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# COMPUTING in CANADA

## Building a Digital Future

**Zbigniew Stachniak**
York University

**Scott M. Campbell**
University of Waterloo

Canada Science and Technology Museum
Musée des sciences et de la technologie du Canada

Canada

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**Zbigniew Stachniak**
York University

**Scott M. Campbell**
University of Waterloo

Canada Science and Technology Museum
Musée des sciences et de la technologie du Canada
Ottawa, Canada
2009

## Library and Archives Canada Cataloguing in Publication

Stachniak, Zbigniew, 1953-
Campbell , Scott M., 1975-

Computing in Canada: building a digital future / Stachniak, Zbigniew, Scott M. Campbell

(Transformation series = Collection Transformation ; 17)
Includes bibliographical references and index.
Prefatory material in English and French.
ISBN 978-0-660-19909-2
Cat. no.: NM33-1 / 17E

1. Electronic digital computers--Canada--History. 2. Computers --Canada--History. I. Campbell, Scott M II. Canada Science and Technology Museum III. Title. IV. Series: Transformation series (Ottawa, Ont.) ; 17

QA76.17 S72 2009 004.0971 C2009-980114-0



Printed in Canada

Imprimé au Canada

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# Abstract

No singular technological invention or event, no matter how groundbreaking, can account for the creation of the digital electronic computer. Similarly, no digital computer, no matter how early, how powerful or versatile, can singularly explain the rapid transition of our civilization into that of consumers of digital information. The history of computing is indeed a vast and complex discipline bridging ancient past with modern technologies, inventors with events in times of war and peace, and across continents.

This monograph focuses on one specific region, Canada, and offers an in-depth analysis of the development of the computer and information technologies from the unique Canadian perspective. There are two dominant themes in this study: the early origins of computing in this country, and the later development of microcomputing. These themes correspond to two critical periods in the Canadian history of high-technology, one characterized by actively pursuing the creation of self-reliant computer and digital electronics industries, and the other, by the explosion of technological and social activities leading to the development of the personal computer and its profound technological status and social acceptance.

This text summarizes a great deal of what is known about the history of computing in Canada. However, it is by no means a comprehensive document that covers all aspects of computing and many important areas were left out from this study, such as computer software and services, networking and communication technologies, computer ethics, security, and crime. They are themselves fully autonomous topics that deserve their own independent studies.

# Résumé

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# Foreword

Dag Spicer

Recent scholarship in the history of computing has increasingly looked to countries outside of the United States for broader insight into the nature of innovation, national styles of engineering and computing, and how regional cultures adapt, and adapt to, computers.

*Computing in Canada* is a welcome addition to this literature. Zbigniew Stachniak and Scott M. Campbell have written an excellent overview of the computing landscape that ranges from the zinc-plated, vacuum tube culture of the 1940s to the arrival of early personal computers in the 1980s.

Like all countries, Canada's path was uniquely an amalgam of existing technical options common to many nations, what Fernand Braudel called "the realm of the possible," and factors that existed only in a Canadian context. Early Canadian work, for example, was strongly driven by military needs, especially intelligence work, a factor it shared with the United States and Great Britain. Yet funding options and technical decisions reflected local conditions.

*Computing in Canada* is itself an amalgam of the local and the transnational, which is what makes it so interesting to read. It is written for a general audience and reflects a sophisticated understanding of the literature and its meanings. It also provides a very thoughtful overview in the history of computing as a global enterprise, one in which many nations played their individual parts.

It is a delight to recommend this book to those seeking a deeper understanding of the history of computing and a refreshingly new perspective of Canada's unique role within it.

# Avant-propos

Text will go here

## Notes

1 Dag Spicer is Senior Curator at the Computer History Museum in Mountain View, California.

# Acknowledgments

*Computing in Canada: Building a Digital Future* had its origins in another Computing in Canada text that was written for the Canada Science and Technology Museum. In 2008, Dr. Randall Brooks proposed the idea of expanding the historical assessment document we had prepared for the Museum a year earlier into a monograph and to publish it in the Museum's *Transformation* series. Our special thanks go to Dr. Brooks, not only for giving us an opportunity to develop the historical assessment text into a more mature monograph form, but also for shepherding this project along while providing us with all the support and help that we needed. We also thank Dr. David Pantalony for his many insightful comments on the historical assessment document, which helped us in our work on the monograph.

Finally, we would like to thank the Archives of Ontario, the Canada Science and Technology Museum, York University Computer Museum, the University of Toronto Archives and the University of Waterloo Archives for providing access to their collections and archives. Special thanks go to the technical and editorial staff at the Canada Science and Technology Museum for preparing the photographs and final version of the manuscript.

# Remerciements

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**CHAPTER ONE**

# INTRODUCTION

# 1 Introduction

## 1.1 Prologue

The challenge for any writer of a historical monograph is to provide a compelling and relevant narrative for a reader otherwise unacquainted with the subject matter. This may seem to be a particularly difficult prospect for the author of a history of computers. After all, when most of us reflect upon the impact of technology on society, computers represent a canonical example of high technology in constant motion, advancing at a speed that makes projections of its future milestones hopeless. New systems can be rendered dated or even obsolete in a matter of months after the advent of a successive generation of hardware and software.

For example, about ten years ago a top-of-the-line consumer microprocessor such as the Intel Pentium II featured some 7.5 million transistors and had a clock speed of about 450 Mhz. Such processors could, in principle, execute only one software thread at a time, though their speed gave the impression of multi-tasking. In recent years, so-called multi-core processors (multiple processors residing on a single silicon die) have begun to replace the traditional single-core microprocessors. This is an important technological leap that not only dramatically increases the processors' speeds and transistor counts, but also allows full parallel execution of multiple software threads. A top-of-the-line microprocessor from Intel today, such as the Core i7-975, has four processors, each running at a maximum speed of 3.33 Ghz, with a total of 731 million transistors.

On the software side, since 1998 Microsoft has offered six different versions of its flagship operating system: Windows 98 (1998), Windows 2000 (2000), Windows Millennium Edition (also 2000), Windows XP (2001), Windows Vista (2005) and Windows 7 (2009. Apple Computer, one of Microsoft's main competitors for consumer-level operating systems, has also released six versions of its latest operating system, Mac OS X, in the last eight years. While both these examples represent relatively distinct software generations, over this same period countless operating systems based on the Linux kernel have evolved because of continuous support of the free-software and open-source movements.

That computer technology can progress so quickly can make writing a history of the field a bit daunting. How can a thirty- or sixty-year-old machine, fractionally as powerful or convenient to use as a modern computer, be relevant to a user gazing ahead at future generations of hardware and software?

It is an added challenge for any account of the Canadian history of technology to avoid the temptation to list every possible invention, contribution or innovation that originated in Canada or that was first deployed within Canada. Such nationalist lists are not uncommon here or elsewhere in the world, but they rarely tell a complete or compelling story.

Consider the light bulb. It is one thing to invent it, as Canadians Henry Woodward and Matthew Evans did in 1874. It is quite another to invent, build and, finally, sell an entire electric lighting system to thousands of customers, as the American Thomas Edison did so famously. Despite numerous claims that the light bulb was invented in Canada, Edison is more frequently and more rightly given credit for having introduced electric light bulbs to the world. At the same time, it is important to note that Edison purchased Woodward's and Evans's patent while developing his own design and, though it is unlikely that his ultimate success hinged on their work, there is no question that the Canadian light bulb played a part in helping to push forward the associated social and technological changes.

No invention occurs without a technological, scientific and social context created in part by an earlier chain of discoveries, inventions or contributions. Alone, the links in this chain can appear insignificant and are often ignored or forgotten, but frequently they will have prepared the ground for more significant contributions.

Ferranti Canada's DATAR (Digital Automated Tracking and Resolving) of the early 1950s was a daring, high-tech anti-submarine computer system, designed for the Royal Canadian Navy, that tested many new principles of digital information processing, communication and display. Though the project was cancelled in 1956, it led to other world firsts from Ferranti Canada: a computerized mail-sorting system in 1956 and a computerized airline passenger reservation system in 1963. Though Ferranti Canada would bow out of the computer industry the following year, these and other early projects were exciting opportunities for many young Canadian engineers and fledgling computer scientists to test their mettle.

Canada is no longer a nation of hewers of wood or drawers of water, and it has many computing achievements to be proud of. It has been home to many high-tech innovations that deserve recognition, and numerous Canadians have worked together to build a global digital future. In the late 1960s, a Canadian start-up company, Consolidated Computer, designed, manufactured and successfully marketed a new key-to-media data entry system. Multiple data entry terminals (keystations) of the company's Key-Edit 100 system were connected to a shared minicomputer, which allowed operators to enter, screen edit, verify, combine and store data on a magnetic drum, among other functions. Almost overnight, Consolidated Computer became one of the most innovative and internationally recognized Canadian high-tech companies of the period. Other manufacturers soon responded to the Key-Edit's success with similar data entry devices, and in the 1970s and 1980s these key-to-media systems dominated the data entry market worldwide. Their success first significantly reduced and eventually eliminated the reliance on punch cards for data entry.

The current success of Canadian high-tech companies such as Research in Motion and Matrox Electronic Systems points to the continuity of world-class research and development activities in computer and information technologies in Canada. But we must also be mindful that "Made in Canada" progress in computing has had its limits. The United States is Canada's largest trading partner and was the dominant computing nation of the twentieth century. Both factors had a significant impact on the development of Canadian computing. Nonetheless, the stories of Canadian computing that follow will help the reader better understand the various technological and social connections with roots in Canada that helped shape one of the most important technologies of the twentieth century.

## 1.2 Are Computers More Significant than Washing Machines?

In the early 1980s, computing historian Paul Ceruzzi was once asked what was special about the history of computers. As the questioner put it: "Why not study the history of washing machines?"[1] Washing machines were (and remain) relatively large and complex pieces of technology that affected many people's lives and had a long and complicated history involving corporations, standards, consumer acceptance, and so on. As one might expect, there are museums and special collections devoted exclusively to the history of these machines, the washing machine collection at the Canada Science and Technology Museum in Ottawa being one of them.

The implied message in the question was that, from the socio-technological point of view, computers were no different than washing machines, and certainly no more special than any other day-to-day technology, and thus their history deserved no privileged treatment. Of course, at that time, though personal computers such as the Canadian MCM/70 and French Micral had been introduced in the early 1970s, personal computer ownership was not yet widespread and direct experience with computer technology was limited for most people. Indirect contact was more common, via computerized payrolls or the occasional punch card received from a public utility with a bill statement on it. The future of computing was far from obvious to society at large, and few could truly appreciate or anticipate the depth of changes to come.

But now, in the opening decade of the twenty-first century, few would put the washing machine on the same level as the computer. While everyone knows and understands that a washing machine might have several computerized controllers, none would expect it to power a laptop or desktop computer. Simply put, computers have penetrated almost every aspect of modern living, in obvious, immediate and broad ways that cannot be matched by washing machines or any other home appliances or pieces of office equipment.

But how have these changes come about? How have computers and our use of them changed over time? Has all the impact of computing and information technologies on modern society been positive, planned or anticipated? To answer these questions, we need to start at the very beginning. When and why was the modern computer invented, and who were the first users? This must be followed by asking: How has the definition of a computer changed over time (from a person who computed to a personal computing device), and how has the identity of typical computer users changed (from mathematicians to almost anyone)?

These kinds of questions help us track and even project the development and trajectory of a technology within society. Certainly, we do not have to examine the history of computing for very long to recognize that ideas fall in and out of favour on a regular basis, but these cycles still account for long-lasting and profound technological advancements. Consider the 1955 remote computing experiment carried out by the universities of Toronto and Saskatchewan, which connected remote users on the Prairies to the first (and only) computer in Canada, located at the University of Toronto. The experiment helped prove the utility of computers and encouraged another university to establish their own long-distance connection to the computer at the University of Toronto, and helped to encourage other schools to buy their own computer, particularly as costs came down later in that decade. Eventually, most universities and other large organizations had their own computer, and the experimental connection to the University of Toronto was abandoned.

A quarter of a century later, the price and size of computers were a small fraction of those of the mid-1950s, and microcomputers were arriving en masse on desks in offices, homes and schools. But again, one of the prevailing problems of the day was to find a way to connect these computers to each other, and to provide remote usage of computational resources to share application programs and files, and to send electronic mail. Many research groups experimented with various hardware and software solutions to these problems. In the late 1960s, the U.S. Department of Defense sponsored one such project, known as ARPANET, which has famously evolved into the Internet.

In the early 1980s the University of Waterloo began experimenting with microcomputers for their own educational purposes. They developed several microcomputers of their own, known as the MicroWAT and SuperPET, and networking systems that connected personal computers to each other and to central mainframes. The latter technology was sold by IBM to many of its own clients, and it encouraged even more computer growth and usage, much as the Ferut experiment in 1955 had. Of course, we should not make too much of this Waterloo project. Computer networking is an old idea, and most people who have ever used a computer have at one time or another probably wanted to be able to connect it to another computer. Instead, the lesson is to watch for enduring or repetitive trends that cross multiple generations.

Even the idea of the personal computing device is one with historical resonance. In the early twentieth century, the Automatic Adding Machine Company of New York manufactured the GEM Calculator and marketed it as "your personal adding machine, for desk and pocket." By the 1960s, the educational toy market was offering a range of "computers of your own," and science fiction authors were anticipating the day when computers could be used in a personal context. They did not have to wait long, as some of the minicomputers of that same decade could easily have fit that description were it not for their price, which made personal ownership of such computers impossible. In the 1970s, personal computers were relatively inexpensive and underpowered microprocessor-based computers, the majority of which were manufactured for hobbyists and, later, for the educational, small business and home entertainment markets. Businesses, by and large, took little interest in these devices until the computer, running the VisiCalc spreadsheet program, attracted considerable attention from financial analysts and planners. Then, it was IBM's turn. In 1981, the company released its Personal Computer (IBM PC), making the concept of a personal computer more significant to a larger segment of the population. Today, the personal computer of the 1980s no longer exists in the same form; it has been replaced by a variety of personal computing devices—laptops, tablets, notebooks, even smart multi-purpose cellphones—for which the adjective "personal" is integral and assumed.

## 1.3 Generations of Computers

A casual glance at the history of modern computers reveals the persistent theme that computer technology has progressed in terms of eras. That is, there have been at least three successive generations of computers: mainframes, minicomputers and microcomputers. According to this classification, each generation is physically smaller and less expensive than the previous one, but sufficiently powerful and versatile to entice existing computer users to adopt the new technology. To a large degree, this impression of computer history can be tied to the material progress of the underlying technology of modern computers: from vacuum tubes to transistors, first integrated circuits and, finally, microprocessors. This technological progression approximates, to some extent, the three generally defined computer generations.

Mainframes are often thought of as large, hulking machines. Many of these behemoths of the 1950s and 1960s required specially constructed rooms, power substations, air conditioners, even whole buildings to contain and protect them, but some smaller models were not much larger than a typical household washing machine or refrigerator. Early models contained thousands of vacuum tubes, though transistors replaced them in the 1960s. A select "priesthood" of operators and programmers, who alone were granted access to the mysteries that could tame these monsters, typically controlled the larger installations. Virtually all of these machines were expensive, and therefore rare, and could be found only on the premises of the largest or richest organizations: banks, insurance companies, government or military offices or research groups, industrial corporations or selected universities. Those who could not afford the monthly payments to own or lease one rented blocks of time at a computer service centre, or did entirely without. The latter options were common, because few could justify the expense of owning or leasing the computers, and a large number had little inkling of their utility. At a series of computer conferences held in Canada from 1958 to 1962, the unofficial theme of each was: "We must get a computer," "Must we get a computer?" and "Well, the payroll is working, so now what?"

By the mid-1960s, knowledge of computers had gradually spread, and so had the desire for affordable computing. The next generation of computer hardware—minicomputers—made computing on demand a reality for mid-size companies and organizations. Minicomputers were less expensive to own (or lease) and operate than mainframes. They were also smaller, transportable and more reliable. Because of these features, minicomputers were widely used as business machines, research workstations, industrial controllers, and data collection and processing stations. Minicomputers, such as the immensely popular PDP-8s manufactured by Digital Equipment Corporation, changed the face of academic computing, as they were popular choices to support research and teaching.

The next generation of computer hardware—microcomputers—emerged in the early 1970s with the introduction of the first commercial microprocessors: central processing units (CPUs) realized on one—or a few—LSI (large-scale integration) or VLSI (very large-scale integration) integrated circuits. The novelty of the microcomputer architecture was the use of the microprocessor to implement the computer's CPU. Since microprocessors were small, inexpensive and reliable, so were microcomputers. The use of microprocessors in computer hardware advanced affordability, transportability, public access to information and even personal ownership even further than minicomputers had. In less than a decade from the appearance of the first microcomputers, small home and personal computers began to enter homes and schools by the million each year. By the end of the twentieth century, microcomputers and information technologies had elevated our civilization to a new stage, in which digital information affected nearly every facet of an individual's life. Our society has become a consumer of digital information, and reliant on microcomputer and information technologies for everything from communications, business, research and education, to entertainment and new forms of social interaction.

It can be astonishing to contemplate the technical advances made across these three generations of computers. Consider an early computer such as the IBM 650, which was the most popular computer in Canada in the late 1950s. Its magnetic drum stored 10 000–20 000 digits, and it could add or subtract 78 000 numbers per minute at most. Primary input and output were handled via punch cards, a printer and a very limited (by early twenty-first-century standards) operator's console. In 1958, it cost the University of Toronto $40 000 per year to rent an IBM 650; this amount included most of the "bells and whistles" and a significant educational discount of up to 60 percent.[2] Even though the IBM 650 was just a mid-range computer of its day, the various components that made up a complete system still occupied considerable space, as can be seen in Figure 26.

By the mid-1980s, a mid-range personal microcomputer, such as one of the many IBM PC, XT, or AT clones, cost between $1 500 and $3 000, including a monitor, some software and a printer. The system would have sported, for instance, the Intel 8088 microprocessor or its much faster successor, the 80286. It would have been equipped with at least one built-in 5.25″ diskette drive and, possibly, a hard drive. The computer would have been operated under a version of MS-DOS or, after 1985, perhaps one of the early Windows operating systems from Microsoft.

In 2009, the year of this publication, a mere $600 can buy a lightweight mid-range laptop computer that outperforms an IBM 650 millions of times in terms of speed and storage capacity. Much of this chapter was written on such a computer.

We must be careful to avoid seeing the definitions of these hardware categories as implying a discontinuous sequence of upgrades or improvements from one generation to the next, or as providing exhaustive coverage of all computer and data processing equipment of the second half of the last century. Not long ago, research and business offices were full of computational devices, such as programmable calculators and programmable digital word processors, that would not fit into any of these categories. By the end of the 1980s, when the majority of operating computers had become microprocessor-based, the technology-driven categorization of computer hardware had become less relevant, giving place to new classifications based on intended applications. We now speak of servers, workstations, desktops and laptops.

Consider one of the first groups to adopt microcomputers in the mid-1970s: electronics hobbyists, excitedly experimenting at the forefront of the new technology. But they did this in their spare time and, for many, their day job was working with corporate mini or mainframe computers. The microcomputer was important to them not simply because it made use of the microprocessor, but because it was a critical key to the development of personal computing—one person with one computer, to use however he or she wished. This new vision of the social status of computing inspired many of the early adopters, who were fascinated, even obsessed, with building personal computers at home, in basements and garages. It was, importantly, a social event for many of them: joining computing clubs, writing for newsletters, magazines or bulletin boards, sharing software and expertise. Some of these hobbyists participated directly in the creation of the early personal computer industry. They funded microcomputer hardware and software companies, opened computer stores, and organized computer fests and computer literacy programs.

## 1.4 Epilogue

This monograph is neither the first nor the most complete treatment of the history of computing in Canada. Books written by Beverley Bleackley and Jean La Prairie, Roger Voyer and Patti Ryan, David Thomas and John Vardalas all offer in-depth analyses of the development of the computer and information technologies from the unique Canadian perspective.[345] Instead, this monograph examines two critical periods in the history of Canadian high technology, one characterized by the active pursuit of the creation of self-reliant computer and digital electronics industries, and the other by the explosion of activities leading to the development of the personal computer and its profound technological status and social acceptance.

In Computing in Canada, there are two dominant themes: the early origins of computing in this country, and the later development of microcomputing. This should be seen not as a division along the lines of mainframes and microcomputers, but as a portrayal of the most important developments in the industry. With a few notable exceptions, such as Geac minicomputers, there was very little minicomputer development in Canada. Of course, some minicomputers were manufactured in Canada by subsidiaries of U.S. minicomputer makers, and there were many groups that made use of minicomputers. However, there was an enormous acceleration of computing activity in the late 1950s and early 1960s among various groups that sought out and used their first computer, and a second burst of growth in the 1970s when the first microprocessor-powered computers appeared.

Any history of computing is incomplete without a full exploration of who was using these machines and for what purpose, and what relevant changes were occurring in academia, government, business, industry and, of course, society at large. While it is important to document the technical elements of an invention, of equal importance are its various technological and social contexts, its road map, and even corporate histories of the many organizations that participated at various times. All of these factors shaped the unique characteristics of the history of computing activities in Canada.

The history of computing is a vast subject that cannot be covered adequately in a single monograph. For this reason, many important areas, such as computer software and services, networking and communication technologies, computer ethics, security and crime, to name just a few, were omitted from this monograph.

# Notes

1. Paul E. Ceruzzi, *A History of Modern Computing* (Cambridge, MA: MIT Press, 1998), 2.
2. In 2009 dollars, $40 000 would be equivalent to at least $400 000, perhaps more than $1 200 000; such historical comparisons are difficult.
3. Beverley J. Bleackley and Jean La Prairie, *Entering the Computer Age: The Computer Industry in Canada: The First Thirty Years (*Agincourt, ON: The Book Society of Canada, 1982).
4. Roger Voyer and Patti Ryan, *The New Innovators: How Canadians Are Shaping the Knowledge-Based Economy* (Toronto, ON: James Lorimer & Company, 1994).
5. David Thomas, *Knights of the New Technology: The Inside Story of Canada's Computer Elite* (Toronto, ON: Key Porter Books, 1983).
6. John N. Vardalas, *The Computer Revolution in Canada: Building National Technological Competence* (Cambridge, MA: MIT Press, 2001).
7. For further discussion of some of these subjects, the reader is referred to B. Dewalt, *Building a Digital Network: Data Communications and Digital Telephony, 1950–1990, Transformation* No. 2 (Ottawa, ON: National Museum of Science/Technology, 1992); Martin Campbell-Kelly, *From Airline Reservations to Sonic the Hedgehog: A History of the Software Industry* (Cambridge, MA: MIT Press, 2003); and Steven Levy, Crypto: *How the Code Rebels Beat the Government, Saving Privacy in the Digital Age* (New York: Viking Penguin, 2001).

**CHAPTER TWO**

# BUILDING THE FIRST COMPUTERS IN CANADA

# 2 Building the First Computers in Canada

## 2.1 Introduction

As many people are often amused to learn, the word "computer" originally referred to a human being. The seventeenth-century definition of a computer was "one who computes."[1]

It was only midway through the twentieth century that the meaning of the word changed to refer to automatic calculating machines for performing mathematical or logical operations. At that point, there were many different types of computing devices in use, employing a variety of technologies and principles, but only one type came to dominate and redefine the word as it is used today. A modern computer is one that is electronic, digital and binary, and is a "stored-program" machine— that is, the computer stores and manipulates instructions in the form of programs in the same fashion as data.

Historically, the modern computer was a direct product of the computational demands of the Second World War. Ballistic firing tables, the Manhattan Project, cryptographic analysis and other urgent scientific programs quickly exceeded the computing capacity of existing tools. There were two main developmental thrusts in the United States and the United Kingdom to overcome this deficiency. One was a dramatic improvement and expansion of existing technologies to increase speed, accuracy and flexibility, but without any major technological breakthroughs. For example, massive differential analyzers that were several orders of magnitude larger than existing implementations were constructed, and human computing projects to produce mathematical tables were expanded to encompass thousands of additional personnel.[2]

The other main developmental thrust came from mathematicians and engineers, who envisioned a new generation of much faster calculating machines powered by electronic components. A handful of people on both sides of the Atlantic realized in the early 1940s that electronics, and especially vacuum tubes, could be used to increase computational performance thousands of times beyond the capabilities of any mechanical or electromechanical device.

The first large-scale, electronic, general-purpose, digital (but not yet stored program) computer to publicly demonstrate these principles was the Electronic Numerical Integrator and Computer (ENIAC), built at the Moore School of Electrical Engineering of the University of Pennsylvania at the behest of the U.S. Army. The ENIAC was completed and shown to the public in 1946, too late to assist in any meaningful way with wartime calculations.

While the ENIAC was under construction, a number of crucial improvements were suggested for a follow-up machine. These changes were described in a 1945 report written by the famous polymath John von Neumann, and the most important was the notion of storing both data and program in primary computer storage, which created a vastly more flexible machine.[3] Computers that conform to this architecture are often called von Neumann machines, even though von Neumann himself probably did not initiate the idea. Instead, it is likely that many people contributed at different stages of the ENIAC's development, and credit was given to von Neumann as the most senior scientist.[4]

In any case, it was the final piece of the puzzle, helping to spark an explosion of postwar modern computer development.[5]

Those who chose to design a computer in those early days faced two technical dilemmas. The first involved choosing a primary storage device (or inventing a new one). A stored-program computer, by its nature, required a large amount of storage for both data and program. There were at least four

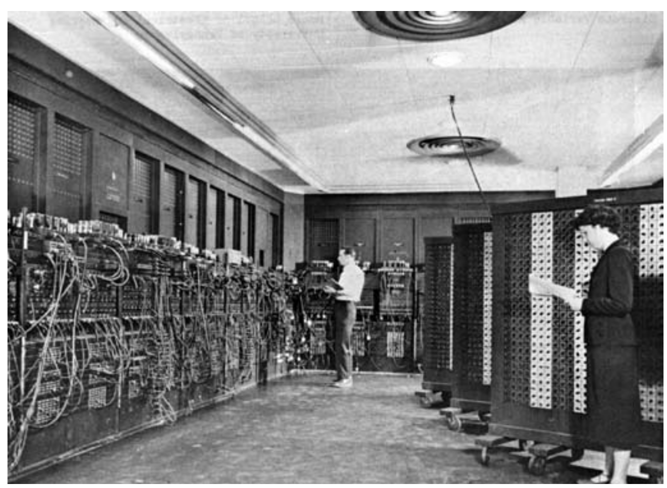


**Figure 1:** The Electronic Numerical Integrator and Computer (ENIAC), the first significant electronic computer (1946). Left: Glen Beck; right: Frances Elizabeth Snyder Holberton. (U.S. Army photograph of the ENIAC in BRL building 328, from K. Kempf, "Historical Monograph: Electronic Computers Within the Ordnance Corps," Aberdeen Proving Grounds, MD, November 1961)

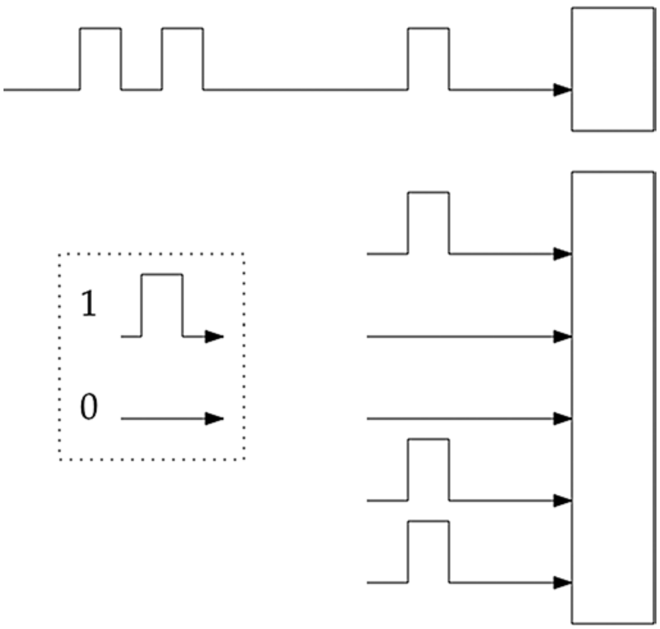



**Figure 2:** Serial vs. parallel transmission of the number 10011 (19 in decimal format).

criteria for an ideal storage device: it should be inexpensive, have low power consumption, allow rapid access, and be available in large quantities. As historian Michael Williams has pointed out, all four criteria were not satisfied until the 1980s and the advent of very large-scale integration (VLSI) memory chips.[6] Many different technologies were tested, including schemes based on magnetism and heat conductance. Two types proved most successful: delay lines, which typically stored data as repeating sound waves in a tank of mercury; and electrostatic cathode ray tubes—or Williams tubes, named for the inventor Frederick Williams—which stored binary digits on the face of the tube. Implementations of these two types were found on both sides of the Atlantic in the late 1940s and early 1950s. Core memory and transistors were not used for storage to any degree until the late 1950s and late 1960s, respectively.

The other technical dilemma for a computer designer was to choose between serial and parallel architecture. A second problem was to decide how the computer would treat information internally. Though it was common for electromechanical, or even a few electronic, computing devices to store decimal numbers, modern computers generally used a binary system, storing data as a sequence of binary digits, or bits. Architecturally, each grouping of bits was known as a "word," and there were two techniques used to store a word and transfer it throughout the computer.

A serial computer transmitted words as a series of pulses, on or off, serially down a single wire, whereas a parallel computer transmitted each bit of a word simultaneously down an equal number of parallel wires. The former was more common in early computers, because it was simpler to design and implement, but parallel computers were much faster: a word n bits long could be transmitted n times faster than with a serial design. Thus, parallel designs were more popular among those groups building a high-performance computer, but the price of speed was increased complexity in the design of synchronization circuitry, which typically led to construction delays. Again, serial and parallel designs were found on both sides of the Atlantic in early developments, but the parallel design eventually won out.

At least three historically significant computers were specifically developed as a result of the 1945 report as direct successors to the ENIAC: the EDVAC, the UNIVAC and the IAS computer. The Electronic Discrete Variable Automatic Computer (EDVAC) was the official successor to the ENIAC, and it was eventually completed at the Moore School in 1951. It had a serial design, with delay line storage. Interestingly, several of those responsible for the 1945 report abandoned the ENIAC and the EDVAC to build their own computers. J. Presper Eckert and John Mauchly, the ENIAC's engineering duo, had a patent dispute with the University of Pennsylvania and left academia to start their own computer company. They designed and built the Universal Automatic Computer (UNIVAC), the world's first commercial computer with a serial design and mercury delay lines. John von Neumann and Herman H. Goldstine were the other two to launch their own project to construct a modern computer. They did so at von Neumann's academic home, Princeton's Institute for Advanced Studies (IAS). The IAS computer was also running in 1951; its parallel design used Williams tubes as the primary storage device.

There were also three significant modern computers constructed in the United Kingdom around the same time. Some, but not all, of the technological transfer occurred over the summer of 1946, when the Moore School hosted a series of lectures on the design of the ENIAC and EDVAC. These were moderately well attended, but became widely influential after the lecture proceedings were distributed extensively. One attendee was Maurice Wilkes of Cambridge University, who returned to the United Kingdom thoroughly inspired by the talks. He built the Electronic Delay Storage Automatic Calculator (EDSAC), a serial design with mercury delay lines; it was operational in May 1949, making it the first modern stored-program computer capable of practical computations. The distinction is necessary, as another British group at Manchester University had a simple prototype system known as "the Baby" operating in June 1948, which ran the world's first stored program, but it was capable of only trivial calculations. Its more sophisticated successor was not ready until the fall of 1949. Known as the Manchester Mark I, it used Williams tubes (invented at Manchester), but in a serial arrangement. Finally, the United Kingdom's National Physical Laboratory housed the development of the Pilot ACE designed by Alan Turing. Like many other computers mentioned already, it used mercury delay lines for storage.

The modern computing club remained quite small until the advent of commercial computing in the following decade. Indeed, there were many good reasons for people to avoid joining that club by designing and building their own computer. As indicated above, though the field had settled on vacuum tubes as the primary component, there were unresolved debates as to the best architecture and storage techniques. Those unprepared to work at the leading edge of technology considered it prudent to wait until such major design decisions were settled.

Furthermore, the financial cost was quite high, as each new computer—effectively a unique prototype—cost at least several hundred thousand dollars. In contrast, the annual rental charge for a moderately capable IBM punch card calculator did not typically exceed a few thousand dollars. The vast speeds of the new machines made small-scale computations appear inconvenient and time-consuming, but few organizations could justify establishing an expensive electronics laboratory and development program. One of the most respected voices of the time—George Stibitz, designer of the Bell Laboratories relay-based computer—advised caution and substantial planning before a commitment to such a project.[7] In the 1940s, he repeatedly expressed concerns about the cost-effectiveness of modern computers, and warned people that they were not toys, but expensive and unpredictable prototypes. The average scientist could obtain sufficient computational results for much less money.[8] In some cases, results could be obtained much faster too: the scarcity of modern computers meant that only high-priority research was given access, and less important work sat in long queues. One computing centre specifically advised potential clients that, if they could complete their work by hand in less than three months, it would almost certainly be faster than waiting for a computer.[9]

Ultimately, modern computing had very little overall effect on science in the 1940s, though it was obvious to many observers that computing was a technology full of promise once implementation details had been solved.

## 2.2 The Computation Centre and the UTEC at the University of Toronto

The Second World War did not generate the same scale of computational needs in Canada as in the United States and the United Kingdom, and so it was not unexpected that modern computers arrived here later. Yet, Canadians were not so far behind: the first modern computer in Canada, the University of Toronto Electronic Computer Mark I, or UTEC, was built between 1948 and 1952. The UTEC was part of a larger strategy to establish a computing centre at the university that could handle large-scale calculations on behalf of Canadian scientists.[10]

In 1945, a group of professors at the University of Toronto had grown curious about the recent computing activities in the United States. It is unlikely that they knew about the ENIAC, but several impressive large-scale devices had been used during the Second World War. For example, Howard Aiken's Harvard Mark I—otherwise known as the IBM Automatic Sequence Controlled Calculator (ASCC)—had been finished in 1944, and the Rockefeller Differential Analyzer (RDA), built at MIT, had been operating since 1942. The Toronto group formed a committee to study the technology and recommend what action, if any, the university should take. After all, Toronto had no tradition of computing or large-scale electronics research, and nor were its faculty members generating much demand for large-scale computational assistance. The committee organized a tour of computing facilities in the United States, which took place in the summer of 1946. By this time, the ENIAC had been revealed to the public, but the tour took place too early to coincide with the upcoming lecture series at the Moore School. Otherwise, the group visited virtually every major computing centre in the United States.[11]

With their first-hand look at the latest advances in large-scale computing, and new knowledge as to how these devices operated and what problems could be tackled, the members of the committee came away from the tour well informed about the state of the art and of anticipated developments. Though the high costs and relatively immature state of the technology made them hesitate initially, the committee members had been seduced and soon devised a strategy that would lead to the construction of their own computer. The committee recommended that a national computing centre be established at the University of Toronto, to support all Canadian scientific research in need of large-scale computations; as part of this mandate, the centre would develop an electronic computer. The committee realized that the university could not afford to pay for such an enterprise, and applied for federal funding by presenting the computing centre in terms of national pride. If Canada lacked a computing centre and an electronic computer, important computational work might be sent to the United States or the United Kingdom.

This argument was apparently convincing enough for the National Research Council (NRC) and the Defence Research Board (DRB), for early in 1948 the two agencies agreed to co-fund the establishment of the Computation Centre at the University of Toronto. It is worth noting that there were no other candidates for such a program, and the grant was made in recognition of the strength of the applied mathematics program at Toronto and not because of any particular engineering prowess. Almost immediately, a small team of graduate students was hired to design and build a prototype

Figure 3: R. J. Johnston, Joseph Kates and Leonard Casciato with the UTEC computer. (Courtesy University of Toronto Archives, digital image no. 2001-77-169M; original item no. B2002-0003/001P-01)

computer as a test bed and practice run, prior to building a full-scale version. The two key members of this team were Joseph Kates and Alfred Ratz, who were recent University of Toronto graduates.[12] In the meantime, knowing that a viable computer might take years to complete, the Centre rented electromechanical calculating equipment from IBM to provide the computing service.

Serious planning began in the fall of 1948 for what would become known as the UTEC. That October, the team decided in favour of a parallel design, clearly influenced by the design of von Neumann's computer at the IAS. Kates and Ratz believed that this choice would lead to a fast machine and a simple design. Despite the obviously simpler nature of a serial design, a minority of early computer engineers perceived greater elegance in the parallel approach. Unfortunately, they failed to anticipate the many implementation difficulties. The other major decision concerning the UTEC was the type of storage and, as with the IAS computer, the UTEC was to be equipped with Williams tubes arranged in a parallel fashion. There is no doubt that this was an ambitious design, and considerably more so than that of most other university computing projects underway in the late 1940s. All three major British machines were serial, as were most U.S. designs.

After the design had been laid down, the team began to assemble a laboratory, and individual blocks were constructed through 1949. By March 1950, the arithmetic unit was complete, but much of the rest of the project was stalled; there were numerous delays with the storage tubes, and the input/output unit remained in the planning stages for months. However, by early 1951 most of the components had been tested and were awaiting final integration. A functional version had been assembled by October 1951, and the finished UTEC prototype used about 800 vacuum tubes. It was a binary, one-address computer, with twelve parallel Williams tubes providing a total of 512 twelve-bit words of storage. Each word could contain a signed eleven-bit number (about three decimal digits), or a three-bit instruction coupled with a nine-bit address. Input/output was handled with modified six-hole Flexowriter paper tape equipment. Physically, the computer was approximately six feet high, eight feet wide and one foot deep. By the time the hardware was ready, a library of multiple-word arithmetic subroutines was also available, but untested.

In the end, a full-scale version of the computer was never built. Not long after the prototype was assembled in the fall of 1951, the NRC suggested that the project be abandoned. Instead, it proposed that the university purchase a large-scale computer from Ferranti, a British company that was selling a properly engineered version of the Manchester Mark I. The logic was reasonable: for about the same amount of money as it would cost to build a full-scale UTEC, the Ferranti Mark I could be shipped across the Atlantic. More importantly, the Mark I could be installed in a matter of months, compared to the two to three years it would take to complete the UTEC. Given that the explicit purpose of the Computation Centre was to provide a national computing service, the NRC's offer proved difficult to refuse, though there were protests from the engineering group. Ultimately, in February 1952 the university agreed to purchase the Mark I, and virtually all work on the UTEC stopped. The new computer was quickly nicknamed Ferut ("Ferranti at the University of Toronto"), and it arrived in April 1952. Though the UTEC prototype was nominally operational by then, it was never used for any non-trivial computation.

Though it may be tempting, the UTEC project should not be perceived as a simple failure or as "an opportunity lost for Canada," as some have done.[13] The stated goal of the UTEC prototype was to provide necessary experience in advance of a full-scale model. Given the lack of consensus among other computer designers in the late 1940s, and the absence of strong electronics experience in Toronto, this was a prudent decision. Arguably, by 1951 the technology was more stable, and the electronics team was confident in its ability to build the final version. Unfortunately, this confidence did not translate into the construction of a reliable computer; it was said that combing your hair in the same room as the UTEC could destroy the contents of the poorly shielded electrostatic storage tubes. Yet, not all the blame can be laid at the door of the engineers. The project was hobbled by poor leadership and weak management by the NRC, the DRB and the University of Toronto, which all failed to supervise the novice engineering group adequately.

But should the UTEC be considered a lost opportunity for Canada? Probably not. There were a number of significant positive effects that flowed from its cancellation. The most important was that the University of Toronto got out of computer design and into computer applications much earlier than most other universities. Ferut was the second commercial computer to be delivered in the world, which gave the University of Toronto a jump-start on other schools. Many other universities with early hardware development programs were unable to convert their initial success into strong departments of computer science in the 1960s. If the UTEC had not been cancelled, it seems likely that energy would have been poured into hardware development at the university rather than programming, thus eliminating an important advantage. It must also be said that the UTEC prototype was unreliable and small, and its design was derivative rather than influential; a full-scale version would probably not have improved any of these features. It is difficult to see what opportunities could have been gained had it been built. Finally, two of the electronics team members—Kates and his assistant Leonard Casciato—founded one of Canada's first and most historically significant computing consulting companies, KCS Data Control (see section 3.3.5). The cancellation of the UTEC had left both of them jobless for a brief time, which led to the creation of KCS in 1955.

**Figure 4:** Ferut at the University of Toronto, with Calvin C. "Kelly" Gotlieb sitting at the main console. Visible are six (two large, four small) circular Williams tubes used to display current storage contents. (Courtesy University of Toronto Archives, digital image no. 2005-42-2MS; original item no. B2002-0003/001P-06)

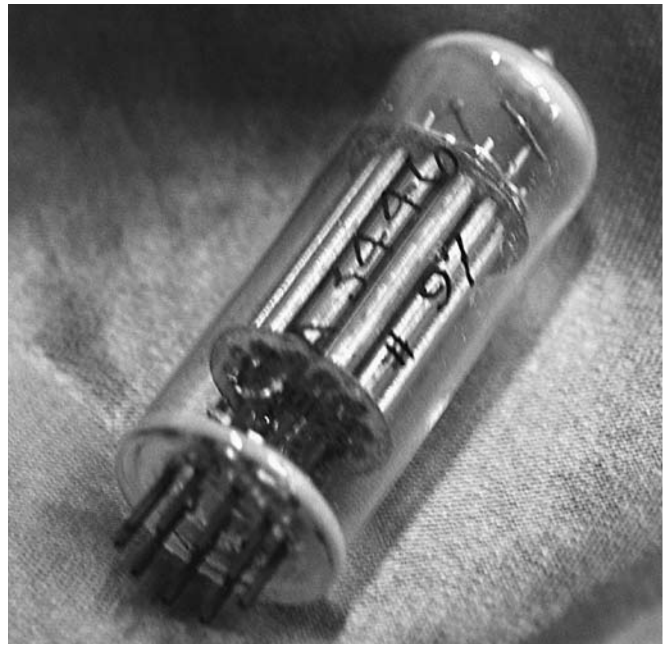


**Figure 5:** Joseph Kates's binary adder tube known as the Additron. (CSTM 1990.0221.001)

Kates himself was responsible for some of the delays related to the UTEC when he became distracted by two related projects that were, ultimately, non-essential to finishing the prototype. First, he attempted to devise a theory of electrostatic storage to better explain the operation of Williams tubes. The technology had been invented at Manchester in 1946 and several other groups had made important advances since then, but Kates hoped to make improvements based on his own theories. These efforts had mixed results, which contributed to the delays.

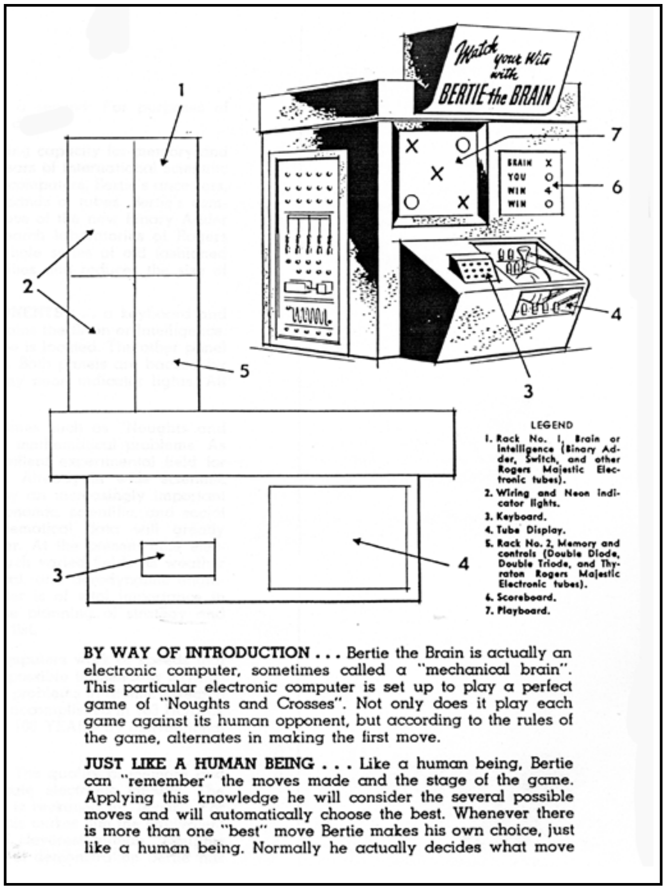



**Figure 6:** "Bertie the Brain," a Tic-Tac-Toe-playing computer that was installed at the CNE in 1950. (John Vardalas, The UTEC and Ferut at the University of Toronto Computation Centre, NMST CR 1986, Appendix 1. Original from a Rogers Majestic publication.)

Kates also devised, in co-operation with Rogers Electronic Tubes, a binary adder tube known as the Additron. Again, Kates's plan was to use the Additron with the full-scale UTEC, but various difficulties delayed matters. His Additron was only ever used in an early special-purpose computer. Rogers had hoped to produce large quantities of Additrons, and to publicize them Kates helped to design and build a Tic-Tac-Toe computer named "Bertie the Brain," which was installed at the Canadian National Exhibition (CNE) in 1950 and attracted large crowds.[14]

These were relatively trivial accomplishments, and on the whole the overall significance of the Computation Centre at the University of Toronto had little to do with the UTEC. When the Centre was established in 1948, there were several other computation projects launched as stop-gap measures until the computer was running. These included renting relatively sophisticated punch card calculators from IBM, hiring human computers to operate mechanical desktop calculators, and buying or building a large electromagnetic relay-based computer. The latter project never got off the ground, but the IBM calculators and the human computers proved far more capable than initially assumed. It was here that the Centre earned its reputation as a reliable, efficient and useful service, and it was on the basis of these strengths that the NRC and the DRB were convinced that Toronto would be the ideal host of the Ferranti Mark I.

Ultimately, the University of Toronto's experimental computer projects made it a Canadian pioneer in modern computing. The UTEC deserves recognition as the first modern computer in Canada, built by Canadians for Canadians, but we must also acknowledge that it was never used for non-trivial computations, and that virtually all electronics knowledge accumulated during its development dissipated soon after it was cancelled.

## 2.3 Special-purpose Computing

Computers can be classified as special-purpose or general-purpose, just as they can be categorized as analog or digital, mechanical or electronic, stored-program or not. Throughout most of the history of modern computing, there have been special-purpose models intended to operate on a limited class of problems, in contrast to general-purpose ones capable of solving, in principle, almost any numerical problem.

Special-purpose computing devices have never attracted as much attention as general-purpose ones, but the early decades of the twentieth century saw a growth in such dedicated devices: an integrator performed mathematical integrations; differential analyzers excelled at solving differential equations; a network analyzer was used to study problems of electrical power systems; and logic machines (both mechanical and electrical) could test logical syllogisms. Such specialization did not last long after the arrival of fast and flexible

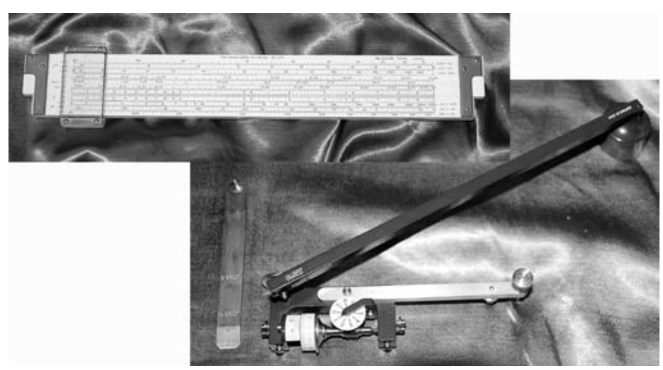


**Figure 7:** Two early special-purpose computing devices: a planimeter (lower right) and a slide rule. Both greatly simplified calculations, but were limited to certain kinds of work. (CSTM 1990.0219, CSTM 1995.0741)

general-purpose modern computer hardware, but for many applications it could be a much cheaper solution. One of the largest computer projects following the Second World War was Project Whirlwind. Built at MIT, it was originally envisioned as a special-purpose analog computer, which would provide a simulated instrument panel for training bomber crews. After the initial implementation was deemed too slow, the project shifted toward using digital electronics, which improved the speed and also led to a general-purpose system.[15]

In Canada in the late 1940s, there were two companies of note that tackled special-purpose computing projects: Ferranti Canada, a subsidiary of the United Kingdom's Ferranti Ltd., and the newly formed Computing Devices of Canada (ComDev). The Royal Canadian Navy (RCN) sponsored efforts by both companies to build special-purpose electronic digital computers, but neither was successful in the most direct sense. A prototype of Ferranti's system did work well during tests, but a full-scale version was never built. The ComDev computer project was also cancelled without having achieved its purpose. But success can be measured in other ways: both companies were able to parlay these early experiences into other projects well into the 1950s, when it must be said that Canadian computing truly got off the ground.

## **2.3.1** Ferranti Canada and DATAR

The Canadian military emerged from the Second World War with a great resolve to retain a sizable and skilled armed force that would be better prepared to enter future conflicts than it had been at the beginning of the war. Crucial to this plan were advanced scientific and technological knowledge and expertise, combined with effective partnerships between academic, industrial and military research branches. The DRB was created in 1947 to organize and oversee these efforts.

One outcome was that "in 1948 the Royal Canadian Navy turned to the still-unexplored world of digital electronics in an effort to assure itself of a sovereign and important role in the postwar era."[16] During the war, the RCN had acquired a remarkable degree of autonomy from the United States and the United Kingdom for all surface and anti-submarine patrols on the western half of the Atlantic. To maintain this military sovereignty, the RCN identified and sought to eliminate one of the greatest technical limitations it had suffered during the war: its inability to rapidly convey tactical information pertaining to the movement of Allied and enemy ships, aircraft and submarines. Research officer Lieutenant Jim Belyea proposed an information processing system known as DATAR (Digital Automated Tracking and Resolving), but the Canadian military lacked the experience or well-equipped laboratories necessary to develop his idea. It therefore turned to private industry in 1948 for potential partners for this and other similar projects.

One of the companies to respond was Ferranti Electric Ltd. of the United Kingdom, looking to enter the North American defence market. However, one of the DRB's stipulations was that such defence contracts had to involve Canadian facilities and personnel. Unfortunately, Ferranti's Canadian subsidiary, Ferranti Canada, had no research or electronics experience, and the parent company was not prepared to underwrite any research costs directly. However, Lt. Belyea was able to issue a number of relatively small contracts, capturing Ferranti's attention to the extent that it sent an engineer across the Atlantic to establish an electronics research and development (R&D) group at Ferranti Canada and commence work on DATAR. When the Cold War intensified and hostilities in Korea began in 1950, the RCN started increasing the size of its research contracts to the point that it spent over $1 900 000 between 1948 and 1953 to develop a DATAR prototype.

Despite the funding, progress on DATAR was not especially quick, though there were some important milestones. In February 1950, the research group successfully demonstrated pulse code modulation (PCM) transmissions of digital radar tracking data in an encoded form over long distances, and in 1951 Ferranti Canada was asked to build the special-purpose DATAR computer at the heart of the proposed system. It took

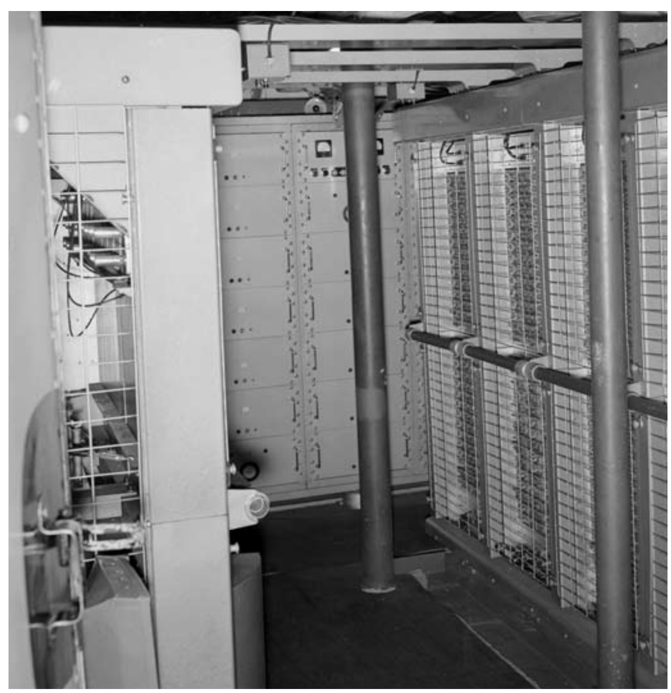


**Figure 8:** DATAR shipboard rack room, containing thousands of vacuum tubes. (Courtesy Archives of Ontario, Ferranti-Packard Collection, subseries F-4142-12-5-1, container RC5, image 186E)

the knowledge that the British Royal Navy was preparing to test a rival tracking system as early as 1953 to send the DATAR group into high gear. The RCN's worry was that, if the Royal Navy's system was able to establish a standard for digital tracking among the three major Atlantic navies, DATAR would sink and take with it the RCN's sovereignty.

The accelerated pace led to live DATAR demonstrations on Lake Ontario over the summer and fall of 1953, with two minesweepers and with a shore station simulating a third ship. The system used about 30 000 vacuum tubes and a magnetic drum storage system (Williams tubes being deemed too unreliable). Radar information, taking into account the relative position and motion of each station, was shared via PCM among the three ships and was displayed on sophisticated cathode ray tubes. Targets could be selected on the display tubes via a primitive trackball.[17] By all accounts, the demonstrations were very successful and the RCN was quite pleased. However, as was common at the time, the reliability of the vacuum tubes remained a significant concern for the project. On board, Ferranti Canada engineers, armed with bandoliers of tubes, jumped to replace each blown tube. As Vardalas explains, the complexity and failure rate of the tubes caused a bottleneck, delaying DATAR and crippling its potential.[18]

However, the ultimate success of DATAR depended on whether it could be sold to the U.S. Navy, which had not yet developed its own tracking system. The Royal Navy was already committed to its own, less flexible, analog design. If the United States could be persuaded to accept the DATAR communication protocol as the standard, even if not the entire DATAR system, the project would be a success and Ferranti Canada might profit from foreign sales. But if it rejected DATAR, the Canadians would almost certainly be forced to adopt whatever technology the Americans or British invented. Unfortunately, though the U.S. Navy appreciated DATAR's features—such as the decentralized nature of the communications network—in 1956 it established a $10 million crash program to develop its own tactical information system, which spelled the end for DATAR. Though there were limited attempts to integrate DATAR within the U.S. system, "after 7 years of daring pioneering work in real-time digital information processing, communication, and display, DATAR was abandoned."[19]

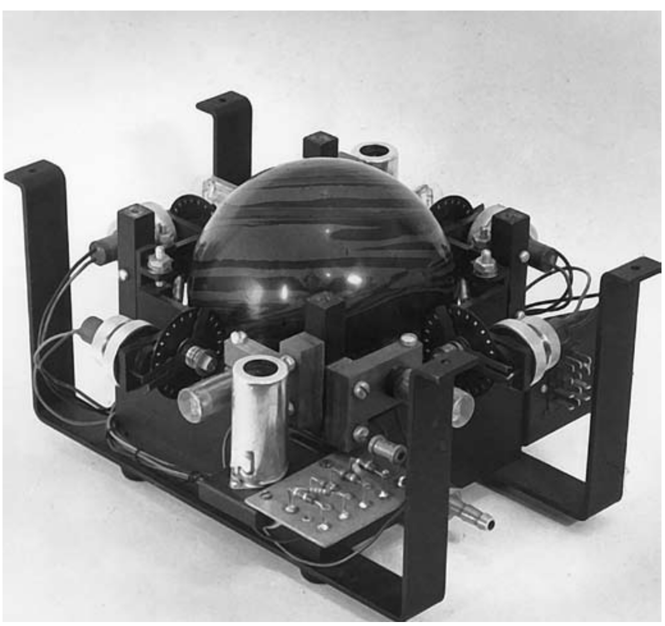


**Figure 9:** The trackball developed for DATAR by Fred Longstaff and Tom Cranston, ca 1953. At the centre is a Canadian-style five-pin bowling ball.

**Figure 10:** DATAR submarine display. (Courtesy Archives of Ontario, Ferranti-Packard Collection, subseries F-4142-12-5-1, container RC5, image 187E)

The Canadian military's enthusiasm for computing and electronics was also diminished in the wake of DATAR's demise. Ferranti Canada had two options: it could pursue the civilian computing market or it could dismantle the R&D group that had formed around DATAR. Most of the young engineers had not been imported from the parent company in England, but had been drawn from the pool of recent Canadian university graduates. They were anxious to explore other avenues of development, but it was not an easy issue for upper management to address. Ferranti Canada's traditional market was in electrical power: transformers or meters. To design and build another special- or general-purpose computer and enter the almost non-existent computer market in Canada in the mid-1950s would be a daunting challenge. But, as we will see, the company accepted the challenge and followed through with several further world firsts.

## 2.3.2 Computing Devices of Canada

ComDev was founded in 1948 in Ottawa by three partners: George Glinski, Joseph Spychalski and Peter Mahoney. Glinski and Spychalski were Polish émigrés, who had apparently known each other earlier at the University of Grenoble. In 1948, Glinski was an electrical engineer working at Northern Electric, and he has been portrayed as the technical wizard of the three; in 1956, he left ComDev to help found the University of Ottawa's Department of Electrical Engineering. Spychalski had been running an engineering firm in Toronto before joining the other two, and had more marketing know-how than his partners. He outlasted them at ComDev as well, retiring in 1966 after almost twenty years and having since changed his surname to Norton. Mahoney was an electronics hobbyist, who founded an electronic supply company and sold components to the government and the military around the end of the Second World War. He also financed ComDev and served as the first president, but he was bought out in the early 1950s. Together, the three created one of the most influential high-tech companies in the Ottawa region: many former employees of ComDev went on to establish or take key positions at other successful electronics companies, including Leigh Instruments, Digital Equipment Canada, DY 4 Systems, Prior Data Sciences Ltd., Gallium Software, Lumonics Inc., Gandalf Technologies Inc., Senstar Corporation, Norpak Corporation and NABU Manufacturing Corporation.[20]

Despite its celebrated influence, ComDev did not have an auspicious beginning. Its first project was, in one historian's words, "a Goldbergian naval strategy computer, which cost the taxpayers a fortune, and finally had to be junked."[21] Shortly after the war, the RCN sought to build a tactical electronic computer to simulate battles at sea for training sailors, but found the project beyond its own immediate capabilities. It contracted out a $4 000 feasibility study, which was awarded to Glinski, Spychalski and Mahoney. They formed ComDev to perform the work, opening a laboratory in an old grocery store next to a fireworks shop near downtown Ottawa. The first study led to a full contract to construct a Tactical Battle Simulator, and by 1949 ComDev had forty employees working on the trainer and had opened a new laboratory and office. Around this time, ComDev was also contracted to develop cathode ray tube display equipment for a DATAR experiment.[22] Since ComDev was already building the Tactical Battle Simulator, "it seemed only natural that the same company design the DATAR computer."[23] It was awarded $45 000 for a nine-month preliminary study, but the RCN grew fearful that the company could not handle both DATAR and the simulator, so DATAR was given wholly to Ferranti Canada. Little else is known about the simulator, except that it was cancelled in 1956, having never been used. During construction, it had outgrown three laboratories until it occupied a space of 1 020 $m^2$ and used about 8 000 vacuum tubes. For comparison, when the ENIAC was finished a decade earlier it was only about 170 $m^2$, but used nearly 18 000 tubes. One account suggests that the trainer could simulate about forty ships and aircraft simultaneously. From what must have been a long list of reasons for the cancellation, two have been cited: the arrival of transistorized computers in the second half of the 1950s, which marked the end of the use of vacuum tubes; and a building fire in Halifax that left the RCN without a home for the computer.

Fortunately, by the time the simulator project died ComDev had diversified into more successful ventures. First, it had begun to manufacture the Position Homing Indicator (PHI), a special-purpose aviation computer invented in 1952 by Parsons, Dunlop and Curran. The PHI was a homing device for fighter jets, and ComDev sold the devices in at least seventeen countries. Second, the company had become the distributor for several U.S. and British computer companies, selling and servicing foreign-built computer models across Canada, though this initiative is best taken up in the next chapter.

# 2.4 Conclusion

Though these stories of the late 1940s and early 1950s are relatively unknown and unappreciated today, Canadians were early and active participants in the modern computing era. Of course, the obscurity may have something to do with the relative lack of success of the ventures, but in all cases failure led to greater things.

The UTEC was exciting for those involved and deserves recognition as the first modern computer in Canada, but it was of no lasting value to Canadians in general or the university in particular. Aside from its cripplingly small capacity, it was not particularly reliable and was uninfluential in terms of design and theoretical developments; though it achieved its primary goal—to provide experience for the electronics team before it moved on to a full-scale machine—there was no follow-through. In such circumstances, the low profile of the UTEC among computer historians outside Canada is understandable. Yet, the Computation Centre did help to put the University of Toronto at the forefront of Canadian computing activity, mainly because of the mathematical work on the punch card calculators and the subsequent arrival of Ferut. Abandoning the UTEC and computer design in general gave the university the opportunity to be one of the first schools in the world to focus on computer applications, which gave it a significant advantage in years to come.

The military-sponsored special-purpose computing projects at Ferranti Canada and ComDev were also of middling success. The first example, DATAR, was a technological breakthrough, stunning in both ambition and implementation, but hampered by technological, financial and political limitations. Far less is known about ComDev's Tactical Battle Simulator project, but it too failed in 1956. Fortunately for both companies, they were each able to convert small initial contracts into millions of dollars of funding and to gather together a core of motivated and skilled engineers. By the time the RCN ended the companies' contracts, both already had other large projects underway in related fields.

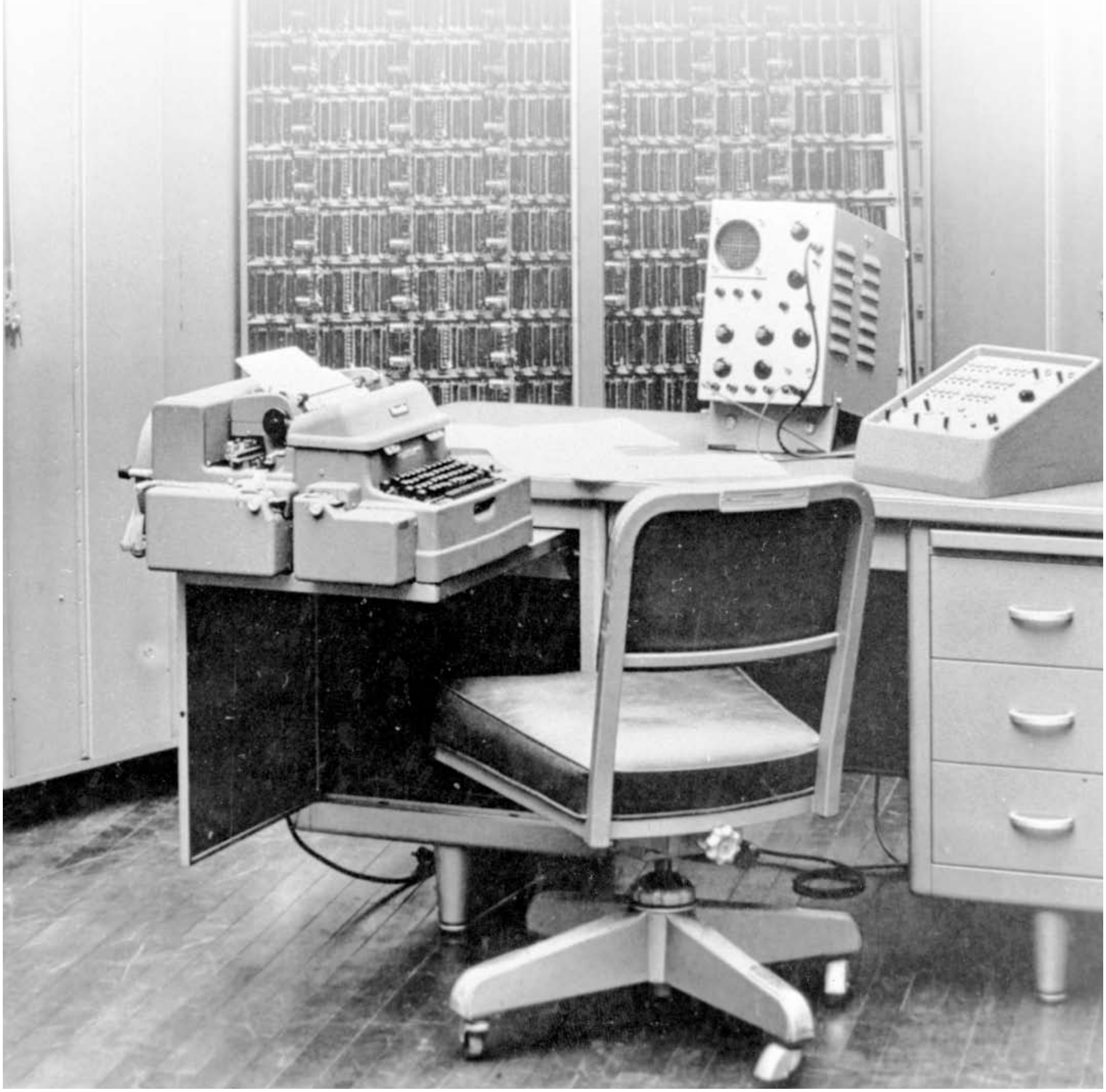
In summary, a small number of Canadians were anxious and quick to join the world of modern electronic computing in the only way possible—by building their own machines. These efforts had a limited immediate effect outside their own R&D groups, and most Canadians would have to wait until the mid-1950s before they could enter the first era of modern computing.

# Notes

1. *The Oxford English Dictionary*, 2nd ed. (Oxford: Oxford University Press, 1989).
2. There are many valuable sources dealing with the early history of computing technology. See Michael R. Williams, *A History of Computing Technology*, 2nd ed. (Los Alamitos, CA: Computer Society Press, 1997); Raúl Rojas and Ulf Hashagen, eds., *The First Computers: History and Architectures* (Cambridge, MA: MIT Press, 2000); Martin Campbell-Kelly and William Aspray, *Computer: A History of the Information Machine* (New York: Basic Books, 1996); and Brian Randell, ed., *The Origins of Digital Computers*, 3rd ed. (Berlin: Springer-Verlag, 1982).
3. John von Neumann, *First Draft of a Report on the EDVAC* (Philadelphia, PA: Moore School of Electrical Engineering, University of Pennsylvania, 30 June 1945).
4. David Alan Grier, "From the Editor's Desk," *Annals of the History of Computing* 26, no. 3 (July–September 2004): 2–3.
5. John V. Atanasoff's and Clifford Berry's 1943 computer, the ABC, at the University of Utah, and T. Flower's 1943 Colossus built in England both predate the ENIAC as electronic computers, but for reasons of obscurity and national security were not nearly as influential. That said, some ideas developed by Atanasoff and Berry for the ABC may have been appropriated for the ENIAC. However, it was the improvements made to the ENIAC that truly paved the way for modern computing.
6. Michael R. Williams, "A Preview of Things to Come: Some Remarks on the First Generation of Computers," in Rojas and Hashagen, eds., *The First Computers*, 4.
7. Nancy Stern, "The Eckert-Mauchly Computers: Conceptual Triumphs, Commercial Tribulations," *Technology and Culture* 23, no. 4 (October 1982): 575.
8. George R. Stibitz, "Introduction to the Course on Electronic Digital Computers," in Martin Campbell-Kelly and Michael R. Williams, eds., *The Moore School Lectures: Theory and Techniques for Design of Electronic Digital Computers* (Cambridge, MA/Los Angeles: MIT Press/Tomash Publishers, 1985), 5–16.
9. Larry Owens, "Where Are We Going, Phil Morse?: Changing Agendas and the Rhetoric of Obviousness in the Transformation of Computing at MIT, 1939–1957," *Annals of the History of Computing* 18, no. 4 (1996): 36.
10. Scott M. Campbell, "The Premise of Computer Science: Establishing Modern Computing at the University of Toronto (1945–1964)" (Ph.D. thesis, Institute for the History and Philosophy of Science and Technology, University of Toronto, 2006).
11. Specifically, the tour took them to the following: the Naval Research Laboratories; the Pentagon; the Moore School of Electrical Engineering, where the ENIAC and the EDVAC were designed and built; the Aberdeen Proving Grounds; Eckert's and Mauchly's fledgling company in Philadelphia, hard at work on a commercial computer; Bell Laboratories, home of a series of electromagnetic telephone relay calculators; IBM; the Harvard Mark I; and the Massachusetts Institute of Technology (MIT) to see the differential analyzers. See Byron A. Griffith, "My Early Days in Toronto," *Annals of the History of Computing* 16, no. 2 (1994): 55–64.
12. Both would eventually earn doctoral degrees in the process of completing the UTEC prototype: Joseph Kates, "Space Charge Effects in Cathode-Ray Storage Tubes" (Ph.D. thesis, University of Toronto, 1951); and Alfred G. Ratz, "The Design of the Arithmetic Unit of an Electronic Digital Computer" (Ph.D. thesis, University of Toronto, 1951).
13. Beverley J. Bleackley and Jean La Prairie, *Entering the Computer Age: The Computer Industry in Canada: The First Thirty Years* (Agincourt, ON: The Book Society of Canada, 1982), 10.
14. According to Kates, Danny Kaye was one of the headliners at the CNE that year and visited Bertie, but was unable to defeat it. Henry S. Tropp, Interview with Joseph Kates, Computer Oral History Collection, edited transcript of tape recording (29 June 1971), Archives Center, National Museum of American History.
15. Kent C. Redmond and Thomas Malcolm Smith, *Project Whirlwind: The History of a Pioneer Computer* (Bedford, MA: Digital Press, 1980).
16. John N. Vardalas, *The Computer Revolution in Canada: Building National Technological Competence* (Cambridge, MA: MIT Press, 2001), 46. Historian John Vardalas has done an excellent job of analyzing the history of Ferranti Canada and the role of the RCN in jump-starting electronics research in Canada. This text can only offer a summary; interested readers should consult his work directly for additional details. See also Norman R. Ball and John N. Vardalas, *Ferranti-Packard: Pioneers in Canadian Electrical Manufacturing* (Montreal, QC: McGill–Queen's University Press, 1994); and John N. Vardalas, "From DATAR to the FP-6000: Technological Change in a Canadian Context," *Annals of the History of Computing* 16, no. 2 (Summer 1994): 20–30.
17. A trackball is like an inverted mouse. Instead of a device that is physically moved across a surface to control a pointer on a computer screen, a rotatable ball is held in a stationary housing; rotation of the ball in any direction corresponds to the movement of the pointer on a computer screen. The DATAR prototype used a Canadian-style five-pin bowling ball.
18. Vardalas, *The Computer Revolution in Canada*, 69–70.
19. Ibid., 74.
20. A complete history of ComDev does not yet exist. A few newspaper articles and anecdotes are all that is easily available. See Kathryn May, "'Granddad' of High-Tech: Computing Devices Thriving at Age 40," *Ottawa Citizen* (1 November 1988): B1; Marlene Orton, "A Host of Firsts: Computing Devices: The Year Was 1948 and Its Three Founders Launched Canada into the High-Tech Arena," *Ottawa Citizen* (5 October 1999): E9; and Karyn Standen, "High Tech Turns 50: Ottawa's First Techies Arrived from Poland a Half-Century Ago and Created Computing Devices," *Ottawa Citizen* (6 April 1998): C1.
21. J. J. Brown, *Ideas in Exile: A History of Canadian Invention* (Toronto, ON: McClelland and Stewart, 1967), 93.
22. Vardalas, *The Computer Revolution in Canada*, 58.
23. Ibid., 60.

**CHAPTER THREE**

# THE GROWTH OF COMPUTING IN CANADA



# 3 The Growth of Computing in Canada

## 3.1 Introduction

Several prominent figures from the mid-twentieth century are said to have stated that the world would only ever need five or six computers. One of them was Thomas J. Watson Sr. (1874–1956), president of IBM from 1915 (when it was still known as Computing-Tabulating-Recording Company, or CTR) to his death in 1956. He is alleged to have made the comment in 1943. Another was Howard Aiken (1889–1973), mathematician and inventor of the 1944 Harvard Mark I, one of the first large-scale electromechanical calculators. A third was Douglas Hartree (1897–1958), British mathematician and strong advocate of modern computing in England and North America post-Second World War.[1] Not surprisingly, there is considerable doubt that any of these extremely well-informed individuals did actually express any such idea about a top-end of half a dozen computers. If they did, their remarks must certainly have been taken out of context.[2]

And yet, in the 1940s, accurately assessing the potential and future need of large-scale computers was not a straightforward matter. Few people anticipated these expensive machines would have much use beyond advanced scientific computing. No commercial market existed for them, only a handful of organizations could identify a need for large-scale computers and, more importantly, few groups could conjure half a million dollars or more to build one.

Much of this changed in the 1950s and early 1960s. Though there was a brief period when there were only five or six computers in the world, by the early 1960s there were thousands of them. The million-dollar machines from IBM and UNIVAC gave way to dozens of different kinds of smaller and less expensive computers. In part, this change was driven by technological developments. Though for computer logic, vacuum tubes still dominated, advances in magnetic cores and drums allowed cheap and reliable storage.

Transistorized computer logic was, however, on the horizon, replacing vacuum tubes in experimental machines in the second half of the 1950s and in expensive commercial computers toward the end of the decade and into the 1960s. As more computers became available, new uses for them were discovered that went beyond the original one of rapid scientific calculation. By the end of the 1960s, data processing and real-time data analysis or control were common uses for almost every kind of computer, from the largest, most complex and expensive mainframes to the smallest, least sophisticated and inexpensive systems. Nonetheless, computer companies had recognized that different users preferred different operating characteristics—data processing generally required good alphanumeric capabilities while floating-point arithmetic was valuable to scientists—and so many vendors offered at least two lines of semi-specialized machines, leading to a great diversity of computers.

In Canada, there were approximately thirty to thirty-five general-purpose modern computers installed (rented or owned) or on order by 1960, and within another ten years there were nearly 2 000. During the 1950s, though there was no domestic computer industry to speak of, a handful of organizations had continued building their own special and general-purpose computers. This practice would come to an end in the early 1960s, until microprocessors revitalized the industry in the early 1970s, as described in the following chapter. The biggest change for Canadian computing occurred in the middle of the 1950s, when computer companies in other countries began to sell their products in earnest through Canadian subsidiaries, or engaged Canadian companies as agents and distributors to handle sales and service. The use of computers expanded considerably at this point, following the initial excitement of the University of Toronto's Ferut in 1952. By the 1960s, financial organizations, government offices, manufacturers, distributors, utility companies and the military had all joined the modern computer era. This chapter summarizes computing activity in Canada up to that point, and hints at what was to follow.

### 3.1.1 The Royal Commission

An important report written in 1955 gives us an overview of computing expectations in Canada in this early period. That year the Computation Centre at the University of Toronto was invited to contribute a submission to the Royal Commission on Canada's Economic Prospects, otherwise known as the Gordon Commission (named after its chairman Walter Gordon). The University of Toronto's earlier success (described in sections 3.3.1 and 3.3.6) had attracted the attention of the Commission, the theme of which was economic nationalism and levels of foreign investment and control over Canadian resources and businesses.

The Computation Centre's report to the Commission addressed "possible general effects on the national economy due to the rapid deployment of electronic computing devices."[3] Foremost was the observation that few people in

Canada had directed significant attention toward the potential roles and effects of computers, suggesting that Canadians were about five years behind Americans when it came to modern computer use. To that end, the report examined five areas relevant to modern computer usage: clerical work, economic planning, engineering research, scientific research and industrial production. In summary, the report stated that, in areas where mechanized calculation or automation had already proved useful, electronic computers could be expected to accelerate these effects, improving productivity in many sectors, easing scientific research and helping to optimize industrial production. However, to accomplish this Canada would need a cohort of young men and women well-educated in the ways of modern computing, to further the field through research, and to teach existing and future students.

Coming from an institute of higher learning, these conclusions were somewhat self-serving. However, between the lines the report hinted at the likely future of computing in Canada, making it clear that any successful exploitation of computer technology would necessarily be at the hands of its users, that is, accountants, scientists and applied mathematicians, rather than designers or electronic engineers seeking to build or manufacture computers. As the following examples show, virtually all attempts to establish a domestic computer manufacturing industry in Canada in the 1950s and 1960s met with failure. At the same time, Canadian expertise in computing applications and services was growing considerably.

## 3.2 The Builders

There were several groups building computers in Canada in the 1950s, including various military and government agencies and private corporations. For such groups, the most significant technological change related to computer design was the shift away from tubes toward semiconductors and solid state components. Though very few transistorized computers were sold in that decade (only a handful were available prior to 1960), there was a great deal of experimentation and most groups building computers were actively seeking replacements for vacuum tubes or developing entirely new designs.

### 3.2.1 Computing Devices of Canada and AECL

In the 1950s Computing Devices of Canada (ComDev), under contract to the Chalk River laboratories of Atomic Energy of Canada Limited (AECL), built a special-purpose computing system known as a “Kicksorter.” This was a twelve-bit core memory machine designed to assist with electronic pulse height analysis. Anecdotal evidence suggests that the Kicksorter was close to being a general-purpose computer, and was similar in size and scope to a minicomputer. Large numbers of these systems were built for AECL between 1957 and 1963, when they were replaced by minicomputers from Digital Equipment Corporation (DEC).[4]

As an interesting aside, DEC is famous as a progenitor of the minicomputer. This new style of computer was less complex, smaller and cheaper than a large-scale mainframe. DEC’s first model, the PDP-1, was introduced in 1960, and AECL was one of the company’s first customers when it purchased a system for additional pulse height analysis. AECL’s close relationship with DEC led to it having a direct influence on the development of a later model, the PDP-5.[5] This machine was the immediate precursor to the PDP-8,

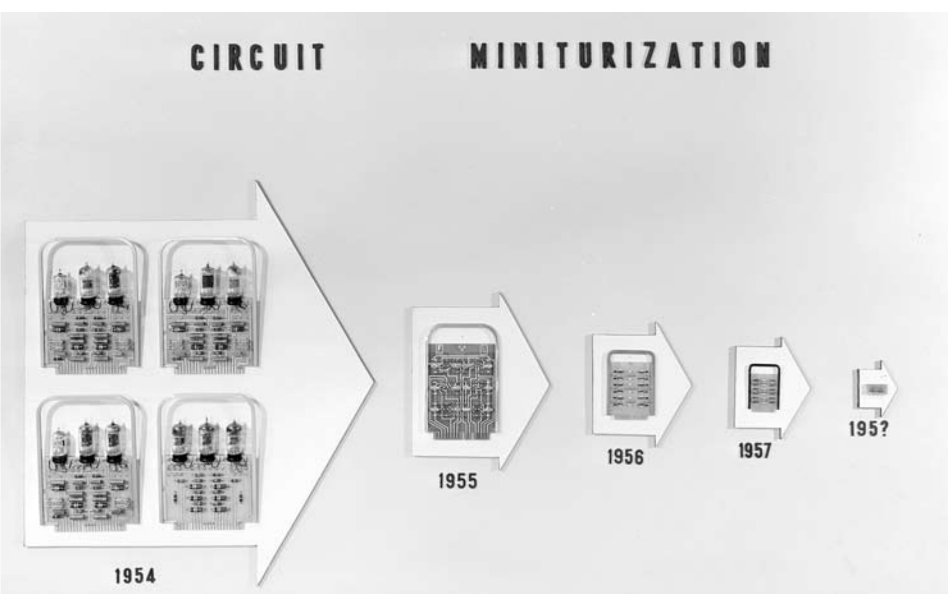



**Figure 11:** Ferranti circuit display, anticipating a modular future without tubes and continued miniaturization. (Courtesy Archives of Ontario, Ferranti-Packard Collection, subseries F-4142-12-5-1, container A-1081, image 1316)

which was the first widely successful minicomputer and, to some, the archetype for this class of computers. It is tempting to ruminate on the possible scope of Canadian influence with regard to the PDP-8, but little is known on the subject.

## **3.2.2** The DRTE Computer

The Defence Research Board (DRB), through the Defence Research Telecommunications Establishment (DRTE), built its own general-purpose transistorized computer, known as the DRTE computer, in the late 1950s and early 1960s.[6]

Technically, the DRTE computer did not run until the very early 1960s, but its genesis can be found in the early 1950s. At that time, the DRTE was created "to help establish technological control (through improved communications) over the vast, sparsely populated and strategically crucial Canadian North."[7] Three main divisions—a Radio Physics Laboratory (RPL), an Electronics Laboratory (EL) and a Communications Laboratory (CL)—were created under the DRTE's mandate. One of the EL's goals was to give Canadians the opportunity to design and construct circuitry driven by solid state transistors, which were a recent invention. An unexpected outcome of that opportunity was the first general-purpose transistorized computer built and designed in Canada: the DRTE computer, known informally as "Dirty Gertie." Interestingly, the computer was not even EL's largest project in the 1950s: that honour goes to a Doppler navigation radar for the CF-105 Avro Arrow.[8]

The origins of the DRTE computer can be traced to the invention of a new and advanced type of transistorized flip-flop circuit invented by Norman Moody, head of the EL.[9] Moody already had considerable experience with this kind of circuit, having used it in counting circuits for nuclear instrumentation while working at the Electrical Branch at the AECL's Chalk River laboratories. While he was experimenting with a transistorized version at DRTE's EL, it was suggested that designing and building a computer would provide a means of testing the complicated flip-flop circuitry and assessing its reliability. A reliable arithmetic unit was built in 1957 and a full-scale version, which took about two years to design, was finished in late 1960. It employed a forty-bit, three-address word referring to a core memory of 1 024 words. A simplified order code provided twenty instructions, while an expanded and more powerful order code added instructions for more experienced programmers. The floating-point arithmetic unit included a square-root function, which was highly unusual but was justified as an interesting design challenge, satisfying the overall goal of improving the EL group's understanding of semiconductor circuits, and increasing the speed of computations. The core memory design was innovative, but relatively unique; it was only ever used on the DRTE computer and a derivative special-purpose device known as a Digital Analyzer and Recorder (DAR).[10] Input and output was handled with a rather prosaic Flexowriter paper tape unit.


**Figure 12:** DRTE computer. (CSTM 1966.0193.001)

In addition to fulfilling the goal of providing experience with circuits, the computer was used by DRTE and DRB staff for scientific computations until 1966, when it was decommissioned and replaced by a machine sold commercially. The DRTE computer is known to have been used for power calculations and tracking equations related to the flight of the Allouette I satellite in the early 1960s. Speculation exists that it was also used directly or indirectly for code-breaking or encryption by a top secret Canadian agency, though this is almost entirely a matter of conjecture.

The following is an "Ode to Gertie." The original author is unknown, although the poem was found in the files of George Lake, a Dirty Gertie engineer. The verses aptly recount the history of the machine.

One winter's night in fifty-eight
The research board was sitting late
They'd dealt with matters grave and serious
In ways that were a bit imperious
For round their chairs, up to their hips
Were torn up pink promotion slips.
The junior member had the task
Of serving whiskey from a flask.
And also cleaning up the room,
A prospect that he viewed with gloom.
For it involved keeping the score
Of all the slips upon the floor.
"I wish" said he, with sudden heat,
"That all of you would lift your feet.
It's difficult to make a list
When someone's standing on your wrist.
We really should have a machine
To keep the record straight, I mean."

This chance remark caused them to think,
And after all had had a drink
The chairman said, "I like the scheme.
In fact I think we need a team
Of scientists to do this chore
I'm sure we could get by with four."
"The sort of thing that I propose,"
He said whilst scratching at his nose,
"Would add, subtract, perhaps collate.
Of course it should be solid state.
And could include that priceless gem,
The circuit called P N P N.
"I know the chap to head the thing
An emigrant from Bristol ENG.
Whom we have lured to old EL.
In fact there's many more as well
Rot in the lab in dark despair.
They can't go home without the fare.
We'll use them all and others too.
Twill give them something else to do
'Sides sitting round cursing their fate.
There must be some can calculate
In floating point and excess six,
And similar computational tricks.
Thus a computing team was born.
In pain and travail and the scorn
Of other groups, who said of them
"They can't compete with IBM."
And self-styled wits inferred with caution,
"It's not a birth but an abortion."
Breakthroughs were made with verve and dash,
Despite the chronic lack of cash.
A register quite versatile
Constructed with infinite guile,
Would shift both left and right and do
A count by any power of two.
The ANDs and ORs were hard to grasp.
The adder was a vicious asp.
Addends and augends by the score
Were trampled in the work room floor.
And one poor soul went round the bend
Trying to dance a minuend.
Although one chap, the memory man;
Fled quickly to Saskatchewan.
Leaving behind a wiring scheme
That almost caused the rest to scream.
They buckled to and made it store
Ten two four words, magnetic core.
Another rather cunning knave,
Did secretly set out to save
His fare to England home and beauty,
Neglecting all the calls of duty.
And one night boarded a liner
Complete with wife and Morris Minor
A new recruit(4) filled up the gap.
A bluff and hearty jovial chap.
Whose hearty laugh and dainty tread
'Twas said would wake the very dead.
He built a unit that could spout,
Converted numbers in and out.
Despite the jeers and slights and sneers,
The work progressed for three whole years.
Until one day in sixty one
When finally the job was done.
And there before the scoffer's eyes
Was a computer, medium size.
Now that austerity's in force,
This great machine has run its course.
No longer needed by the board,
To count promotions and record
The increments given annually
To those who work at DRB.
Instead it can play Tick Tack Toe
Or Colonel Bogie, tremolo.
And will a birthday list compile,
For anyone who'll stay a while.
And as for those who come to gape.
It punches names in paper tape.

## 3.2.3 The NRC Computer

The National Research Council (NRC) was behind the development of another electronic digital computer—a special-purpose machine—from 1954 to 1961. Design and construction was carried out by the Defence Research Section (DRS) of NRC's Radio and Electrical Engineering division.[11]

Like the DRTE computer, the NRC computer was transistorized, although it was initially conceived of as an analog electronic machine. The NRC computer also had a special purpose: to provide real-time sound-range processing in the field, under military ruggedized conditions. Unfortunately for the DRS development group, funds and staffing resources were limited, and these conditions played a determining role in the design and implementation of the computer. Its unusual memory arrangement, which physically separated data storage and program storage, was an apparent step back from the advantages provided by the combined approach of the "von Neumann architecture."[12] However, this design decision was made for military and financial reasons: to help protect a program from being accidentally erased in the field, and to optimize the use of expensive storage technologies. The designers employed NOR gate circuit logic for the entire computer, which was atypical, but it provided important engineering, development and cost advantages that were crucial given the limited financial and staffing resources. A final note concerns the asynchronous design—an extremely

**Figure 13:** NRC computer. (CSTM 1979.0912.001)

rare choice at the time—which was chosen to increase speed, but would also allow the design to remain independent when expected improvements were made to transistor technology. The NOR circuitry was assembled in modules in such a way that it would be able to accommodate faster transistors at later stages of development or deployment.

The NRC computer proved successful in field tests, but the Canadian military failed to make use of the computer and, instead, awarded ComDev a contract to build a different computer for sound-ranging processing. This rendered the DRS model largely irrelevant and forced the group to abandon computer design; it moved instead to study computer-assisted learning, using a DEC PDP-8 minicomputer to interface with the NRC computer. Though, in principle, the design of the special-purpose NRC computer could have been adapted for other projects or upgraded, it was doomed by the widespread commercial availability of far less expensive, transistorized minicomputers in the mid- and late 1960s.

## **3.2.4** Ferranti Canada

The history of Ferranti Canada is relatively well-known and documented in a handful of books and articles.[13] As noted in section 2.3.1, when the DATAR project collapsed Ferranti Canada was left with a band of eager young electronics engineers who were anxious to continue developing electronic digital computers. In the 1950s they succeeded, for the most part, in applying their knowledge and experience toward this goal. But despite the fact that their work was technically innovative and exciting, commercial success was often elusive.

Ferranti's first major project, in 1955, was its construction of a prototype computerized mail-sorting system—the first in the world—for Canada Post. The transistorized system made use of the real-time processing know-how of Ferranti's engineers; it could sort 37 000 letters per hour via an optical bar-code scanner. Though the experiment attracted considerable attention from outside Canada (the first computerized mail-sorting system in the United States was not operating until 1960), political interference led to its collapse in 1957. The federal Liberal government was defeated that year, and the Conservatives who came to power chose not to build a million-dollar full-scale model.

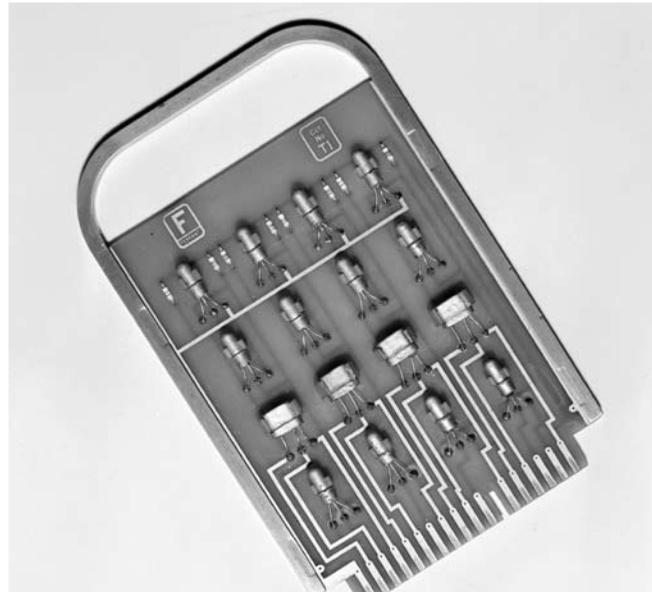


**Figure 14:** Mail-sorting computer, transistor board, 1955. (Courtesy Archives of Ontario, Ferranti-Packard Collection, subseries F-4142-12-5-1, container A-1080, image 1093)

Ferranti Canada's next major project was another world first: a computerized airline reservation system it produced for Trans-Canada Air Lines (TCA).[14] TCA had been running reservation simulations and tests on the Ferut as early as 1953, and again in 1957. That year Ferranti was awarded a contract to build six prototype reservation terminals, known as transactors.

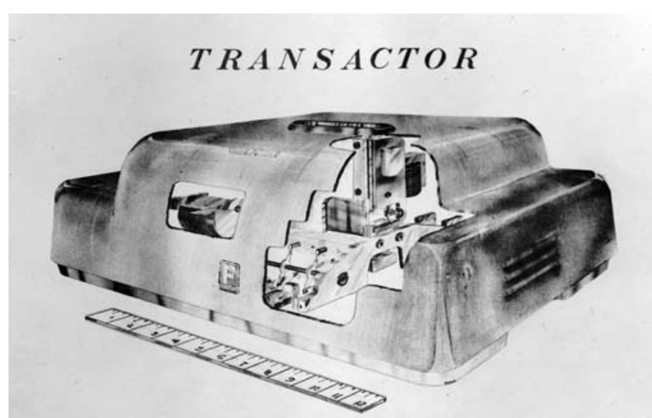



**Figure 15:** Transactor for the ReserVec system, 1956. (Courtesy Archives of Ontario, Ferranti-Packard Collection, subseries F-4142-12-5-1, container A-1081, image 1320)

**Figure 16:** Trans-Canada Air Lines booth at the 1958 CNE, demonstrating the interface to the ReserVec system. (Courtesy Archives of Ontario, Ferranti-Packard Collection, subseries F-4142-12-5-1, container RC5, image 168E-2)

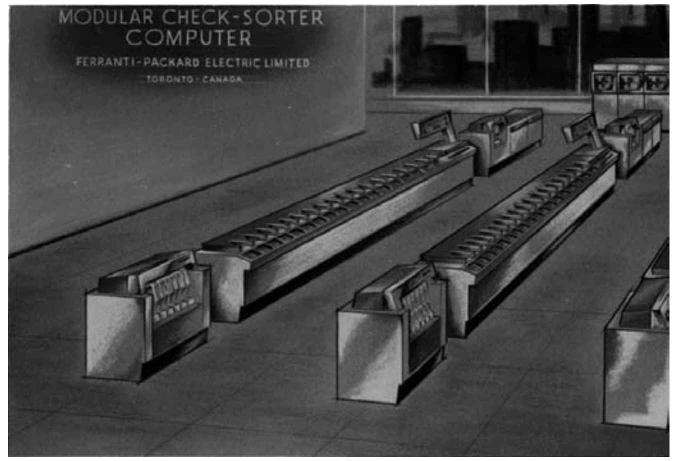



**Figure 17:** Ferranti cheque-sorting computer. (Courtesy Archives of Ontario, Ferranti-Packard Collection, subseries F-4142-12-5-1, container RC6, image 551E)

**Figure 18:** Installation of FRB computer in New York City. (Courtesy Archives of Ontario, Ferranti-Packard Collection, subseries F-4142-12-5-1, container RC6, image 680E)

Successful tests of the transactors led to Ferranti's $2 million contract to build a full-scale reservation system, consisting of some 350 transactors and a centralized real-time computer known as the Gemini, which would be linked by standard teletype lines. The entire system was known as ReserVec. Interestingly, Gemini consisted of two individual computers, with shared storage, running in parallel.

When ReserVec was fully operational in January 1963, TCA sales agents across Canada used transactors and special punch cards to query seat availability or make a reservation; response time was one to two seconds, and the system could handle more than 60 000 transactions per day. At around the same time, American Airlines and IBM collaborated in constructing the SABRE reservation system. SABRE was considerably more expensive than ReserVec, as it was built around two costly IBM 7090 mainframes, and when it was finally operational in 1964, SABRE could handle only a third of ReserVec's volume of transactions.

Unfortunately, Ferranti Canada was unable to sell the system to any other airline. IBM (and, to a lesser extent, UNIVAC) had locked up the U.S. market and Ferranti U.K. preferred to develop its own system for its market. However, these contractual projects and special-purpose computers sustained the Ferranti Canada development group until it moved into general-purpose computing in the 1960s with the FP-6000.[15]

The FP-6000 has many roots, but it can be traced in particular to a special-purpose cheque-sorting computer designed and built by Ferranti Canada and installed in 1958 at New York's Federal Reserve Bank (FRB). Building on its mail-sorting experience, the company used Magnetic Ink Character Recognition (MICR) to scan and sort cheques in this new system. When the FRB sought a replacement in 1961, Ferranti

**Figure 19:** FP-6000, ca 1962. (Courtesy Archives of Ontario, Ferranti-Packard Collection, subseries F-4142-12-5-1, container RC6, image 821E)

**Figure 20:** FP-6000 with peripherals, ca 1962. (Courtesy Archives of Ontario, Ferranti-Packard Collection, subseries F-4142-12-5-1, container RC6, image 979-12C)

Canada's electronics group, recognizing that the special-purpose computing business was too weak, proposed a new general-purpose computer that could handle both cheque-sorting and the bank's general data processing needs.

This computer was known as the FP-6000. Its design was based largely on the Gemini's transistorized logic. It offered the advantage of multi-programming (the ability to run two or more programs simultaneously) at a much cheaper price than IBM's products. It was, by all accounts, a technically brilliant computer, but Ferranti Canada's lack of a strong sales and maintenance organization led to the death of the FP-6000 in a marketplace dominated by the more efficient and effective sales forces of IBM and "the seven dwarfs" (Burroughs, UNIVAC, NCR, Control Data Corporation, Honeywell, RCA, and General Electric).

Only a handful of FP-6000s were ever built and sold, but a few Canadian organizations took it upon themselves to "buy Canadian." Aside from New York's FRB, purchasers included the Defence Research Establishment Atlantic in Dartmouth, Nova Scotia, the Toronto Stock Exchange and the Saskatchewan Power Corporation.

A worse blow came in 1963, when the parent company, Ferranti U.K., decided to sell off all its non-military computer assets to a competitor, International Computers and Tabulators Limited (ICT). The assets included the FP-6000 and ICT, recognizing its strengths, based its new 1900 and 2900 series of computers on the original design. Backed by a larger and more effective organization, ICT's versions met with spectacular success in Europe.

The sale of the FP-6000 saw the end of nearly a decade-and-a-half of computer development by Ferranti Canada. Though

**Figure 21:** Santa delivers an FP-6000. (Courtesy Archives of Ontario, Ferranti-Packard Collection, subseries F-4142-12-5-1, container RC6, image 780-2C)

**Figure 22:** Saskatchewan Power Corporation was one of the few customers to buy an FP-6000, ca 1965. (Courtesy Archives of Ontario, Ferranti-Packard Collection, subseries F-4142-12-5-1, container RC7, image 1180-5)

this has been portrayed as a crushing defeat for an inventive group of young engineers, it should be noted that many members of Ferranti Canada's development groups went on to found important computing, electronics, communications and computer services companies in Canada. One such company, I. P. Sharpe Associates, became one of the most significant companies in the field during the 1970s. The history of I. P. Sharpe is an important one, but has not yet been told.

## 3.2.5 The University of Toronto and the ILLIAC II

As discussed in the previous chapter, the arrival of the Ferut at the University of Toronto in 1952 led directly to the cancellation of the UTEC. At the time the UTEC was cancelled, the DRB had encouraged a limited amount of research and development (R&D) to continue, but few of the engineers involved wanted to work on a balkanized version of their project. Of the two individuals most directly involved, Alfred Ratz left for private industry almost immediately, while his partner Joseph Kates remained at Toronto for a limited time before he too left to pursue an entrepreneurial rather than academic career. And yet, at the university, ambitions to build a computer were attenuated only temporarily.

In the mid-1950s, when the Ferut was beginning to show its age, Computation Centre staff began looking for a replacement, and an interest in building a computer rather than buying one was rekindled.[16] This time, the plan was to piggyback on the efforts of a more successful first-generation development group at the University of Illinois, which was now moving toward a transistorized future. The ILLIAC was a computer built at the University of Illinois in 1952 and modelled directly on John von Neumann's IAS computer, but, by 1955, plans were afoot to build a successor known as the ILLIAC II. This was to be a high-speed, solid state transistorized machine—one of the fastest computers in the world. The Computation Centre's plan was to assist with the R&D at Illinois by sending professors and students for limited research terms; once the ILLIAC II was fully operational in the late 1950s, a clone would be built in Toronto. This was not an inexpensive plan: even if it could forego most of the development costs, a copy of the ILLIAC II would still cost the university around $1 million, which it did not have. A plan was launched to try to justify the expense to the DRB and NRC, in the hope that they would help pay to have the supercomputer built for the University of Toronto.

But the plan had its complications. Although the phrase "computer science" did not yet exist, the director of the Computation Centre proposed a new graduate department be dedicated to the study and use of high-speed computing machinery. This new department could, in his mind, easily justify a million-dollar computer. Without the computer, he argued, the new department would never be able to compete internationally with other universities considering similar expansion. It was a somewhat specious proposal, since the first

ILLIAC II was not yet complete, but it helped convince the DRB and NRC to provide continued, if minimal, financial support until a final decision on funding could be made.

Unfortunately, progress at Illinois was slow, and the project ran behind time and over budget. By 1960, it was clear that a copy of the ILLIAC II in Toronto would cost at least $1.2 million and would take much longer than had been anticipated. The Ferut had already been replaced by an IBM 650 in 1958, but this was a marginal improvement and a shamefully common computer for what was the oldest computing centre in the country. Toronto was desperate to acquire a more prestigious system and so, rather than forge ahead on the ILLIAC II project, it chose to install an IBM 7090, (Toronto later upgraded its set-uip to an IBM 7094-II). Even though it was the most powerful computer in Canada, it was not the supercomputer Toronto had hoped for. Illinois did eventually finish the ILLIAC II, but this was the "last gasp" for university-designed large computers, as the economics of developing hardware no longer favoured small research organizations. Not until microcomputing technology arrived a decade or so later could universities and academics return to designing their own computers.

The arrival of the IBM 7090 was matched by the creation of the Institute of Computer Science in 1962, which both replaced the Computation Centre and—academically—opened a number of doors. For the first time, graduate students in Canada could obtain recognition and direct supervision for computing-related research.

**Figure 23:** UMAC-5 transistor/drum memory. (CSTM 1985.0359.001)

What is remarkable about this story, and that of the UTEC in the previous chapter, is that there was no communication between the University of Toronto and any other group at Ferranti Canada, the DRTE or the NRC. A satisfactory reason for this has never been presented, aside from the determination on the part of the Computation Centre to "go it alone," which would not have been in character with the era: with the exception of confidential military or defence-related projects, most computer development groups were very open with their research. Ignorance of other projects is a more likely explanation for the lack of discourse.

The question of whether or not the Ferut survived also remains unanswered. After it left Toronto in 1958 it was passed on to the NRC Structures Laboratory. It remained in use there for at least two or three years, alongside several analog computers. Its whereabouts beyond that are unknown, though, sadly, its destination was likely the scrap pile, an ignoble end for the machine that launched the computer era in Canada.

## **3.2.6** Sperry Canada and the UMAC-5

In the early 1960s Sperry Gyroscope of Canada (known as Sperry Canada), the Canadian subsidiary of the Sperry-Rand Corporation in the United States, brought to market the world's first computer numerical control (CNC) machine tool system, the UMAC-5 (Universal Multi-Axis Control Mark 5).[17]

Sperry Canada was founded in 1950 in Montreal to take advantage of the increased military spending expected to flow from the Korean War. After an initial foray into high-precision aviation manufacturing, it turned to developing numerical control (NC) machine tools, an area of specialization brought about through its U.S. parent company's orders to develop diversified product lines that would not overlap with that of any other subsidiary. It achieved notable success in the field. And so in 1962 Sperry Canada decided "to bring the programmable electronic computer directly into the hands of the machinist on the shop floor."[18] By aiming for the high end of the machine tool market with a flexible system, Sperry helped create CNC, marrying stored programmability with multi-axis machine tools.

Ironically, the UMAC-5's hardware was not particularly innovative or state-of-the-art. For example, it used magnetic drum storage, rather than the more logical but more costly option of magnetic cores. Even more remarkable was the fact that Sperry Canada engineers were able to protect the electronics from the unfriendly shop environment, "characterized by high temperatures, dust and grease, flying pieces [of] metal cuttings, etc."[19]

But whereas hardware was a relatively straightforward problem, software development became a serious issue. The programmability of the UMAC-5 was its distinguishing selling point because of its users extreme flexibility. At the same time, management at Sperry Canada failed to prioritize software development appropriately, which led to cost overruns and considerable delays in implementing this feature. Attempts to arrange financial assistance from the federal government during the development phase also met with delays, which held the project back. By the time the UMAC-5 was available, after 1965, it was too expensive for its own target market. There were simply too few applications for such a complex and sophisticated system, and few machine shops, particularly those located in Canada, could justify the cost.

Much like the FP-6000, the UMAC-5 was a technologically brilliant system. There is little doubt that it anticipated the entire field of computer assisted design (CAD) and computer assisted manufacturing (CAM), but sales were poor and in 1967 Sperry Canada discontinued its production. The company chose instead to manufacture and sell a much simpler NC system known as the UMAC-6 and, later, the UMAC-7.

## **3.2.7** Control Data Corporation and the Cyber 170

The story of Control Data Corporation (CDC) and the Cyber 170 series of mainframes covers a period from the late 1960s to the mid-1970s. It marks the end of large computer development in Canada and offers important hints at the future of smaller, microprocessor-based computing.[20]

The Minneapolis-based CDC was founded in 1957 by William Norris. His company had specialized in high-performance computers (later known as supercomputers) for scientific computing almost since the company's inception. The fact that CDC was not competing directly for IBM's much broader customer base, with its more general computing needs, meant that CDC remained successful for many years. In part, this also led to CDC rapidly becoming the second most profitable computer manufacturer in the world. In the late 1960s, CDC began to move into high-end electronic data processing to compete with IBM and its System/360 line of computers. To do this, CDC decided to use a single architecture for a new supercomputer called the STAR 100, as well as a low-end computer line (suitable for scientific or business use) called the PL-50.

In order to finance the PL-50 R&D, CDC turned to its Canadian subsidiary, CDC-Canada. Recognizing that the Canadian government was interested in fostering a domestic computer industry, in the fall of 1969 "CDC raised the idea of shifting the PL-50 project to Canada if the government was willing to share in its costs."[21]

After a year of negotiations, a financial agreement was reached—one of the largest of its kind for the Canadian government. The two parties established four objectives: "to create a permanent mainframe R&D facility in Canada, to design the PL-50, to create the infrastructure and transfer the know-how to manufacture the PL-50, and to foster the emergence of Canadian sourcing for the various components used in manufacturing mainframes."[22] With regard to the final objective, it was hoped that Microsystems International Limited (MIL, see the following chapter) would be closely involved with the PL-50 development and manufacturing, but little appears to have come of this intention. Some of the other objectives did meet with success, [23] for example, CDC-Canada established a Canadian Development Division in Toronto, and several engineers were transferred from Minneapolis to Toronto, at least until sufficient know-how could be transferred to the new office. But unfortunately the PL-50 project broke down, for a number of reasons, in 1972. By this time it had become clear that it would be impossible to use the advanced STAR 100 architecture in a low-cost machine.

**Figure 24:** CDC Cyber 170. (CSTM 1986.0819.001 and 1986.0820.001)

In the meantime, however, CDC had updated its 6000 series using improved and less expensive transistors, renaming it the Cyber 70 series. It sold well, in part because customers could upgrade to these faster computers without the expense of rewriting software. The Canadian Development Division, initially demoralized by the failure of PL-50, then took the initiative and extended the Cyber 70 idea by further redesigning the 6000 series to include leading-edge integrated circuits and semiconductors replacing the computer logic and magnetic core storage. The computer was known as the Cyber 173. Careful planning and tight integration with production engineers led to the Canadian Development Division generating considerable performance gains with their redesign. As before, CDC customers could move to this new line, the Cyber 173, without having to replace existing software.

The co-operative venture between the Canadian government and CDC was deemed only partly successful, as not all of its initial goals were achieved. For instance, plans for a manufacturing facility requiring staff with less technical training for Quebec had to be cancelled with the collapse of the PL-50; the renewed emphasis on careful production engineering had led to automated rather than manual assembly. It is also arguably the case, however, that the Cyber 170 was the most important computer ever sold by CDC, as the immediate and substantial sales helped save the company from financial collapse after its strategy to compete directly with IBM and its System/360 failed.

## 3.3 The Growth of Computer Use in Canada

### 3.3.1 Ferut and the St. Lawrence Seaway Backwater Calculations

As noted above, the first electronic computer in Canada was the Ferut at the University of Toronto. It arrived in April 1952, and was nominally operational by September 1952. Its proud new owners had two main goals that fall. First, the staff of the University of Toronto's Computation Centre had to learn how to use the new computer and build a library of useful subroutines to simplify application development. At the same time, the Centre had been engaged by the Hydro-Electric Power Commission of Ontario to carry out a series of backwater calculations related to the course of the proposed St. Lawrence Seaway and Power Project. These calculations would be the first major challenge for the new computer.[24]

By 1952, Canadian authorities had decided to go ahead with construction of the St. Lawrence Seaway, using an all-Canadian navigation route if necessary. Their American counterparts had not yet agreed to participate in the project. This meant there were several possible passages for ships, although the location of the power dam at Cornwall was relatively fixed for a variety of geographical and political reasons. The various options for navigation routes and power generation meant that the backwater calculations would be a crucial part of any negotiations between the two countries.[25] Producing such calculations was considered tedious and complex, making it an ideal project for electronic computation, and so the Hydro commission approached the Computation Centre for assistance. For its part, the Centre agreed readily; anxious to demonstrate the importance and capabilities of the Ferut, it made the backwater calculations its top priority.

The staff of the Computation Centre were relatively inexperienced, so they turned for help to Christopher Strachey, a seasoned programmer on loan from the United Kingdom.[26] His final program contained about 2 000 instructions, and the narrow paper data tape ran to almost 2.5 kilometres. The Ferut was not a particularly reliable machine and the enormous data tape exceeded the computer's storage capacity, and so considerable care was taken to manage both the results and data. It took eight months to write the program and compute the results, but it was estimated to have saved twenty years of manual computation.

Interestingly, only a few reports describing the project were ever published.[27] This is due in part to the sensitive political nature of the negotiations: the Canadian parties were able to engineer a Seaway more favourable to Canadian interests thanks to the backwater calculations, but were simultaneously disinclined to boast or embarrass the Americans. Nonetheless, the calculations were a vital training ground for the Computation Centre staff and the positive results attracted attention from other scientific organizations such as the Dominion Observatory, financial and insurance corporations such as Manufacturer's Life, and industrial companies such as Eastman Kodak and Imperial Oil. Though the DRB and NRC had paid for the Ferut and would make good use of it, many other organizations—eager and curious about the potential of electronic computation—began to test it.

Not long after, by the mid-1950s, most of the first generation of computer manufacturers from the United States had begun opening offices and selling their products north of the border. For instance, IBM and UNIVAC were soon competing in Canada with the same determination as in the United States. Manufacturers of smaller computers, such as Computer Research Corporation, MacBee or Burroughs, would typically enter the Canadian market by selling their systems through Canadian distributors.

## 3.3.2 The Computing and Data Processing Society of Canada

Between 1952 and 1958 computer use in Canada expanded considerably, maturing to the point that a society dedicated to computing in Canada was founded in 1958. It was called the Computing and Data Processing Society of Canada (CDPSC).

While the Ferut remained the only general-purpose commercial computer in Canada until 1955, the number of computers rose exponentially after that, as seen in Table 1, 1964–1969 (see Table 1, Number of computers in Canada, 1952–1969). The second and third computers in Canada were relatively small and inexpensive NCR-102As that were both installed in 1955 for scientific research. One went to A. V. Roe at Malton, Ontario, and the other to the Royal Canadian Air Force (RCAF) at Cold Lake, Alberta.[28]

The next year several more organizations joined the modern computing community in Canada, though most had a greater interest in data processing than scientific research. Many chose an IBM 650, a popular mid-range magnetic drum-based machine, to enhance or even replace their clerical and accounting operations (see section 3.3.3 below). Most of those with an interest in computerized data processing had previous experience with automatic mechanical or electromechanical office equipment and punch card record keeping, and so the shift toward electronic records management was not necessarily seen as a gigantic leap.

Importantly, many of those who implemented the new technologies had prior affiliations with the National Machine Accountants Association (NMAA) or the National Tabulating Management Society (NTMS), both U.S.-based organizations dedicated to pooling knowledge and experience in the earlier era of pre-electronic office equipment.[29]

Users faced with unfamiliar computer technology and new techniques created new organizations to serve their needs. One of the first was an informal users' group known as the Tape Users Conference, which met "to discuss similar problems and their solutions, and how computer technology could apply," and it was soon followed by the CDPSC.[30]

The CDPSC was, in many ways, distinct from its immediate predecessor and from other large computing associations elsewhere. Firstly, it was more formally organized than the Tape Users Conference. In addition, it was not tied to any one specific machine, unlike SHARE, which was arguably the world's first collaborative computer user group. SHARE was formed in the United States in the mid-1950s by users of the IBM 704. That particular computer was particularly popular in Southern California, home of a burgeoning aerospace industry. However, SHARE was not a professional society but an informal organization dedicated to gathering a coherent body of practical knowledge of immediate use to computer programmers, technicians and administrators. Only later did SHARE come to include users of other IBM computing.[31] Although a sizable SHARE meeting was held in 1962 in Toronto, it was never a significant or particularly relevant organization for Canadians in the early years.[32]

The CDPSC also differed from the Association for Computing Machinery (ACM), an organization formed in 1947 to encourage discussion and distribution of ideas fundamental to the modern computing era. ACM had greater intellectual aspirations than SHARE. As an academic society with broad interests,[33] in 1952, only a few years after it was founded, the ACM held an annual conference at the University of Toronto, a rare meeting organized outside the United States.[34] The meeting offered the University of Toronto a chance to demonstrate the Ferut (barely installed and operational), the existing UTEC prototype, and its successful operations with the IBM punch card calculators. Unfortunately, the meeting did little for Canadians not otherwise already involved with computing.[35] Again, for many years ACM had few Canadian members outside the University of Toronto.

Instead, the CDPSC was, at least initially, a "big tent" association that welcomed all Canadians with an interest in scientific computing, data processing or any other "effective application of the modern high speed machine."[36] Efforts had began as early as 1955 to initiate such an organization but the Computation Centre remained reticent, believing, perhaps correctly, that there was too little genuine interest in the field as yet. Only in 1957 did the university agree to host a preliminary meeting. Representatives from computer companies, computer consultants and early computer users then established an executive and program committee that went on to organize the first Canadian Conference for Computing and Data Processing, which was held at the University of Toronto

**Table 1:** Number of computers in Canada, 1952–1969

| 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 3 | 7 | 13 | 24 | 40 | 64 | 145 | 296 | 477 | 538 | 889 | 1036 | 1383 | 1613 | 1928 |

**Table 2:** Demographics of attendees at the first Canadian Conference for Computing and Data Processing, June 1958

| Field | Attendees | Executive Committee | Program Committee |
|---|---|---|---|
| Academic | 26 | 1 | 2 |
| Computer Industry | 52 | 3 | 6 |
| Government | 45 | 0 | 0 |
| Insurance & Finance | 49 | 1 | 2 |
| Management & Accounting | 17 | 1 | 1 |
| Manufacturing & Industry | 65 | 0 | 0 |
| Defence | 13 | 0 | 0 |
| Petroleum | 33 | 0 | 1 |
| Publishing | 2 | 0 | 0 |
| Research & Science | 23 | 1 | 1 |
| Retail | 11 | 0 | 0 |
| Transportation & Utility | 39 | 1 | 1 |
| Unknown or Unaffiliated | 13 | 0 | 0 |
| **Total** | **388** | **8** | **14** |

in June 1958. Most of the 388 registrants were from Toronto (67 percent), followed by Montreal (12 percent) and Ottawa (7 percent)—which was not a surprise, given the number of large corporate headquarters and government offices located in these cities. Of the remaining attendees, all but twenty were within half a day's drive of Toronto. Nevertheless, as Table 2 and Table 3 (from CDPSC Conference Proceedings, 1958–1962) make clear, the conference attracted an incredibly varied group of registrants.

Conference proceedings for the first three biennial CDPSC-sponsored conferences were published in 1958, 1960 and 1962, providing a clear picture of the overall aims of the society, the themes of the conferences and changes in the field. For instance, at the 1964 meeting, the keynote speaker suggested in retrospect that the unofficial theme of the meetings could have been, respectively, "We must get a computer," "Must we get a computer?" and "Well, the payroll is working, so now what?"[37]

It is certainly clear that, by the time of the inaugural conference in 1958, the original scientific impetus for electronic computing was no longer a driving force for those interested in computers. Less than half of the registrants were connected to a scientific, academic or corporate entity interested in scientific computation. Instead, the majority were attracted by the potential of computers for data processing, as best characterized in the talk, "Planning a Data Processing System," given by H. O. McNutt of Imperial Oil.[38] At the time, data processing was a new term, but not a new activity. Many in McNutt's audience would have been familiar with terminology he used to describe storage, retrieval and manipulation of units of data related to planning and operating a business. In any medium-size to large organization, tasks such as accounting, scheduling, managing inventory, projecting sales statistics, etc., were already highly mechanized, thanks to typewriters, mechanical calculators, tabulators and punch cards. Since the nineteenth century, when the data processing industry was born and the first office appliances were put to use, large ranks of middle managers and clerks had been forming.[39] But those who attended McNutt's talk were curious about applying the new electronic technology to data processing, either to improve the overall quality and usefulness of processed data, or to deal more efficiently with the increasing paperwork and associated data. Several of the 1958 conference presentations had this kind of audience in mind, in introducing new concepts related to computer hardware or programming, describing hypothetical uses of computers, outlining what computers could not do, or providing real examples from early adopters with a few years' experience operating a computer for data processing. Such examples were limited, since the majority of experience with computers in Canada to that point was scientific.

**Table 3:** Subjects addressed in CDPSC conferences

| Subject | 1958 | 1960 | 1962 |
|---|---|---|---|
| General Concerns | 4 | 3 | 1 |
| Introductory, or Suggested Usage | | | |
| General | 10 | 4 | 6 |
| Data Processing | 6 | 6 | 5 |
| Scientific Computation | 3 | 3 | 2 |
| Real Examples and Lessons | | | |
| Data Processing | 10 | 6 | 7 |
| Scientific Computation (incl. scientific papers) | 17 | 5 | 7 |
| Real-time Processing | 0 | 1 | 5 |
| Hardware Development | 0 | 4 | 0 |

To fully appreciate the rising interest in data processing in Canada, another event that took place in 1958 is worth exploring. That year, C. C. Gotlieb and J.N.P. Hume published the first Canadian computer textbook, High-Speed Data Processing.[40] Nominally, Gotlieb and Hume were both physics professors at the University of Toronto, but they had long been involved with the Computation Centre. In particular, the two had been teaching evening, non-credit courses about data processing. These were increasingly popular courses; enrolment peaked at over 200 students during the 1956–1957 academic year. Their 1958 book drew from their lecture notes, while also clarifying and stabilizing computer terminology. As an introductory text, it proceeds from fundamentals of computer operation and design to programming to specific applications in accounting, insurance, planning and scheduling. For their pioneering work, the authors and their text are recognized by The Oxford English Dictionary in twelve computer-related entries: block, character, datum, generator, housekeeping,

**Table 4:** Digital, electronic computers in Canada, ca 1958

| Computer | Organization |
|---|---|
| ALWAC III-E | University of British Columbia |
| | Canadian Armament Research and Development Establishment (CARDE) |
| | Naval Research Establishment (NRE) |
| Bendix G-15 | NRC, Mechanical Engineering Division |
| | RCAF Cold Lake |
| | Computing Devices of Canada |
| | University of Manitoba |
| Burroughs E101 | NRC, Radio and Electrical Engineering Division |
| Datatron 205 | Atomic Energy of Canada Limited |
| | McGill University (planned) |
| Ferranti Mark I (Ferut) | |
| | University of Toronto |
| | NRC42 |
| IBM 650 | Canadair Limited |
| | Canadian General Electric Company |
| | Canadian National Railways |
| | Ford Motor Company of Canada |
| | Great West Life Assurance Company |
| | IBM Data Centre, Toronto |
| | Imperial Oil Limited |
| | KCS Data Control Limited |
| | Laval University (planned) |
| | Manufacturer's Life Insurance Company |
| | Ontario Hydro-Electric Power Commission |
| | Orenda Engines Limited |
| | Prudential Insurance Company of America (two installations) |
| | Royal Canadian Army Pay Corps |
| | Trans-Canada Air Lines |
| | Workmen's Compensation Board |
| | University of Ottawa (on order) |
| | University of Toronto |
| | University of Western Ontario (on order, 1959) |
| IBM 704 | Avro Aircraft Limited |
| IBM 705 | Confederation Life Association |
| | Drug Trading Company Limited |
| | Imperial Oil Limited |
| LGP-30 | University of Alberta |
| | University of Saskatchewan |
| NCR 102A/D | RCAF Cold Lake |
| UNIVAC II | London Life Insurance Company |
| | Ontario Hydro-Electric Power Commission |
| | Sun Life Assurance Company of Canada |

in-line, interpreter, keyboard, logical, loop, matrix and simulate.[41] Though one reviewer criticized the text as being limited to discussions of relatively modest computers and failing to focus on the largest, most impressive and most expensive computers, a focus on the former was more realistic for a Canadian audience.[42]

## 3.3.3 The First Survey of Canadian Computers, or, Why an IBM 650?

While some particularly large organizations could afford the top offerings from IBM or UNIVAC, as can be seen in Table 4 most were content with a middle-range IBM 650. Indeed, in 1958 the IBM 650 was the most popular computer in both Canada and the United States. First introduced in 1954, there were about a thousand installations by the end of its lifespan: far more than any other computer of that era.[45] Success came through various means. Though it was a relatively slow tube-based computer with a magnetic drum for primary storage (which was much slower than state-of-the-art magnetic core storage) the IBM 650's drum speed was the second fastest in a relatively crowded market of mid-range systems. IBM salesmen could also point to the 650's genuine reputation for reliability and its relatively easy programming environment.

Those same salesmen had another distinct advantage: "IBM's base of punched card and time clock users gave the

**Figure 25:** Trixie Worsley and Irene Ploester at the IBM 650 computer in the University of Toronto Computation Centre. (Courtesy University of Toronto Archives digital image no. 2004-51-1MS; original item no. B2002-0003/001P 14)

company the insight and knowledge of their users' businesses and needs."[46] IBM had the largest pre-existing sales and service organization among Canadian computer companies. The 650 competed directly with other drum-based computers such as the LGP-30, the NCR 102A/D, the Bendix G-15 and the ALWAC III-E, which were all sold by small Canadian subsidiaries of American corporations or by small Canadian distributors. For example, the Canadian subsidiary MacBee sold the LGP-30 but, with each sale, was forced to open a new office in the town of its latest customer.[47] The NCR 102A/D and the Bendix G-15 were sold by Computing Dev, a computer company that was both building special-purpose electronic devices and selling other manufacturers' general-purpose computers. The ALWAC III-E, manufactured in California by Alwac Computer Division El-Tronics Incorporated, was sold in Canada by Adalia Limited. This small consulting company had been founded in Montreal by Sir Robert Watson-Watt, who had made his name as a radar pioneer a decade earlier.[48] Not one of these companies was as familiar with the world of punch card data processing as IBM.

It is worth noting that IBM had originally marketed the 650 as a business machine, as part of a strategy to offer both scientific and business-oriented computers. Yet a close look at Table 4 reveals that the 650 was the most popular computer among Canadian universities, a situation that was even more pronounced in the United States. The explanation for this is that IBM frequently offered a substantial educational discount—up to 60 percent—for those schools that agreed to introduce computing courses using the new hardware. And while other manufacturers offered similar deals, IBM had yet another lure: academic grants and fellowships that were conditional on choosing an IBM computer. For many schools, the discount was sufficient and, consequently, an entire generation of students and faculty were introduced to computers through the 650. In the 1960s, many of these individuals would go on to create a new discipline known as computer science. In all, the IBM 650 was an affordable and effective computer for a variety of uses and needs.

### 3.3.4 Early Patterns of Computer Use

Manufacturer's Life installed the first IBM 650 in Canada in 1956.[49] An internal committee at the company began to study the potential of electronic data processing in the early 1950s, and several test runs were conducted with the Ferut in 1954 and 1955. Rather than purchase (or rent) a large, expensive computer such as Confederation Life did with an IBM 705 in 1958, a medium-scale 650 was chosen to mechanize operations gradually, "on the basis of creating minimum disturbance in other divisions of the company."[50] The company planned to upgrade to a larger system only when its data processing needs were well understood and demands had risen sufficiently. The IBM 650 itself was assembled at IBM's Don Mills plant in Toronto, though the component parts were manufactured in the United States.[51]

In contrast, around 1958 Sun Life chose a large, expensive computer, the UNIVAC II, Remington- Rand's successor to the UNIVAC, the world's first commercial computer that was first sold in 1951. As with Manufacturer's Life, an internal committee at Remington-Rand had been studying electronic computers since the early 1950s and tracking the introduction of computers at other companies, particularly those in the insurance industry. Tests were run with a Ferut, a UNIVAC and an IBM 705, simulating activities related to ordinary policy service, with the aim of automating much of the company's operations, reducing clerical work, and saving storage space by converting two million policies from punch card to 300 hundred reels of magnetic tape. The UNIVAC II was selected as "the only machine which has the necessary speed of input and output and for which the necessary auxiliary equipment will be available."[52] The new computer (the first in Canada and Remington-Rand's third delivery from its Saint-Paul factory) arrived in June 1958.[53] Like Manufacturer's Life, Sun Life publicized its computerization project widely among employees, clients and the public. In contrast to Manufacturer's Life's gradual approach, Sun Life planned broad and immediate changes to their billing, policy issue, accounting, claims and actuarial statistics activities.

Moving away from insurance, another early adopter was Imperial Oil. It had been one of the earliest clients to make use of the Ferut at the Computation Centre at the University of Toronto, putting a problem regarding an inventory control system for its warehouses to the applied mathematicians there.[54] Imperial Oil then acquired an IBM 650 and made plans in 1958 to install a large IBM 705 II to handle a vast number of applications, from record keeping to corporate planning. As was common at the time, Imperial Oil was able "to draw upon the advanced experience of affiliated companies in the United States," and this explains its ambitious plans.[55] In the early 1960s, when the University of Toronto was contemplating building the ILLIAC II (and, later, buying the IBM 7090), Imperial Oil was seen as a vital supporter that was certain to buy machine time. Imperial Oil was also a founding member and long-time supporter of the CDPSC.

Other early users were less aggressive in adopting computers. In 1956, Canadian National Railways (CNR), perhaps the largest employer in Canada, ordered a no-frills IBM 650 to computerize and centralize its payroll operations. For CNR, these operations were already highly dependent on punch card processing, and its system should therefore have been ideal to computerize. However, the new system was not finished until April 1958, and implementation was not problem-free. Centralizing payroll meant that pay cheques had to be flown across the country rather than generated locally, and some pay cheques arrived late on occasion. Some CNR bookkeepers kept parallel records (against company policy) long after the 650 arrived, on the assumption that "the other system" (the computer) would probably break down eventually. And they wanted to have complete and accurate records just in case."[56] Only after its payroll system was perfected did CNR gradually move into other areas of electronic data processing, including a car accounting project. As one CNR computer representative observed, computerization required caution and careful justification; most problems encountered would be administrative rather than technological.[57]

In contrast to CNR, Canadian Pacific Railways (CPR) took a broader approach, installing a very large IBM 705 in 1957 at a new computer centre in Montreal, to assist with the three most important aspects of operations: "freight, payroll and material."[58] Plans were made to track freight cars mechanically and monitor movements centrally, transfer all payroll operations to the computer, and create a centralized inventory management system. But CPR had some hard lessons to learn: about proper staffing of a computer centre, overestimating the technical capabilities of computers and their peripheral input/output devices and, in general, about the transition period of computerization sometimes being long, hectic and non-productive.

Computer centre staffing was a serious concern in the 1950s, and not just in Canada. Soon after the first commercial computers were sold and delivered, the proud new owners realized that their expensive new tools also required a new kind of employee. Programmers, analysts, operators and technicians were all in high demand, but there was an extremely small pool of talent with modern computing experience. An entire conference dedicated to this problem was held in 1954 at Wayne University, focusing on the problems of staffing requirements, educational programs, and collaboration between universities and industry in rectifying the shortage of skilled programmers.[59]

In Canada, one 1958 estimate suggested that within just two years staffing requirements would reach 1 800 for programmers or analysts, 300 for operators and 300 for maintenance technicians, and warned that at current graduation rates Canadian universities would be unable to satisfy this demand.[60] For those organizations unable to wait for new graduates, internal, on-the-job training and promotion was the preferred (and only) option, as existing employees should at least already be familiar with company policies and procedures. As such, identifying employees with the right potential and training them became a high priority. Candidates could be selected through standardized testing mechanisms such as IBM's Programmers Aptitude Test, and most manufacturers offered programming courses, often on-site.

## 3.3.5 Early Computer Services and Consulting

For those companies interested in computers, but unable or unwilling to rent or buy their own, there were two options: purchase machine time at an existing computer centre or hire a computer consultant to handle all operations off-site.

The University of Toronto's Computation Centre was the first modern computer service in Canada. Prior to the arrival of the Ferut in 1952, it had been offering computer services via IBM 602A punch card calculators to various faculty members, government agencies and other external organizations. Few, if any, of its clients learned how the 602A operated, instead, they submitted problem descriptions to the Computation Centre staff operating the calculators. In most cases, there was no charge for this service, although some problems were given higher priority, especially those relating to AECL's Chalk River laboratories.

When the Ferut arrived, there were no existing models for operating a modern computing centre effectively, and so all-new methods were needed.[61] With regard to cost, the DRB and NRC had declined to cover the vast annual operating costs of the Ferut (about $50,000), and so most clients were charged for all programming and computing services. An early notion of charging $4 per line of code lasted about a year until a new hourly charge of $200 was instituted. This was comparable to the commercial rates that had developed in the United States.

The Ferut, like all other Ferranti Mark Is, was perhaps the most difficult computer of its day to program. With no real hope of understanding its abilities or limitations, prospective clients had little choice but to submit problems to the Computation Centre staff, who would then decide whether reaching a solution was feasible. To assist in this matter, the DRB, NRC and AECL all hired and stationed their own programmers in Toronto to liaise more effectively with their own scientists, based mostly in Ottawa. To simplify matters for all, in 1954 Computation Centre staff created TRANSCODE, an automatic coding system described below. In short, TRANSCODE simplified programming for the Ferut considerably, reducing the workload for those in the Centre and enabling those outside to write and submit their own programs.

TRANSCODE heralded a change in direction for the Computation Centre. A new policy in 1956 stated that it would only take on programming problems that were particularly interesting from a mathematical or research point of view. Though this did result in a drop in service income, it helped the Centre distinguish itself on campus as a research organization, rather than simply a service centre. This change in direction was a response to the notion held by some faculty and university administrators that operating a computer service was not particularly appropriate for academics, and was best left to private industry. This seemingly logical view was supported by the increasing numbers of computers in Canada, and so the Centre began to emphasize its research and pedagogical responsibilities, laying the groundwork for the establishment of a department of computer science (see section 3.3.6).

Meanwhile, as IBM, UNIVAC, ComDev and other companies rang up computer sales across the country, their new customers were faced with the immediate challenge of figuring out how to use their new acquisitions. The choice was to train their own employees or hire external consultants. In the latter case, this often meant turning to the computer provider for assistance. For example, after selling an NCR-102A to the DRB in 1955, ComDev operated the computer at the RCAF station at Cold Lake, Alberta for many years.[62] Even those companies choosing the former option would lean heavily on the manufacturer from time to time. For example, because Manufacturer's Life was IBM's first Canadian customer to rent an IBM 650, for important projects it was able to call on IBM programmers for assistance at a moment's notice. Confederation Life's IBM 705 served double duty: IBM operated it as a service centre, selling time to other customers, while its programmers also developed a series of insurance applications for Confederation Life.[63] IBM operated a series of service centres across the country, as did, to a lesser degree, most other computer manufacturers, including UNIVAC, Burroughs and NCR. Such computer service centres provided custom programming and application development: in an era before prepackaged software, almost every problem demanded a unique solution.

At the same time, there was also a growing demand in Canada for experienced programmers and consultants who could offer independent advice and assistance. Not surprisingly, two of the earliest computing consulting companies in Canada—H. S. Gellman and Company and KCS Data Control—were created by early Computation Centre employees who left the excitement (and chaos) of the university to satisfy their more entrepreneurial ambitions.

Harvey S. Gellman, a Polish immigrant, was the third person to join the Computation Centre. Hired in 1948 to operate the 602A calculators, he specialized in atomic energy computations for the Chalk River laboratories. When the Ferut arrived, Gellman stayed at the Computation Centre but was hired by AECL to act as its liaison programmer in Toronto. In 1955 he founded H. S. Gellman and Company Limited, a computer consulting company specializing in engineering and scientific computation. AECL, perhaps not surprisingly, was one of his first clients. Initially, Gellman purchased computer time on the Ferut, but as his business expanded he bought any available time on any computer in the Toronto area. He and his company acquired a strong reputation for understanding both the technical requirements and personal needs of his clients.[64]

KCS Data Control Limited was also formed in 1955. The name was taken from the initials of its three founders: Joseph Kates, Leonard Casciato and Joe Shapiro. Kates had been one of the two primary engineers behind the UTEC. When it failed, he had worked briefly for Sir Watson-Watt's company Adalia, and assisted with the initial design of the ReserVec system. Kates was somewhat unhappy as an employee, and in 1955 his former assistant from the UTEC project, Casciato, convinced him to leave and help form a computing consulting company. The third partner was Shapiro, whom Kates and Casciato had met while working at the Computation Centre. Like H. S. Gellman and Company, their firm moved away from data processing but, instead of scientific work, KCS aimed more toward technical or planning related computations, which it carried out on the Ferut until it could rent its own IBM 650.[65]

Perhaps the most important project KCS took on during its first decade was the Toronto Traffic Signal System. In 1957, the company was awarded a small contract from the Metro Toronto Chief Traffic Engineer for a feasibility study regarding computer control of traffic signals. The contract was based on a small demonstration previously conducted on their IBM 650. This was then expanded into a considerably larger contract for a pilot project: a live, on-the-street trial of computer-controlled traffic signals. Although traffic signal automation extended as far back as the 1920s, when traffic engineering was born, this would be the world's first signal system to use a general-purpose computer to analyze and respond to real-time traffic flow. Traffic was detected through radar, while the pilot system relied on a centralized computer (KCS's IBM 650) to process the data and control the signals; if the computer or the connection failed, each individual signal controller would revert to a fail-safe mode.

When a full-scale system controlling 500 signals was proposed at a cost of about $3.2 million, the project moved from the technical to the political domain. The new system sparked public debate over its cost, complexity and necessity, as well as the fact that it would have to include the individual municipalities that made up Metropolitan Toronto, which were normally responsible for their own traffic control. Although the technical work by KCS until that point was effective, the size of the new contract and difficulty in navigating local politics worked against the young company. Four companies submitted bids for the control system and two—IBM and Ferranti-Packard—attempted to challenge the technical specifications proposed by KCS, in order to sway the Metro council toward their own systems. The other two—UNIVAC and Control Data—declined to challenge the specifications, but only UNIVAC could promise to manufacture at least part of the system in Canada. This apparently influenced the council, for it selected a UNIVAC 1107 computer for the system. Unfortunately, UNIVAC then failed to live up to its promise: "the entire computer system was manufactured in UNIVAC's U.S. plants."[66] Nonetheless, it proved to be a reliable system. It was installed in Toronto's former City Hall and lasted until 1982, easily surpassing its expected service life of ten years.

KCS and H. S. Gellman and Company are but two of the earliest and more influential Canadian computer consulting companies. Just as these firms were able to capitalize on their early experiences at the University of Toronto, as the number of people exposed to computers grew, so did the number of consultants specializing in one or another field of modern computing. Despite the lack of a strong domestic computer manufacturing industry, there were many Canadian computer service and consulting companies. It is unfair to focus on the former without acknowledging the latter.

## 3.3.6 Computers in Academia and the Creation of Computer Science

Computer science departments were first established in Canadian universities around 1964. At that time the phrase "computer science" was only about five years old. Nevertheless, at the end of the 1950s there were several Canadian universities (besides the University of Toronto) that had already acquired their own computers or valuable experience in using them. Though the University of Toronto's early entry gave it certain advantages when it came time to institutionalize the academic study of computers, other schools were also able to achieve considerable success.[67]

There can be little doubt that the University of Toronto benefited greatly from its DRB and NRC grants in the early days of computing. Without this federal funding, it is unlikely that the university could have undertaken the UTEC project or ordered the Ferut in 1952. Instead, computational efforts at Toronto would likely have expanded more gradually with electromechanical desk calculators or an applied mathematics or statistics program. Federal grants were essential to its early entry into the field.

Consider, for example, the University of British Columbia (UBC), where an ALWAC III-E arrived in 1957, making it the second Canadian university to install a computer. It arrived thanks to a capital grant from the DRB, which intended it to provide "a digital computation facility for PNL [Pacific Naval Laboratory] and for DRB grantees in the area."[68] UBC had no great computational needs driving the acquisition of a computer, but many west coast organizations, both public and private, would find a use for the computer.[69] Eventually, an IBM 1620 replaced the ALWAC in the early 1960s, followed by an IBM 7040. The 1620 was a relatively mediocre machine of the day (though it was transistorized), but the 7040 was an incredibly popular computer for Canadian universities in the 1960s, being less powerful than the 7090 but considerably more affordable.

**Figure 26:** The ALWAC III-E arrived at the University of British Columbia in 1957. (Courtesy John Chong, UBC)

Given the expense of buying or even renting an electronic computer, many schools chose to purchase computer time at an existing computer service centre. Early adopters close to the University of Toronto made considerable use of the Ferut in this way, to both test the waters and solve any computational needs. But for those out of a relatively short geographic range (e.g., a day's drive), this was difficult to do. In partial response to this situation, in 1953 the Computation Centre developed TRANSCODE, an automatic coding system, or autocode, for the Ferut. Similar to a modern assembler or compiler, TRANSCODE simplified most programming tasks considerably, and reduced from months to hours the time it took to learn how to program. It was so simple and straightforward that programs could be written on paper and submitted by mail.[70] Documentation could be ordered easily from the Computation Centre, and the new programming system was popular among the NRC, DRB and other government users in Ottawa. They and other groups could make more effective use of the Ferut from afar, without relying extensively on a liaison programmer stationed in Toronto. For much the same reasons of simplicity and reduced learning time, TRANSCODE also found favour among students and staff at the University of Toronto in the growing number of computer courses and research projects conducted by faculty and graduate students.

A remarkable case of remote use of the Ferut took place in December 1955 between the Computation Centre and the University of Saskatchewan. Earlier that year, a doctoral student from Saskatchewan had travelled to Toronto to carry out some computations using the Ferut, and on return he began teaching TRANSCODE to others in Saskatoon. However, rather than have them submit programs by mail, one night a teletype was used to transmit programs from Saskatoon, along a borrowed line, directly to the Computation Centre in Toronto. In the first experiment, ten programs were transmitted over the line to be run on the Ferut and their results were returned, saving about a thousand hours of work at desktop calculators in Saskatoon.[71] Programs were transmitted regularly this way for several months and, in 1957, the entire system was replicated successfully between the University of Alberta in Edmonton and Toronto.

These remote programming experiments helped prove the viability of TRANSCODE but also speak to the geopolitical reality of Canada and the typical use of computers in Canada over the following twenty years or so. As one newspaper account stated: "The use of a central brain would overcome many of the problems created by decentralization of business."[72] Indeed, computing power remained centralized until the arrival of microprocessors and personal computers in the 1970s and 1980s. Although minicomputers helped push computing toward a slightly more decentralized model in the 1960s, the scales were not tipped until the 1980s, with the widespread availability of personal computers. But for students and faculty at the universities in Saskatchewan and Alberta, having access to the Ferut during such an early period provided meaningful computing experiences, before either of the universities could afford to acquire its own computer. For the University of Alberta, it was able to convert this exposure into a leading computer science program in the 1960s.[73]

**Figure 27:** Ferut computer telegraph connection to the University of Saskatchewan, 1955. (Courtesy University of Toronto Archives, digital image no. 2005-58-1MS, original item no. B2002-0003/001P-04)

Other Canadian schools with early and important computer science programs include the University of Toronto, the University of Western Ontario and the University of Waterloo. Of the four mentioned, Waterloo had the most stratospheric rise, though all were eager promoters of the new discipline before it was even recognized as such.

As mentioned, the phrase "computer science" did not exist until the late 1950s, and there was little recognition among academics that a single, coherent body of knowledge related to the study of computers might exist. In addition, there was serious doubt as to whether such study was appropriate or relevant for universities, rather than being suited to short training courses or, at most, study at a technical college. However, around the turn of the decade a number of proponents came forth to suggest that a new discipline was emerging, though it remained difficult for many years to delineate computer science from other subjects. Unlike some disciplines, such as physics or biology, computer science lacked a cornerstone of study, like the atom or the cell. Was the principal interest of computer science the design of computers, their application or computational methods? Was it more akin to engineering, physics or applied mathematics? Answering these questions took many years and some were not fully resolved until the 1970s.[74] In some ways this was a secondary matter, as the first self-proclaimed practitioners of computer science were more concerned with the goals of achieving structural autonomy from other university departments, in order that they might determine their own future.[75] As one observer put it, independent computer science departments were necessary "to allow freedom of choice in policy that can respond to the rapidly changing situations . . . without the constraints imposed by an existing structure designed to cope with situations which no longer exist."[76]

At the University of Toronto, the Computation Centre was able to initiate this process in 1962 with the creation of the Institute of Computer Science (ICS). The new Institute recognized both the new phrase "computer science," in that it replaced the Computation Centre and introduced a new emphasis on academic computer activity with the ability to co-supervise graduate students. Toronto had the supposed advantage of early entry but, as historian William Aspray has shown, this could easily have been a curse. Many schools in the United States in similar positions failed to transform their success in the 1940s and 1950s into strong computer science programs in the 1960s.[77] Yet Toronto had a considerable amount of blind luck on its side. In particular, the outside decision to cancel the UTEC and forge ahead with the Ferut was fortuitous, as Toronto was able to gain very early expertise in computer applications and scientific computation: this expertise was a key element in the development of computer science. Most other universities with computers in the early 1950s were more concerned with building future computers, and not necessarily with the problems of using them. Toronto also lacked relevant competition from other Canadian universities until the 1960s in terms of staffing or attracting students. However, it did face the uphill battle of converting the established Computation Centre from a service department into an academic one. It was not until 1962 that the arrival of the IBM 7090 and the growing interdisciplinary use of the facility convinced the university's administration that the study of computing contributed both depth and breadth to the school, and was now a vital component of academia. Computer science had arrived in Canada, though the ICS was but a halfway measure. It lacked autonomy for both its cross-appointed faculty and co-supervised students.

It took a further two years to acquire complete independence. In 1964 the first graduate department of computer science in Canada was created at the University of Toronto to take over the academic functions of the ICS. Internally, there had been a strong push to acquire the necessary autonomy to direct research, award graduate degrees and establish boundaries for the new discipline.

**Figure 29:** Wes Graham at the console of the University of Waterloo's first computer, an IBM 1620, ca 1963. (Courtesy University of Waterloo Archives, photo 63-1748)

**Figure 28:** The University of Alberta in Edmonton installed an LGP-30 in 1957. (Courtesy Keith Smillie, University of Alberta)

On the outside, competition from other Canadian universities was also increasing. In 1963, the University of Alberta and the University of Western Ontario both announced that they would be forming computer science departments in the next year; the University of Waterloo followed suit not long after. In fact, only Alberta posed an immediate and close threat to Toronto's graduate student activity, as the other two universities were building undergraduate departments. Nevertheless, this would create more intense competition for faculty members, staff and students, as these were all schools with meaningful experience with modern computing. The university in Edmonton had one of the oldest university computing programs, having participated in the remote Ferut project in 1957, installed an LGP-30 later that year and an IBM 1620 in 1961. It also had plans to add an IBM 7040 in 1964. Western's computing program was not quite as old, having only installed an IBM 650 in 1959, but it was led by J. F. Hart, a University of Toronto graduate with considerable computer experience. The University of Western Ontario also had plans to install an IBM 7040 in 1963.

The eventual success of Waterloo's computer science program might not have been particularly obvious in 1963 but, in hindsight, the university did have a few crucial differences that set it apart. Like Alberta, it too had an IBM 1620, and plans to install a 7040 in 1964. However, one of the distinguishing characteristics of Waterloo was its co-operative education program, and determined efforts to establish and maintain tight connections to industry. Its primary focus was a pragmatic undergraduate experience, and a concerted effort to teach as many students as possible the practical skills of programming led it to create student-oriented versions of several computer languages.

In the 1960s, FORTRAN was the programming language of choice among scientists and engineers, but most FORTRAN systems were optimized to reduce program run time at the cost of lengthy compilation and debugging times. This wasn't appropriate for beginner programmers, who have a tendency to make frequent mistakes. For a student using a FORTRAN compiler supplied by the computer manufacturer, a single cycle of submitting a program, getting results, correcting the program and resubmitting it could take a day or more. This was not a suitable environment for learning to program, and so many universities with a large population of undergraduate computer users turned to alternate FORTRAN compilers that provided more immediate feedback and useful diagnostics to ease debugging.

At Waterloo, the choice for its IBM 1620 was FORGO, a student-oriented version of FORTRAN developed at the University of Wisconsin that better fit the university's needs. When Waterloo's IBM 7040 arrived in late 1964, a student-oriented FORTRAN compiler for the 7040 was not available yet, so four undergraduates were selected to write one, supervised by two faculty members. Known as WATFOR (Waterloo FORTRAN IV), it was completed in September 1965 and became an immediate success. The IBM 7040 was a popular choice for Canadian universities unable to afford the more desirable but much more expensive IBM 7090, and so many schools in Canada and abroad, including industrial or scientific programmers who preferred WATFOR's diagnostics to the IBM-supplied version of FORTRAN, found it useful on their own machines as well.

Waterloo soon found itself at the hub of a busy network of highly satisfied WATFOR users. Requests soon began arriving for a version that would work on IBM's System/360, a new and powerful series of computers that replaced both the 7040 and 7090. Although Waterloo had its own System/360 on order, it was cautious about such a development effort. For the 7040 version, Waterloo made copies of WATFOR free to anyone who sent in blank media but, as other universities with similarly popular programs discovered, maintenance and documentation costs could be high, and doing the same for what would likely be a vastly larger number of System/360 systems would be prohibitively expensive. In keeping with its entrepreneurial nature, the university decided that, instead of giving copies away, it would charge users just enough to cover the various costs involved. Charging this relatively small fee enabled Waterloo to continue its efforts, and 360 WATFOR—finished in April 1967—was phenomenally successful around the world. Hundreds of thousands of students learned how to program with WATFOR, and the money raised enabled Waterloo to develop additional student-oriented software. There is little doubt that the WATFOR project helped put the young university on the international stage. In 1972, the two leaders of the 360 WATFOR team, Paul Cress and Paul Dirksen, shared the ACM's Grace Murray Hopper Award, given to an outstanding young computer professional each year.

Technically, neither version of WATFOR was particularly revolutionary or innovative; instead, recognition should go to Waterloo's solid commitment to practical, low-cost educational software, and a focus on providing a valuable undergraduate computing experience, an approach that paid off. By the early 1980s, the University of Waterloo's computer science program was recognized as among the top in the world, comparable to MIT, Stanford or Carnegie Mellon.[78]

**Figure 30:** Installing the IBM 7040 at Waterloo, ca 1964. WATFOR was originally written for this computer, a relatively popular model among most Canadian universities. (Courtesy University of Waterloo Archives, photo 2003-12-60)

## 3.4 Conclusion

Though Canadian engineers and scientists were unable to establish a meaningful domestic computer manufacturing industry during this period, early adopters of computers did not suffer a similar rate of failure. American manufacturers were able to penetrate the Canadian market quickly, and established similar sales patterns to those in the United States, which is to say that IBM was the dominant force, with the IBM 650 by far the most popular computer in Canada until the early 1960s, though there were occasional surprises, such as Sun Life's choice of a UNIVAC II.

That the University of Toronto turned away from designing computers toward using them at such an early stage should be recognized as a crucial turning point for Canadian computing. The Ferut was one of the first computers in the world to be purchased commercially and installed outside a government or military agency, and Toronto was certainly one of the first universities in the world to turn away from computer design in favour of computer applications (even if the decision was forced). This new focus gave Canadians certain advantages. The Ferut's assistance with the St. Lawrence Seaway backwater calculations provided negotiators with immediate and direct rewards. At the same time, there were many indirect benefits in having hundreds of people learning to program via TRANSCODE and making the Ferut available to test corporate computer plans. It is unlikely that KCS Data Control and H. S. Gellman and Company would have formed when they did, if at all, had a full-scale UTEC been under construction in the early 1950s. It is difficult to say if this would have altered the computing landscape, perhaps demoting Toronto as the defacto headquarters of activity. The city of Toronto was already home to IBM Canada and several other important corporate headquarters, but perhaps a boost provided by military and atomic research closer to Ottawa would have led to a more balanced outcome between Toronto, Ottawa and perhaps Montreal in terms of computer ownership and usage.

## Notes

1. Vivian Bowden, "The Language of Computers," *American Scientist* 58 (January 1970): 43–53.
2. I. Bernard Cohen, "Howard Aiken on the Number of Computers Needed for the Nation," *Annals of the History of Computing* 20, no. 3 (1998): 27–32.
3. William H. Watson and Calvin C. Gotlieb, *Submission to the Royal Commission on Canada's Economic Prospects* (Toronto, ON: Computation Centre, University of Toronto, October 1955), 1.
4. Beverley J. Bleackley and Jean La Prairie, *Entering the Computer Age: The Computer Industry in Canada: The First Thirty Years* (Agincourt, ON: The Book Society of Canada, 1982), 29.
5. Ibid., 46–47.
6. For more information about the DRTE computer see John N. Vardalas and Teddy Paull, "Early Computer Development at the Canadian Defence Research and Telecommunications Establishment" (Computer History Research Project, National Museum of Science and Technology, 1986); Linda Petiot, "Dirty Gertie: The DRTE Computer," *Annals of the History of Computing* 16, no. 2 (1994): 43–52; and John N. Vardalas, *The Computer Revolution in Canada: Building National Technological Competence* (Cambridge, MA: MIT Press, 2001).
7. Edward Jones-Imhotep, "Disciplining Technology: Electronic Reliability, Cold-War Military Culture and the Topside Ionogram," *History and Technology* 17, no. 2 (2000): 130.
8. Ibid., 161.
9. A flip-flop is a circuit that has two stable states and is often ideal for storing a single binary digit of information, i.e., a 0 or 1.
10. This DAR, built by members of the DRTE computer team, was used to quickly record and tag information generated by a rocketry program at the Prince Albert Radar Laboratory.
11. See John N. Vardalas, "The NRC Computer" (Computer History Research Project, National Museum of Science and Technology, 1986).
12. Separating data and program storage is known as "Harvard architecture," after the series of automated calculators and computers designed by Howard Aiken at Harvard in the 1940s and early 1950s.

13. See Norman R. Ball and John N. Vardalas, *Ferranti-Packard: Pioneers in Canadian Electrical Manufacturing* (Montreal, QC: McGill–Queen's University Press, 1994); Alan Dornian, "ReserVec: Trans-Canada Air Lines' Computerized Reservation System," *Annals of the History of Computing* 16, no. 2 (1994): 31–42; John N. Vardalas, "From DATAR to the FP-6000: Technological Change in a Canadian Context," Annals of the History of Computing 16, no. 2 (Summer 1994): 20–30; and Vardalas, The Computer Revolution in Canada.
14. Aside from Vardalas's work on the subject, see Dornian, "ReserVec: Trans-Canada Air Lines' Computerized Reservation System." For a contemporary description, see L. C. Richardson, "The Electronic Reservation System for Trans-Canada Airlines," in Computing and Data Processing Society of Canada 2nd Conference: June 6,7, 1960, Proceedings (Toronto: University of Toronto Press, 1960), 24-43."
15. FP stands for Ferranti-Packard; Ferranti Canada had recently merged with Packard Electric.
16. Scott M. Campbell, "The Premise of Computer Science: Establishing Modern Computing at the University of Toronto (1945–1964)" (Ph.D. thesis, Institute for the History and Philosophy of Science and Technology, University of Toronto, 2006).
17. See John N. Vardalas, "The Sperry Gyroscope Co. of Canada's UMAC 5: A Canadian First in Computer Numerical Control" (Computer History Research Project, National Museum of Science and Technology, 1986); John N. Vardalas, "Moving Up the Learning Curve: The Digital Electronic Revolution in Canada, 1945–1970" (Ph.D. thesis, University of Ottawa, 1998); and Vardalas, *The Computer Revolution in Canada.*
18. Vardalas, *The Computer Revolution in Canada*, 198.
19. Vardalas, "The Sperry Gyroscope Co. of Canada's UMAC 5."
20. See Vardalas, *The Computer Revolution in Canada*, 223–74.
21. Ibid., 237.
22. Ibid., 244.
23. Ibid., 237.
24. See Scott Campbell, "Backwater Calculations for the St. Lawrence Seaway and the First Computer in Canada," *Canadian Journal of Civil Engineering* (forthcoming).
25. "Backwater" refers to the changes in upriver water flow and water levels that would come about due to the deepening of the St. Lawrence for larger ships, and to the construction of a power dam at Cornwall.
26. Christopher Strachey was an employee of the British National Research and Development Corporation (NRDC), an organization designed to exploit and patent British technology; the NRDC had agreed to loan Strachey to the Canadian group to help promote the Ferranti Mark I. Martin Campbell-Kelly, "Christopher Strachey, 1916–1975: A Biographical Note," *Annals of the History of Computing* 7, no. 1 (1985): 25, 27.
27. See Calvin C. Gotlieb, "Backwater Computations for the St. Lawrence Power Project, Part B: Backwater Calculations on the Ferranti Digital Computer," *The Engineering Journal* 43, no. 2 (February 1960): 61–66; and H. M. McFarlane, "Backwater Computations for the St. Lawrence Power Project, Part A: Hydraulic Engineering Aspects of Computations," *The Engineering Journal* 43, no. 2 (February 1960): 55–60, 66.
28. See J. L. Howland and Keith W. Smillie, "Some Mathematical and Programming Techniques Employed in the Operation of a Scientific Computing Facility," in *Canadian Conference for Computing and Data Processing, Proceedings* (Toronto, ON: University of Toronto Press, 1958), 78–87; and Keith W. Smillie, "Velvet Gloves and Latin Squares: Memories of Some Early Computing in Canada," in *Canadian Information Processing Society*, Session 84, Proceedings, ed. L. Gotlieb (Toronto, ON: Canadian Information Processing Society, 1984), 323–26.
29. The NMAA and NTMS would eventually merge and become the Data Processing Management Association. See Eddie Ashmore, Interview with Daniel Willis, Charles Babbage Institute, 23 August 1985.
30. Bleackley and La Prairie, *Entering the Computer Age*, 20.
31. Atsushi Akera, "Voluntarism and the Fruits of Collaboration: The IBM User Group SHARE," *Technology and Culture* 42, no. 4 (October 2001): 710–36.
32. SHARE had only three Canadian members in 1962, including IBM's own Toronto Data Centre. Beatrice H. Worsley, "News of Toronto and the Toronto Section," *CDPSC Quarterly Bulletin* 3, no. 2 (January 1963): 12.
33. See Samuel B. Williams, "The Association for Computing Machinery," *Journal of the ACM* 1, no. 1 (1954): 1–3.
34. J. W. Forrester and R. W. Hamming, eds., ACM '52: Proceedings of the 1952 ACM National Meeting (Toronto) (New York: ACM Press, 1952).
35. Robert F. Johnston, "The University of Toronto Electronic Computer," in *ACM '52: Proceedings of the 1952 ACM National Meeting* (Toronto).
36. William H. Watson, "On Learning to Do Better," in *Canadian Conference for Computing and Data Processing, Proceedings* (Toronto, ON: University of Toronto Press, 1958) , 1–5.
37. J.N.P. Hume, "The Promise of Computer Science," in *Proceedings of the Fourth National Conference, Computing and Data Processing Society of Canada, University of Ottawa, 1964* (Toronto, ON: University of Toronto Press, 1964), 3–8.
38. H. O. McNutt, "Planning a Data Processing System," in *Canadian Conference for Computing and Data Processing, Proceedings* (Toronto, ON: University of Toronto Press, 1958) , 29–41 .
39. James W. Cortada, *Before the Computer: IBM, NCR, Burroughs, and Remington Rand and the Industry They Created, 1865–1956* (Princeton, NJ: Princeton University Press, 1993).
40. Calvin C. Gotlieb and J.N.P Hume, *High-Speed Data Processing* (New York: McGraw-Hill, 1958).
41. In the case of "in-line" and "loop," *High-Speed Data Processing* is listed as having the earliest citations.
42. H. Campaigne, "Review: High-Speed Data Processing," *Mathematical Tables and Other Aids to Computation* 12, no. 64 (1958): 315–17.
43. Scott M. Campbell, "The Premise of Computer Science: Establishing Modern Computing at the University of Toronto (1945–1964)" (Ph.D. thesis, Institute for the History and Philosophy of Science and Technology, University of Toronto, 2006).
44. When the Ferut was decommissioned at the University of Toronto in 1958, it was passed on to the NRC, where it was used in the Division of Chemical Engineering until the mid-1960s.
45. Paul E. Ceruzzi, *A History of Modern Computing* (Cambridge, MA: MIT Press, 1998), 43.
46. Bleackley and La Prairie, *Entering the Computer Age,* 17.
47. Ibid., 30.
48. Vardalas, *The Computer Revolution in Canada*, 129.
49. For a good introduction to early computer use by the Canadian insurance industry, see Nicholas Bergeron, "Insurance Industries, Computers, and the University of Toronto: Creating a Network of "Informatisation"" (HPS2000Y Research Paper, Institute for the History and Philosophy of Science and Technology, University of Toronto, 2001).
50. H. W. Rowlands, "The Canadian Scene in Computing and Data Processing," in *Canadian Conference for Computing and Data Processing, Proceedings* (Toronto, ON: University of Toronto Press, 1958), 295.
51. "Automation Machine Ends Office Drudgery," *The Globe and Mail* (23 March 1956): 10.
52. Cited in Bergeron, "Insurance Industries, Computers, and the University of Toronto," 21.
53. Sun Life had installed an IBM 650 in May 1956, as an interim machine, but declined to make much use of it, preferring to wait for the UNIVAC II and to avoid the expense of rewriting any software.
54. J. H. Chung and Calvin C. Gotlieb, "Test of an Inventory Control System on FERUT," *Journal of the ACM* 4, no. 2 (1957): 121–30.
55. Rowlands, "The Canadian Scene in Computing and Data Processing," 296.
56. Bleackley and La Prairie, *Entering the Computer Age*, 22.

57. A. A. MacKey, "Data Processing at the Canadian National Railway," in *Canadian Conference for Computing and Data Processing Proceedings* (Toronto, ON: University of Toronto Press, 1958), 67–77.
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**CHAPTER FOUR**

# MICROCOMPUTING IN CANADA

# 4 Microcomputing in Canada

## 4.1 Introduction

Until the mid-1970s, computing was expensive and dominated by large mainframes and smaller, but still expensive, minicomputers. The high cost of computing had a direct impact on the number and processing power of computer equipment installed in Canada in that period. According to the 1975 Canadian Computer Census, based on data prepared by the Canadian Information Processing Society and published in the CIPS Computer Magazine (vol. 7, no. 1), there were 2 037 digital computers and process controllers in 1969, the majority in Ontario (1 045) and Quebec (485) and only one in Prince Edward Island. By 1974, the total number of such equipment had risen to 3 897, with the majority of installations still in Ontario (1 894) and Quebec (879). Individual and interactive use of computers was possible only on time-sharing systems, a popular technique that allowed multiple users (almost) simultaneous access to the system's resources.

In the fall of 1971, Intel Corporation of Santa Clara, California, announced a new era in integrated electronics, to be brought about by the microprocessor—the company's novel semiconductor device that realized a computer's central processing unit (CPU) on a single integrated circuit. Intel promoted its early microprocessors by claiming that they offered the power and flexibility of a dedicated general-purpose computer at a low cost.

By 1975, most of the major semiconductor companies offered their own four- and eight-bit microprocessors. These novel devices created an opportunity for companies as well as individuals to design and manufacture inexpensive computer hardware. Early microprocessor-based computers, or microcomputers, presented a cost-effective and low-maintenance alternative to high-performance minicomputers that dominated the computer scene in the 1970s. Their utilization was confined largely to applications that did not require the full processing power of the minicomputers. More importantly, the realization of the idea of a "computer on a chip" unleashed engineering creativity and social forces that, when converged, created the foundation of the microcomputer industry and the personal computer movement, which were to bring such profound changes to society. The personal computer was born—an affordable, general-purpose computer for personal use.

By the end of the first decade of its development, the microcomputer industry was already engineering a major shift toward microprocessor-based computing and information technologies. The industry was manufacturing all kinds of practical computers by the million. By the end of the 1980s, microprocessor-based computing had become a major force in redefining modern society and engineering its digital future.

This chapter covers the first years of microcomputing in Canada. Canadian firms participated actively in the formation of the microprocessor and microcomputer industries by creating unique products and technologies and making them available worldwide. They were among the first electronics firms to fully recognize and take advantage of the emerging microprocessor technology. Some unique aspects of the Canadian computer scene of that period were the focus on affordable, public access to computing and digital services, and the significant involvement of the federal government (through technological and industrial initiatives, as well as high-tech development grants).

The history of computing in Canada in the 1970s and 1980s is a vast subject, which includes many important technological initiatives outside of microcomputing that cannot be covered adequately in a single monograph. For this reason, the corporate histories of companies such as ATI Technologies Inc., Bell Northern Research, Consolidated Computer, Corel, Geac, Gandalf Technologies Inc., I. P. Sharp Associates, Mitel, Mosaid Technologies, Newbridge Networks, Norpak Corporation, Rapid Data, Remanco and Targa Systems, to name just a few, and initiatives such as the Telidon videotex system have been mostly omitted from this survey.

## 4.2 The Beginning of the Semiconductor Industry in Canada

In 1966, the Canadian Department of Industry estimated that Canada's trade imbalance in the computer industry reached $60 million in that year alone, and projected that the imbalance would increase steadily in future years. The Department also concluded that the lack of computer manufacturing, and research and development (R&D) in Canada damaged the Canadian economy in a number of ways: lost employment, underutilization of skilled human resources and unnecessary support of foreign R&D activities estimated at $10 million in 1966. The Canadian high-tech industry could not properly develop and stay competitive in the world's markets without investing in electronics. Electronics, especially microelectronics, was viewed as the most important sector of the economy and an inability to develop it would put Canada in a position of technological inferiority and overdependence on foreign economies.

Between 1966 and 1968, the Department of Industry conducted an intensive search for a possible partnership to establish Canadian facilities for designing and manufacturing computer equipment. In the end, the government teamed up with Northern Electric Company, Bell Canada's wholly owned manufacturing arm, which had already established the Advanced Devices Centre in Ottawa to research, develop and manufacture discrete devices such as transistors, diodes and some integrated circuits. In support of its choice of partner, the government stressed that "[t]he Northern Electric Company[,] has the product 'know-how,' the research capability, the user relationship, the market access, the management competence, the need and the corporate commitment which when combined with adequate Government assistance provides an excellent opportunity for the development of an efficient, internationally competitive and self-sustaining production facility in the microelectronics area for Canada."[1]

In October of 1968, with a $48 million package from the Canadian Treasury Board, Northern Electric transformed its Advanced Devices Centre into a new company called Microsystems International Ltd. (MIL). In March 1969, MIL opened its doors, with its headquarters in Montreal and its manufacturing facility in Ottawa. The company's focus was to be on new semiconductor technologies and products. In a short period of time, MIL acquired state-of-the-art integrated circuit technologies and the second-source rights to a number of products. MIL reached one of the most important agreements with Intel Corporation on 2 July 1970. In 1970, Intel was one of a very few semiconductor manufacturers in possession of MOS (metal oxide silicon) silicon-gate process capable of delivering integrated circuit devices of vast complexity cost-effectively. It was Intel's MOS technology that enabled the company to develop and offer to the electronics market a successful line of semiconductor memories and the world's first single-chip microprocessors—the Intel 4004 in 1971 and the 8008 in 1972. Under the terms of the agreement between MIL and Intel, the Canadian company was to get MOS silicon-gate technology and the second-source rights to Intel's semiconductor memories. Intel was to set up a production line for MOS integrated circuits at MIL's Ottawa facility and guarantee the critically important quality performance. Later, MIL would also acquire the second-source rights to Intel's 8008 microprocessor.

MIL was rapidly gaining expertise in the design and production of semiconductor memories. The company's memory products, such as the MF1101, MF1103, MF1701 and MF1702 devices, and the MF8008 microprocessor placed the company among the semiconductor leaders in the international market. MIL was the first company to bring a 4 096-bit dynamic RAM chip to market. The company was growing fast: to strengthen its manufacturing capabilities and international presence, it opened an assembly plant in Malaysia, subsidiaries in Germany, Malaysia and the United States, and international marketing offices in the United States, United Kingdom, Belgium and Germany.

MIL recognized immediately the importance of Intel's new microprocessor devices and their potential impact on microelectronics. Not only did MIL acquire the second-source rights to Intel's 8008 microprocessor (MF8008), but it also initiated the development of new microprocessors. The four-bit MF7114 microprocessor was developed by MIL between 1970 and 1972 (cf. Fig. 32), and the eight-bit MF8080 (modelled after Intel's 8080 microprocessor) was offered in early 1975.

MIL also designed and manufactured three microcomputers. The first of these devices was the CPS/1 system, designed in 1972–1973 around the four-bit MF7114 microprocessor. MIL began advertising its CPS/1 computer and the MF7114 microprocessor in late 1972 (cf. Figure 32). Though only


**Figure 31:** The MIL MP-1 chip set, consisting of the MF7114 CPU, the MF1601 ROM and the MF7115 RAM. Image of MIL's MP-1 promotional paperweight. (Courtesy York University Computer Museum)

a few CPS/1 systems were sold (mainly due to financial difficulties at MIL that forced the company to close the CPS/1 microprocessor hardware and software projects), the computer is an example of one of the very first microcomputers designed specifically for the commercial market.

MIL's first eight-bit microprocessor—the MF8008—required hardware and software tools that the company could offer to those customers who wanted to build the MF8008-based applications. To this end, in 1973 MIL designed and manufactured another small computer—the MOD8. The *MF8008 Applications Manual*, published by MIL in 1974, provided, among other technical information, a detailed design and the technical specifications of the MOD8 computer and the listing of its MONITOR8 software.

The MOD8 (and its successor, the MOD80) was intended as a development tool for systems engineers. However, it was also used by North American computer enthusiasts, who made the MOD8 a popular 8008-based microcomputer kit in 1975 and 1976, and the *MF8008 Applications Manual* one of the most widely read early documents on eight-bit microprocessors.

Despite MIL's broad range of high-quality products and its strong international presence, the company never made a profit. From 1972, the sales shot up, but so did the losses ($4.2 million in 1972, $10.1 million in 1973, $10.5 million in 1974). In spite of a reorganization to bring operating expenses in line with declining demand for semiconductor products, followed by management shuffles and employee layoffs, the company closed its operations in June 1975. However, MIL's demise seeded the Canadian high-tech sector with scores of semiconductor, computer and telecommunications start-ups founded by former MIL employees. New companies took advantage of the scientific and engineering knowledge built at MIL to develop innovative products ranging from microprocessor-based hardware and telecommunications equipment to integrated circuit designs. Some of these companies grew into successful, internationally renowned firms. Mitel, co-founded by Michael Cowpland and Terence Matthews, serves as one example. It quickly became a market leader for small microprocessor-based telephone switch equipment (PBX or Central Office).

Another successful company with its roots in MIL was Mosaid Technologies, co-founded in Ottawa by Richard Foss and Robert Harland. At MIL, Foss had headed the semiconductor memory design group, among other responsibilities; he had also been a member of the CPS/1 microcomputer group. Mosaid's main line of business was DRAM (dynamic random access memory) chip design. The company's first memory product—the four-kilobyte DRAM chip—had been, in large part, developed at MIL. Later, Mosaid's pioneering work on CMOS devices resulted in a number of significant early CMOS patents that laid the foundation for the company's present business of licensing intellectual property.[2]

## 4.3 Personal Computing in Canada, 1973–1985

There are many ways in which to render the term "personal computer." In this monograph, we use the term in reference to a general-purpose digital computer built around a microprocessor and designed specifically for personal use. This definition distinguishes personal computers not only from computing devices that did not use microprocessors (e.g., all computers manufactured until 1971, including the relay-based Simon "personal computer" designed by E. Berkeley in the late 1940s), but also from the microprocessor-powered hardware designed exclusively for specific applications (e.g., electronic calculators and controllers). Canadian companies were among the world's first firms to design and manufacture microprocessor-based computers for personal use. This section discusses the formation of the personal computer industry in Canada.[3]

### 4.3.1 Micro Computer Machines

The design work on microcomputers for the commercial market began soon after the announcement of the first four- and eight-bit microprocessors by Intel. In 1972, the prototypes of the first microcomputers were operating on-site at Réalisations et Études Électroniques (R2E), located in the suburbs of Paris (the Micral computer), at Micro Computer Machines (MCM), with its headquarters situated on the outskirts of Toronto (the MCM/70 computer), and at MIL (the CPS/1 computer).

The world's earliest microcomputer designed specifically for personal use was possibly the MCM/70, first demonstrated by MCM in May 1973 during the Fifth International APL Users' Conference in Toronto. The computer was developed primarily to serve the computational needs of individuals in areas ranging from business and research to education. It was meant to be affordable and as easy to use as a hand-held calculator. It was also MCM that explicitly used the term "personal computer" for the first time. The MCM/70, invented by Mers Kutt, the founder and first president of MCM, was a remarkable machine for its time. In comparison with minicomputers of the time, it was very small, portable, inexpensive, and programmable in a sophisticated APL programming language. The computer was

**Figure 32:** The MCM/70 personal computer.
(Courtesy York University Computer Museum)

designed in a desktop style with a small plasma display, built-in keyboard, and up to two cassette drives mounted on the top of the case. The computer's hardware was built around the Intel 8008 microprocessor—the world's first, commercially available eight-bit CPU on a single chip.

The first shipments of the MCM/70 began in 1974. The computer was sold in North America and Europe. In the United States and Canada, the MCM/70 computers were operated by, among other institutions and agencies, the Chevron Oil Research Company, Firestone, the Toronto Hospital for Sick Children, the Mutual Life Insurance Company of New York, the Ontario Hydro-Electric Power Commission, the NASA Goddard Space Flight Centre and the U.S. Army.

The MCM/70 was followed by models MCM/700 (1975), MCM/800 (1976), MCM/900 (1979), Power System and Mini-Power (1980). Financial difficulties forced MCM to close its operations in May 1982.[4]

## **4.3.2** Dynalogic Corporation

Dynalogic Corporation was among the first Canadian microcomputer manufacturers. Founded by C. Murray Bell in Ottawa in 1973, it initially focused on the design of floppy disk systems and interfaces for minicomputers and desktop calculators. In 1975, Dynalogic embarked on the design of a firmware-controlled, microprocessor-based floppy disk system that could be interfaced with a range of minicomputers via the industry standard RS-232C interface. The result of these R&D efforts—the Series 7000DynaTermDisk—was presented at the 1975 Canadian Computer Show.

In 1976, the company moved into the general-purpose computer market. On 1 October 1976, it announced the Dynalogic Microcomputer System (DMS)—an advanced


**Figure 33:** The Dynalogic DMS-8 microcomputer.
(Courtesy York University Computer Museum)

microcomputer that employed Motorola's 6800 processor. The DMS was among the earliest microcomputers with built-in floppy disk drives. It operated under a sophisticated proprietary DYNAMO operating system. The first DMS was delivered to Algonquin College of Technology in Ottawa in the fall of 1976. Other DMS systems were sold in Canada, the United States and Europe.

In 1981, Bytec Management Corporation took over Dynalogic. In the same year, work had begun on the design of a portable desktop microcomputer—the Hyperion—and this continued at a new Bytec subsidiary called Dynalogic Info-Tech. The Hyperion was unveiled at the 1982 spring COMDEX computer show in Atlantic City; Dynalogic promoted it as the "most powerful, portable, business computer in the world." The first Hyperions were manufactured in January 1983, and the sales continued throughout 1983 and 1984 in Canada and the United States. The Hyperion quickly became the best-known Canadian personal computer. Hyperion user groups sprang up across Canada (see Table 7).[5]

**Figure 34:** The Bytec Hyperion personal computer.
(CSTM, 2001.0013)


**Figure 35:** Commodore 202 calculator, 1962. (Courtesy York University Computer Museum)

**Figure 36:** Commodore C110 calculator, 1969. (Courtesy York University Computer Museum)

## **4.3.3** Commodore Business Machines

Commodore was founded in 1958 by Polish-born Jack Tramiel as a small typewriter sales and repair shop located in downtown Toronto. The company went public in 1962 as Commodore Business Machines, Canada. Over the years, Commodore became a major player in the adding machine and electronic calculator markets, and then in the microcomputer industry. The C110 calculator, one of the first hand-held calculators, was a product of Commodore Business Machines (Canada) Ltd. (1969).

In the 1970s and 1980s, the company had a profound impact on personal and home computing all over the world. Commodore entered the microcomputer market in 1976 with its purchase of MOS Technology and, with it, the KIM-1 single-board microcomputer. At the first West Coast Computer Fair in San Francisco in April 1977, Commodore launched its PET 2001 all-in-one computer. Twenty-five thousand PETs were sold by Commodore in 1977 and 1978 alone. In 1980, the VIC-20 home computer was unveiled and, soon after, was manufactured by, among other companies, Commodore Business Machines (Canada) in its plant in Agincourt, Ontario.

**Figure 37:** Commodore VIC-20 home computer, manufactured by Commodore Business Machines (Canada) of Agincourt, Ontario. (Courtesy York University Computer Museum)

By the end of 1982, there were over 800 000 VIC-20s worldwide. Sales reached one million in early 1983, when Commodore was shipping its small computers at the rate of 100 000 units a month. The Commodore C64 computer, which replaced the VIC-20, was even more successful.

Commodore's history and impact on home and desktop business computing are well researched and documented.[6] Perhaps a lesser-known chapter in Commodore's corporate history is the making of the Commodore SuperPET computer (the SP9000). The SuperPET story began in 1979 with a study on the state of academic computing at the University of Waterloo in Waterloo, Ontario. One of the main conclusions of the study was that many educational objectives could be achieved economically with microcomputers instead of expensive mainframe computers. However, there were a few serious obstacles in the way of implementing the introduction of inexpensive microcomputers into the educational system at Waterloo. First, none of the off-the-shelf microcomputers could support the advanced software that the Waterloo researchers wanted to run (due, among other problems, to insufficient memory and inadequate handling of input/output). Second, none of the microcomputers on the market was supported with programming tools compatible with the software used by the university.

Therefore, it seemed reasonable to develop the necessary hardware and software at the university. The required microcomputer software could be developed on the basis of work done by Waterloo's Computer Systems Group, headed by James Wesley Graham. The group had gained international recognition for its software products (Waterloo FORTRAN—WATFOR and WATFIV, Waterloo COBOL—WATBOL, Waterloo word processor SCRIPT). As for hardware, the Computer Systems Group had prior experience with the Commodore CBM 8032 (the group had developed the Waterloo BASIC for the CBM/PET). It was therefore decided to convert the 8032 computer into a "micro-mainframe" by expanding its hardware capabilities. (There was an alternative hardware program that resulted in the development of the MicroWAT computer by Northern Digital Ltd. of Waterloo; an early prototype of the MicroWAT was operational in December 1980, and dozens were produced in 1981 and 1982, cf. Figure 54.)


**Figure 38:** The Commodore SuperPET microframe. (Courtesy York University Computer Museum)

The general architecture of the Commodore SuperPET computer was the work of Waterloo's Computer Systems Group, but the concept was fully developed into a working prototype by BMB CompuScience Canada Ltd. of Milton, Ontario. In 1981, the production and sale of the SuperPET began under licence from BMB. The computer provided full support for the new Waterloo microSystems Language Processors Package (which consisted of microAPL, microBASIC, microFORTRAN, microPASCAL and microEDITOR software) and for the Waterloo microSYSTEMS Supervisor—the SuperPET operating system.

The success of the SuperPET was limited and short-lived mostly because of the introduction and instant success of the IBM PC in 1981.

## 4.3.4 NABU Manufacturing Corporation

Since the early 1970s, much effort had been expended around the world on bringing a range of electronic information services directly to homes and offices by utilizing the common-carrier telephone line, television (TV) cable, or other interactive network or broadcast system. These home and business information services, such as trendy videotex systems, typically provided two basic types of service: information retrieval (national news, stock market data, sports) and transaction services (home banking, home shopping, home travel agent services, etc.). For example, a videotex system allowed users to retrieve information stored in computer-controlled databases and have it displayed on their home TV sets or dedicated video-display terminals.

In 1978, Canada had joined the videotex community by announcing its Telidon videotex system, developed by the Communications Research Centre, Canada's leading federal communications R&D laboratory. For residential applications, Telidon used an ordinary TV set with a Telidon adaptor and a push-button keypad for navigating the Telidon service guide and for accessing the desired information.


**Figure 39:** Telidon videotex system. (CSTM 1985.0382)

However, in spite of global R&D efforts, most videotex systems were unable to become dominant information service systems. They could not sufficiently address critical issues such as transmission speeds or the ability to evolve from a purely broadcast model of services to a fully interactive one. Since the early 1980s, North American households had been turning their attention to home and personal computers rather than to videotex services. Inexpensive computer modems for home computers, such as the popular VICmodem for the Commodore VIC-20, allowed a large number of people to go on-line and try electronic mail or browse through the libraries of information available on local bulletin board systems (BBSs) and commercial computer networks for the first time. A number of on-line information services, such as CompuServe, Delphi, the Dow-Jones News Retrieval Service, MicroNET and The Source, owed their popularity and growth to the low-cost modems for home computers.

The idea of providing more interactive videotex services to homes and schools, based on the convergence of computer and communications technology, was fully explored for the first time by NABU Manufacturing Corporation, founded in Ottawa by John Kelly. Between 1981 and 1983, NABU Manufacturing designed and implemented its NABU Network. The network was based on the concept of home personal microcomputers linked to cable TV networks, which could supply a constant

**Figure 40:** The NABU PC. (CSTM 1991.0391)

stream of computer programs and information to an almost unlimited number of users at high speed (at the rate of 6.5 megabits per second with the use of cable TV). Subscribers to the NABU Network rented or bought a general-purpose NABU Personal Computer (NABU PC), together with a dedicated network adaptor, and used an ordinary TV set as a display monitor. Once connected to the network, a user could choose from various application programs and services in such categories as entertainment (mostly computer games), information and guides, education (including educational programming for schools) and professional programs (ranging from home financing to programming languages). Dedicated NABU magazines, newsletters, programming guides and user groups provided subscribers with supplementary information and support. The NABU PC could also be used as a stand-alone personal computer.

The NABU Network was an innovative attempt to radically reshape the principles of personal computer-based public access to services and programming. After its official launch on Ottawa Cablevision in October 1983, the NABU Network was introduced by Ottawa's Skyline Cablevision in 1984 and, a year later, in Sowa, Japan, via a collaboration between NABU and ASCII Corporation. However, financial difficulties led NABU Network Corporation (formerly NABU Manufacturing) to close down its operations in August 1986. The broadcasting technology built up at NABU was acquired, developed and successfully deployed internationally by International Datacasting of Kanata, Ontario.

Apart from the NABU PC, NABU Manufacturing developed other microcomputers, including the NABU 1600 desktop and the NABU 1100 workstation.[7]

## **4.3.5** Other Canadian Microcomputer Manufacturers

Commodore, Dynalogic, MCM and NABU were not the only Canadian companies that manufactured microprocessor-based hardware products in the 1970s and 1980s. From east to west, the Canadian microcomputing landscape had been saturated with a variety of companies, from small firms such as Ottawa area-based Mini-Peripherals, Great Northern Computers and Tarot Electronics, and Toronto-based J.L.S. Computers, Lanpar Technologies and Nelma Data Corporation, to large corporations, such as Automatic Electronic Systems (AES), DY 4 Systems, Matrox Electronic Systems, Micom Data Systems and Northern Telecom. While U.S. imports dominated the Canadian microcomputing market,[8] Canadian-made microcomputer products were finding their way into business offices, research institutions,


**Figure 41:** Mini-Peripherals M101 microcomputer. (CSTM 1990.0235)

schools and homes.

Most of the Canadian microcomputer companies were developing general-purpose computers, while other firms developed microcomputers with specific applications. NABU Manufacturing designed its NABU PC primarily


**Figure 42:** DY 4 Orion IV computer. (Courtesy York University Computer Museum)


**Figure 43:** Matrox MACS CCB-7 industrial microcomputer. (Courtesy York University Computer Museum)

to support the operation of its NABU Network. Montreal-based Matrox Electronic Systems focused on computer graphics-oriented hardware. In the 1980s, Ottawa-based DY 4 Systems manufactured a number of microcomputers and graphics terminals for educational and office markets before turning to microcomputer products requiring high reliability when operated in rugged or harsh environments. By the mid-1990s, DY 4 had become one of the world's top manufacturers and independent suppliers of computer systems based on the so-called VME (Virtual Machine Environment) open architecture standard and destined for rugged military and aerospace applications.[9]

Table 5 lists some of the Canadian manufacturers of microcomputers and digital word processors between 1973 and 1985.

## 4.4 Industrial Microcomputers

A variety of industries, such as telecommunications, industrial automation, environmental and medical monitoring and control, space and defence, demand reliable, heavy-duty computer equipment for effective communication, control, data retrieval and processing. Some industrial applications rely on dedicated computer hardware engineered with the highest-quality components to withstand hostile and harsh environments.

Since the mid-1970s, a number of Canadian companies have been involved in the design and manufacture of industrial microcomputers. Possibly the earliest Canadian manufacturer of such computers was MIL. Though its MOD8 and MOD80 computers (discussed earlier) were designed primarily to support the development of rudimentary microcomputer hardware and software, their modular design and low cost made them useful tools for industrial applications that did not require significant computational power, such as rudimentary control systems.

Some Canadian companies had established themselves as industry leaders in the area of high-integrity embedded computer systems for harsh and rugged environments. DY 4 Systems of Ottawa, founded in 1979 and discussed in the previous section, and Toronto Microelectronics, established in 1986 in Mississauga, Ontario, serve as examples. Transduction, founded in 1975 in Mississauga, is another company created to develop world-class microcomputers with high reliability, longevity of product supply, and hardware revision control in mind. Currently, Transduction specializes in reliable rack mount and panel mount computers and disk storage systems for industrial and military applications.

Lorne Trottier and Branko Matic founded Matrox Electronic Systems in Montreal in 1976. The first product launched by Matrox was a specialized video-display device called Video RAM, which interfaced with a computer to display computer-generated alphanumeric data. It was a novel device on the worldwide market. In the 1980s, Matrox manufactured a line of MACS computers for industrial and research applications. Some of these computers found their way to the National Research Council's Algonquin Radio Observatory and are now held at York University Computer Museum. Presently, according to the company's own marketing advertisement (http://www.matrox.com), Matrox stand-alone vision systems represent "a unique combination of embedded PC technology, compact size and ruggedness [which] make Matrox Imaging's stand-alone platform the ideal solution for cost-sensitive machine vision, image analysis and video surveillance applications."

Some Canadian companies developed microcomputer products for their own use rather than buying such products from other manufacturers. In the early 1980s, the Computing Technology Group at Bell Northern Research (Northern Telecom's R&D subsidiary) designed its own workstation—the XMS computer—and equipped it with software. Four

**Table 5:** Some Canadian microcomputer and digital word processor manufacturers, 1973–1985

| Manufacturer | Location | Selected hardware |
|---|---|---|
| Andicom Technical Products | Toronto, ON | S-100 cards, NABU PC |
| Arcon Electronics | Toronto, ON | CP/IO-1 |
| Arisia Microsystems | Mississauga, ON | S-100 systems |
| Automatic Electronic Systems (AES) | Montreal, QC | AES 90 and other AES series word processors |
| BMB CompuScience Canada Ltd. | Milton, ON | SuperPET |
| Canadian Educational Microcomputer Corporation (CEMCorp) | Toronto, ON | ICON ("Bionic Beaver") PCs and servers |
| Commodore Business Machines (Canada) Ltd. | Agincourt, ON | VIC-20, 4+ |
| Computech Micro Designs | Mississauga, ON | Genesys PC |
| CYCOM Systems Ltd. | Willowdale, ON | Snowbird PC |
| dAVID Computers | Kitchener, ON | dAVID |
| DY 4 Systems | Ottawa, ON | Orion, single-board VME computers |
| Dynalogic Corporation | Ottawa, ON | DMS-8, Hyperion |
| Exceltronix Components and Computing | Toronto, ON | Multiflex, 6809 board |
| Great Northern Computers | Ottawa, ON | GNC8, GNC80 |
| HAL Computer Company | Toronto, ON | HAL PCs |
| Harris Data Systems | Scarborough, ON | HDS-80 |
| Innovative Electronics | Burnaby, BC | Proteus PC |
| J.L.S. Computers | Toronto, ON | J.L.S Board, JLS PC, JLS XT |
| Lanpar Technologies | Toronto, ON | Variety of PCs and terminals |
| Logic/One Ltd. | Mississauga, ON | Duramax System 2 |
| Matrox Electronic Systems | Montreal, QC | MACS |
| Megatel Computer Corporation | Weston, ON | Megatel Quark |
| Micom Data Systems | Montreal, QC | Micom 2000 and other Micom series word processors |
| Micro Computer Machines (MCM) | Toronto, ON | MCM/70, MCM700, MCM/800, MCM/900 |
| Microsystems International Ltd. (MIL) | Ottawa, ON | MOD8, MOD80 |
| Mini-Peripherals | Ottawa, ON | M101 system |
| Multibest Industrial & Manufacturing Inc. | Toronto, ON | PC motherboards |
| Multiflex Technologies Inc. | Toronto, ON | Multiflex, 6809 board |
| NABU Manufacturing Corporation | Ottawa, ON | NABU PC, NABU 1100, NABU 1600 |
| Nelma Data Corporation | Toronto, ON | Persona PCs, WORD 70-2 word processor |
| Network Data Systems Ltd. | Toronto, ON | NDS 1000 word processor |
| Northern Digital Ltd. | Waterloo, ON | MicroWAT |
| Northern Telecom | Ottawa, ON | XMS systems |
| Omega Systems Inc. | Toronto, ON | C4P-MF, C2-OEM, C2-D computer systems |
| Orange Computers Inc. | Mississauga, ON | Orange Peel |
| Orcatex Inc. | Ottawa, ON | Orcatex |
| Patrick Computer Systems | Winnipeg, MB | Patrick |
| Protec Microsystems Inc. | Pointe-Claire, QC | Protec PRO-80, PRO-83 single-board computers |
| Seanix | Richmond, BC | Seanix PCs |
| Semi-Tech Microelectronics | Toronto, ON | Pied Piper |
| Soltech Industries Inc. | Surrey, BC | Soltech PCs |
| Spetrix Microsystems Inc. | Markham, ON | Spetrix-100 system |
| Tarot Electronics | Ottawa, ON | Mimic systems |
| TEK | Stoney Creek, ON | TEK-1802 |
| Wynchester Systems & Electronics | Weston, ON | Wynchester PCs |

different models of the XMS workstation were developed. The XMS architecture was extensively used by Northern Telecom as a development platform and as the basis for the company's future products. Several thousand XMS workstations, as well as file and print servers, were manufactured and deployed.

## 4.5 The Clones

In the early 1980s, the North American personal and home computer market was shared among hundreds of manufacturers. Microcomputer sales were climbing, and with them the demand for more sophisticated microcomputer software. In 1980, Apple Computer sold 130 000 Apple IIs, while Tandy sold 175 000 of its TRS-80 computers. Sales of tiny Sinclair ZX-80 and ZX-81 computers, introduced in 1980 and 1981, respectively, had reached 400 000 by 1982. By the end of 1982, there were over 800 000 Commodore VIC-20s worldwide. Sales of Commodore VIC-20s reached one million in early 1983, and the same year both Texas Instruments and Apple Computer also shipped over one million of their TI-99/4A and Apple II computers. These were staggering numbers in comparison with the sales of minicomputers and mainframes worldwide. Though most of the manufactured microcomputers were based on a relatively small number of microprocessors (including Intel 8086 and 8088, Motorola 6800, 6809 and 68000, MOS 6502, Zilog Z80 and Z80A, RCA COSMAC 1802 and Texas Instruments TMS 1000), most of these computers were hardware- and software-incompatible.

On 12 August 1981, IBM announced its IBM Personal Computer (PC), the company's first microcomputer. To IBM's surprise, reaction to its computer from the business community, for years reluctant to embrace microcomputers, was overwhelming. By the end of 1981, IBM had sold tens of thousands of its personal computers and the company could not keep up with demand. IBM sold 538 000 personal computers in 1983, and that number climbed to 1 375 000 the following year.[10]

On the one hand, the success of the IBM PC in the marketplace, which was followed by its informal acceptance as the industry standard for a business desktop computer, had a positive effect on the issue of software and hardware compatibility. A number of software and hardware companies took immediate advantage of the IBM PC's popularity and IBM's disclosure of the machine's design. They began by providing software, plug-in expansion cards and hardware add-ons for the computer. Then, they started to clone it. Cheaper IBM PC hardware- and software-compatible computers started to appear in late 1982. On the other hand, the IBM PC had a devastating effect on the diverse microcomputing landscape. Many computer manufacturers that decided to defend the unique hardware and software makeup of their computers collapsed or had to withdraw from the personal computer market altogether. After the microcomputer market's "correction," the personal computer scene was effectively reduced to two hardware platforms: the IBM PC and the Apple Macintosh.

Many established manufacturers of home and personal computers gave in and started to manufacture new hardware products compatible with the IBM PC and its refinements. By the mid-1980s, these manufacturers, as well as countless microcomputer start-ups, had saturated the vast and lucrative personal computer market with IBM PC-compatible computers and IBM PC clones— inexpensive microcomputers whose hardware and software were compatible with the IBM PC (and, later, with the IBM XT and AT) products. The cloning of the popular Apple II-series computers also became a very profitable enterprise all over the world.

The earliest IBM PC-compatible computers were possibly those manufactured by Compaq Computer Corporation in the United States and Dynalogic Info-Tech in Canada. The Compaq Portable was an inexpensive (and soon popular) alternative to the IBM PC. On the other hand, the Dynalogic Hyperion was neither cheap nor completely compatible. Interestingly, both of these computers were portable.

Compaq and Dynalogic were soon followed by a fast-growing group of other manufacturers that were cloning not only the IBM PC hardware, but also software and documentation, frequently infringing on IBM's copyrights. In many cases, the only thing that visually distinguished an IBM PC clone from the genuine product was the absence of the "IBM PC"' logo on the computer's case. Even the documentation and its packaging prepared for the clones followed the same style and packaging as that of the original IBM PC documentation.

The Canadian IBM PC cloning industry was strong, especially in Ontario. A number of Canadian manufacturers, small and large, offered inexpensive IBM PC look-alikes as early as 1983. It was in 1983 that a small Toronto-based company, J.L.S. Computers, owned by Joe Loren Sutherland, started to supply local computer manufacturers and electronics stores with its clones of the IBM PC and IBM XT motherboards. In the early 1980s, Sutherland was a legendary figure in Toronto's "computer underground," and his status helped with the distribution of his boards. The J.L.S. motherboards, packed in Taiwan-made cases, showed up in Ontario and beyond with many different model and company name stickers affixed to the cases. J.L.S. also offered its own clones, the JLS PC and XT, which were not only cheaper than the IBM machines but, according to some technology experts, also an improvement on the original designs to make the clones faster.[11]

A detailed list of Canadian manufacturers of IBM PC-, XT- and AT-compatible or clone computers is difficult to compile. Some manufacturers of such hardware supplied their computers with illegal copies of the Basic Input/Output System (BIOS) program developed by other firms. These activities forced such unscrupulous "cloners" to hide any traces that could lead to the disclosure of their identity. The list of cloners that played by the industry rules is long and includes, among other companies, Computech Micro Designs, ECS Computers, IDM Research Industries, COR BIT Computer Industries Ltd., Exceltronix Components and Computing, HAL Computer Company, J.L.S. Computers, Lanpar Technologies and Soltech Industries Inc.


**Figure 44:** Lanpar Technologies microcomputer (1983), one of the numerous IBM PC-compatible computers manufactured in Canada. (Courtesy York University Computer Museum)

The IBM PC and XT were not the only computers subjected to replication. The Apple II microcomputers were cloned on an unprecedented scale almost everywhere in the world, from North and South America to Asia and Europe. Apple Computer spent years in court, fighting some of the major computer companies whose products infringed on Apple Computer technology for its Apple II products; among the companies sued by Apple Computer were Franklin Computer Corporation and VTech. A typical Apple II clone consisted of a set of printed circuit boards obtained from various, frequently unidentifiable, sources, packed in a computer case that, in most instances, closely resembled the genuine Apple II, II+ or IIe case. In other instances, Apple II clones were packed in unique cases that masked their kinship with the genuine Apple II family (see Figure 46). As in the case of the IBM PC and XT clones, some of the Apple II look-alikes were not only compatible with the original computers but, in some cases, also offered some hardware improvements.

**Table 6:** Some computers compatible with Apple II and IBM desktops manufactured and/or sold in Canada.
Apple II (resp. IBM desktops) compatible products are tagged with "Apple" (resp. "IBM").

| Manufacturer | Location | Selected hardware |
|---|---|---|
| Audiovision | Toronto, ON<br>Vancouver, BC | Audiovision board (Apple) |
| Best Systems | Mississauga, ON | Compact 286, Compact 86, AVT 10 286 (IBM) |
| Computech Micro Designs | Mississauga, ON | Genesys (IBM) |
| COR BIT Computer Industries Ltd. | Toronto, ON | Super PC, Super XT |
| ECS Computers | Mississauga, ON | ECS PC, ECS XT (IBM) |
| Exceltronix Components and Computing | Toronto, ON | Best computers (IBM) |
| HAL Computer Company | Toronto, ON | HAL, HAL plus (IBM) |
| IDM Research Industries | Rexdale, ON | IDM computers (IBM) |
| J.L.S. Computers | Toronto, ON | JLS PC and XT (IBM) |
| Lanpar Technologies | Toronto, ON | Lanpar PC (IBM) |
| Mega Byte Micro Systems | Montreal, QC | Golden II (Apple) |
| Micro Computech Electronics | Toronto, ON | ATD FDD-810 (Apple) |
| Orange Computers Inc. | Mississauga, ON | Orange Peel (6502 Board Kit Apple II) |
| Orion Electronic Supplies | Kitchener. ON | (Apple) |
| O. S. Micro Systems | Unknown | OS-21, OS-22, Arrow-1000 (Apple) |
| Parts Galore | Toronto, ON | Parts Galore board (Apple) |
| Pineapple Computer Products | Markham, ON | Pineapple (Apple) |
| Primax Businessworld | Brampton, ON | Primax Executive (IBM) |
| Soltech Industries Inc. | Surrey, BC | Soltech (IBM) |
| Supertronix | Toronto, ON | Supertronix (Apple) |
| Surplustronics | Toronto, ON | Super 6502 (Apple) |

The Canadian personal computer market of the early 1980s was also heavily involved in Apple II cloning activities. At one point, the area of Toronto between Queen, College and Bloor streets was informally referred to as the Canadian capital of Apple II clones, since almost every electronics and computer store in that area (and there were many of them) was selling Apple II clones as kits or fully assembled computers.[12]

The list of Canadian-made Apple II clones is extensive. Some of the manufacturers and computer stores involved in the Apple II cloning business were: Audiovision, Exceltronix Components and Computing, Mega Byte Micro Systems, Orange Computers Inc., Orion Electronic Supplies, Parts Galore and Pineapple Computer Products. However, after twenty-five years, the manufacturers of some of the clones or their locations are difficult to identify, as is the case with the makers of the APCO and CV-777 computers and with Logistics Products and O. S. Micro Systems. Some distributors of Apple II clones are listed in Table 6.

The IBM PC and Apple II clones were inexpensive alternatives to the generic products from IBM and Apple Computer. The forceful wave of legal compatibles and pirated clones was a major factor in bringing the era of hobby and home microcomputers to an end. It was also a major factor in the reduction of costs associated with personal computer hardware, allowing many individuals to purchase their first microcomputers.


**Figure 45:** The Decider microcomputer (manufacturer unknown) belongs to a large family of Apple II compatible computers sold in Canada in the early 1980s. This computer's hardware consists of a motherboard made by Unitron, a Brazilian company (one of the best-known manufacturers involved in cloning Apple Computer products) and some peripheral cards manufactured in Canada. The external diskette drives were manufactured in Taiwan. (Courtesy York University Computer Museum)

## 4.6 Microcomputer Peripherals

Computer peripherals—such as display terminals, printers, plotters, modems and external storage devices—are integrated components of a computer environment. Since the peripherals' function is to support CPU hardware, they are frequently omitted from historical texts on personal computing. There are, however, notable exceptions to such omissions: the invention of the floppy disk, hard drive, mouse and laser printer, for example.

The successful Canadian computer peripheral companies that supported the microcomputer industry in the 1970s and 1980s can be classified into four main groups, determined by type of manufactured product. The first three groups are computer terminal manufacturers, data communications equipment manufacturers and video card manufacturers. The fourth group includes all the remaining manufacturers of computer peripherals, such as computer cards and boards for a variety of microcomputer platforms.

A number of Canadian companies made their mark on the computer terminal market: DY 4 Systems, Lanpar Technologies, Matrox Electronic Systems, NABU Manufacturing Corporation, Nelma Data Corporation, Norpak Corporation, Northern Technologies Ltd. and Volker-Craig Ltd., for example.

Volker-Craig Ltd. (VC) was established in Waterloo, Ontario, in 1973 to manufacture low-cost computer terminals. It was one of the first University of Waterloo high-tech spinoffs. Among the early successful VC products were the VC-303 and VC-404 terminals, implemented using TTL (transistor–transistor logic) technology. Later products, such as the VC-4404, were microprocessor-based. In 1981, Volker-Craig was sold to NABU Manufacturing Corporation of Ottawa, but after NABU's reorganization (followed by the company's closure) Volker-Craig re-emerged as an independent company. The VC terminals (such as those mentioned above and the VC 2100, VC-6220 and VC-6221) were popular North American low-cost computer displays.

Another Canadian company that was successfully involved in the production of display terminals was Lanpar Technologies. Lanpar aimed to produce inexpensive computer terminals compatible with popular VT display terminals from Digital Equipment Corporation. Among the best-known Lanpar terminals manufactured in the 1980s were: Lanpar Vision II (models 3220, 3221 and 3222), LanparScope XT-50 and XT-51, and Max 331 Intelligent Terminal.

A few Canadian companies, such as Norpak Corporation and Network Data Systems Ltd., were involved in the development of an interactive colour display technology and specialized display terminals for the ill-fated Canadian Telidon/Teletext initiative. These terminals were never intended to operate with microcomputer equipment, but they are mentioned here to complete the information on computer terminal manufacturing in Canada.

Since the late 1970s, a number of Canadian companies had started to design and manufacture computer graphics cards for microcomputer equipment. Two of them, Matrox Electronic Systems and ATI Technologies Inc., quickly became industry leaders. In 1977, Matrox released its first ALT-256**2 Graphics Board and the MTX GRAPH software package for the Matrox ALT-256 graphics display. These were popular products among the users of microcomputers that were designed around the S-100 bus (the so-called S-100 systems). In the early 1980s, Matrox offered graphics cards for a range of hardware platforms from S-100 systems to Intel's multibus. Since then, Matrox's state-of-the-art software and hardware products have established the company as an industry leader in the fields of graphics, video editing, image processing and new business media.

ATI Technologies Inc. was founded in 1985 in Markham, Ontario. The company has since grown into one of the world's largest suppliers of 3-D graphics and multimedia technology for the desktop and notebook platforms, workstation, set-top box, game console and hand-held markets. In 2006, the company was bought by Advanced Micro Devices.

Canadian companies successfully competed in other segments of the computer peripherals industry. Manufacturers of data communications products (modems, terminal adaptors, networking products) included DY 4 Systems, Gandalf Data Communications, General DataComm, Mitel, Newbridge Networks, Datamex, Paradyne Corporation and ATI Technologies Inc.[13] Companies such as Andicom Technical Products, DY 4, Matrox Electronic Systems, Multibest Industrial & Manufacturing Inc., Seanix and


**Figure 46:** Gandalf Data Communications SAM 201 modem. (Courtesy York University Computer Museum)

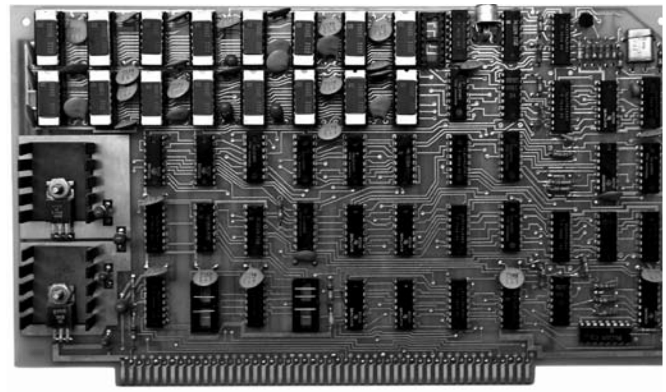

**Figure 47:** Matrox 256

Toronto Microelectronics were involved in the design and manufacture of computer board level products such as memory cards, serial and parallel interface boards, and disk and hard drive controller cards. Their products were designed to support a variety of hardware platforms, from IBM PC and Apple to VME.

## 4.7 The Computer Hobbyists' Movement in Canada

The role of the computer hobbyists' movement in the defining and developing of the personal computer industry is well documented.[14] Some of the world's largest microcomputer software and hardware companies, such as Apple Computer and Microsoft, originated from the hobbyists' movement, as did one of the best-known Canadian electronics companies—Matrox Electronic Systems.

While Matrox's first product (a specialized video-display device called Video RAM) had nothing to do with the hobbyists, the company's next line of products was specialized video graphics cards for some of the most popular hobby computers.

The formal beginning of computer hobbyist activities can be traced to the second half of the 1960s and the formation of special interest groups such as the RESISTORS (Radically Emphatic Students Interested In Science, Technology or Research Studies) club, created by students at Hopewell Valley Central High School in Pennington, New Jersey. The most significant of these early hobby computer initiatives was the creation of the Amateur Computer Society (ACS) by Stephen B. Gray in May 1966. The ACS Newsletter, published quarterly, was a forum for the exchange of information on computers among electronics enthusiasts and experimenters, a number of whom were Canadian members of ACS. An alternative to an expensive minicomputer, contemplated by some ACS members, was a home-brewed computer, and some had their home machines constructed as early as 1966.

With the advent of the microprocessor, and especially with the introduction of Intel's first eight-bit microprocessors (the 8008 and 8080 single-chip CPUs), the movement's activities exploded. In 1974 and 1975, a number of low-cost microcomputers, frequently in a do-it-yourself kit form, were created by or offered to computer hobbyists (for example, SCELBI Computer Consulting SCELBI-8H (1974), Jonathan Titus's Mark-8 (1974), MITS Altair 8800 (1975) and MIL MOD8 (1974)). Soon after, a large number of microcomputer user groups and computer clubs sprang up to provide support and to exchange information on programming and programming aids, hardware extensions and modifications, peripherals and literature. The wave of microcomputer newsletters, dedicated computer magazines, shows and fests, as well as the first computer stores, formed an essential part of the infrastructure of the emerging personal computing movement.

In Canada, the hobby computer movement in an organized form began with the formation of the Canadian Computer Club in Brandon, Manitoba, in late 1975 and the official launch of the Toronto Region Association of Computer Enthusiasts (TRACE) in Mississauga, Ontario, in January 1976. By 1977, there were at least seven computer clubs, and by the end of the 1970s there was a computer club or user group in every major Canadian city. Among Canada's most successful computer user groups were: the Loyal Ontario Group Interested in Computers (LOGIC), the Ottawa Computer Group, the Toronto Personal Computer Club (TPCC), the Toronto PET Users Group (TPUG) and TRACE. Some of these organizations, such as TPUG, TPCC and LOGIC, still exist. TPUG was established in 1978 and was devoted primarily to Commodore hardware. In 1984, at the peak of its activities, it had over 15 000 members, making it the world's largest Commodore user group. Table 7 lists some of the early Canadian computer user groups and clubs.

Canadian computer hobbyists played a pivotal role in supporting and sponsoring computer literacy programs and in bringing personal computers to Canadian homes. Through the organization of computer shows, fests and training sessions, through publication of newsletters, magazines, software and books, and through the creation and maintenance of BBSs services, the hobbyists contributed significantly to the rapid proliferation of microcomputers and to the emergence of the present-day information-consuming society.

At first, the main activities of the early Canadian computer clubs were focused on self-education in the area of microprocessor-based computer electronics and on building rudimentary microcomputers. These early activities developed into the assembly of computers from kits made available by early microcomputer manufacturers (such as Micro Instrumentation and Telemetry Systems (MITS) in the United States and MIL in Canada). Later, hobbyists became involved in the search for useful applications for their computers and in computer literacy activities. The peak of these activities occurred in the first half of the 1980s. Though there were those who still preferred to put together their own microcomputer rather than buy a ready-made one, by then most hobbyists owned a fully assembled computer manufactured by one of the myriad microcomputer companies.

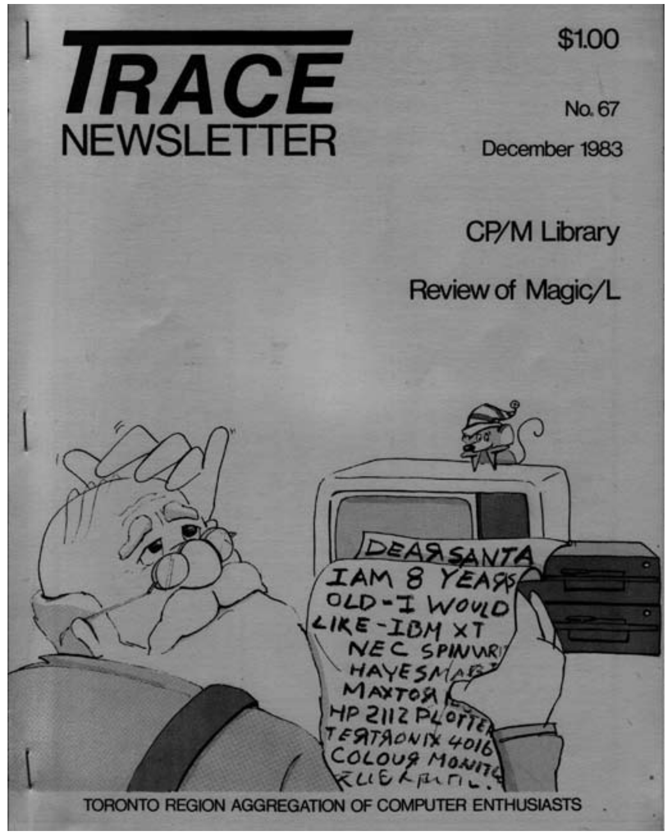


**Figure 48:** TRACE Newsletter, December 1983. (Courtesy York University Computer Museum)

Some of the early computer clubs, such as the Ottawa Computer Group, covered a wide spectrum of microcomputer products. Other clubs and user groups were associated with and supported a specific hardware or manufacturer. Since its inception, TPUG has focused on Commodore computers, while LOGIC has concentrated on Apple Computer products. There were numerous user groups dedicated to the Canadian-made Hyperion: the Hyperion Users Group of Montreal, the Calgary Hyperion User Group (CHUG), the Hyperion Users Group of Ottawa (HUGO), the Toronto Hyperion Users Group, the Hyperion Users Group of Saskatoon, the Welland Hyperion Users Group, the Hyperion Users Group of BC and the Laurentian University Hyperion Users Group.

A separate category of computer club activities was the publication of newsletters and magazines, as well as the maintenance of computer BBSs services. The newsletters published by these early groups constitute a valuable source of information about the first decade of personal computing in Canada.

As in the United States, computer hobbyist activities in Canada created a new nationwide retailing phenomenon—computer stores. In 1976, there was a computer store in almost every major Canadian city, serving hobbyists' needs: the Computer Store Division of Hart's in Montreal, the First Canadian Computer Store, Inc. in Toronto, the Computer Hobby Shop in Calgary, the Pacific Computer Store in Vancouver and SDS Technical Devices Ltd. in Winnipeg. Some early computer stores were located in smaller towns, such as Brandon, Manitoba, which was home to Canadian Microcomputer Systems & Associates. By the mid-1980s, hundreds of computer stores across Canada were selling microcomputer systems and products, serving both hobbyist and business needs. In addition to microcomputer hardware and software, such stores offered computer books, magazines and, of course, computer services.

By the mid-1980s, the computer hobbyists' movement was over. As one of the authors of this monograph has stated elsewhere, by that time the microcomputer hobby culture would mostly diffuse and its remnants would merge with new forms of microcomputer activities focused on a unique microcomputer or manufacturer, or on forming virtual communities around popular BBS systems. The nerds and geeks of the 1970s would mostly retire from their hobby

**Table 7:** Some Canadian computer user groups and clubs, 1975–1985

| Name | Location | Newsletter |
|---|---|---|
| Amateur Microprocessor Club of Kitchener-Waterlo | Waterloo, ON | Unknown |
| Apple-Can | Toronto, ON | Unknown |
| Apples BC Computer Society | Burnaby, BC | ApplesBC Newsletter |
| British Columbia Computer Society | Vancouver, BC | Unknown |
| Calgary Hyperion User Group | Calgary, AB | CHUG CHIMES |
| Calgary PC User Society | Calgary, AB | Unknown |
| Canadian Computer Club | Brandon, MB | Unknown |
| Canadian Computer Club | Saskatoon, SK | Unknown |
| Halifax Area MS-DOS Computer Club | Halifax, NS | HACC Newsletter |
| Hyperion Users Group of BC | Richmond, BC | Unknown |
| Hyperion Users Group of Montreal | Montreal, QC | Unknown |
| Hyperion Users Group of Ottawa | Ottawa, ON | HUGO News |
| Hyperion Users Group of Saskatoon | Saskatoon, SK | Unknown |
| IBM PC Users Group of Toronto | Toronto, ON | Newsletter |
| Kaypro Users of Toronto and Environs | Toronto, ON | KUTE News |
| Loyal Ontario Group Interested in Computers | Toronto, ON | LOGIC |
| MacDeLUS | Sherbrooke, QC | Le Verger BBS |
| Montreal Area Computer Society | Montreal, QC | MACS Newsletter |
| Montreal Micro-68—Club de l'Ordinateur—Computer Club | Montreal, QC | Micro-68 Newsletter |
| Mount Bruno Computer Club | Saint-Bruno-de- Montarville, QC | CHIP |
| Muddy Waters Osborne Group | Winnipeg, MB | Unknown |
| National Capital Atari Users' Group | Ottawa, ON | Unknown |
| Osborne/Keypro Users' Club of Toronto | Toronto, ON | Newsletter |
| Ottawa Computer Group | Ottawa, ON | OCG Newsletter |
| Ottawa IBM PC Users' Group | Ottawa, ON | Newsletter |
| Ottawa Region Computer Club | Ottawa, ON | Unknown |
| Toronto Amateur Computer Users Society | Toronto, ON | Unknown |
| Toronto Atari Association | Toronto, ON | Phoenix |
| Toronto Hyperion Users Group | Toronto, ON | Unknown |
| Toronto Microcomputer Users Group | Toronto, ON | TMUG Newsletter |
| Toronto Personal Computer Club | Toronto, ON | TPCC Newsletter |
| Toronto PET Users Group | Toronto, ON | TPUG Newsletter |
| Toronto Region Association of Computer Enthusiasts | Mississauga, ON | TRACE |
| Victoria Personal Computer Users' Group | Victoria, BC | Big Blue |


**Figure 49:** Product catalogue published in the late 1970s by The Computer Place store, located in Toronto's famous Queen–College–Bloor microelectronics retail area. (Courtesy York University Computer Museum)

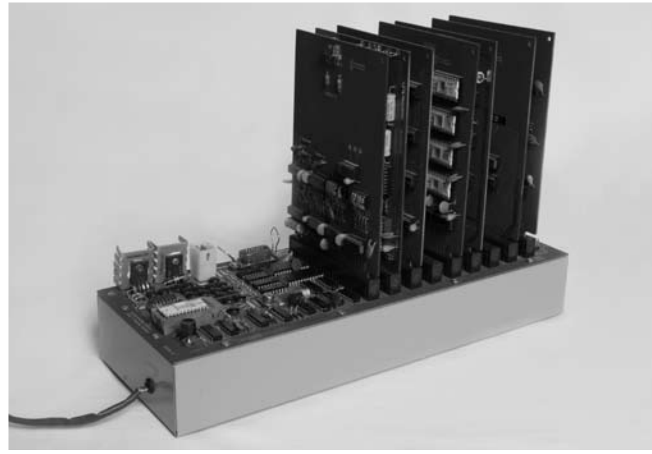

**Figure 50:** The MIL MOD8 microcomputer. (Courtesy York University Computer Museum)

activities making space for loosely knit communities of highly skilled and knowledgeable wiz-kids and computer hackers. Some of the hackers would venture into destructive activities from writing and propagating computer viruses to unleashing potentially destructive cyber-attacks, crippling targeted computer systems or shutting them down completely. Computer crime would become one of the distinct features of the new computer-based culture.[15]

## 4.8 Canadian Computer Hardware for the Hobbyist Market

In the 1970s, the capabilities of the early microprocessors were quite limited in comparison with the state-of-the-art circuitry of CPUs designed for large computers. The majority of the early hobby microcomputers were unable to perform the computational tasks that were routinely done on mainframes and minicomputers. But that was not a deterrent to the hobbyists' activities, which were firmly based on the assumption that it was microprocessor technology that, in the end, would allow them to own and operate a computer of their own.

The earliest microcomputers designed by or for hobbyists used Intel's first eight-bit microprocessor, the Intel 8008. Between 1974 and 1975, a variety of such computers was offered both as "self-assembled," do-it-yourself kits and as fully assembled and tested computers (see Table 8 for some of these early computers). Canadian computer hobbyists began their acquaintance with microprocessor technology by experimenting with rudimentary microcomputers offered as kits by some semiconductor and computer manufacturers and, later, by dedicated computer stores. While the majority of the early computer kits were manufactured in the United States, there were also "made in Canada" products.

In 1974–1975, the Canadian semiconductor giant MIL offered its MOD8 and MOD80 microcomputers. The MOD8, one of the earliest commercial microcomputers made in Canada, was designed by MIL's Systems Applications Group. The computer, built around MIL's MF8008 microprocessor, was easy to interface with external devices, to expand and to modify: to build an MF8008-based system of a desired configuration, a user simply plugged the required memory and interface cards into the bus connectors, which in the MOD8 case were mounted on top of the computer's aluminum chassis. When the MF8008 CPU plug-in card was replaced with the MF8080 CPU board, the user ended up with the more powerful MOD80 computer based on the MF8080, MIL's second-generation eight-bit microprocessor.[17] The MIL *MF8008 Applications Manual* provided complete technical information on the MF8008 microprocessor and the MOD8 computer.

Both the MOD8 and MOD80 computers were intended for the systems engineering market, as tools for the development of applications that utilized MIL's microprocessor devices. However, it was North American computer hobbyists who made the MOD8 and MOD80 computers popular. A special MOD8 and MOD80 interest group was formed


**Figure 51:** Howard Franklin with his MF8008-based microcomputer, Toronto, 2004. (Courtesy York University Computer Museum)

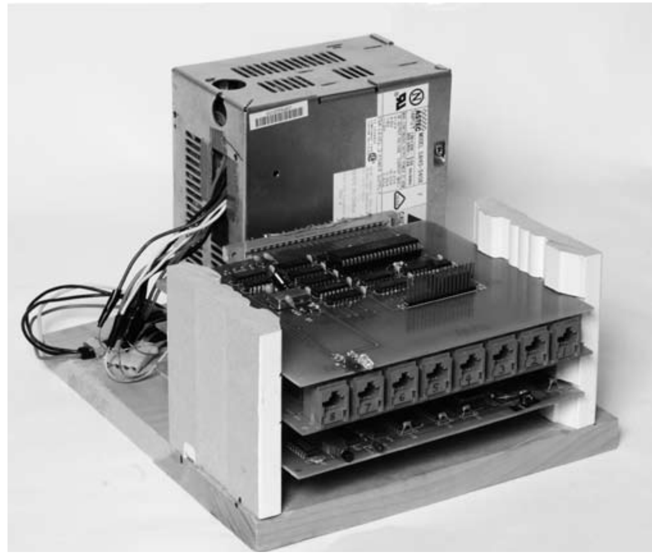

**Figure 52:** Dave Dunfield's 6809 microcomputer. (Courtesy York University Computer Museum)

within TRACE to provide hardware and software support to those members who wanted to build and operate a MOD computer. MiniMicroMart, a popular computer store located in Syracuse, New York, was selling not only the MOD8 and MOD80, but also a range of MOD80-like computers developed around other popular CPUs, such as the Zilog Z80 and Motorola 6800. Despite MIL's closure in 1975, the popularity of the MOD8 and MOD80 hardware among hobbyists continued until 1977. The computers continued to be sold by MODUCOMP Inc. of Brockville, Ontario, and by Great Northern Computers (under the names GNC8 and GNC80, respectively). The MOD8 and MOD80 influenced other microcomputer designs for the hobbyist market, such as the Mike 2 computer from Martin Research of Northbrook, Illinois, and the C-MOD80 kit from Celetron Corporation of Syracuse, New York.

The members of the Ottawa Computer Group embraced another Canadian computer in a do-it-yourself form. Tarot Electronics, a small company formed in 1973 in Kanata, Ontario, designed and manufactured microprocessor hardware called Mimic. The CPU part of a Mimic system was a single-board computer, which first used the MIL MF8008 processor and later the Intel 8080 microprocessor. Shortly after Tarot switched to the 8080 CPU, the company realized that, when coupled with its MicroTerminal and Process operating system, a Mimic system was a useful and inexpensive single-board computer. Tarot offered its Mimics at a reasonable price to the membership of the newly formed Ottawa Computer Group. Tarot sold several hundred Mimics to the hobbyists, beginning in April 1977, and they were accepted with enthusiasm. The company also helped the hobbyists with assembling and testing these computers.

One of the most original hobby computers was devised in 1974 by a young Torontonian, Howard Franklin. He designed and constructed a fully functional microcomputer using an MIL MF8008 microprocessor. His computer, which is now in York University Computer Museum, is possibly the earliest

**Table 8:** Some early Intel 8008-based hobby computers[16]

| Model | Manufacturer/ designer | Year | Country |
|---|---|---|---|
| Mark-8 | Jonathan Titus | 1974 | United States |
| Mike 2 | Martin Research | 1975 | United States |
| MOD8 | MIL | 1974 | Canada |
| RGS 008A | RGS Electronics | 1974 | United States |
| SCELBI-8H | SCELBI Computer Consulting | 1974 | United States |

**Figure 53:** The Multiflex Z80A single-board computer. (Courtesy York University Computer Museum)

example of a Canadian hobby microcomputer and is one of the earliest such microcomputers ever designed.

Franklin's construction of a home-made computer was not an isolated event, and other attempts at designing microcomputers from scratch continued into the 1980s. In 1981, Ottawa engineer Dave Dunfield designed, built and equipped with software his Dunfield 6809 portable computer. Since then, he has built a number of clones of his computer, one of which he donated to York University Computer Museum.

Since the late 1970s, the main suppliers of computer hardware, software and literature to Canadian hobbyists have been computer and electronics stores. Exceltronix Components and Computing, a popular Toronto electronics store, offered its own line of single-board computers, starting with its Multiflex board. This was followed by the popular University of Toronto board (or "6809 board") and by the Multiflex Z80A single-board computers. They were available as kits, as well as fully assembled systems.

By the end of 1981, the number of computers built for the hobby and home computer markets had reached two million in the United States alone. This was mostly due to the large demand for small home computers from Apple Computer, Atari, Commodore, Radio Shack and Texas Instruments. By 1983, this rapid increase in demand for home computers had become a hasty decline, caused by the introduction and unprecedented success of the IBM PC in 1981 and the "correction" in the home computer market that took place in 1982–1983. By the mid-1980s, individual computer users were shifting their attention to more powerful desktop microcomputer platforms, represented by the IBM PC and the Apple Macintosh.

## 4.9 Microcomputing and Education

This section traces the introduction of microcomputers into the academic environment in Canada. It also sketches the early use of these computers in Canadian elementary and high schools.

### 4.9.1 Academic Computing: From Mainframes to Microcomputers

The routine use of computers for academic research and teaching at Canadian universities had begun in the early 1960s (see section 3.3.6). During these early years, computer resources were offered free to academics to encourage the scientific and educational use of computers. But by the end of the 1960s, "with the maturing of the computer technology . . . the demand for computing in universities in Ontario has grown to an estimated $12 million annually. This demand has evolved in an artificial environment where computing has been a free resource." [18]

The staggeringly high costs of providing computing services to Canadian academic communities included the rental of mainframe computers and their peripherals and the acquisition of software, as well as the maintenance of university computing centres. For instance, in 1968–1969 York University paid $247 300 to cover only the rental of an IBM 360/40 computer and its peripherals.

The skyrocketing computing expenses at universities forced provinces to look for ways to reduce and recover the costs. The two most discussed approaches were the creation of service-oriented regional computing centres for universities and the development of methods for financing computing services.

In Ontario in June 1968, the Minister of University Affairs, the Committee on University Affairs, and the Committee of Presidents of Universities of Ontario (CPUO) agreed to investigate the creation of service-oriented regional computing centres for Ontario universities. The draft of the *Report on Regional Computing Centre Development*, published in February 1969, advised that regional centres could, if properly set up, provide a feasible way of meeting the new computing needs of Ontario universities. One of the main underlying assumptions was "that computing services should not be planned for operation as a free commodity in a university . . . Rather, the allocation of the computing resources should be made part of the ordinary budgeting process" (p. 9). It was expected that these centres would resolve the teaching needs of member universities at low cost. The report recommended the initial creation of a pilot Ontario university regional computing centre in Metropolitan Toronto. Its location was not to be on the campus of any of the participating universities. The centre was also planned to be at arm's-length from the member universities.

In the end, the idea of service-oriented regional computing centres for universities was not fully implemented. The York–Ryerson Computing Centre, established in the mid-1970s, was short-lived. Similarly, the Ontario Centre for Large Scale Computation at the University of Toronto, established in the second half of the 1980s to provide super-computing services to research and business communities, collapsed under mounting debt.

The second approach for controlling the costs of academic computing—charging for computing services—had already been contemplated and partially adopted by a number of universities in the late 1960s. In December 1969, the CPUO established a Task Force on Computer Charging to advise universities on policies on computing services. The committee's objectives were to develop guidelines and to identify alternative methods for pricing computing services and developing budgetary procedures for financing these services.

The 1970 report released by the Task Force on Computer Charging stressed that the universities could not afford to operate computing services free of charge and that computing resources allocated to academic programs should be planned and evaluated in the same way as other resources, such as personnel, buildings and laboratory equipment. The Task Force further recommended that, "Once the costs for the provision of the services are known, a university should choose a charging policy which will recover a majority of the costs from the users" (p. 9).

While most Ontario universities attempted to move away from providing computing services free of charge and adopted some policies for charging for the services, it became clear that the full computing costs associated with teaching could not be recovered within the funding formula for Ontario universities.

A new solution to the problem of high computing costs at universities presented itself with the advent of the microcomputer. In the late 1970s, a microcomputer, though slower in performance than a typical minicomputer of the time, offered a cost-effective alternative to expensive minicomputers and mainframes in educational and research applications where the high performance of hardware was not a significant factor. Multiple microcomputer stations set up on university campuses could provide general-purpose services for students and faculty. Furthermore, though it was not economically possible to provide each student in specialized

**Figure 54:** The MicroWAT computer, designed at the University of Toronto, and developed and manufactured by Waterloo-based Northern Digital Ltd. (Courtesy York University Computer Museum)

software engineering and digital electronics laboratory courses with a minicomputer, it was certainly feasible to provide them with a microcomputer.

Canadian universities responded in a number of ways to the rapidly developing microcomputer industry. In the late 1970s, microcomputers in academia were used rather sporadically and mostly by individual faculty who were looking for ways to reduce research costs and who recognized the potential of microprocessor technology for effective teaching and research. The Commodore PETs and Apple IIs were popular choices, as were the myriad other microcomputers offered by smaller manufacturers in the United States and Canada.

Possibly the earliest entry of microcomputers into a Canadian institution of higher learning was that of MCM/70 computers, installed in 1975 at St. Lawrence College, Kingston, to support the school's programs in mathematics and computer studies. Another Canadian microcomputer, a Dynalogic DMS-8, was acquired by Algonquin College of Technology in Ottawa in the fall of 1976.

Some universities decided, for various reasons, to develop their own microcomputers. In 1979, the University of Toronto's Department of Electrical Engineering designed the University of Toronto board (also known as the "6809 board"). The computer was used in digital electronics laboratories at the University of Toronto, as well as in a number of other Ontario universities, and introduced students to the principles of microprocessor-based digital electronics. It was also a popular hobby computer sold in Toronto by Exceltronix Components and Computing until the mid-1980s.

In the early 1980s, the University of Waterloo developed two microcomputers: the SuperPET and the MicroWAT.

The genesis of these computers is discussed in section 4.3.3 of this monograph.

Since the introduction of the IBM PC in 1981, microcomputers had started to play a more dominant role in academic life. Not only had they begun to push electric typewriters and digital word processors (such as the Canadian-built AES and Micom processors) off the desks of university administration offices but, more and more frequently, they had become research machines and laboratory workstations, replacing minicomputers from Digital Equipment Corporation or Data General Corporation. For instance, the Orion microcomputers, manufactured by Ottawa-based DY 4 Systems, had been in use in various laboratories at Carleton University since the early 1980s.

The beginning of the 1980s also brought dedicated microcomputer laboratories to universities to support a range of non-hardware courses in computer science, from introductory courses in computing and programming to computer graphics. The Department of Computer Science at York University created such a laboratory using, first, Apple IIs from Apple Computer and the Arisia computers manufactured (or, rather, put together from off-the-shelf components) by Arisia Microsystems of Mississauga, Ontario. By 1984, the laboratory had expanded its microcomputer resources with the addition of Apple Lisa and Macintosh computers.

Some universities entered into business agreements with microcomputer manufacturers and negotiated attractive prices for microcomputers that could be purchased by students and faculty. In 1985, Queen's University made such an arrangement with Zenith Data Systems. In 1984, the federal government negotiated a special educational price for the Dynalogic Hyperion. Many teachers and researchers took advantage of the Hyperion offer and bought their first microcomputer. Thanks to this discount on Hyperions, part of the computing services at George Brown College in Toronto was configured around the Dynalogic hardware.

### **4.9.2** Microcomputers in Schools

The use of microcomputers in preschool, elementary and secondary education in the 1970s and 1980s is a vast and complex subject. It spans all types of educational activities and initiatives, such as computer literacy programs, computer-assisted instruction, training of teachers, distance learning, and the creation and evaluation of educational hardware and software (including educational computer games). Since a fair treatment of these subjects requires a multi-volume study, this monograph provides only a brief historical overview of the impact of the microcomputer industry on education at the primary and high-school levels.

The history of computer education can be traced to the first days of modern computing. In the late 1940s, Edmund Berkeley, a great enthusiast of computing and computer education, conceived his first small computing device and named it "Simon." The computer, whose design was published by Berkeley between 1950 and 1951 in the pages of Radio Electronics, was not a scientific tool but "an educational aid to exhibit in simple understandable form the essential principle of any artificial brain."[19] In the 1950s and 1960s, Berkeley designed a number of popular educational computer toys, such as the Brainiac, Tyniac and Geniac. His work inspired others to work on bringing an understanding of computers and their role in modern society to schools and homes. In the 1960s, many innovative computer toys made of plastic, cardboard and other materials were offered to children. One of the more creative designers of such computer toys was an RCA engineer, Joseph Weisbecker.

Computer laboratories in schools were already being discussed in the 1960s. However, the main obstacle to the implementation of such computer-equipped classrooms was the high cost of minicomputers and their peripherals. At best, a school was equipped with a single minicomputer or simply with a terminal connected (via a modem) to a minicomputer shared by other schools in the area. As Alan Pollock recollected in a February 1986 article posted on Netweaver (the electronic newsletter of the Electronic Networking Association), "From time immemorial it seems, The Protestant School Board of Greater Montreal (P.S.B.G.M.) has used a Hewlett-Packard HP-2000F minicomputer to teach programming in Montreal's high schools. Equipped with a terminal and a modem, each district school communicated with this one computer which was located at the P.S.B.G.M.'s central office. The system worked well; students actually learned to program."

The HP-2000F was an expensive time-sharing BASIC system introduced by Hewlett-Packard in 1974. There were more affordable minicomputers for the education market, such as Digital Equipment Corporation's EduSystems based on the company's best-selling PDP-8 computer, but in the end it was microcomputers and not commercial minicomputers that integrated computer technology with teachers' working environments and, most importantly, made computer education a part of schools' curricula. *The MCM/70 in Education*, a promotional document prepared by MCM in 1973 on the occasion of the unveiling of its personal microcomputer, the MCM/70, proclaimed a new era in computer education. A small MCM/70 was to bring "to the world of education a technological solution to the problem of introducing economical interactive computer systems." According to MCM's vision, inexpensive school laboratories equipped with MCM/70 computers could be created to "provide each student in a computer equipped classroom with his own individualized interactive computer."

One of the main and persistent difficulties in bringing microcomputers to schools was the lack not of inexpensive hardware and software, but of qualified teachers. This was somehow balanced by the great enthusiasm of some teachers who, like Berkeley and Weisbecker, were fascinated by computer technology and were dedicated to the introduction of computer education into classrooms.

Initially, computer education was an optional subject, in which teachers emphasized computer programming, considered by many an essential skill in the development of the modern individual. But that was soon to change. In a 1981 report, the National Council of Teachers of Mathematics (founded in 1920 and with thousands of members across the United States and Canada) adopted a position that gave computer literacy a more fundamental place in contemporary education programs:

Mathematics programs must take full advantage of the power of computers at all grade levels. Students and teachers should obtain a working knowledge of how one interacts with computers and uses their capacities. Computer literacy is an essential outcome of contemporary education.

By the mid-1980s, it was recognized that, while not everyone would need to learn how to program a computer (any more than everyone had to be a mechanic or an engineer in the petroleum industry to drive a car), it was essential for everyone to be familiar with computer use and applications.

The early North American computer education market was dominated by computers from Apple Computer (the Apple IIs). A few other microcomputer manufacturers had a sizable share of the education market: Texas Instruments' TI-99/A, Atari's 400 and 800 computers, Radio Shack's TRS-80, and Commodore's PETs, VIC-20 and C64 were also popular choices for school computers. The Canadian education market was of a similar makeup, except that Commodore was in a much stronger position with a 65 percent market share in 1983. A unique Canadian educational computer—the ICON—is discussed below.

All major microcomputer manufacturers developed educational software. For instance, Commodore had vast libraries of educational programs for all its computers. In 1983, Commodore introduced the "Computer Educator"—a library of educational programs for its immensely popular VIC-20 computer; many of these programs were published in Canada by Commodore Business Machines Ltd. The 1983 Commodore educational software catalogue (for the VIC-20 and C64) lists over 600 programs. The education divisions of Radio Shack and Apple Computer undertook extensive development efforts to produce instructionally sound, effective and properly validated microcomputer-based educational materials for use in the classroom.

A large number of independent software companies in the United States and Canada were developing a vast variety of educational software for major microcomputer platforms from Apple Computer, Atari, Texas Instruments, Radio Shack and other manufacturers. The software catalogues from U.S.-based companies such as Micro-Ed, American Peripherals, Davidson & Associates and the Minnesota Education Computing Consortium included hundreds of titles for all school grades.

One of the best-known Canadian educational software companies was Logo Computer Systems Inc. (LCIS), founded in 1980 and with headquarters in Montreal. Among its earliest successes was the implementation of the educational programming language LOGO for the Apple II computer. The LCIS Apple LOGO was used in schools around the world, gaining the company international recognition.

The growing popularity of home and personal computers and their educational value prompted government institutions in some countries to create regional and national microcomputer literacy programs. One of the best-known and most successful programs of this kind was the Computer Literacy Project developed by the British Broadcasting Corporation (BBC). In 1981, in response to a successful documentary series *The Mighty Micro*, the BBC aired a ten-part TV series devoted to microcomputers and their applications.

To support its Computer Literacy Project, the BBC decided to create its own microcomputer. To this end, it composed a

**Figure 55:** CEMCorp ICON ("Bionic Beaver").
(Courtesy York University Computer Museum)

fairly ambitious list of hardware features and started searching for a manufacturer. Eventually, the BBC selected Acorn Computers Ltd., and this led to the creation of the BBC Model A and B computers in late 1981.

The BBC Computer Literacy Project, as well as the BBC computers, had a tremendous impact on the education market in the United Kingdom. The computers created a substantial computer education industry, as most U.K. schools adopted the BBC computers for their programs. In 1983, the BBC computers had 60 percent of the education market; a year later, 80 percent of all computers ordered under the United Kingdom's Primary School Scheme were the BBC microcomputers.

It is unclear whether the success of the BBC Computer Literacy Project had anything to do with the Ontario Ministry of Education's 1981 Canadian Educational Microcomputer initiative to create a powerful microcomputer for schools. Since the late 1970s, the microcomputers installed in Ontario schools had been hardware-incompatible, making the development of computer-oriented courseware for Ontario schools difficult. The proposed solution was the creation of a single microcomputer platform for Ontario schools. Ontario teachers were initially involved in drawing up the specifications of the computer, and the Canadian Educational Microcomputer Corporation (CEMCorp) was formed to develop and manufacture it. The result of this initiative was the ICON computer, often referred to as the "Bionic Beaver," which was introduced in late 1983.

The ICON was developed for CEMCorp by Micro Design and assembled by Microtel Ltd. of Brockville, Ontario. Its design was controversial. Most teachers were expecting a microcomputer powerful enough to run a range of good-quality educational software available on the market, while Micro Design's philosophy was to provide a unique computing environment, a new "educational approach" to computer education, with adequate hardware to support it.

The technical specifications of the ICON were impressive for the early 1980s: the Intel 80186 microprocessor, 384 kilobytes of RAM, monochrome and colour display with high-resolution graphics, bilingual keyboard, trackball controller, high-capacity disk storage, and Apple Lisa-like windows user interface. On the software side, the ICON project called for a variety of programming languages developed by the University of Waterloo and QNX—a Unix-like operating system from Quantum.

The first ICONs were manufactured in December 1983 and were installed in twenty school boards in Ontario. The provincial government covered 75 percent of the computers' costs. In 1984, the ICON came under the control of a new company, CEMCorp International. New models of ICONs were manufactured and distributed to schools in Ontario, New Brunswick, Manitoba and Alberta.

The Canadian Educational Microcomputer initiative was not as successful as its BBC counterpart. The BBC selected a computer from existing hardware that could be modified to match the specifications drawn up by the corporation. That resulted in almost instantaneous manufacturing of the first BBC computers. The ICON started as a controversial hardware/software concept that took a long time to develop. When the computer was finally manufactured, educational computing was moving away from hardware platforms incompatible with either the IBM PC or the Macintosh.

In 1983, TVOntario broadcast a twelve-part computer education series called *Bits and Bytes*. It was a popular program, similar to the BBC's Computer Literacy Project, and was sponsored by several computer manufacturers: Apple Computer, Digital Equipment Canada, NABU Manufacturing Corporation, Radio Shack and Xerox. The program was addressed to students, teachers and anybody else who wanted to learn about computers. Instead of dedicated computer hardware, Bits and Bytes used various computers from Commodore, IBM, Apple and other manufacturers.

Educational programs for networked microcomputers were offered by NABU Manufacturing Corporation for its NABU Network, described in section 4.3.4. One of the targets of the NABU Network was the education market and, to capture its attention, the company offered three categories of educational software: Family Learning (programs for small children); Family Education (advanced educational software, such as programming languages); and School Education (a range of educational programs for elementary schools). In 1985, the Education Channel Advisory Committee of parents and teachers was set up to advise NABU on matters of computer education. The committee's activities and recommendations could be reviewed on-line by accessing the appropriate pages of NABU's dedicated Education Channel. By 1986, the Education Channel offered one hundred educational programs. NABU reported in *The Hard Copy*, its monthly newsletter, that, in the same year, twenty-five schools in the Ottawa area were using NABU microcomputers in their classrooms to access educational programs available on the NABU network.[20] Furthermore, "A special Introductory Educational Package has been offered to students, and formal proposals have been made to both the Ottawa Board of Education and the Ontario Ministry of Education, recommending expanded use of NABU technology in school boards throughout the province." (p. 1)

Unfortunately, as reported by the *Ottawa Citizen* on 29 July 1986, in spite of the success of NABU's educational channel, the Ontario Ministry of Education refused to finance a field trial of the network in Ottawa-area public schools from the provincial government's $1 billion high-tech initiative. This decision was one of the contributing factors to the NABU Network's abrupt closure in August 1986.

## 4.10 Conclusion

In Canada, microcomputing had begun in the early 1970s with the announcement of Intel's first microprocessors. Since then, Canadians had been actively involved in the proliferation of early microprocessor technology, as well as in the development of the first microprocessor-based personal computers. Through the 1970s and 1980s, Canadian firms contributed their fair share of technological innovations in the areas of semiconductor, computer and information technologies; they helped to reshape the social status of computing worldwide and to integrate computers into everyday activities.

Though there are a number of unique milestones in the history of the Canadian microcomputing industry (such as the development of the world's first dedicated personal microcomputer by MCM), the events that shaped the microcomputer scene in Canada shared many characteristics with similar developments that were occurring elsewhere in the world: for example, worldwide experimentations with early microprocessor technology, leading to the development of the first microcomputers; the role and strength of the computer hobbyists' movement; and the patterns of social acceptance of microcomputers in North America, Europe and Asia.

One example of the similarities between Canada and the rest of the world in the development of microcomputers is provided by Réalisations et Études Électroniques (R2E), a small French electronics company. In 1972, it started to design its own microcomputer, which, like the Canadian-built MCM/70, was based on the Intel 8008 microprocessor and had its roots in the Intel SIM8-01 development system. The R2E Micral and the MCM/70 were introduced in February and May 1973, respectively, and are among the earliest mass-manufactured microcomputers. While unable to penetrate the North American market, the Micrals were popular in Europe, especially in France, where the sales of the MCM/70 were also strong.[21]

There were also similarities in the approaches taken to embrace personal computing. One example is the role of children in making home computers a part of their environment and, to some extent, less intimidating for their parents. Marketing of computer technology frequently used a child theme (such as an image of a child playing with a computer terminal) to communicate a rather simple message to the adult audience: if children find computers interesting and easy to use, then so should you. While children could not possibly find the operation of sophisticated minicomputers exciting or simple, their fascination with home microcomputers was genuine.

Young children adored Mickey Mouse, Bugs Bunny, Kermit the Frog and Daffy Duck, and followed their adventures with excitement. However, they were unable to interact with their fictional TV celebrities at any satisfactory level. They could, of course, wave plastic replicas of E.T. and Cookie Monster in front of the TV screen and sing along with Kermit the Frog, but they could not capture their attention. However, with the advent of the home computer, children could not only follow the events in a game or other computer program as they unfolded, but could interact with the characters by communicating with them, controlling their movements, making them stronger or wiser, happy or sad. Older children could learn programming (typically in BASIC) and could create their own virtual realities (mostly represented as computer games).

In 1976, Intel placed an advertisement in a number of magazines that depicted an enthusiastic kid named Rickey posing with a soldering iron over a sophisticated Intel 8080-based single-board computer, the SDK-80. As portrayed by Intel, Rickey was a curious but otherwise typical kid of his age who liked soccer, lizards, hot fudge sundaes, skateboards and microscopes. But now, according to Intel's advertisement, "Rickey's tackling the SDK-80 microcomputer kit for his next science project . . . He may be the first kid on his block with his own computer,"[22] implying that "If Rickey can do it, then so can you."

Advertisements similar to that of Intel's Rickey were also created outside North America by companies such as the Japanese electronics giant NEC. In 1975, NEC introduced its clone of the Intel 8080 microprocessor. Noting the strength of the computer hobbyists' movement in North America and its role in the proliferation of microprocessor technology, NEC decided to create a single-board computer (the TK-80) similar to Intel's SDK-80 and to offer it in kit form to computer enthusiasts in Japan. The kit was introduced in August 1976 and, to support its product, the company soon opened a microcomputer showroom in the centre of Akihabara, Tokyo's renowned consumer electronics district. The showroom quickly became a popular meeting place for Tokyo's microcomputer enthusiasts of all ages.

In one of NEC's advertisements, Intel's Rickey was reincarnated as a young computer enthusiast named Takashi Hoshino, a fourteen-year-old student at Ohfuna Junior High School. On the cover of the June 1978 issue of *Gakusyu-Computer,* NEC set up an interchange between Takashi's father, the technology provider, and Takashi, an enthusiastic youth and NEC's agent of change:

> One day, after his visit to Akihabara my son said to me:
> "Dad, I want a microcomputer kit."
> "Oh!?"
> "It's a microcomputer!"
> "Yes?"
> "I really need it."
> "Then tell me, what can you do with it?"

"Dad, it is not 'what' but 'how.' I can program a microcomputer to do what I want and, then, I can run it to do that for me."

"Well . . ."

"OK Dad?"

My son had always enjoyed playing with all sorts of machines and devices. But I would never have imagined that he would be able to put a computer together.

Of course, Takashi gets his computer and now Takashi is working on a new game with his friend Hashida. What kind of a game will they create on Takashi's microcomputer? Would it be better than Star Trek?

This marketing strategy seemed to work for NEC; as reported by the Computer Museum of the Information Processing Society of Japan, by mid-1978 NEC had sold approximately 66 000 of its TK-80 boards. Similar marketing strategies involving children were adopted by most of the major microcomputer manufacturers around the world. In Canada, NABU Manufacturing Corporation marketed a large number of its NABU Network programs to children. Some of the company's newsletters were addressed, in part, to children and included, among other activities, sample LOGO and BASIC programs (e.g., Kid's Korner in *The Changing Times*, published monthly by NABU).

From the second half of the 1980s, the microcomputing market became even more homogeneous. One of the contributing factors was the "correction" in the home and personal computer market caused by the strength of the IBM PC-compatible hardware and software industries. Other significant contributing factors were the rise of Microsoft and the popularity of its Windows operating system, as well as the creation and global acceptance of the Internet and the World Wide Web. In less than thirty years from its creation, the world of computing was in the hands of microcomputer companies that manufactured powerful sixteen- and thirty-two-bit microcomputers by the million each year. In this short period in microcomputing history, the majority of operating computers became microprocessor-based, making the terms "microcomputer" and "computer" synonymous.

# Notes

1. National Archives of Canada, RG 19, Records of the Department of Finance, vol. 4475, file ID 9167-07-2 Part 1, Northern Electric Micro-Electronics Facility.
2. Those interested in the microprocessor and systems activities at MIL are referred to Zbigniew Stachniak, "The MIL MF7114 Microprocessor," *Annals of the History of Computing* (forthcoming). Corporate histories of Mitel, as well as other start-ups founded by former MIL employees, such as Corel and Newbridge Networks, are presented in Roger Voyer and Patti Ryan, *The New Innovators: How Canadians Are Shaping the Knowledge-Based Economy* (Toronto, ON: James Lorimer & Company, 1994).
3. For background information on microcomputing, see Zbigniew Stachniak, "Microcomputers," Benjamin W. Wah, ed., *Wiley Encyclopedia of Computer Science and Engineering*, vol. 5 (Hoboken, NJ: John Wiley & Sons Inc., 2009), 1860–68.
4. Zbigniew Stachniak, "The Making of the MCM/70 Microcomputer," *Annals of the History of Computing* 25, no. 3 (2003): 62–75; Zbigniew Stachniak, "The MCM/70 Computer," Core 4, no. 1 (2003): 6–12; and Stachniak, "The MIL MF7114 Microprocessor," *Annals of the History of Computing* (forthcoming).
5. The corporate history of Dynalogic and the making of the Hyperion are among the subjects covered by David Thomas in *Knights of the New Technology: The Inside Story of Canada's Computer Elite* (Toronto, ON: Key Porter Books, 1983).
6. See, for instance, Brian Bagnall, *The Commodore Story: A Company on the Edge* (Winnipeg, MB: Variant Press, 2006); and Stan Veit, Stan Veit's History of the Personal Computer (Asheville, NC: WorldComm Press, 1993).
7. John Kelly's entrepreneurial profile and the origins of the NABU Network are covered in Thomas, *Knights of the New Technology.*
8. Some of the major U.S. microcomputer manufacturers (1975–1982) were: Altos Computer Systems, Apple Computer, Commodore, Cromemco, Digital Group, Heath Data Systems, Hewlett-Packard, IBM, IMS Associates, Micro Instrumentation and Telemetry Systems, Morrow Designs, Non-Linear Systems (Kaypro Corporation), North Star, Ohio Scientific Instruments, Osborne, PolyMorphic Systems, Processor Technology Corporation, Radio Shack/Tandy, RCA, Rockwell, Southwest Technical Products Corporation, Sphere Corporation, Texas Instruments, Vector Graphics, Xerox and Zenith Data Systems.
9. The corporate history of DY 4 is discussed in Voyer and Ryan, *The New Innovators.*
10. Robert X. Cringley, *Accidental Empires* (New York: HarperBusiness, 1996), 169.
11. See Steve Rimmer, "The Legend of J.L.S.," *Computing Now!* (August 1983); Steve Rimmer, "The Further Legend of J.L.S.," *Computing Now!* (December 1983); and Steve Rimmer, "Fables of Three Blue Clones," *Computing Now!* (June 1984).
12. The Apple II cloning culture in Canada (with the focus on Ontario) is documented in an interesting way in Steve Rimmer, "Apple Pirates," *Computing Now!* (April 1983): 44–46.
13. DY 4, Gandalf, Mitel and Newbridge Networks are discussed at length in Voyer and Ryan, *The New Innovators.*
14. See, for instance, P. Freiberger and M. Swaine, *Fire in the Valley: The Making of the Personal Computer* (Berkeley, CA: McGraw-Hill, 1984).
15. Zbigniew Stachniak, "Microcomputers," 1860–68.
16. Source: Zbigniew Stachniak, "Intel SIM8-01: A Proto-PC," *Annals of the History of Computing* 29, no. 1 (2007): 34–48.
17. See ibid., for a complete discussion of the relationship between the MOD8 and SIM8-01 computers.
18. *Report of the Task Force on Computer Charging*, Ontario, 1 June 1970, 7.
19. E. Berkeley and R. A. Jensen, "World's Smallest Electric Brain," *Radio Electronics* (October 1950): 29–30.
20. *The Hard Copy* 1, no. 4 (1986): 1.
21. See Stachniak, "Intel SIM8-01."
22. *Byte* 14 (October 1976): 21.

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