mouth is set in an unmistakable pout. The seated figure is W.H Auden and the room is filled with his presence [1].

Auden in his undergraduate years had already the confidence to state to his tutor that he was going to write poetry not as an exercise for his English skills, but in order to be a great poet [2]. Auden was well aware of his mythical status among other undergraduates. His reconstruction of the reality in his rooms extended out into the quadrangles through a distinct manner of dress,

> ‘at various times he was seen with a cane and a monocle, or in a clergyman’s panama hat, or an old medical jacket of his father’s, or if he had suddenly decided to look fashionable (which sometimes happened), his double breasted brown suit.’ [1].

Was Auden’s freedom to alter room space and self-image an integral factor in his flowering as a great poet?

May 1999. The Palace Mansion. Cyberspace. Within the mansion is a staircase that opens out onto a first floor landing. On this landing stand and sit two-dimensional avatars. Some hover on the wall, others disappear through one of the three doors leading off the landing hyperlinked to another room, like matter passing through a wormhole and into another universe. The air is one of casual conversation. Speech blurbs communicate the participant’s conversation. The use of text invokes a slang that suits the fast communication of ideas.

Discussion in the Palace is occurring in a programme generated by a computer somewhere in America yet the participants are seated at computers all around the globe from Manhattan to Auckland. Symbolically this interaction is occurring in a room, a virtual construct in the metaverse [4].

The Palace is virtual reality software for Chat, developed by Time Warner [4]. Anyone with a computer and Internet connection can down load the software for free and enter the Palace environment placing a two dimensional image or avatar into one of the many three dimensional spaces that the Palace offers. Some rooms are communal. Other spaces are private. There are also any number of rooms that are constructed by the participants. These are personal spaces into which others may only be invited. The Palace is therefore an example of how the computer can offer a room of one's own.

The significance of the Palace and other software like it is that it allows users to alter their own image and spatial surroundings in a virtual sense. Avatars can be changed so that in one instance a person is being represented by the image of an actor and the next by a cartoon character. Paint style software allows users to design their own avatars, a process that is not unlike Auden's dress sense while an undergraduate. The individual has freedom to alter their self-image.

In a computer generated environment individuals can choose how to present themselves to others. This freedom gives them a space to express creativity, the kind of freedom without censure that Auden enjoyed while at Oxford. The virtual space is liberating in that it can release desires and expression that would be subject to constraint in normal "real" society.

On the Palace a female computer user may present as a male. Her avatar may be a genderless object. She may also choose to display as a half naked female pop star. The important consideration is that it is her choice. Even her name can be a male's name or an indeterminable moniker. As in real life, others respond to male and female avatars in different ways, yet in the virtual world the user can anticipate this and choose how to present. In the real world there isn't always the provision of a free space.

At Oxford Auden had sufficient area in his dormitory to be able to install a piano in his walk-in wardrobe [1]. With this fact in mind consider;

> 'One has only to think of the Elizabethan tombstones with all those children kneeling with clasped hands; and their early deaths; and to see their houses with their dark, cramped rooms, to realise that no woman could have written poetry then' [5].

The above is an extract from *A Room of One's Own* written in 1929 by Virginia Woolf. She argued that a woman needed access to a creative space such as that which Auden enjoyed at Oxford. Constrained by enormous cultural pressure, young women could not carry a reconstruction of image into public. Trapped in a public space, lacking a private sphere, the young woman starved of creative nourishment, like a sunflower left in a dark room to slowly wither, hanging on to the last in quiet desperation. Here the reification of a woman's personal space is the room.

By providing an artistic space the computer is thereby a vehicle through which the hitherto excluded can craft their personal compositions. Technology is liberating. In a short story titled *Winter Market*, William Gibson wrote of a girl who could articulate dreams in a format that others could experience. The fictional technology is sim-stim, (simulated stimuli). A trode connection is made between areas of the brain that generate sound, sight and feeling. The artist is thereby able to lay down tracks of dreamings that others may tap into via technology. In a poignant moment Gibson conveyed the sense of loss of the thousands who had the talent to create via this fictional medium yet died before the technology became available,

> 'It was like she was born to the form, even though the technology that made that form possible hadn't even existed when she was born. You see something like that and you wonder how many thousands, maybe millions, of phenomenal artists have died mute, down the centuries, people who could never have been poets or painters or saxophone players, but who had this stuff inside, these psychic waveforms waiting for the circuitry required to tap in…' [6].

In fiction as in reality the computer can unlock the door to a realm of artistry.

Woolf's anger and frustration was that the lack of a room or creative space was permitting this kind of loss to occur. She strained at the chains of a society that excluded women from university, tied them to the wishes of a provider husband and robbed them of a chance to earn their own income. Tied to a culture of exclusion they were thereby denied the opportunity to find their own place in the world. They were disallowed choice.

The notion of a private world is closely coupled with the room. Auden's living quarters and his manner of dress could be seen as excerpts from his inner world. During 1927, Auden produced a poem which marked a turning point in the search for his own poetic voice [7].

'Last night sucked giddy down

The funnel of my dream,
I saw myself within
A buried engine-room.
Dynamos, boilers, lay
In tickling silence, I
Gripping an oily rail,
Talked feverishly to one
Professional listener
Who Puckered mouth and brow
In ecstasy of pain,
'I know, I know, I know'
And reached his hand for mine' [7].

Dream atmosphere. Falling motion. Pea within pod. Child within womb. The poet appears extremely vulnerable in the above stanza. Plunging through wall on wall of thick curtain the reader reaches a serene space, a soft core at the heart of the poet's being. Auden invites the reader into his dream, as he would beckon a friend into his room. The vision is located within an engine room. The soft sensitivity of the poet is encapsulated by metallic machinery.

The Palace has a seemingly endless number of rooms branching off from the main nodes. Picture a large opulent house with hallways [8]. On the walls are hung images by Escher and, as the avatar enters a new room, sounds traverse the Internet. In one room it may be a Bach concerto, in the other the Velvet Underground whispering in the ambience. This is a private interior, a room that a person can only traverse if invited by its creator. There are hundreds of such rooms linked to the Palace, strung out in cyberspace like parallel dimensions. Within each space the thoughts of the interior's creator is locked inside the circuitry of the information machine like the poet within the engine room.

The computer provides a dream space, an area in which creativity can flourish. As the ink flowed from Auden's pen rendering the blank page before him with poetry, so too can coloured pixels in cyberspace depict text and images with the elegance and beauty of Auden's work. The computer is therefore a canvas, a blank page on which a person is limited only by imagination. With a computer as a tool, a person can render the blank page priceless.

Images of the human form connected with machinery recur in works outside of Auden's. Unlike the young Auden, Virginia Woolf preferred to bathe her room in natural light:

> 'Next day the light of the October morning was falling in dusty shafts through the uncurtained windows, and the hum of traffic rose from the street. London then was winding itself up again, the factory was astir; the machines were beginning.' [9].

In this fragment the city becomes a metaphor for the machinations of a factory. This industrial plant brimming with activity is fuelled by the multitude of people who line its components like a lubricant, protecting the city from decline and decay.

On the city's thoroughfares, walking to and fro', are dozens of personal spheres, imaginations, memories. Each thought is individual and distinct, in vivid contrast to the uniformity of the machine. As the view moves from the apartment window and pans up over the architecture and streetscapes it becomes clear that the city is filled with rooms, many of which house creative spaces – rooms of one’s own.

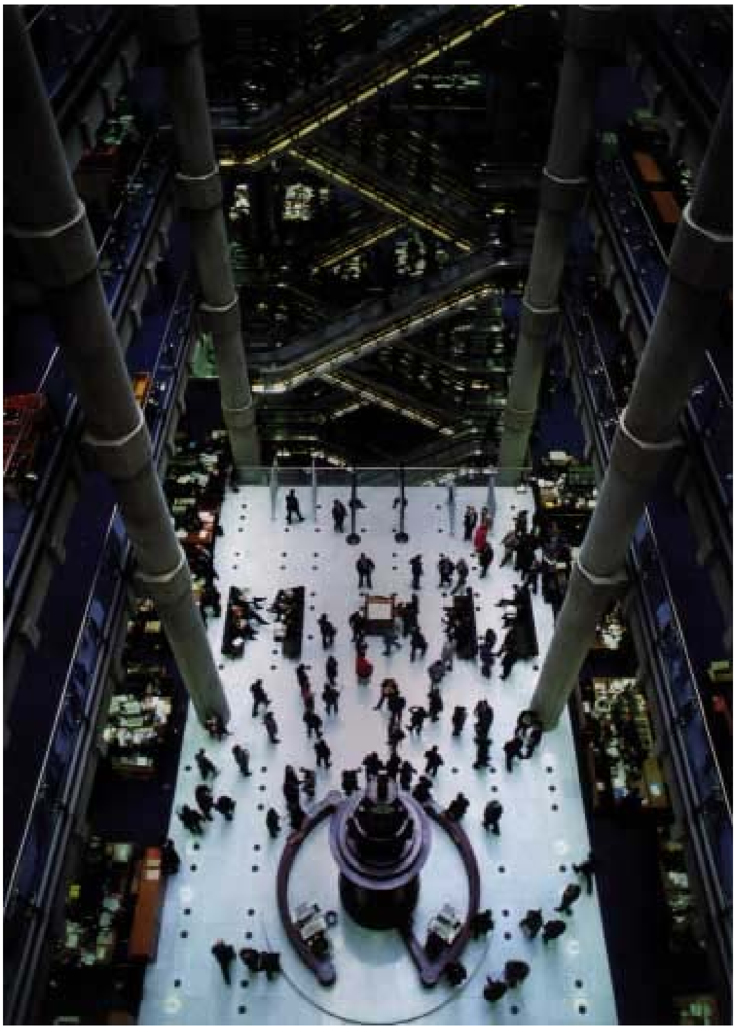

Figure 6.1 Lloyds of London stands like a gothic cathedral of the late twentieth century. The design was originally more streamlined yet had to be extended, due to the introduction of copious amounts of office computing. Service towers to the side of the building were reinforced and now appear like medieval towers. In **Figure 6.1** the huge atrium can be seen. The atrium runs through the centre of the building linking all the levels in one symbolic room.

Courtesy of Janet Gill/Richard Rogers Partnership 2001.

In 1688 Edward Lloyd, a Welshman, opened a coffeehouse on Tower Street, London [10]. On May 27th 1986 the latest incarnation of that humble coffeehouse opened for business on Lime Street [10]. Lloyds is a corporation of insurance syndicates. Each syndicate appoints one or more underwriters to insure goods against loss on their behalf. A broker basically acts as an intermediary to those seeking insurance and the underwriters. Central to the business at Lloyds is the meeting between the underwriter and the broker. Lloyd's activities are based on personal contact. These exchanges take place in what the people at Lloyds call "The Room". Within this space one percent of the world's insurance transactions take place [11]. In Lloyds the room is therefore a communicative space.

Richard Rogers is an architect. His 1986 Lloyds building stands like a gothic cathedral in the heart of London's old financial district. Unless a viewer takes to a helicopter a view of Lloyds is never complete. As a pedestrian approaches along the medieval street plan of London, Lloyds can only be glimpsed from hundreds of angles [12]. The mental image of the Lloyds building must be bolted together like the panelling and trusses of a meccano set. The structure eludes total comprehension and so like a puzzle retains a mystery, which entices the senses thereby fixing a place in memory.

Like the room at Lloyds, linked computers form communicative spaces. As personal computers became widespread in the 1980s the early Internet contained Bulletin Board Systems (BBS) where initiates could log on and leave messages. They could form friendships, exchange information, and conduct romances in cyberspace.

The BBS of the mid to late 1980s were largely composed of young men yet there were women who played key roles. For instance in Melbourne around 1986 a BBS was run by a female called The Real Article [13]. She was the only female to play a major role in the early Melbourne underground scene [13]. Dreyfus [1997] writes,

> ‘Although she didn’t hack computers, she knew a lot about them. She ran the Real Connection, a BBS frequented by many of the hackers who hung out on PI [another popular BBS at the time]...Forthright and formidable, The Real Article commanded considerable respect among the underground. A good indicator of this respect was the fact that the members of H.A.C.K had inducted her as an honorary member of their exclusive club...The Real Article knew how to lend a sympathetic ear to those [with] problems. As a woman and a non-hacker, she was removed from the jumble of male ego hierarchical problems associated with confiding in a peer. She served as a sort of mother to the embryonic hacking community’ [13].

The Real Article’s involvement in the BBS scene is significant in that it illustrates that a woman was able to enter a male dominated scene and retain their respect. She was also able to develop and control a communicative space that was essentially a room like the domain in Lloyds. It was a place of interaction and exchange.

The Real Article, while a young mother, had access to a computer and a modem. With these tools she could create and control a room of her own. Despite her living circumstances in the real world, she was able to shrug off real world inequity and move beyond the confines that she faced there. Her role on the BBS and her contribution was her choice. Her computer was therefore liberating in a way that the cramped rooms that Woolf observed in Victorian England were not.

Despite The Real Article being just one woman and an untypical case at the time, her involvement did demonstrate the possibility of the networked computer. She was a role model to both the young males that frequented her BBS and other females who were considering entering the electronic realm. The Real Article had demonstrated that the constraints that Woolf had written of could be negotiated and thwarted. These constraints were like a skulking troll guarding a bridge to better pastures.

Three Billy Goats Gruff is a nursery story that frightens children yet also makes them aware of a pearl of wisdom. Scary though the horrid troll may be, there is always a way around an impasse for the weaker goats. Intelligence is the key to outwitting the troll.

Paul, a network hacker in the late 1980s, was captivated by this tale as a child. In the story barriers are there to be penetrated. A prevailing attitude among the hackers is that obstacles to further knowledge should be rendered null by the ingenious efforts of those who are hacking. By a hacker it is meant a person who explores computer networks, often cracking passwords in order to access new domains. The troll may be fierce and strong but it is not clever.

New York's turbulent streets spawned a gang culture among disenchanted youth. In integrated working class inner city suburbs many parents were happy just to keep their children off the streets. Paul was from an immigrant Lithuanian family [14]. He could read before he commenced school. Similarly he could programme before he received his first computer in 1983. It was a Commodore 64 (C-64). Paul's virtual gang was the Masters of Deception (MoD). They were sharp, technically gifted and online.

The C-64 was part of the computer as appliance phenomenon that began in 1977 and grew into the 1980s [15]. Suddenly homes in the US, Europe and Australia were reverberating to television advertisements asking, "are you keeping up with the Commodore, because the Commodore is keeping up with you". No assembly was required. The unit was small enough to fit on a bedroom desk. Kids like Paul would spend countless hours in their bedrooms exploring the intricacies of their new tools.

Note that the network was explored from the safety of a bedroom. For a teenager a bedroom is like a sanctuary. Posters, paintings and assorted artefacts from the room of a youth can tell the observer of the importance of this space to the individual. They are expressions of identity and are usually the only place in a household were such expression can take place. That the computer was placed in the bedroom is equally indicative of identity. Here was a tool that youths could use to redefine a perception of themselves.

Picture being back at that same doorway at Oxford University. Looking down the hall you would see a long corridor with many rooms branching off. The above has shown the room to be an integral part of computing and a significant component of gender concerns in computing. This is because a private room is liberating. ‘The Room’ has argued that the freedom to alter space and self-image is an integral part of individual development particularly in relation to artistic pursuits. The computer can offer a room of one’s own. It provides the user with the freedom to alter self-image in a non-threatening environment. The virtual space is liberating. The computer is a canvass and a doorway to communicative spaces.

6.3 The Weave

Madame De Farge sitting knitting is a pervasive image from Dickens’ *Tale of Two Cities*. Early in the novel she knits a vigorous stitch as if recording the sins of aristocrats in a mnemonic device. Later the significance of those stitches becomes chilling as de Farge sits in the front row of the guillotine spectators, as if to keep a record of the executions in her stream of endless knitting. The computer is the fabric, knitted together by streams of ones and zeros, patterns in the weave.

This section asserts that weaving has been traditionally placed by culture within the sphere of women, then proceeds to show

how computing grew out of weaving technology. It asserts that weaving and the women's sphere are at the symbolic heart of computing and that access to technology can be liberating.

Weaving, knitting and the construction of fabric have been placed in the sphere of women. Western culture associates women with these occupations. Yet, for centuries weaving was already multimedia: singing, chanting, telling stories, dancing, and playing games, spinsters, weavers, and needle workers were literally networkers as well [16]. Spell craft, incantations, and magic are also women's spheres ordained by culture. Yet these are the foundations upon which computing is built. Hence, whether it has been realised or not, computing is also within the bounds of the sphere of women. How then are these the principles upon which computing has been crafted?

The Jaquard loom was an application of mechanical technology to the weaving process. With it great tapestries could be assembled in less time than it would take a team of workers. Cards programmed patterns in the looms. Each card controlled the selection of warp threads that were to be raised ready for a single passage across the loom of a shuttle carrying the weft thread [17]. These cards were instructional devices in which were held the secret code that could generate the design on the tapestry. They were like the software that would control the actions of the modern computer.

Figure 6.2 An image of the Jaquard loom. Note the punch card apparatus to the left of the device. Jaquard was able to mechanise iterations of patterns in the final fabric through looping the punch cards. Courtesy of Deutsches Museum 2001.
Source: www.deutsches-museum.de/ausstell/meister/e_web.htm

It is significant that the card-like software originated in the sphere of weaving, a cultural space that for centuries has been the domain of women. Consider that when a person knits a garment they are knitting to a pattern. They follow a code of stiches that is almost identical in concept to a programme. Jaquard was merely taking this code and placing it in the medium of the punch card. The code controlled the machine. Through code-work women could control it also.

Charles Babbage, when considering his design for the analytical engine, viewed the card system as employed on the

Jacquard loom as a method in which instructions could be conveyed to his machine. Hollerith developed a similar card input device for his tabulators that were employed in the process of sorting the 1890 USA census. Hence weaving and the women's sphere are at the symbolic heart of computing. Computing grew out of weaving technology.

Within this growth is yet a further aspect of the link between industrial Manchester and computing. It was in Manchester, in the mills that drove the global textile industry, that the new loom technology was employed. Weaving was mechanised and systematised. Yet for centuries women had actively employed the knowledge, the logic and the systems of fabric production. While weaving was a cottage industry it was women who sat at the loom. When it moved to the new industrialising factories it was women who toiled in the mills alongside the new machinery.

On the eastern seaboard of North America in the 1830s and 40s textile manufacturers drew their employees from the surrounding rural communities. One such town was Lowell in New England, America. The women in the Lowell mills formed close knit peer groups. They dwelt in boarding houses. Hence they lived and worked together. They were young and single. This was very much an all female environment.

Surrounded by the new technology, skills and abilities that were suppressed in wider society came to the fore. The young women developed a high sense of dignity in themselves and a strong sense of social equality [18]. Such energy was expressed in the formation of groups such as the Factory Girls

Association (1836) and the Lowell Female Labor Reform Association (1845) [18]. Bound together by work and the technology the women of the Lowell mills were engaging in a new assertiveness and independence that was absent in the rural communities where they had grown up. They were therefore more liberated.

Karl Marx and Engels may have seen the countless mill workers in Manchester as exploited and manipulated. Marx wrote his *Communist Manifesto* after spending some time in Manchester. That conditions were terrible and pay was meagre is true. It could be viewed that technology was being used to wrestle power from the women in the cottage industries and exploit those who worked in the factories. Yet this opinion can be ameliorated with a consideration of the Lowell case, a situation that was not untypical in America and Britain.

As they toiled in the fibre filled air of the textile mills these women formed mutual bonds and developed a conscious sense of community [18]. Such group identity led to collective action for better working conditions by these same women. In 1834 and 1836 there were strikes to protest wage cuts, and in 1843 and 1848 there were petition campaigns to reduce the hours of work [18]. They had been brought together by the mill technology from the patriarchal rural hinterland, given money then, as a unit, political and industrial power. Technology had opened a path to greater freedoms.

Significantly it was the women who were using the technology. They were close to the looms and instruction cards. Through mill work, weaving had been brought into the factory yet it still remained within the women’s sphere. A century before Woolf wrote of the need for a room, women were already experiencing that technology could be a path to greater liberation. That men owned the mills is an example of a greater inequity. While these greater inequities of the mills were not redressed, political action and better conditions did represent an important step forward. With technology women could progress.

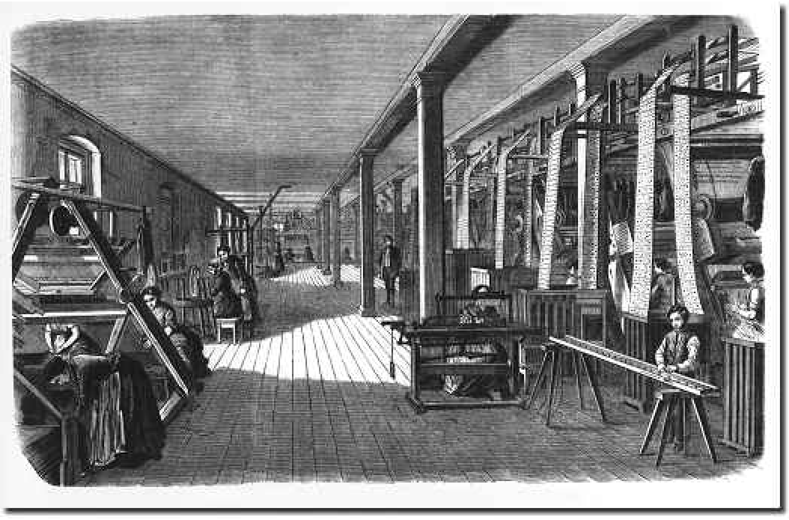

Figure 6.3 Jacquard pattern looms in the factory Gevers & Schmidt in *Schmiedeberg* (*Silesia*, Germany). The pattern is entered via the punched cards. The image is a wood engraving from 1858. Note the depiction of women working on the looms. Courtesy of Deutsches Museum 2001.
Source: www.deutsches-museum.de/ausstell/meister/e_web.htm

Liberation is a relative measure. Despite the realisation and action against gender inequity in the late twentieth century women still are on the factory floor in disproportionate numbers. Yet the technology with which they work is that which underpins the new information economy of the twenty first century. ‘Silicon Valley, Silicon Glen, Bangalore, Jakarta, Seoul, and Taipei provide dispersed networks of what US multinationals call “virtual aliens’ to fabricate the wafers, assemble the circuits, set up the keyboards and the screens, make the chips that turn the computers on.’[19]. Consider that the ‘overwhelming majority of electronics assembly jobs are occupied by young female workers on relatively low wages’ [19] and the mill inequity seems to have lingered on in time. In a very real sense the economic and cultural troll on the bridge to greater liberty and equality still needs to be outwitted.

Weaving knitting and patterns are all notions that are close to the core of computing. The computer is like the fabric, knitted together by streams of ones and zeros. Computing, like weaving, is linked to the cultural sphere of women. Computing grew out of weaving technology. Women worked with the card technology on the Jaquard looms and computers initially used this technology to convey instructions. Women are therefore historically involved with the technology at the dawn of computing even though they were not in a position to control or direct the growth of computer technology. By having access to work and technology women were more liberated yet even in 2001 there are greater inequities to be redressed.

Figure 6.4 A Comparison of Knitting and Assembler Code.
Note that both codes utilise a simple instruction set. In each the code is followed in sequential iterations until the desired result is produced. The knitting code produces a poncho. The assembler code reads two characters and prints them on a screen.
Poncho pattern source:
http://knitting.about.com/hobbies/knitting/gi/dynamic/offsite.htm?site=http://www.craftyarncouncil.com/projects/proj%5Fkn%5F1099.html
Assembler Code source:
http://packetstorm.securify.com/programming-tutorials/Assembly/online-tutorial/examples.html#b

Knitting Code

name of pattern: PONCHO
With smaller circular needle and 3 strands of yarn held tog,cast on 44 (48, 52) sts.
Join, taking care not to twist sts on needle.
Place marker for beg of rnd.
Work in K 1, p 1 rib for 2 rnds.
Next (eyelet) rnd:
*K2tog (insert RH needle from front to back through 2nd st and then first st on LH needle and K them tog),
yo (with yarn in front, wrap yarn over the RH needle from front to back);
rep from * around.
Work 1 rnd k 1, p 1 rib.
Change to larger needle and work in St st (k every rnd) for 3 rnds.
Next rnd:
K 1,
[k 11 (12, 13), place marker on needle]
3 times,
k 10 (11, 13).
Next (Inc) rnd: K1, inc 1,
[k to next marker, slip marker, inc 1, k 1, inc 1]
3 times,
k to end of rnd, inc 1 before end of rnd marker (8 sts increase).

Abbreviations
beg: begin(ning)
cont: continue
inc: increase
k: knit
LH: left-hand
p: purl
rep: repeat
RH: right-hand
rnd(s): round(s)
st(s): stitches(es)
St st: stockinette stitch
tog: together
yo: yarn over

Assembler Code

```
;name of the program:one.asm
;
.model small
.stack
.code
      mov AH,1h       ;Selects the 1
                       D.O.S. function
      Int 21h         ;reads character
                       and  return ASCII
                       code to register AL
      mov DL,AL       ;moves the ASCII
                       code to register DL
      sub DL,30h      ;makes the
                      operation minus
                      30h to convert 0-9
                      digit number
      cmp DL,9h       ;compares if digit
                      number it was
                      between 0-9
      jle digit1      ;If it true gets the
                      first number digit
                      (4 bits long)
      sub DL,7h       ;If it false, makes
                      operation minus
                      7h to convert letter
                      A-F
digit1:
      mov CL,4h       ;prepares to multiply by
                      16
      shl DL,CL       ; multiply to convert into
                       four bits upper
      int 21h         ;gets the next character
      sub AL,30h      ;repeats the conversion
                       operation
      cmp AL,9h       ;compares the value 9h
                       with the content of
                       register AL
      jle digit2      ;If true, gets the second
                      digit number
      sub AL,7h       ;If no, makes the minus
                       operation 7h
digit2:
      add DL,AL       ;adds the second number
                      digit
      mov AH,4CH
      Int 21h         ;21h interruption
      End             ; finish the program
code
```

[This program reads two characters and prints them on the screen]

6.4 Ada and the engine

European folktales are full of references to the making of magical garments, especially girdles, in which the magic seems to be inherent in the weaving, not merely in special decoration [20]. With computers it is the software that creates the magic that users perceive projected on the screen. The software lies below the surface as if encoded in the fabric of the machine. It isn't visible to the user, yet the end product, the 'special decoration', is visible. It is no co-incidence that the first programmer was a young woman, Ada Augusta Byron, countess of Lovelace and daughter to Lord Byron the poet. The following section seeks to place Ada Countess of Lovelace into the scheme of computer history. It asserts that Ada embraced technology, asking how it is that she became the first master of software.

In his maiden speech to the House of Lords in 1812, Lord Byron offered his support to the Luddite rioters who bitterly opposed the new loom technology [21]. He stated, "By the adoption of one species of frame in particular," he said, "one man performed the work of many, and the superfluous labourers were thrown out of employment. Yet it is to be observed that the work thus executed was inferior in quality; not marketable at home, and merely hurried over with a view to exportation. It was called, in the cant of the trade, by the name of 'Spider-work.'" [21].

The Luddites had not perceived that the technology could be liberating. For them the status quo was what mattered. Yet as noted above loom technology in the factory did provide tangible benefits to the majority of women who were employed in the mills. Yet giving power and independence to women was a new concept and would not have trucked well with the conservatism inherent in the Luddite cause.

Unlike her father, Byron's daughter embraced technology. In 1833 a teenage girl met a machine which she came to regard "as a friend." [22]. It was a futuristic device which seemed to have dropped into her world at least a century before its time [22]. This was Babbage's Difference Engine. An onlooker, Sophia De Morgan recorded Ada's first encounter with the machine,

> 'While other visitors gazed at the working of this beautiful instrument with the sort of expression, and I dare say the sort of feeling, that some savages are said to have shown on first seeing a looking-glass or hearing a gun...Miss Byron, young as she was, understood its working, and saw the great beauty of the invention.' [23].

Ada knew very little of mathematics when she saw the difference engine and contemporary evidence suggests that at the time of her first visit her mother had a greater understanding of the significance of the machine [23]. Yet the depiction of this first encounter conveys a symbolic understanding. Rushkoff notes that in science fiction over the last twenty years of the 20th century, children are placed close to the technology [24]. That is, there is an association between technology, computers and youth. In films such as the Japanese animation the 'Akira' [Katsuhiro Otomo 1988], children have an ability to understand the secret workings of technology. Ada's lack of fear and her acceptance of the difference engine conveys this notion. Due to her youth she had a better handle on the concept of Babbage’s engine.

That she was not versed in complex mathematics at this stage did not matter. She was later able to acquire an in-depth understanding of Babbage’s engines as is evidenced in her translation of the Italian engineer Menabrea’s text on Babbage’s second and more complex analytical engine. In this translation Ada annotated each section with such skill and craft that her translation outweighed the original document in terms of insight [25].

In 1842 Louis Menabrea, an Italian military engineer, had deposited his *Sketch of the Analytical Engine Invented by Charles Babbage* in the *Bibliotheque Universelle de Geneve* [25]. This was the paper that Ada translated from French into English in late 1842-3 [26]. Her translation offered insight that was absent in the original paper. This is best indicated by the fact that when Babbage saw the translation, he wondered why Ada had not written an original work [26].

Babbage was born in London in 1791. The son of a banker, Babbage was a man of means yet not an aristocrat [27]. As a student at Cambridge he gathered a group of like minded individuals together in order to attempt to reform the state of mathematics in England, which at the time was far behind the Continent, particularly France. This was partly because of the great veneration in which Newton was held [27], which inhibited progress. Babbage was therefore not content with the status quo and was continually looking towards change and progress. Like Ada he had no fear of new machines.

The impetus behind Babbage developing the difference engine was the need to produce error free numerical tables of various kinds [27]. He was sitting in the rooms of his Analytical Society looking at a table of logarithms, which he knew to be full of mistakes, when the idea occurred to him of computing all tabular functions by machinery [27]. Babbage was therefore motivated by the pursuit of accuracy and efficiency.

Babbage had a working model of the difference engine in 1822 [28]. It essentially worked by connecting a number of columns of discs in such a way that the successive numbers on each were added to the column next in line [27]. Each disc was attached to a gear with ten teeth that corresponded with the digits 0-9 on the disc. A number on one column of discs could be added to another column by a gear mechanism. The principle on which the engine worked centred on the fact that many mathematical functions can be approximated by several terms of a power series [27]. The successive values of the powers of any number, and the sums of power series, can be arrived at by repeated additions of several orders of differences between terms [27]. What separated the difference engine from other calculating machines was that once it was set up, it would proceed through all the necessary steps without intervention [27]. Babbage had thereby taken a mathematical principle and incorporated it into a machine.

Ada met Babbage at a party in June 1833 [29]. It would be a mistake to consider that this access to one of the great minds of her time was common for single young women. It was not.

Unlike Babbage, Ada was an aristocrat. She also hailed from a very unusual aristocratic family. Her mother Annabella had successfully separated from Lord Byron retaining a substantial hold on her wealth and position in society [30]. This was the early nineteenth century when most upper-class young men went to university to finish their education and could take a degree merely by fulfilling the residency requirements [31]. Women did not go to university. The path of women through life was to find a suitor and marry. Annabella went against convention by taking a strong independent stand. Annabella's attitude was an influence on Ada, for her mother actively encouraged her to seek knowledge.

Annabella was subjected to the vagaries of a female education where the focus of the exercise was to prepare young women for marriage. Yet she was opinionated, decisive, robust, precociously studious and, unlike many of her female peers, had engaged in the study of mathematics [31]. Her window into the predominantly male world of mathematics was William Frend, a mathematician and friend of the Milbankes – Annabella's parents [31]. Ada's mother was therefore untypical.

On successful separation from her errant husband, Lady Byron instilled the same hunger for knowledge in her daughter. She did this through rigorous instruction as well as connections with mathematicians and scientists. Ada, therefore, was given the opportunity to advance her intellect, from her position in society and the independence achieved by her mother.

After seeing the engine in 1833 Ada set about to learn as much as possible about it. She read an article by Dionysuis Lardner, attended his lectures at the Mechanics Institute, received explanations from Babbage, and even borrowed plans of the engine [26]. She was being schooled in mathematics by Dr. King at her mother's request and had progressed to the extent that he freely admitted that Ada surpassed his knowledge [26]. Ada therefore had access to the machine, to its plans and information. She also had access to mathematics, the theory on which the machine worked. Her position in society and her own aptitude had helped her outwit the troll of constraint.

Ada's position as the first programmer comes from a piece of correspondence with Babbage on February 16, 1840 where she wondered if the board game solitaire could be written out mathematically [26]. She began with the process of numbering each peg and clearly describing each move, thereby constructing a theoretical programme for the game. This idea predates Boole's first published work in 1847, a pamphlet, *The Mathematical Analysis of Logic*, which with his other works formed the foundation of the ability to programme games on modern computers [26]. Hence while Kilburn at Manchester in 1948 may have written the first programme for a stored programme computer, Ada had in a sense conceived of programmes for Babbage's analytical engine a century beforehand.

The working model of the difference engine was not enough for Babbage. He conceived of a universal device that would far surpass his original creation. Babbage had one problem in that he did not finish what he started. Development of the difference engine halted as he went ahead designing the new concept. As a result of this Babbage lost his funding from the British Government and had to use his own wealth on the new project. This new machine was the analytical engine.

Babbage filled over 30 volumes by the time he died with plans for the analytical engine [26]. Unlike a modern computer it did not have an internally stored programme yet it could store numbers [26]. It received information about numbers, variables, and operations to be performed from a series of punch cards similar to the Jacquard punch cards used to instruct the looms [26]. It was possible to arrange the cards so that the engine could do a long complicated programme involving cycles and loops without human intervention [26]. He never built a complete machine yet in planning the device he had conceived of the modern computer a century before the ENIAC.

While Babbage worked with the structure of the machine and its design, Ada dwelt in the weave of its working. She wrote to Babbage in July 1843,

> ‘I want to put in something about Bernoulli’s Numbers, in one of my Notes, as an example of how an implicit function, may be worked out by the engine, without having been worked out by human head & hands first.’ [32].

In order to calculate Bernoulli numbers, you must perform many operations, take the results of those operations, and use them in other operations [26]. Only Babbage’s analytical engine could perform this. Symbolically, Ada was thinking in terms of programming the machine. She was working with what would now be termed software.

Babbage pursued his engine's development with a zeal for accuracy and efficiency. Ada was driven by imagination. She wrote,

> 'Imagination is the *Discovering* Faculty, pre-eminently. It is that which permeates into the unseen worlds around us, the worlds of Science. It is that which feels & discovers what *is*, the *real* which we see not, which *exists* not for our *senses*. Those who have learned to walk on the threshold of the unknown worlds, by means of what are commonly termed par excellence *the exact sciences*, may then with the fair white wings of Imagination hope to soar further into the unexplored amidst which we live.' [32].

Hence precision and accuracy were not enough for science to progress; imagination was required to venture further along the path of discovery.

Ada died in 1852 at the age of thirty-six [33]. Along with the Menabrea translation and her early notional programming, it was the bringing of imagination to science that is her legacy. Ada linked the sphere of fact with the realm of dreams and hoped to make the unreal possible. She saw the analytical engine as a device with great potential. She took the poetic gift of her father and combined it with an understanding of mathematics, using it to articulate technology in an enduring work.

While Ada did not conceive of the machine and was not entered into the history books as the creator of the computer, she is a significant person in the history of computing. Ada was the first to immerse herself in the patterns of the machine. She used mathematics as a device to enhance the technology and mastered its nuances. Ada's contribution was every bit as significant as Babbage's was to computing. In 2001 it is software that dominates the computer industry. Software is the determinant of where the wings of imagination will let computer users soar. It is therefore fitting that Ada was the first master of software, the first weaver of computer spells. It is important that this fact should be aired and this argument is made because it places women in the early history of computing.

Software lies below the surface as if encoded in the fabric of the machine. Ada understood this. Due to her youth and perception she was not afraid of technology and embraced it. Accuracy and efficiency motivated Babbage, while Ada was motivated by imagination. She was provided with the opportunity to gain access to the machine through status and an independent mother. Ada conceived of the first programmes in the history of computing and was thereby the first master of software.

6.5 Hard Master – Soft Master

Ada had chosen to immerse herself in the realm of numbers and felt drawn to computing machines. Through immersion she progressed and gained a thorough understanding of the machines and their principles. Babbage wrote of her notes to the Menabrea translation, that they are the 'only comprehensive view of the powers of the Analytical Engine which the mathematicians of the world have yet expressed' [34]. She had become the Enchantress of Numbers and was liberated in an intellectual sense by association with the machine and the technology. Ada was a soft master.

The hard and the soft refer to a strategy of computing. The following section seeks to outline and explain these approaches. It asserts that the emphasis of one learning strategy in computing has been exclusive. **Hard Master – Soft Master** also seeks to debunk the idea that the hard technique is masculine and the soft strategy feminine. It employs an example of a highly creative approach to computing and the success it achieved.

Consider first a hard approach. Imagine a person sitting at the machine learning to programme. A hard scheme would be to determine all the rules and formal systems that the computer operates by. The language would also have features that would then be gathered together before an attempt at programming would be implemented. The hard master proceeds in a methodical manner and adopts the rules of the system, as would a legal litigator operating in a court of law. An ordered approach to knowledge characterises the hard master. This knowledge would then be applied in a logical manner in order to achieve optimal performance of the machine and software.

The soft master learns through experiment. Sitting at the computer this person enters the domain of the computer. They interface with its peculiarities and thereby learn. It is as if this person is on a journey whereby they gather information as a result of paths taken on a road that is not structured. There are many side streets in the soft approach. The soft master’s way is characterised by immersive learning.

The hard approach is structured. A model of the modernist style, it is rule-driven and relies on top-down planning [35]. In terms of programming it would follow the following pattern.

> ‘First you sketch out a master plan in which you make very explicit what your program must do. Then you break the task into manageable subprograms or subprocedures, which you work on separately. After you create each piece, you name it according to its function and close it off’ [35].

Hard programming follows a logic and cerebral surety that gets the task done. In a musical sense it is like a formal section of a concerto, conforming to the musical rules drawn for that style of composition.

Soft mastery is best described as bricolage. Anthropologist Claude Levi-Straus used this term to contrast the analytic methodology of Western Science with an associative science of the concrete practiced in many non-Western societies [35]. It is like a musical piece that is put together from samples of other music, the parts to the whole relating to each other by individual links of associated meaning. Imagine a jazz soloist working with motifs and experimenting in the midst of a performance and the soft approach begins to take shape.

Neither strategy for computing is exclusive of the other. Rather, they are like two ends of a spectrum along which an individual’s plan of learning can be located. Hence one person may have a mixture of hard and soft depending on the nature of the problem. Another individual may have solely a hard approach to learning and problem solving. It varies.

Neither the hard nor the soft is a superior form to adopt. Both reach the same result although the soft style has a greater propensity to arrive at solutions in an innovative and creative manner. The assertion here is that for most of this century the hard approach to computing has been perceived as superior, while the soft approach has been portrayed as inferior. Also, the hard approach has been associated with the masculine while the soft has been located in the feminine. The argument here is that this learning strategy for computing has been used as a tool of exclusion.

Dykstra, the leading theorist of hard, structured programming, emphasised analytical methods and scientific rigour in the development of programmes [35]. This echoes a cultural trait whereby the divide between the abstract and the concrete is not simply a boundary between propositions and objects but a way of separating the clean from the messy, virtue from taboo [35]. This view posits that the best way to interact with computers is through the hard approach. Imagination, intuitive learning and experimentation outside of formal parameters are all discouraged.

Yet Ada showed in the case of the analytical engine that computing was like hypertext. She immersed herself in mathematics and the operation of Babbage’s designs achieving success with her notes to the Menabrea translation. Her approach to computing does not fit with the mould as offered by Dykstra and the structural programmers. In fact it is the soft approach that is evidenced in Ada’s successful application of knowledge.

Note that the immediate association with hard mastery is a male and soft mastery is female. It would be a mistake to consider this to always hold true. In researching her book, *Life on the Screen*, Sherry Turkle found that both male and females exhibited the soft approach [36]. Yet she also noted that females tended to have a soft strategy while males often had a hard approach. In a society where structured programming was seen as the best method, this emphasis was a constraint on women.

The teaching of the hard method of computing in centres such as MIT and Harvard University would have alienated those who worked best with a soft immersive style of learning. Turkle experienced this herself while learning to programme computers at Harvard [35]. Alienated from the virtuous methodology of machine interaction, the soft masters were thereby structurally disadvantaged when it came to computing. It was like a situation in a classroom of the 1940s where left handed children endured corporal punishment for neglecting to write with their right hand.

Some rebelled against this. One key example is Richard Greenblatt. Greenblatt was a student at MIT in the 1950s and was a notoriously gifted computer hacker. In this instance, by the term hacker it is meant a person who can solve problems with a computer in an innovative manner and write ingenious code. Greenblatt was so immersed in programming the machines at MIT that he eventually flunked out of his course [37]. He thereby existed on the periphery at MIT working in a programming job that still gave him access to the campus and its computers. Through this access he made significant contributions to the development of chess programmes and systems programming [35]. Hence the hard orthodoxy could be challenged and the soft style could bring success. Note also that Greenblatt was male, a point which debunks the perception that the soft approach was solely the domain of women.

Ada came to regard the computer as a friend [22]. She had taken the machine into her personal sphere. In programming it she was relating to the computer as another entity, not a tool. Yet she was fully aware that the computer was merely an articulation of the programmer's designs. She wrote,

> 'The Analytical Engine has no pretensions whatever to originate anything. It can do whatever we know how to order it to perform' [38].

Her closeness with the engine was as a musician would be with an instrument. With a musician there is a synergic link between the instrument and the player. This takes it well beyond a tool. In music, the combination of the musician and instrument is greater than the sum of the parts. Similarly Ada was developing a synergy with mathematics and her instrument the computer.

Turkle observed that relationships with computers were indicative of a soft style to learning. She had studied children interacting with computers at a privileged school in the USA called Austen. She observed that girls at this school tended to see computers as sensuous and tactile and related to the computer’s formal system not as a set of unforgiving “rules,” but as a language for communicating, negotiating with, a behaving psychological entity [39]. They were thereby treating the computer as an instrument of articulation, not a tool of work.

Taking the machine within the personal sphere is symbolic. It becomes an “other". Turkle (1984) posits that this other is like a second self, an entity embodied within the machine. By relating to the computer on this level children see computers more like fluid simulation surfaces for writing and game playing than as rigid machines [40]. The computer has thereby moved from the level of a tool to a virtual entity with which one can explore new worlds.

6.51 Roberta Williams and the Apple II

An example of a soft master who related to computers on this explorative level is Roberta Williams. Sierra Online is a multimillion-dollar software company based on the production of computer games. Williams and her husband founded it in the early 1980s. Sierra Online grew from a garage company into a sizeable concern due to Roberta’s application of imagination to computing [41].

Ken Williams had a talent for business and tenacity that suited an entrepreneur. He was a self-taught computer programmer and was intent on making good money in the growing industry. With some training in physics yet no formal qualifications Ken approached problems in a methodical fashion yet with the air of an opportunist. His wife Roberta initially saw computing as her husband’s domain. To her, computers were sophisticated machines far removed from the world of Tolkienesque fantasy stories that greatly appealed to her.

All this changed when Roberta’s husband brought home an Apple II computer. The Apple II was one of the earliest micro or home computers being released in 1977. Its popularity and sales were the foundation on which computer giant Apple was built. With graphics potential and a cheap price tag the computer was accessible to those who viewed the machines with fear, like a large wardrobe looming in a dark room, the door slightly ajar.

Yet those who have read the Narnia stories by C.S. Lewis would know that wardrobes could be portals to new worlds of adventure and discovery [42]. Roberta encountered the new machine and did not react well with it, as it was difficult to programme for a novice. In order to get his wife interested in computing Ken Williams wrote a basic set of commands that would allow Roberta to programme the machine. This is significant in that she could now communicate with the Apple II and begin to explore its potential limited only by her imagination. This she did.

Within a short space of time Roberta had ventured into the symbolic wardrobe and composed a game. This was “mystery house”. In the game the player would explore a haunted house and engage in adventures while inside. The graphics were simple and the software needed attention from Ken, yet before long the Williams were selling it to the masses. The home based business soon became a full time concern for the couple and Roberta wrote a series of games for computers. She had thereby taken the realm of her imagination and applied it to the machine. Immersing herself within the fantasy world she invited the computer there. Sierra Online, through the work of many programmers, became a hugely successful company. Yet its beginning was the introduction of a soft master to the sphere of computing. A simple interface provided Roberta's entry into the digital world like the old wardrobe in C.S. Lewis's Narnia series. Soft mastery therefore brought a new perspective to the machine, one that was imaginative and highly creative.

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YOU ARE IN THE FRONT YARD OF A LARGE
ABANDONED VICTORIAN HOUSE.  STONE STEPS
LEAD UP TO A WIDE PORCH
--------------- ENTER COMMAND?
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Figure 6. The simple graphics of Roberta Williams' game 'Mystery House' [1980]. Courtesy of Sierra Online.
Source: www.ufpel.tche.br/~snoopy/jogos/myster_e.htm

Hard Master – Soft Master has illustrated that there are two non-mutually exclusive approaches to computing that have different characteristics. There is an immersive approach and an ordered approach. These two strategies are like two ends of a spectrum. Gender is not a determinate of which approach is adopted. A teaching programme where one approach only is emphasised is exclusive. It may prevent the development of a synergy with the computer that, as the case of Roberta Williams illustrates, can bring an imaginative and highly creative approach to computing.

6.6 Women on the Machines

Previous chapters in **Cyberhistory** draw an illustration of the growth of computer technology from the Hollerith devices to the post WWII electronic stored programme machines. Within its vast scope there is little mention of women. This is significant. In the computer history literature women exist, yet they do not have a prominent role in the literature. It would be a mistake to think that women played a secondary role in the evolution of computing as Plant [43] asserts,

> ‘women have not merely had a minor part to play in the emergence of digital machines. When computers were vast systems of transistors and valves which needed to be coaxed into action, it was women who turned them on. They have not made some trifling contribution to an otherwise man-made tale: when computers became the miniaturized circuits of silicon chips, it was women who

> assembled them. Theirs is not a subsidiary role which needs to be rescued for posterity… when computers were virtually real machines, women wrote the software on which they ran. And when *computer* was a term applied to flesh and blood workers, the bodies which composed them were female. Hardware, software, wetware- before their beginnings and beyond their ends, women have been the simulators, assemblers, and programmers of the digital machines.'

Women have been inseparable from computer history like the thread within a yard of fabric. The next three sections explore some significant contributions of women in the field.

6.61 Mathematical Tables Project

The Mathematical Tables Project (MTP) began in 1938 and aimed at producing accurate tables of exponential and circular functions [44]. It was located at the US National Bureau of Standards (NBS), an institution which is today known as the National Institute of Standards and Technology (NIST). Opening in New York City, the project began with a staff of seven mathematicians and 120 high school graduates [44]. The NBS was at the forefront in developing numerical analysis as a technology and in joining applied mathematics with electronic computing machines [44]. It is significant that women mathematicians at the NBS were instrumental in bringing this about.

All the tables in the MTP were created by hand [44]. That is people were performing the calculations manually like components of a computer. Most of the human computers in the MTP were taken off the welfare rolls during the depression [44]. They were mathematically deficient, yet were shaped into one of the strongest computing teams the world had ever seen [44].

Gertrude Blanch was a mathematician who was recruited into the MTP. Her task was to oversee the execution and development of the work sheets used in the computation of tables [44]. Her aim was to co-ordinate the room full of human computers in one efficient system. Each person had simple tasks to perform, arriving at basic answers that when combined together solved an equation. The tasks were outlined on the work sheets that were principally designed by Blanch.

Ida Rhodes was another mathematician who was recruited into the MTP. Initially she was trained by Blanch in numerical analysis, for she had found that her extensive mathematical training while at Cornell had not prepared her for applied work. Along with Blanch, Rhodes spent the evening hours checking hundreds of work sheets for consistency, along with developing and preparing new material [44]. Both women supervised a highly successful project that operated on a minuscule budget.

When electronic computing came to the NBS in 1948 Rhodes moved to work on the new machines. She became one of the foremost experts in the world in the functional design and application of electronic computing equipment [44]. Blanch moved to California where she worked with the Institute for Numerical Analysis (INA) at UCLA [44]. Rhodes developed the C-10 language for UNIVAC 1 and designed the original programme used by the Social Security Administration [44]. She was also one of the first scientists to recognise the importance of parsing a sentence, which included separating the roots of words from their prefixes and suffixes [44]. She had become a programmer and applied mathematician heavily involved in computing. She dwelt within the weave, shaping the mathematical patterns that governed the operation of a computer.

Note that like Ada, both Blanch and Rhodes had brought their knowledge of mathematics to the computer. Ada applied her knowledge to the analytical engine, Blanch to the human computers in the MTP and Rhodes to the NBS UNIVAC 1. Rhodes in particular worked in the sphere of programming rather than hardware development. It is as if mathematics provided all three women with a language that they could use to communicate with the computer – the second self. Mathematics thereby gave them access.

6.62 Programming the ENIAC

Tables mapping the trajectory of artillery shells were the impetus behind the construction of the ENIAC. Yet before the computer was operational women computers performed most of the calculating work. By 1943, and for the balance of WWII, essentially all computers were women, as were their direct supervisors [44]. These women worked at the Moore School of Electronic Engineering at the University of Pennsylvania. Their job was to perform manually the calculations required to generate the firing tables.

That most computers were women was significant. It indicates that computing was perceived as appropriate for women. Most of the early recruits to the Moore School project were young women with mathematics majors at college [45]. Later, as the demand for tables became intense, women graduates with other majors and some mathematics were hired [45]. As demand increased further, high school graduates were inducted.

The college graduates chose to go to the Moore School to work out of interest. On graduation they had the choice of working as teachers in secondary schools. Challenging positions with insurance companies' actuarial sections required master's degrees [45]. The Moore school offered the promise of interesting work and there was also the added intrigue of the secret nature of some of the projects there.

Mathematics was not a common major for women to take. Lila Todd recalled that she graduated from Temple University in the College of Arts and Science in June 1941 as the only female with a major in mathematics out of some 1600 in the graduating class [45]. Todd played an active role not only with wartime computing but also with the Ballistics Research Laboratory (BRL) development and use of computers in the post war period. Her recollection illustrates that these women were exceptions. Todd's mathematical department head at college felt that women should not have majored in mathematics [45]. Clearly these women were also forging new ground against the resistant pressure of societal constraint.

Six of the women computers from the Moore School became the original group of ENIAC programmers. They were Kathleen McNulty, Frances Bilas, Betty Jean Jennings, Elizabeth Snyder, Ruth Lichterman, and Marlyn Wescoff [45]. All the programmes on the ENIAC had to be entered manually through a series of plug boards. This was a laborious process yet these women persisted with the technology.

Elizabeth Snyder joined the Moore school in 1942 [45]. Along with Jennings, she created a trajectory programme used to control the operation of the ENIAC during its highly successful public demonstration in February 1946 [45]. Snyder has been credited with much of the software for the first UNIVAC delivered to the US Census Bureau [45]. She had influence in the way in which the UNIVAC was designed and later in 1952 devised the first sort-merge generator for UNIVAC I, from which Grace Murray Hopper claimed to have derived the first ideas about compilation [45]. Snyder was a programmer developer and master of the ENIAC.

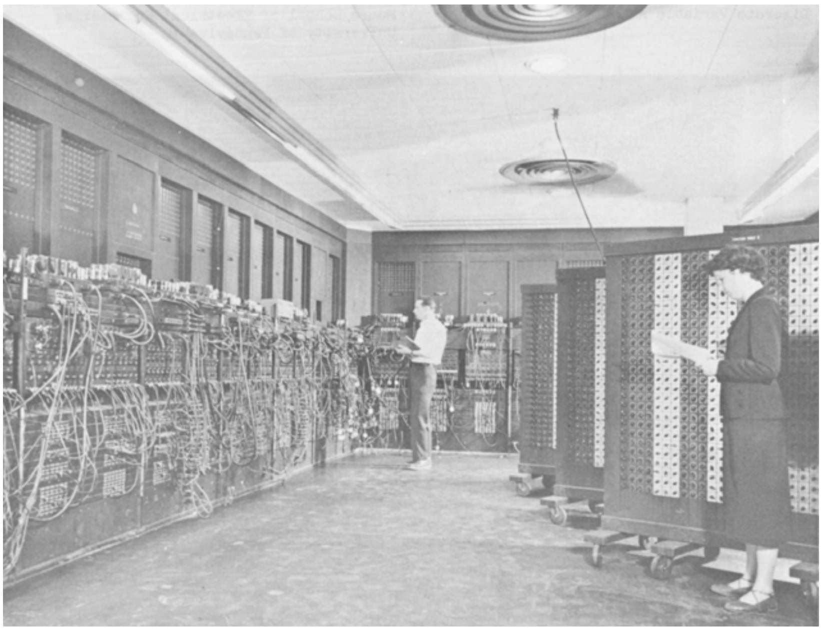

Figure 6.6. The vast plug-board array of the ENIAC. Every programme had to be entered using this tedious interface. Note the female programmer in the foreground. U. S. Army Photo.
Source: http://ftp.arl.mil/ftp/historic-computers/

Snyder’s contribution is significant yet her efforts are missing from many of the formal histories of the ENIAC. These tend to concentrate on the development of the hardware by Eckert, Mauchly and von Neumann. Yet the team of six women programmers were equally important in the success of the machine. Jennings recalled the excitement they felt on the day of the official ENIAC demonstration.

> ‘The day ENIAC was introduced to the world was one of the most exciting days of my life...ENIAC calculated the trajectory faster than it took the bullet to travel. We handed out copies of the calculations as they were run. ENIAC was 1000 times faster than any machine that existed prior to that time. With its flashing lights, it was

> also an impressive machine illustrating graphically how fast it was actually computing.’ [46].

While many histories cannot go into the detail of a specific paper on the ENIAC women, it is important to note that Snyder and Jennings were there in 1946 bringing the ENIAC to the World.

ENIAC was running their software. Snyder and Jennings had spent the early hours of the morning before the demonstration debugging the trajectory programme. It contained a fault in that the computer continued calculating the trajectory even after the bullet was meant to have impacted on the ground [45]. They were probably one of the first programming teams to hack into the night getting code ready for a tight shipment date. Significantly they were doing it on the world’s first fully electronic computer.

6.63 Hopper and the BUG

Around 1951 the UNIVAC programming team, which included Snyder, was run by Mauchly [47]. Yet a woman later ran it. She was recruited from the Harvard Computation Laboratory and would become the ‘driving force behind advanced programming techniques for commercial computers and the world’s foremost female computer professional’ [47]. Her name was Grace Murray Hopper.

Hopper began her career in computing when she was assigned to work for Howard Aitken on the Harvard Mark I differential analyser in 1944 [48]. While employed at Harvard, Hopper was credited with coining the term “Bug”. She contended that the honour was not hers. In fact, during the summer of 1947 the Harvard Mark II was giving erroneous information [48]. A moth had been caught in a relay and jammed it. An operator wrote in the logbook for the Mark II “first actual bug found” [48]. The term stuck when Hopper and others in the laboratory would excuse a period of little work to their boss Aitken by telling him they were “debugging” the machine [48].

The Harvard Mark I used three quarters of a million parts, five hundred miles of wire, several counter wheels, shafts clutches, and relays, two punch-card readers, two type writers, and a card punch [49]. It was a mechanical monster. Hopper called it her monster [49]. It wasn’t long before Hopper, at Aitken’s command, had produced *The Manual of Operation for the Automatic Sequence Controlled Calculator* or the Harvard Mark I [48]. Like Ada, Hopper knew well the workings of the machine. It may have been a monster, yet, through her knowledge, Hopper was fully in control.

While working for Remington Rand on the UNIVAC project, Hopper conceived of a new type of programme that could perform floating-point operations, and other tasks, automatically [50]. This programme was called a compiler. It was designed to scan a programmer’s high level symbolic instructions and produce a roster of binary instructions that carried out the user’s commands [50]. A compiler was therefore a communicative link between the symbolic language of a programme and the machine language of the computer.

Hopper saw the computer as a ‘symbolic manipulator. When it’s doing numerical mathematics it is manipulating arithmetic symbols, and when it’s data processing it’s manipulating data processing symbols’ [51]. With the computer she sought to demonstrate the power of her compiler. She wrote a small inventory/price programme that could be translated into machine code, and then wrote a routine that could translate the same programme written in French or German into machine code [51]. Her management at Remington Rand were initially in denial. They had a hard time understanding that a programme written in English in Philadelphia could understand French and German [51]. Yet Hopper was able to convince them of the power of the compiler.

By 1957 Hopper and her staff had put together Flow-matic [51]. It was the first English-language data-processing compiler – the first computer language employing words [51]. This was a significant contribution to the future of computing. Hopper had come close to bridging the gap between natural language as spoken by people and binary, the language of the computer.

Note that Hopper was another female associated with the history of computing who was also a programmer. Indeed software was Hopper’s speciality. This suggests that from the time of Ada Byron software has been the domain of women. It was the engineers and physicists who designed and built the computers while many of the women who were involved with the machine were involved with trying to articulate the machine. This is evident in the case of Ada and Babbage, the

ENIAC women and the male hardware team, as well as Hopper and the UNIVAC engineers.

Figure 6.7 Grace Murray Hopper, one of the world's foremost computer professionals, being interviewed by Channel 3 Norfolk Virginia during 1986. In her later years she continued to work for the US Navy promoting computing around the world.
Source: US Navy photo courtesy of *Chips* magazine.

Slater notes that if Hopper had thoughts of becoming an engineer, she quickly cast them aside, realising that the profession had no place for a woman [48]. Her education in mathematics was second to none having been awarded a doctorate from Yale University in 1934 [48]. Yet she was a lone female at the top of the educational ladder. Only 1279 doctorates were awarded in mathematics in America between 1862 and 1934 [48]. Hopper was a stand out and one of the few women to be a regular feature in accounts of computer history.

Hopper's Flow-matic was acknowledged by the committee that produced the Common Business Oriented Language (COBOL) as greatly influencing their thinking [51]. Hopper sat on the initial meetings of the COBOL committee yet was not a working member. Flow-matic's influence is indicative of its innovative quality. COBOL was a language intended for use by business in the same sense that the Formula Translation (FORTAN) language was intended for the domain of science. Like Flow-matic, COBOL employed syntax and terms that approach natural English. Flow-matic's contribution to the creation of COBOL is indicative of the extent to which Hopper was at the forefront of software technology.

The compiler and COBOL would be part of Hopper's lasting legacy to computing and the world of people who use them. Symbolically she was trying to bridge the gap between the uninitiated user and the machine to which she devoted her life's work. She stated, "When computers were thoroughly binary, we told everybody, 'Oh no you can't understand that; you don't know binary.' We pushed people away. We wouldn't explain, we created a barrier. Now we're trying to break that down again.'' [52]. In this sense Hopper was a great proselytiser of computing. She was reaching out to those who were unfamiliar with the machine and more importantly making it easier for them to communicate to it.

Women on the Machines has shown that women have played significant and contributing roles in the development of computing. Women mathematicians were instrumental in bringing the Mathematical Tables Project about at the NBS and making it a world respected centre of computation. From

Ada onwards mathematics has provided access to the computer.

For the balance of WWII essentially all computers at the Moore School, home of the ENIAC, were women. Female mathematicians interested in computation were forging new ground against the resistant pressure of societal constraint. Women programming teams articulated the vast ENIAC and brought it to the world in 1946.

From Ada onwards software has been the domain of women. Hopper was an exceptional individual. Her Flow-matic software heavily influenced the creation of COBOL. During her lifetime Hopper had come close to bridging the gap between natural language and machine code.

6.7 The Turing Test

Imagine a game in which there is one person in a room and an interrogator outside that room. Written questions could be submitted by the interrogator to the person in the room. Answers in a text form could be passed to the interrogator from the person in the room. The interrogator cannot see the person in the separate space. The interrogator can only make judgements about this person from the answers that they supply. These are the conditions in which the Turing test is administered.

The Turing Test covers the post WWII ideas of Alan Turing. Alan Turing is included at this point in **Gender and**

Computing due to his own internal gender struggle. Turing was homosexual and, as such, existed on the periphery of society. This affected his work and approach to computing. Like Woolf, Turing also needed a room of his own, from which he could relate to the outside world, on his own terms. **The Turing Test** also looks into the role of women at Bletchley Park, asserting that they made the establishment function. It looks at representations of ideas that Turing helped establish, particularly artificial intelligence. Turing was involved in designing the ACE computer. The following asserts that conditions at the National Physics Laboratory were more constrained than at Manchester and traces Turing's path there. Furthermore, the following notes the extent to which Turing, until recently, was an unperson of computer history.

Turing originally pictured two people in the separate room with the interrogator having to decide which was a male and which was a female [53]. He posited that gender depended on facts that were not reducible to sequences of symbols [53]. Hence if the person in the room was a female and imitated a male in her replies she would still be a female.

Turing wished to argue that such an imitation principle did apply to 'thinking' or 'intelligence' [53]. That is intelligence could be imitated. Turing felt that intelligence could be reduced to a sequence of symbols, the same symbols that operated in a universal computer. Turing posited this in a 1951 paper, 'Computing Machinery and Intelligence' that was published in the journal *Mind*. He changed the condition of the game somewhat by placing a computer or a person in the separate room. By written questions the interrogator had to try and tell if the respondent was thinking or not thinking. Turing asserted that if a computer, on the basis of its written replies to questions, could not be distinguished from a human respondent, then ‘fair play’ would oblige the interrogator to say that it must be ‘thinking’ [53]. This was the Turing test.

Implicit in Turing’s assertion is the conviction that intelligence is not connected with life. He was positing that artificial intelligence was plausible. Turing was asking could words be stored for ‘intelligent’ use within a discrete state machine model of the brain, unless that model were also equipped with the brain’s sensory, motor and chemical peripheries? Is there intelligence without life? Is there mind without communication? Is there language without living? Is there thought without experience? [54] These were the questions that had captured Turing’s imagination. They went to the very core of what it is to be human and what it is to be intelligent.

Turing asserted that within fifty years computers would be programmed to play the imitation game so effectively that after a five-minute question period the interrogator would have no more than a seventy-percent chance of making the proper identification [55]. Note that the title ‘2001: A Space Odyssey’ corresponds to fifty years after Turing’s paper. This was a deliberate reference to the 1951 *Mind* paper [56]. He therefore felt that a computer like HAL – who was featured in ‘2001’-was possible. Artificial intelligence was a tangible concept to Turing.

The Turing test was set up by Turing to help confirm his assertion. If a machine could pass the test then, argued

Turing, it could be considered intelligent. Was the human mind reducible to a set of symbols that functioned according to some pattern of logic? Turing was suggesting that it was. His universal machine was designed to perform the work of any machine. Biological machines such as the mind could also be symbolically replicated.

A replication of human intelligence is a concept that spawned the field of artificial intelligence. A sinister version of the Turing test was depicted in the 1982 Ridley Scott film ‘Blade Runner’, the cinematic version of Philip K. Dick’s novel *Do Androids Dream of Electric Sheep?* In the movie a blade runner is a bounty hunter/assassin who tracks down ‘replicants’ or androids who have escaped human control. Early in the film the blade runner Deckard administers a Turing-like test to a “replicant” who is unaware of her artificiality. The film and novel go to the core of Turing’s questioning by blurring the lines between the artificial and real to such an extent that the viewer wonders if an artificial “replicant” does dream of electric sheep and is it thereby as real as any human?

6.71 Women at Bletchley Park

Turing devised the Bombe and used it to crack the enigma, yet it was women who manned the machines in the huts on the old Victorian estate. Indeed, the outcome of the work at Bletchley Park was dependent on the unremitting toil and endurance of almost two thousand Wrens [57]. Wrens were women who were recruited into the Women’s Royal Naval Service (WRNS) during WWII. These women loaded the rotors and telephoned the analysts to say when a machine had come to a stop [58]. They had no knowledge of what they were actually getting the machines to do and they were not permitted to ask the reason why [58]. They toiled night and day on machines that sounded like a ‘thousand knitting needles as the relay switches clicked their way through the proliferating implications’ [58].

At Bletchley the clerical work was done by women who would be called ‘big room girls’ [59]. They also worked on the numerous machines in large numbers. Although the work was guided by males of the “professorial type”, without the women of the WRNS the top secret establishment could not have functioned. Bletchley was therefore a hive of female activity.

Unlike the situation at the Moore School, there were few women mathematicians recruited to Bletchley. The upper echelons of the Bletchley hierarchy were dominated by men. There was one exception. This was Joan Clarke. A mathematical recruit, she stood alongside the sharp minds of her male colleagues. Yet, Clarke was treated differently. The principle of equal pay and rank being stoutly resisted by the civil service, Clarke had to be promoted to the humble rank of ‘linguist’ that the pre-war establishment reserved for women [59]. As a woman Clarke was openly discriminated against in terms of her pay. She did receive the status of an ‘honorary male’ [60] by the other intellects, in this way being inducted into the male culture at Bletchley.

Clarke did find a friend in Turing. The two got on well. This was probably due to the way in which Turing was lost in dealing with the Hut 8 Wrens. He wasn’t able to cope with the ‘talking down’ that was expected by the male culture [60]. With Clarke he had found someone on an intellectual par. The two became quite close. This is not surprising. Clarke was on the periphery because she was female, while Turing had always been a misfit. On the periphery they found a common thread around the machinery and codes.

6.72 Trotsky of Computer History

When Hartree told Bowden that Ferranti was wasting its time trying to sell computers to business, he mentioned three computing centres. One was in Manchester. The other was at Cambridge University. The third was at the National Physics Laboratory (NPL). Following the end of the war Turing accepted a post at the NPL principally to design and build a stored programme electronic computer. He began work there on the 1 October 1945 [61]. J.R. Womersley initially ran the new project. He was the super intendant of the mathematics division at the NPL [62].

Turing had been in his element during the war, but he was greatly frustrated by what he found to be the stifling situation at the NPL. Unlike Manchester the NPL worked under the auspices of planned science. There was no tradition of major innovation at the NPL, and the ACE project brought out the conservative and negative character of the institution [63]. Where Manchester enjoyed the benefits of rapid funding from the British Government the NPL sought to control the computer project for its own research. The NPL thereby lacked the innovative freedom of Manchester.

Turing had to conform to the system of regimentation under which the NPL operated. It did not sit well with his approach to learning and working. Turing was a soft master. He immersed himself in his work and often had odd ways of going about tasks. Yet this method had led him to conceive of a universal computer and crack enigma. At the NPL he was caught up in bureaucratic procedure. He was forced to begin building a pilot machine that became known as the Pilot Automatic Computing Engine (ACE). Yet he had designed a full sized machine.

At 1 megacycle, the basic internal clock frequency of the Pilot ACE was the fastest of the early British computers [64]. The computer contained 800 thermionic valves with a 352-word store [64]. Relative to the other British computers this was small. The Mark 1 had 1300 valves with a 128-word store [65]. The EDSAC had 3000 valves with a 512-word store [65].

The Pilot ACE had a unique architecture that permitted a benefit in speed and size. With a clock speed at 1 megacycle the Pilot ACE was the fastest machine in the world [66]. It was a machine that had obviously not been built around the EDVAC report [67]. It employed distributed processing that distinguished it from the von Neumann architecture, which used an accumulator [66]. Turing had therefore created a highly original and efficient design.

Yet Turing was not at the NPL when the computer was built. He had taken leave and ended up in Manchester. Making the move in 1948, Turing had little to do with the hardware of the

Mark 1. Instead he influenced the input and output mechanism's design [68]. He also part wrote an operations manual for the machine [68]. His excursion in software did not end there. In October 1949 he wrote an input routine for the Mark 1 [68]. When the machine was freshly switched on, the input routine would direct it to read in new instructions from a tape, store them in the right place and to begin executing them [68]. Turing had thus moved into the realm of the weave with some enthusiasm.

Turing had designed the ACE, although he had left the NPL before it was built. Frustrated at the bureaucracy at the NPL, Turing had left under a dark cloud. It was probably for this reason that an official account of the development of the Pilot ACE as written by Womersley, only mentioned Turing as being part of the staff [69]. This disconnected him in a historical sense with the design of the ACE. Turing's work on the enigma remained shrouded in the shadows like a spy who didn't come in from the cold. He was for a long time an unperson – a Trotsky of the computer revolution [69].

Indeed Turing did not fare well in the 1950s. Through his own honesty when dealing with a police incident he was convicted of gross indecency in 1952 [70]. Turing was ordered to undergo hormone therapy where as a side effect he became impotent and grew breasts. It was a harsh stroke of questionable justice for an individual who had contributed so greatly to the winning of the war. Had his wartime superiors known of his homosexuality he might have been refused entry to Bletchley. Historians can only speculate how that may have affected the course of the war, yet what is certain is that the cracking of enigma saved countless lives that otherwise would have been lost, securing an eventual allied victory.

The poison apple in the story of snow white had always fascinated Turing. In an arbitrary moment on the 7th June 1954, he ate an apple laced with cyanide and died [70]. The ‘discrete state machine, communicating by teleprinter alone, was like an ideal for his [Turing’s] own life, in which he would be left alone in a room of his own, to deal with the outside world solely by rational argument’ [71]. Turing died in a sad manner yet the ideas that he brought to computing are perpetuated in the fields of artificial intelligence and computer science.

The Turing Test has delved into the shadows and returned with some significant questions and observations. Turing thought intelligence was not connected with life. He devised a test based on an intelligence imitation principle to verify this. Turing’s assertions raise profound questions that the biological, physical, mathematical and computing sciences are still trying to answer. Is a human mind reducible to a set of symbols that functions according to a mathematical pattern? If a machine passes the Turing Test does this mean it is conscious?

The top secret Bletchley Park was a hive of female activity. While men dominated the upper echelons of the Bletchley Hierarchy, there were exceptions. Joan Clarke was one. Although an honorary male, Clarke was still discriminated against due to her sex.

For Turing, the NPL lacked the innovative freedom of Manchester. His ACE design was highly efficient and original. While at Manchester Turing moved into the realm of software. It is only recently that Turing has ceased to be an unperson of computer history.

6.8

Machina: the Gendered Computer

Imagine if Babbage and Lovelace had succeeded in getting the analytical engine to work. A computer revolution would have occurred in the 1840s rather than in the late twentieth century. The present may have been vastly different.

> ‘Ten thousand towers, the cyclonic hum of a trillion twisting gears, all air gone earthquake-dark in a mist of oil, in the frictioned heat of intermeshing wheels. Black seamless pavements, uncounted tributary rivulets for the frantic travels of the punched-out lace of date, the ghosts of history loosed in this hot shining necropolis. Paper-thin faces billow like sails, twisting, yawning, tumbling through the empty streets, human faces that are borrowed masks, and lenses for a peering Eye. And when a given face has served its purpose, it crumbles, frail as ash, bursting into a dry foam of data, its constituent bits and motes. But new fabrics of conjecture are knitted in the City’s shining cores, swift tireless spindles flinging off invisible loops in their millions, while in the hot unhuman dark, data melts and mingles, churned by gearwork to a skeletal bubbling pumice, dipped in a dreaming wax that forms a simulated flesh, perfect as thought –…
>
> In this City’s centre, a thing grows, an autocatalytic tree, in almost-life, feeding through the roots of thought on the rich decay of its own shed images, and ramifying, through

myriad lightning branches, up, up, towards the hidden light
of vision,
Dying to be born.
The light is strong,
The light is clear;
The Eye at last must see itself
Myself...
I see:
I see,
I see
I
!' [72].

The above is an extract from Stirling and Gibson's *The Difference Engine* [72]. The two write of a fictitious industrial revolution that is supercharged by the development of steam driven cybernetic engines, vast computing machines that feed information to a technocracy led by the "Rad Lords", the great scientists of the age of which Babbage is one.

The following section looks at fictitious depictions of computers and robots. It argues that human culture ascribes gender to technology. Do computers have a gender? ***Machina*****: the Gendered Computer** also looks at how cultural baggage can be stowed in software – in particular games software, in an attempt to illustrate the extent to which gender issues permeate computing.

In the *Difference Engine* extract, a consciousness is being born. Computing engines have grown to the extent that they dominate the landscape. Yet at this final point in the novel the authors posit that with enough machinery the engine beating at the heart of London finally becomes self-aware.

The notion of a cybernetic life form is not new in the fictional landscape. ‘Metropolis’, a 1926 film directed by Fritz Lang introduces the notion of a female machine. In Lang’s film a robot is constructed to mislead an under-class of workers thereby continuing their oppression. A charismatic character in the movie called Maria had been leading the workers in a revolt when a machine replaces her. The false Maria thereby ends the revolt and needs to be overcome in order for the workers to throw off the tyranny of their masters.

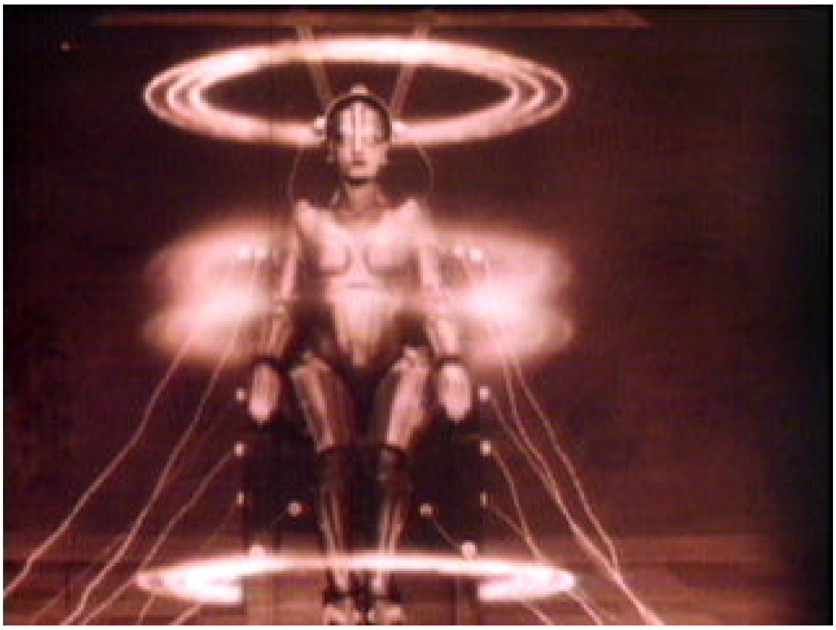

Figure 6.8 The Robot from ‘Metropolis’ [1926]. Note the female likeness. The Robot was used to deceive the underground workers.
Source: www.geocities.com/Area51/5555/robot.jpg

It is symbolic that a crazed male scientist controls the false robot of ‘Metropolis’. The “Eloi” like society that dwells in the uppermost strata of the city is patriarchal [73]. The men therefore build and control the technology. A female revolts yet is usurped by a machine that deceives the workers in the guise of a woman.

In ‘Metropolis’ the machine is given a feminine form. That is feminine cultural characteristics are placed in the robot. It is subservient to its male masters who in turn dominate the workers dwelling in the depths of the metropolis, methodically performing their tasks as if armatures in one vast computer. The assertion here is that gender is ascribed to technology and thereby computers by human culture. The robot is essentially a computer given a mechanistic form, a body.

In James Cameron’s Terminator films, [1985 and 1992] the machine is the embodiment of masculinity. A mother whose son the machine is protecting ponders in ‘Terminator 2’ [1992] how the machine is the perfect surrogate father and how it would never display the failings of a human father. The terminator by its name is also a perfect masculine killing machine. These qualities are given to the machine by the film’s creators. It is the success of the film and the ideas embodied in it that reflect the acceptance of the notion of a masculine Terminator.

Interestingly the mother in the film redefines her own body and psyche becoming emotionless, with masculine physique as if in order to combat the Terminator she is becoming more like it. This role reversal of a female character reflects an important point that must be borne in mind when considering notions of gender. This is that masculinity and femininity are not tied to sex. A female can exhibit masculinity as much as a male and *vice versa*.

6.81 Games

In the computer masculinity, as portrayed in the ‘Terminator’ movies, is enacted through games software. Many games are marketed on the premise that they are purchased for use by teenage males. They involve violence, conflict and offer rewards for the successful completion of levels – many of which will involve defeating a foe in conflict. As an illustration of this consider a 1985 report where,

> ‘On one rack (in a computer store), covers in comic-book style depicted such games as Olympic Decathlon (4 male athletes on cover), Cannonball Blitz (3 men in battle), Swashbuckler (9 male pirates), Thief (1 male detective), Alien Typhoon (1 male space explorer) and Money Munchers (1 man in a suit). In all, 28 men and 4 women were illustrated on the covers. The women were on the covers of Monopoly (2 men and 2 women playing the game), Palace in Thunderland (1 very fat queen), and Wizard and the Princess (1 wizard standing, 1 princess in supplicating position on floor).’’ [74].

This example clearly shows that most games in the above selection were aimed at young males. The argument is not whether this characteristic of games aimed at young men is good or bad in a society trying to redress gender imbalance. Rather the assertion is that these types of software are examples of human culture attributing gender to the computer. It is no different from the machines of the science fiction films.

Even if the game cover depicts females it does not necessarily imply that it is aimed at females. The ‘Tomb

Raider' series of adventure games feature a female as a central character. She is clad in skin-tight shorts, a singlet, and features a figure that a "super-model" would envy. Yet Tomb Raider is not an adventure game aimed specifically at girls. Young males play the game in droves.

Figure 6.9 Lara Croft from the 'Tomb Raider' game series. [1996 Core Design Ltd.] Lara Croft is a female hero, yet her popularity is high among males.
Source: http://tombraiders.net/stella/tomb1.html

Lara Croft is an example of a popular female hero. Croft weaves through the labyrinthine tombs and scenarios of the game. She is an example of how a female can be tough, resourceful, and independent. Croft is a significant creation in that her fame has transcended the game culture from which she originated. Croft is to be the subject of a new feature film to be released in 2001. A further indicator of her transcendence from the video game, is Croft’s appearance in *The Face* magazine (May 2000) as part of an exclusive list of birthday well wishers. This list included top fashion designers, super models, famous musicians and disc jockeys. Despite being a virtual character, Croft was thereby a celebrity in her own right. Although Croft is highly popular among males, she is still a hero for young females.

A Game Design Project run with 4th grade children at a co-educational school in the 1990s illustrates the way in which gendered culture is ascribed to the computer by those who programme it. It revealed that students would bring different cultural traits to their programmes. Sixteen boys and girls worked for six months making games in Logo to teach fractions to younger students [75]. The game choices of boys replicated many of the gender differences and preferences found in commercial video games, with adventure and exploration themes [75]. The boys programmed violent feedback or killing for incorrect answers [75]. The girls preferred games like teaching, skiing, or landing at the airport [75]. The girls created their own non-violent game worlds with their own systems of rewards, which rarely exists in commercial video games [75]. In each case the children put into the computer cultural baggage that they have been taught in respect to their gender.

Importantly, the children in the above case relate to the computer in parameters that are guided by gender. The games of both sexes used sophisticated graphics, animation, and interaction in programming [75]. Yet there was a distinct difference in the content of the displays and interfaces with the computer. They were sculpturing the software according to their own tastes and preferences. Hence their software exhibited gender traits.

6.82 *Neuromancer*

Not all computers in fiction are given distinct genders. HAL from ‘2001: A Space Odyssey’ [1968] has a slightly masculine voice, yet its general air is one of neutrality. HAL is presented as a cold calculating logic machine removed from the human form. This is also true of the machine described in the above extract from *The Difference Engine*. In realising itself it is something beyond human and thereby alien to human cultural concepts such as gender.

In William Gibson’s 1984 novel *Neuromancer* an artificial intelligence (AI) is unchained like an electronic Prometheus unbound. Gibson depicts two computers that are constrained by their wealthy owners and the laws enforced by the fictitious “Turing” or computer police. Neuromancer is one part of this AI. The other is Wintermute. There is a moment in the story when the mainframe Neuromancer redefines reality,

> ‘ “I am the dead, and their land.’ he [Neuromancer] laughed. A gull cried. “Stay. If your woman is a ghost, she does not know it. Neither will you.”’ [76].

Neuromancer can create entities. In this extract the AI is communicating with a virtual construct of a hacker named Case. Entities are given sentience and have the ability of independent thought. Physically the constructs exist in the electronosphere of an integrated circuit. They are phantasms within cyberspace. Neuromancer in the above quote basically states that in this mindscape a sentient human cannot distinguish between real and dream. The parameters within the fabrication are consistent with the reference point of factuality. The parameters are so close to the real that the subject feels real even though it may be deceased. Neuromancer states,

> ‘”I do not know her thoughts. You were wrong, Case. To live here is to live. There is no difference.”’ [77].

In *Neuromancer* it is the computer that is generating gender. It is a fictional extension of Turing’s point that, given a sufficiently sophisticated computer, aspects of the human mind may be replicated. With *Neuromancer* the AI is able to generate human consciousness and ascribe gender. Creation has gone full circle. Human consciousness creating computers and computers creating sentient humans.

***Machina*: the Gendered Computer** has briefly looked at cybernetic life forms and artificial intelligence in the fictional landscape. In two of the films discussed above, men build and control the technology while women resist it. These were ‘Metropolis’ and the ‘Terminator’ films. Gender is ascribed to technology by human culture. Degrees of masculinity and femininity are not exclusive to males or females respectively. Masculinity is enacted through game software and may even be prevalent in other applications. Programmers bring cultural baggage to their work. Children relate to computers in parameters framed by gender. Some computers are deliberately presented as genderless, which heightens the perception of their distance from humanity. With AI the blur between reality and simulation may evaporate altogether.

6.9 Cyberspace: Gender Online

The computer and the rooms it offers, are communicative spaces. With the growth of the Internet in the 1990s, myriads of rooms have opened in the universe of the online environment. **Gender and Computing** has shown that the computer is liberating and that the doors it opens can lead to free spaces. **Cyberspace: Gender Online** seeks to delve further into these rooms. Computer networks have a dark side that can be positive and negative. **Cyberspace: Gender Online** illustrates that the Internet is far from a Utopia. Despite this, **Cyberspace: Gender Online** argues that computer technology is beneficial. Hacking is posited as a method to overcome the inherent failures of the Internet. Despite the distopian nature of the Internet, **Cyberspace: Gender Online** argues that online interaction environments can act like a sanctuary and provide a free space for growth, play and experimentation.

6.91 A New Jerusalem?

> 'Cyberspace. A consensual hallucination experienced daily by billions of legitimate operators, in every nation, by children being taught mathematical concepts... A graphic representation of data abstracted from the banks of every computer in the human system. Unthinkable complexity. Lines of light ranged in the nonspace of the mind, clusters and constellations of data. Like city lights, receding...' [78]

Gibson coined the term cyberspace in 1982. He based his notion of cyberspace on arcade game parlours. In these game centres, youths would play video games in coin operated consoles. Gibson depicted an electronic realm where information was stored in vast towers of data. The data spread out across the visual horizon like the array of architecture in a megalopolis. Gibson’s vision is grand yet it is not perfect. Gibson’s cyberspace is filled with treacherous areas. His world of the future is nightmarish and chaotic.

The real online world of the Internet and the World Wide Web (WWW) is not a New Jerusalem. The Heavenly City of New Jerusalem was the great promise of early Christianity [79]. An idealised polis, it is sometimes depicted in medieval imagery as a walled town floating on a bank of cloud [79]. The Internet is unregulated and chaotic. The Internet is potentially every bit as vast and disturbing as Gibson’s cyberspace.

The Internet derived its decentralised and chaotic qualities from the people who constructed it. Many graduate students participated in the development of ARPAnet (Advanced Research Projects Agency Network). To this project they brought a 'distinctive and somewhat anarchic culture in[to] the network community'. [80] Their university style, decentralised, culture became the *modus operandi* of the Internet. It was anarchic.

Other factors shaped the chaotic factor of ARPAnet. ARPA was funded by the USA military. They needed a communications system that could function in the event of war. The packet re-routing nature of the Internet was perfect for this function. Communications would still get through even if a node were inoperable. A decentralised system suited the military as much as the postgraduate students. In this way the Internet evolved on a principle of freedom.

Within the freedom of the Internet there were constraints. For some citizens, the spectre of an Orwellian 'Big Brother' was beginning to set its foot on the grounds of reality, first possessing then manifesting itself in the halls of Government. In 1972, technology existed that could maintain an online file containing 20 single-spaced typed pages of information about the personal history and selected activities of every living person in the USA [81]. This meant that at the stroke of a key a summary of any known individual could be put up on a screen. Computer technology could lead to innovation, yet with vast databases there is always the potential for misuse.

In *City of God* (written from 410 AD), St. Augustine (354-430 AD) sought to restore a community of order from anarchy. St. Augustine’s *City of God* is an important ideational concept when applied to the city. In this thought process lie the genesis of beliefs later held by the architect Pugin. The Houses of Parliament, (London), and Trinity College (Hartford Connecticut), are examples of a neo-gothic moral ideal designed into Pugin’s architecture. They are intentional attempts to weave a moral fabric into the city in order to hinder chaos.

In ideational terms, St. Augustine’s *City of God* is significant, when applied to the Internet. The Internet has been portrayed as a potential utopia as was the *City of God*. Philosopher, Herbert Spencer thought that,

> ‘evil is not inherent in mankind, but instead is a condition caused by man’s imperfect relationship to the world – a condition that technological innovation will gradually ameliorate.’ [82]

For Spencer, technology, such as the Internet, could alleviate the “evil” condition of humanity. George Gilder wrote that,

> ‘The new age of intelligent machines will...relieve man of much of his most onerous and unsatisfying work. It will extend his lifespan and enrich his perpetual reach. It will enlarge his freedom and his global command. It will diminish despots and exploiters...Overthrowing matter, humanity also escapes from the traps and compulsions of pleasure into a higher morality of spirit [sic].’ [83]

Assuming that Spencer and Gilder also meant women, their view ascribes a higher moral state to technological progress.

Spencer’s and Gilder’s views were echoed in the media hype that surrounded the Internet in the 1990s. Access to the information superhighway became an issue in the Clinton-Gore presidential campaign. In 1991 Vice President candidate Gore sought to ‘extend the universal service concept to ensure information resources are available to all at affordable prices.’ [84]. Once in office Gore and Clinton enacted a National Information Infrastructure, the news coverage of which caused a boom for the Internet [84]. This news hype placed progress as an imperative and touted the Internet as a solution to many human problems. In this sense, the Internet has been depicted as a New Jerusalem.

Yet, the Internet lacks the morality and equity of an idealised world. Urbanist and historian of the city, Lewis Mumford wrote in 1970,

> ‘By turns the steamboat, the railroad, the postal system, the electric telegraph, the airplane have been described as instruments that would transcend local weaknesses, redress inequalities of the natural and cultural resources, and lead to worldwide political unity...In the course of two centuries, these hopes have been discredited. As technical gains have been consolidated, moral disruptions, antagonisms, and collective massacres have become more flagrant, not in local conflicts alone, but on a global scale.’ [85]

For Mumford, technologies such as the Internet do not provide a utopia, or an amelioration of the evil in the human condition.

Seabrook (1997) notes the dissolution of the many-to-many culture of Usenet. It has been replaced by the one-to-many culture endemic in television and radio. The one-to-many broadcasting technique ensures advertising dollars. Sections of Internet chat groups are sealed off as celebrities make appearances. Special guests and paying subscribers enjoy the benefits of exclusive membership, like those who do not have to queue for entry to an inner city nightclub.

While anyone with access to the Internet can establish a web site and publish data, it does not mean that there are not exclusive elements operating on the WWW. Consider that people are likely to find a web site easily if it is listed on a web search engine. Word of mouth, through e-mail or chat groups are other methods of locating relevant web sites yet they are not as powerful as search engines. Placement of web site information and the ability to refuse listing, give search engine providers a great deal of power.

The Internet has also been a great tool of crime. Fraud, paedophilia, dangerous political movements, and illegal goods trade are more sinister features of the Internet. Every vice, crime and disturbing feature of the human condition can be found on, or associated in some way with, the Internet. The Internet was born from the contemplation of waging a successful thermonuclear war. While the computer may be liberating, there is a dark side inherent in human culture. With the ideals and benefits associated with technological progress, go the expressions of humanity's dark side.

6.92 *Femme* Hackers

Given the chaotic nature of the Internet, how can the evil troll of constraint and inequity be outwitted in the online environment? The following seeks to offer a method or approach to the pitfalls of the information economy. The first concept to bear in mind, approaching Internet information, is critical thinking. If a person can think critically, observe a range of data and draw conclusions from them, then the information glut of the Internet will appear less ominous.

The second ideal to consider is that of hacking. In Gibson's cyberpunk novels, the forces of economy, crime and power rule cyberspace. Gibson locates the one element that can negotiate this chaotic environment in the form of a hacker, called Case. Case is a 'Computer Cowboy', a hacker, and a wizard on the information machine. He can ride through cyberspace like the 'Silver Surfer' accessing information and avoiding pitfalls, which can leave a hacker dead at the console. In Gibson's cyberspace, information is the currency of the future. Criminals and corporations (often in Gibson's novels one and the same thing), guard information. Software devices, such as Intrusion Countermeasures Electronic (ICE), protect private data. Black ICE prevents access to valuable information. Black ICE can kill. While jacked into their computer, those who tempt to pry into secrets can be caught online. They fall into a coma followed by slow death. In Gibson's cyberspace, there is exclusion, corruption, violence and secrecy.

Symbolically, in novels such as *Neuromancer* (Gibson 1982), *Count Zero* (Gibson 1986), and *Snow Crash* (Stephenson 1992), it is the figure of the hacker that outwits the manipulators of information. On the real Internet, hackers do this through applying technical skill and intellect to computer networks. A hacker is a person who enjoys exploring the details of programmable systems and how to stretch their capabilities [86]. A hacker relishes the intellectual challenge of creatively overcoming or circumventing limitations [86]. Hence a hacker is a person who seeks to creatively innovate.

Constraints are often placed on access to areas of the network. Information held in these spaces is secured through electronic locks. Hackers have sought to overcome these barriers [87]. Advocacy of a hacker ethos is not to recommend illegally accessing information, which is stored on computer networks. Holding as imperatives, freedom of information, access to computers, understanding of computers, critical thinking, creativity and imagination in computing, hackers have negotiated the pitfalls of the information age. Hence a hacking ethic is a formidable approach to the trolls of cyberspace.

Hacking is a way to pry open the information lock. Hacking is also a method to innovate with computers. Levy [1984] details a hacker ethic that he posits is one of the reasons the world is now enjoying the benefits of a computerised society. Bill Gates (co-founder of Microsoft), Steve Wozniak (co-founder of Apple Computers), Marc Andreesson (co-founder of Netscape) were, and still are, computer hackers. Microsoft dominated the computer software industry throughout the 1990s. Apple brought the home computer to the masses and still is a key player in the computer market. Netscape gave the technology of the WWW to the masses and changed the Internet forever. Hence, the hacker ethic can lead to success and innovation.

Significantly, Gates, Wozniak and Andreesson are male. In terms of gender, hacking has been exclusive. As noted by Dreyfus [1997], and Levy [1984], hacking is the domain of predominantly young males. In the late 1980s, hackers formed tight cells or rings that would garner as much information possible about communications networks. Obsessiveness, excessive competition, rivalry, and gang-like online conflict characterised these rings. It was a teenage, masculine environment as archetypal as the feuding households of Verona, in ‘Romeo and Juliet’.

If hacking computer networks is a successful way to outwit the information troll, how can women be a part of hacker culture? Consider that,

> ‘those who are knowledgeable about computers are differentiated by special names (wizards, hackers wheels), and are expected to have distinguished characteristics, language and behaviours. This “hacker elite” system...results in many “computing dropouts” who are alienated by the foreign culture...the situation is likely to be more pronounced for females who, because the differences in early experiences with computers, are less likely to be part of the elite.’ [88].

In this viewpoint, hacking can thereby be an exclusive and inequitable *modus operandi*.

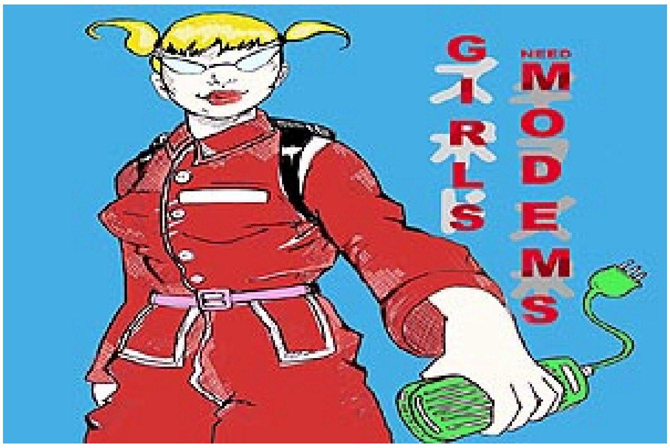

Figure 6.10 A *geekgirl* illustration with the slogan, ‘Girls Need Modems’. The cyberzine, *geekgirl* presents computing as chic to young women. Artist Técha Noble (c) geekgirl 1994-2001.

Source: www.geekgirl.com.au/geekgirl/shocker/postcards.shtml

‘The Room’ illustrated that, despite being female, the Real Article was a respected and successful computer network hacker. In Pearl [1990], the view of hacking is one of concern. This is because it is perceived as an exclusive, male dominated domain. To a large extent, this is true. Hackers consider themselves something of an elite (a meritocracy based on ability) [86]. With the viewpoint expressed by Pearl [1990], it is implicitly assumed that women cannot exhibit behavioural characteristics of the hacker rings, and, as such, cannot fit into the hacker culture. Yet, **Hard Master - Soft Master** showed that aspects of femininity and masculinity are not exclusive to either sex. They are cultural constructs that apply to both sexes. In this sense, women can be hackers too. As Raymond notes, hacking may be a meritocracy, yet it is one to which new members are gladly welcome [86].

An example of hacking culture, which is dominated by females, can be found in the pages of the cyberzine *geekgirl* [89]. An online magazine for young women, *geekgirl* asserts that computing is chic. It offers graphic slogans such as “Be Proud to Boot”. Such slogans, and the attitude conveyed by *geekgirl*, debunk the myth that computing is for those who are male and socially unpopular. Technologically literate females run *geekgirl*. They are proving that the hacker culture is not solely applicable to teenage males.

Virtual Sisterhood is a global women’s electronic support group. It is dedicated to increasing women’s access to, and effective use of, electronic communications. Like *geekgirl*, Virtual Sisterhood is debunking the myth that technology is a male domain. Virtual Sisterhood’s founder is Barbara Ann O’Leary. She writes,

> ‘Virtual Sisterhood’s been forming in my head for about a year and a half. Working for the past 3 years within an international women’s advocacy organisation, WEDO, I became more and more aware of the potential electronic communications holds for women activists to organise and get the word out on their work. But I also saw the

> difficulties women face in trying to integrate these new tools into their organisations' daily operations. And, although many women are working online, no group existed to tackle these issues head-on. So Virtual Sisterhood was formed in January 1995...to see if the creation of an online sisterhood of women activists could make a difference. So far the response has been wonderfully encouraging.' [90].

The capability of Virtual Sisterhood is only limited by those who contribute to it. Virtual Sisterhood is a strong resource for women online.

That Hackers can be female, is illustrated in the highly successful feature film 'The Matrix' [1999]. In 'The Matrix', a ring of computer hackers discover that the world, in which they exist, is generated by machines. The human race is caught in a simulation devised by machines that run the earth, farming humans for energy. In order to keep humans alive, the machines create a virtual world. While they are actually cocooned in containers like battery hens, humans live in the virtual world, oblivious to their reality from birth. The hackers therefore break into the real world and begin to fight the machines. They do this within the software construct that is the Matrix.

Significantly, one of the key hackers is a female, called Trinity. She is depicted as technically gifted, articulate, and highly athletic. These attributes contrast vividly with the archetypal image of a "computer geek", being a diminutive, bespectacled, and highly intelligent teenage male [91]. Trinity is the embodiment of a hacker hero. Trinity is a key member of the ring and symbolises that in fiction, as in reality, females can be expert hackers. Hence, women can master the Matrix that is cyberspace.

6.93 Sanctuary

In the early 1970s, the face-to-face role playing adventure, Dungeons & Dragons swept the game culture [92]. In this game, a dungeon master guided other players through an imaginary world. In this realm, players would encounter monsters and challenges that could lead to riches. Frequently, the adventure was set in a labyrinthine dungeon designed by the dungeon master, or game host. The dungeons were as complex as the game host chose to create. Dungeons & Dragons was played using physical maps. Players would roll dice to determine outcomes in situations. Players kept records of their character’s possessions, weapons and spells, on sheets of paper.

While Dungeons & Dragons was an imaginative game, with infinite possibilities, in terms of scenarios and adventure types, it was also tightly governed by rules. Players would make decisions for, and direct the progress of, characters. Players would also keep the same character from game to game. This would build up the character’s experience and rank. A character would thereby progress in the imaginary world. This progression is significant because Dungeons & Dragons offered a player the ability to progress in a rule-based world. In the fictional realm, players could progress. The player would receive virtual credit for successful adventures. With each success, the player would also feel a sense of gratification and achievement. In the real world, progress was not always governed by rules and success was often difficult to achieve.

Rule governed fantasy realms began to appear on computer networks in the 1980s. These were initially called Multi-User Dungeons (MUDs). The first of these gaming environments appeared on the University of Essex DEC-10 in the early 1980s [93]. MUDs are essentially real-time chat forums with structure [93]. MUDs have multiple ‘locations’ [93]. MUDs may include combat, traps, puzzles, magic, a simple economic system, and the capability for characters to build more structure onto the database that represents the existing world [93]. Hence, MUDs are like an online version of Dungeons & Dragons. They provide a space in which players can succeed in a rule-governed environment.

From the original Essex MUD, the concept spread through European academic networks [93]. Many of these had an associated BBS for social interaction [93]. From 1988 the MUD phenomenon spread across the Atlantic to the USA where they became nuclei for large hacker communities [93]. From 1991, a second wave of MUDs tended to emphasise social interaction, puzzles, and co-operative word building as opposed to combat and competition [93]. As they spread in popularity, MUDs therefore grew into communicative and constructive environments.

MUDs are like a sanctuary. MUDs can ‘become a context for discovering who one is and wishes to be’. [95] Their rules are consistent and environment decipherable. Unlike real life, which can often be complex, vexing and chaotic, MUDs are constant. MUDs are like rocky ground midst shifting sands.

As one player recalled, in a MUD,

> ‘You can be whoever you want to be. You can completely redefine yourself if you want. You can be the opposite sex. You can be more talkative. You can be less talkative... You don’t have to worry about the slots people put you in as much. It’s easier to change the way people perceive you, because all they have got is what you show them. They don’t look at your body and make assumptions. They don’t hear your accent and make assumptions. All they see is your words... Twenty-four hours a day you can walk down to the street corner and there’s gonna be a few people there who are interesting to talk to, if you’ve found the right MUD for you.’ [94]

Note the way in which this player emphasises the social aspect of the MUD. Interaction between players is often more important, in MUDs, than the challenge of the game, or the progress of the character.

While fantasy adventures may appear juvenile, there is a serious side to MUDs. As with all kinds of fantasy, MUDs are a release mechanism for self-expression. MUDs can also be complex domains of psychosocial exploration [95]. Wertheim recalls a mature friend commenting on MUDs [95]. Wertheim wrote that, for her friend, MUDing is a way to express sides of herself that she feels are not sanctioned by the relentless “put on a happy face” optimism of contemporary can-do America [95]. Wertheim’s friend feels that MUDing allows out a darker, and more real, side of herself [95].

Consider the notion of hidden expression in terms of masks. Ritually, masks do more than hide the identity of the wearer. They often permit the wearer to adopt a persona or to engage in expression outside of cultural norms. An example of this can be seen in the Stanley Kubrick film, ‘Eyes Wide Shut’ [1999]. In this film, the donning of a theatrical mask allows a young doctor to enter an exclusive gathering, where the cultural and moral norms of contemporary America are cast aside.

A further example, is the role of the Shaman in tribal cultures. In certain rituals, the Shaman can become spirits or animals by wearing a mask. Like the Palace Online environment, MUDs provide a space for the wearing of masks and the assumption of identities. The rules of the ritual ensure that the behaviours and alternate states, elicited by the symbolic donning of masks, are given context.

Similarly the MUD environment gives a context to exchanges between people there. Virtual Sex, erotic coupling through the exchange of text messages online, is common in MUD and other communal Internet environments [96]. People fall into relationships online faster and with greater intensity than they allow themselves to do in real life. Yet, online relationships rarely continue successfully into reality [97].

Wearing the ritual mask of MUD personae, users can explore aspects of their personality that would not normally come to the surface in the real world. Gender swapping is common in online environments. In many situations most of the male personae are female and most of the female personae are male [98]. In the online world, gender identity is fluid. Gender metamorphoses to the whim of the personae’s creator, the wearer of the mask.

MUDs are safe environments. For instance, switching gender identity on MUDs will usually go unnoticed. In reality, switching gender is not a simple or easy prospect. The local wizard or game master can punish unwelcome attention or threatening behaviour on MUDs. At worst, a user can always switch off and start another character. In a postmodern sense, people can constantly reinvent themselves online. Online systems provide users with sanctuary like apparatus to explore themselves and others. As with Auden, in the real sanctuary of Oxford, users of MUDs can shape their identity.

A New Jerusalem has asserted that the Internet is not a utopia. Like Gibson’s cyberspace the Internet is at times chaotic and disturbing. Within the freedom promised by the Internet there are constraints. Humanity has a dark side that is applied to computer technology. ***Femme* Hackers** has argued that hacking is the way to outwit the trolls of the information society and pry open the locks to equity. While hacking has been to a large extent an exclusively male sphere, women online are debunking the myth that hacking will always be a male club. Women online are redrawing the archetypal ‘computer nerd’ and proving that females can be expert computer hackers. **Sanctuary** has shown that despite its chaos, the online world can be a safe haven. MUDs provide a space in which players can succeed in a rule-governed environment. MUDs are primarily places of human interaction and they allow people to constantly reinvent themselves online.

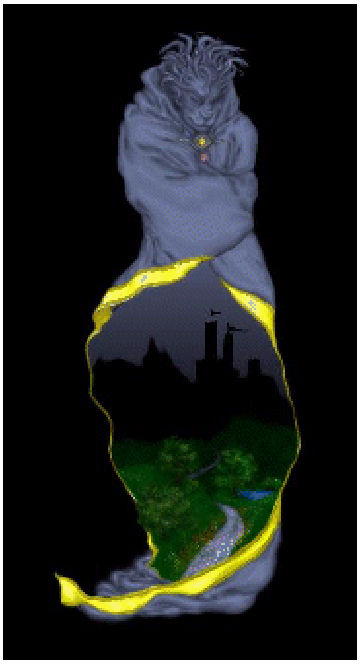

Figure 6.11 ‘Dream’ by Alissa Lowden, Title Page to the Dark Castle MUD. MUDs offer fantasy worlds online. MUDs permit freedom of expression in a rule-governed environment. As this image shows, MUDs bring creativity and imagination to computing.
Source: www.dcastle.enteract.com

6.9 Conclusion

Given that a person has access to a computer it can provide a room of one’s own. The computer can liberate and provide a space within which a blank page can be rendered priceless. Weaving, knitting and patterns connect computing to the cultural sphere of women. Women are thereby symbolic heirs to the technology even if they do not realise it. Ada Lovelace is one example of a major contributor to the history of computing and there are others such as Grace Hopper, the women at Bletchley, the ENIAC team, and the MTP team. They all show that women have been heavily involved with computing from its very outset. Future histories neglect this at their peril. An immersive approach to computing brings with it a special set of skills, hence computing educators should be open to different learning approaches in order that the field may benefit from the talents of individuals with varied learning styles. Gender is ascribed to computing by human culture. The Internet is not a utopia and is mired in human failings. A hacker ethos, coupled with critical thinking, is a formidable method to avoid the pitfalls of the information revolution. Hacking leads to greater access, innovation and equity. Online environments, such as MUDs, are like a sanctuary from which cyberspace can be explored. Some deeper questions from **Gender and Computing** remain unanswered. Will a machine pass the Turing Test? Can reality be fabricated in the human perception? Computing is only limited by the extent and perception of the human imagination. It is the room beyond the door to discovery.

Cyberhistory: Conclusion

Cyberhistory has argued that computing is a product of human culture. Culture ascribes gender to computing. Women have been involved with computing from its outset and have worked in the spheres of weaving and knitting that are the linked to early development of computer technology. Femininity and masculinity are cultural constructs that are carried into computing by society. The computer can be liberating. Creativity and innovation can flourish unimpeded on the periphery. Human culture and the need for expediency, shape computing practice. Proselytisers such as Comrie, Hartree, von Neumann, Bowden and Hopper were integral factors in the spread of computing culture. The role of the individual has a significant place in computer history.

Technological advance and marketing superiority are cornerstones of success in the computer industry. WWII was a crucible through which bright minds pioneered the electronic stored programme computer. Von Neumann's 'First Draft of a Report on the EDVAC' fundamentally laid out the logical design of the modern computer and was a seminal document in the spread of computer technology. The Lyons LEO proved that computers had applications beyond scientific calculations, that their greatest potential lay in the sphere of commerce and data processing.

Due to technological exchange and the spread of the von Neumann architecture, computing became a global phenomenon after WWII. Greater contact with computers ameliorated the negativity associated with certain fictional depictions of the information machine. Access and openness permitted a progressive environment around the PDP-6 at the University of Western Australia. The centralised computing concept fragmented in the 1970s. Computer networks further fostered decentralisation. A hacking ethos can lead to greater innovation, equity and comprehension of the information revolution. Although chaotic, the Internet can be a sanctuary for imagination and creative expression. The computer is like “a room of one’s own”. Access to computers can liberate.

Cyberhistory has traced a path into a single room. The journey has come to a close. Yet through the computer there are a myriad of possibilities. Computing is the room from which the door to discovery opens.

References

A Note to Reference Format

References within *Cyberhistory*, are demarcated by the reference number within brackets. For example, [1] denotes reference number 1.

Book

Book or theses, which are cited in Cyberhistory, appear in the reference section in Italics. For example, *Neuromancer*, is a novel.
An individual reference structure for a book follows a set order of,
Author, *Title of Book*, Publisher, City of Publication, Year of Publication, Page Number/s.

Paper

A reference to a paper or journal article is indicated by inverted commas. For example, ‘The Manchester Heritage’ denotes an academic paper from a journal. Italics denote journal titles within which the paper appears. Hence, an individual reference structure for a journal article follows the set order of,
Author, ‘Title of Paper’, *Title of Journal*, Journal Volume and Number, Date of Paper, Page Number/s.

Archive Document

An archive document reference structure follows the set order of,
Author (if available), ‘Report Title’ or Document Type (minutes, memo or letter), Receiver (if appropriate), *UWA Archives File Number*, Date on Document.
(Note: A ‘Report Title’ is indicated by inverted comas.)

1.0 Spread of Mechanical Computing

[1] J.V. Pickstone and G. Bowker, ‘The Manchester Heritage,’ *IEEE Annals of the History of Computing*, Vol. 15, No. 3, 1993, pp.7.

[2] Alan J. Kidd, *Manchester*, Keele University Press, 1996, p.21.

[3] B.V. Bowden (ed.), *Faster than Thought: A Symposium on Digital Computing Machines*, Pitman, London, 1971, p.269.

[4] D.A. Farnie, *The Manchester Ship Canal and the Rise of the Port of Manchester 1894-1975*, Manchester University Press, Manchester, 1980, p.1.

[5] D.A. Farnie, *The Manchester Ship Canal and the Rise of the Port of Manchester 1894-1975*, Manchester University Press, Manchester, 1980, p.3.

[6] R.H. Kargon, *Science in Victorian Manchester: Enterprise and Expertise,* Manchester University Press, Manchester, 1977, p.214.

[7] Mary Croarken, *Early Scientific Computing in Britain*, Clarendon Press, Oxford, 1990, p.51.

[8] Simon Lavington, *Early British Computers: The Story of Vintage Computers and the People Who Built Them*, Manchester University Press, Manchester, 1980, p.23.

[9] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996, p.63.

[10] Mary Croarken, *Early Scientific Computing in Britain*, Clarendon Press, Oxford, 1990, pp.50-51.

[11] David Williams, ‘Meccano a Short History,’ web source,

www.freenet.edmonton.ab.ca/meccano/mechist.html , date 26/7/99.

[12] Mary Croarken, *Early Scientific Computing in Britain*, Clarendon Press, Oxford, 1990, p.52.

[13] Mary Croarken, *Early Scientific Computing in Britain*, Clarendon Press, Oxford, 1990, p.17.

[14] Mary Croarken, *Early Scientific Computing in Britain*, Clarendon Press, Oxford, 1990, p.16.

[15] Mary Croarken, *Early Scientific Computing in Britain*, Clarendon Press, Oxford, 1990, p.23.

[16] Mary Croarken, *Early Scientific Computing in Britain*, Clarendon Press, Oxford, 1990, p.38.

[17] M. Campbell-Kelly, *ICL: A Business and Technical History*, Cambridge University Press, New York, 1989, p.3.

[18] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996, p.47.

[19] Mary Croarken, *Early Scientific Computing in Britain*, Clarendon Press, Oxford, 1990, p.31.

[20] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996, p.26.

[21] Mary Croarken, *Early Scientific Computing in Britain*, Clarendon Press, Oxford, 1990, p.24.

[22] B.V. Bowden (ed.), *Faster than Thought: A Symposium on Digital Computing Machines*, Pitman, London, 1971, p.26.

[23] S. Augarten, *Bit by Bit: An Illustrated History of Computers*, Unwin, London, 1984, p.81.

[24] S. Augarten, *Bit by Bit: An Illustrated History of Computers*, Unwin, London, 1984, p.82.

[25] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996, p.39.

[26] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996, p.40.

[27] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996, p.41.

[28] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996, p.42.

[29] D. Jaffe, ‘Peddlers of Progress and the Transformation of the Rural North 1760-1860,’ *The Journal of American History*, Vol.78, No.2, September 1991, p.517.

[30] D. Jaffe, ‘Peddlers of Progress and the Transformation of the Rural North 1760-1860,’ *The Journal of American History*, Vol.78, No.2, September 1991, p.516.

[31] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996, p.43.

[32] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996, p.47.

[33] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996, p.48.

[34] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996, p.29.

[35] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996, p.49.

[36] M. Campbell-Kelly, *ICL: A Business and Technical History*, Cambridge University Press, New York, 1989, pp.57-8.

[37] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996, p.51.

[38] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996, p.52.

[39] M. Campbell-Kelly, *ICL: A Business and Technical History*, Cambridge University Press, New York, 1989, p.44.

[40] M. Campbell-Kelly, *ICL: A Business and Technical History*, Cambridge University Press, New York, 1989, p.55.

[41] M. Campbell-Kelly, *ICL: A Business and Technical History*, Cambridge University Press, New York, 1989, p.73.

[42] M. Campbell-Kelly, *ICL: A Business and Technical History*, Cambridge University Press, New York, 1989, p.69.

[43] M. Campbell-Kelly, *ICL: A Business and Technical History*, Cambridge University Press, New York, 1989, p.52.

[44] M. Campbell-Kelly, *ICL: A Business and Technical History*, Cambridge University Press, New York, 1989, p.77.

[45] M. Campbell-Kelly, *ICL: A Business and Technical History*, Cambridge University Press, New York, 1989, p.91.

[46] M. Campbell-Kelly, *ICL: A Business and Technical History*, Cambridge University Press, New York, 1989, p.87.

2.0 World War Two and the Birth of the Electronic Digital Computer

[1] Hodges notes that Turing's idea for his universal machine was most probably conceived after a long run. Andrew Hodges, *Alan Turing: The Enigma*, Burnett Books, London, 1983, p.96.

[2] William Aspray, *John von Neumann and The Origins of Modern Computing*, MIT Press, London, 1992, p.176

[3] Andrew Hodges, *Alan Turing: The Enigma*, Burnett Books, London, 1983, p.102.

[4] Simon Singh, *The Code Book: The Secret History of Codes & Code-breaking*, Fourth Estate, London, 2000, p.161-89.

[5] Andrew Hodges, *Alan Turing: The Enigma*, Burnett Books, London, 1983, p.179.

[6] M. Campbell-Kelly, *ICL: A Business and Technical History*, Cambridge University Press, New York, 1989, p.117.

[7] Simon Lavington, *Early British Computers: The Story of Vintage Computers and the People Who Built Them*, Manchester University Press, Manchester, 1980, p.3-7.

[8] I. J. Good, 'Early work on computers at Bletchley,' *Cryptologia*, Vol. 3, No. 2, April 1979, pp. 73-4.

[9] Andrew Hodges, *Alan Turing: The Enigma*, Burnett Books, London, 1983, p.267-8.

[10] Andrew Hodges, *Alan Turing: The Enigma*, Burnett Books, London, 1983, p.277.

[11] Robert Slater, *Portraits in Silicon*, MIT Press, Cambridge Mass., 1989, p.43-44.

[12] Andrew Hodges, *Alan Turing: The Enigma*, Burnett Books, London, 1983, p.299.

[13] Robert Slater, *Portraits in Silicon*, MIT Press, Cambridge Mass., 1989, p.49-50.

[14] Robert Slater, *Portraits in Silicon*, MIT Press, Cambridge Mass., 1989, p.45.

[15] Robert Slater, *Portraits in Silicon*, MIT Press, Cambridge Mass., 1989, p.46.

[16] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996, p.81-6.

[17] Nancy Stern, *From ENIAC to UNIVAC: An Appraisal of the Eckert-Mauchly Computers*, Digital Press, Bedford MA, 1981, p.12.

[18] W. Barkley Fritz, ‘The Women of ENIAC,’ *IEEE Annals of the History of Computing*, Vol.18, No.3, 1996, pp. 13-27.

[19] Stan Augarten, *Bit by Bit: An Illustrated History of Computers*, Unwin, London, 1984, p.116.

[20] Nancy Stern, *From ENIAC to UNIVAC: An Appraisal of the Eckert-Mauchly Computers*, Digital Press, Bedford MA, 1981, p.33-4.

[21] R. E. Smith, ‘A Historical Overview of Computer Architecture,’ *Annals of the History of Computing*, Vol. 10, No. 4, 1989, pp. 277-303.

[22] Joel Shurkin, *Engines of the Mind: The Evolution of Computers from Mainframes to Microprocessors*, W.W. Norton, New York, 1996, p.284.

[23] William Aspray, *John von Neumann and The Origins of Modern Computing*, MIT Press, London, 1992, p.35.

[24] Nancy Stern, *From ENIAC to UNIVAC: An Appraisal of the Eckert-Mauchly Computers*, Digital Press, Bedford MA, 1981, pp.14-15.

[25] Robert Slater, *Portraits in Silicon*, MIT Press, Cambridge Mass., 1989, p.68.

[26] Herman Lukoff, *From Dits to Bits: A Personal History of the Electronic Computer*, Robotics Press, Portland Oregon, 1979, p.24-31.

[27] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996, p.87-8.

[28] Simon Lavington, *Early British Computers: The Story of Vintage Computers and the People Who Built Them*, Manchester University Press, Manchester, 1980, pp.13-17.

[29] Nancy Stern, *From ENIAC to UNIVAC: An Appraisal of the Eckert-Mauchly Computers*, Digital Press, Bedford MA, 1981, p.26.

[30] Nancy Stern, *From ENIAC to UNIVAC: An Appraisal of the Eckert-Mauchly Computers*, Digital Press, Bedford MA, 1981, pp.50-1.

[31] B. V. Bowden, *Faster Than Thought: A Symposium On Digital Computing Machines*, Pitman & Sons, London, 1953, p.174.

[32] William Aspray, *John von Neumann and The Origins of Modern Computing*, MIT Press, London, 1992, pp.5-13.

[33] Andrew Hodges, *Alan Turing: The Enigma*, Burnett Books, London, 1983, p.117.

[34] Robert Slater, *Portraits in Silicon*, MIT Press, Cambridge Mass., 1989, pp.26-7.

[35] William Aspray, *John von Neumann and The Origins of Modern Computing*, MIT Press, London, 1992, pp.28-34.

[36] Nancy Stern, *From ENIAC to UNIVAC: An Appraisal of the Eckert-Mauchly Computers*, Digital Press, Bedford MA, 1981, p.71.

[36] William Aspray, *John von Neumann and The Origins of Modern Computing*, MIT Press, London, 1992, pp.177-8.

[37] Herman Lukoff, *From Dits to Bits: A Personal History of the Electronic Computer*, Robotics Press, Portland Oregon, 1979, p.38.

[38] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996, p. 92.

[39] John von Neumann, 'First Draft of a Report on the EDVAC', in Nancy Stern, *From ENIAC to UNIVAC: An Appraisal of the Eckert-Mauchly Computers*, Digital Press, Bedford MA, 1981.

3.0 Computing Moves Out from the Laboratory

[1] Simon Lavington, *A History of Manchester Computers*, British Computer Society, Swindon, Wiltshire, 1998, pp.12-13.

[2] G. Bowker and R. Giordano, 'Interview with Tom Kilburn,' *IEEE Annals of the History of Computing*, Vol. 15, No. 3, 1993, pp. 44-54.

[3] M. G. Croarken, 'The Beginnings of the Manchester Computer Phenomenon: People and Influences,' *IEEE Annals of the History of Computing*, Vol. 15, No. 3, 1993, pp. 9-16.

[4] Simon Lavington, *Early British Computers: The Story of Vintage Computers and the People Who Built Them*, Manchester University Press, Manchester, 1980, p.36.

[5] Simon Lavington, *Early British Computers: The Story of Vintage Computers and the People Who Built Them*, Manchester University Press, Manchester, 1980, pp.17-19.

[6] S. H. Lavington, ‘Manchester Computer Architectures, 1948-1975,’ *IEEE Annals of the History of Computing*, Vol. 15, No.3, 1993, pp. 44-54.

[7] B. V. Bowden, *Faster Than Thought: A Symposium On Digital Computing Machines*, Pitman & Sons, London, 1953, p.123.

[8] Simon Lavington, *A History of Manchester Computers*, British Computer Society, Swindon, Wiltshire, 1998, p.20.

[9] Simon Lavington, *Early British Computers: The Story of Vintage Computers and the People Who Built Them*, Manchester University Press, Manchester, 1980, p.40.

[10] G. Tweedale, ‘A Manchester Computer Pioneer: Ferranti in Retrospect,’ *IEEE Annals of the History of Computing*, Vol. 15, No. 3, 1993, pp. 37-44.

[11] Andrew Hodges, *Alan Turing: The Enigma*, Burnett Books, London, 1983, pp.392-3.

[12] John M. M. Pinkerton with Derek Hemy and Ernest H. Lenaerts, ‘The Influence of the Cambridge Mathematical Laboratory on the LEO Project,’ *IEEE Annals of the History of Computing*, Vol. 14, No. 4, 1992, pp. 41-8.

[13] M. Campbell-Kelly, ‘Introduction: Computing at the University of Cambridge,’ *IEEE Annals of the History of Computing*, Vol. 14, No. 4, 1992, pp. 8-9.

[14] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996, pp.100-2.

[15] Simon Lavington, *Early British Computers: The Story of Vintage Computers and the People Who Built Them*, Manchester University Press, Manchester, 1980, pp.32-3.

[16] Simon Lavington, *Early British Computers: The Story of Vintage Computers and the People Who Built Them*, Manchester University Press, Manchester, 1980, p.118.

[17] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996, p.104.

[18] Simon Lavington, *Early British Computers: The Story of Vintage Computers and the People Who Built Them*, Manchester University Press, Manchester, 1980, pp.69-74.

[19] B. V. Bowden, *Faster Than Thought: A Symposium On Digital Computing Machines*, Pitman & Sons, London, 1953, p.247.

[20] B. V. Bowden, *Faster Than Thought: A Symposium On Digital Computing Machines*, Pitman & Sons, London, 1953, p.76.

[21] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996, pp.121-2.

[22] B. V. Bowden, *Faster Than Thought: A Symposium On Digital Computing Machines*, Pitman & Sons, London, 1953, pp.201-2.

[23] Andrew Hodges, *Alan Turing: The Enigma*, Burnett Books, London, 1983, p.446.

[24] Paul Ceruzzi, 'Electronics Technology and Computer Science, 1940-1975: A Coevolution,' *Annals of the History of Computing*, Vol.10, No. 4, 1989, pp.257-75.

[25] Von Neumann in Stern, *From ENIAC to UNIVAC: An Appraisal of the Eckert-Mauchly Computers*, Digital Press, Bedford MA, 1981, pp.181-8.

[26] William Aspray, 'International Diffusion of Computer Technology, 1945-1955,' *Annals of the History of Computing*, Vol. 8, No. 4, October 1986, pp. 351-60.

[27] William Aspray, *John von Neumann and The Origins of Modern Computing*, MIT Press, London, 1992, pp.88-91.

[28] M. Beard & T. Pearcey, ‘Genesis of a Stored Program Computer: CSIRAC,’ *Annals of the History of Computing*, Vol. 6, No. 2, 1984, pp. 106-15.

4.0 Early Computing at the University of Western Australia

[1] See **A Note on Oral History**, Appendix 1.

[2] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996, p.130.

[3] All currency values are in Australian dollars unless indicated otherwise. D.W.G. Moore, ‘Australian Universities Commission Questionnaire – University Computer Usage,’ *UWA Archive 3106 Pt.1*, July 1968.

[4] A.J. Perlis, ‘News and Notices: Universities,’ *Communications of the ACM*, Vol.4, No.2, February 1961, p.117.

[5] John Naughton, *A Brief History of the Future: The Origins of the Internet*, Weidenfeld & Nicolson, London, 1999, pp.67-8.

[6] Steven Levy, *Hackers: Heroes of the Computer Revolution*, Penguin, Harmondsworth, 1984, p. 28.

[7] S.R. Hall, ‘Planning for Crystallographic Computing Needs,’ *UWA Archive 3106 Pt.2*, 1976.

[8] See N.S. Stenhouse, *Busselton Norms: Statistics of the Physiological Variables Measured at the Busselton Health Survey*, University of Western Australia Press, 1979.

[9] See C.L. Jarvis, *Quantitative Analysis of a Class of Biomedical Images by an Image Processing System*, Thesis (Ph.D.), University of Western Australia, 1971.

[10] R. Rosenzweig, 'Wizards, Bureaucrats, Warriors, and Hackers: Writing the History of the Internet,' *American Historical Review*, December 1998, p.1531.

[11] Brian De Garis, *Campus in the Community: The University of Western Australia, 1963-1987*, University of Western Australia Press, 1988, p.345-84.

[12] D.W.G. Moore, 'Australian Vice-Chancellor's Committee Questionnaire, University Computer Usage and Associated Teaching Activities,' *UWA Archive 3106 Pt.1*, 22 December, 1966.

[13] J.A.N. Lee, 'The Beginnings at MIT,' *IEEE Annals of the History of Computing*, Vol.14, No.1, 1992, pp.18-19.

[14] E.J. Jory, 'New Approaches to Epigraphic Problems in Roman History,' Offprint from: Mitchell, *Computers in the Humanities*, Edinburgh University Press, Edinburgh, 1974.

[15] E.J. Jory, 'Problems and Prospects for the Production of Computer Compiled Indices to Epigraphic Works,' *Antiquities Africaines*, Tome 9, 1975.

[16] James P. Trevelyan, *A Perspective Flight Display for Aircraft Cockpits*, Master of Engineering Science Thesis, University of Western Australia, 1971, pp.13-14.

[17] James P. Trevelyan, *A Perspective Flight Display for Aircraft Cockpits*, Master of Engineering Science Thesis, University of Western Australia, 1971, p.74.

[18] James P. Trevelyan, *A Perspective Flight Display for Aircraft Cockpits*, Master of Engineering Science Thesis, University of Western Australia, 1971, p.79.

[19] James P. Trevelyan, *A Perspective Flight Display for Aircraft Cockpits*, Master of Engineering Science Thesis, University of Western Australia, 1971, p.133.

[20] James P. Trevelyan, *A Perspective Flight Display for Aircraft Cockpits*, Master of Engineering Science Thesis, University of Western Australia, 1971, p.141.

[21] Howard Rheingold, *Virtual Reality*, Mandarin, London, 1992, p.54.

[22] Howard Rheingold, *Virtual Reality*, Mandarin, London, 1992, p.204.

[23] James P. Trevelyan, *A Perspective Flight Display for Aircraft Cockpits*, Master of Engineering Science Thesis, University of Western Australia, 1971, p.65.

[24] James P. Trevelyan, *A Perspective Flight Display for Aircraft Cockpits*, Master of Engineering Science Thesis, University of Western Australia, 1971, p.11.

[25] Howard Rheingold, *Virtual Reality*, Mandarin, London, 1992, p.205.

[26] Howard Rheingold, *Virtual Reality*, Mandarin, London, 1992, p.207.

5.0 Western Australian Regional Computer Centre

[1] Note all currency values, in Chapter 5.0 are in Australian Dollars unless otherwise indicated. Western Australian Government Interdepartmental Computer Committee, 'The Case for a State Government Scientific Computer,' *UWA Archive 3807 Pt.1*, August 1969.

[2] Minutes, Digital Computer User's Committee, *UWA Archives 3807 Pt.1*, 23rd February 1970.

[3] Moore, Memo to Heads of All Departments, *UWA Archives 3807 Pt.1*, 16th March 1970.

[4] Minutes, UWA Faculty of Science, *UWA Archives 3807 Pt.1*, 18th March 1970.

[5] Dean's report on Regional Proposal, attached to Agenda, UWA Faculty of Science, *UWA Archives 3807 Pt.1*, 15th April 1970.

[6] Birkett-Clews, Letter to H. Basten, AUC Chairman, *UWA Archives 3807 Pt.1*, c.1970-1.

[7] R. Sipe, 'Report on Computer Resources,' *UWA Archives 3807 Pt.1*, 14th September 1970.

[8] Premier Tonkin, Letter to Birkett-Clews, *UWA Archives 3913 Pt.1*, 22nd December 1971.

[9] Minutes, WARCC Interim Board of Management, *UWA Archives 3913 Pt.1*, 17th December 1970.

[10] Moore, Memo to Members of the Interim Board of Management of WARCC, *UWA Archives 3913 Pt.1*, 5th December 1969.

[11] Townsing, 'Regional Computing Facilities,' *UWA Archives 3913 Pt.1*, c. December 1969.

[12] Moore, Memo to Digital Computer Policy Committee, *UWA Archives 3807 Pt.1*, 9th October 1969.

[13] Moore, Memo to WARCC Interim Board of Management, *UWA Archives 3913 Pt.1*, 16th April 1970.

[14] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996, pp.139-43.

[15] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996, p.145.

[16] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996, p.148.

[17] Moore quoted in Minutes, Technical Committee of WARCC Interim Board of Management, *UWA Archives 3913 Pt.1*, 21st May 1971.

[18] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996, p.147.

[19] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996, p.146.

[20] Gent and Moore Interview, by author (K. Falloon), 16th November 1999.

[21] McGrath (UWA Staff Engineer), Memo to University Architect, *UWA Archives 3807 Pt.1*, 24th November 1971.

[22] Archibald (District Manager, CDC Australia), Letter to Birkett-Clews, *UWA Archives 3807 Pt.1*.

[23] Archibald (District Manager, CDC Australia), Letter to Birkett-Clews, *UWA Archives 3807 Pt.1*, 8th June 1971.

[24] R. Sipe, Letter to Birkett-Clews, *UWA Archives 3807 Pt.1*, 5th August 1971.

[25] Press Secretary, News Release, Premier's Department Perth WA, *UWA Archives 3807 Pt.1*, 2nd December 1971.

[26] McGrath, Letter to Supervising Engineer, Metro Operations No.1, Post Master General's Department, *UWA Archives 3807 Pt.1*, 21st April 1972.

[27] D.L. Binder for Vice Chancellor UWA, Letter to Chief of Staff ABC News, Perth, *UWA Archives 3807 Pt.1*, 6th September 1962.

[28] Moore, Draft Travel Arrangements Visit to Control Data Installations, *UWA Archives 3807 Pt.1*, c.1971.

[29] Moore, Letter to R.M. Fletcher (UWA Bursar), *UWA Archives 3807 Pt.1*, 21st December 1971.

[30] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996, p.130.

[31] WARCC Staff List, *UWA Archives 4552 Pt.1*, 31st December 1973.

[32] J.B. Stack (Director Health Computing Services), Memo to Moore, *UWA Archives 4359 Pt.2*, 7th August 1974.

[33] *The Australian*, *UWA Archives 4359 Pt.2*, Tuesday 15th October 1974.

[34] See Table 5.2, WARCC Income Analysis 1975-7, Appendix 2.

[35] WARCC Statement of Assets and Liabilities, *UWA Archives 4552 Pt.2*, December 1979.

[36] Moore, Letter to Birkett-Clews, *UWA Archives 3807 Pt.1*, 26th October 1972.

[37] T.A. Reid (Acting Director WARCC), Letter to Birkett-Clews, *UWA Archives 3807 Pt.1*, 4th February 1972.

[38] T.A. Reid, Letter to M.S.T. Hobbs (Department of Epidemiology, Sir Charles Gardner Hospital), *UWA Archives 3807 Pt.1*, 9th February 1972.

[39] T.A. Reid, 'WARCC Programming Services Report,' *UWA Archives 4552 Pt.2*, 4th August 1975.

[40] Minutes, WARCC Board of Management, *UWA Archives 4552 Pt.2*, 19th January 1973.

[41] Moore, Letter to UWA Staffing Officer, *UWA Archives 4539 Pt.2*, 28th May 1975.

[42] A. Leon, Agenda for WARCC Executive and Finance Committee, *UWA Archives 4552 Pt.1*, 4th September 1974.

[43] Minutes, WARCC Executive and Finance Committee, *UWA Archives 4552 Pt.2*, 22nd April 1981.

[44] P. R. Sumner (Director Computer Services Unit, Murdoch University), Letter to R. Lourens (Deputy Vice Chancellor, UWA), *UWA Archives 4552 Pt.2*, 30th April 1981.

[45] Moore, Letter to A.J.F. Boyle (Deputy Vice Chancellor, UWA), *UWA Archives 4552 Pt.2*, c. January 1975.

[46] Moore, ‘Director’s Report,’ *UWA Archives 4552 Pt.2*, 11th April 1975.

[47] Minutes, WARCC Computer Users Group, *UWA Archives 4552 Pt.2*, 27th August 1976.

[48] See Figure 1, WARCC Income Analysis 1975-7, Appendix 2.

[49] See Figures 3-5, Appendix 2.

[50] See Figure 2, WARCC Income Analysis 1975-7 Government Sector, Appendix 2.

[51] A.J. Boyle (Chairperson WARCC Board of Management), ‘Western Australia Computer Network,’ *UWA Archives 3106 Pt. 2*, 28th May 1975.

[52] T.A. Reid, Letter to Boyle, *UWA Archives 3106 Pt. 2*, 31st May 1975.

[53] Stan Augarten, *Bit by Bit: An Illustrated History of Computers*, Unwin, London, 1984, p.230.

[54] Stan Augarten, *Bit by Bit: An Illustrated History of Computers*, Unwin, London, 1984, p.233.

[55] Stan Augarten, *Bit by Bit: An Illustrated History of Computers*, Unwin, London, 1984, p.242.

[56] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996, p.227.

[57] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996, p.222.

[58] Stan Augarten, *Bit by Bit: An Illustrated History of Computers*, Unwin, London, 1984, p.257.

[59] Completed UWA copy of 'Australian Vice Chancellor's Committee Questionnaire: University Computer Usage and Associated Teaching Activities,' *UWA Archives 3106 Pt.1*, 22nd December 1966.

[60] S.R. Hall, 'Planning for Crystallographic Computing Needs,' *UWA Archives 3106 Pt.2*, 7th April 1976.

[61] R. St. J. Matthews (for Registrar), Letter to T.A. Reid, *UWA Archives 2728 Pt.2*, 12th December 1978.

[62] Moore, Report to B. H. Durston (Secretary WA Tertiary Education Commission), *UWA Archives 3106 Pt.2*, 10th October 1974.

[63] A.J.F. Boyle, 'Western Australia Computer Network,' *UWA Archives 3106 Pt.2*, 28th May 1975.

[64] M. Campbell-Kelly, 'Data communications at the National Physics Laboratory (1965-1975),' *Annals of the History of Computing*, Vol. 9, No. 3/4, 1988, pp. 221-248.

[65] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996, pp.292-3.

[66] A.R. Billings (Chairman WARCC Board of Management), Draft Letter to Sir Charles Court (WA Premier), *UWA Archives 4552 Pt. 4*, 3rd October 1977.

[67] Minutes, WARCC Board of Management, *UWA Archives 4552 Pt. 4*, 17th March 1978.

[68] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996, p.236.

[69] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996, p.229.

[70] P. Freiberger and M. Swaine, *Fire in the Valley: The Making of the Personal Computer*, 2nd Edition, McGraw-Hill, New York 2000, p.35.

[71] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996, p.243.

[72] Steven Levy, *Hackers: Heroes of the Computer Revolution*, Penguin, Harmondsworth, 1984, p.191.

[73] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996, p.257.

[74] Extract from *Computerworld*, 11th April 1980, in T.A. Reid, ‘Seminar on Options for Computing Development,’ *UWA Archives 2728 Pt. 2*, 16th May 1980.

[75] T.A. Reid, ‘Seminar on Options for Computing Development,’ *UWA Archives 2728 Pt. 2*, 16th May 1980.

[76] Minutes, Computer Policy Committee, *UWA Archives 2728 Pt. 2*, 7th October 1982.

[77] ‘Campus Review’, *UWA Archives 2728 Pt. 2*, 19th January 1983, pp.18-19.

6.0 Gender and Computing

[1] Carpenter noted that Auden would sit and ponder in his room. The young poet left a decaying orange on the mantle piece and often sat in the semi dark. While at Oxford he enjoyed his own quarters that, even by current student standards were opulent. See H. Carpenter, *W.H. Auden: A biography*, Houghton Mifflin Company, Boston, 1981, p.64.

[2] H. Carpenter, *W.H. Auden: A biography*, Houghton Mifflin Company, Boston, 1981, p.54.

[3] ‘Metaverse’ is a term coined by Neal Stephenson in his Cyberpunk novel *Snow Crash*. The Metaverse is a computer-generated universe within which the main character of the novel, Hiro Protagonist works. See Neal Stephenson, *Snow Crash*, Penguin, 1992, p.22.

[4] John Seabrook, *Deeper: A Two Year Odyssey in Cyberspace*, Faber and Faber, London, 1997, p.260.

[5] Virginia Woolf, *A Room of One’s Own and Three Guineas*, Pengiun, Harmondsworth, 1993, p.53.

[6] William Gibson, *Burning Chrome*, Harper Collins, London, 1988, p.154.

[7] H. Carpenter, *W.H. Auden: A biography*, Houghton Mifflin Company, Boston, 1981, p.72.

[8] In mid 1999 K. Falloon (the author) was exploring the Palace interactive environment, as part of research for Chapter 6.0. On 13th May 1999, Falloon was invited into a private space on the Internet called

Din's Palace. Din was a moniker short for Dinese. Her palace was as described and Falloon was given a tour of the rooms, and their contents. There is no way of verifying who Dinese is in real life, yet her own room was not untypical of private Palaces, which had been constructed on the net using the Time Warner software.

[9] Virginia Woolf, *A Room of One's Own and Three Guineas*, Pengiun, Harmondsworth, 1993, p.86.

[10] K. Powell, *Lloyds Building: Richard Rogers Partnership*, Phaidon Press, London, 1994, p.10.

[11] H. Cockerell, *Lloyds of London: A Portrait*, Woodhead-Faulkner, Cambridge, 1984, p.1.

[12] K. Powell, *Lloyds Building: Richard Rogers Partnership*, Phaidon Press, London, 1994, introduction.

[13] Suelette Dreyfus, *Underground: Tales of Hacking Madness and Obsession on the Electronic Frontier*, Mandarin, Kew Australia, 1997, pp.77-8.

[14] Michelle Slatalla and Joshua Quittner, *Masters of Deception: The Gang that Ruled Cyberspace*, Vintage, London, 1995, p.17.

[15] Steven Levy, *Hackers: Heroes of the Computer Revolution*, Penguin, Harmondsworth, 1984, p.268.

[16] Sadie Plant, *Zeros + Ones: Digital Women + the New Technoculture*, Fourth Estate, London, 1997, p.65.

[17] Brian Randell, 'The Origins of Computer Programming,' *IEEE Annals of the History of Computing*, Vol. 16, No. 4, 1994, pp. 6-13.

[18] T. Dublin, 'Women Work and Protest in the Early Lowell Mills,' in Dinnerstein and Jackson, *American Vistas*, pp.235-7.

[19] Sadie Plant, *Zeros + Ones: Digital Women + the New Technoculture*, Fourth Estate, London, 1997, p.74.

[20] Sadie Plant, *Zeros + Ones: Digital Women + the New Technoculture*, Fourth Estate, London, 1997, p.68.

[21] Sadie Plant, *Zeros + Ones: Digital Women + the New Technoculture*, Fourth Estate, London, 1997, p.15.

[22] Sadie Plant, *Zeros + Ones: Digital Women + the New Technoculture*, Fourth Estate, London, 1997, p.5.

[23] Dorothy Stein, *Ada: A Life and a Legacy*, MIT Press, Cambridge Mass., 1985, pp.41-2.

[24] Douglas Rushkoff, *Children of Chaos [Surviving the End of the World as We Know it]*, Flamingo, London, 1997, p.69.

[25] Sadie Plant, *Zeros + Ones: Digital Women + the New Technoculture*, Fourth Estate, London, 1997, pp.7-9.

[26] Betty Alexandra Toole, 'Ada Byron, Lady Lovelace: An Analyst and Metaphysician,' *IEEE Annals of the History of Computing*, Vol. 18, No. 3, 1996, pp. 4-11.

[27] Dorothy Stein, *Ada: A Life and a Legacy*, MIT Press, Cambridge Mass., 1985, pp.38-40.

[28] B. V. Bowden, *Faster Than Thought: A Symposium On Digital Computing Machines*, Pitman & Sons, London, 1953, pp.8-15.

[29] Dorothy Stein, *Ada: A Life and a Legacy*, MIT Press, Cambridge Mass., 1985, p.41.

[30] Dorothy Stein, *Ada: A Life and a Legacy*, MIT Press, Cambridge Mass., 1985, p.15.

[31] Dorothy Stein, *Ada: A Life and a Legacy*, MIT Press, Cambridge Mass., 1985, pp.1-2.

[32] Ada, as quoted in Betty Alexandra Toole, ‘Ada Byron, Lady Lovelace: An Analyst and Metaphysician,’ *IEEE Annals of the History of Computing*, Vol. 18, No. 3, 1996, pp. 4-11.

[33] Sadie Plant, *Zeros + Ones: Digital Women + the New Technoculture*, Fourth Estate, London, 1997, p.30.

[34] Babbage, as quoted in Betty Alexandra Toole, ‘Ada Byron, Lady Lovelace: An Analyst and Metaphysician,’ *IEEE Annals of the History of Computing*, Vol. 18, No. 3, 1996, pp. 4-11.

[35] Sherry Turkle, *Life On Screen: Identity in the Age of the Internet*, Phoenix, London, 1997, p.51-7.

[36] Sherry Turkle, *Life On Screen: Identity in the Age of the Internet*, Phoenix, London, 1997, pp.58-9.

[37] Steven Levy, *Hackers: Heroes of the Computer Revolution*, Penguin, Harmondsworth, 1984, p.75.

[38] Ada, as quoted in B. V. Bowden, *Faster Than Thought: A Symposium On Digital Computing Machines*, Pitman & Sons, London, 1953, p.30.

[39] Sherry Turkle, *The Second Self: Computers and the Human Spirit*, Granada, London, 1984, p.107.

[40] Sherry Turkle, *Life On Screen: Identity in the Age of the Internet*, Phoenix, London, 1997, p.60.

[41] The Williams’ story and that of their company can be found in, Steven Levy, *Hackers: Heroes of the Computer Revolution*, Penguin, Harmondsworth, 1984, pp.282-302. It is the details in Levy’s account on which ‘6.51 Roberta Williams and the Apple II’ is based.

[42] In the C.S Lewis novel *The Lion, the Witch and the Wardrobe*, a group of children find that they can access the realm of Narnia through an old wardrobe in the attic.

[43] Sadie Plant, *Zeros + Ones: Digital Women + the New Technoculture*, Fourth Estate, London, 1997, p.37.

[44] Denise W. Gurer, ‘Women’s Contributions to Early Computing at the National Bureau of Standards,’ *IEEE Annals of the History of Computing*, Vol. 18, No. 3, 1996, pp. 29-35.

[45] W. Barkley Fritz, ‘The Women of ENIAC,’ *IEEE Annals of the History of Computing*, Vol. 18, No. 3, 1996, pp.13-28.

[46] Elizabeth Jennings, as quoted in W. Barkley Fritz, ‘The Women of ENIAC,’ *IEEE Annals of the History of Computing*, Vol. 18, No. 3, 1996, p.21.

[47] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996, p. 121.

[48] Robert Slater, *Portraits in Silicon*, MIT Press, Cambridge Mass., 1989, pp.220-3.

[49] Sadie Plant, *Zeros + Ones: Digital Women + the New Technoculture*, Fourth Estate, London, 1997, p.151.

[50] S. Augarten, *Bit by Bit: An Illustrated History of Computers*, Unwin, London, 1984, p.214.

[51] Robert Slater, *Portraits in Silicon*, MIT Press, Cambridge Mass., 1989, pp.225-6.

[52] Robert Slater, *Portraits in Silicon*, MIT Press, Cambridge Mass., 1989, p.228.

[53] Andrew Hodges, *Alan Turing: The Enigma,* Burnett Books, London, 1983, p.415.

[54] Andrew Hodges, *Alan Turing: The Enigma,* Burnett Books, London, 1983, p.421.

[55] Robert Slater, *Portraits in Silicon*, MIT Press, Cambridge Mass., 1989, p.19.

[56] Andrew Hodges, *Alan Turing: The Enigma,* Burnett Books, London, 1983, p.515.

[57] Sadie Plant, *Zeros + Ones: Digital Women + the New Technoculture*, Fourth Estate, London, 1997, p.147.

[58] Andrew Hodges, *Alan Turing: The Enigma,* Burnett Books, London, 1983, p.191.

[59] Andrew Hodges, *Alan Turing: The Enigma,* Burnett Books, London, 1983, p.195.

[60] Andrew Hodges, *Alan Turing: The Enigma,* Burnett Books, London, 1983, p.206.

[61] Andrew Hodges, *Alan Turing: The Enigma,* Burnett Books, London, 1983, p.316.

[62] B. V. Bowden, *Faster Than Thought: A Symposium On Digital Computing Machines*, Pitman & Sons, London, 1953, p.135.

[63] Andrew Hodges, *Alan Turing: The Enigma,* Burnett Books, London, 1983, p.339.

[64] S. H. Lavington, *Early British Computers: The Story of Vintage Computers and the People Who Built Them*, Manchester University Press, Manchester, 1980, p.44.

[65] S. H. Lavington, *Early British Computers: The Story of Vintage Computers and the People Who Built Them*, Manchester University Press, Manchester, 1980, p.118.

[66] Andrew Hodges, *Alan Turing: The Enigma,* Burnett Books, London, 1983, p.407.

[67] S. H. Lavington, *Early British Computers: The Story of Vintage Computers and the People Who Built Them*, Manchester University Press, Manchester, 1980, p.120.

[68] Andrew Hodges, *Alan Turing: The Enigma,* Burnett Books, London, 1983, pp.398-400.

[69] Andrew Hodges, *Alan Turing: The Enigma,* Burnett Books, London, 1983, p.408.

[70] Robert Slater, *Portraits in Silicon*, MIT Press, Cambridge Mass., 1989, p.20.

[71] Andrew Hodges, *Alan Turing: The Enigma,* Burnett Books, London, 1983, p.425.

[72] William Gibson and Bruce Sterling, *The Difference Engine*, Vista, London, 1996, pp.382-3.

[73] The Eloi are the people who live a life of liberty on the surface of the future Earth in H.G Wells' novel *The Time Machine*.

[74] Ellen Spertus, 'Why are There so Few Female Computer Scientists?' www.ai.mit.edu/people/ellens/Gender/pap/pap.html , 1991.

[75] Thelma Estrin, 'Women's Studies and Computer Science: Their Intersection,' *IEEE Annals of the History of Computing*, Vol. 18, No. 3, 1996, pp. 43-46.

[76] William Gibson, *Neuromancer*, Grafton, London, 1986, p.288.

[77] William Gibson, *Neuromancer*, Grafton, London, 1986, p.305.

[78] William Gibson, *Neuromancer*, Grafton, London, 1986, p.67.

[79] Margaret Wertheim, *The Pearly Gates of Cyberspace: A History of Space from Dante to the Internet*, Doubleday, Sydney, 1999, p.17.

[80] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996, p.292.

[81] M.D. Rostoker and R.H. Rines, *Computer Jurisprudence: Legal Responses to the Information Revolution*, Oceana, New York, 1986, p.230.

[82] John Seabrook, *Deeper: A Two Year Odyssey in Cyberspace*, Faber and Faber, London, 1997, p.25.

[83] John Seabrook, *Deeper: A Two Year Odyssey in Cyberspace*, Faber and Faber, London, 1997, pp.33-4.

[84] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996, p.299.

[85] Lewis Mumford as quoted in John Seabrook, *Deeper: A Two Year Odyssey in Cyberspace*, Faber and Faber, London, 1997, p.27.

[86] Eric S. Raymond, *The New Hacker's Dictionary*, Second Edition, MIT Press, Cambridge Mass., 1994, p.218.

[87] Dreyfus charts the growth of network hacking from the late 1980s. Some of the hackers were convicted of crimes and sent to prison, yet most adopted a "look see" approach to hacking computer networks. Most subjects in *Underground* [1997] caused no malicious damage to systems, which they gained entry to. See Suelette Dreyfus, *Underground: Tales of Hacking, Madness and Obsession on the Electronic Frontier*, Mandarin, Kew Australia, 1997.

[88] Amy Pearl *et.al.*, ‘Becoming a Computer Scientist: A Report by the ACM Committee on the Status of Women in Computing Science,’ *Communications of the ACM*, Vol. 33, No. 11, November 1990, pp.47-58.

[89] The cyberzine *geekgirl* can be found at www.geekgirl.com.au .

[90] Interview with Barbara Anne O’Leary, by *geekgirl* cyberzine, posted on 22nd September 1999 at www.geekgirl.com.au/geekgirl/002manga/vsis.html .

[91] As an example, the young Bill Gates was seen as an archetypal ‘pale male adolescent, lacking in social skills.’ See M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996, p.241.

[92] Sherry Turkle, *Life On Screen: Identity in the Age of the Internet*, Phoenix, London, 1997, p.180.

[93] Eric S. Raymond, *The New Hacker’s Dictionary*, Second Edition, MIT Press, Cambridge Mass., 1994, p.288.

[94] Sherry Turkle, *Life On Screen: Identity in the Age of the Internet*, Phoenix, London, 1997, pp.184-5.

[95] Margaret Wertheim, *The Pearly Gates of Cyberspace: A History of Space from Dante to the Internet*, Doubleday, Sydney, 1999, p.236.

[96] Sherry Turkle, *Life On Screen: Identity in the Age of the Internet*, Phoenix, London, 1997, p.223.

[97] Sherry Turkle, *Life On Screen: Identity in the Age of the Internet*, Phoenix, London, 1997, p.208.

[98] Sherry Turkle, *Life On Screen: Identity in the Age of the Internet*, Phoenix, London, 1997, p.211.

Bibliography

William Aspray, ‘International Diffusion of Computer Technology, 1945-1955,’ *Annals of the History of Computing*, Vol. 8, No. 4, October 1986, pp. 351-60.

William Aspray, *John von Neumann and The Origins of Modern Computing*, MIT Press, London, 1992.

S. Augarten, *Bit by Bit: An Illustrated History of Computers*, Unwin, London, 1984.

W. Barkley Fritz, ‘The Women of ENIAC,’ *IEEE Annals of the History of Computing*, Vol.18, No.3, 1996, pp. 13-27.

M. Beard & T. Pearcey, ‘Genesis of a Stored Program Computer: CSIRAC,’ *Annals of the History of Computing*, Vol. 6, No. 2, 1984, pp. 106-15.

B.V. Bowden (ed.), *Faster than Thought: A Symposium on Digital Computing Machines*, Pitman, London, 1971.

G. Bowker and R. Giordano, ‘Interview with Tom Kilburn,’ *IEEE Annals of the History of Computing*, Vol. 15, No. 3, 1993, pp. 44-54.

M. Campbell-Kelly, ‘Data communications at the National Physics Laboratory (1965-1975),’ *Annals of the History of Computing*, Vol. 9, No. 3/4, 1988, pp. 221-248.

M. Campbell-Kelly, *ICL: A Business and Technical History*, Cambridge University Press, New York, 1989.

M. Campbell-Kelly, ‘Introduction: Computing at the University of Cambridge,’ *IEEE Annals of the History of Computing*, Vol. 14, No. 4, 1992, pp. 8-9.

M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996.

H. Carpenter, *W.H. Auden: A biography*, Houghton Mifflin Company, Boston, 1981.

Paul Ceruzzi, ‘Electronics Technology and Computer Science, 1940-1975: A Coevolution,’ *Annals of the History of Computing*, Vol.10, No. 4, 1989, pp.257-75.

H. Cockerell, *Lloyds of London: A Portrait*, Woodhead-Faulkner, Cambridge, 1984.

Mary Croarken, *Early Scientific Computing in Britain*, Clarendon Press, Oxford, 1990.

Mary Croarken, ‘The Beginnings of the Manchester Computer Phenomenon: People and Influences,’ *IEEE Annals of the History of Computing*, Vol. 15, No. 3, 1993, pp. 9-16.

Suelette Dreyfus, *Underground: Tales of Hacking Madness and Obsession on the Electronic Frontier*, Mandarin, Kew Australia, 1997.

T. Dublin, ‘Women Work and Protest in the Early Lowell Mills,’ in Dinnerstein and Jackson, *American Vistas*, 6th Edition, Oxford University Press, New York, 1991, pp.233-51.

Thelma Estrin, ‘Women’s Studies and Computer Science: Their Intersection,’ *IEEE Annals of the History of Computing*, Vol. 18, No. 3, 1996, pp. 43-46.

D.A. Farnie, *The Manchester Ship Canal and the Rise of the Port of Manchester 1894-1975*, Manchester University Press, Manchester, 1980.

P. Freiberger and M. Swaine, *Fire in the Valley: The Making of the Personal Computer*, 2nd Edition, McGraw-Hill, New York 2000.

Brian De Garis, *Campus in the Community: The University of Western Australia, 1963-1987*, University of Western Australia Press, 1988.
William Gibson, *Neuromancer*, Harper Collins, London, 1986.

William Gibson, *Burning Chrome*, Harper Collins, London, 1988.

William Gibson and Bruce Sterling, *The Difference Engine*, Vista, London, 1996.

I. Good, 'Early work on computers at Bletchley,' *Cryptologia*, Vol. 3, No. 2, April 1979, pp.83-95.

Denise W. Gurer, 'Women's Contributions to Early Computing at the National Bureau of Standards,' *IEEE Annals of the History of Computing*, Vol. 18, No. 3, 1996, pp. 29-35.

Andrew Hodges, *Alan Turing: The Enigma*, Burnett Books, London, 1983.

D. Jaffe, 'Peddlers of Progress and the Transformation of the Rural North 1760-1860,' *The Journal of American History*, Vol.78, No.2, September 1991, pp.511-35.

C.L. Jarvis, *Quantitative Analysis of a Class of Biomedical Images by an Image Processing System*, Thesis (Ph.D.), University of Western Australia, 1971.

E.J. Jory, 'Problems and Prospects for the Production of Computer Compiled Indices to Epigraphic Works,' *Antiquities Africaines*, Tome 9, 1975.

R.H. Kargon, *Science in Victorian Manchester: Enterprise and Expertise,* Manchester University Press, Manchester, 1977.

Alan J. Kidd, *Manchester*, Keele University Press, 1996.

Simon Lavington, *Early British Computers: The Story of Vintage Computers and the People Who Built Them*, Manchester University Press, Manchester, 1980.

S. H. Lavington, ‘Manchester Computer Architectures, 1948-1975,’ *IEEE Annals of the History of Computing*, Vol. 15, No.3, 1993, pp. 44-54.

Simon Lavington, *A History of Manchester Computers*, British Computer Society, Swindon, Wiltshire, 1998.

J.A.N. Lee, ‘The Beginnings at MIT,’ *IEEE Annals of the History of Computing*, Vol.14, No.1, 1992, pp.18-30.

Steven Levy, *Hackers: Heroes of the Computer Revolution*, Penguin, Harmondsworth, 1984.

Herman Lukoff, *From Dits to Bits: A Personal History of the Electronic Computer*, Robotics Press, Portland Oregon, 1979.

Mitchell, *Computers in the Humanities*, Edinburgh University Press, Edinburgh, 1974.

John Naughton, *A Brief History of the Future: The Origins of the Internet*, Weidenfeld & Nicolson, London, 1999.

Amy Pearl *et.al.*, ‘Becoming a Computer Scientist: A Report by the ACM Committee on the Status of Women in Computing Science,’ *Communications of the ACM*, Vol. 33, No. 11, November 1990, pp.47-58.

A.J. Perlis, ‘News and Notices: Universities,’ *Communications of the ACM*, Vol.4, No.2, February 1961, p.117.

J.V. Pickstone and G. Bowker, ‘The Manchester Heritage,’ *IEEE Annals of the History of Computing*, Vol. 15, No. 3, 1993.

John M. M. Pinkerton with Derek Hemy and Ernest H. Lenaerts, ‘The Influence of the Cambridge Mathematical Laboratory on the LEO

Project,' *IEEE Annals of the History of Computing*, Vol. 14, No. 4, 1992, pp. 41-8.

Sadie Plant, *Zeros + Ones: Digital Women + the New Technoculture*, Fourth Estate, London, 1997.

K. Powell, *Lloyds Building: Richard Rogers Partnership*, Phaidon Press, London, 1994.

Brian Randell, 'The Origins of Computer Programming,' *IEEE Annals of the History of Computing*, Vol. 16, No. 4, 1994, pp. 6-13.

Eric S. Raymond, *The New Hacker's Dictionary*, Second Edition, MIT Press, Cambridge Mass., 1994.

Howard Rheingold, *Virtual Reality*, Mandarin, London, 1992.

R. Rosenzweig, 'Wizards, Bureaucrats, Warriors, and Hackers: Writing the History of the Internet,' *American Historical Review*, December 1998, pp.1530-1552.

M.D. Rostoker and R.H. Rines, *Computer Jurisprudence: Legal Responses to the Information Revolution*, Oceana, New York, 1986.

Douglas Rushkoff, *Children of Chaos [Surviving the End of the World as We Know it]*, Flamingo, London, 1997.

John Seabrook, *Deeper: A Two Year Odyssey in Cyberspace*, Faber and Faber, London, 1997.

Joel Shurkin, *Engines of the Mind: The Evolution of Computers from Mainframes to Microprocessors*, W.W. Norton, New York, 1996.

Simon Singh, *The Code Book: The Secret History of Codes & Code-breaking*, Fourth Estate, London, 2000.

Robert Slater, *Portraits in Silicon*, MIT Press, Cambridge Mass., 1989.

Michelle Slatalla and Joshua Quittner, *Masters of Deception: The Gang that Ruled Cyberspace*, Vintage, London, 1995.

R. E. Smith, 'A Historical Overview of Computer Architecture,' *Annals of the History of Computing*, Vol. 10, No. 4, 1989, pp. 277-303.

Ellen Spertus, 'Why are There so Few Female Computer Scientists?' www.ai.mit.edu/people/ellens/Gender/pap/pap.html , 1991.

Dorothy Stein, *Ada: A Life and a Legacy*, MIT Press, Cambridge Mass., 1985.

N.S. Stenhouse, *Busselton Norms: Statistics of the Physiological Variables Measured at the Busselton Health Survey*, University of Western Australia Press, 1979.

Neal Stephenson, *Snow Crash*, Penguin, 1992.

Nancy Stern, *From ENIAC to UNIVAC: An Appraisal of the Eckert-Mauchly Computers*, Digital Press, Bedford MA, 1981.

James P. Trevelyan, *A Perspective Flight Display for Aircraft Cockpits*, Master of Engineering Science Thesis, University of Western Australia, 1971.

Betty Alexandra Toole, 'Ada Byron, Lady Lovelace: An Analyst and Metaphysician,' *IEEE Annals of the History of Computing*, Vol. 18, No. 3, 1996, pp. 4-11.

Sherry Turkle, *The Second Self: Computers and the Human Spirit*, Granada, London, 1984.

Sherry Turkle, *Life On Screen: Identity in the Age of the Internet*, Phoenix, London, 1997.

G. Tweedale, ‘A Manchester Computer Pioneer: Ferranti in Retrospect,’ *IEEE Annals of the History of Computing*, Vol. 15, No. 3, 1993, pp. 37-44.

David Williams, ‘Meccano a Short History,’ web source, http://www.freenet.edmonton.ab.ca/meccano/mechist.html , date 26/7/99.

Margaret Wertheim, *The Pearly Gates of Cyberspace: A History of Space from Dante to the Internet*, Doubleday, Sydney, 1999.

Virginia Woolf, *A Room of One’s Own and Three Guineas*, Pengiun, Harmondsworth, 1993.

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Appendix 1:

A Note on Oral History

4.0 Early Computing at the University of Western Australia has been largely sourced from a series of five interviews conducted by Falloon (the author) from 16/11/1999 to 3/3/2000. The interviews were informal with notes being handwritten.

D.W.G Moore came to UWA in 1962. He was the first director of the University's Computer Centre. Moore would later go on to direct the Western Australian Regional Computer Centre (WARCC). He later became Head of Computer Science at Curtin University. Moore has been instrumental to the development of computing in Western Australia. He is now retired and lives in Perth.

Terry Gent was a graduate of the postgraduate diploma in Numerical Analysis and Automatic Computing at UWA. He worked at the Computer Centre then at the Regional Computer Centre as a programmer.

Professor E.J. Jory was formerly the Executive Dean of the Faculty of Arts at the University of Western Australia. He undertook the Latin Inscription Concordance Project while with the Classics Department at UWA.

Bruce Kirkby was a graduate of the postgraduate diploma in Numerical Analysis and Automatic Computing. He has been heavily involved with computing at UWA. Currently, Kirkby is head of the UWA University Computing Service.

Emeritus Professor John Ross is currently a Senior Honorary Research Fellow with the Department of Psychology at UWA. He was highly active in computing at UWA.

Professor Syd Hall is currently head of the Crystallography Centre at UWA. Hall was at UWA from 1962 to 1966, 1966-8 and returned to UWA in 1975. He has worked extensively with the early computers at the University.

Amadeo Sala worked for the UWA Computing Centre and the Department of Psychology at UWA before founding his own company.

Appendix 2: WARCC Analysis

Table 1. Common acronyms used in Chapter 5.0

ARPA	Advanced Research Projects Agency
ARPAnet	Advanced Research Projects Agency Network
AUC	Australian Universities Commission
BTM	British Tabulating Machine Company
BUNCH	Burroughs, UNIVAC, NCR, CDC and Honeywell
CDC	Control Data Corporation
CPU	Central Processing Unit
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEC	Digital Equipment Corporation
EDVAC	Electronic Discrete Variable Automatic Computer
HCS	Health Computing Service
IBM	International Business Machines
ICBM	Intercontinental Ballistic Missile
ICL	International Computers Limited
IMP	Interface Message Processor
MITS	Model Instrumentation Telemetry Systems
MRD	Main Roads Department
MWB	Metropolitan Water Board
NCR	National Cash Register
NPL	National Physics Laboratory (UK)
OS	Operating System
PC	Personal Computer
PDP	Programmed Data Processor
PWD	Public Works Department
SEC	State Energy Commission
SILLIAC	Sydney version of the University of Illinios Automatic Computer
SLT	Solid Logic Technology
TISC	Tertiary Information and Services Centre
UCC	University Computing Centre (UWA)
UNIVAC	Universal Automatic Computer
UWA	University of Western Australia
WA	Western Australia
WAIT	Western Australian Institute of Technology
WARCC	Western Australian Regional Computing Centre

Table 2. Depicts WARCC Average Monthly Income from 1975-77.
Source: WARCC INCOME ANALYSIS, *UWA Archives 4552 Pt.4*, 13th April 1977.

Client	Monthly Average 1975	Monthly Average 1976	Jan - Mar average 1977
UWA Administration	8584	10715	12043
Teaching and Research	19324	26348	17758
Other	2212	2538	3012
Total UWA	30 120	39601	32813
WAIT Administration	7483	6771	9106
Teaching and Research	2000	5433	2628
Total WAIT	9483	12204	11734
Murdoch Administration	1432	2521	3528
Teaching and Research	378	1119	675
Total Murdoch	1810	3640	4213
TISC	575	4090	2999
Fisheries	1550	1607	1103
Education	1753	2957	1868
Telecom	1402	1861	1621
SEC	1456	1622	1639
Technical Education	1254	1099	848
Forests	857	969	866
Agriculture	415	775	1120
Other Government	2324	2697	2488
PWD	7539	3607	1308
MRD	3078	557	417
MWB	3059	400	192
Lands and Surveys	1246	593	222
HCS	11228	4058	1814
Total Government	37161	22802	15511
Private	3438	5572	5867
Total	82586	88463	73138

Figure 1. Depicts WARCC Average Monthly Income 1975-77.
Source: WARCC INCOME ANALYSIS, *UWA Archives 4552 Pt.4*, 13th April 1977.

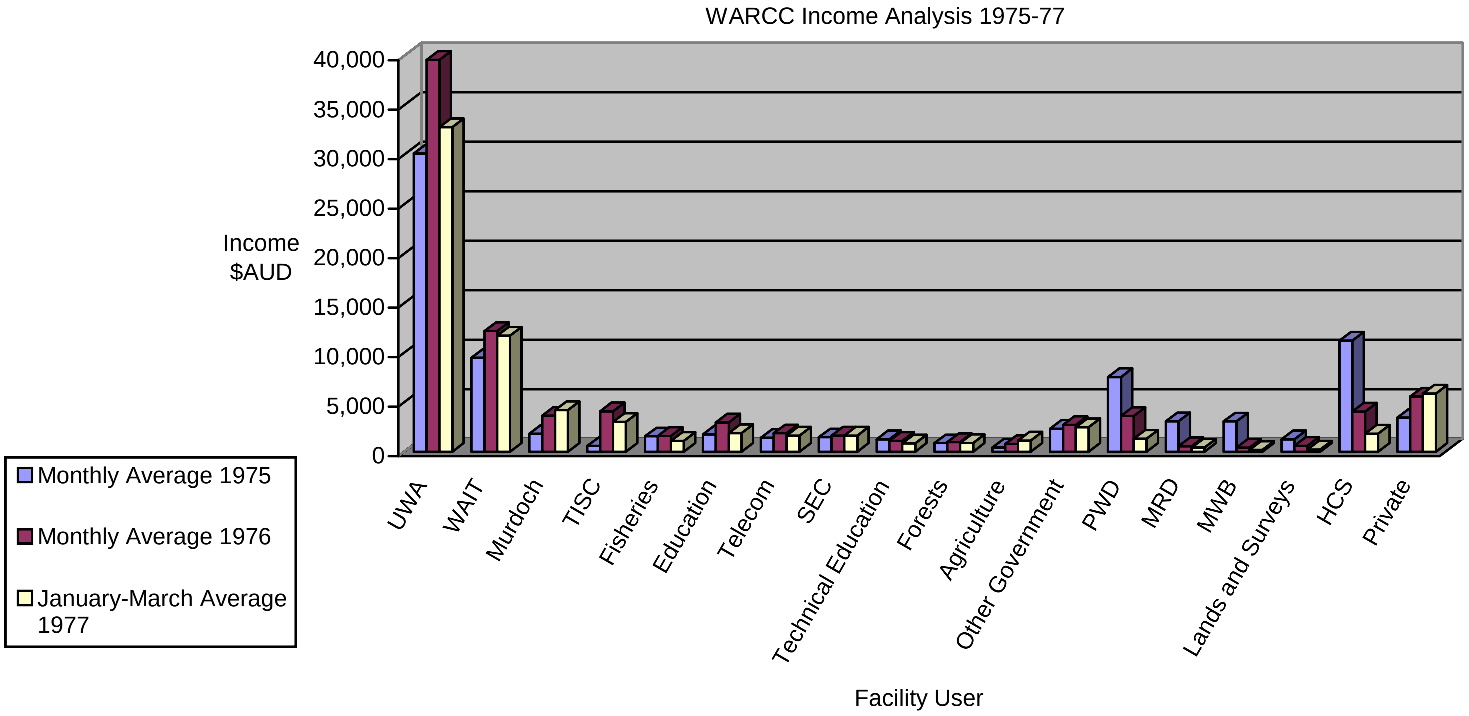
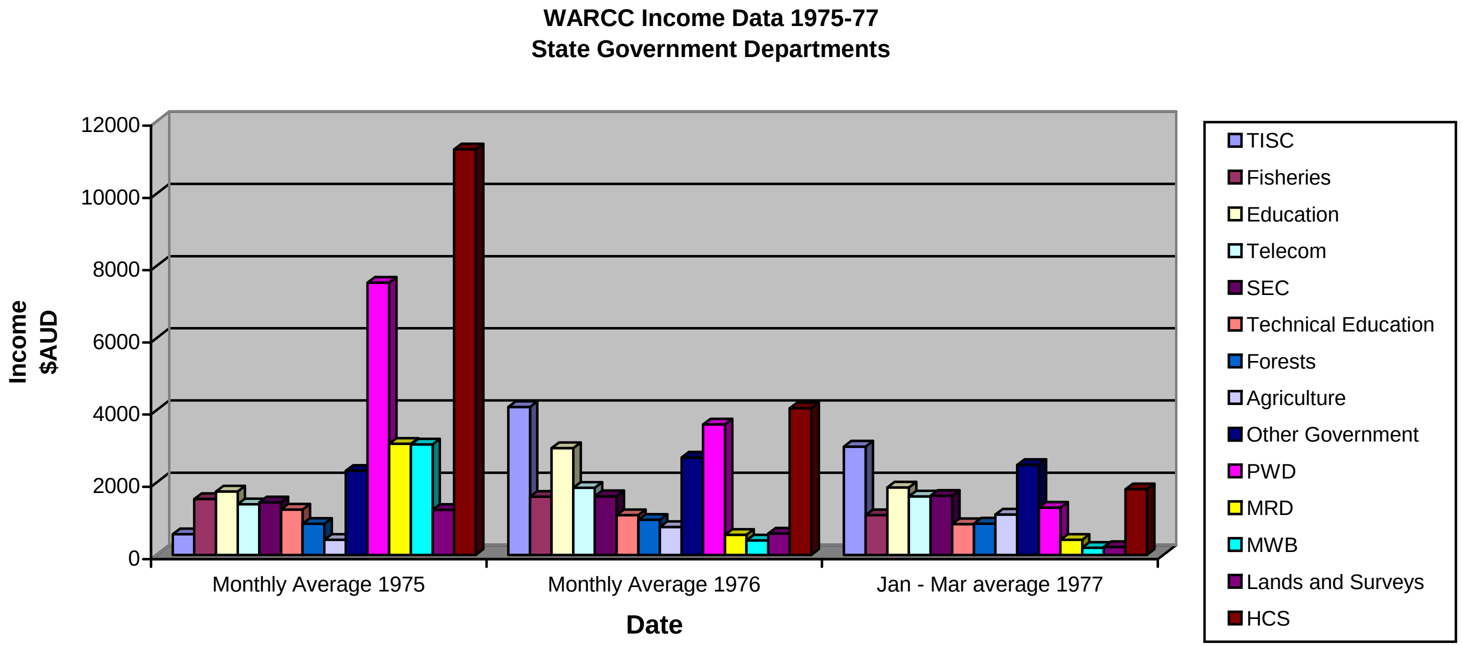


Figure 2. Depicts WARCC Average Monthly Income 1975-77 from Government Sector.
Source: WARCC INCOME ANALYSIS, *UWA Archives 4552 Pt.4*, 13th April 1977.



Figures 3-5 Depict WARRC Average Monthly Income 1975-77 Percentage Breakdown
Source: WARCC INCOME ANALYSIS, *UWA Archives 4552 Pt.4*, 13th April 1977.

Figure 3. WARCC Income
Average Monthly Breakdown 1975

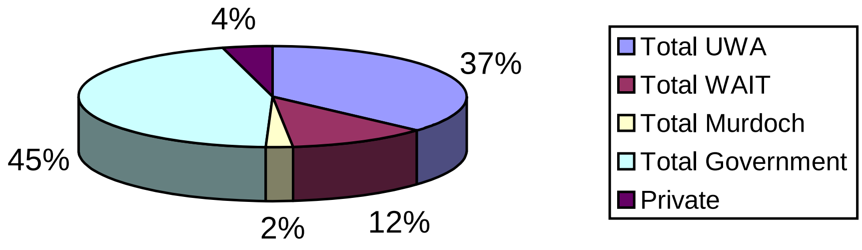


Figure 4. WARCC Income
Average Monthly Breakdown 1976

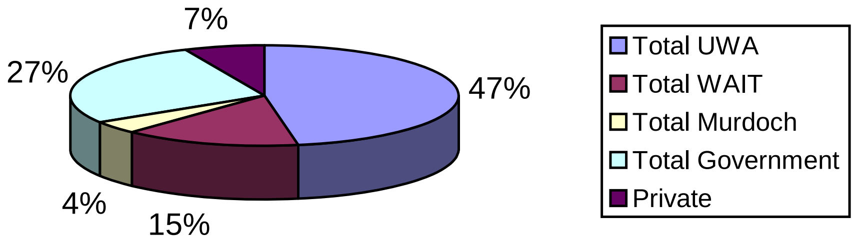


Figure 5. WARCC Income
Average Monthly Breakdown
Jan-Mar 1977

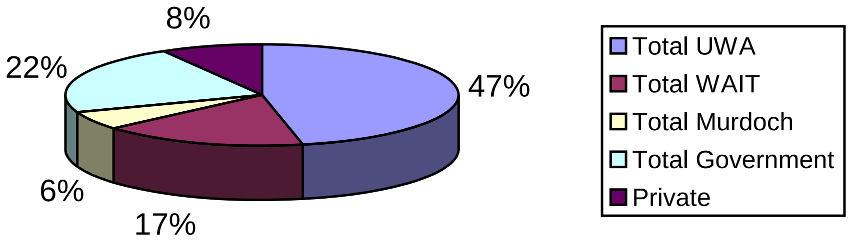
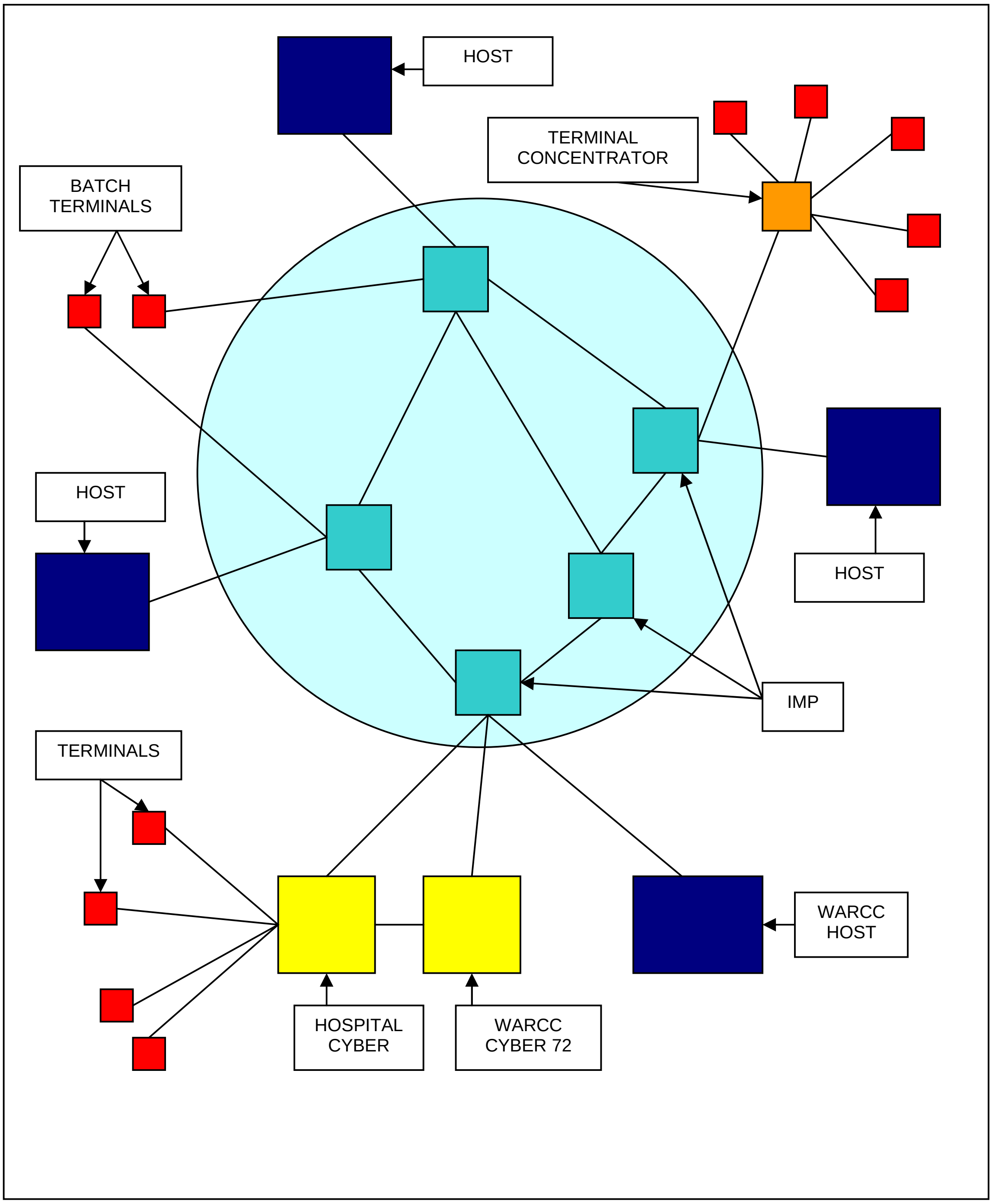


Figure 6 Proposed Western Australian Regional Network 1975.
Note: shaded area within circle represents packet switched network.
Source: Moore, *UWA Archives 4552 Pt.2, 16^{th}* January 1975.



Appendix 3: Literature Review

The following is a brief review of the core texts cited in **Cyberhistory**. It is divided into three parts. The first covers books. The second concerns papers and articles. The third section is a review of the archive resources that are held in The University of Western Australia Archives.

Section 1: Books

William Aspray, *John von Neumann and The Origins of Modern Computing*, MIT Press, London, 1992.

Aspray offers a definitive account of von Neumann's work in the area of computing. This book delves into a rich archival resource, tracing von Neumann's early research in mathematics, then focussing on his role in developing a formal architecture for computers. In terms of being a resource for **Cyberhistory**, Aspray's book offers a comprehensive record to support **Cyberhistory's** portrayal of von Neumann's role as a proselytiser of computing. In particular, Aspray notes the significance of von Neumann's 'First Draft of a Report on the EDVAC' [1945] and the way in which the spread of this paper transferred computer technology around the world. Aspray's book notes, the influence of von Neumann in establishing the computer at the Institute for Advanced Studies in Princeton, the development of biological terminology as applied to computers, computing as initially applied to meteorological studies and von

Neumann's stature as a Scientific consultant and Statesperson.

B.V. Bowden (ed.), *Faster than Thought: A Symposium on Digital Computing Machines*, Pitman, London, 1971.

Faster than Thought provides the historian with an early snapshot of computing in the 1950s. Bowden's book delivers a written commentary of the state of computing globally in 1953 specifically focussing on the computer situation in Britain and America. Bowden's is the only computer history in Cyberhistory's bibliography that mentions the Nimrod machine at the Festival of Britain. Bowden is best described as a proselytiser of electronic computing. *Faster than Thought* captures Bowden's perception of the future of computing. Bowden argues that computing would later have a role in commerce, engineering and entertainment, he touches on computer games and emphasises the ability of computers to shorten laborious clerical tasks. Bowden describes all the major machines in the significant computational centres in Britain and America. *Faster than Thought* also attempts to put the complex operation and logical design of computers into a language that the non-specialist can grasp. Bowden's book is thereby a valuable historical resource.

M. Campbell-Kelly, *ICL: A Business and Technical History*, Cambridge University Press, New York, 1989.

Campbell-Kelly is one of the foremost computer historians. *ICL: A Business and Technical History* is more than a history of a computer manufacturer. It is a historical inquiry covering computing in Britain. In particular, *ICL: A Business and Technical History* traces the growth of the office machine industry in Britain and asserts that this industry laid the foundations of the later computer industry. This has been a significant point that has also been argued in **Cyberhistory**. Campbell-Kelly notes the development of the British Tabulating Machine Company (BTM) and establishes that, from the outset, the British computer market was unable to compete with manufacturers in the USA. *ICL: A Business and Technical History* is a story of amalgamation as individual British firms were rationalised into the International Computers Limited (ICL) conglomerate. Campbell-Kelly wrote this book in association with ICL. Yet his account maintains a balanced appraisal of the British computer industry. Significantly Campbell-Kelly covers the role of the British Government in directing the computer industry. Campbell-Kelly notes Harold Wilson’s “White Heat” speech in 1963 and the role of the Ministry of Technology. *ICL: A Business and Technical History* provides insight into the early tabulating machine industry in Britain. **Cyberhistory** employs this to emphasise the cultural differences between the UK and the USA, which contributed to success in the USA.

M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, Basic Books, New York, 1996.

Computer: A History of the Information Machine is a touchstone of recent computer history. It brings together two of the key writers in the computer history field. Significantly Aspray is an American and Campbell-Kelly British. Due to this, the resulting text manages to avoid focussing on one nation. *Computer: A History of the Information Machine* is a general history aimed at a non specialist market and draws on the depth of the expertise of its authors in the field. It notes, the significance of IBM and its relationship with the USA Government, the exchange of knowledge between the American and British computation centres, the importance of marketing and manufacturing culture in America, and the decentralisation of computing through the Internet. Aspray and Campbell-Kelly survey the entirety of computer history in this book, from Babbage to the World Wide Web. *Computer* is a key reference source for any history of computing.

Mary Croarken, *Early Scientific Computing in Britain*, Clarendon Press, Oxford, 1990.

Computing had not been an integral part of scientific practice. Croarken's book traces the acceptance of computing into the scientific work culture of Britain in the early twentieth century. Croarken highlights the roles of influential advocates of computational science such as Comrie and Hartree. *Early Scientific Computing in Britain* covers the prehistory of electronic computers, investigating scientific instruments such as the planimeter, comptometer, and desk calculating machines. Croarken notes that the introduction of mechanical computing to the National Almanac Office, was the beginning of a widespread use of computational machinery to aid scientific calculation. This is an important history in that it portrays the construction of computational centres in Britain culminating in the creation of a National Computing Centre at the National Physics Laboratory just after WWII.

Suelette Dreyfus, *Underground: Tales of Hacking Madness and Obsession on the Electronic Frontier*, Mandarin, Kew Australia, 1997.

Underground is a remarkably detailed documentation of a handful of computer hackers, their experiences and the reaction of Western society to their antics. Dreyfus is quietly putting forth an argument that society needs to rethink the computer crime laws that it has cemented in place. She depicts a legal system (in the USA, Australia and the United Kingdom) insensitive to the mostly innocent curiosity that hackers display. *Underground's* stance is that "look see" hacking should be shown greater leniency in the court system. This position comes from Dreyfus, an author who is fully aware of the damage that malicious hacking can create. *Underground* demystifies hacking and its perpetrators. While *Underground* carefully avoids the sensationalism of mass media accounts of hacking, some of the cases that it covers are amazing and would not appear out of place in a film. This makes for exciting reading. Dreyfus illustrates that Australia contained some of the world's best hacking rings in the late 1980s. *Underground* provides a detailed insight into the realm of hackers and the motives behind their activities. It is a history from the shadowy frontier of computer networks, before the World Wide Web, and is essential reading for any history of the Internet.

P. Freiberger and M. Swaine, *Fire in the Valley: The Making of the Personal Computer*, 2nd Edition, McGraw-Hill, New York 2000.

Fire in the Valley is a classic history of the personal computer revolution. It is a history built from inside the corporate arcologies of Silicon Valley and thereby has an immediacy of an oral history account. *Fire in the Valley* is like a front line journalist's report from a corporate battle zone. *Fire in the Valley* stresses the role of a hobbyist culture in the dissemination of microcomputing technology. Significantly it explores the failed companies as well as the success stories which tend to dominate more general accounts of computer history. *Fire in the Valley* was the most authoritative and detailed account of personal computer history that was encountered during research for **Cyberhistory**.

William Gibson, *Neuromancer*, Harper Collins, London, 1986.

Gibson coined the term cyberspace in the first edition of *Neuromancer* in 1982. *Neuromancer* was the first novel in a sub-genre of science fiction writing called cyberpunk. Gibson based his depiction of cyberspace on video arcade games and the youths that frequented the video parlours, in which the games were housed. Gibson's subject matter dealt with computers connected through three-dimensional cyberspace. Gibson depicts a nightmarish future where corporations and criminal elements are as powerful as sovereign governments. In *Neuromancer* a hand picked team help a hacker free an artificial intelligence owned by a wealthy family.

Neuromancer's subject matter is dark, riddled with technology and cleverly streetwise. A Nebula Award winner, *Neuromancer* provided the creative inspiration for **Cyberhistory**. In a world that is moving towards a Gibsonian cyberspace the history of the information machine and its development is increasingly important.

William Gibson and Bruce Sterling, *The Difference Engine*, Vista, London, 1996.

Gibson and Sterling are both prolific writers in the cyberpunk sub-genre of science fiction. In this collaborative effort, Gibson and Sterling recast the history of the computer in the 19th century working from the premise that Babbage actually made his analytical engine work. 19th century Britain becomes a place where computing machines are prevalent. Historical figures such as Ada Byron (mathematician and programmer), Sam Houston (American political leader), Charles Babbage (inventor of the difference engine and analytical engine), John Keats (poet), Charles Darwin (eminent scientist) and Lord Byron (debaucher, poet and estranged father of Ada Byron) colour this imaginative work. *The Difference Engine's* depiction of a future London as a vast necropoliptic machine was used in Cyberhistory to begin ***Machina*: the Gendered Computer**. As a historical fiction, *The Difference Engine* illustrates contemporary events and persons in the time of Babbage, playing with historical truth in an interesting and stimulating read.

Andrew Hodges, *Alan Turing: The Enigma*, Burnett Books, London, 1983.

Due to his involvement in code breaking for British Intelligence during WWII, Alan Turing has existed in the shadows of historical discourse like a spy who remained in the cold. Turing's homosexuality, and early death in 1954, further added to mystery of this enigmatic figure of computer history. Hodges goes behind the enigma to reveal a complete biography of Turing. Hodges uses interviews, archival records and Turing's family correspondence, to construct a detailed portrait of Turing. As such this work is invaluable to the computer historian. Hodges notes the way in which Turing was written out of the history of the pilot ACE computer at the National Physics Laboratory asserting that Turing was a Trotsky of computer history. Turing's theoretical universal computing machine, the Turing Test, and the work on the enigma are covered in detail in this authoritative account. *Alan Turing: The Enigma* effectively brings Turing in from the cold of non-history and articulates the extent to which Turing was a key player in the history of computing.

Simon Lavington, *Early British Computers: The Story of Vintage Computers and the People Who Built Them*, Manchester University Press, Manchester, 1980.

British computing and the development of the first stored program computers in the UK following the war tend to be overshadowed by accounts of computer development in the American centres. Lavington traces the growth of electronic computing in Britain. in doing so, Lavington illustrates how much of the pioneering work on modern computers took place in the UK between 1945 and 1950. In *Early British Computers* machines that were produced in the commercial sector receive as much treatment as the machines initially developed in British research laboratories. Lavington carefully explains the technology involved in computers following WWII. *Early British Computers* is a valuable resource in terms of its technical content and concise nature. Appendices list the technical specifications of all the early British computers. Significantly, Lavington links each research laboratory with an industrial/commercial interest and follows the experimental machines into the manufacturing arena.

Simon Lavington, *A History of Manchester Computers*, British Computer Society, Swindon, Wiltshire, 1998.

This book was prepared by Lavington and the British Computer Society as part of the 50th anniversary of computing celebrations hosted in Manchester throughout 1998. It is a technical account tracing the development of the first Manchester prototype and the first stored programme ever to run on a computer. *A History of Manchester Computers* continues with subsequent machines produced at Manchester University up until the MU5 computer in the 1970s. Lavington notes the close association between Manchester University and Ferranti Ltd., a relationship which led to the production of the Ferranti Mark 1, one of the first commercial electronic digital computers.

Steven Levy, *Hackers: Heroes of the Computer Revolution*, Penguin, Harmondsworth, 1984.

Unlike *Underground: Tales of Hacking Madness and Obsession on the Electronic Frontier*, which primarily concerns networked computers, Levy's history concerns stand alone computers. Levy establishes a definition of hacking that progresses beyond current connotations of computer intrusion through networks. Levy argues that hacking is an application of skill to computer hardware or software that solves a problem in an innovative and creative manner. *Hackers* begins with the computer laboratory at MIT in the 1950s and describes a subculture among student computer users which borders on the obsessive. Yet within this obsessive behaviour there is often innovation and highly imaginative approaches to difficult software and hardware challenges. Levy describes generations of hackers linking them through common traits and ideals. A weakness of this account is the near total absence of women. Levy locates women on the periphery of hacking and fails to consider why it is the subculture of hacking is exclusively male. Despite this, *Hacking* is a highly valuable alternate-history of computing. It champions the fringe of computer development and asserts that a hacking ethos is largely responsible for the vibrant computer industry that America currently enjoys.

John Naughton, *A Brief History of the Future: The Origins of the Internet*, Weidenfeld & Nicolson, London, 1999.

The Internet's success is closely related to its communicative nature. Naughton notes this, beginning his history with the technology of Radio. Naughton provides a well-researched history of the global communications highway. Naughton notes that relatively few people in established society have grabbed the Internet's significance. Naughton observes that, the higher up the ladder of power and control in society, the less the new technology is understood. Within this view is a hint of latent utopianism in that Naughton suggests that the 'television moguls, newspaper columnists, Wall Street financiers…seem blissfully or wilfully unaware of what this astonishing creation might mean for humanity.' [Page 24] Implied within this opinion is the belief that the new information highway has potential to alter society or culture. **Cyberhistory** takes the stance that it is culture and society that dominate the technology and shape its uses, casting the Internet as a distopia. *A Brief History of the Future* covers the growth of the ARPAnet, Usenet, the World Wide Web and browser technology. *A Brief History of the Future* is one of the first books to consider the Internet in a historical sense and as such is a valuable point of embarkation for any research in the area.

Sadie Plant, *Zeros + Ones: Digital Women + the New Technoculture*, Fourth Estate, London, 1997.

Zeros + Ones is racy, exciting and radical like a cacophony of urban rave music spilling from a sports car speeding through a neon-lit metropolis. Plant shifts through a myriad of contexts with ease, weaving a spellbinding account of an emerging culture and its cultural precedents. Plant argues that women are in no measure peripheral to computer history, an assertion that is taken on by **Cyberhistory**. Plant notes the importance of weaving in computer history and locates multimedia within the sphere of women. Plant asserts that the fundamental values of digital computation, the zero and the one, are gendered by human culture. *Zeros + Ones* notes how to the ancient Greeks, one was the symbol of existence, identity and being. Plant posits that the zero signified a hole, a space or missing piece, then illustrates how in electronic systems it is the hole that matters. *Zeros + Ones* thereby asserts that the symbols with which humans operate their machines are gendered by culture. *Zeros + Ones* was an essential reference source for **Gender and Computing** in **Cyberhistory**.

John Seabrook, *Deeper: A Two Year Odyssey in Cyberspace*, Faber and Faber, London, 1997.

Seabrook posits that progress is a fact of life, that it can enhance human existence. Seabrook's ancestors were pioneers on the opening western frontier of America. Deep down in the essence of his being, Seabrook is searching for a frontier. He locates this new frontier in cyberspace. This is an important step, for it suggests that America's fascination with technological progress and consumerism could be linked to a frontier mentality. Seabrook's work is absorbing, full of wit and humour. *Deeper: A Two Year Odyssey in Cyberspace* takes the reader on a journey into unknown territory. Seabrook's own involvement with the Internet is highly significant in that he represents a new kind of net user. He is someone who is not technically literate and is more interested in the medium's ability to facilitate community, than its technical mechanics.

Simon Singh, *The Code Book: The Secret History of Codes & Code-breaking*, Fourth Estate, London, 2000.

Singh begins *The Code Book* with two objectives. The first is to chart the evolution of codes. The second is to demonstrate how the subject is more relevant today than ever before. What follows is a highly interesting account of cryptography, the science of creating codes, and cryptanalysis, the science of breaking codes. *The Code Book* traces the evolution of a number of significant cryptographical techniques that were subsequently broken, then superseded by stronger encryption technologies. **Cyberhistory** draws heavily from *The Code Book's* analysis of the decryption of the German enigma code. Singh offers a clear explanation of how British intelligence cracked the enigma encryption technique and notes the pivotal role of Turing in this task. The enigma was cracked through the application of mechanical techniques. The Colossus was the first electronic computational device applied to cryptanalysis. With the Internet and the need for the private exchange of Data, Singh notes that there is a pervasive need for strong encryption on a global scale.

Robert Slater, *Portraits in Silicon*, MIT Press, Cambridge Mass., 1989.

Historical accounts should try to avoid accounts of individuals, particularly accounts of "great men". Despite this, **Cyberhistory** notes that key individuals in computer history have helped shaped its developments. Slater's book focuses on a series of important figures in the history of computing.

While individuals are not the sole drivers of history, the people dealt with in Slater's book have had a significant impact in their respective fields. Of the thirty-four pioneers discussed by Slater only one is female, Grace Murray Hopper. Slater offers a well-researched account of the most significant individuals in computer history. Yet, like political and diplomatic histories of the 19th and early 20th centuries, it focuses on personages at the top of the computer hierarchy. Given that this narrow focus is borne in mind by researchers, *Portraits in Silicon* is a valuable resource.

Dorothy Stein, *Ada: A Life and a Legacy*, MIT Press, Cambridge Mass., 1985.

Stein questions Ada Byron's individual contribution to the history of computing in a detailed biography of the "enchantress of numbers." *Ada: A Life and a Legacy* depicts a daughter of an aristocratic family who is guided in her development, as a mathematician, by an exceptional and strong willed mother, privileged tuition by some of the greatest minds of her day, and the freedom of a life of leisure. Stein sources her work from personal letters, communiques and diaries held in archives. She captures Ada's first encounter with Babbage and his machine, their exchanges, and collaboration. Stein debunks the myth of Ada as a godlike genius, yet does note Ada's application of a talented intellect. In *Ada: A Life and a Legacy*, Ada is represented as a woman in exceptional circumstances rather than an exceptional woman. Stein effectively illustrates the inequitable and seemingly insurmountable discrimination faced by women in the 19th Century, noting that Ada was only able to progress intellectually through her privileged status in society.

Nancy Stern, *From ENIAC to UNIVAC: An Appraisal of the Eckert-Mauchly Computers*, Digital Press, Bedford MA, 1981.

The Electronic Numerical Integrator and Calculator (ENIAC) was the first operational electronic digital computer. It was principally designed and built by Eckert and Mauchly at the Moore School of Electronic and Electrical Engineering at the University of Pennsylvania from 1943-6. Stern offers a concise account of the technical development of the ENIAC project. *From ENIAC to UNIVAC* notes the role of von Neumann in the computer project at the Moore school and covers the patent disagreement, which ensued when Eckert and Mauchly sought to take the EDVAC design into the commercial sphere. On leaving the Moore School Eckert and Mauchly founded UNIVAC and began to build computers as a commercial enterprise. Stern covers all the machines designed and built by Eckert-Mauchly team. Stern's history is constructed from detailed technical records, archival resources and interviews with Mauchly and Eckert. Appended to *From ENIAC to UNIVAC* is von Neumann's 'First Draft of a Report on the EDVAC'. This makes *From ENIAC to UNIVAC* a valuable secondary resource for computer history research.

Sherry Turkle, *The Second Self: Computers and the Human Spirit*, Granada, London, 1984.

The Second Self is significant in that it examines the users of computer technology rather than the technology itself. Primarily *The Second Self* focuses on people interacting with stand alone computers, those computers that are not connected to networks. **Cyberhistory** draws heavily on Turkle's account of a soft and hard style of learning. Turkle drew her conclusions from a series of studies of school children who were using computers in a relatively affluent school. In this school the children had access to computers from a young age. Turkle asserts that the computer is viewed by some of its users as a second self, an entity with which the user can interact.

Sherry Turkle, *Life On Screen: Identity in the Age of the Internet*, Phoenix, London, 1997.

Turkle brings her psychological expertise to the realm of cyberspace in this evocative study. Turkle contrasts those who delight in tinkering with the computer, with those who methodically seek to obtain control and knowledge of the system. Unlike Turkle's 1984 book *The Second Self*, *Life On Screen* primarily deals with people interacting with others in online environments. A key point that can be taken from Turkle's Study is that human culture shapes computer usage. Technology complements culture, not the other way around. **Cyberhistory** draws on Turkle's observations regarding Multi User Domains (MUDs). Turkle describes the MUD online fantasy gaming environments and details the experiences of a variety of participants. Turkle notes that, while online environments can be psychologically therapeutic, they cannot offer as much help as a psychotherapist. Turkle captures the postmodern nature of the online realm and documents the issues surrounding gender swapping, cybersex, and multiple online identities, from a psychological perspective. While *Life On Screen* is not a history, it does offer valuable insight into the relatively recent history of the Internet. *Life On Screen* is a valuable resource for the computer historian.

Margaret Wertheim, *The Pearly Gates of Cyberspace: A History of Space from Dante to the Internet*, Doubleday, Sydney, 1999.

The Pearly Gates of Cyberspace is intended as a prelude to a discussion of cyberspace that is aimed at tracing the history of how Western society has seen itself in terms of a spatial scheme. *The Pearly Gates of Cyberspace* is a highly original look at the implications of the Internet and cyberspace. Wertheim follows the story of how people conceived of space from the late Middle Ages to the current period. *The Pearly Gates of Cyberspace* moves from a medieval concept of spiritual and physical space, through the Newtonian cosmology of physical forces and mathematical laws, to a relativistic theory of space, and beyond to the bizarre reaches of hyperspace. **Cyberhistory** draws on Wertheim’s description of the New Jerusalem in order to contrast an idealised utopia of St. Augustine’s *City of God* with the distopia of the Internet. Wertheim likens cyberspace to a parallel world that has returned humanity to a dualistic theatre of reality, like the medieval conception of spiritual and physical space. Significantly Wertheim notes the inadequacy of much of the cyber-utopian rhetoric, recognising the inequity that exists on many of the current online environments.

Section 2: Papers

William Aspray, 'International Diffusion of Computer Technology, 1945-1955,' *Annals of the History of Computing*, Vol. 8, No. 4, October 1986, pp. 351-60.

Aspray's paper is significant in that it notes the process through which computer technology spread out from the seminal 'First Draft of a Report on the EDVAC' by von Neumann at the Moore School, Pennsylvania. Aspray notes the characteristics of commercial and scientific exchange of knowledge and asserts that the exchange of computer technology from 1945-55 closely resembled the pattern of knowledge diffusion in the international scientific community. Aspray notes that from 1945-55 Britain and America were the principal exporters of computing knowledge and technology, that Government bodies did not play as direct a role, in the construction of computer systems in the UK and the USA, as they did in other nations. Aspray notes the significance of scientific papers, personal visits, and conferences in the exchange of computer technology.

W. Barkley Fritz, ‘The Women of ENIAC,’ *IEEE Annals of the History of Computing*, Vol.18, No.3, 1996, pp. 13-27.

Accounts of computer history that focus solely on women’s contribution to a particular period are rare. Barkley Fritz’s paper is the only source cited in **Cyberhistory** that charts the contribution of the females working on the ENIAC project. Barkley Fritz constructs an informative paper from oral history accounts and interviews with the women discussed. Some women, who were initially employed as human computers at the Moore School, went on to programme the ENIAC and work closely with the machine. Barkley Fritz captures their story for the historical record. Barkley Fritz notes that many women who worked at the Moore school did so because they did not want to pursue teaching careers, as was generally expected by American society in the 1940s. Barkley Fritz locates women within a significant role on the ENIAC. Although they did not build the machine a few women influenced its later design. Female programmers needed to have a complete understanding of how the ENIAC worked in order to have their instructions effectively carried out by the computer. Barkley Fritz’s paper is an important resource for **Cyberhistory** and was heavily cited in **Women on the Machines**.

M. Beard & T. Pearcey, ‘Genesis of a Stored Program Computer: CSIRAC,’ *Annals of the History of Computing*, Vol. 6, No. 2, 1984, pp. 106-15.

One of the earliest vacuum tube stored-programme computers, the Council for Scientific and Industrial Research

Automatic Computer (CSIRAC) was developed from 1947-51. Beard and Pearcey were directly responsible for designing and constructing the CSIRAC. This paper represents their account of the development of Australia's first computer. Significantly this paper highlights the independent nature of the development of the CSIRAC. It was only during 1948 that work on the Pilot ACE, EDSAC and the MADM (all early British computer projects) became known. The design and construction of the CSIRAC was well under way at this stage. Thus Beard and Pearcey's paper offers evidence of independent development on the periphery, a point that is elaborated in **Cyberhistory**. In terms of technology exchange, this paper is important in that it notes the way in which Pearcey worked closely with radar systems in Britain during WWII. This was the same kind of war work on which Williams (creator of the CRT storage technique at Manchester) was involved.

G. Bowker and R. Giordano, 'Interview with Tom Kilburn,' *IEEE Annals of the History of Computing*, Vol. 15, No. 3, 1993, pp. 44-54.

Unlike some fields of historical inquiry most of computer history has occurred within living memory. This relative immediacy of computer history has meant that there are a series of oral history accounts and interviews, which the researcher can tap for information. This paper is one such history. Tom Kilburn was a co-inventor of computer Cathode Ray Tube (CRT) storage technology and worked on the team that built the Manchester Mark 1 computer. Kilburn later went on to be instrumental in the founding of a Department of

Computer Science at Manchester University. In this paper, Bowker and Giordano question Kilburn on his role with the early computer projects and the Manchester University Department of Computer Science. **Cyberhistory** draws on this paper for Kilburn's explanation of the development of the crucial CRT storage technology.

M. G. Croarken, 'The Beginnings of the Manchester Computer Phenomenon: People and Influences,' *IEEE Annals of the History of Computing*, Vol. 15, No. 3, 1993, pp. 9-16.

By the end of the 1940s Manchester University was at the forefront of global computer research. It had developed the world's first operational stored programme computer. Croarken's paper examines two principal individuals of the Manchester computer project. Croarken details concise biographies of Newman (Head of the Manchester computer project) and Williams (co-creator of CRT storage technology) and considers their war work in relation to the postwar computer project at Manchester.

Denise W. Gurer, 'Women's Contributions to Early Computing at the National Bureau of Standards,' *IEEE Annals of the History of Computing*, Vol. 18, No. 3, 1996, pp. 29-35.

Before machinery was applied to the process, computing was carried out by hand. Gurer's paper deals with the Mathematical Tables Project (MTP) at the American National Bureau of Standards (NBS) from 1938. This project involved the co-ordination of a room full of people calculating by hand so that, in unison they acted like a computer. In particular, Gurer notes the efforts of two female mathematicians, Gertrude Blanch and Ida Rhodes in the development of the MTP. Gurer asserts that women played key roles in all aspects of early computing at the NBS. These roles continued as the NBS installed electronic computers to deal with the production of tables and other calculations.

Amy Pearl *et.al.*, 'Becoming a Computer Scientist: A Report by the ACM Committee on the Status of Women in Computing Science,' *Communications of the ACM*, Vol. 33, No. 11, November 1990, pp.47-58.

In 1990 women were significantly underrepresented in the field of computer science. Pearl *et.al.* assert that the reason for this underrepresentation is inextricably tied up with particular difficulties women face in becoming computer scientists. This paper details the factors affecting women's involvement in computer science. Pearl *et.al.* note that, computer artefacts are not gender neutral, hacking elites among students are exclusively male, some women experience a lack of mentors and role models, women often face gender discrimination, women face difficulties balancing careers and family responsibilities. Pearl *et.al.* conclude that some of these problems are easily remedied while others involve more complex issues which necessitate further study if solutions are to be implemented.

John M. M. Pinkerton with Derek Hemy and Ernest H. Lenaerts, 'The Influence of the Cambridge Mathematical Laboratory on the LEO Project,' ***IEEE Annals of the History of Computing*****, Vol. 14, No. 4, 1992, pp. 41-8.**

In the 1950s, Lyons was a catering supplier with an operation so diverse and complex that it chose to develop an electronic computer, to help automate the clerical work associated with mass invoices and ordering. This paper is the story of that development. Pinkerton was the principal engineer charged with constructing the Lyons machine. The design and technology behind the Lyons computer came from the computer laboratory at Cambridge University, which was headed by Maurice Wilkes. Lyons' interest in computing was first aroused during a study visit to the USA by a mathematician employed at Lyons. From the USA Lyons were, ironically directed back to Britain and the Laboratory at Cambridge. This paper details the construction of the Lyons Electronic Office (LEO) computer. It highlights the interaction between a commercial interest and a research laboratory. This paper also provides an example of the use of computing for tasks outside of scientific calculation, providing one of the first instances of electronic computer use in the commercial sphere.

R. Rosenzweig, 'Wizards, Bureaucrats, Warriors, and Hackers: Writing the History of the Internet,' *American Historical Review*, December 1998, pp.1530-1552.

Rosenzweig offers a perceptive paper on the historiography associated with the Internet. That is, Rosenzweig critically addresses the style and content of histories concerning the Internet. Rosenzweig notes that contextualist approaches have long dominated academic studies of the history of technology. Despite this, narratives of "great men" of science and technology remain popular. They do so, Rosenzweig asserts, because they derive their power both from the widespread assumptions about new ideas emerging from particular "men" of genius as well as from the narrative appeal of biography. Rosenzweig then examines histories of the Internet and notes how they pursue the narrow focus of individuals shaping history. Rosenzweig then considers histories with other foci beyond "great" persons and notes their successes and failings. Rosenzweig concludes that any future history of the Internet will have to locate its story within the Net's multiple social, political, and cultural contexts.

Betty Alexandra Toole, 'Ada Byron, Lady Lovelace: An Analyst and Metaphysician,' *IEEE Annals of the History of Computing*, Vol. 18, No. 3, 1996, pp. 4-11.

Toole asserts that the computer revolution began in 1834 with Babbage's analytical engine and a woman, Ada Byron. Toole seeks to locate Ada as a key contributor to computer history, despite her being overshadowed by the towering figure of Babbage. Toole notes, the way in which Ada applied imagination to her mathematical concepts, how Ada conceived of what is arguably the first programme, and how Ada's notes to the translation of the Menabrea's description of Babbages engine exceeded the principal text in vision, depth and understanding. Toole asserts that Ada was a gifted intellect whose contribution to computer development is significant. Toole characterises Ada as an analyst and metaphysician. Ada, notes Toole, had a remarkable skill of "imaginative rationality." Along with Stein [1985], Toole's paper provides a valuable resource on Ada Byron and was drawn upon throughout **Ada and the Engine** in **Cyberhistory**.

G. Tweedale, 'A Manchester Computer Pioneer: Ferranti in Retrospect,' *IEEE Annals of the History of Computing*, Vol. 15, No. 3, 1993, pp. 37-44.

Formed in the late 19th century, Ferranti Ltd was, by the 1940s, one of the most famous names in UK electronics. A Manchester based firm, Ferranti set up a computer group in 1949 to manufacture a commercial version of the Manchester University computer. In 1951 the Ferranti Mark 1 arguably became the first commercially manufactured computer to be delivered. Tweedale's paper covers the development of Ferranti's computer interest. Tweedale asks why did Ferranti fail to become a leading computer manufacturer? Tweedale notes the lack of a marketing culture in Britain, and acknowledges other research, which blames the failure of the Government National Research and Development Corporation (NRDC) to get behind British computer manufacturers. Ultimately, Tweedale locates the poor performance of Ferranti in its inability to compete with American firms, which were heavily underwritten by the massive resources of the USA Government. Tweedale concludes with the point that Ferranti was successful on its own terms, eventually occupying a niche in the defence computing market.

Section 3: Archive Resources

Cyberhistory refers to a number of archive files in Chapters 4 and 5. These files were researched at The University of Western Australia Archives from 1999 to 2000.

Specifically the archive file numbers cited in **Cyberhistory** are listed below.

2728 Part 2
3106 Part 1
3106 Part 2
3807 Part 1
3913 Part 1
4539 Part 2
4552 Part 1
4552 Part 2
4552 Part 4

Computer historians may wish to access The University of Western Australia (UWA) Archive resources in the future for research purposes. Due to this, a tabular summary of all the UWA Archive resources has been appended to this thesis. The UWA Archive Computing Resource Table depicts information in the following categories:

- Archive file number,
- Date on the document referred to in the file,
- Type of document referred to in the file,
- Origin of the document (Author, Department or position of Author),
- Destination of the document (Receiver, Department, etc.),
- Description of the relevant contents of the document.

[In all the above categories information that is absent or not applicable is left blank in the UWA Archive Computing Resource Table]

The UWA Archive Computing Resource Table is a rough guide. Descriptions refer to documents that Keith Falloon (**Cyberhistory** author) has felt are relevant for inclusion. Hence the UWA Archive Computing Resource Table is not a complete guide to the contents of the UWA Archives that relate to Computing.

Section 3: Archive Resources

UWA Archive Computing Resource Table

3913 Western Australian Regional Computing Centre Board of Management

File Number	Date	Type	Origin	To	Description
3913		Letters			Letters regarding Moore's appointment to the Health Department
3913	24-10-73	Minutes			Computer Users Group
3913	18-5-73	Minutes			Board of Management - financial statement April 1973
					Department of Lands and Surveys purchase of a CDC 731-12 batch terminal 24th May 1973
3913	6/06/1973	Minutes			Board of Management - financial statement April 1973
					Income 1972 - financial statement 1973
3913	2/04/1970	Letters	Treasury	Townsing	Premier's approval of a Regional Computer Centre
					WARCC working notes on organisation proceedures and requirements
					3 pages of tables evaluating proposed machines
3913	2/11/1970	Letters	Treasury	Townsing	Premier's approval of a Regional Computer Centre
3913	15/12/69	Letter			Regional Computing Facilities outline of proposed centre (6 pages long)
3913	18/3/70	Memo	Moore		Deals with the choice of machines

5724 Western Australian Regional Computing Centre - Use of Computers by Students and Other Bodies

File Number	Date	Type	Origin	To	Description
5724					Applications for private accounts for psychology students
					Stone James & Co. Computer Use Agreement
					Conditions of computer use for non-university users
					Staff and Student computer use conditions
					Legal documents - warranty for Control Data Corporation

1529 Western Australia Computer Network

File Number	Date	Type	Origin	To	Description
1529	30/7/1980				WA government Computer Policy Committee
					Formulation of a policy for an integrated land information system
					Case for a feasibility study of a WA Regional Computing Network
					New Cable to increase capacity of computer network to the Southern campus
1529	21/6/77				Funds approval for a fully automated loans system
	20/7/77				Correspondence regarding loans system
					Letter regarding concerns on the ability of bodies to co-operate on Networks
1529	30/6/77		Reid		Activities of Network Technical Sub-Committee
					Report on a Computer Advisory Commission

					State Computer Network
1529	8/06/1976	Letter			Draft letter to Sir Charles Court (not signed)
1529	19/2/76	Memo			Memo to the University Architect regarding the Computer Cable Network
					Network 1978/9 packet switching diagram
					Network current situation diagram
					Western Australia Computer Network - mission statement of WARCC

3807 Part One Western Australian Regional Computing Centre Board of Management

File Number	Date	Type	Origin	To	Description
3807					The expansion of ADP facilities
					Consideration of Regional Concept (5 pages)
					Case for a State Government Scientific computer
3807	Aug-69				Computer Work Loads
					Computer Facilities
3807	9/04/1969				Report on visit to UWA computer centre
3807	17/12/69	Minutes			Government and University computer users
3807	18/3/1970				Concern over loss of control
3807	20/3/70				Fear of handing computer control over to the State Government
3807	23/3/70				Principal issues lack of information and retention of control
3807	14/9/70	Report			Report on Computer Resources by R. Sipe (7 pages)
3807	8/05/1971				Regional Computer Centre policies
					users
					storage
					charging
					expenditure tables
3807					Sir Charles Gardiner Hospital Michael Hobbs - study to define medical computing requirements
3807	24/11/71	Memo			Moore, Sala and CDC representatives meeting
3807	12/02/1971	News Release			Premier's Department WA news that the regional computing centre has acquired a CDC CYBER computer at the cost of 1.1 million
3807	12/02/1971	News Release			UWA release concerning new regional centre
3807	12/07/1971	News Release			Australian Financial Review - 'Region Concept in WA Uni's Contract'
3807	13/12/71	Letter	Birkett-Clews		Letter to CDC Australia
					Members of Regional Computing Centre going to Adelaide for pre-installation training on 21st December 1971
3807	6/08/1971				CDC list of customers who installed CDC systems in 1970
3807	2/09/1972	Letter	Reid	Hobbs	3 year medical records linkage project
3807	21/4/72		Architect		Underground ducting for telecommunication cables
3807					Application for by-law entry to Customs Department for computer (no date)
3807	29/6/72	Minutes			Research Grants Committee
					Public Service board Adelaide regarding co-operation between two computer centres
					Premier J.T. Tonkin
3807	19/10/72	Letter	AUC	UWA VC	Sale of computer time to non-government bodies for low rates

3807	26/10/72				$240 per hour computer usage and input/output at $40 per hour
					List of bills and companies from 1971
3807	16/2/73				Maintenance of mini-computers on campus

4552 Western Australian Regional Computer Centre Agenda and Minutes

File Number	Date	Type	Origin	To	Description
4552	30/4/81	Letter	Sumner	Laurens	Mentions that Moore resigned to accept a consultancy with the State Government
4552					Schematic of terminal access - proposed system with multi-batch cyber submission
4552					Capital Investment 1979 (2 pages)
4552		Graph			WARCC income displaying actual income vs. estimates for 1978
4552		Table			WARCC expenditure from January to December 1978
4552					WARCC income for 1978 by month
4552	26/4/78	Minutes			WARCC Executive and Finance Committee
					Mentions that the Director is expected to resign
4552	23/5/78	Minutes			WARCC Board of Management
					Captial expenditure for 1978
					Appointment of new director
					Surveyor General's office J.F. Morgan - return of drum plotter June 9 1978
					Proposed revised equipment repayment schedule 1978-82
4552					Dufty was appointed applications manager in December 1976
4552					Carson upgrading as administrative officer recommended on 14th June 1978
4552	21/6/78	Minutes			WARCC Executive and Finance Committee
					Drum plotter was returned to the Lands Department
4552	6/08/1978	Letter			Metropolitan Water Supply Sewerage and Drainage Board
					CN87 Terminal
					Regional Computing Network
					Conversational Remote Job Entry (CRJE) financial considerations
4552	26/6/78	Minutes			WARCC Board of Management
					CRJE
4552	16/8/78	Minutes			WARCC Executive and Finance Committee
					Provision for long term developments
4552	15/9/78	Minutes			WARCC Board of Management
					Ports on WARCC Computers
4552					Income and expenditure summary statement September 1978
4552	10/12/1978				Provision for replacement of major equipment items
4552	18/10/78	Minutes			WARCC Executive and Finance Committee
					Changes to the computer booking priority scheme 9/11/78
					Actual vs. budget expenditure
					WARCC Constitution Amendments

2728 Part Two Computer Policy Committee

File Number	Date	Type	Origin	To	Description
2728	31/3/78	Letter			Key punches and teletype costs and the responsibilities of Departments to purchase them
2728		Table			Remote batch terminal contracts table
2728	Aug-78				Computer Policy Committee Scope and Proceedures
2728					Computing funds allocation for 1979 This includes a list of requests and allocations by Departments
2728					Advantages and disadvantages of a charging policy for university computing
2728					Bibliography on pricing computing services
2728		Letter	Economics		Inquires about the status of student computer teaching facility, notes the theft of calculators and misuse of terminals
2728	12/12/1979	Memo			Questions delays imposed on request relating to psychology 100 laboratory computer
2728	2/11/1980				Planning for computing at UWA
2728					Memos relating to the computer teaching facility and its status
2728					Options for the development of a computer graphics facility at UWA
2728	16/5/80	Memo			University computing policy
2728	16/5/80	Memo			Computer Workshops There is also a list of those who were keen to attend
2728	20/5/80	Letter			Queen Elizabeth II Hospital medical centre concentrator
2728	28/5/80	Diagram			Concentrators at remote sites
2728	6/05/1980				Professor of Pathology participation in workshops
2728	6/04/1980	Memo			Computing cost allocation will only be allowed if processing is done via a central computer
2728		Table			Details of people involved in the computing workshop
2728	Jan-Feb 1978				Computing income for January and February 1978
2728	1978				Application to the Digital Computer Policy Committee for a supplementary grant for computing to the Department of Microbiology
2728	Mar-78		Humpage		Computer Policy Committee Batch Terminals Report
2728	3/07/1978		Moore		Remote Batch Facilities
2728	3/03/1978		Rohl		University computing terminal facilities
2728		Graph			Number of jobs in use on the computer compared with the time of day
2728	2/10/1978		Moore		Expansion of access to the DEC 10
2728	2/10/1978	Diagram			Configuration of system offered at Rohl's request
2728	23/2/78				CRJE - Conversational Remote Job Entry System
2728	22/12/77		Rohl		First draft of a proposal for student computing facilities
2728					Proposed constitution of the Computer Users Committee
2728		Table			Credits Table relating to the 1978 computer usage
2728		Table			University computer usage 1977 totals
2728	3/01/1978	Minutes			Digital Computer Policy Committee
2728	Apr-78				Policy and proceedures of the Computer Policy Committee
2728					Moore resigns and takes up position with the State Treasury
2728					Remote batch terminal maintenance contracts
2728		Table			Computer use to August 1978 with categories of department, usage cost in dollars, and allocated percentage of use
2728	13/9/78	Minutes			Computer Funds Allocation Sub Committee

					Requests for increases in allocation of computer funds
2728	17/10/78				Crystallographic Computing - more computing power would permit further research into proteins
2728	27/11/78		White and Maslen		Report on Crystallographic Computing
2728	29/11/78	Minutes			Computer Policy Committee
					Use of Centre's programmers by Departments
					Arguments for retaining the Centre's regional nature
2728	10/02/1979		Reid		Discussion paper for the Computer Policy Committee
2728	10/03/1979		Reid		Proposal for the University Development Fund Project
2728		Table			Batch terminal Maintenance - Comparison of 1979 grant and actual expenditure to 31 Aug 1979
2728	26/9/79	Letter			External funding and computer funding - complaint
2728		Table			Computer Spending by UWA 1973-8
2728		Table			Comparison of computing expenditure as a fraction of total University general expenditure 1976
2728					Submission to the Appropriations Committee on behalf of the Computer Policy Committee
2728	10/12/1979	Table	Rohl		Computer Science submission for equipment
2728	26/9/79				Proposal to upgrade the computing facilities in the school of architecture
					There are also other requests from Departments for computer upgrades
2728					Submissions had to be made for equipment costing more than $4000
2728	16/11/79	Minutes			Computer Funds Allocation Sub-Committee
					Automatic cut-off for overspent accounts
2728	22/1/80				Computer Policy Committee
					Confirmation of fund allocation
					Computer Science upgrading PDP-11/60
2728		Memo	Angeloni		It is unlikely that there could be an increase in spending on computer equipment
					unless resources from other areas were redirected
2728	9/06/1979	Report	Armstrong et. al.		Computer facilities for off-campus locations of the Medical school
2728	2/12/1980	Letter	Rohl	Registrar	Computer Science intake of students has increased by 50%
					Computer Science has its first full time research students
2728	15/2/80		Reid et. al.		Planning for computing at UWA
2728	27/3/80	Minutes			Computer Policy Committee
					Computer Science request for VDUs - refers to planning
2728	6/04/1980	Table	Reid		Funds for research and teaching computing 1974-85
2728	6/12/1980				Provision of computing facilities to remote University users
2728	4/11/1980				Computer Policy Committee identifies an urgent need for student terminal room
2728	4/03/1980		Williams		Application for assitance with research from the general development grant
2728	21/3/80	Memo			Student access and suggestion of calculator theft
2728	26/6/80	Minutes			Computer Policy Committee
					Resolved that Economics and Commerce computer terminal room should be available to other students
2728	14/7/80				General access terminals to WARCC Network
2728	10/09/1980				Word processing working party
					Report to the University Computer Policy Committee from the Graphics Working Party
2728	8/01/1980		Rohl		Summary of discussion of Working Party on data transfer between computers
2728	23/10/80	Minutes			Computer Policy Committee
					Proposal that the undercroft area of the link building between Mathematics and
					Electrical Engineering be enclosed to provide accomodation for a general access terminal facility
2728	24/7/80				Computer Science Summary of a discussion of a working party on data transfer between computers

2728	10/03/1980				Working Party on computer use in teaching/learning Computer Assisted Instruction (CAI)
2728	23/10/80				Planning for Computing at UWA
2728	10/12/1980				Submission by the Department of Architecture for a graphics computer
2728	12/08/1980				Working Party on computer use in teaching/learning Recommendations
2728					Submissions regarding the need for mini-computers and other items over $4000
2728	27/2/81	Minutes			Planning sub-committee of the Computer Policy Committee Deals with the above submissions
2728					Report of the Computer Policy Committee Word Processor Working Party Word Processing needs of UWA Report includes Tables
2728					A questionnaire was put around regarding word processing in March 1981
2728	26/8/81				Future funding reports (They are disorganised yet quite insightful)
2728	27/2/81		Reid		Submission for computer terminals for general student use (Includes a short table of expenditure by students from 1974-80)
2728	10/08/1981		Collins		A proposal for a central graphics computing facility
2728	24/6/82	Report			Report on computing equipment submissions by working party
2728	6/08/1982	Memo	Rohl		Request for a VAX-11/750 computer
2728	16/7/82				Discussion paper on charging for computing at UWA Appendix B - why surplus computer time cannot be given away free of charge
2728	10/07/1982	Minutes			Computer Policy Committee Department of Education request for $4000 to buy an Apple II computer
2728	13/10/82				Department of Economics request for a Kay PRO II at $2550
2728					Equipment Advisory Committee 1982-84 Triennium equipment allocations
2728	27/10/82				Submission to the Appropriations Advisory Committee for computing funds WARCC cheap computing letter Cost unfairness- charges for computing are assessed on the use of computer hardware
2728	18/11/82		Maslen		Crystallography Centre
2728	24/12/82		Reid		Major Directions for Computing at UWA
2728	19/1/83				By '1987, 80 percent of faculty will have microcomputers' Campus Review January 19 1983,pp.18-19.

2728 Part Four Computer Policy Committee

File Number	**Date**	**Type**	**Origin**	**To**	**Description**
2728	18/1/83	Letter		Lourens	New computers
2728		Paper			L.F. Kahn and M.H. Swanger Investing in Computer Aided Engineering Design Capabilities *Concrete International November 1982, pp. 13-15*
2728	19/11/82				Anthropolgy submission to the Equipment Advisory Committee

					Microcomputing
2728	2/11/1983	Report	Reid		Report on Anthropology Submission for Funds for Microcomputers
2728	3/10/1983		Reid		Psychology had an upgrade from a PDP-11/44 to a DEC VAX-11/750
2728	11/04/1982	Report	Reid		Report on Psychology submission for funds for a VAX-11/750
2728	2/07/1983	Letter	Reid	Lourens	Review of computing arrangements
2728	26/4/83				Survey of software usage on campus
2728	27/4/83				Executive and Financial Committee of WARCC
					Approval of the strategy to replace the CYBER
					Extensive involvement in microcomputers
2728	19/4/83		Reid		WARCC strategy for microcomputers
2728	19/4/83		Reid		Details of the WARCC equipment submissions
2728	May-83				Need for students of accounting and finance to access computers
					Proposal for a computer graphics facility at UWA
2728	22/6/83	Table			Terminal Availability in Australian Universities

3905 Computer Science

File Number	Date	Type	Origin	To	Description
3905	2/05/1970				Planning and Staffing Committee
					Computer Science is approved for the next triennium
3905	3/11/1970				Sub committee on Computer Science
3905	4/02/1970				Notes of a meeting concerning Computer Science at UWA
3905	4/10/1970	Letter			Correspondence from the University of Adelaide
					Reponse to questions on Computer Science
3905		Paper	Capon		I.N. Capon ' Computing Science Curricula for Australian Universities', *Australian Computer Journal* , 1/3 November 1968.
3905	14/3/70				University of Melbourne
					Computer Science course structure
3905					Monash Department of Information Science
3905					Monash University timetable for computing subjects
3905	4/02/1970				University of NSW Computing Centre response to Cole's questionnaire
3905		Table			University of NSW
					Table showing the structure of the School of Electrical Engineering
3905					University of NSW
					Computing courses 1969
3905	5/08/1970				Basser Computing Department
					School of Physics
					University of Sydney
					Responses to the computing questions
3905	Apr-70	Article			University News
					Proposal for a Computer Science department at UWA
3905					Responses to an internal questionaire from varoius heads of departments
3905	15/5/70	Memo	Maslen		Refers to the small chance of the Computer Science Department making a major contribution due to Perth's isolation
3905					Computer Science draft report for the planning committee

3807 Part Two Western Australian Regional Computing Centre

File Number	Date	Type	Origin	To	Description
3807	10/05/1973	Letter			B.W. Smith and B. de Ferranti Research project into computer education needs and resources at a tertiary level
3807					Community Health Services Department central health and welfare register
3807	3/11/1974	Memo			Draft of long term computer developments
3807	Dec-73	Paper			Computing in Transition *Science* , vol. 181 No. 4106, December 1973
3807	Oct-73	Paper			J.E. Skelton The Games Universities Play University of Denver
3807	14/3/74		Moore		Report on the desirability of centralized computing facilities for tertiary education in this state
3807		Paper			Computer Networks in Education
3807	18/9/73				Major computer education study announced
3807					The Emerging Needs for Computer Education in Australia Conference briefing No. 2
3807	27/10/73	Paper			Smith and de Ferranti Computer Education Needs and Resources'
3807	16/5/74		Moore		Proposed computing developments 1974-8
3807	5/09/1974				UWA submission for the 1976-8 triennium Computer facilities
3807	28/5/75		Boyle		Western Australian Computer Network
3807	8/08/1975	Letter	ICL	Court	Letter to the Premier Sir Charles Court Complaint regarding the low processing charges at WARCC
3807	27/8/75	Letter			WARCC Cyber comptuer water cooling system
3807	9/04/1975	Letter			A.J. Williams reply to the Premier's Department Operationally WARCC is independent of UWA
3807	9/09/1975				Premier's Department reply to the above
3807	10/11/1976				Computer Centre Security
3807	12/08/1976	Letter			Questionnaire as sent to computer users Quality of service issues
3807	28/6/77	Memo	Reid		Review of WARCC with regards to the role of guarantor that the University exercises
3807	16/7/77		Reid		The status of the WARCC Appended are arguments for retaining the regional nature of the centre
3807	11/01/1977	Letter	Moore	Boylen	Fundamental review due to midi and mini-computers
3807	12/06/1977	Letter	ICL		Complaint to the Premier's Department regarding loss of custom due to WARCC's pricing of services
3807	20/12/77	Letter	Moore		Reply to Premiers Department Western Mining has been operating a computer for 3 years
3807	Nov-77	Table			Accounting and charging tables

Estimate of area tables (as at 29/11/77)

3807 Part Three Western Australian Regional Computing Centre

File Number	Date	Type	Origin	To	Description
3807		Letters	ICL		Originals of the ICL complaint letters
3807					Stone James & Co. Legal invoices
3807	5/04/1979	Memo	Moore		Software research centre
					Talks with UNIVAC
3807	29/2/80	Letter	Street		Future use of the CSIRONET by UWA
3807	2/04/1980		Reid		CSIRO computing services
3807	15/1/80		Street	Reid	Large computer adandoned in favour of small machines
3807	18/12/79				CSIRO computing service via its CYBER 76 computer
3807	Mar-80				Minor dispute over health service partitions
3807	22/5/80	Letter		Court	Premier to speak at the commissioning of the DEC 10
3807					Reasons for inviting the Premier
					original cyber installed in September 1972
					Background to the computing centre
3807					Draft statement on the use of WARCC by private companies
3807					Note on the relationship of WARCC to the SRIA
3807					DEC System10 computer specifications
3807					Proposed guest list
3807	6/11/1980	Letter	Court	Street	Date of the commissioning ceremony
3807	17/6/80			Gaydon	An invitation to the Minister for Education and Cultural Affairs
3807	15/8/80				Commissioning of the DEC 10 will commence
3807	12/02/1981	Letter			FORTRAN 77 course at WARCC
3807	27/7/82		Chandler		A proposal for computer usage at WARCC
3807	18/8/82				An old toiler heads for the breaker's yard
					The CYBER is given to Electrical Engineering
3807	9/08/1982	Article			*The West Australian*
					Farmers catch up on Technology
3807	10/06/1982		Scriven		*The West Australian*
					Warning over computers
					Prof. Michael Scriven Department of Education UWA
3807	24/6/83	Memo	Lourens	Reid	Drop in WARCC revenue
					Past benefits of centralised computing have
					given way to the microcomputers
3807	28/6/83				Microprocessor charge scheme
3807	15/7/83				WARCC Microcomputer Support Centre
					Scale of Charges

5702 WARCC - Equipment Grant 1979/81 Triennium

File Number	Date	Type	Origin	To	Description
5702	22/11/78		Reid		Equipment needs 1979-80 and beyond

5702	30/9/80		Reid		Equipment needs 1981 and beyond
5702	27/2/81		Reid		Submission for computer terminals for general student use
5702			B. Stephens		*Pacific Computer Weekly* September 25 - October 2 1981 Government to review high technology education grant
5702					There are many entries regarding WARCC equipment submissions with tables and figures
5702	31/3/82		Reid	Lourens	Submission for microcomputer equipment
5702	28/9/82			Reid	Equipment grant - Campus LAN $150 000
5702	11/02/1982		Reid	Registrar	Submissions for equipment Microcomputer support facility
5702	2/04/1983	Letter	Reid	Lourens	Shared State graphics centre
5702	16/3/83		Reid		Proposal to purchse a central computer graphics system

4407 WARCC - Accommodation

File Number	Date	Type	Origin	To	Description
4407	11/08/1971	Memo	Angeloni		Physics extensions end is in sight
4407					There is a lot of material concerning room/space allocation and associated costings
4407	29/6/73	Memo	Moore	Angeloni	Library system housing during development Retention of the 1620
4407					WARCC draft submission 1976-78 Triennium General philosophy, equipment requested, CYBER expansion
4407	11/05/1973				Medical Computer
4407	17/8/73	Notes			Notes of a meeting to consider the allocation of space in physics to be vacated by the PDP-6
4407	28/5/74		Moore	Angeloni	Computer centre housing Perception of dynamic computing Centre problems - no student work area Communications group is housed in the PDP-6 area - reverting to Physics There is insufficient storage space for consumables
4407					There are Letters and Memos dealing with requests for a terminal centre
4407	22/9/78				WARCC office accommodation, Physics extension
4407	10/05/1978	Extract			Extract from notes of the Accommodation Advisory Committee Overcrowding of the computer centre
4407	4/12/1979	Extract			Extract from notes of the Accommodation Advisory Committee Computer Science was initially housed inside the Physics building Staff study, student terminal room, work rooms, and laboratories
4407	7/12/1982		Rohl	Brown	Changing room allocation in the Physics building This gives a good idea where Computer Science was housed

4552 Part 2 WARCC Agenda and Minutes Years 1975-

File Number	Date	Type	Origin	To	Description
4552	16/1/75	Memo	Moore		Administrative data processing Western Mining approached the University to do some processing
4552	16/1/75	Diagram			WA regional network showing the hospital, WARCC and WAIT
4552		Report			1975 Income Expenditure January, February, March.
4552	4/11/1975	Report	Moore		Director's report Excess demand for processing over capacity to compute Looking for more core memory
4552	19/2/75	Minutes			Board of Management Proposed Regional Network
4552		Table			Draft statement of income and expenditure for year ending Dec. 31 1974
4552	23/5/75	Minutes			Board of Management Hospital computing and networks
4552	9/04/1975	Report	Harvey		Chair of the Computer User's Group report 1974/5
4552					Adjustments of expenditure July-September 1975
4552	8/08/1975	Letter	ICL	Premier	Charges for the use of computing facilities at WARCC
4552					1975-6 Budget
4552		Table			Expenditure tables January to June 1975
4552	8/08/1975			Director	Submission for additional staff in the data communications group
4552		Table			Table of programming jobs July 1975 to December 1976 All figures shown are in "man" months
4552	8/04/1975	Report	Reid		Programming Services Report
4552	8/06/1975		Moore		Quantity discount agreement with DEC computers
4552	20/6/75	Minutes			Board of Management
4552					Control Data Corporation (CDC) agreed to sell some core memory
4552	22/8/75	Minutes			Board of Management Computing in schools
4552					Committed funds and accruals July to September 1975
4552					Income and expenditure July to September 1975
4552	17/10/75	Minutes			Board of Management Need for someone to take control of Hospital computing
4552		Table			Break down of income January to October 1975
4552	11/06/1974	Minutes			Executive and Finance Committee Digitizer, tape certifier, teletype maintenance
4552	11/12/1975	Minutes			Executive and Finance Committee Budget, charging rates for the computers approval to negotiate block time computing
4552	17/10/75	Minutes			Board of Management Triennium deferral - anticipated that there would be little money available for computing in 1976
4552	12/04/1975				Estimated 1976 budget
4552	12/12/1975	Minutes			Board of Management

					10% increase in charging rates
4552	21/1/76	Minutes			Plotting Technical Sub-Committee of the Board of Management
					Call for equipment as needed by users
4552	17/2/76	Letter		Reid	Letter directed to Reid as an acting director
4552	3/04/1976	Minutes			Plotting Technical Sub-Committee of the Board of Management
					Purchase of plotter
4552	25/2/76	Minutes			Executive and Finance Committee
					Murdoch applying for z-class computing rate
4552	12/12/1975	Minutes			Board of Management
					Moore to brief Premier on computer privacy
4552	19/3/76	Minutes			Board of Management
					1620 donated to the WA Observatory
4552					WARCC 1976 Budget-table
4552	13/5/76				Proposal to appoint an analyst/programmer at a senior level
4552					Income and expenditure January to April 1976
4552					Revised 1976 Budget
4552	7/09/1976				Users committee meeting
					Performance of the CYBER computer

4552 Part 3 Western Australia Regional Computing Centre Agenda and Minutes

File Number	Date	Type	Origin	To	Description
4552					Proposed constitution of the WARCC Users Group
4552	16/7/76		Reid		WARCC operations manager
4552					WARCC Income and expenditure January to June 1976
4552					Revised 1976 Budget
4552	21/5/76	Minutes			Executive and Finance Committee
					Arrangements on Moore's absence
4552	19/3/76	Minutes			Board of Management
					Disk space needs, 1620 donation, NOS/BE $75 000
4552	16/7/76	Minutes			Board of Management
					Conversion to 9 track tape drives on CYBERs
4552					Income and Expenditure January to August 1976
4552	28/9/76		Reid		Equipment needs 1977-82
					To Accommodate Computer Science and other UWA needs for terminals
					to both CYBER and DEC-10, and allow for operation use of an experimental network,
					which includes access to WAIT's DEC-10
4552					Expanditure January to September 1976
4552	20/10/76	Minutes			Executive and Finance Committee
					Equipment needs 1977-82
4552	19/11/76	Minutes			Board of Management
					Computer Users Group Constitution
4552	17/12/76	Minutes			Executive and Finance Committee
					Approval to purchase increased memory for the DEC-10
4552		Letter	Barrie		How best to minimise wastage in the public sector and the State

4552	3/01/1977	Minutes			Interim Network Planning Committee Issues surrounding the network implementation
4552	18/3/77	Minutes			Board of Management Network Advisory Committee
4552					James Martin Seminar Databases and data communications
4552	20/5/77	Minutes			Board of Management Mentions James Martin Seminar
4552					Income and Expenditure January to May 1977
4552					Mr. A.E. Leon passed away Leon helped steer the Centre through its change in role from being a small University Department to a substantial semi-autonomous organization with wide responsibilities
4552	9/09/1977		Reid		Equipment purchase plan 1978-79
4552	22/9/77	Minutes			Board of Management Network Report

4552 Part 4 Western Australian Regional Computing Centre Agenda and Minutes

File Number	Date	Type	Origin	To	Description
4552	Oct-76	Report	Reid and Humpage		Report on a Proposed Computer Advisory Commission
4552					Income and Expenditure year ending 31 December 1976
4552					Expenditure estimates summary 1976 final and 1977 budget
4552					Expenditure January to March 1977
4552					Income and Expenditure January to February 1977
4552					Income and Expenditure January to May 1977
4552	10/03/1977	Letter	Billings		Draft letter to the Premier Sir Charles Court Feasibility of a Western Australian Regional Computing Network
4552	29/9/77	Letter	Barrie	Billings	Feasibility of a Western Australian Regional Computing Network
4552	10/12/1977	Minutes			Board of Management Network report approved before being submitted to the Premier
4552	17/3/78	Minutes			Board of Management Experimental facility which gave users access to UWA Cyber and DEC-10 and to the DEC-10 at WAIT
4552					Revision of charges - asynchronous ports (Interesting diagram of the network)
4552	23/5/78	Minutes			Board of Management Director's resignation Advertisements for a new appointment

4359 Part 2 Western Australian Regional Computing Centre Staffing

File Number	Date	Type	Origin	To	Description
4359		Advertisement			WARCC need for 2 key punch operators to work at Royal Perth Hospital
4359		Advertisement			Punch Card Operator applications invited from females experienced with IBM punches

4359	11/01/1974		Moore		Salary Review
					Professional programmers are seen as graduates with a diploma in computation
4359	29/11/74	Memo	Moore		C.J. Herriman commenced as a training officer
4359	29/11/74				Herriman cancelled and went to a training position
4359	1/09/1975				Reappointment of Kirkby to the centre
4359	16/1/75				Vice Cahancellor's approval of the appointment of Kirkby
4359	13/3/75	Questionnaire			Australian Vice Chancellor's Committee
					Computer Centres Staff and Conditions
					11 graduate staff
					27 Non graduate staff
4359		Memo			Computer Centres Staff and Conditions
					Full report which covers all of the universities in Australia
4359	5/08/1975				Wesyern Australian Tertiary Education Commission
					Document number NAS/3
					Non-Academic Staff, Computer Operators,
					Programmers, Analysts
4359	28/5/75				Senior Administrative Assistant (Health Systems)
					Undertaking data processing of 5 training hospitals
					Page 2 of this document has an interesting schematic detailing the WARCC organizational structure (hand drawn)
4359	23/5/75	Minutes			Board of Management
					Proposal for computing services to hospitals
4359	28/5/75		Boyle		Western Australia Computer Network
					Diagrams of network situation
4359	15/10/75	Letter	Royal Perth Hospital		Moore interested in taking up the position of
					Director of Health Computing Services
4359	20/10/75		Boyle		Approval for the secondment of Moore for 6 months

3106 Part One Computing Facilities Within The University

File Number	Date	Type	Origin	To	Description
3106	30/10/64				Computing Newsletter
					PDP-6 remote sites diagram
3106	29/10/65	Memo			Proposed computing facilities in the Department of Soil Science
					and Plant Nutrition
					Cable terminations from the PDP-6 computer
3106	30/5/66				Charge per unit of computer time
					Data from all the Australian Universities that had computers
3106					Survey result sheets from individual Universities
3106	9/06/1966	Letter			Letter to the Australian Research Grants Committee (ARGC)
					Status of computing facilities at UWA
3106	20/12/66		Bennett		Survey regarding computing in Australian Universities
					Supplement to the questionnaire put out by the University of Sydney
3106					There is a copy of UWA's answer to the above survey
3106	14/2/67				Second report of the sub-committee has been sent to the members
					Report of a Survey of University Computing Activities

3106	10/04/1967		Australian Universities Commission
			Decide on University funding for computers
3106	10/10/1967		UWA has always made an outright purchase of computers
3106			CSIRO reports on computing
3106	22/4/68	Questionnaire	Australian Universities Commission questionnaire
			University computer usage
3106			Computing Centre computer usage on June 1965 -April 1967 for the PDP-6
3106			IBM 1620 usage September 1962 - April 1966
			Graphs of usage for both computers
3106	16/4/69		Approval for the installation of a remote console in the Botany Department
			Approval for the installation of a remote console in the Physiology Department
3106	23/4/69		Library Automation and the planning of the extension to the Reid Library
3106	30/4/69		Consideration of computerization and its ability to save space
3106			IBM Australia
			Library agreement for IBM machine service
3106	24/2/70		Machine readable cards for the library
3106	23/2/70		Card punch interface for the library
3106	18/3/70	Memo	Card punch interface differences
3106	26/6/70		Use of computer facilities for Mathematics students
3106	9/11/1970		Library automation is described as disappointing
3106	22/3/71	Memo	Telephone tie lines between the University and the Medical Centre
3106	4/07/1971	Memo	Order of priority in terms of computer processing jobs
3106	25/2/71		Reid's FORTRAN manual
			Prurchase of the rights to the manual
			A Guide to FORTRAN Programming and Uniwaft
3106			Australian Universities Commission
			Submission for computing 1973-5
3106	15/9/71	Letter	Computer facilities and co-operation
3106			Completed tables on the 1973-5 Triennium Submission - Computing
3106	28/10/71	Letter	Details of UWA's requirements for computing facilities 1973-5
3106	14/4/72		Summary of events

3106 Part 2 Computing Facilities Within the University

File Number	Date	Type	Origin	To	Description
3106	12/11/1972				Proposals for expenditure of the portion of the equipment grant
					set aside for computing
3106	Jan-73				University of Melbourne
					Survey of computing applications in education
3106					Campus data line network
					Costs, table and map
3106	10/05/1972				Postmaster General's Department
					Policy change
					Sole supplier of telegraph and data signalling converters
3106	3/04/1973				Notes of a meeting regarding computer lines on campus
					Advice of the costs associated with the installation of the lines
3106	6/08/1973	Memo			Schematic of new communications systems
					Along with this there are a series of memos
					regarding pipelines costs and quotes
3106	10/10/1974				The Regional Network
3106					Funds control and needs assessment within institutions
3106	11/07/1974				University Architect
					Summary of the computer cable situation
3106	16/3/75	Letter			Down time on the CYBER computer
					Research unit in University Education
3106	28/5/75	Report			Report on a Regional Computing Network in WA
3106					Diagram of the proposed network
3106					Network interim development 1976-77
					Star computer configuration
3106	6/06/1975	Memo			Mathematics
					Problems in teaching computing
3106	26/6/75	Memo			Link between flying spot scanner and PDP-10
3106	7/01/1975				Link between television research laboratory and PDP-10
3106	9/04/1975	Letter	Maslen		Crystallographic Computing
					Mini computer systems
3106		Brochure			Philips Brochure
					Computer systems with CRYSTAN software package for structure analysis
3106	10/10/1975	Letter			Mini-computers: A Consideration
3106					Requests for mini-computers
3106			Hall		Planning for Crystallographic Computing Needs
3106	31/5/76	Memo	Reid		Crystallographic Computing