The Last of the First

CSIRAC: AUSTRALIA'S FIRST COMPUTER

Doug McCann & Peter Thorne

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PREFACE

This publication describes an Australian technical achievement of great significance.

In the late 1940s Australian scientists embarked on an ambitious project to design and build, from the ground up, a programmable digital computer. They succeeded. The computer they created was not only the first computer in Australia, it was one of the very first in the world. This was the CSIR Mk1 computer (later renamed CSIRAC). It provided a computing service through the 1950s and well into the 1960s. Furthermore, it survives intact and is now considered to be the oldest survivor of the machines which started the digital revolution.

Our goal in publishing this collection of articles and conference papers on Australia's first computer CSIRAC, is to preserve for posterity recent historical research on this unique machine and details of the circumstances surrounding its development. Hopefully this will encourage further investigations to take place, raise public awareness of its existence and importance, and contribute to its long-term preservation.

The book consists of two parts. In the first part we have incorporated a timeline, a description of the hardware, brief biographies of CSIRAC's design and construction team, and memoirs of several of the operating and maintenance staff. The second part consists of papers which were presented at, or arose out of, the 1996 CSIRAC Celebration and Conference. Most of these papers were, in fact, presented at the Conference but a few are reconstructed and edited versions based on conference presentations, question and answer sessions, and later research. Although there is inevitably some degree of repetition in the various presentations we have resisted the temptation to edit this out, as often new general insights can be gained from the consideration of different individual experiences and perspectives.

ACKNOWLEDGEMENTS

I am very grateful for all the help I have received in preparing the conference and this publication. Much of the work was voluntary. Doug McCann played a major role in organising and running the conference and also did most of the editing of this volume; Steven Pass provided considerable technical support for the conference and subsequent activities; Max Burnet from Digital and the ACMS arranged funding for the celebration; Frank Hirst supported the project in many ways.

My thanks to Kate Behan from the ACS for organising publicity and Edwin Parsons for initial help organising the celebration. I am also indebted to the Museum of Victoria, in particular Ruth Leveson, for organising a loan of the CSIRAC computer for exhibition at the University of Melbourne. Other Museum staff who provided valuable assistance and support included Graham Morris, Euan McGillivray, Steve Eather, Jacqui Woolf, Ken Galloway and Geoff Holden.

The Department of Computer Science at the University of Melbourne has housed and supported this project. Thanks are due to the current Head of Department, Professor Leon Sterling and to departmental staff including Roslyn Littler, George Semkiw, David Hornsby, Thomas Weichert, John Horvath and Andrew Peel. Thanks also to former CSIRAC users Terry Holden and John Spencer for their assistance and to former university staff member and CSIRAC engineer Ron Bowles.

John Deane has kindly allowed us to use a substantial extract from his book on CSIRAC for this publication. Colette Bacash began the editing process and Geri Simm and David Hollyfield provided valuable technical support.

The preparation and production of this book has entailed the gathering of oral histories and photographic records and integration of contributions from many authors and sources. The process of gathering and editing these materials has extended over several years. We are particularly grateful for the continuing support and expert assistance of CSIRO staff Kerrie Monzo, Jenny Davies, Rodney Teakle, John Masterson and Mark Greentree in locating historical material from CSIRO records and archives.

In completing this publication we have relied upon the design and layout skills of Bernie Cram of the University of Melbourne Design and Print Centre and the tireless organisational and proof-reading expertise of volunteer Judith Hughes.

This publication is dedicated to the pioneers of Australian computing whose achievements are recorded herein.

Peter Thorne

Introduction

Doug McCann

CSIRAC: At the Forefront of a Technological Revolution

For most Australians the acronym CSIRAC would be meaningless. For children of the 'Lost in Space' and 'Star Wars' era the term 'would not compute'. A few might hazard a guess that it had something to do with CSIRO with which the term has some apparent similarity. A few, well versed in computers and computer history, because of their familiarity with other early computers like the ENIAC, the EDSAC, the EDVAC, the BINAC and the ILLIAC, might even suggest that the AC part of the acronym might mean 'Automatic Calculator' or 'Automatic Computer'. But very, very, few would have even heard of CSIRAC much less know what the acronym stood for. CSIRAC, in fact, is a contraction of *CSIRO Automatic Computer* (or spelt out in full, *Commonwealth Scientific and Industrial Research Organisation Automatic Computer)*.

Yet, despite its anonymity CSIRAC was one of Australia's foremost technological achievements. Some enthusiasts would judge it to be *the* most notable one. This strong claim would have some justification. A case could be made that in light of the computer revolution that followed, and which continues unabated, that there was a moment in history when Australia was at the very cutting edge of technological advancement. That point in time was in the late 1940s, not long after the completion of World War II.

During 1945 and 1946 ideas on the possibility of electronic computing were hatching in the mind of a young English physicist and mathematician, Trevor Pearcey. Upon his arrival in Australia in late 1945 and his employment in the CSIR Division of Radiophysics, Pearcey set about to convince others of the need to devote resources to the exploration of these ideas. He was fortunate. The research climate was right for such investigations to proceed. Australia's isolation in the Second World War and its need to develop radar systems and microwave vacuum tube technology had led in 1939 to the establishment of the CSIR Division of Radiophysics located, along with other divisions, in the grounds of Sydney University. The Division of Radiophysics, with considerable experience in radar pulse techniques, was well placed to direct some of its resources towards the development of electronic computing. By the mid-1940s it had become obvious that the burgeoning sciences would require massive amounts of computing to be done, not only in areas of research carried out in Radiophysics such as radioastronomy, cloud-physics and radio-wave propagation, but also in many allied sciences and, indeed, in other areas of endeavour as well. In early 1947, Edward Bowen, Chief of the Division (with prompting from Pearcey) decided that Radiophysics should enter the field of high-speed electronic computing.

Initially it was intended that a very simple prototype computer be built to illustrate general principles. This was to be followed by another computer which would be available for general use and provide the basis of a computing service. So, in early 1947 Trevor Pearcey teamed up with Maston Beard who was placed in charge of engineering development. Beard was a graduate in

Electrical Engineering from Sydney University and had worked in the Division of Radiophysics during the war. Beard and Pearcey proceeded with the design and construction of the minimum necessary components for an electronic computing system.

A third member of the team, Reginald Ryan, who joined the project in 1948, was set the task of building a mercury delay storage system. Pearcey, in collaboration with Geoffrey Hill, then worked on developing a more detailed logic design to facilitate the engineering and fix the instruction set and to devise a practical programming scheme. In due course, about November 1949 (the exact date is not recorded), the basic units were assembled and the first test-program was run. The result of all this activity was the first automatic electronic computer in Australia and one of the earliest in the world. This was the CSIR Mk1, later renamed CSIRAC.

CSIRAC was probably the fourth or fifth electronic stored-program computer in the world to run a program. It is difficult to definitively assign a ranking to the operational dates of many of these first generation computers because much depends on one's definition of 'operational'. By the term 'operational' do we mean when the first test program operated or when the computer commenced routine operation? These early electronic computers were not regular items of technology, but quite large and expensive pioneering research projects, more like room-sized pieces of custom-built laboratory apparatus than the standardised mass produced personal computers of today. Once the basic principles were demonstrated to be sound these machines were gradually and continuously improved.

After the running of the first test programs in late 1949, CSIRAC was developed to a stage where it was in restricted operation in late 1950. This was despite frustrating delays of six to nine months due to power shortages in Sydney. In addition, before CSIRAC was fully operational Pearcey and Beard were diverted to another major project because of the urgent need by CSIRO to quickly do an enormous volume of decimal multiplications. They designed and built a large decimal relay multiplier for this purpose which proved to be a reliable and useful machine.

A working, though incomplete, CSIRAC (still called the Mk1 at this stage) was publicly demonstrated during the first Conference on Automatic Computing Machines held on the 7th to 9th August 1951. From 1951 to mid-1955 CSIRAC was employed in the Division of Radiophysics, in part to support the cloud-physics and radioastronomy projects, as well as a tool for developing programming techniques. It also provided a computing service for other divisions of CSIRO, universities, and a variety of other research, design and engineering organisations.

During this period CSIRAC underwent further substantial development. Brian Cooper designed and built a magnetic drum secondary store. Work on it began in 1951 and a number of fast and slow designs were trialed. In late 1952 a drum was installed on the computer and gave good service. CSIRAC operated almost continuously during 1953 and 1954 servicing Radiophysics and outside organisations. A second drum with much greater capacity was designed and partially engineered but never completed; instead a disc was constructed, and installed in 1956, replacing the original drum.

Some of the tasks carried out by CSIRAC during its time in operation at Radiophysics included:

- computation of stellar and solar position tables for Sydney area
- extensive computations of molecular analyses for organic chemists
- x-ray spectra data and Fourier syntheses for crystallographers
- analyses of river flood data for the past century and water behaviour simulations for the Snowy Mountains Hydroelectric Authority
- simulation studies of signal patterns for radio antennae used in radioastronomy
- computations relating to the composition of the ionosphere
- studies in road and air traffic congestion
- solution of linear equations and matrices for framework structure design

In addition to these and many other similar tasks, CSIRAC also played an extremely valuable role in providing the first opportunity for users to obtain some knowledge and experience of electronic computing and programming. Although it was not publicly advertised, users from other research and engineering bodies visited Radiophysics to familiarise themselves with the new technology. Some of the more complex projects occupied the system for weeks at a time.

Techno-Paradise Lost: The End of the Mk1 Project

Although it is beyond the scope of this introduction to attempt to document and analyse the reasons for the demise of the Mk1 project a few comments are in order. From the beginning the project had a relatively low profile. It was seen as secondary by the Radiophysics management whose main focus was on the demonstrably more impressive radioastronomy, and the cloud-physics and rain-making project which might stimulate desperately needed rain for the inland, which in turn could revolutionise agricultural production and deliver vast social benefits to the nation as a whole. As it turned out radioastronomy was indeed spectacularly successful while the heroic rain-making project was not. Far less interest was taken in computing which was seen as a necessary but subordinate aid to other activities.

This was not the attitude taken by Trevor Pearcey. It is probably accurate to say that he was acutely aware of the promise and potential of computing as a discipline, a technology and an industry in its own right. He was frustrated by the indifference shown by Radiophysics management which seemed to him to virtually discourage public knowledge of, and use of, the computer (Pearcey, 1994, p.27). This made continued improvement and development very difficult for the small staff involved who laboured on with limited resources and diminishing encouragement. In contrast, overseas in the UK and the USA, resources were pouring into the electronic computing field and Australia rapidly lost the favourable position it held briefly in the late 1940s.

Attempts were made to interest Australian electronics firms in the commercial production of computers based on the CSIRAC design. In October 1952 Philips, EMI, AWA and STC were invited to tender for the construction of up to three machines. AWA and STC responded (there appears to be no record of interest from Philips or EMI), however, nothing eventuated from this exercise.

Doug McCann in front of partially restored CSIRAC at Museum Victoria. 26 November, 1999.

The status of the Mk1 project changed markedly following the appointment of Harry Messel to the Chair of Physics at Sydney University in 1953 and his establishment of the Nuclear Research Foundation. A decision was made to build a more powerful computer based on the design of an American computer, the ILLIAC. In 1954 private funding was secured for the project and it became clear that the Mk1 would soon be rendered obsolete. (The new computer designated the SILLIAC ultimately became operational on 12 September 1956.)

In early 1954 Edward Bowen indicated that he was not in favour of continuing with the Mk1 project and on 13 April 1954 it was officially terminated. Pearcey later lamented that a major Australian project "withered from lack of internal interest and supportive imagination" (Pearcey, 1994, p.30). In March 1954 a decision was made by Radiophysics to relocate the Mk1 and among the institutions considered were the Weapons Research Laboratory (WRE) in South Australia and the Aeronautical Research Laboratories (ARL) in Melbourne. Finally, it was agreed that it should be transferred to the University of Melbourne to serve as a free computing service under the joint jurisdiction of Professor Thomas Cherry, Professor Sir Leslie Martin and Dr Frank Hirst.

The Move to Melbourne

In mid-1955 the Mk1 was dismantled at the Radiophysics Laboratory in Sydney under the supervision of Frank Hirst. The disassembled machine was then loaded onto a semitrailer and transported along the Hume Highway to the Physics Department at the University of Melbourne. A small team from Sydney consisting of Maston Beard, Geoff Chandler, Phillip Hyde and Ron Bowles travelled to Melbourne and reassembled the computer. When that task was complete most of the team returned to Sydney, except for Ron Bowles, who remained in Melbourne as chief maintenance engineer.

On 14 June 1956, the Chairman of CSIRO Sir Ian Clunies-Ross officially opened the new Computation Laboratory at the University of Melbourne and the rebuilt Mk1 was formally recommissioned and named CSIRAC. This occasion marked the beginning of computing in Victoria. At this time CSIRAC was not only the first automatic electronic computer in Victoria but still the only one operating anywhere in Australia. Furthermore, it was the first to go into regular academic service (just preceding the SILLIAC and the New South Wales University of Technology computer UTECOM). Therefore this date is an appropriate one for a celebration of the birth of the computer age in Victoria and a reminder that with the construction of the Mk1 in the late 1940s Australia was once at the forefront of a technological revolution.

While other first generation computers around the world were being shut down and dismantled, CSIRAC at the University of Melbourne began a serviceable second life. Further engineering improvements were gradually incorporated into CSIRAC during its time in Melbourne. For a further 8 years CSIRAC functioned as an open-shop computing service and during this period, from June 1956 to June 1964, CSIRAC was switched on for about 30,000 hours and processed about 700 computing projects. Total maintenance time was approximately 10% of switch-on time.

The computer service at the University of Melbourne was managed by Frank Hirst and the regular operating and maintenance team included Frank Hirst, Ron Bowles, Jurij Semkiw, Peter Thorne and Kay Sullivan (Thorne). Clients included university staff and students, researchers from CSIRO and other government departments, and some paying customers from industry and commerce. As in Sydney a wide variety of programs were run. The first project for an outside organisation was run in 1956. This was the calculation of a set of amortisation tables for the Housing Commission. Another noteworthy project was for the rigid frame analysis of large buildings done by the CSIRO Division of Building Research. This program was used in the design of a number of prominent buildings of the day including: Consolidated Zinc Building (Melbourne), Colonial Mutual Life Building (Melbourne), Reserve Bank Building (Sydney), T & G Building (Perth), and Hotel Chevron (Surfers Paradise).

More than 200 people from the University of Melbourne, CSIRO and other organisations attended programming courses conducted from 1956 until 1963. Undergraduate courses in programming and machine logic were offered and students gained useful practical experience on CSIRAC. A program library of routines and subroutines on 12-hole paper tape was developed and gradually expanded over the years. Eventually most standard routines became available. In 1960 Geoff Hill devised a simple automatic language for CSIRAC titled INTERPROGRAM. With INTERPROGRAM, programs could be written in an English-like language.

Public demonstrations of CSIRAC were very much a part of the policy of the University of Melbourne's Computation Laboratory. During its time in operation hundreds of demonstrations were held for students and the general public throughout the year and on university Open Days. Demonstrations included: computer music, the game Nim, reflex reaction times, determination of the day of the week a person was born, mortgage loan calculations, and, of course, various numerical computations. CSIRAC computed its final program on 24 November 1964 and was donated to the Institute of Applied Science of Victoria. (Since then the 'Institute' has been through a number of name changes including the 'Museum of Victoria', now 'Museum Victoria'.)

By any measure CSIRAC was a remarkable Australian achievement. It was one of the earliest automatic electronic stored-program computers in the world. It was designed and developed in relative isolation from the rest of the world. It paralleled similar developments in the UK and USA but was independent of them, construction was already under way before the other projects became known. It was a singular and elegant design, a number of its features equal or superior to other contemporary designs of the time. Although engineering compromises were made, the logical design allowed good program economy and flexibility. Considering the relative lack of resources, experience, knowledge, personnel, funding and administrative support, the Mk1 achieved a admirable standard. By the time CSIRAC was decommissioned it was, by far, the oldest first generation computer still in operation.

Is it reasonable to assume that CSIRAC could have led to an Australian-based hardware industry? Trevor Pearcey for one argues that it could have and should have. He maintains that "the expertise and new ideas stemming from the experience of the Mk1 project" could have used to great effect "in new small-scale, custom-designed machines using read-only storage in major applications, and towards an indigenous computer industry" (Pearcey, 1994, p.30). Pearcey insists that "lack of support was the main reason why no early computer industry developed in Australia even though there was sufficient expertise" (Pearcey, 1994, p.28). A sad but familiar Australian technological tale.

Background to the 1996 Conference

At the time of CSIRAC's shutdown in November 1964 it was already recognised by its operators to be an historically important technological artefact. This realisation was probably the major factor that contributed towards its preservation. Most other first generation electronic computers were dismantled and scrapped. In most cases only a few minor artefacts remain extant. Although Museum Victoria accepted CSIRAC for its collection the computer was never put on public display. Its sheer bulk, and the relative drabness of its exterior, mitigated against it being easily placed in any exhibition. From 1964 to 1980 it was kept in storage at the museum's warehouse at Abbotsford where it was only sighted by staff and a few enthusiasts.

After several career moves, Trevor Pearcey in 1972 commenced employment at the Caulfield Institute of Technology where he became Dean of the School of Computing and Information Systems and later Foundation Dean of the Faculty of Information Technology. In 1980, Gerry Maynard, then Head of the Department of Electronic Data Processing at Caulfield, decided it would be an appropriate tribute to Trevor Pearcey to have CSIRAC placed on display at Caulfield. Arrangements were made to move the computer from Museum Victoria to the Caulfield campus. Assembly was supervised by John Daly. From 1980 to 1992 CSIRAC remained on show at Caulfield and was a popular public attraction on Open Days. In September 1992 the computer was returned to Museum Victoria (Scienceworks), but once again was placed in storage, this time at a museum store in Maribyrnong. While in storage there, CSIRAC, in January 1995, was lucky to survive a flood of the Maribyrnong River. Water reached the base of the computer but fortunately no damage was done.

When CSIRAC was decommissioned in 1964 not all of the original artefacts associated with the computer went to Museum Victoria. It was agreed by the operating staff which included Frank Hirst, Kay Thorne and Peter Thorne that the small collection of remaining artefacts and documents associated with CSIRAC should not be discarded. Eventually Peter Thorne became custodian to the collection which included an archive of documents, many of which related to the arrival of CSIRAC in Melbourne. The collection also included the program library of routines and subroutines on 12-hole paper tape. Other items included the original door to the Computation Laboratory and an electric CSIRAC sign. Thorne also built up a small collection of early pre-CSIRAC calculators and post-CSIRAC computers.

Thorne, who as a young undergraduate student had worked on the CSIRAC team as weekend supervisor and troubleshooter, was well aware of the historical significance of the computer. In the latter part of the 30-odd years that he and Jurij Semkiw were guardians to the collection, Thorne nurtured the idea that some sort of CSIRAC celebration would be in order. Perhaps also a plaque could mark the site where Victoria's (and Australia's) first computer operated, and maybe CSIRAC could even be permanently displayed in the University of Melbourne's Computer Science Department (especially since it was merely sitting in storage in a museum store and possibly even deteriorating).

Around 1994 or 1995 Thorne, now Head of the Department of Computer Science, chanced to meet the Director of Museum Victoria, Graham Morris, at a university function and suggested that, since CSIRAC was a technological artefact of world significance, surely it should be a candidate for display in the propose Museum Victoria. Morris was enthusiastic and Thorne was reassured that sometime in the near future CSIRAC might receive public recognition as an important part of Australia's technological heritage. Then in 1995 Thorne became aware of the Australian Science Archives Project (ASAP) and met with them to discuss a formal archiving project. As a result ASAP was commissioned to collate, list and archive the CSIRAC documents. That work was carried out by Christopher Jack and the result is now publicly available on the Internet.

From that project Thorne learned of the embryonic Voices of Australian Science and Technology (VAST) project. Thorne then commissioned VAST to organise a CSIRAC celebration. A team was formed within the Department of Computer Science, consisting of Peter Thorne, Doug McCann, Jurij Semkiw, Steven Pass and Roslyn Littler with valuable input from other staff members and volunteers. The conference was jointly organised and sponsored by the Department of Computer Science at the University of Melbourne and the Australian Computer Society (ACS) with help from Digital Equipment Corporation (DEC) and the Australian Computer Museum Society (ACMS).

Kate Behan from the ACS played a major role in organising and advertising the conference. Max Burnet from DEC and a founding member of the ACMS arranged for vital financial support. Burnet also organised the production of an attractive CSIRAC poster.

Ruth Leveson from Museum Victoria was pivotal in arranging visits to the Museum to view CSIRAC and later for its transferral from the Museum to the University of Melbourne for exhibition. All the Museum staff including Ruth Leveson, Graham Morris, Euan MacGillivray, Steve Eather, Jacqui Woolf, and Ken Galloway were extremely helpful and accommodating.

The first visit by the team to view CSIRAC in storage at Maribyrnong was a poignant and memorable occasion for those present. The group included Peter Thorne, Jurij Semkiw, Doug McCann, Steven Pass and museum staff. At first, Thorne and Semkiw had trouble recognising the computer. For a brief moment they thought that the collection of grey cabinets they were viewing was not CSIRAC. The problem was that they were viewing a machine that had been dismantled and was in sections. In addition, miscellaneous parts appeared to be scattered somewhat randomly among other items of technology. Gradually however as each piece was identified it became clear that most, if not all, of the computer was there. Semkiw recognised labels he had attached to the computer when it was dismantled in 1964. Although Thorne had retained an interest in the location of the computer over the years, he and Semkiw had not sighted it since that time. It was a moving moment for those present, akin to a reunion with a family member one had not seen in 30 years.

After negotiations with Museum Victoria it was agreed that the computer would be made available for exhibition and historical research. After taking out a million dollar insurance policy the museum allowed the transfer of CSIRAC to the University of Melbourne. In early June 1996 the various sections of CSIRAC were shifted by truck to the University of Melbourne and reassembled in the basement of the Department of Computer Science by the former maintenance engineers Ron Bowles and Jurij Semkiw with help from departmental staff. The computer was on display for the conference where it was viewed with interest by conference participants most of whom had not seen it since they last used it in the late 1950s or early 1960s.

The Conference: 13 & 14 June 1996

The CSIRAC Celebration held on 13 and 14 June 1996 included a two day conference, a public meeting and a dinner.

According to all indications, including feedback from the participants, the conference was an unqualified success. The participants themselves thoroughly enjoyed it. Presentations were given by a number of personnel who had a close association with CSIRAC (and the CSIR Mk1) either as users or operators as well as others associated with the history of computing generally. The presentations were video recorded for historical purposes. The spectrum of speakers included scientists, technicians and engineers, and also historians, museum staff, archivists and others. The ACS public meeting, held on the evening of 13 June, was also a great success with several hundred members of the public attending. This was followed by a dinner held at University House. For many of the pioneers it was a stimulating and emotional reunion.

The organisers had hoped for a large turnout from the general public for the conference sessions themselves but for various reasons this was not to be. However, there was a compensation in that this allowed the opportunity for more intimacy and frankness at the conference, and in any case there was a gratifying turnout for the ACS public meeting. The celebration attracted some useful publicity which resulted in several newspaper and journal articles and an interview for the ABC Science Show.

Almost all of the Melbourne staff associated with CSIRAC were present at the conference but this was not the case with the earlier Sydney pioneers. Several of the original workers were deceased including programmer Geoff Hill. Because of his age and fragile physical condition Maston Beard declined to attend. Brian Cooper who built the first magnetic disk for the Mk1 was overseas at the time of the conference. Reg Ryan was (wrongly) believed to be deceased. At the time of the conference Trevor Pearcey was recovering from illness in the Beleura Private Hospital in Mornington. He indicated that he was very pleased that the celebration had been organised and arrangements were made for him to open the conference by telephone from his hospital bed.

During his opening remarks he stressed the important, but perhaps sometimes underrated, contribution of Maston Beard to the success of the Mk1 project.

In his opening address to the conference Peter Thorne pointed out that the CSIRAC celebration, which was organised to celebrate 40 years of computing in Victoria, brought together a number of elements including: the computer itself - the commissioning of which marks the beginning of computing in Melbourne; also, the pioneers; and, the people who operated the computer; and, by telephone, Trevor Pearcey who, with Maston Beard, was the designer of the computer when it was conceived in Sydney in the late 1940s. Thorne emphasised that the celebration also marked the origin of the University of Melbourne's Computer Science Department, and also the University Computing Service.

Overall, the conference achieved most of the organisers' goals, the major one being the recognition by relevant professionals, and some of the public, of the historic importance of CSIRAC. Considering that prior to the celebration CSIRAC was largely a neglected and unknown artefact, both internationally and locally, the event was a worthwhile exercise. The celebration marked the beginning of the process of identifying, collecting, recording and collating the history of one of Australia's most notable technological achievements.

Contents

CSIRAC CONFERENCE PROCEEDINGS 13 & 14 JUNE, 1996

Timeline :

THE GENESIS AND BIOGRAPHY OF A NEW MACHINE

Doug McCann

The following time-line and commentary provides a broad chronological history of CSIRAC from its conception to the present emphasizing some significant dates and facts.

1940 Trevor Pearcey graduated from Imperial College London and started work on radar systems. He spent from 1940 to 1945 in the UK working on mathematical aspects of development of short wave and microwave radar which required large scale computation and the use of analogue and digital aids. In the latter part of this period he worked with Douglas Hartree and Leslie Comrie.

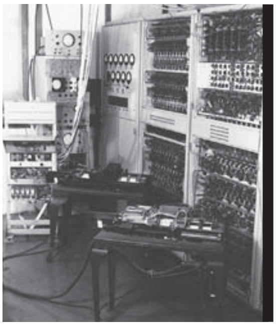
Conception: Mid to Late 1940s

1945 (Early) Pearcey (while still in the UK) had discussions with Douglas Hartree on the possibility of using electronics for fast computation (note: At this stage Pearcey was unaware of the top-secret WWII Colossus project).

1945 (Late) Pearcey migrated to Australia to take up a position in the CSIR Division of Radiophysics in Sydney.

1945 (October to December) En route to Australia Pearcey met Howard Aitken at the Cruft Laboratory and viewed the Harvard Mk1 (or Automatic Sequence Controlled Calculator) in operation. He also viewed the latest Bush electromechanical differential analyser at MIT (note: Pearcey was unaware of ENIAC which had just gone into operation). Pearcey was aware, however, of the neurological work of McCulloch and Pitts (1943) and of Gold's work at Haslemere in the UK on the use of acoustic delay lines for radar signal enhancement and the possibility of this as a storage medium.

1946 (Early) Pearcey formulated preliminary ideas on computing techniques. During 1946-7 Pearcey experimented with small-scale constructions using telephone relays with very small contact stacks to illustrate the possibilities of performing controlled sequences of binary arithmetical operations (similar work already done by Konrad Zuse was unknown outside of Germany).



1946 Chief of Radiophysics Edward Bowen and Assistant Chief Joseph Pawsey decided on radioastronomy and rain-physics as the two main areas of research. Radio propagation was a third, but was soon dropped in favour of the development of electronic computing.

Design and Construction: 1947 – 1950

1947 (Early) CSIR Division of Radiophysics decided to investigate high speed electronic computer techniques.

In early 1947 Pearcey and electrical engineer Maston Beard formed a team. Beard was a graduate from Sydney University in 1939 and was involved in radar work until joining Pearcey on the computer development team in 1947. Design and construction of the Mk1 began. The early small-scale experiments led to more extensive studies in logical design of automatic high-speed systems which could operate at about 500 to 1000 operations per second. During 1947 information about the ENIAC became available.

1947 (Late) Towards the end of 1947 a complete logical design was formulated by Pearcey.

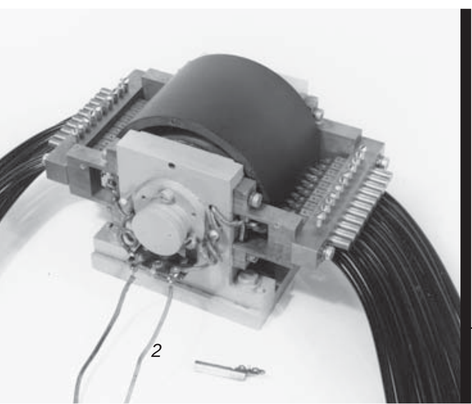
1948 Design and construction continued. Aided by Geoffrey Hill, Pearcey continued to develop a more detailed logic design to assist the engineering and define the instruction set, and leading to a programming scheme. Reginald Ryan developed a mercury delay storage system. The team became aware of parallel developments on the EDSAC at Cambridge, the MADM at Manchester and the pilot ACE at Teddington. During November and December 1948 Pearcey visited all three projects, however, decided not to change the logical design. The main advantage gained from the visit was the detailed electronic designs of some functional elements, such as arithmetic circuits and the more complex gates. (The BINAC and EDVAC were not heard of until later).

First Test Program: c November 1949

1949 (c November) About November 1949 CSIR Mk1 ran its first test program (the precise date is not recorded). Development and construction continued.

Regular Operation (Sydney): Mid 1951 – Mid 1955

1951 From late 1950 the CSIR Mk1 was continually improved and progressively applied to many types of computational problems such as in the cloud-physics and radioastronomy projects within Radiophysics and also in projects in outside departments and organizations such as other divisions of CSIRO, universities, and research and engineering bodies like the Snowy Mountains Authority. Also used as a tool for studying programming techniques. Pearcey ran programming courses in the Department of Mathematics at Sydney University during this. Many people visited the Mk1 to learn about automatic electronic computing.



The Mk1 was very much a ‘programmer’s machine’, designed for engineering simplicity and economy and flexibility since the main objective was the development of programming techniques leading later to breadth of application.

The computer was entirely serial in operation, with 20 bits (binary digits) per instruction/number (word) and performed about 500, later 1000, operations per second using the mercury acoustic delay store of up to 1024 words. Input and output, initially via punched cards, was changed to 12-hole paper tape.

1951 (August) A working, but still incomplete, machine was demonstrated at the first Conference on Automatic Computing Machines held at the Department of Electrical Engineering at Sydney University on 7–9 August 1951.

1951 Music first played on the Mk1 (possibly the world’s first computer music?).

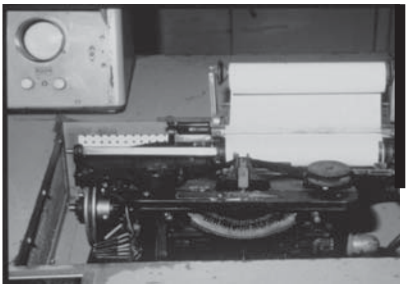
1951 Brian Cooper started design work on a magnetic drum secondary store. In late 1952 a drum was installed which gave good service.

1953 and 1954 During 1953 and 1954 CSIR Mk1 was used almost continuously for solving problems both for the Radiophysics Laboratory and for outside organizations.

1954 (Early) Radiophysics chief Edward Bowen indicated his desire to terminate the CSIR Mk1 project.

In early 1954 newly appointed professor of Physics at the University of Sydney, Harry Messel, established the Nuclear Research Foundation. It became clear that the research envisaged would require a much faster computer than the Mk1. Messel decided to build a new, more powerful computer, the SILLIAC, based on the successful operation of the University of Illinios machine, the ILLIAC, whose plans would be available. A funding appeal was launched in early 1954.

Other reasons that have been suggested for the termination of the Mk1 project include: The earlier recommendation in 1949 by David Myers to the CSIR Executive that work on development of computer machinery should be confined to components only, until a cheap, reliable and easily accessible storage medium became available; the failure to convince the Australian electronics industry to build on the success of the Mk1 and invest in the production of a locally designed and manufactured computer; delays in the development of the Mk1 project; the CSIRO Executive’s belief that Australia’s main interest still lay in her primary industries rather than



secondary; and, significantly, Edward Bowen's desire for Radiophysics to focus on basic research projects such as radioastronomy and cloud-physics, particularly the promising rain-making research to which Bowen was strongly committed. Thus, CSIRO ceased computer development.

1954 (March)

Radiophysics decided to relocate the computer. The Mk1 was offered to a number of institutions among them the Weapons Research Establishment (WRE) in Salisbury, South Australia and the Aeronautical Research Laboratories (ARL) in Melbourne.

1954 (August 12)

Formal recommendation from Radiophysics to CSIRO Executive that the computer be transferred to the University of Melbourne.

1955 (June)

Under the supervision of Frank Hirst the Mk1 was dismantled and transported on a semi-trailer along the Hume Highway from the Radiophysics Laboratory at Sydney University to the Physics Department at the University of Melbourne. The computer was reassembled by Maston Beard and a CSIRO Radiophysics engineering team, which included the chief maintenance engineer Ron Bowles.

Regular Operation (Melbourne): June 1956 – November 1964

1956 (June 14)

The new University of Melbourne Computing Laboratory was officially opened by the Chairman of the CSIRO Sir Ian Clunies-Ross and the Mk1 was formally recommissioned and named CSIRAC (an acronym derived from 'Commonwealth Scientific and Industrial Research Organisation Automatic Computer'). CSIRAC was the first automatic electronic computer in Victoria and even at this stage it was still the only one in operation in Australia! It was also the first to go into regular academic service (preceding by a few weeks the SILLIAC and UTECOM).

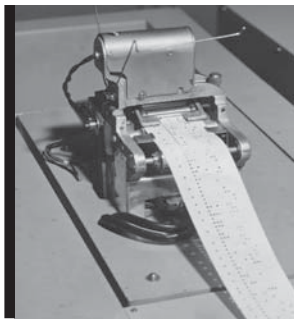
CSIRAC operated in Melbourne for eight years as a free scientific computing service under the jurisdiction of Professors Thomas Cherry and Leslie Martin and Dr Frank Hirst. Its regular operating team consisted of Frank Hirst, Ronald Bowles, Jurij Semkiw, Peter Thorne and Kay Thorne.

A new magnetic disc was installed replacing the magnetic drum used in Sydney. It arrived in Melbourne with the Mk1 without magnetic surface and several weeks were spent investigating a way of spraying a rotating disc with magnetic paint so that the surface was free from occlusions. The resultant magnetic disc gave excellent service. The new disc had a 1024 word capacity per side. The second side was not utilised until 1962 following extensive transistorised additions to the original circuitry.

Further engineering improvements were gradually incorporated into the internal design of CSIRAC during its time in Melbourne. For example, the PK facility, allowing one command to modify the following, was introduced. Extensive modifications were made to the mercury delay line store, in particular new modulators were constructed and the tubes containing the mercury were changed from monel metal to stainless steel. This greatly improved the life-time of the delay lines so that the mercury store, which had previously been problematic, became relatively reliable.

Another extension in Melbourne was the addition of 5-hole paper tape input and output peripheral equipment, this greatly improved output speed and data punching. Modifications to the logical design of the control and arithmetic circuits reduced addition time to 1 millisecond.

Programming courses for CSIRAC were conducted from early 1956 until 1963. Over 200 people attended these courses from the University of Melbourne, CSIRO and other outside organizations. Undergraduate courses in programming and machine logic were arranged for physics, engineering and mathematics students, who gained practical experience on CSIRAC. Machine code was arranged in a mnemonic fashion and was fairly easy to learn. The relatively simple assembly system aided programming.



In Melbourne, a program library of routines and subroutines on 12-hole paper tape was developed and gradually expanded over the years. The first library program was a tangent subroutine. Eventually most standard routines and several unique routines became available.

1960

A simple automatic language for CSIRAC titled INTERPROGRAM was developed by Geoff Hill. This enabled program statements to be written in an English-like language.

In Melbourne, CSIRAC operated as an open-shop. Users included university staff and students, researchers from several divisions of CSIRO, personnel from government departments and some paying customers from private enterprise. CSIRAC repaid many times over its development cost.

During its eight year operating period in Melbourne, from June 1956 to June 1964, CSIRAC was switched on for approximately 30,000 hours and processed about 700 computing projects. Total maintenance time was about 10% of switch-on time.

1964 (November 24)

CSIRAC computed its last program (the tangent routine test) and was decommissioned. CSIRAC was donated to the Institute of Applied Science of Victoria (now Museum Victoria).

Retirement: 1964 – Present

1964-1980

CSIRAC was not exhibited by Museum Victoria but kept in storage

at its warehouse at Abbotsford. In 1972 Trevor Pearcey joined the Caulfield Institute of Technology where he became Dean of its School of Computing and Information Systems. In 1980, Gerry Maynard, then Head of the Department of Electronic Data Processing, arranged for CSIRAC to be transferred to the Caulfield Institute of Technology and put on public display.

1980-1992

CSIRAC remained on public display at the Caulfield (later Chisholm) Institute of Technology from early 1980 until late 1992 then returned to the Museum of Victoria (Scienceworks).

1992-1996

Again CSIRAC was not exhibited at the Museum of Victoria but was put into storage in a warehouse in Maribyrnong. In Januarary 1995 CSIRAC survived a flood of the Maribyrnong River, fortunately rising water only touched the base of the computer.

1996

Peter Thorne of the Department of Computer Science at the University of Melbourne organised a CSIRAC celebration conference and arranged for the computer to be moved from museum storage to the University and reassembled with the assistance of former maintenance engineers Ron Bowles and Jurij Semkiw.

1996 (June 13 & 14)

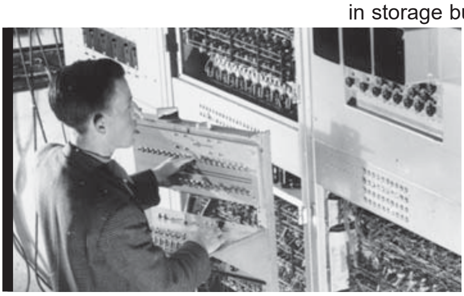
The CSIRAC Celebration Conference was held celebrating 40 years of computing in Victoria; an era which began with the arrival of the CSIR Mk1 from Sydney in 1956. The conference included a reunion of many former CSIRAC operating staff and users. The conference was officially opened by Trevor Pearcey by telephone from his hospital bed. An exhibition featuring CSIRAC and associated artifacts was staged along with the conference.

1996 (June)

The reassembled CSIRAC continued on display in the Department of Computer Science at the University of Melbourne until December 1996.

1996 (December)

CSIRAC was returned to Scienceworks where it was again placed in storage but able to be viewed during specially arranged store tours. Museum Victoria indicated that they planned to include CSIRAC as a major item for display in the proposed new Melbourne Museum at Carlton Gardens scheduled to open in 2000. Due mainly to the impetus provided by the University of Melbourne's CSIRAC history research team led by Peter Thorne, CSIRAC is now recognised as one of Australia's premier technological icons.



CSIRAC Hardware

John Deane

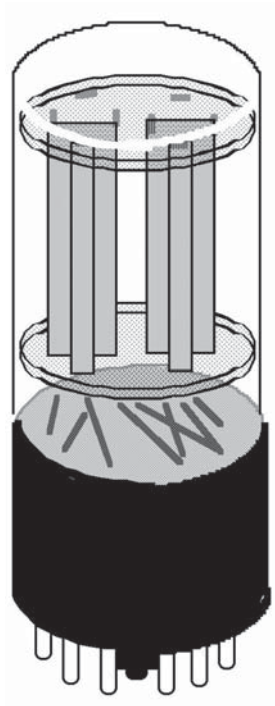
Extracted from *CSIRAC – Australia's first computer,* published by the Australian Computer Museum Society, 1997.

The Computer

What computer hardware does has not changed: it has to switch lots of things on and off. What it switches has not changed: it still pushes electrons around and about. What it uses to do that has changed a bit.

The Mk1 was designed with WWII radar technology, that is, a memory based on mercury filled acoustic delay lines and switching elements which were thermionic valves.

A glass bubble enclosed a metal structure in vacuum. A small heater warmed the cathode plate and the cloud of electrons produced were attracted to the anode at the top. The electron flow was switched on or off by the voltage applied to an open grid of wires between cathode and anode. A valve like this, ie cathode, anode and one grid, was a "triode". The 6SN7 was a twin triode with connections like:



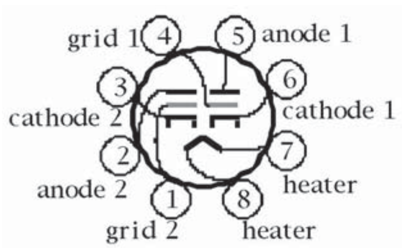
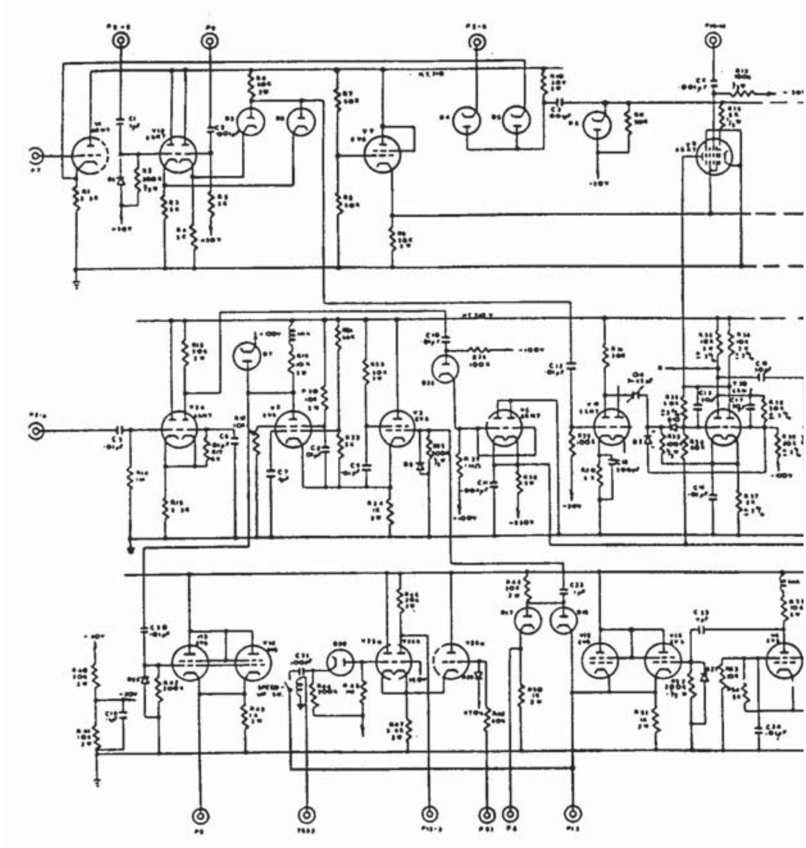


Diagram of a 6SN7 valve and the connections for the valve

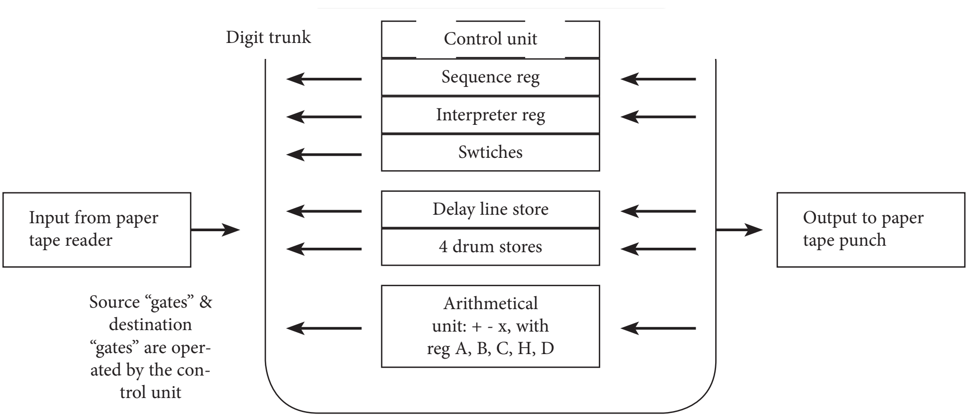
The Mk 1 used about 2,000 valves. Many of these were 6SN7 twin triodes so this represents under 4,000 logic elements. It was a very economical design. The machine was composed of a considerable number of circuits similar in style to this:



A fraction of the circuit of the improved sequence unit

The Logical Design

The essential elements of the Mk1 were:



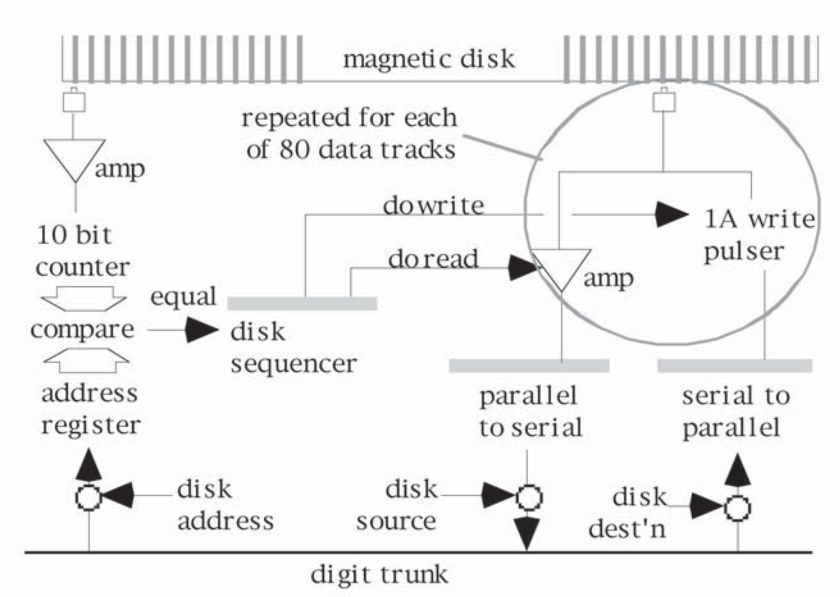
The elements of this diagram are described in the paragraphs following.

Digit trunk

This wire connected the source of an operation to the destination. In a parallel computer this would be an internal bus many bits wide, but Mk 1 was a serial computer so this bus was one bit wide.

Stores

- The primary store was the acoustic delay line memory of 1,024 words. This was provided by 32 metal tubes filled with mercury[1]. Initially, each of these held 16 words being constantly rotated, counted and used when the counter matched the required address. Reg Ryan found that the initial memory capacity could be doubled by interleaving two 16 word streams. All program instructions resided here and data often would too. An additional tube, kept at the same temperature as the memory, generated synchronised timing for the control unit. The delay line memory had a cycle (or access) time of 1 msec.
- In addition a magnetic disk developed by Brian Cooper and Maston Beard provided four 1,024 word stores. This had an average access time of 10 msec.



Only one logical disk of 1024 20 bit words was implemented initially, using 20 heads to read and write data on one side of the disc. A 21st track held a pre-recorded timing "clock" track. The expansion to four logical disks was to be provided by using another set of heads on the other side of the disk and by doubling the density of storage on each track. It was intended to use a relay to switch the heads, thus avoiding duplication of the read/write electronics. The physical disc had positions for up to 30 heads on each side, allowing for the clock track and enabling heads to be moved to new track positions in case particular tracks proved unusable. The heads were set 1/25 mm (0.0015") above the 360 mm (14") diameter iron-oxide coated disk rotating at 3,000 rpm The recording density ranged from 25 bpi to 45 bpi from the outer to inner track and each word (or bit) was 20 msec long. The disk store contributed about 350 valves to CSIRAC.

[1] This was the capacity. Usually there were only 24 tubes being used for 768 words of main store

When the disk capacity was increased in Melbourne the second side was brought into use, increasing the capacity to 2048 words, using a new set of read-write circuitry(built with transistors). This avoided the use of the relay to switch the heads electro-mechanically. Double-density recording was never implemented.

Sequence register

This held the address to read the next instruction. It included arithmetic to add one normally and to add values (which could be positive or negative) from the digit trunk.

Interpreter register

The instruction to be executed was loaded into this register and groups of bits were used to control which parts of the machine were connected. The source bits were decoded and passed to the source gates to select which register was connected to feed bits onto the digit trunk. Similarly, destination bits selected the register or function via the destination gates to receive bits from the digit trunk. If one of the stores is involved then its internal address was supplied from the store address bits.

Bits	p20 p19 p18 …p11	p10, p9 …p6	p5 p4 …p1
Group	Store address	Source	Destination
c(A)→16	0 0 0 0 0 1 0 0 0 0	0 1 0 0 1	0 0 0 0 0

See later for a list of the source and destination addresses.

Arithmetic unit

This is what the rest of the computer was built to support! All the registers here were implemented in mercury delay lines.

Register	Size	Functions
A	20 bits	×2, ÷2, +, −, AND, XOR, NAND
B	20 bits	÷2, ×C
C	20 bits	÷2, +, -
H	10 bits	store upper or lower half word
D	16 × 20 bits	÷2, +, -

Numbers could be 20 bit integers or, for the multiplier unit, signed 19 bit fractions:

Bit	p20 p19 p18 ...p11	p10 p9 ... p6	p5 p4 ... p1
Value	Sign 2^{-1} .... 2^{-9}	2^{-10}	............2^{-19}
eg +3/4	0 1 1 0 0 0 0 0 0 0	0 0 0 0 0	0 0 0 0 0

Input register

This read a word from the 12 channel paper tape reader at about 50 rows per second using photocells and could be set to transfer a bit pattern or to interpret it as a decimal digit.

Output register

From here a character (5 bit Baudot code) was sent to the console printer (a modified Post Office teleprinter) working at up to 6 characters per second, or punched on the 12-hole paper tape punch at about 16 rows per second.

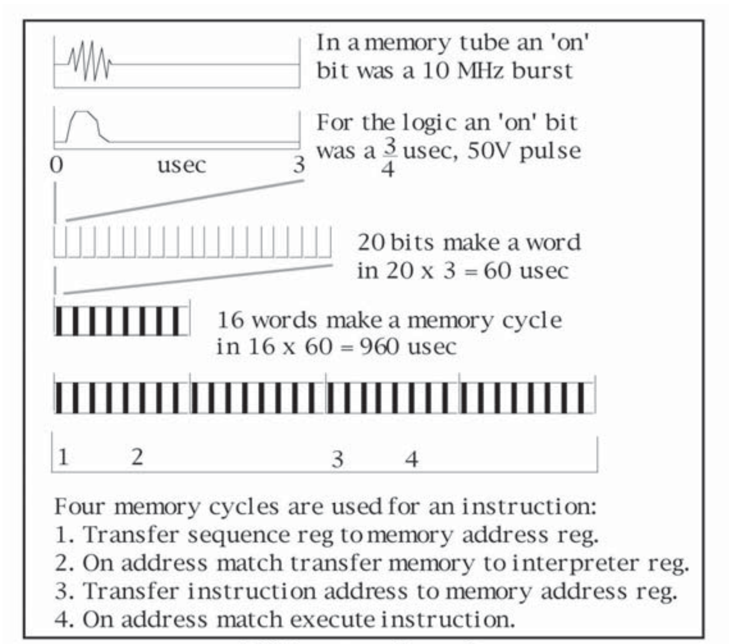
Constant registers

Three rows of switches on the operator's console could be read.

Control unit

This critical unit provided all the timing to coordinate operation of the different elements of the computer. It had a basic cycle of reading an instruction, addressed by the sequence register, from delay line memory into the instruction register. Next it controlled the gating of source and destination registers through the digit trunk. It provided bit-by-bit timing for the serial operation (synchronised with the various delay line memories). Signals for various significant bits control operations in many places (eg bit 1, 11 and 20).

The Mk 1 control unit operated on a fixed cycle of 4 memory cycles.



Mk 1 control cycle

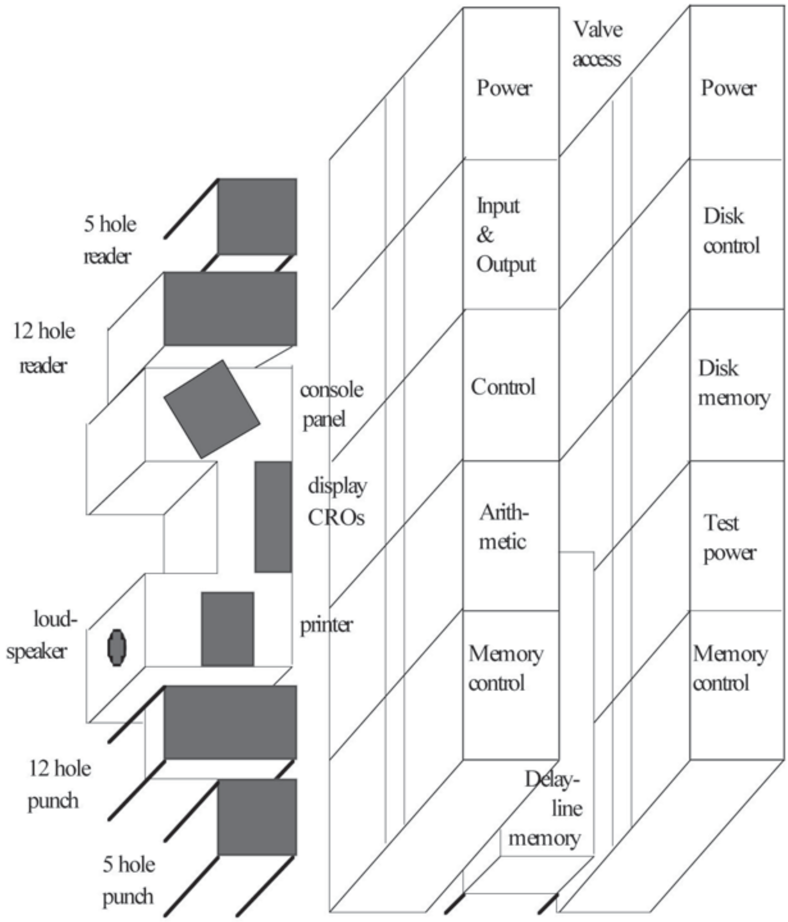
Control unit – Mk2

Steps 1 and 3 above use part of a memory cycle. As a result steps 2 and 4 need to extend into the next memory cycle to ensure a memory address match occurs. Maston Beard's Mk2 design checked whether the memory address was found before the "wasted" cycle started. If so, either step 3 could occur a cycle earlier or the next instruction cycle could start a cycle earlier. The Mk2 instructions executed in 2, 3 or 4 memory cycles depending on the instruction address and the memory address used by the instruction (except multiply which needed four cycle times anyhow). CSIRAC could run at up to 500 instructions per second (0.0005 MIPS!).

ETC

CSIRAC's power supply was 415 volts, 3 phase, 30,000 watts. Cool air was blown up through the cabinets from the basement below. There was also an editing station with paper tape reader and punch, keyboard, control unit and card punch.

Cabinet layout from above



Source and Destination addresses

The computer fundamentally worked by connecting a source of bits to the digit trunk along with a destination for the bits. The available units were:

Source address	Function	CSIRO symbol	U.Melb symbol
0	Main store (n = 0 to 1023)	(n)	n M
1	Input register	(I)	I
2	Switch register 1	(N_1)	NA
3	Switch register 2	(N_2)	NB
4	A register	(A)	A
5	A - sign bit (20) as bit 1	s.(A)	SA
6	A - shifted right 1	$^1/_2(A)$	HA
7	A - shifted left 1	2(A)	TA
8	A - bit 1	$p_1.(A)$	LA
9	A - then clear it	c(A)	CA
10	A - non zero test to bit 1	$\bar{Z}(A)$	ZA
11	B register	(B)	B
12	B - sign bit (20) as bit 1	(R)	R
13	B - shifted right 1	r(B)	RB
14	C register	(C)	C
15	C - sign bit (20) as bit 1	s.(C)	SC
16	C - shifted right 1	r(C)	RC
17	D register element 0 to 15	(D_m)	n D
18	D element - sign	$s.(D_m)$	n SD
19	D element shifted right 1	$r(D_m)$	n RD
20	Zero	(Z)	Z
21	H register low half (10 to 1)	(H_l)	HL
22	H upper half (bits 20 to 11)	(H_u)	HU
23	Sequence reg. as upper half	(S)	S
24	Upper one (bit 11 = 1)	p_{11}	PE
25	One	p_1	PL
26	Interpreter reg. (bits 20 to 11)	(K)	n K
27	Disk 1 word (n = 0 to 1023)	(n_1)	n MA
28	Disk 2 word “	(n_2)	n MB
29	Disk 3 word “	(n_3)	n MC
30	Disk 4 word “	(n_4)	n MD
31	Sign bit (bit 20 = 1)	p_{20}	PS

Destination address	Function	CSIRO symbol	U.Melb symbol
0	Main store (n = 0 to 1023)	n	n M
1	Set binary (if non zero) or decimal (if zero) input (in Melb no-op)	I_t	Q
2	Type character (generated by logical sum of relevant bits of upper and lower half word of output register) on console printer	O_t	OT
3	Punch row (generated by logical sum of relevant bits of upper and lower half word of output register) on tape.	O_p	OP
4	A register	A	A
5	A - add into	+A	PA
6	A - subtract into	-A	SA
7	A - AND	.A	CA
8	A - XOR	vA	DA
9	A - NAND	~A	NA
10	Loudspeaker	P	P
11	B register	B	B
12	B - multiply: B = A + source × register C	×B	XB
13	A and B shifted 1 left IF source bit 20 is set	L	L
14	C register	C	C
15	C - add in	+C	PC
16	C - subtract in	-C	SC
17	D element (n = 0 to 15)	D_n	n D
18	D element - add in	$+D_n$	n PD
19	D element - subtract in	$-D_n$	n SD
20	Null	Z	Z
21	H as lower half (p10 to p1)	H_l	HL
22	H as upper half (p20 to p11)	H_u	HU
23	Sequence register (ie jump)	S	S
24	Sequence register - add in	+S	PS
25	Sequence register - count in	cS	CS
26	Instruction register – add upper half to next instruction	+K	PK
27	Disk 1 word (n = 0 to 1023)	n_1	n MA
28	Disk 2 word "	n_2	n MB
29	Disk 3 word "	n_3	n MC
30	Disk 4 word "	n_4	n MD
31	Stop if non zero	T	T

Programming

The basic operation for the Mk 1 is a transfer of a number from a source address to a destination address. Some objects, like the main store, require a third address.

Programs for the Mk 1 were initially written using

$\rightarrow$	to indicate a transfer,
+ -	etc. modifiers on the arrow to indicate functions,
( )	for the use of the contents of an object,
12	ie a number as source, indicated a 10 bit number in the instruction, so the source is the interpreter register.

for example:

(42)	$\rightarrow$	A	transfer the contents of store location 42 to the A register,
(42)	$\xrightarrow{+}$	A	add the contents of the same location to the A register,
42	$\rightarrow$	A	transfer the address 42 (held in top 10 bits of word) to the A register.

When the Mk 1 became CSIRAC at the University of Melbourne its written programming conventions were simplified. Instructions were written using A to Z and 0 to 9 only, formatted like

address *source* *destination*

The above examples would appear as

42	M	A
42	M	PA
42	K	A

Actually, addresses were written as a pair of decimal numbers in the range 0 to 31, so the maximum address 1023 was written 31 31.

Jumps in the sequential execution of instructions could be made by operations on the sequence register 'S'. For example:

CSIRO symbols	U.Melb. symbols	
103 $\rightarrow$S	3 7 K S	continue the program at location 103 (=3×32+7), ie jump absolute,
7 $\xrightarrow{+}$S	7 K PS	go ahead 7 locations (actually counted from the location after the instruction as S has already been incremented for the next instruction location), ie jump relative,
p_{20}·(A) $\xrightarrow{c}$ S	SA CS	ie "select bit position 20 from register A, and count it into the sequence register", or in other words, if (A) is negative skip the next instruction, a basic arithmetic test.

This allows for "position-independent" programs which are essential for the creation of a generally useable library of sub-routines.

Tables of numbers in memory could be used with an interesting indexing operation.

CSIRO symbols	U.Melb. symbols	
(A) $\rightarrow$ K	A PK	If register A held the current index value, then loading this into register K (the interpreter register) will modify the next instruction.
(100) $\xrightarrow{+}$ B	3 4 M PC	So, this would add the element of a table, which begins at 100, and addressed by the value in A, to register C.

Subroutines were called by storing a return address in a D register. For example:

	CSIRO symbols	U.Melb. symbols	
	(S) $\rightarrow$ D_{15}	15 S D	save the next location, X,
X	sub $\rightarrow$ S	sub K S	go to the subroutine,
X+1	…	…	next instruction of main program

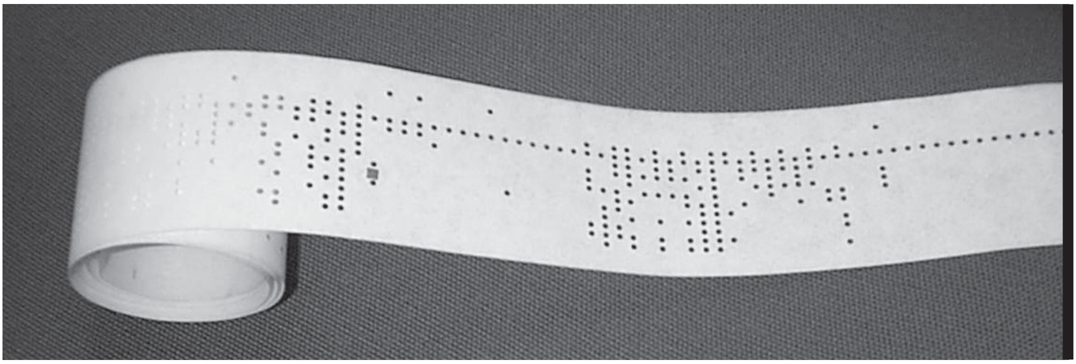
…

sub	P_{11} $\xrightarrow{+}$ D_{15}	15 PE PD	add 1 (in digit position 11) to the return address
	…	…	the subroutine commands...
	(D_{15}) $\rightarrow$ S	15 D S	and jump back to the main program., ie return..

A little program to total the numbers from 1 to 10 could be written

	CSIRO symbols	U.Melb. symbols	
	0 $\rightarrow$ A	0 K A	set the total in A to zero
	10 $\rightarrow$ C	10 K C	start from 10
add	(C) $\xrightarrow{+}$ A	C PA	the add
	1 $\xrightarrow{-}$ C	1 K SC	subtract 1 from C
	p_{20}.(C) $\xrightarrow{c}$ S	R CS	all done ? ie. is C = -1 ?
	-4 $\xrightarrow{+}$ S	31 28 K pS	no, jump back to the add
	1 $\rightarrow$ T	1 K T	yes, the total is in A, stop

While you could read the value in A from the console display in binary, a real program would include subroutine calls to print the answer out.



12-Hole paper tape

First generation programmers had to design their programs then use the special purpose hand punch to prepare a paper tape containing binary instructions. Later, they could also use a library of subroutines to do particular jobs such as maths functions and formatted output. In Melbourne, these subroutines lived four to each small box in a wooden rack near the computer. An "editing station" allowed the required library tapes to be copied onto the main program tape.

Finally the time the programmers had booked would arrive and they could actually use the only computer in the southern hemisphere…

The Mk 1 did not have an operating system which started automatically and allowed a user to type in commands to, say, run a program from paper tape. They were presented with a machine with an empty memory and a bank of buttons and switches. Something was needed to transfer the user's program into memory.

Originally a primary input program of 22 instructions was wired into Post Office uniselectors[1] (read only memory!). The computer could transfer this "bootstrap" into its delay line memory and this could run the user's program.

By about 1953 the uniselectors had proven unreliable and the "Primary" bootstrap was read from 12 channel paper tape. This was loaded by setting a special operating mode (console switch "S&N_1 to INT"). In this mode the following sequence was repeated:

- console switch bank N_1 was added to the current sequence register value,
- the result was executed as an instruction,
- the sequence register was incremented.

By setting N_1 to 00000,00000,00001,00000 the instruction was (I) $\rightarrow$ M (input from tape reader to memory) and the tape was read into succeeding memory locations. As this only loaded 12 bits into each 20 bit word some ingenious programming was required (see "Primary" + "Control").

In either case the user then

- Started the bootstrap to enter a secondary input program ("Control") of 16 instructions,
- Executed "Primary & Control" to enter the user's program and subroutine libraries. This relocating loader interpreted special codes to allow subroutine libraries to have addresses adjusted to the actual place they were loaded in memory,
- Executed the user's program with any required input data ready in the input reader.

[1] A multi-pole switch which could be set to a starting position and electro-magnetically stepped through all its positions. These were the basis of pulse dialled telephone exchanges.

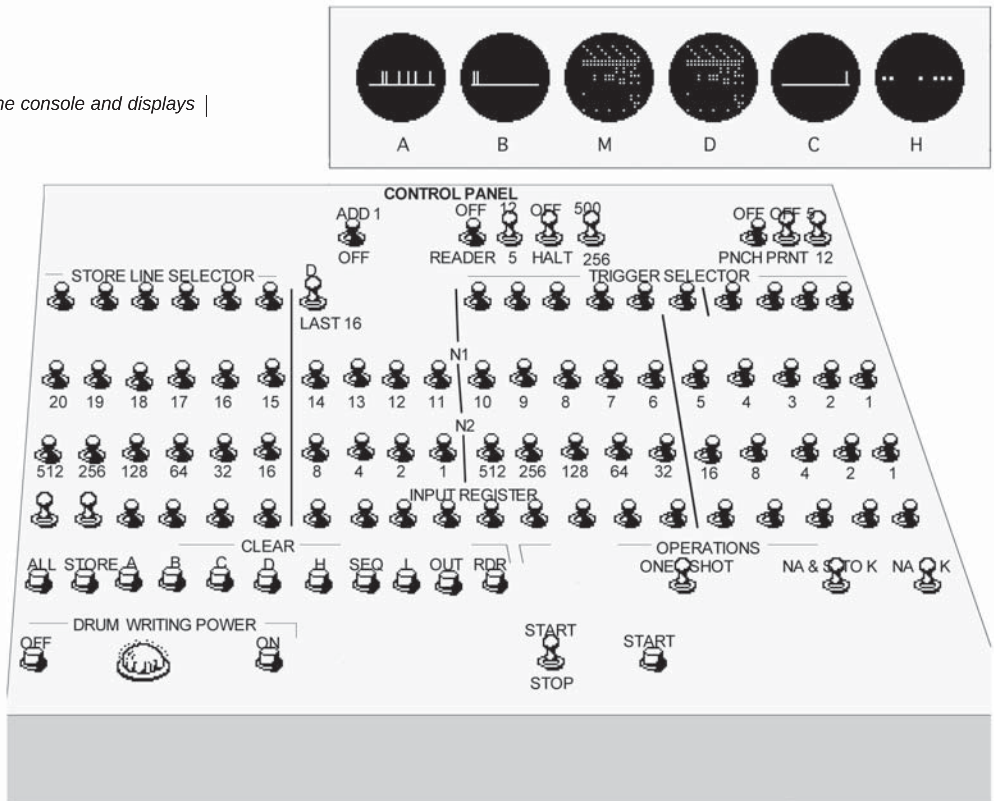
The output was either printed on a Post Office teletype or punched out on paper tape. However, 12-hole tape could only be printed using the computer itself to drive the output teleprinter. (Later, in Melbourne, standard 5-hole punched paper tape was used. This allowed output tapes to be printed off-line using Friden "Flexowriters". A Flexowriter could also be used to prepare program or data tapes.)

Now all the user had to do was to make the program work properly...

And Mk 1 helped there too. It could display all its working registers and the last 16 instructions executed. It could be given an address at which to stop (a "breakpoint"), and be stepped by one instruction at a time. It even had lights to show the computer's internal states.

This was a user-friendly computer.

The console and displays



"Primary" & "Control"

The fundamental operating programs for the Mk 1 were its "Primary", or bootstrap, which read 12 channel paper tape, and "Control" which interpreted the codes read to load a user's program into memory. There were various versions of these – the following are from 1955.

Primary

	CSIRO symbols	U.Melb symbols	Primary Routine Operation
0	$(0) \xrightarrow{c} S$	0 M CS	Command contains 3 bits, ie goto 4.
1	$(C) \xrightarrow{+} K$	C PK	The load address in C is added to the next instruction.
2	$c(A) \rightarrow 0$	0 CA M	Transfer the word in A to the memory location addressed by C.
3	$p_{11} \xrightarrow{+} C$	PE PC	"C + 1" for the next memory addr.
4	$(Z) \rightarrow B$	Z B	Flag "non X row" for instruction 15
5	$(D_0) \rightarrow H_l$	0 D HL	Save 10 input bits in H.
6	$(D_0) \xrightarrow{+} D_0$	0 D PD	Move input X row bit 19 into 20.
7	$s(D_0) \xrightarrow{c} S$	0 SD CS	If X row skip the next instruction.
8	$(0) \xrightarrow{c} S$	0 M CS	Non X row, do S + 3 = goto 12.
9	$p_{11} \rightarrow B$	PE B	Flag "X row" for instruction 15.
10	$(H_l) \xrightarrow{+} A$	HL PA	For an "X row" save low 10 bits.
11	$p_1 \xrightarrow{c} S$	PL CS	Skip the next instruction.
12	$(H_u) \xrightarrow{+} A$	HU PA	For a "non X row" save high bits.
13	$(I) \rightarrow D_0$	0 I D	Read tape, p_{19} as X, p_{20} as Y punch.
14	$s(D_0) \xrightarrow{c} S$	0 SD CS	If "Y row" skip the next instr.
15	$(B) \rightarrow S$	B S	If "X row" last goto 1, else goto 0.
16	$(D_0) \rightarrow H_l$	0 D HL	16 to 19 is "one time" code:
17	$(H_u) \rightarrow C$	HU C	Reset load address as input.
18	$(D_0) \xrightarrow{-} D_0$	0 D SD	Clear the "X row" flag.
19	$(Z) \rightarrow S$	Z S	Restart the Primary.
		Blank tape	As this blank tape runs through the reader the operator must switch off the special loading mode, ie "S&N_1 to INT" and the Primary will start executing at 0.
		16Y	Remaining blank tape will be read and ignored up to this 16 + "Y" punch. This uses the code at 16 to reset the load address to the read value (ie 16).

The first time the Primary executed, all registers were 0 so it essentially "fell through" to the first read instruction (at 13). Any stray activity here, or blank leader tape, would be overwritten by the first real data punch (which did not have the X row punched). The second row would have the X row punched and it would be interpreted as bits 20 to 11 to be stored with bits 10 to 1 saved from the previous read.

Following the "16Y" row the instructions started for the compact and subtle "Control" routine which was a relocating program loader.

Control

	CSIRO symbols	U.Melb symbols	Control Routine Operation
16	(Z) $\rightarrow$ B	Z B	Set "non X" in B
17	(D_0) $\rightarrow$ H_l	0 D HL	Use the value in the Y row -
18	(H_u) $\xrightarrow{+}$ S	HU PS	- to jump to 19,20,21,22,23,24 or 25
19	(28) $\xrightarrow{+}$ A	28 M PA	0Y: 24 becomes n $\xrightarrow{+}$ C (n K PC)
20	(27) $\xrightarrow{+}$ A	27 M PA	1Y: " (28+n) $\rightarrow$ C (28+n M C)
21	(26) $\xrightarrow{+}$ A	26 M PA	2Y: " (C) $\rightarrow$ 28+n (28+n C M)
22	(19) $\xrightarrow{+}$ A	19 M PA	3Y: " (28+n) $\xrightarrow{+}$ A (28+n M PA)
23	c(A) $\rightarrow$ 24	24 CA M	4Y: put the command in 24
24	[p_{20} $\rightarrow$ T]	[PL T]	5Y: this STOP instruction is replaced!
25	13 $\rightarrow$ S	13 K S	6Y: go back for next input
26	0, 0,13,27		"(C) $\rightarrow$ M" - "(M) $\xrightarrow{+}$ A"
27	31,31,18,14		"(M) $\rightarrow$ C" - "(C) $\rightarrow$ M"
28	31, 4,26, 0		"(K) $\rightarrow$ C" - "(28) $\rightarrow$ C"

At location 18 the value punched with a "Y" was added to the sequence register so "0Y" started at 19 and did all the instructions down to 25, "1Y" started at 20, etc. The constants from 26 to 28 were constructed so that adding them in the right sequence would make the desired computer instruction. At location 23 this instruction was inserted over the instruction at location 24, then executed! A number of locations following 28 were used as address pointers for the loading process.

An extra value ("n") could be punched in the row before the "Y" row and used as follows:

Symbol	Punch	Description
n T	n, 0Y	At 19: Transfer: add "n" to the load address in C.
n C	n, 1Y	At 20: Continue from a load address saved at "28+n"
n S	n, 2Y	At 21: Store a load address in "28+n".
n A	n, 3Y	At 22: Add a load address in "28+n" to the last read instruction.
D	4Y	At 23: Do the last read instruction.
U	5Y	At 24: Unchanged: do the last operation again.
N	6Y	At 25: Null does nothing.

While these routines are not easy to follow they demonstrate the capabilities of the machine's instruction set and the considerable abilities of 1950s programmers working in a very limited memory space.

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(Note “RPR” references are Radiophysics Research Reports)

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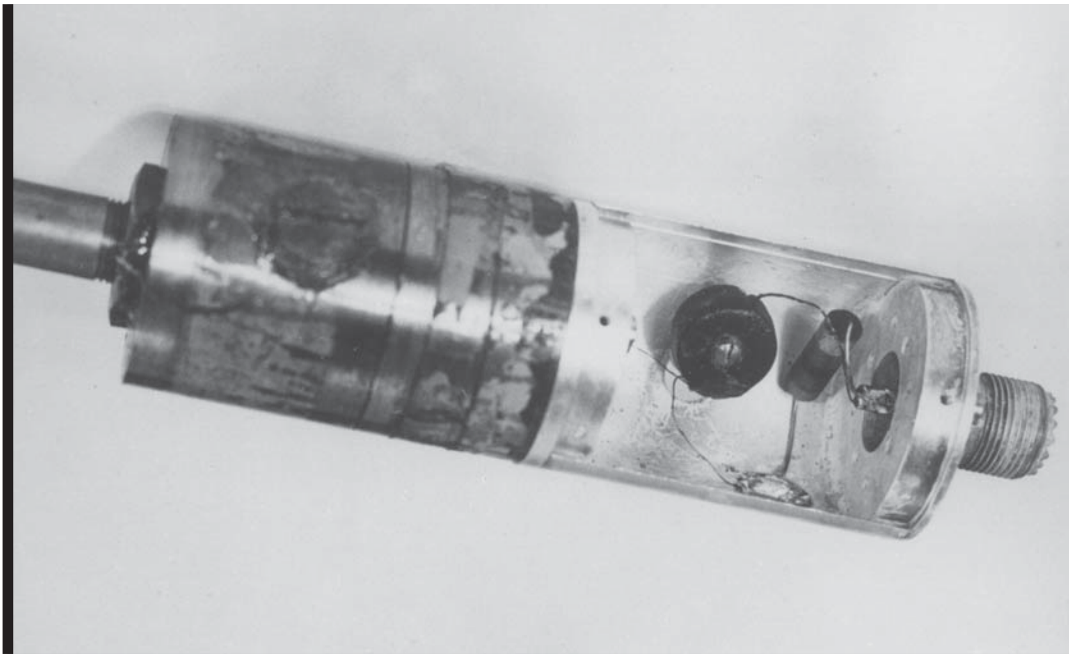


Photo: CSIRAC archive,
the University of Melbourne

Top: *End of mercury delay line showing coupling to external circuitry. c.1950.*

Right: *Disassembled end of mercury delay line. c.1950.*

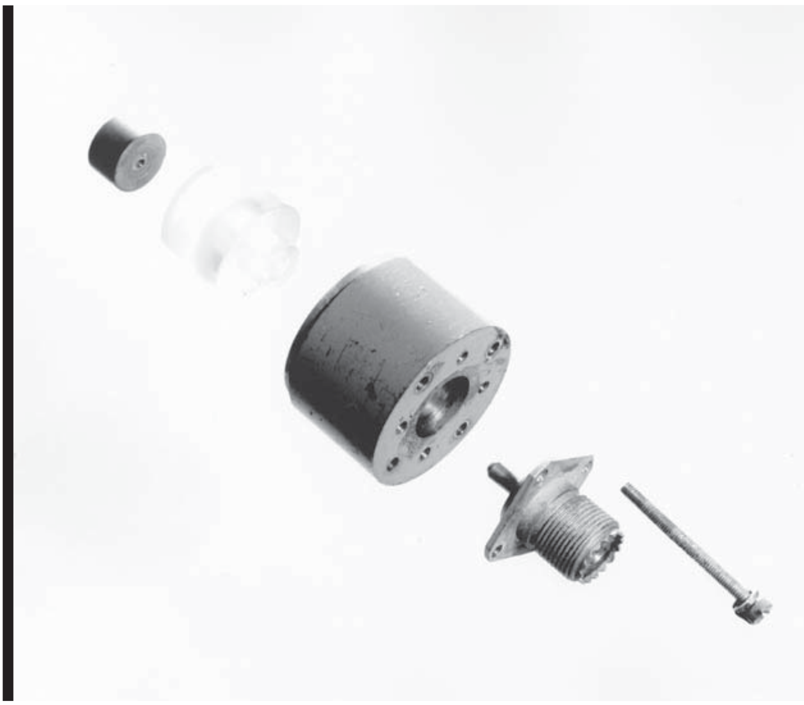


Photo: CSIRO archive.

THE CSIRAC TEAM

Design, Construction, Programming and Maintenance

Trevor Pearcey

Obituary 27 January 1998

Peter Thorne

Dr Trevor Pearcey who died on Tuesday, 27 January 1998, pioneered computing in Australia.

Born in the UK, he graduated in 1940 from Imperial College with First Class honours in Physics and Mathematics. He terminated his PhD studies due to the war and joined the Air Defence Research Development Establishment (ADRDE).

In late 1945, Pearcey came to Australia to work at the Radiophysics Division of the Council for Scientific and Industrial Research (CSIR). In 1948 he, with Maston Beard, commenced the design of a stored program electronic computer. This machine, the CSIR Mk1, was developed largely independently of work then underway in the UK and USA. The Mk1 ran its first program in November 1949. It was the fourth or fifth stored program electronic computer in the world and the first outside the UK and USA.

The Mk1 was transferred to the University of Melbourne in 1955 and recommissioned in June 1956, at which time it was renamed CSIRAC. CSIRAC was the first computer in an Australian university and the first computer in Victoria. The Computation Laboratory which was established upon the arrival of CSIRAC in 1955 later evolved into an academic department – The Department of Computer Science – and a computer service department now called Information Technology Services. As a consequence of the arrival of CSIRAC in the mid 1950s, the University of Melbourne has one of the longest established Computer Science Departments in the world.

CSIRAC provided a computing service to scientists, engineers and the Melbourne business community until 1964. The computer still exists intact making it the oldest surviving electronic computer in the world, the only survivor of the handful of machines which launched the information age.

It was a matter of regret to Pearcey that Australia did not capitalise on these early successes. However, CSIRAC played a major role as a training ground for many of the men and women who were to lead the computer revolution in Australia and overseas.

Pearcey participated in the design of several other notable Australian designed and constructed computers. He was the original architect of the CSIRO computing facility of the 1960s, leading to the establishment of the CSIRO

Division of Computing Research and the nationwide CSIRONET system. After a brief period with Control Data Corporation, Dr Pearcey became the first Dean of Computing at Caulfield Institute of Technology (later Chisholm Institute and now a campus of Monash University).

Apart from his pioneering work with computers, Trevor Pearcey was a prodigious publisher of scholarly papers. His interests included work in radio propagation, physical optics, scheduling of air traffic, crystallography, viscous flow and classes of non-linear systems which exhibit what is now referred to as aperiodic chaos. His collected works for the DSc awarded to him by the University of Melbourne in 1972, comprise three volumes of telephone book thickness, totalling almost 1800 pages.

Among these papers is an article, published in the *Australian Journal of Science* in February 1948, which may be considered prescient. Pearcey wrote:

> *"…in the non-mathematical field there is wide scope for the use of the techniques in such things as filing systems. It is not inconceivable that an automatic encyclopaedic service operated through the national teleprinter or telephone system, will one day exist."*

This was written long before the CSIR Mk1 (or even the Manchester Mk1 machine, which is generally considered to be the first real computer) was operational and decades before the evolution of on-line databases, the Internet and the World Wide Web.

In recent years Dr Pearcey lived on the Mornington Peninsula south of Melbourne. He kept in touch by e-mail with colleagues and friends (particularly those who are documenting Australia's early achievements in computing). It is fitting that he was able to do this by means of the technology which he pioneered.

Trevor Pearcey in front of CSIRAC. CSIRAC cabinets in centre and right. Test equipment cabinet to the left. Pearcey working with Hollerith equipment. Early photograph, 21 September, 1951.

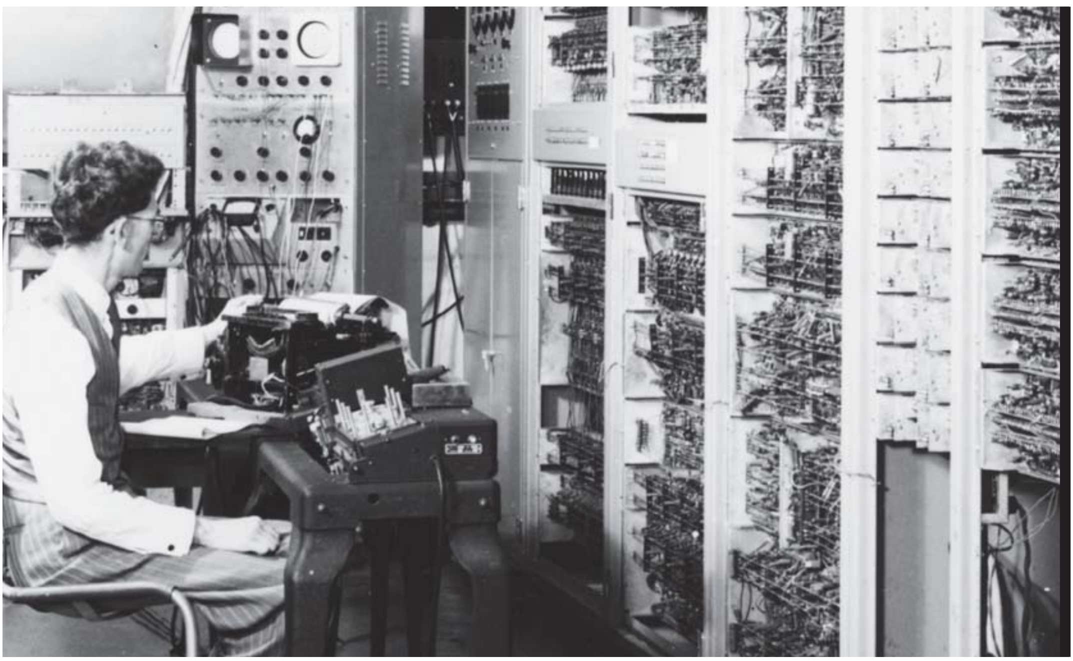


Photo: CSIRO archive

Maston Beard

Maston Beard, Betty Beard & Beverley Ford

Maston Beard attended Sydney Boys' High School 1929-33. In 1934 he enrolled at the University of Sydney and in 1937 gained a BSc degree, which was followed by a BE degree, with First Class Honours, in Mechanical and Electrical Engineering in 1939. Later, in 1958, he received a ME degree. His thesis was titled "The Design and Operation of a High Speed Electronic Digital Computer". After graduating in 1939 he gained employment in the Transmission Laboratory of Standard Telephones and Cables (STC) Pty Ltd. At STC he engaged in the development and design of radio transmitters and receivers and during this period spent three months at the Canberra Wireless Station in connection with the installation and testing of equipment.

Beard joined the Radiophysics Laboratory of the Council for Scientific and Industrial Research (CSIR) in Sydney in March 1941 as an Assistant Research Officer working on electronic circuit design and radar development. From February 1943-1945, he worked as a Scientific Liaison Officer in Washington.

On returning to the CSIR Radiophysics Laboratory in 1946 Beard worked on navigational aids and was involved in the design and development of the Multiple Track Range (MTR). He demonstrated the system to representatives of member nations of the Provisional International Civil Aviation Organisation (PICAO) in October 1946 in Montreal, Canada. The MTR sys-

CSIRAC staff in computer room at Radiophysics Laboratory, Sydney. May 1955. L–R; Geoff Chandler, Phil Hyde, Maston Beard, Ron Bowles. Although poorly focussed, this is one of the few photographs of the hardware engineers in Sydney.

Photo: CSIRAC archive, the University of Melbourne

tem was designed to guide air traffic into or from a base on as many as 60 different tracks at the same time and to operate with a high degree of accuracy in all weathers at a distance of 120 miles.

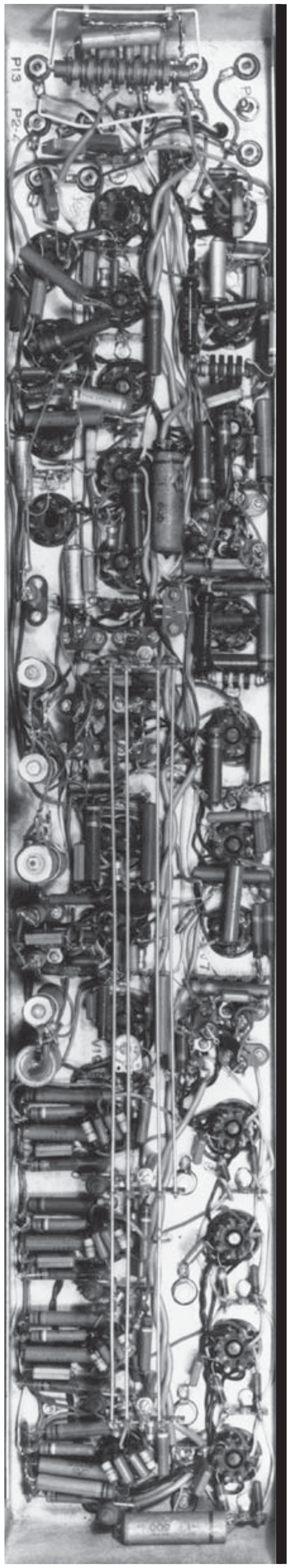
Trevor Pearcey, a British radar scientist, emigrated to Australia after World War II arriving on Boxing Day, 1945. He had joined CSIR as an Assistant Research Officer. During the course of the next year he persuaded Dr Bowen and Dr Pawsey, Chief and Assistant Chief of the Radiophysics Division, to agree to an electronic computer research project. Preliminary ideas for computing techniques were formulated by Pearcey during 1946 and 1947. Beard commenced working with Pearcey in early 1947, studied hardware components and, with Pearcey, pursued associated electrical and electronic aspects of the design. Their early progress is documented in two reports published in 1948:

(i) "The Logical Basis of High-Speed Computer Design" *CSIR Division of Radiophysics Report No. RPR 83* April 1948.

(ii) "The Organisation of a Preliminary High-Speed Computer" *CSIR Division of Radiophysics Report No. RPR 84* June 1948.

The construction of the Computer, CSIR Mk1, commenced in 1948 and the first programme was run in late 1949. Reginald Ryan designed and built the primary memory store which could accommodate up to 32 acoustic mercury delay lines. CSIR Mk1 was in operation by June 1951, just in time for the first Australian Automatic Computing Conference held in the Department of Electrical Engineering, University of Sydney. In 1952 Beard published: "Electronic Computer" *CSIRO Division of Radiophysics Report No. RPR 117* September 1952. The Mk1 was steadily improved between 1951 and 1955. The capacity of the delay line memory was doubled through the work of Reginald Ryan who also built monitoring displays and debugging equipment. A fast magnetic drum was developed by Brian Cooper which greatly extended the memory capability of the Mk1.

In early 1954 the CSIRO Executive decided to scrap the project to concentrate on rainmaking. Projects relating to radioastronomy, cloud-physics and the primary industries were competing with the computing project. Apparently the Executive believed that Australia should concentrate on primary industry rather than using resources competing in computing with Britain and the United States. Furthermore no-one in Australia was willing to take up the Mk1 as a commercial enterprise. At first it was contemplated



A section of the CSIRAC circuitry – time selector.

Photo: CSIRO archive

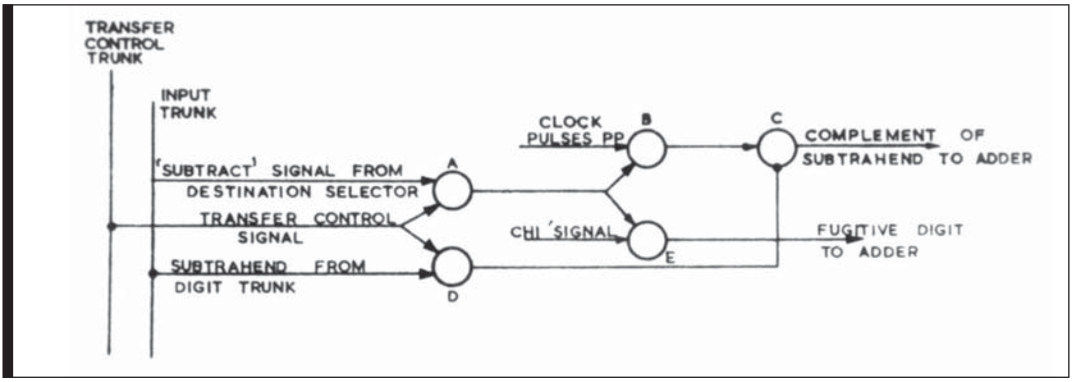


Photo: CSIRAC archive, the University of Melbourne

Circuit diagram of the Complementor.

that the computer be transferred to the Aeronautical Research Laboratories in Melbourne but later it was decided that it should be housed where it was more readily accessible to different users.

In August 1954 a formal recommendation was made that the Mk1 be offered to the University of Melbourne for use as a service and research facility. At this time Beard redesigned the central control unit (the 'sequencer') to improve both reliability and speed. In mid 1955 the improved 'Mk2' was dismantled and taken to Melbourne on a semi-trailer. Beard accompanied the computer when it was moved to the University of Melbourne and supervised its reconstruction during the remainder of 1955, then visited Melbourne periodically in the first half of 1956 until installation was complete. The computer, now called CSIRAC, was recommissioned on 14 June 1956 and for the next eight years, until the end of 1964, was used by various groups including CSIRO Divisions, university departments, ANU School of Physics, Australian industry, and teaching and research schools.

In 1957 Beard continued work on aids to navigation and returned to data processing and development of equipment for the Parkes telescope involving digital computer programme development and radioastronomy operations. The 64 metre Parkes radio telescope was designed by Freeman Fox and Partners. Construction began in 1959. The antenna and complex drive equipment were installed in late 1961 and the telescope was opened on 31 October 1961.

Beard then joined the Solar Astronomy group and with M. Morimoto and P. Hedges was responsible for the design of the CSIRO Culgoora Radioheliograph control computer, near Narrabri, NSW. Two papers on this project were co-authored by Beard and published by the Institution of Radio and Electronics Engineers (IREE) Australia:

(i) M. Beard, G. Chandler, P. Hrebeniuk and M. Willing. "The Culgoora Radioheliograph: 11-The Recording and Display System" *IREE (Aust) Proceedings* Vol 28, No 9. September 1967. pp. 334-344.

(ii) M. Beard, M. Morimoto and P. Hedges. "The Culgoora Radioheliograph: 12-The Computer" *IREE (Aust) Proceedings* Vol 28, No 9. September 1967. pp. 345-352.

In 1967, after representations made by the Australian Academy of Science and the Royal Society of London, the Australian and British Governments and the Australian National University decided to build a large optical telescope which was to be built at Siding Spring Mountain, near Coonabarabran, NSW. A

Project Office to supervise the construction of the telescope was set up in January 1968 by the Joint Policy Committee, which was succeeded by the Anglo-Australian Telescope Board in 1971.

During the late 1960's and early 1970's Beard was involved with work for both the Anglo Australian Telescope (AAT) and the CSIRO Division of Radiophysics. During 1972 he spent some time at the AAT project office in Canberra and was responsible for the computer and autogliding system, and interfacing of these to the drive and control system. He resided at Siding Spring during 1974 and was involved with the complex work of adjustment and instrumentation of the telescope. He was present at the inauguration of the telescope by HRH, Prince Charles on 16th October, 1974.

In August 1977 Beard transferred to Canberra as Assistant Chief (Operational Systems) Division of Computing Research (DCR) and held the position for one year carrying responsibility for service operation and system development. He retired from CSIRO in 1978.

Following his retirement he served as a Senior Research Fellow, Division of Radiophysics, CSIRO at Epping (1979-1980). In 1980 he was awarded an Order of Australia Member (AM), in recognition of services to Radiophysics. In the early 1980s Pearcey and Beard collaborated on a paper published in the *Annals of the History of Computing* Vol 6, No 2. April 1984. pp. 106-115, titled "The Genesis of an Early Stored-Program Computer: CSIRAC".

Frank Hirst (seated) at CSIRAC console with (L–R) Ron Bowles, Maston Beard and Ernest Palfreyman grouped around console. 15 June, 1956.

Photo: Age (& Leader)

Geoffrey Hill

Doug McCann

Geoff Hill was born at Hawthorn, Victoria on 16 February 1928. He worked in the CSIR Division of Radiophysics as a student employee from December 1946 and concurrently studied for a BSc in mathematics and physics at the University of Sydney, which he completed in 1949.

Towards the end of 1947 Trevor Pearcey assembled a preliminary logical design for the CSIR Mk1 computer. Pearcey then collaborated with Hill in the development of a more detailed logical design. The aim of this work was to assist the engineering, define the instruction set and to develop a programming scheme. When the Mk1 became more or less fully functional (basically from mid-1951 to 1955), the programming staff, which consisted of Pearcey, Hill and Brian McHugh, assisted in all the projects which were run on the computer (although they often did not get recognition for their input in the official reports). Hill was awarded an MSc from the University of Sydney in 1954 with a thesis titled 'Programming for High Speed Computers'.

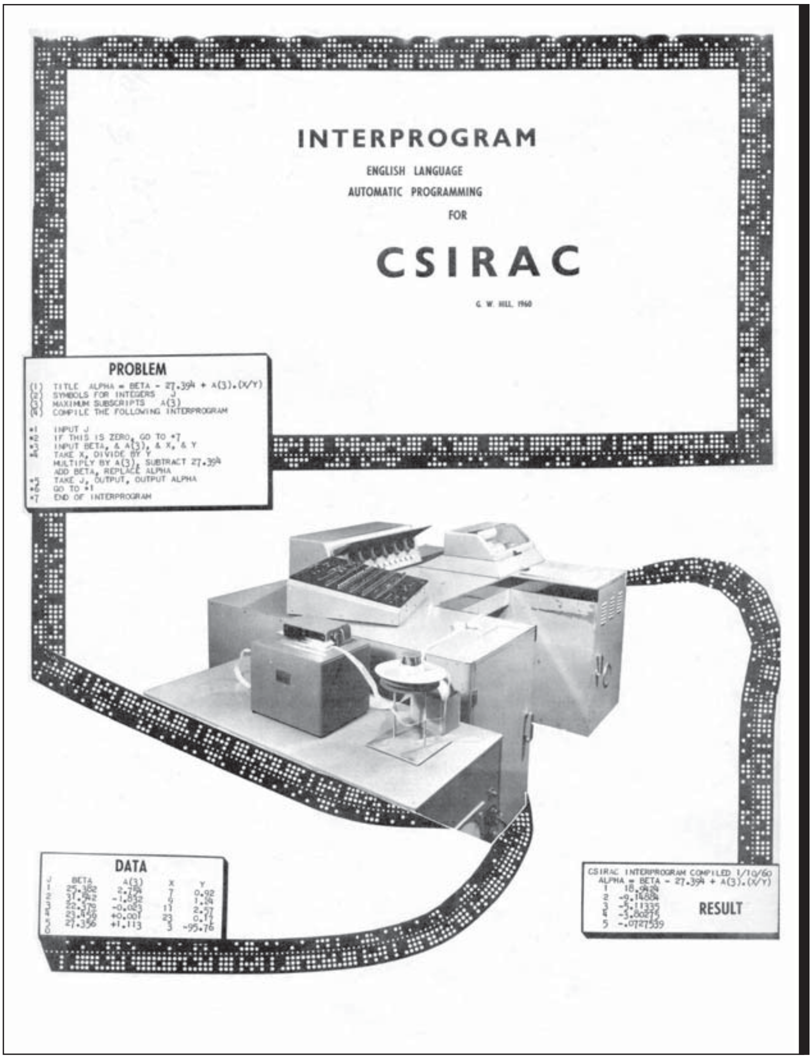
Following the termination of the Mk1 project and its disassembly in mid-1955, Hill transferred to CSIRO's Division of Mathematical Statistics in Adelaide. Then, in 1957 he was seconded to the Computation Laboratory at the University of Melbourne to again work with the Mk1 computer – now improved and renamed CSIRAC. His brief was, 'to continue to undertake work for the Division of Mathematical Statistics and his main duties will be to prepare programmes, for use on 'CSIRAC', of work being done by the Division in Adelaide.'

Hill went on to develop a simple 'English language' code for CSIRAC called 'INTERPROGRAM'. This was introduced in 1960 and was an automatic interpretive language which greatly simplified programming for users; following its introduction most clients adopted it because it was much more 'user-friendly' than the standard CSIRAC machine code and a more efficient use of their time. A 1960/61 CSIRO estimates report praised Hill's efforts as follows:

> *Hill has therefore concentrated his efforts on assisting C.S.I.R.O. officers in making use of 'CSIRAC' for their computing needs. The success of this venture, and some measure of the intensity of Hill's unaided effort, are indicated in the review of C.S.I.R.O. computer utilisation for the year 1958-59. In 1957-58 C.S.I.R.O. used 165 hours' computing time on 'CSIRAC'; in 1958-59, the computing*

time was 1100 hours, an increase by a factor of 6.7. I think the Executive should be impressed with these facts …Hill will be an outstanding officer of the future.

In July 1963 Hill (and Pearcey) were transferred to a new CSIRO Section – Computing Research – which represented CSIRO's re-entry into the field and was set up to serve the growing needs of its various Divisions and to carry out research in computing techniques. In 1964 Hill became a Fullbright Scholar. In 1970 he transferred to a position as Research Mathematician (Information Science) at CSIRO Head Office Library in Melbourne. During 1973 and 1974 he served as Acting Chief of the CSIRO Division of Mathematical Statistics. Following this he was redeployed back in Melbourne. In August 1976 he transferred to the Division of Mineral Chemistry in Port Melbourne. He died 15 November 1982.



Title page from the INTERPROGRAM manual. 1960.

Photo: CSIRAC archive, The University of Melbourne

Reginald Ryan

Doug McCann

Reg Ryan was one of the engineering staff who worked on the development of the CSIR Mk1 computer. He was born on 5 January 1925 at Kensington NSW and completed a Bachelor of Science with Honours in Physics at the University of Sydney in 1946. This was followed by a Bachelor of Engineering with Honours in Electrical Engineering at the University of Sydney in 1948. During this period (September 1946 to March 1947) he worked under Harry Minnett on a radio camera project.

In March 1948 he was appointed a Research Officer at the Division of Radiophysics, Council for Scientific and Industrial Research (CSIR) and became a member of the team who built the CSIR Mk1 computer. He was assigned the task of designing and building the primary memory store. It had to be totally built from scratch, unlike most of the rest of the computer which was constructed from standard components available from the well-established radio industry. The primary memory store, together with the computer's cabinets and electronic chassis, was fabricated on site.

The primary memory store which Ryan constructed could accommodate up to 32 acoustic mercury delay lines. Each line was a five foot long monel metal tube, coated with lacquer, and filled with mercury. Initially the capacity was fairly small; each tube held 16 instructions or 'words'. Later Ryan found a way of doubling the capacity by interleaving two 16 word pulse streams, thereby raising the overall memory store capacity from a maximum of 512 words to a maximum of 1024 words, without the need for further mercury delay lines.

Ryan also developed a range of test equipment for checking and debugging the computer. Most of the test equipment is still extant and in storage at the Museum of Victoria. The Radiophysics management credited Ryan with making "valuable contributions of his own" during the development of CSIR Mk1 machine.

Towards the end of Mk1 project Ryan was transferred to a physics group to work on semiconductors. In 1955 he took on the job of converting the 'Distance Measuring Equipment' (DME) to transistor operation. Like the development of the Mk1 computer the DME was another technology that grew out of the wartime radar experience. It was invented and developed by Jack Piddington and Brian Cooper between 1945 and 1955. Ryan was

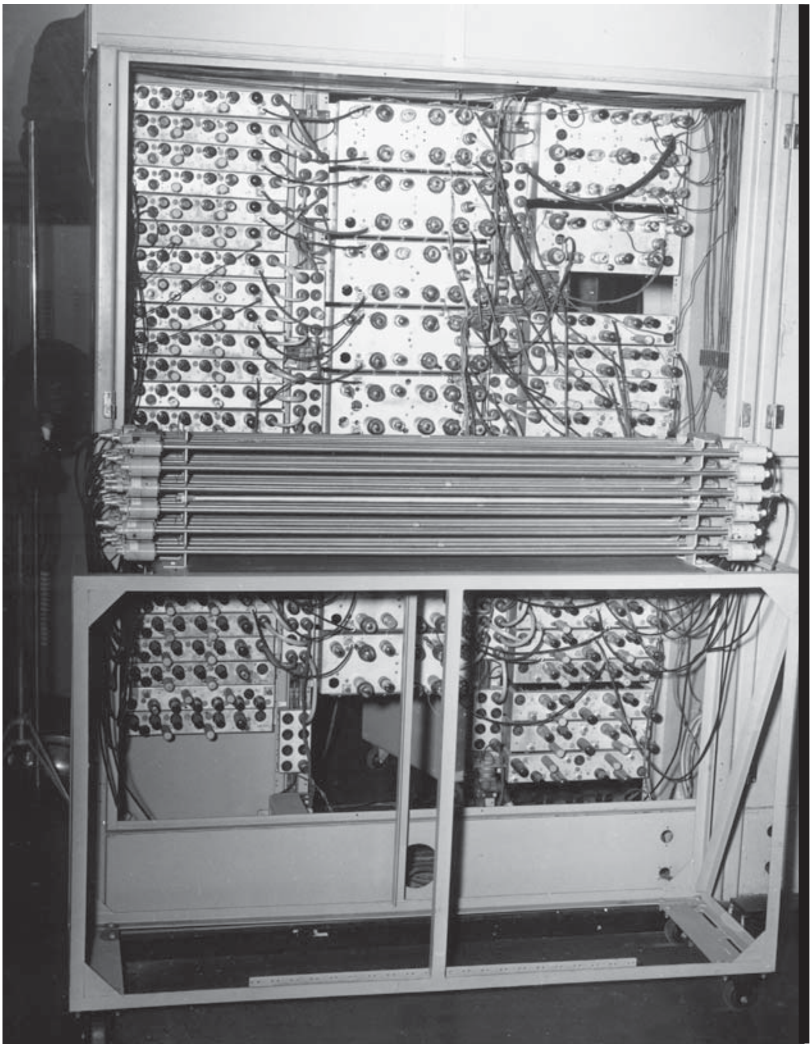


Photo CSIRO archive

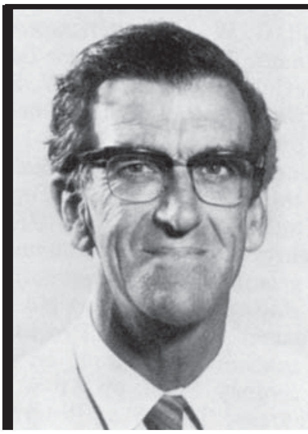
CSIRAC memory cabinet with mercury delay lines on stand in foreground. 23 May, 1952.

responsible for fully transistorising the DME equipment, greatly reducing its bulk. As a result it was decided to re-equip all Australian commercial aircraft with this instrument.

In June 1961 Ryan resigned from CSIRO Division of Radiophysics to accept an appointment as a Senior Lecturer in Medical Physics, School of Physiology, University of NSW. Then, from 1964 to 1978, he worked for the Australian Atomic Energy Commission (AAEC) and participated in the development of the first Gallium Arsenide radiation detectors.

Experience gained at the AAEC led to Ryan joining the Australian Safeguards Office in 1978 as Principal Research Scientist where he was involved in work in support of national and international safeguards for radioactive material. His experience in computer development proved relevant here with the introduction in the 1980s of timely safeguards verification of research reactor spent fuel, first using a programmable calculator (HP41), and later laptop computers, starting with the Australian Dulmont Magnum/ Kookaburra. He retired in December 1989.

Brian Cooper



Brian Cooper & Doug McCann

Brian Cooper was born in England in 1917. He graduated BSc in 1939 and BE (later ME) from the University of Sydney in 1941. In 1940 he joined the CSIR Division of Radiophysics. During WWII – until 1945 – he worked on a number of developmental aspects of ground and airborne radar. In the immediate post-war period he designed the prototype Distance Measuring Equipment (DME) – an air navigation aid - which went into production for use on Australian airlines and later was adopted internationally.

In 1946-47 he spent a period on leave of absence with the National Research Council in Canada and developed an airborne radar device for recording ground profiles. On returning to Australia, Radiophysics Chief, Edward Bowen asked him to design an instrument to be carried into rain clouds by a weather balloon to measure the size distribution of raindrops. After successful trials of that instrument he joined the CSIR Mk1 computer group to develop a form of secondary storage for the computer – a magnetic drum. At this time the Mk1 computer was already in operation with a mercury delay line primary storage system and the magnetic drum was added to provide additional data storage capacity.

Work on the drum began during 1950 and was completed and trialed by the end of 1952. Cooper published a description of the work in a paper titled 'A magnetic drum digital storage system' in *Proceedings of the IRE* July 1953. The drum had a capacity of 1024 'words' of 20 binary digits and a rotational speed of 6000 rpm with a mean access time of 5 milliseconds.

Cooper began the magnetic drum project by consulting the available literature on the general principles of magnetic storage, e.g. Booth (1949), Cohen (1950), etc., and then proceeded to experiment with various materials which could be used as a recording medium. Nickel plating was considered but was found to be unsatisfactory. It was decided that the best medium would be a commercially-prepared magnetic iron oxide lacquer which could be sprayed onto the surface of the drum. The supplier was an English company - Thermionics Products Limited - which specialised in supplying materials for the tape-recording business. Some experimentation was carried out before a satisfactory result was achieved. For example, initially the coating was sprayed onto a sheet of plastic which was to be wrapped around the drum, but this resulted in too many surface irregularities and was not comparable with what could be achieved when employing a precision surface with a very thin coating on it.

The heads which functioned for both reading and recording were made by Cooper's assistant, Jack Palmer, who cut out thin strips of metal a couple of millimetres wide, wound a few turns of wire around them, bent each one round into a U-shape, and fixed them as close to the drum as practicable with the smallest possible air-gap. Motive power was provided by an internal DC motor which was taken from an aircraft gyroscope. This motor provided quiet running at a speed of 6000 rpm. The finished drum was connected to the computer and gave useful service.

Trevor Pearcey requested that another drum be built with quadruple the storage capacity but although the production of a second drum reached an advanced stage it was never completed. Instead, it was decided to build a disc rather than a drum. The disc was fitted to the computer and coated with iron oxide lacquer when the computer was transferred from Sydney to Melbourne – and like the drum it also gave very good service.

Magnetic drum. Built by Brian Cooper in 1950-52 as auxilliary storage. It was intended as an experimental prototype, however, it was actually installed and gave good service during the time the computer operated in Sydney. It was replaced by a disc when CSIRAC recommenced operation in Melbourne in 1956. 23 October, 1951.

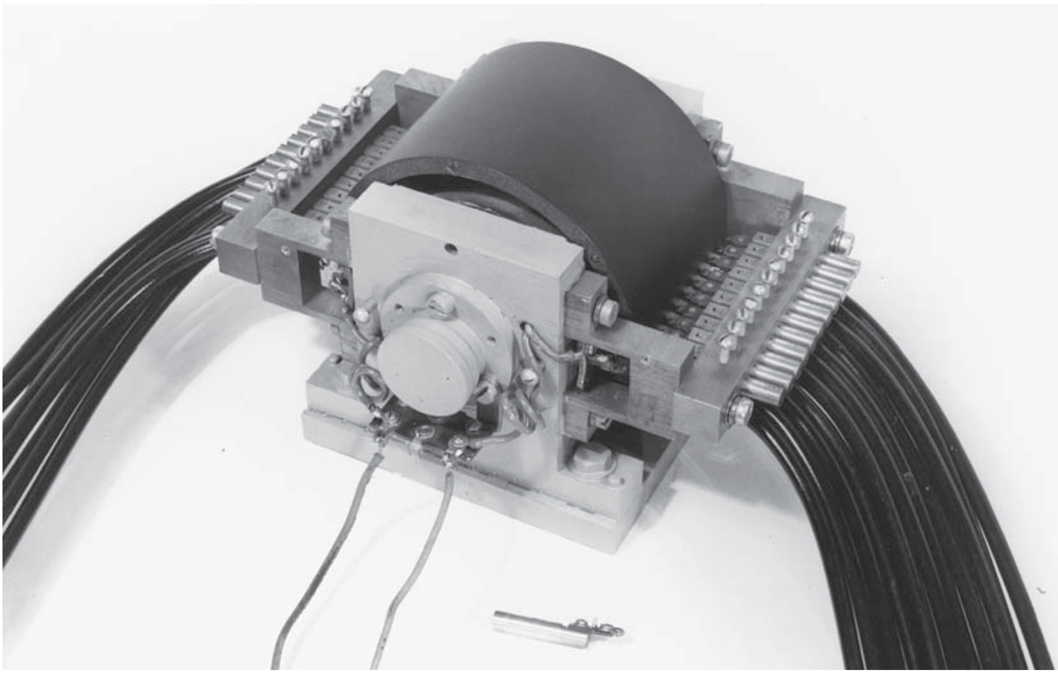


Photo CSIRO archive

In 1949 a group had been established at Radiophysics to make solid-state devices and transistors. Cooper was transferred from the magnetic drum project and put in charge of a group investigating the application of these devices. By 1958 the 210-foot Parkes radio telescope project was well under way and Cooper headed a team which provided receivers for the telescope. While the telescope was under construction he spent about eighteen months with the Harvard radio astronomy group building a low-noise maser receiver with the intention of utilising this experience for the production of such receivers for the Parkes 210-foot radio telescope. Cooper's association with the Parkes radio telescope continued until 1974 when he joined Paul Wild's Interscan group. He continued working on the Interscan Microwave Landing project until his retirement in 1978. He died 20 June 1999.

Brian McHugh

Doug McCann

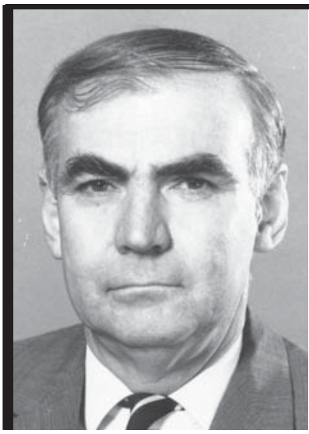
Brian McHugh was one of Australia's first computer programmers. He worked alongside Trevor Pearcey and Geoff Hill as a programmer on the CSIR Mk1 project. McHugh was born at Willoughby, New South Wales on 3 November 1929. He completed a BSc in 1950 and took up employment as a Research Officer in CSIRO Division of Radiophysics in 1951.

From 1952 to 1954 he worked as a member of the programming staff on the CSIR Mk1. He also utilised other calculating machines such as BTM (British Tabulating Machine Company) punched-card machines which were used to gain experience in programming and to perform calculations related to radio astronomy, crystallography, meteorological statistics and other specialities. Because of pressure to do a large amount of decimal multiplications, before the Mk1 became fully operational, Pearcey and Maston Beard found it necessary to design and construct a 10x10 decimal relay multiplier. It was fed input from, and output to, a BTM card summary punch and was found to give valuable and reliable service. It was used by McHugh and the programming staff for viscous flow calculations of airflow around raindrops, the results of which were later used in cloud-life computations on the Mk1.

Following the termination of the Mk1 project McHugh worked as a programmer on other early computing projects including a period in the UTECOM Laboratory from 1959 to 1965 where he carried out computations for various commercial, industrial and research organisations. From 1956 to 1964 he also lectured at the University of NSW in mathematics and computing.

After a period as a programmer in the CSIRO Division of Animal Genetics from 1965 to 1972 he joined the staff of the CSIRO Division of Computing Research and worked there from 1972 to 1986 on a diverse range of projects including CSIRONET. In the latter part of this period he lectured in computing at Canberra TAFE. He died 18 July 1997.

Frank Hirst



Frank Hirst

My introduction to computing devices, was like most people, to a slide rule. Then in third year chemistry, at the University of Melbourne, we used a large cylindrical calculating device, known as a Fuller Calculator, which gave an accuracy of 5 decimal places.

In third year Pure Mathematics, there was a section on numerical methods and the computation was undertaken on a heavy Madas calculator. One set the numerals on sliding scales and wound a handle to operate the machine. After my BSc degree, whilst working on shift work at ICI, I studied third year Physics. On day shift I missed three lectures. I was fortunate to copy and borrow the lectures from John Liddy, a class mate. John Liddy returns to my story later.

One of the practical exercises was to measure length accurately using fringes of sodium light. The technique employed was called "The Method of Coincidences". This required working to 15 decimal places. The only computing instrument available was a mechanical Ohdner calculator with 10 decimal places. However, by working the top 10 decimal digits of the 15 decimal numbers and then the bottom 10 decimal places, there was an overlap in the middle of 5 decimals, so it was possible to match top and bottom and so obtain the 15 decimals of precision required. Little did I realise then that I was performing on a Ohdner calculator what is now fashionably called double precision arithmetic.

After the war, I returned to the Physics Department of the University of Melbourne to complete my MSc and PhD degrees. I then obtained a position as Principal Scientific Officer at the United Kingdom Atomic Energy Research Establishment at Harwell, UK where I was involved with Nuclear Physics research. One Saturday night we held a dance in the dining room of the staff house "Ridgeway House", which during the war was the refectory of the Officers' Mess, Harwell being a war time Air Force station. I asked a pretty young lady for a dance, during which she asked me would I like to take a walk outside. As this sounded marvellous, I quickly agreed and she led me to the Control Tower of the former Air Force base.

The girl turned out to be a programmer for the relay computer housed in the Control Tower. The relay computer was a large device full of clicking relays, with numerous loops of paper tape and operated continuously night and day,

Photo: Age (& Leader)

Frank Hirst (seated) and Ernest Palfreyman at CSIRAC console. 15 June, 1956

seven days a week. All this lady wished to do was to check that the machine was working satisfactorily.

After more than two years at Harwell, I obtained a lectureship in the Physics Department of the University of Melbourne. I arrived back on the 2nd of June 1954. As all the lecture programmes were arranged for the year, the Professor of Physics, Professor L. H. Martin (later Sir Leslie) asked me to build a scaler (a counter used to count atomic particles from a Geiger counter) using the newly developed Philips E.1.T. 10 state electronic tubes. I went to a great deal of trouble even installing chromium plated escutcheons. Professor Martin was pleased with the outcome and said – "Laddie" – as he used to call me, the University has been offered an electronic computer by the CSIRO, would you be prepared to travel to Sydney and arrange its transfer. I said that I knew nothing about electronic computers. Professor Martin replied, "All you have to do is to unplug it, load it on a truck and bring it to Melbourne." I agreed, not fully realising what I was letting myself in for, since the computer in question was hard-wired and to say "unplug it" was the understatement of the century.

I read an article on how electronic computers operated in a popular magazine so I obtained the gist of how an electronic computer worked. At the time I subscribed to "Radio and Hobbies". In one issue there was an article on binary arithmetic which I duly digested. So with that scanty information, I drove to Sydney early in January 1955 and presented myself at the Computer Section, of the Division of Radiophysics, CSIRO, which at that time was situated in the grounds of the University of Sydney.

My reception was mixed. Trevor Pearcey might have said one "Hello". The other staff members introduced me to the 'CICERO Mk1' as the computer was then called. ['CICERO' being presumably a phonetic form of 'CSIRO'].

When I realised what the computer could accomplish I thought to myself "CSIRO must be mad giving this computer away." It was no wonder Trevor was unhappy having his creation moved out from under him. I could not get the computer back to Melbourne quickly enough. However, one thing I noticed, all the doors of the cabinets were off. I said to myself, in Melbourne all those doors are going to be in place. CSIRO was still using the computer and so I started to learn programming. I wrote an elementary program, and when working, the late Geoffrey Hill said "Oh but it would be better if you wrote it this way". So I rewrote the program and when in operation, Geoff said "Oh but it would be better if you wrote it like this" and so the tease went on.

Pearcey and Hill had written three papers in the CSIRO Scientific Journal. The first was about machine language programming for the Mk1, the second on interpretive programming and the third on automatic programming. Reprints were available. Naturally I tackled the first paper. I was reading the bottom of a page on machine language programming and turned to the top of the next page. The sentence was continuous, the page numbering correct, but I soon commenced reading about automatic programming. I was rather perplexed until I realised it was April 1st. Someone had lifted the staples of my reprint and taken out the centre double page and inserted another.

When the time came to disassemble the computer I managed to acquire a fair number of packing cases. I tested over 2000 vacuum tubes and wrapped the satisfactory ones in newspaper as though I were packing eggs. Eventually the Mk1 was dismantled, loaded onto a truck and transferred to Melbourne during July 1955.

At the University of Melbourne, the computer was under the administration of a triumvirate, consisting of Professor T M Cherry (later Sir Thomas), Professor of Mathematics, Professor L H Martin, Professor of Physics and myself as Officer in Charge. We had only one committee meeting of five minutes duration when, by chance, the two Professors were visiting the Computation Department at the same time. In my office they asked if everything was proceeding satisfactorily and when I replied in the affirmative the meeting concluded.

After almost a year spent on the installation of the computer in the Computation Department of the University of Melbourne, on June 14th, 1956, it was officially declared open and named CSIRAC by Sir Ian Clunies-Ross.

Whilst in Melbourne, several hardware improvements to CSIRAC were accomplished. The tubes containing the mercury for the delay line store, together with the terminating heads, were changed from monel metal to stainless steel. This greatly improved the lifetime of the delay lines so that the mercury store, which had hitherto been a source of constant trouble, stayed reasonably reliable. It became possible to extend the storage and maintain its capacity at 768 words.

Although CSIRAC in Sydney was equipped with a 1024 word magnetic drum backing store, this proved to be unsatisfactory and a new magnetic disc was constructed. The disc arrived in Melbourne without magnetic surface. Several weeks were spent investigating how to spray a spinning disc with magnetic paint free from occlusions. Finally, courage was taken and the new memory disc was successfully coated and gave excellent service, extending the backing store to 2048 cells.

A noteworthy extension to the original design was the addition of five-channel tape input and output equipment. A Ferranti Mk11 tape reader was arranged in parallel with the existing 12-channel tape reader. Thus, assembly program was read via the 12-channel reader and data, produced on a Flexowriter, was read by the 5-channel reader. By means of a Creed punch (in parallel with the original 12-channel punch), 5-channel tape output was obtained and then listed by the Flexowriter. The 5-channel equipment greatly improved the speeds of data input and output (by several times) since the on-line printer printed only five characters per second.

CSIRAC performed an excellent job in Melbourne and, after a respray, all the doors were in place. For the period June 1946 to June 1964, CSIRAC was switched on for 30,000 hours, during which time 700 computing projects were processed. Maintenance amounted to only ten percent of switch-on time, due to the constant vigilance of Ron Bowles, Jurij Semkiw and Peter Thorne.

Trevor Pearcey, after the computer left Sydney, proceeded to undertake programming research at the Telecommunications Research Establishment at Great Malvern, UK. He returned to the Division of Mathematical Statistics, CSIRO, and early in 1959 was seconded to the CSIRAC laboratory.

I believe that he was extremely pleased when he witnessed how the computer was instrumental in undertaking so much teaching and research at the University of Melbourne. In fact Trevor and myself undertook fundamental research into sub-harmonic motion together and we have been cordial friends ever since.

CSIRAC was finally switched off on November 24th, 1964. With the blessing of CSIRO, I contacted my previously mentioned friend, John Liddy, who was Deputy Director of the Institute of Applied Science of Victoria and arranged with him to transfer CSIRAC to what is now the Museum of Victoria, a fitting resting place for a grand old lady.

I shall now mention some case studies of computation undertaken on CSIRAC.

The first was to evaluate for the Forestry Commission of Victoria, the growth rate of a stand of Pinus Radiata growing in the Ovens Valley. I was given a model of a pine tree which was a cone on the frustum of a cone. The foresters measured the girth of the pine tree at breast height, ie: 4.5 feet from the ground, the girth at 11 feet from the ground and estimated tree height by means of a theodolite.

The foresters measured some 100 trees per thousand and wished me to estimate total volume of timber by means of a multiple regression analysis. In checking the data, I noticed that two trees had a larger circumference at breast height than their height. Statisticians designate wayward observations as outliers. However, I called these faulty data throw-outs, and they were not used, although dismissing data is considered to be not quite out of the top drawer.

I wrote a program for the multiple regression analysis and when in execution in forming the correlation matrix, I found I was trying to divide by zero and even CSIRAC was not up to that. I realised that the 2 girths, being only 6.5

feet apart were highly correlated and so I changed the model to a simple cone and used only the girth at 11 feet and obtained an estimate of total wood volume. When the Forest Commission officer came for the results, he asked me why I had used the 11 feet girth instead of the girth at breast height. I said a tree was smoother in circumference at the 11 feet height. In order to get the same accuracy using breast height you would have to measure 20 more girths. The Forest Commission officer said this would be preferable as it was easy to measure girth at the breast height but to measure the 11 feet girth, one had to carry a ladder around the Ovens Valley. With CSIRAC available, a re-calculation was soon achieved using breast height.

The second computation which I shall recount was to calculate a loan repayment schedule for a University staff member's housing loan. The staff loan repayment schedules were calculated each month by the administration. A desk calculator was employed and calculations were performed to the nearest shilling. I was requested to write a program and undertook these calculations on CSIRAC. It was a tricky actuarial calculation. To obtain the required accuracy it was necessary to work to double precision, the A register storing pounds and the C register the fraction of a pound. The latter was changed to shillings and pence on printout. I produced a table giving for each month the interest paid and amount outstanding for the lifetime of the loan. At the bottom, I showed total interest paid along with total payments. One day it was pointed out to me that if the individual items in the columns were added, they could be a penny out from the total at the bottom. This was due to rounding and I pointed out that administration only worked to the nearest shilling. However, I soon fixed this difficulty, by instead of using fraction of the pound in the machine, I took the shillings and pence and turned them back to a fraction of a pound and proceeded using this value. Thus, the rounding difficulty was overcome and administration was happy.

Frank Hirst at operating console with Herald staff reporter Kerry Pearce. Note: this was a publicity photograph. In practice CSIRAC storage capacity at this stage would have been insufficient to hold a program sophisticated enough to play chess. 15 June, 1956.

Photo: Herald Sun

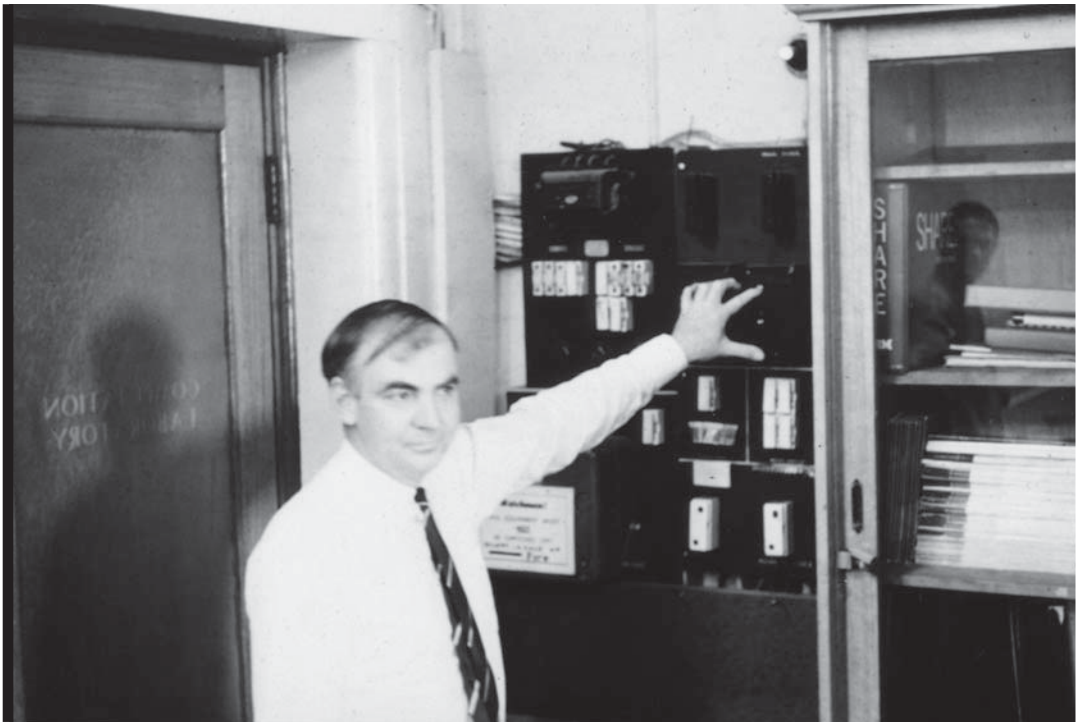


Photo: CSIRAC archive, the University of Melbourne

Frank Hirst switching CSIRAC off for the last time. November 1964. Significantly this event also marked the end of the first generation of computing. CSIRAC was one of the world's first electronic digital stored program computers and was the last of the first generation computers in service.

Colonel Jacoby, who was in charge of the Signals Branch of the Army and stationed at Albert Park Barracks, requested that CSIRAC compute the radiation patterns emanating from the rhombic antennae situated at Donnybrook.

The Donnybrook base was used for army communications. Jacoby required radiation patterns for various frequencies and input power. As I was away on my honeymoon, Professor Cherry undertook the programming. It was a complicated formula and the program required 766 memory cells of the 768 individual cells available. After my return to work, Jacoby came into my office and showed me a polar diagram of the radiation lobes he had plotted from the CSIRAC computations. The main lobe instead of being smooth, was re-entrant in the centre. I took the Marchant calculator home for the weekend and started calculating by hand the rhombic antenna formula. I calculated all day Saturday, Saturday night and Sunday. I must say that I was rather unpopular with my new wife. Towards the evening on Sunday I discovered the trouble, the nesting of the brackets in one of the floating point routines was incorrect. To patch the program required three commands, and only having two memory cells available, I followed the program and deleted the nearest rounding instruction so obtaining an extra memory cell. Of course there was quite a deal of address changing needed, but after the patch the program ran perfectly and the bump in the main lobe disappeared.

Ron Bowles

Ron Bowles

I joined the Division of Radiophysics, CSIRO in Sydney during May 1951 to work on a project that was investigating the upper wind structure over Sydney, and at its conclusion I joined the cloud and rain physics group. In both these projects I was involved with the maintenance and use of radar equipment of which I had first gained experience as a ground radar mechanic during four years service with the Royal Australian Air Force during World War II.

In May 1954 I was offered the position of maintenance engineer of the CSIR MkI computer. There was a proviso however - it would be transferred to Melbourne some time in the future and the engineer would be expected to go with it. As I had lived in Melbourne prior to joining CSIRO and having experience with radar circuitry which I hoped would be useful, I accepted the offer. On reflection it was probably one of the better decisions I have made, but at the time however, as each day I discovered more and ever more circuits existed, and extra chassis almost seemed to grow in the array of cabinets that greeted me each morning, I soon realised that I had not appreciated the sheer size and complexity of the computer on my initial inspection prior to acceptance of the job.

Programs were still being run by the computer programming group for CSIRO projects as well as their own investigations into new techniques. This meant the computer was still in operation quite frequently and that meant faults were likely to occur. Not very long after I started, the previous maintenance engineer left to join the SILLIAC group (hence my appointment), so I think that many of those early faults that were not just a valve failure or simple malfunction, must have resulted in a call for help from Maston Beard, the electronic design engineer right from its very inception. I must say that Maston was always generous and patient when I approached with my queries.

The circuit design of the computer had been finalised by the latter part of 1954, but some modifications to the circulator and modulator sections of the mercury delay line loops were still in progress, and these required new chassis. Also a new interpreter was to be built, with a dynamic register replacing the static one, to enable the PK facility to be incorporated, thus allowing a command to modify the following one, a most desirable programming feature.

The proposed move to Melbourne would require a stripping down of the computer to individual cabinets, and the severing of all connections between them which by now was starting to acquire that 'birds nest' appearance.

To assist in the reassembly at the new location, a signal trunk of parallel wires with terminal blocks, at appropriate positions for individual chassis connections, was to be designed for each cabinet. This required an investigation of most of the circuits and chassis to produce a layout of where all waveforms were generated, and then used within the computer and its peripheral units, including a more elaborate control desk; at its conclusion I began to feel on more intimate terms with the computer.

Early in 1955 the University of Melbourne accepted the CSIRO offer of an indefinite loan of the computer, so its exact destination was known, and shortly afterwards Frank Hirst from the Physics Department of that university arrived to see just what they had been offered. I doubt very much that Frank realised when he left for Sydney that he would spend most of the next five months finding out about this 'computer thing' he had to take to Melbourne.

Eventually the time came for the power to be removed from the computer and the dismantling process commenced. At the time I wondered how long, if ever, before that familiar cry of "Ron" sang out letting me know there was a machine fault, or rather a suspected machine error. It turned out to be the following year. Finally the computer, all securely packaged, along with every other item that could possibly be associated with it, was transported to Melbourne on a semi-trailer during June 1955.

CSIRAC being loaded onto semi-trailer at the Department of Radiophysics, University of Sydney. June 1955.

Photo: CSIRAC archive, the University of Melbourne

A most suitable location had been provided in the north-west corner of the Physics Department, and I had the good fortune of having a small office with windows facing north and west; a friendly elm tree outside provided shade in summer whilst allowing sunshine in during the winter months. Yes, I was most impressed with the new home for the computer.

Maston Beard headed the small team of four CSIRO staff that came to Melbourne to work on the reassembly of the computer. Geoff Chandler stayed until the modified chassis for the new circulators in the memory section were completed. Phillip Hyde was the wiring expert who worked on the redesigned chassis that had not been finished in Sydney. Some of the earliest chassis were

Ron Bowles seated at the controls of CSIRAC in the Computation Laboratory, University of Melbourne. June 1956.

Photo: CSIRAC archive, the University of Melbourne

also rewired as these had rubber insulated wire that had started to deteriorate due to prolonged heat and ageing.

With Maston Beard's supervision and assistance the task of reconnecting all the cabinets and peripherals began, and it was certainly made easier by the layout designs undertaken before we left Radiophysics.

Our first visual inspection did not show any damage to the computer items, which seemed to have survived the journey south unscathed, and extensive testing later on confirmed our initial impressions.

The floor in the Physics department was about a metre above ground level and this provided a large pool of cool air which could be passed through the computer cabinets. This helped to remove the heat generated by the 30KW of power consumed within them, and it was then ducted to the outside. At Radiophysics such a system had been used successfully with the cooling air coming from the basement, and all of the ducting from that system had been included in the transfer.

One of the most tedious tasks was testing all the valves with over two thousand of them in the computer itself. Fortunately a tester had been designed and built, with a separate socket for each type of the most frequently used valves, namely 6SN7, 6V6, KT61, 6AC7, 6SJ7, and EA50, also germanium diodes which had replaced many of the EA50 thermionic type originally used. This tester eliminated the need to set up a bank of switches for each type of valve, making it a much easier task than if we had to use a conventional one.

There were two main HT supplies used, each of 210 volt DC and a load capacity of 10 amps; both were treated with the respect they deserved. One of these was used in the memory circuitry and, because of the constantly varying load this imposed, the supply was fully regulated. The rest of the circuitry was more constant in its demand and performed quite well using the other supply unregulated. To start them off in Melbourne with a new lease of life, new banks of rectifiers were installed in each of these power supplies.

By the end of 1955 the computer was in a working condition again, albeit with only a small number of memory locations available, but still enough to allow test programs to be run. In Sydney the mercury delay line memory was perhaps the weakest link. The considerable attenuation of signal strength was increased with any contamination of the mercury or deterioration of the smoothness of the lacquer coated inner surface of the monel metal tubing. To improve the memory performance and reliability it was decided to use stainless steel in the delay line construction, gradually replacing the existing ones as these were produced. The mercury was all triple distilled and the inner surface of the stainless steel tubes polished, using pull-throughs, to a finish that would even satisfy a sergeant-major on rifle inspection.

The magnetic disc, usually referred to as a drum, had been made at Radiophysics but was brought down uncoated. Following much investigation, and testing on static and moving surfaces with mixtures of suitable magnetic properties, the drum itself was finally sprayed. After allowing plenty of time for the coating to dry and harden, it was decided to put a single pulse on the drum while it was stationary. One of the read/write heads designed and built at Radiophysics was spaced 1.5 thousandths of an inch from the coated surface, and a condenser, with an appropriate charge, was then discharged through it. The drum was brought up to speed, approximately 3000 rpm, and the head output, via one of the amplifier channels, was observed on the CRO (cathode ray oscilloscope). A nice sized pulse appeared and I think faint sighs of relief were heard. Later, a clock track was written on the drum, and eventually 20 parallel tracks plus a spare or two were working reliably.

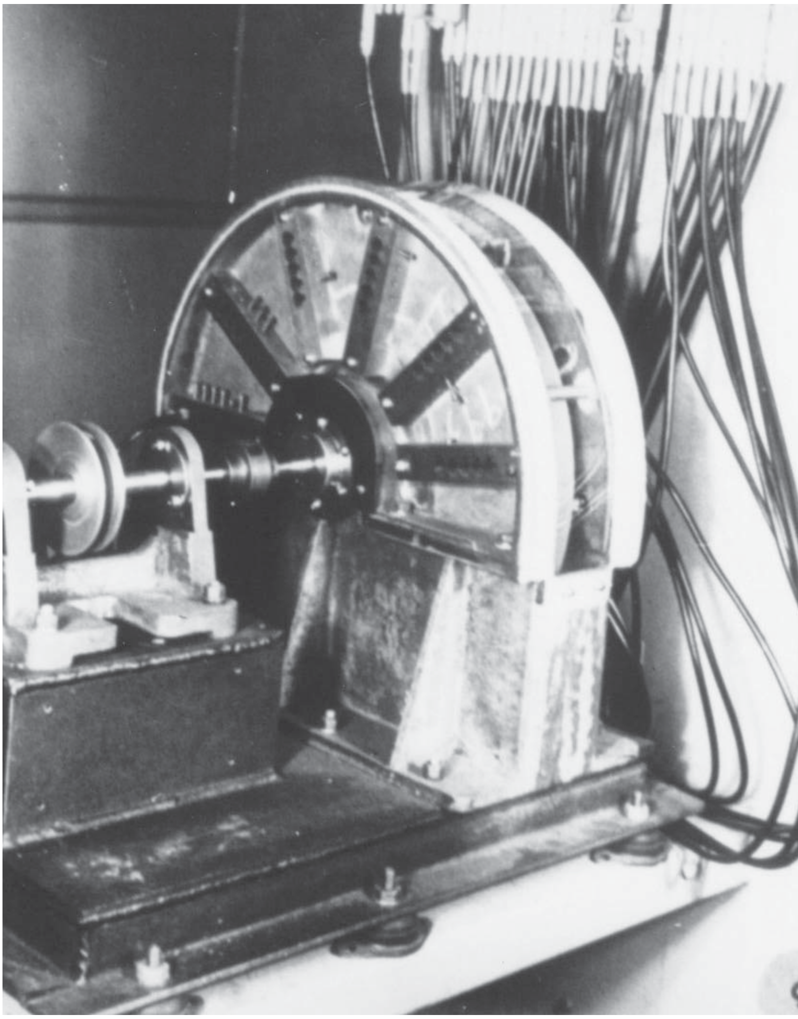
Since arriving in Melbourne the CSIRO team had worked closely with Frank Hirst, who had been appointed by the University of Melbourne to manage what was to be known as the Computation Laboratory. A radio engineer, Jurij (George) Semkiw had joined the staff to assist in maintenance work on the computer, and also a tool maker to work in the Physics workshop on the stainless steel delay lines and other mechanical requirements. Without all this help our progress could not have proceeded so smoothly and with such pace.

In June 1956 the computer had a reliable drum of 1024 locations, each of 20 bits, and sufficient memory operational for significant computations to be attempted. On Thursday the 14th of June 1956 the ‘handing over’ ceremony took place.

The final part of the ceremony was to be in the Computation Laboratory with the Vice Chancellor starting the computer which would print out the following message:

> *Mr Vice Chancellor*
> *Thank you for declaring me open. I can add, subtract and multiply; solve linear and differential equations; play a mediocre game of chess and also some music.*

Now it would have been most disappointing if anything went amiss when the computer was to play its part in the ceremony. It was not planned to read the program in at that time to produce the print out, it would already be in the memory. The most likely thing to go wrong over a period of time, was for the program to change because of extra pulses appearing due to external influences, or some going missing during recirculation.



CSIRAC magnetic disc "drum". An early photo 1956.

Photo: CSIRAC archive, the University of Melbourne

The chance of this was not high, but 'Murphy's Law' existed, even more so in those days. To find out if any change had occurred, a checksum of the program was obtained by adding all the relevant memory locations into the arithmetic register which was displayed on the operator's console. A copy of the memory program was held on the magnetic drum and, if a memory summation showed a change in the checksum, the program could be restored in a few seconds by using the appropriate switches on the operator's console.

All of this had happened prior to the ceremony and, while the formal speeches were taking place in one of the theatres of the Physics Department, I waited at the computer console occasionally doing a memory summation to be sure the program was still correct. I cannot say from memory if at any time it was in error and had to be restored from the drum, but eventually the guests arrived and put a finish to my check procedure.

A parchment scroll, with details of the indefinite loan to the University of Melbourne by the CSIRO of a computer which would be now known as CSIRAC, had been attached to a central panel of the computer. It had been opened out flat, and held that way by an energised electro-magnet behind the panel attracting a thin steel bar attached, out of sight, behind the bottom of the parchment.

Sir Ian Clunies-Ross, as chairman of the CSIRO, asked the Vice-Chancellor, Professor Paton (later Sir George) to accept the formal delivery of CSIRAC and pressed one of the buttons on the control panel. This de-energised the electro-magnet and the scroll rolled up into its preferred shape without apparent cause. In responding, Professor Paton officially declared CSIRAC open and started it by using the appropriate switch; CSIRAC commenced typing out its message to the Vice-Chancellor.

At its speed of barely five characters per second it would have only been just over a minute before it finished, but it seemed like ages. Although most had seemed to be watching the ever changing display lights on the generous number of monitors on CSIRAC, I knew the message would be examined thoroughly by many, including the press. As soon as possible I checked and found that CSIRAC had performed up to all expectations. Trivial perhaps, by today's standards, but CSIRAC was to be responsible for extending the horizons of many who used it in those early days.

After the official hand over of CSIRAC to the University of Melbourne there was an increase in its usage; more potential users had become aware of its existence both within the university and outside. This was no doubt due in part to the publicity given to the ceremony, in pictures and articles, by the morning and evening papers the following day.

A daily procedure for using CSIRAC had evolved. The first hour after switch on was to be used by the engineer for testing the computer's performance and any current developmental work. This hour was generally known as the 'warm-up period' as when using valves they were most likely to fail or deteriorate at switch-on, or in the next few minutes. To minimise this chance of failure, several time delays were built into the power switching sequence so that the valve filaments were on for a suitable time prior to the high voltage and bias supplies being applied to them. It was an infrequent event to find a valve failure during these first few minutes so I am sure the staggered switch-on worked well, remembering there were over 2000 valves in CSIRAC.

Special 12-hole tapes were available for testing the memory, output, input, and arithmetic functions, and these were used during this first hour to make sure the computer was functioning correctly. It was possible to vary both 210 volt supplies some 10 per cent either side of their correct value, and the tests were run whilst varying these voltages. Correct operation with a variation of at least 2 per cent high, and low, was considered satisfactory; but the higher the deviation that still gave correct test results, the more confident you felt that the machine would run without fault. This marginal testing also provided early warning of likely areas that may give rise to errors in the future.

When satisfied that all was well with the computer operation, then the rest of the first hour was used in testing any new equipment that had been constructed. In the first year or so these could be new delay lines, receivers or circulators for the memory loops, as it was most important to maximise the memory capacity and so increase the computing power of CSIRAC. The design capacity of the mercury delay line memory, with the interspacing feature, was 32 delay lines each containing 32 twenty-bit words, a total of 1024 words. About 1958 or 1959 CSIRAC had 24 delay lines working, giving it a total capacity of 768 words, about 3K bytes in today's terminology, and this capacity was maintained until its retirement in 1964.

An early program I can recall produced a series of loan repayment schedules for the Housing Commission of those days. The loan value and total repayment period could be entered on the hand set registers of the operator's control panel, and the program would calculate the monthly or quarterly repayment amount, giving a print-out of all relevant details at each payment period. I spent a lot of time in the operator's chair while CSIRAC churned out many of the longer tables. At its speed of three lines per minute, and that's an 80 column line, CSIRAC is probably the only computer that ever achieved that myth of the seventies, a paperless office; a whole day's output could be rolled up and stuffed in a rather small waste paper basket; but the speed at which those calculations were done was magic in those days.

From the earliest days it was recognised that the input and output mediums slowed down the potential of the computer, and the Maston Beard designed 12 hole punch and paper tape readers were a big improvement over the original 80 column card input and output devices. Some time after CSIRAC was handed over to the university, commercial 5-hole punches, off-line printers and 5 hole paper tape readers became available, and eventually a 5-channel Creed punch, operating at 25-30 rows per second was installed in parallel with the existing 12-hole punch. This increased the output speed by a factor of 6 at least, and the paper tape produced was translated on one of several Flexowriters that were now available in the expanding Computation Laboratory. Later a Ferranti Mk II 5-hole paper tape reader was installed in parallel with the 12-hole unit, the new high speed reader being used for input of data produced on the Flexowriters. Later, in 1960 it was used as the input medium for programs written in "Interprogram", an automatic programming system developed by Geoff Hill, one of the original Radiophysics programming team, during the period he was seconded to the Computation Laboratory.

From its start in Melbourne CSIRAC was operated in an open shop manner, and the users were from a variety of disciplines. Each had attended a programming course, a demonstration of the use of the editing equipment and the operator's control panel; all necessary for them to write, produce on paper tape, and then run on the computer, their own designed program. This new procedure added another facet to the maintenance of CSIRAC. Occasionally, after a user running his own program had reported a computer error, the test programs would run without any indications of errors. If the user's program still gave an apparent error it meant stepping through each instruction until the appearance of the suspect result. At each step the contents of all the arithmetic registers were displayed on small cathode-ray tubes on the console, the memory location of the current instruction appeared on a ten digit neon register and, on a set of all the command mnemonics the source and destination of the current instruction was indicated by lit neons. On many of these occasions it turned out to be the user misunderstanding what the result would be of a particular computer operation.

In the real world of computer errors, when one occurred during the multiplication process and it was not due to a valve failure, it could turn into a lengthy search through much circuitry as it involved three arithmetic registers, two of them having adder sections. Although these registers were mercury delay lines they were only a single word length, so a much stronger signal was available at the receiving end. It was usually timing changes due to resistor or capacitor variations, rather than signal strength of the circulating pulses, that caused the error.

Another arithmetic area, the D-registers, contained 16 addressable single word registers stored in a mercury delay line of similar length to the memory ones. The circuitry for its circulation loop was also the same, with an adder and other functions of course; but with no interspacing feature the digit density of 3 microseconds was only half that of the memory, and the reduced duty cycle load made for less critical timing demands and this area was not too troublesome - except for one occasion I can still remember. It was early days, probably some time before the hand over and the test procedure had shown errors in the D-registers. I had just started investigations when an unexpected visitor from Sydney called in to have a look at the computer, the next few hours were most frustrating. All the waveforms seemed correct but the timing would just not coincide. I was almost convinced it should never have worked in the first place. In the end a little tweak here, replace this resistor, which was only a little off correct value, and so on, then suddenly all was working well again even with the marginal voltage tests. I was never sure what was really wrong, just a combination of minor things I guess, but I'm afraid my visitor was not impressed with the computer, nor my efforts either.

CSIRAC was very popular on the University open days, when the demonstrations were mostly of the entertainment type. By giving their date of birth visitors could find out on what day of the week they were born; they could test their reaction time by flicking a switch when prompted by the computer, or try to beat it playing Nim. Another popular game was to guess which way a ball would bounce. The ball was imaged in the centre of the 20 by 16 raster on the D-register screen, and its position was indicated by the lights on the computer cabinet. The user had to guess if the ball would move right or left the next time the computer was activated.

The 12-hole paper tape was an ideal souvenir for the open day visitors and unwanted lengths were made available. Even before these had all gone, the temptation to tear a little off a program tape after it had passed through the reader was irresistible to some. Anticipating this there were spare copies of the programs available, but when some of the smaller visitors managed to get behind the paper tape reader and started to souvenir some of the tape before it had even been read into the computer, a no-go area had to be enforced around the reader. Certainly the early open days were enjoyable, the tedium of repetition over several hours more than relieved by some amusing and ingenious questions on what was thought to be going on inside those metal cabinets that housed CSIRAC.

There were other demonstrations to groups when more serious applications of CSIRAC were appropriate. On a visit by the then Institute of Radio Engineers (IRE), the usual welcoming message was to be printed out prior to the demonstrations and explanations. At this stage I guess I had become a little blasé about the reliability factor, and put the program into the machine after the group had assembled around the printer, and there it came out, "CSIRAC welcomes members of the IRA" etc. A bad start, the memory had dropped a digit, turning an E (00100 in binary) into an A (00000), trying to explain that it was a little joke by CSIRAC didn't really go over that well, but

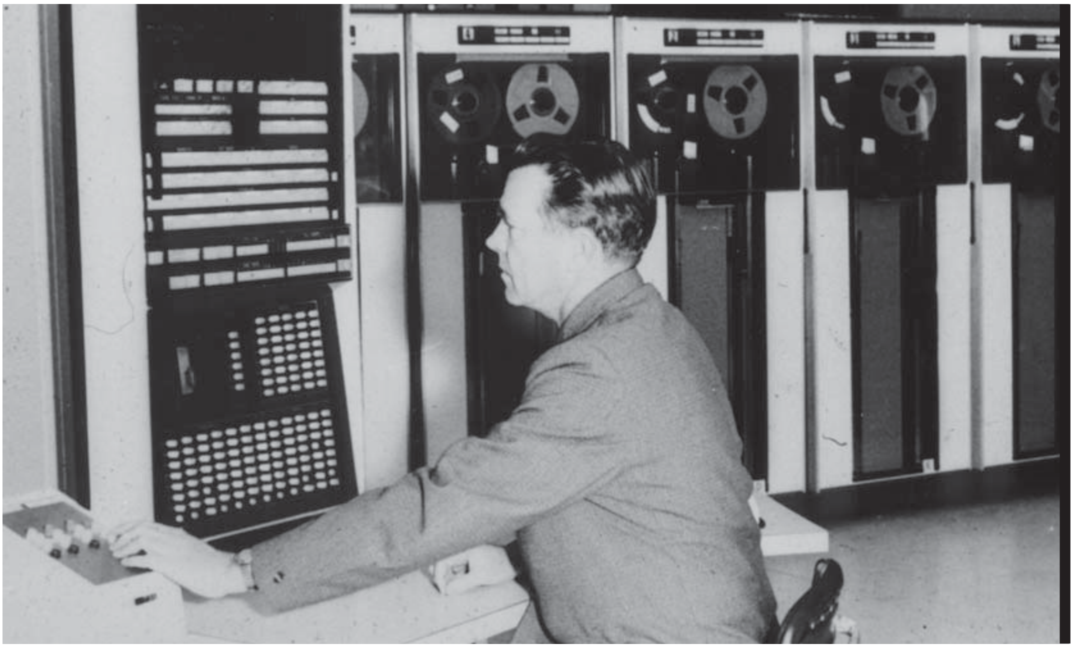


Photo: the University of Melbourne.

CSIRAC's successor.
Ron Bowles at the console controls of the IBM 7044/1401 at IBM (Fitzroy St, St Kilda) 1964.

the correct explanation along with their interest in the electronics and the inspection of the inner works of the computer soon had things back on track again.

Early in 1962 the magnetic drum capacity was doubled to 2048 words by using the other face of the disc, and read/write heads that had been made at Radiophysics. Rather than increase delay time by using the original design of a change-over relay, to physically switch from one set of heads to the other, extra electronics were constructed. A new set of transistorised amplifiers, designed by Jurij Semkiw, along with another set of write amplifiers were incorporated into the drum circuitry. The drum had given excellent service and was very reliable. A further increase in capacity by doubling the track density, which was in the original design, was likely to reduce this reliability and so was not attempted.

The inertia of the drum was such that to bring it up to speed without causing vibrations, and the possibility of damage to some read/write heads, it was coupled to an externally mounted motor via a slipping V-belt. When this motor was switched on the V-belt was tensioned by a judiciously applied screwdriver of appropriate size. This was only done by maintenance staff, or in later years by a small number of trusted users, working at night when no maintenance was available. It was most important that the drum had reached its correct rotational frequency before any drum 'write' commands were executed. Any 'one' bits so written could not be completely changed to a 'zero' bit at a later time, when the drum was running at its correct speed, due to their slightly incorrect position. Fortunately this could be corrected by an off-line procedure that set all of any track to the zero bit magnetisation state.

In the later half of 1962 the speed of CSIRAC was increased by some modifications to the control circuits; these resulted in many of the arithmetic operations, excluding multiplication, to be completed in 1 millisecond rather than the previous minimum time of 2 milliseconds. It was possible to

Ron Bowles at the CSIRAC conference at the University of Melbourne – 14 June, 1996.

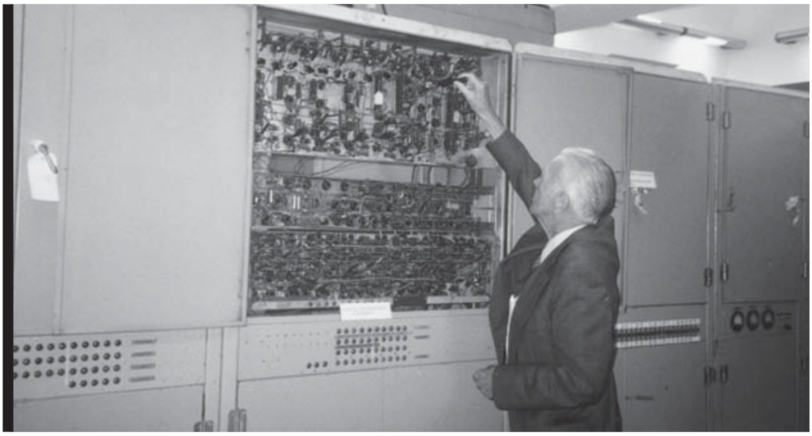


Photo: CSIRAC archive, the University of Melbourne

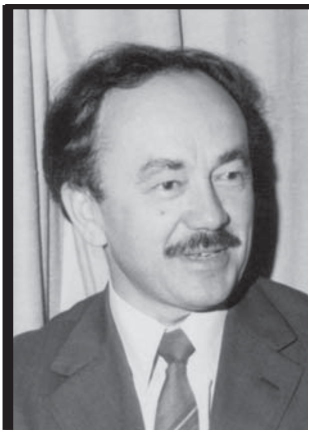
operate CSIRAC in the previous mode, or the new faster mode, by using a simple toggle switch on the operator's console. Running a program that included using the loudspeaker destination at various stages within the computation, the arithmetic test was one, and then switching to the new mode, gave a practical and accurate measure of the increased operating speed by the increase in occurrence of the loudspeaker notes. By optimising, where possible, any address within the commands, maximum benefit could be obtained from this new feature.

With its new found vigour CSIRAC continued operating with an even bigger work load, until in February 1964 an IBM 7044/1401 configuration began to take over gradually, as users became familiar with its requirements. The last project was run on CSIRAC on 24th November 1964. Once again CSIRAC was to suffer the indignity of being dismantled to cabinet size as had happened almost 10 years earlier at Radiophysics in Sydney. Fortunately it still exists intact, along with most of its peripheral equipment. In June 1996 to celebrate the 40th anniversary of computing in Victoria, a two-day conference was held at the Department of Computer Science and other venues on the University of Melbourne campus. Much interest was shown in the static display of CSIRAC which had been re-assembled in the Department of Computer Science, a giant task for some of the enthusiastic members of the Department and the joint organisers of the conference.

It would be most satisfying to have available the original maintenance records to show just how successful CSIRAC was during its lifetime. As things stand now (1997), a large number of the original circuits have been located and are in the process of being documented, but none of the maintenance log books recorded by myself or the other members of staff have been located.

During its lifetime I cannot deny there were times when CSIRAC caused tears of frustration, and not always was it alone at fault, but this was compensated many times over by the number of users who were able to achieve new goals, previously denied them by time consuming calculations. The challenge was still there however, as the ultimate speed was determined by the users' skill in programming and its economy. In retrospect the time I spent with CSIRAC was most rewarding as it occurred during the period when you still dirtied your hands maintaining the equipment under your care, and included the last few years when valves were still supreme.

Jurij Semkiw



Jurij Semkiw

My association with CSIRAC began indirectly in 1955, when I first met Frank Hirst at Melbourne Technical College (now RMIT), where we were both enrolled in a course in television theory. John Spencer, who later became a CSIRAC user, was also enrolled in the same course.

While attending the course, I noticed an advertisement on a notice board for a position with the Computation Laboratory at the University of Melbourne, placed there, as I later found out, by Frank Hirst. As I was interested in pulse techniques used in radar, the technology of first generation electronic computers, I decided to apply for the position. At the time I was working in Department of the Army, where I was maintaining radio equipment and before that I worked for the Department of Civil Aviation building and testing communication equipment. This work experience, I felt, was relevant to the advertised position.

Prior to the interview I had never heard of CSIRAC, but I had heard of 'electronic brains' and knew that they involved the kind of technology in which I was interested. I had a short interview with Frank Hirst and in late August 1955 was accepted for the position. Midway through September I commenced work as assistant to engineer Ron Bowles. My initial assignment was to assist in the reassembly and testing of the CSIR Mk1. In Melbourne the original Mk1 was partially redesigned, modified and rebuilt. I became progressively familiar with testing procedures and the electronics of the machine. It took almost a year to complete the reassembly and testing and prepare it for its recommissioning.

In setting up, every aspect of the machine had to be rigorously tested. Testing continued even when the computer became operational as further developments evolved and as subsystems were upgraded. CSIRAC was a serial machine, requiring a precise relationship between the length of the mercury delay lines and the frequency of the main clock, which in turn were dependent upon temperature and supply voltages. This necessitated continual readjustment as it would only work within a limited range. This work was the responsibility of the maintenance engineers. CSIRAC users were only permitted to make elementary adjustments to the hardware thus ensuring efficient

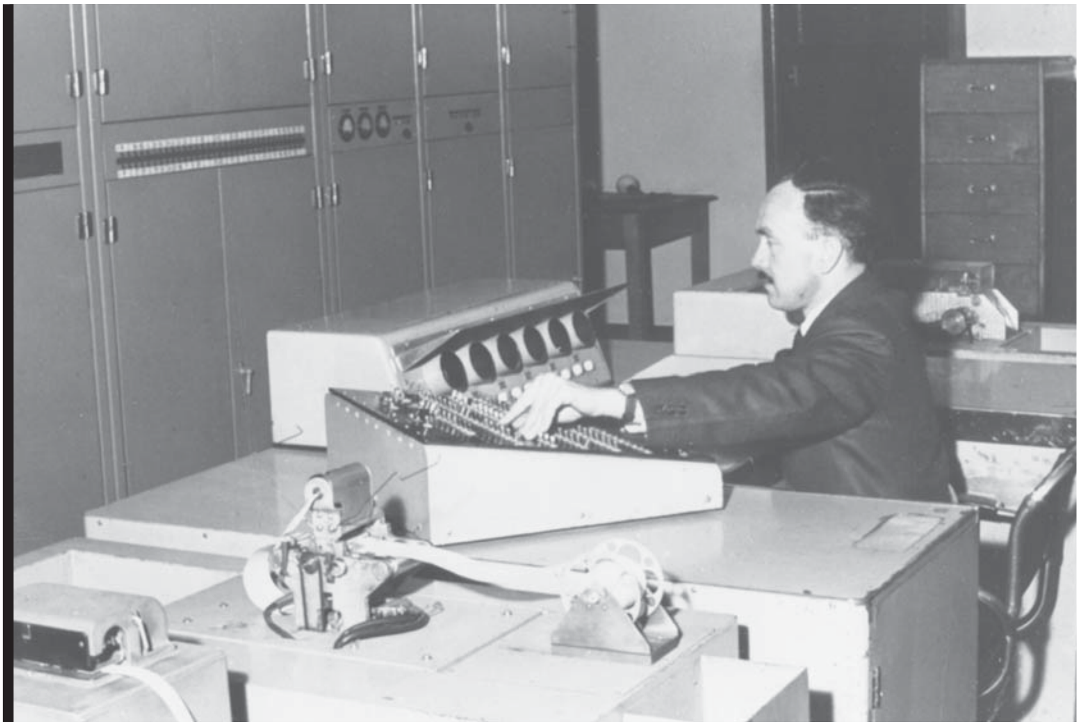


Photo: CSIRAC archive, the University of Melbourne

A view of Jurij Semkiw at operating console, with 12-hole tape reader in background and 5-hole tape reader in foreground. Main computer in the background at left. Taken in the early 1960s.

and continued operation. If, for example, it was found that the memory was losing bits, users were permitted to boost up the voltage.

The room in which CSIRAC was housed was ventilated but not air-conditioned. To help regulate the operating temperature, air was drawn in from under the floor, passed through the machine and expelled from the building. In summer, when the temperature was in the high thirties it had to be switched off in order to prevent it from overheating.

By mid 1956 CSIRAC was finally reassembled, tested and ready for operation. In the preparation for the opening it was all hands on deck. Everyone in the Laboratory was involved to some degree. On 14 June 1956 a large gathering of people in the Computation Laboratory witnessed Sir Ian Clunies-Ross from CSIRO invite the Vice-Chancellor George Paton to press the start button and to officially recommission the computer. The computer was formally renamed CSIRAC. Although the official ceremony was now over, for the maintenance engineers the work had only just begun. From now on it was the responsibility of Ron Bowles and myself to continuously maintain and periodically upgrade CSIRAC. One of the aspects that needed working on was increasing CSIRAC's fairly small memory store.

CSIRAC's primary memory store consisted of acoustic delay lines - metal tubes, filled with mercury. Memory capacity was increased by adding more and more lines. The original delay lines were made from monel metal, the interior of which was coated with lacquer. These tubes were filled with mercury, which acted as the medium along which acoustic vibrations passed from a 'transmitter' unit to a 'receiver' unit. These units, known as transducers, consisted of a quartz crystal mounted on a small lead cylinder. However, it soon became apparent that there was a problem with the choice of material used to construct the delay lines. The mercury would somehow react with both the lacquer and the metal and become contaminated. The crystal in the transducers would become coated with oxides, forming a thin film, which interfered with the acoustic coupling. The acoustic signal would be reflected rather than absorbed and become too weak to be detected and so information would either be lost or distorted.

When lines became inoperative the contaminated mercury was emptied out of the line and refilled with fresh triple-distilled mercury. It wasn't simply a matter of emptying and refilling the lines. A strict procedure had to be adhered to. The lines had to be disassembled, cleaned, and the oxides on the surface of the crystal had to be removed. When the lines were put back into operation they had to be individually tested and the timing adjusted. Everyone in the Laboratory was exposed to the mercury to some extent, but I had a lot of exposure to mercury metal and mercury vapour because it was mostly my responsibility to empty and refill the lines. In those days there was little consciousness or concern of the toxic side effects of mercury. Eventually the monel metal lines were replaced with polished stainless steel which reduced the contamination.

Another aspect of CSIRAC which had to be addressed was extension of the capacity of the magnetic drum. The original drum specifications included provision for increasing the drum capacity. There were two ways in which this

Jurij Semkiw displaying a mercury delay line. 1956.

Photo: CSIRAC archive, the University of Melbourne

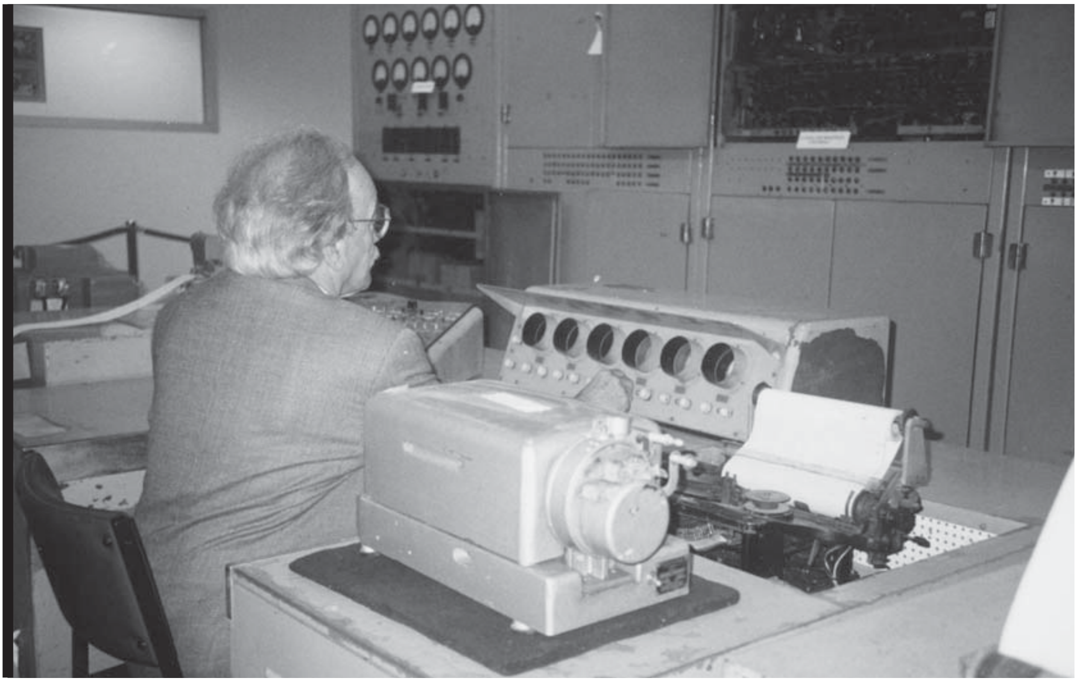


Photo: CSIRAC archive, the University of Melbourne

Jurij Semkiw at the console during the CSIRAC conference at the University of Melbourne – 14 June, 1996.

could be achieved. One way was by using heads on both sides of the drum, the other was by doubling the frequency of the drum clock. It was decided to use heads on both sides of the drum, but it became then necessary to duplicate the writing and reading circuitry. Instead of using valves we looked into the feasibility of using transistors, which had just become available, although we didn't have any detailed knowledge of, or direct experience with, this new technology.

After a great deal of experimenting and testing I designed and built a set of transistorised amplifiers for reading information off the drum. However, valves were still used for writing information onto the drum because power transistors were not available or were prohibitively expensive. I also experimented with printed circuit design which was a new technology at the time. Transistorised read amplifiers were built on printed circuit boards. The use of printed circuits later became standard procedure in the construction of electronic devices, but at the time the manufacturing had to be done in the Department.

Although I interacted with many of the users of CSIRAC, I was less involved with them than Ron Bowles. As Ron's assistant, I was more directly focused on working on the hardware than on management and programming aspects of the computer. Ron was more intimately acquainted with the computer having worked with it since its latter days in Sydney.

However, I didn't spend all my time working on CSIRAC; concurrent with my work on CSIRAC there were other projects. I worked on a very early xerography project. The idea came from Jack Meiss, an American who worked for a time at the Weapons Research Establishment (WRE) in Adelaide, where some original work was done on the system. It was a wet copying process that used paper coated with zinc oxide. A sheet of paper was first electrostatically charged, an image was then projected on it and after a few seconds it was developed in a specially formulated ink solution. Again all hardware had to be built in the Department. An ordinary filing cabinet was modified to house the copier. We even treated the paper ourselves. Zinc oxide was mixed in solution and coated onto the paper. The high voltage electronics for the charging circuit had to be built. Optics of the apparatus consisted of a special silver-coated mirror surface and a large lens. Every stage of the process was extremely tricky. For a clear image the charge and resistivity of the paper had to be just right. The xerography project probably took place over several years in the late 1950s and early 1960s. Although it was a very interesting project, it was eventually discontinued when commercial copiers became available.

At the time of the closing down of CSIRAC on 24 November 1964 Ron Bowles was working on the IBM 7044 so it was left to me to disassemble it. I carefully took it apart, dismantling in such a way that it could be reassembled again if need be. All the wires soldered between the cabinets had to be cut, then all separate components and interconnecting wires had to be labelled. Everything, including the circuit diagrams and CSIRAC logbooks was then sent to the Science and Technology Museum and were placed in a museum store in Abbotsford. Currently CSIRAC is in storage at the Scienceworks museum.

CSIRAC marked the beginning of my career in computers. I started working with CSIRAC in 1955 and retired from the Department of Computer Science in 1994. Over the years I have frequently been asked how I could stand working in the one department, at the one job, all of the time. My answer is that working on CSIRAC was an introduction to an ever changing technology, which provided me with continual learning experience. Technology was rapidly evolving and I had the opportunity to keep abreast with the latest innovations in computer engineering – something which I always found both challenging and absorbing. During this period I worked on many interesting projects, in a very stimulating environment, with many creative people.

Kay Thorne

Kay Thorne

I started work on CSIRAC in the Computation Laboratory which was then situated in the University of Melbourne's Physics school, just before the beginning of the academic year in 1959. I had completed my matriculation examinations in physics, chemistry and two mathematics at the University High School the previous year. I had then taken a job as a TA (Technical Assistant) with the CSIRO Division Meteorological Physics for the vacation before the start of the University year. I had hoped to get a Commonwealth Scholarship which would have paid my university fees but did not, and could not go to university full time. My plan therefore was to do a BSc part time and to do that I thought I would maximise my time available for study by applying for a TA position in a University Department.

About a week before the academic year began I searched the classified pages of The Age for a TA job in the University of Melbourne (then the only University in the State). There were two advertised. One, I think, was in Pharmacology, the other was working with CSIRAC in the Computation Laboratory. I had never heard of CSIRAC but a school friend Peter Thorne, had seen CSIRAC on a school visit some time before and he said that was the job to go for. So I applied, was interviewed and got the job. I started the next week as I did not want to miss any lectures in Part 1 Science. There was an added bonus in working at the University. In those days as a member of staff, if you passed a university subject in an approved course, the University refunded the subject fees paid. I did my whole course part time in this way and at least for me the scheme was a success. I graduated BSc and was promoted during my course, finishing up as a Technical Officer. I left the Department of Computer Science and the University of Melbourne in 1976 but returned later to undertake postgraduate studies. Peter Thorne, who recommended that I apply for the job, also subsequently worked with CSIRAC, and we later married.

When I am asked what I did on CSIRAC and in the Computation Laboratory I find it difficult to answer – because there were no job descriptions in those days and if there had been, the job description for a TA would have been "do anything and everything". The core staff of the Laboratory in those days was Frank Hirst, Ron Bowles, George Semkiw and me. There was also, for about a year, a programmer (Jean Power) who later returned to England. Because she was only there a short time and worked I think on a project basis she was not

University of Melbourne CSIRAC staff. (L–R) Peter Thorne, Kay Thorne, Jurij Semkiw and Frank Hirst. November 1964.

Photo: CSIRAC archive, the University of Melbourne

part of the basic team. The rest of us had a small cluster of rooms on one side of the Lab. Frank and Ron had offices side by side with George and I sharing a room which Ron and Frank had to pass through to get to their offices. We all kept our doors open and we could all hear anything that was said.

We operated as a team, sharing the successes and disasters. If something was lost we all searched for it, if the machine wasn't working we all made suggestions and held the instruments used in testing. Frank's "valve tester" was invented in just such times. CSIRAC was a valve machine and valves can malfunction so that there is an intermittent fault – it goes wrong once, then works OK for a while – this drives engineers and programmers potty! Frank's valve tester was a stick with I think, a rubber stopper on the end. He used to tap suspect valves so that the intermittent fault became permanent and the valve could be identified and replaced. Sometimes we had a fault that was around over a longish period – more than half a day, and we would have to start cancelling bookings. When things got very tense there would be long discussions between Ron and George, I would be cancelling bookings and explaining delays to users (as we called those who booked the computer) while Frank made everyone a cup of tea.

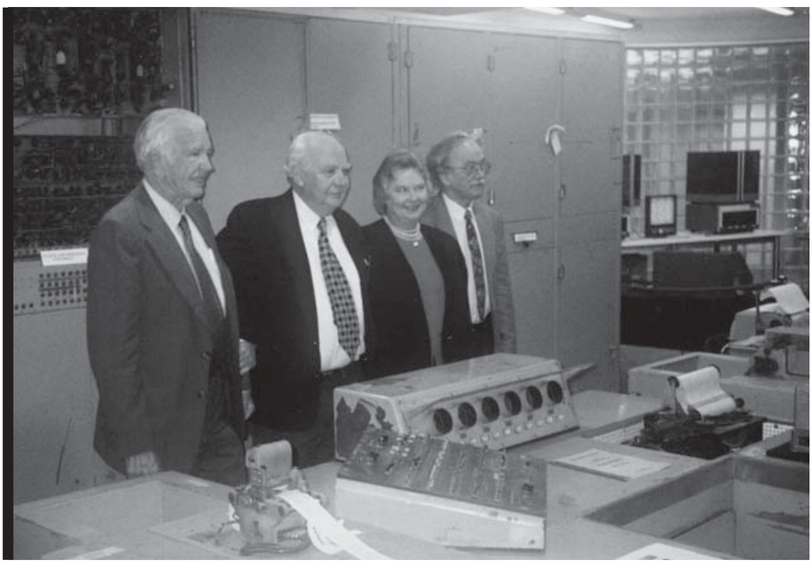
Often the first we would see of someone wanting to use the computer would be the person arriving for an appointment with several boxes and sheaves of paper spilling out everywhere. He would be trying to sort results from some experiment or data collection according to some criteria or process which was only in his head, and wanted to know if the computer could help. We usually started out by explaining that if the potential user could write down on a piece of paper exactly what he did, so that someone else could sort or process the data and get exactly the same result, then we could look at using the computer. Frank then showed them around the laboratory very briefly and sent them off to sort out what they were really trying to do. Many came back triumphantly in a few days with their piece of paper and some were never seen again.

CSIRAC was not a user friendly machine. The real role of the staff was to be the user friendly interface between the users and the machine. This was really the philosophy with which we worked. Remember too that most of the users were first time users not only of CSIRAC, but of any computer. Demystifying the computer, programming and data preparation and helping people to gain rather than lose confidence was our role. It is very satisfying now to realise that many people from the University, CSIRO, industry and commerce learnt first about computers from CSIRAC and went on to plan and run computer installations in their own organisations.

We ran computer programming courses for University people and for industry. It was Frank's firm belief that each of the people on the course "had to get their feet wet" by actually running a little bit of code that they had written on the computer and getting out a result, no matter how trivial the process they were encoding. It might only be sorting the even numbers from a list of numbers one to ten but once they had done that, and seen the output printer print out 2,4,6 etc., they had got started and usually went on to use the computer to do what they wanted to do.

I have been asked to comment on the role of women in computing in those days. It was common for women to be the data processors in scientific environments. This was usually done using large calculators of which Marchants were the best known at the time. Betty Laby ran a laboratory in the Statistics Department in which a large number of women operated these calculators, processing data for the predominantly male staff and research workers. The women were often called computers, and it was a skilled and demanding occupation. When the computer became more available a few women, such as Alison Doig, were amongst the early users. They were usually research workers who wanted to process their experimental results. The calculator operators gradually disappeared as their work was done by computers.

The days working with CSIRAC were very exciting days, and for me formative. We did have a sense of being at the beginning of something new which had a long way to go. We did not know where it was going and most of the emphasis in the early days was on the potential for commercial data processing (accounts, inventory etc) and large scale scientific calculations. Although we did not see the enormous potential of computers in word processing, we did use a Flexowriter which produced punched paper tape to do some of our



(L–R) Ron Bowles, Frank Hirst, Kay Thorne and Jurij Semkiw at the CSIRAC conference at the University of Melbourne. 14 June, 1996.

Photo: CSIRAC archive, the University of Melbourne

departmental word processing at the time, so we had at least recognised some of the possibilities.

CSIRAC enabled those of us working with it to do something which was in those days fairly rare. We worked closely with people from many disciplines and departments of the University, from other scientific organisations and utilities such as CSIRO, PMG, SEC, SRWSC and from companies, both those based in scientific industries such as ICIANZ and those commercially based such as banks and insurance companies and we crossed the boundaries of disciplines and organisations. This gave us tremendous insights into those different organisations and the ways they worked, the pressures and motivations, and the ways they approached using new technology. I have found ever since that I enjoy most working on those interfaces between different organisations and structures when they are coming together for a common purpose, and that is still my work.

Working with Trevor Pearcey who had designed CSIRAC and Geoff Hill, and the many people who were attracted early to the excitement of working with new technology was intellectually challenging. Imagine the conversation over morning tea in the caf! On a daily basis, the atmosphere was the most intellectually challenging and the most fun I have ever encountered in a workplace – we didn't accept limitations, just challenges, and there were virtually no demarcations based on rank. It was quite common for Trevor, Frank and Geoff to spend time helping me collate a new printing of the programming manual or helping George and Ron repair the old printer, while discussing random number generators, the need for a new subroutine, or CSIRO politics. That was the sort of place it was. It is also the group of people to whom I feel most bonded – we not only shared an adventure, every day was an adventure.

Peter Thorne

Peter Thorne

I would have first seen CSIRAC when I was a student at University High School in late 1956 when I was in Year 11, or in early 1957 when I was in Year 12. I would have been aged about 17 at that time. Because University High School is just across the road from the University of Melbourne it was quite common to have expeditions to look at activities in the University. One of those expeditions was to the Physics School and being very interested in physics I joined that excursion. We saw various pieces of equipment; we saw the cyclotron for example. I remember walking into a laboratory and being shown an electronic computer. I recall seeing a couple of people hovering over the console, seeing the flashing lights and being very impressed with the size of it, and the wonderment of it, but not understanding anything about it.

I next saw CSIRAC a year or two later, when Kay Sullivan – who later became my wife – had taken up employment in the Computation Laboratory. She had worked at CSIRO on vacation and was now working in the Computation Laboratory. I had a strong interest in electronics so I went to see where she was working and to look at the computer. I walked through the door and was shown the computer by George Semkiw and I asked the usual questions that people asked in those days about computers. I was curious about its memory, and how long could it store things in its memory, and how much could it store. I was surprised to find that as far as the main memory was concerned, it had very little storage, and in fact it was erased when the computer was turned off! I was surprised because the popular science-fiction descriptions of computers at the time referred to these things as 'electronic brains' and invariably gave them far more capability than they actually had.

I was a part-time student, working on electronics at the time, and as often happened in those casual days, I hung around and made myself useful. Frank Hirst, who was the Reader in Charge and Head of Department, asked me whether I would take on the role of looking after CSIRAC on weekends. I lived quite close – just across in Parkville – so I was the person who could turn it on at weekends and warm it up for people to use, and also to fix it if it broke down.

Consequently, by the early 1960s I had become a part-time support service engineer for CSIRAC and I met many of the users through this – though, of course, with my own studies I was in and out of the Laboratory anyway for some of this time. I was studying physics in the same building and was a staff member at another place in the University as well as doing my weekend work on CSIRAC. I became involved in many of the projects there which, quite apart from computing, were very interesting; for instance, some of the research undertaken in the Computation Laboratory in the area of xerography or photocopying.

I completed my physics degree and Frank Hirst suggested that perhaps I might undertake post-graduate work with him. I would have been the first post-graduate student in computation (although a higher degree had been taken in the Department by someone else in a related field). I agreed to do this. I'd had a chequered career because of the fact I had worked part-time and had financial difficulty. Frank made it clear that for me to be accepted, I would have to do my honours year in physics, where I would write a brief research report. I could do that with him, but I was going to have to do very well in the course work component. I would now have an opportunity to do this without some of the pressures I had as an undergraduate, but I was going to have to prove myself. I did manage to do that; I did well at the course work and also produced an interesting project which used some of the work that Hirst and Pearcey had developed on CSIRAC. I did not actually use CSIRAC in the project directly although I did work in the Laboratory on the bench behind the computer. So ultimately my work was accepted as being Masters level. That, I suppose, would have happened about the time that CSIRAC was decommissioned. I graduated in 1962 and I would have been at Masters level about 1964. By the time I had completed my PhD in 1967, CSIRAC had been in storage for three years.

I was involved on a day-to-day basis in the operation of CSIRAC and the provision of the computer service, helping out, though I was a student. It was the kind of place where everyone helped in every way that they could. I was there when the black and white film was made by the CSIRO Film Unit in which most members of the Laboratory figure in some way or another. Certainly George Semkiw, Kay Thorne, Frank Hirst and Trevor Pearcey were all involved. By then Ron Bowles was minding another computer for the University. I was the clapper boy for that film and really enjoyed the experi-

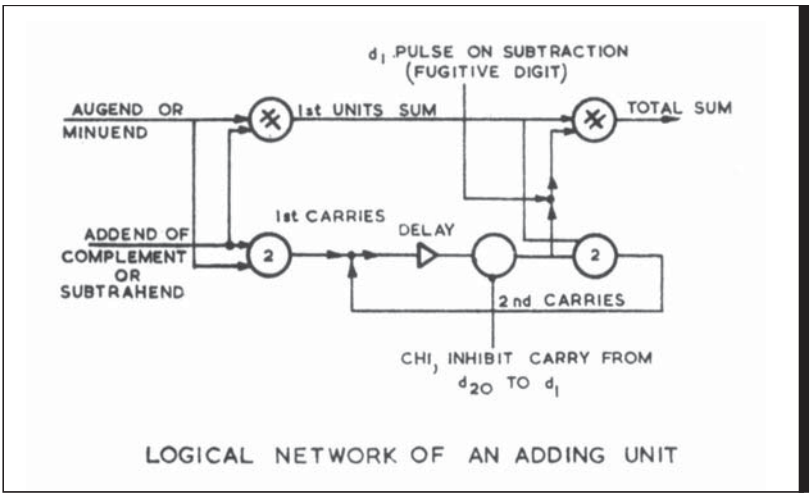


Photo: CSIRAC archive, the University of Melbourne

Computer test equipment designed by Reg Ryan for use with CSIRAC. c.1952.

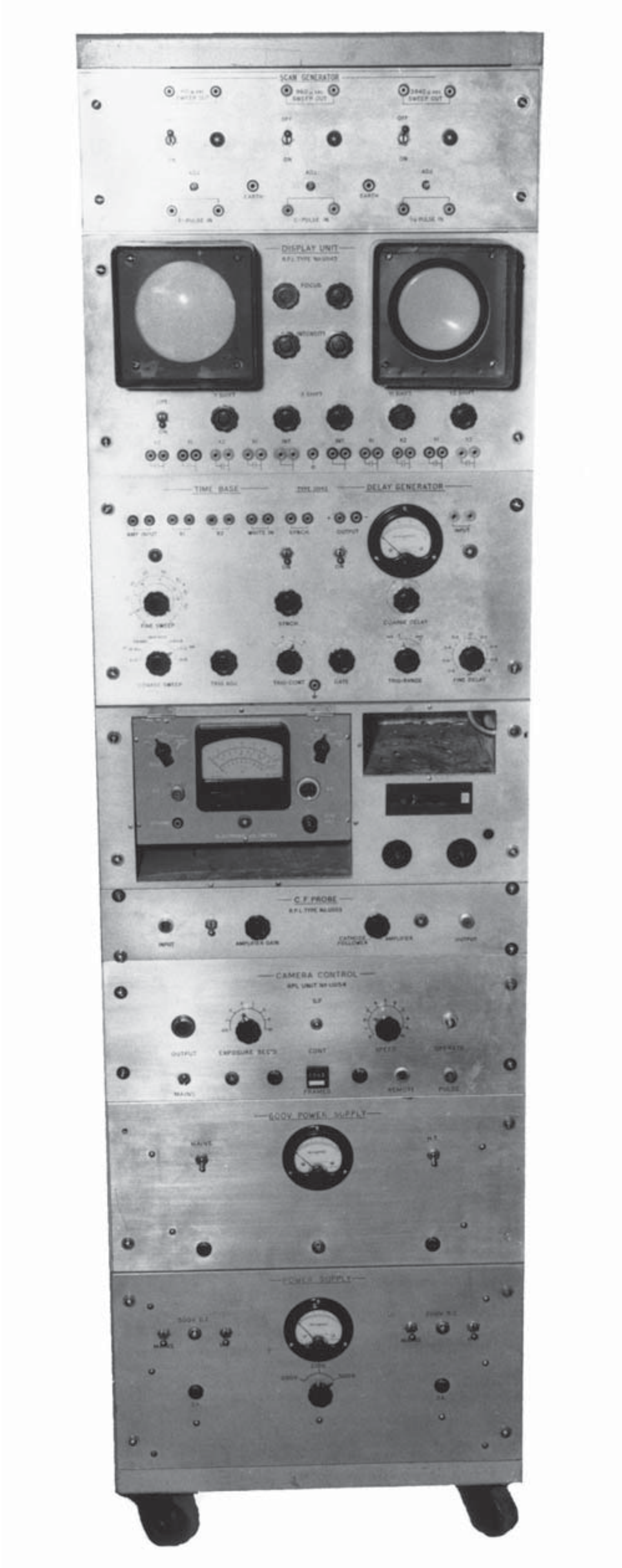


Photo: CSIRO archive

ence of working with a film crew for what now looks like an old and primitive film, but in those days it was all quite exciting.

I was there at the time when George Semkiw dismantled the computer, which was to go off for storage in the Museum. That was my last direct association with CSIRAC until 1996. I did program CSIRAC as part of my physics practical work and I could operate it, but I never wrote any long or extended programs for the computer. I was a hardware person in those days, rather than a software person. During my time there I shared an office with Trevor Pearcey and other staff, so I was really part of the Laboratory from the late 1950s – certainly until CSIRAC was decommissioned. After that, the Department moved to another building, and I have been in the Department in various capacities ever since.

CSIRAC Users

There were users who had long sustained projects on CSIRAC, like Dick Jenssen who was a meteorologist. He developed early programs on weather forecasting, and incidentally wrote computer games. One was called 'The way the ball bounces' which would attempt to predict from your pattern of moving a switch up or down, whether you would move it 'up' or 'down' next time. You had the choice of one or zero – yes or no – and the computer would look at your past behaviour and make a prediction. I think this might have come from his prediction work in weather patterns. It was a simple computer game, using the lights and switch on the console. Kay Thorne was the person who was most likely to beat the computer and trick it; about the time it seemed to be predicting the pattern of her choices she would do something quite different.

There were people like Geoff Hill who did his research with CSIRAC; writing INTERPROGRAM – an interpretive programming language – amazing that it could fit in so small a memory space. He spent night after night in the Laboratory. I would see him in the evenings, because I was working late. Then there were CSIRO researchers like Terry Holden, John Spencer and John Russell who were regular heavy users of the computer and would book it at nights and come in and sit at the console. In some cases they would still be there in the morning!

Using the computer didn't mean sending in your program or sitting remotely, people would book their hours of use days or weeks ahead and come in and sit at the console and 'drive' the machine. So people would come in, in some cases on a regular schedule. If the computer didn't work at weekends I would ring them up to tell them it was not operable – or if it looked like a simple problem I would attempt to get it working and keep it operating while they did their work. I was not very good at fixing it, and if something very complicated went wrong, it inevitably waited until Monday for Ron Bowles or George Semkiw to attend to, because they were the real engineers and I was pretty much an amateur.

Programming Courses

Frank Hirst in particular was an enthusiastic teacher. One of the important activities in the University was to teach people about programming CSIRAC, and along the way teach people about computers. Programming manuals were produced and courses were run. Participants came from across the University – and outside the University – to attend them.

One of the things that affected my subsequent career in the University was the number of notable University personnel I met as a result of their enrolment in the programming courses. If you look at the university participants in those early programming courses, it reads like a Who's Who of people who later became senior significant people in the University, for example, Vice-Chancellors, Deans – the people who were forward-looking. People like David Caro, Len Stephens, Sam Hammond, and so on. David Caro became Vice-Chancellor, Len Stephens became Dean of Engineering. Sam Hammond later became Dean of the Faculty of Arts; he was a psychologist who needed to do computations as part of his research. The Computation Laboratory was a meeting place for people from a variety of disciplines who came to these courses and then became users. We still have some of those early program manuals that were written for the courses. Programming manuals in those days didn't just teach you how to write programs, they often explained to you what binary numbers were and how things were added and how the arithmetic worked in the computer; we were really starting from scratch.

Later on when INTERPROGRAM – the programming language developed by Geoff Hill – was adopted, many of the ordinary users used that. It was much more friendly than trying to write optimised code for CSIRAC, so the average user tended to use it. It wasn't as efficient from a computing point of view, but it was a much more efficient use of their time. They didn't have to learn the idiosyncrasies of this machine. They didn't need to be super programmers, they just wanted to get a job done, so INTERPROGRAM courses were provided for them.

Undergraduate programming subjects were taught as part of the physics and mathematics courses. Some of those early courses were possibly the earliest computing courses taught to undergraduates anywhere in the world.

Some Memorable Moments with CSIRAC

I remember many of the projects that CSIRAC was used for. There was a project done for one of the banks, I think the person who did it was Joe Josephs. He was calculating the real cost of processing a cheque through one of the major banks, computing a large number of small cost components. The answer he came up with was surprisingly large. In fact, it took more time and cost much more money for the banks to process a cheque before they were using computers – much more than the banks anticipated.

There was a very diverse range of projects and calculations carried out on CSIRAC. There were calculations which Frank Hirst did with a statistician, Tony Verhagen, who worked for CSIRO. These calculations related to waiting times for drought relief in Queensland; if you had a drought, by looking at the history of drought in Queensland, estimates were made on how long it would be before the drought would break. There were people doing building computations and physics computations and processing survey data; for example, how much timber there was in a stand of forest, this was done by measuring trees at various heights, and having models for the forest, and so on.

Calculations were done by CSIRAC which would nowadays seem simple, for instance, loan repayment calculations (shown in the CSIRO film) were done for the University. Staff could get loans in those days at particularly low interest rates and you could compute how long it would take to pay off the loan and how much interest you would have paid at the end assuming a certain repayment rate and a certain interest. There were various ways of calculating the loans – these could be programmed. One of the University staff members has recently provided us with details of his loan which was calculated and printed out by CSIRAC, just as it was done in the film. It was a common feature on University Open Days to calculate loans for people, who were invariably horrified with what they might be paying – more than what they had borrowed if the loan went on for very long!

The power system for the computer was such that there wasn't much excess capacity. CSIRAC had a mean time between errors of probably about an hour. It was sensible to write out intermediate results frequently, so that one could recover from a failure without total loss of all the work to that stage. We had a tea-room and we were all keen tea drinkers. On one occasion somebody plugged in the electric jug on the 59th minute of somebody's program and the power went off because the jug overloaded the system. Unfortunately they had written a program in such a way that they didn't get any intermediate results out. All their work was lost. They had waited a week or a fortnight for opportunity to use the computer and now all their work was gone – someone had plugged in the jug!

In the Laboratory, on one side, there was a Van de Graaff style of generator, called the Statitron, which I think Frank Hirst might have worked on. It generated about 600,000 volts on one of those big globes that could spark to ground. When it did spark to ground, pulses appeared in CSIRAC's memory – extra bits grew in the memory. On the other hand, across the walkway outside there was a cyclotron. When they turned on the cyclotron which had a huge magnet (it used a big Tramways generator to develop the direct current) the power used to go down, and you were likely to lose pulses and bits out of the memory. We were also actually in a radioactive area; there were parts of the Laboratory where you were not supposed to linger, particularly when some of the neighbouring Physics Department equipment was working, because the radioactivity levels were above those recommended.

End view of the mercury delay line temperature controlled cabinet. The"memory hot box" receiving end with the lid off. c. 1956.

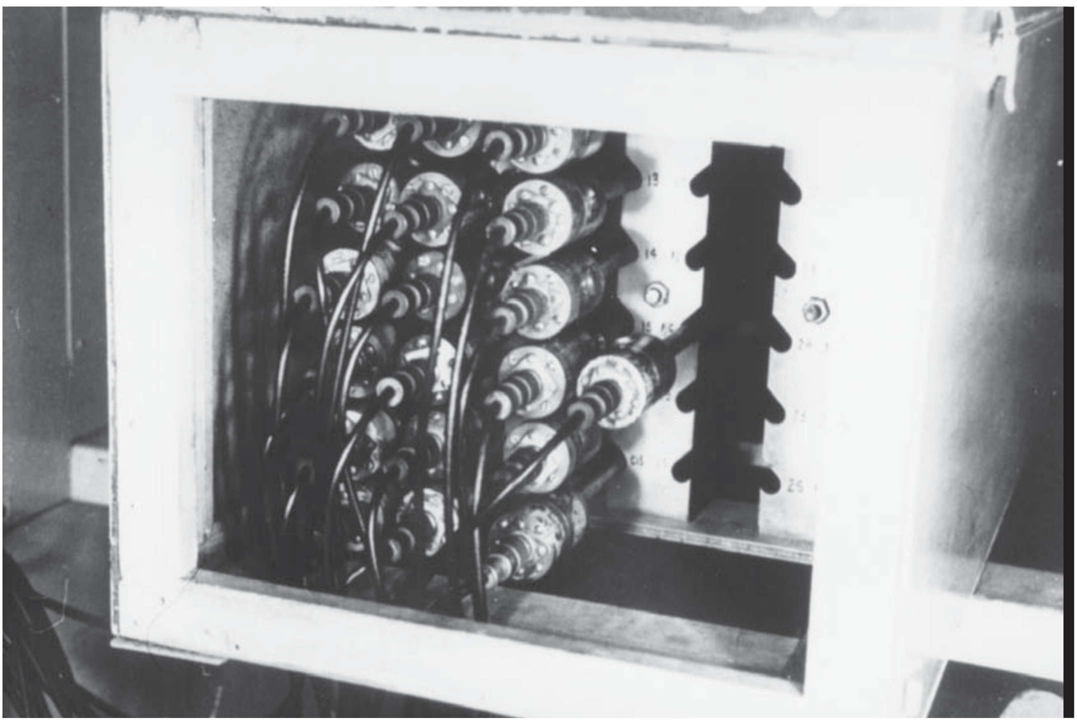


Photo: CSIRAC archive, the University of Melbourne

Ron Bowles was a central character in the operation and maintenance of the computer, and Ron was very quick on his feet. We used to punch out paper tape, particularly later on the narrow 5-channel variety, and take it across the computer room and put it into things called Flexowriters – which were like electric typewriters with a paper tape reader on them – which would then print out the results from the paper tape. So it was a form of off-line printing. The thin tape frequently used to fold over and jam. But Ron could get from one side of the computer room to the other very quickly. You could hear the note of these tape readers change as the paper started to jam. Ron could get from one side of the room to the other and stop them before the paper tape actually tore. He used to do this by running and then skidding on the polished floors to a halt alongside the printer just in time to switch it off.

Fire was a bit of a worry to us and you weren't supposed to smoke in the computer room. On one occasion Ron was sitting on the console working away, and he suddenly saw this huge cloud of smoke coming from behind the computer. He raced around immediately only to find somebody was puffing a cigarette there. (I know people did smoke because, in the office I shared with Trevor Pearcey, Bill Flower was there and he used to smoke. I think people also used to smoke at the console, but I don't remember exactly).

CSIRAC's memory was temperature controlled; it was normally held at about 103 degrees Fahrenheit. On very hot days this temperature could be exceeded in which case the computer wouldn't function.

We had a constant stream of night operators, and a large science-fiction library, with many paperbacks – authors like Isaac Asimov – and we used to tell people and visitors this was actually our advanced research library. You can see in some of the photographs that there is a bookcase near the entrance of the Laboratory – on the lefthand side as you came in. Somebody on one occasion put some manuals or something in the bookcase and had the idea of locking it with a combination lock. This, of course, was just too much of a challenge for the night operators. You would come in to the Laboratory in the morning and see a note on the console saying "I've tried everything up to 7231, you push on from there!", and so the night operators spent their time, when they were waiting for the computer to spit out results, working their way systematically and painfully through all the combinations on this lock. Oh yes, they cracked it!

I remember an amusing incident involving Trevor Pearcey. The whole planning for the CSIRO computer network which was to be a major national project was actually done by Trevor Pearcey, certainly in the early stages. (This is quite a significant story and one of the other major participants in this is still alive i.e., Trevor Robinson, who was later an adviser to Senator Button, and still a very active member of the computing community. He was the Head of Control Data Corporation in Australia over many years). This would have been before 1964, because we effectively vacated the area that CSIRAC was in by 1964, so this would have been in the early 1960s. Trevor Pearcey was doing the planning for what became known as CSIRONET – the CSIRO computer system – which grew to be a major national resource with one of the first major national computer networks.

Trevor had very limited space, a small desk, a rubbish bin and not much else. He had all the tender documents and computer manuals. In those days things were less formal than now; these days when tenders are conducted there is enormous security and so on. Trevor, running out of space, put the manuals on the rubbish bin and forgot that he had done this, and the cleaners evidently cleaned them out and put them outside with the rest of the rubbish from the Physics building. Frank Hirst, who was a collector and didn't like to see anything wasted, came back from lunch and saw them there and thought they looked like useful manuals (possibly he just wanted to save the folders). He took them inside to his office. A while later Trevor approached him and said "Frank, I think I've done a terrible thing, I think I've lost significant tender documents." Frank reached down and said "Trevor, I think I've got them here" …much to Trevor's relief as you can imagine.

Frank Hirst was, and still is, a very resourceful man, and when he went to CSIRO Radiophysics in Sydney to collect CSIRAC he was evidently taken into a room and told "Anything you want in this room you should take with you". Well, he brought back to Melbourne everything he could lay his hands on; the spares, nuts and bolts, various other components, and so on. We still have some of those items in the Department and still use some of them in the Computer Science workshop. They were still in their original cardboard boxes. This is now the late 1990s and Frank would have collected them in 1955! But the amusing thing is that he also brought back with him things like blinds, light fittings, everything …so he set us up pretty well.

The other thing worth recording is the technique used to start the drum (which was really a disc). The drum was quite a large diameter disc with the heads facing on a flat surface and was driven by a V-belt which came from an electric motor. This was around the back of the computer. It turned out that the inertia of the disc, like a stationary flywheel, was too much to get the motor started. So a technique was developed (I think they had previously tried a clutch or flexible couplings) of driving the motor through a V-belt which had a degree of slip in it, so if the motor varied in speed the flywheel effect of

The 12-hole paper tape reader opened for loading or unloading of the tape. c. 1956.

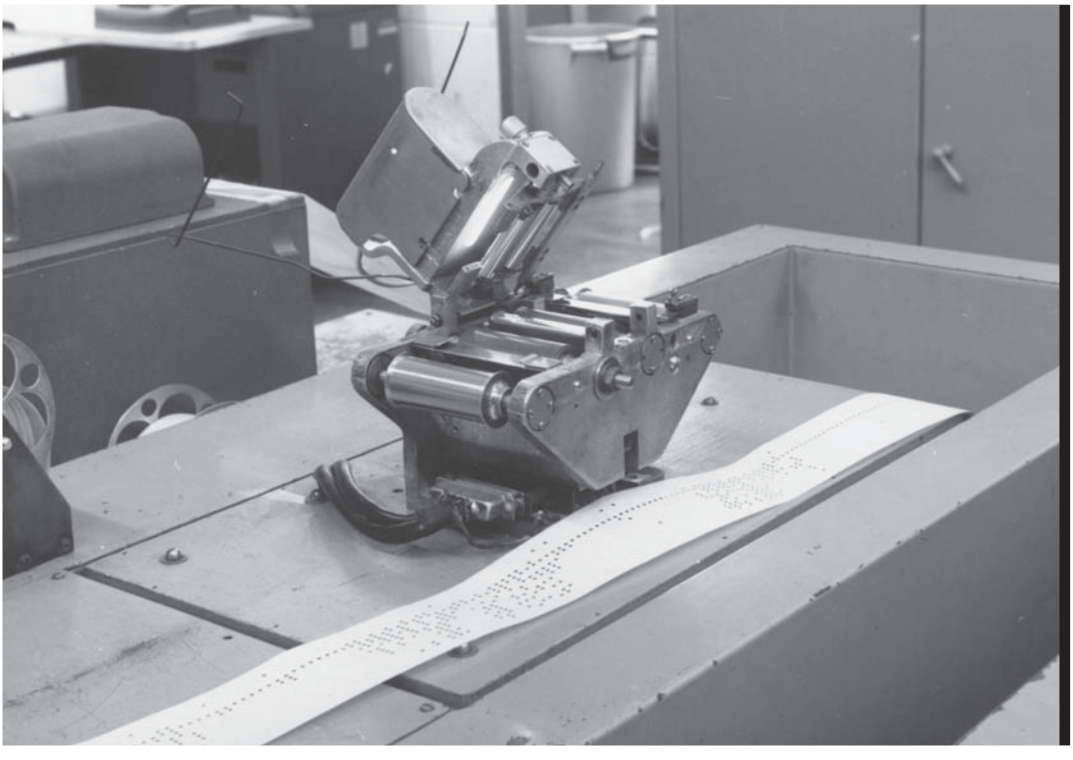


Photo: CSIRAC archive, the University of Melbourne

the big disc would ride through the variations. One would go around the back of the computer, turn on the motor which would come up to speed, and apply a large screwdriver (which is an artefact we still have) to the side of it, flat on the V-belt, to increase the tension to bring the disc up to speed. Then the disk would stay at that speed. But if you were not very good at this, or the belt was loose, the disk might never get up to speed and it could stabilise at a lower speed with a bit of slip in the belt. In this case data could be written on the disk in such a way that you couldn't erase it under program control. You would then have to demagnetise the whole disk. The engineers, of course, weren't too happy if you had an inexperienced applicant of the screwdriver who didn't know how to bring the disc up to speed.

With CSIRAC itself, the main power supplies were high voltage ones for the vacuum tubes, and there were strips of wire – busbars – running along the back of the computer. If you put your hand on those you were going to be across a 300 volt power supply and receive a very major electric shock. But people used to open the cabinets, and leave them open and I didn't see anyone get a shock from it. In fact, I had electric shocks from everything else I worked on at that stage and never received a shock from CSIRAC.

The vacuum tubes were relatively unreliable and if you worked out the 'mean time before failure' for a vacuum tube and multiplied it by the number of vacuum tubes in a particular computer, then in theory some of these early machines shouldn't have worked at all. In fact, it turned out that the vacuum tubes or 'valves' did work reliably for reasonable periods of time. The best thing was to leave them *in situ*. Old vacuum tubes when they had settled in were not too bad, and when they ultimately failed, the machine became increasingly reliable as we replaced them with better quality vacuum tubes. CSIRAC was working as reliably as it ever worked the day it was turned off.

Some of the recent computer reconstruction work in England has shown that vacuum tubes which were manufactured in the late 1950s and 1960s achieved a high level of reliability – significantly better than that of the earlier ones. Technology which was about to be superseded reached its peak in the latter days of its life.

We still did have the problem that little metal particles would get between the electrodes and short them out, so the technique developed was to use Frank Hirst's valve tester, which was a big rubber stopper on the end of a stick (Frank's famous 'rubber donger'). You would run a diagnostic tape that was checking the computer and you would open the cabinet doors and walk down behind the cabinets and go 'bong, bong,' …sooner or later you would hit a valve, and
the program would stop, so you would then start the program again, hit the valve again, and if it stopped again, you would conclude that this was a suspect valve. So you would take that one out and put in a new one. There was also a standard valve tester; you would plug a valve into it if you had any doubt about its integrity.

Public Knowledge and Perception of CSIRAC

Public knowledge of CSIRAC was, of course, limited. We tried hard to overcome this. There was at least one session, given in one of the large physics lecture theatres, called 'Any computer questions?', to which a wide range of people were invited.

Frank Hirst used to go and talk at almost any public forum about computers and the future of computers. In fact, once he was invited to the Municipal Association of Victoria's annual dinner, and he went along, and part way through the evening, unexpected by him, they announced that Dr Frank Hirst from the University was going to talk about computers in public sewerage and sanitation. So he stood up and gave an off the cuff talk – which was very well received – on the future of computing in this domain, presumably with a few appropriate references.

A lot of PR work was done about computers and their potential. Frank in particular put a lot of work into that. A very difficult area because the Press used to overplay everything. The Computer Society was formed during this time.

After CSIRAC

The next computer the University bought was, for its day, a very large computer; it was an IBM 7044, worth almost one million pounds. Dick Jenssen who was overseas when we bought it, could not believe that we had managed to buy one as big as this. Unlike CSIRAC, this was a locked box, you didn't fiddle with it; it came with a service agreement, it was a very expensive machine. It was purchased in the early 1960s and overlapped with CSIRAC. Then CSIRAC went and it was the University's main computer.

But about the time I finished my PhD in 1967 Frank Hirst learned about the existence of the PDP 8, a small computer you could afford to own and fiddle with. David Dewhurst – a Reader in Biophysics in the University – had one of these. Frank said, "We must have one of these machines", and we managed to buy a PDP 8. They were really a laboratory type of computer, so we got one and worked over it, and added bits to it, and altered it. We bought it from Max Burnet, one of the founding members of Digital Equipment Corporation in Australia. That became the core of our experimental developmental computer systems, whereas the IBM 7044 was too large and too many people depended on it. It was too expensive for us to start tinkering with, whereas we could fiddle with the PDP 8, which was a predecessor of microcomputers, and PCs, and so on. Max is now an enthusiastic computer historian and helped us in many ways with the 1996 CSIRAC celebration.

Concluding Remarks

People have asked me whether it was exciting working with CSIRAC and in that environment, I have to say that for me it was. As a young student I had always been interested in electronics and amateur radio and electronic devices, and in science and technology in general. I had always known I wanted to work in science, and although I'd had some difficulties in continuing my education, that had been my driving enthusiasm. And, unexpectedly, suddenly, I found myself associated with a group of people who were minding and operating this very large electronic machine – one of the largest electronic machines in the country in those days (I guess by the time I became involved SILLIAC was working in Sydney). At this time it certainly was the largest machine in Victoria anyway.

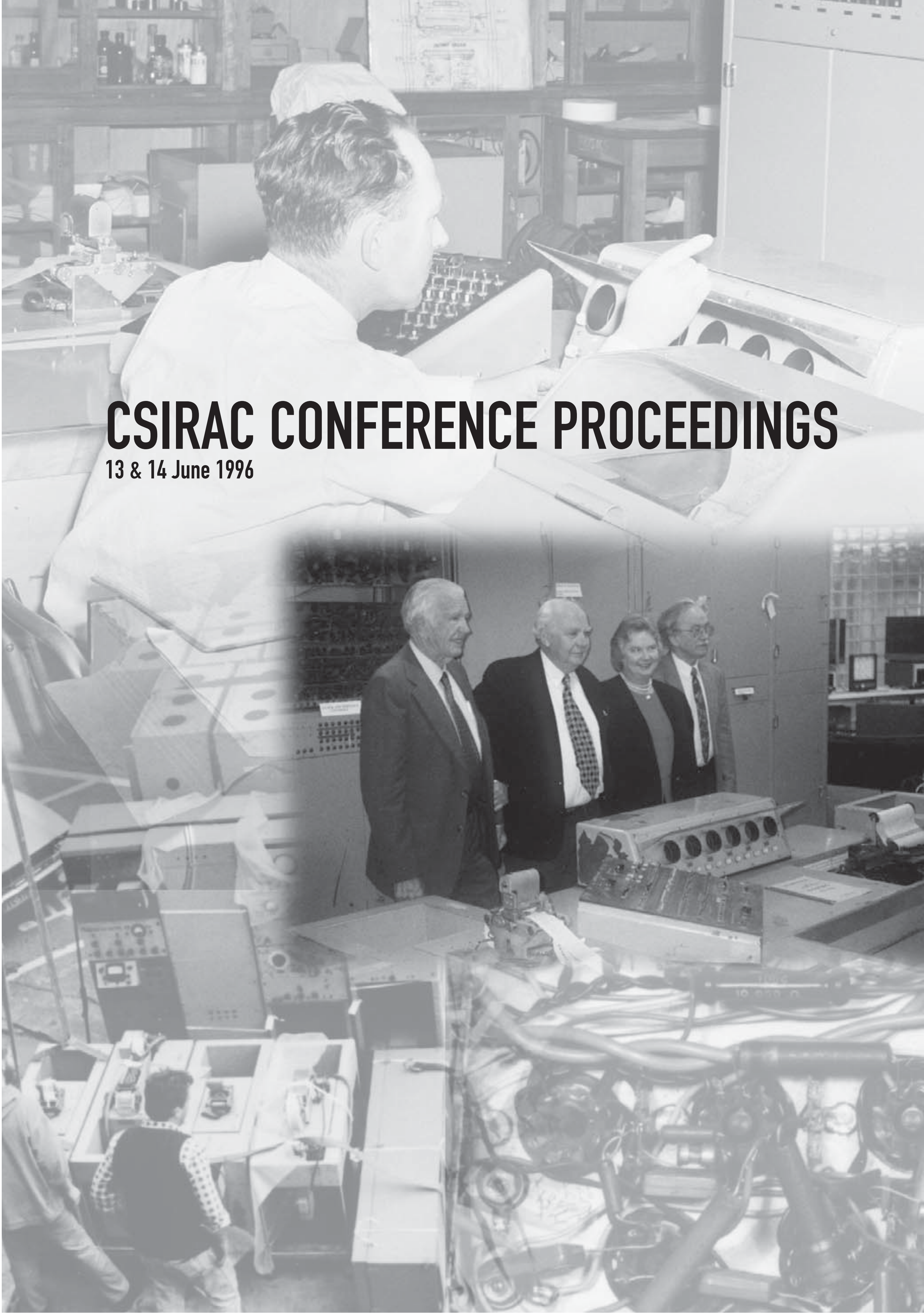
So I found myself working in an environment, which was obviously important and significant, and the laboratory itself was a very interesting place to work, where we all helped each other. There was more job demarcation in 1950s than now, but it didn't apply in our laboratory. Frank Hirst would answer the telephone, any of us would help out in a particular task. We saw ourselves as providing a service for people as well as undertaking research and teaching in this area. It was an interesting Department playing a leading role in an interesting field and ahead of its time in the way it approached its clients and its operation.

Because we were in the middle of a Physics building, we had other projects. There was a project in building photocopying systems (which I think we used in the end to copy the papers for Trevor Pearcey's DSc thesis). We still have copies made in that era, 30 odd years ago, which have survived till now, on what was a home-grown xerox system – one of the early xerox systems – all developed in the laboratory by George Semkiw, with all of us contributing.

One benefit was meeting scientists who were coming in to run programs. It was an exciting area of science, where you felt you didn't need to have millions of dollars, or have to buy in technology, you could do exciting things on the spot. So the time spent working with CSIRAC was for me a highlight in my career. George Semkiw showing me that computer marked a turning point in my life.

CSIRAC CONFERENCE PROCEEDINGS

13 & 14 June 1996



Background to Organisation of the Celebration

Peter Thorne

This celebration, which has been organised to celebrate 40 years of computing in Melbourne, brings together a number of elements: the computer itself – the commissioning of which marked the beginning of computing in Melbourne; the pioneers; also, the people who operated this computer; and, by telephone, Trevor Pearcey who, with Maston Beard, was the designer of the computer when it was in Sydney.

My motivation for organising the 1996 CSIRAC Celebration stems from the fact that I had worked on it as a weekend maintenance supervisor while an undergraduate in the late 1950s and I was aware that the computer was still in existence and in storage somewhere at the Museum of Victoria. It was installed at the University of Melbourne in 1955 and was in service here from 1956 until late 1964. We all knew when it was decommissioned that it was the oldest extant computer in the world and we were careful about the way it was turned off, packed, and sent to the Museum because by then it was 15 years old and already had a potential place in the history books.

The origins of the computer in Sydney, in the late 1940s, with Trevor Pearcey and Maston Beard and others, are important aspects – perhaps the most important aspects – of the history of the computer, but in Melbourne we don't have a lot of evidence about that phase of its development and we're going to have to reconstruct that early period with Trevor Pearcey and others, and from the early documentation. It's a critical period because it is so early in the history of computing. What we can talk about with more confidence, particularly among those present at this celebration and conference, is the period when CSIRAC was in Melbourne, from 1955 through to the end of 1964.

The computer was the first university computer in Australia in the sense that it was installed in a university department and used as a university teaching research tool, though with access to personnel from CSIRO and industry and other bodies. The computer was operated by a team under the leadership of Frank Hirst, who is with us at the celebration. Frank was there at the founding of the Computation Laboratory. He was Reader in Charge until he left to take up the foundation Chair of Computing at the University of Adelaide in the early 1970s.

The celebration therefore marks the beginning of the Department of Computer Science as it is now called, which goes back to the Computation Laboratory. It was the origin of the academic Computer Science Department, but also of the University computing services. The Computation Laboratory was renamed the Computation Department in the early 1960s. I am not sure if it was done officially, we just started using the name on our letterhead. And, it remained the Computation Department until the late 1960s, when as a consequence of a review by the University, it was decided to split the service function from the academic. The Computer Centre was formed and also what became known as the Department of Information Science, which was changed to Computer Science in 1976.

Photo: CSIRAC archive, the Universtity of Melbourne

Delivery of CSIRAC to the University of Melbourne for the conference – 6 June, 1996.

So the origins of both the Computer Centre, now the University Computing Service, and the academic Department can be traced back to the day we are celebrating in 1956. The first Head was Frank Hirst, and Bill Flower was an interim Head after Frank went to Adelaide, then Peter Poole became Foundation Professor of Computer Science in 1975 – about 20 years after the event we're celebrating here, and then I became Head about 15 years after that. So I'm proud to be the Head of Computer Science in a direct line of succession from Frank Hirst.

Other significant players who worked on, or with, CSIRAC in Melbourne were Ron Bowles, who came from Sydney, from Radiophysics with the computer, George (Jurij) Semkiw who was introduced to the team as Service Engineer assisting Ron Bowles, Kay Thorne who joined in the late 1950s as a Technical Officer in the laboratory and played a range of roles, and of course there were other people such as Geoff Hill who spent a lot of time in the Computation Laboratory although he was a CSIRO person, and Trevor Pearcey who spent time there in various capacities for CSIRO. Other players in Melbourne, many of whom are here at the celebration, include people like Don Beresford, Arthur Cope, Terry Holden, Alan Head, Alan Moore, Jim Morrison, Peter Murton, John Russell, John Spencer. Others not present, include Dick Jenssen, Roy Muncey and many others – people who were users of this first computer in Victoria, and used it as a tool for their scientific computations.

The computer itself is really a focal point of the celebration. George Semkiw packed it up and it was sent away in 1964. Neither George nor I saw the computer again until 1996. It was sent to the Applied Science Museum, which later became part of the Museum of Victoria. It was taken out of storage in 1980 and it was on display for many years at the Chisholm Institute of Technology (now the Caulfield campus of Monash University), as a recognition of the role that Trevor Pearcey played in that institution and as well, of course, of his role as the logic designer of CSIRAC.

The existence of the computer was not forgotten by me, and over many years I'd had plans to commemorate the computer in some way, possibly with a plaque on the University building, possibly with a celebration, always in the expectation that one day CSIRAC would be on display again. I had raised this matter over many years with Ray Marginson, who was the Vice-Principal of the University of Melbourne and was also involved in Museum activities in Victoria. In 1995, I met Graham Morris, who was the Director of the Museum of Victoria, at a University function and we discussed CSIRAC. He made it clear that he was aware of its existence and its importance, and that it would play a role in the new Museum of Victoria, which was then being planned.

The original door from the Computation Laboratory, one of the artifacts which have survived from the time of CSIRAC.

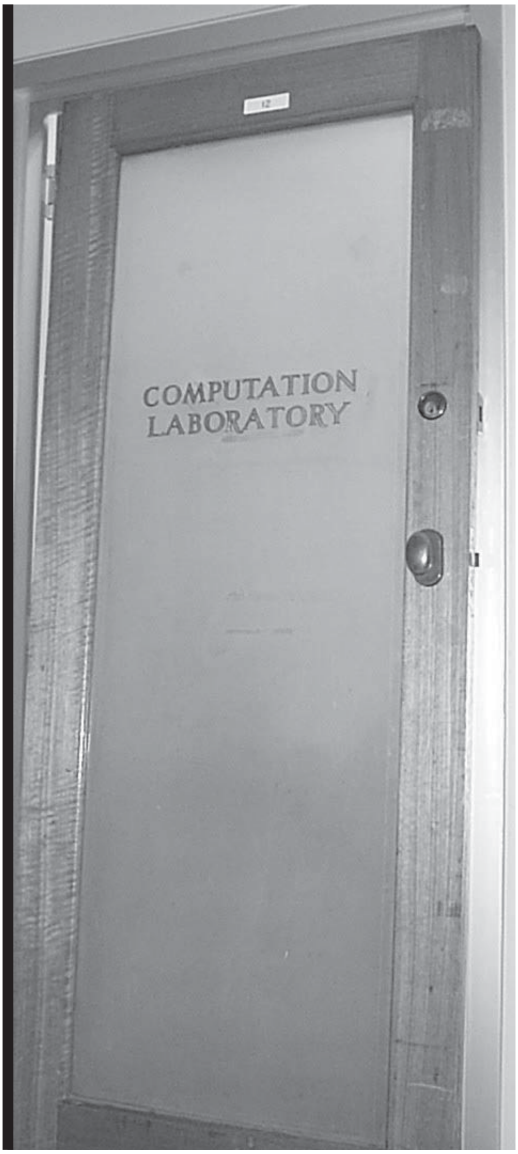


Photo: CSIRAC archive, the Universtity of Melbourne

We had kept a collection of the documents relating to the early history of CSIRAC before it came to Melbourne. I carried them with me from building to building as the Department had developed, and we had also kept various artefacts. For example, we had the software library on 12-channel paper tape, or much of it. We had the door from the Computation Laboratory which we had put on the computer room in the various locations the Department had occupied since CSIRAC had been decommissioned. We had the CSIRAC 'sign' and various other parts of the machine.

In 1995 I decided it was appropriate that we took steps to have a proper archiving job done on the documents, and since the Australian Science Archive Project (ASAP) was housed next door to our new building in Bouverie Street, Carlton, it was arranged with them that they would catalogue, index and store these documents in the appropriate acid-free conditions.

This was done, and as part of that process I encountered an organisation which was gathering oral histories, Voices of Australian Science and Technology (VAST), and in particular Doug McCann, who is an historian with a particular interest in the history of science and technology. From that relationship grew the idea of having a celebration. June 14, 1996 seemed an appropriate date in that it marked the 40th anniversary of the recommissioning of CSIRAC in Melbourne and thus the beginning of computing in Victoria.

The task that faced us was: what kind of celebration should we have and what should we do about the computer itself? The first visit to the Museum, with George Semkiw, Doug McCann, and others, was a memorable experience for me, in that I hadn't seen the computer since 1964. When I first saw it in storage, only the backs of the cabinets were visible, so I wasn't even sure we were looking at the right machine. We identified it piece by piece and were relieved to find it was still effectively an intact machine, complete but not integrated. We then had the task of arranging insurance and moving it to the Computer Science building at the University of Melbourne which was difficult, but we were fortunate in having a part of the building with a reinforced floor, although it was somewhat inaccessible – there was an awkward doorway to negotiate. With the assistance of Ron Bowles we have been successful in getting the computer set up again very much in the way that it was set up in the old Computation Laboratory in the 1950s and 1960s, with the same physical arrangement of the software library and the data preparation station, et cetera.

The possibility of having the computer gave us a focal point for the celebration. The other part that needed to be done was to locate and convince the pioneers to come and talk to us, to record their recollections and to celebrate the fact that this machine had played a large part in all our lives. We also wanted to involve people from the earlier days of CSIRAC, and are very pleased to see people like Geoff Chandler who has come from Sydney to be with us.

The celebration is an opportunity to address a number of questions and open a number of issues regarding those early days. Some of these questions relate to the computer in Sydney, and its conception and development, and some to its time in Melbourne. The opportunity to gather information from the pioneers, and to open up leads to other people whom we should talk to, is a very important one. There are a lot of questions about CSIRAC which we need to address if we're going to write the history and make sure it occupies the proper place in the history of computing.

We are not sure what program was first run, or of the date, although we have strong indications that it was in late 1949 when the first program was operated with CSIRAC in its preliminary test mode. We are not sure about the history of the computer music. We can all recall that CSIRAC used to play music, some was written by Thomas Cherry, Professor of Mathematics at the time. But Trevor Pearcey and others remember it played music in Sydney, and if that is so, then that is one of the very early examples of computer music. So we need to find out more. More about the origins of the magnetic drum/disk system. We have got both the drum and the disk.

The celebration is also an opportunity for people to bring artefacts of their own, so that we can increase the background history of the computer, not only with oral histories and people's recollections, but with artefacts that were developed for, and were appropriate for, the time. It is unfortunate that Trevor Pearcey cannot be with us physically, although he will communicate with us by telephone and hopefully add further to our understanding of the earlier days of the computer and its genesis, the ideas behind it, and its development and construction.

Opening Address of 1996 CSIRAC Conference

Trevor Pearcey

This address was delivered via telephone by Trevor Pearcey on 13 June 1996 from his hospital bed in the Beleura Private Hospital in Mornington, Victoria.

I would like to welcome all of you to the CSIRAC conference. I would also like to thank all those who have brought about this celebration and in particular Professor Peter Thorne for his part in initiating and organising it. It is gratifying to me personally that there is such a revival of interest in the CSIRAC computer and in the history of the project itself. I was very much hoping to attend the celebration and make my reacquaintance with some of my old colleagues but unfortunately that is not possible at present. Although I am unable to be present in person due to illness, I am very pleased to be able to declare the celebration and conference officially open.

I have been invited to say a few words about CSIRAC. I understand that many of you at the conference know about or were associated with CSIRAC in its later years at the University of Melbourne. Since some of you may not be so familiar with the earlier years in Sydney it has been suggested that I make a few brief comments about that period and about the events leading up to that period.

The origin of CSIRAC lies with a visit I made to the Harvard Mk 1 in late 1945, while I was crossing America to join Division of Radiophysics of the CSIR (Council for Scientific and Industrial Research), as it was then. In fact I landed at Eagle Farm in Sydney on Boxing Day 1945, and I lost Christmas Day sitting on top of a load of mail bags in an American Air Force Sky Master. The future course of science at the time I was visiting the Harvard Mk1 was clearly going towards team work, and a variety of instrumentation, with plenty of data and masses of computation work being necessary. That wasn't really why the Harvard Mk1 was there, but the later Harvard Marks were certainly already oriented in that direction.

The Mk 1 showed me some very important facts; it had program input on paper tape, 6 inches wide, data came out either on a typewriter or was imported as tables on the same kind of paper tape, and this only operated at about two operations per second. Well, two operations per second for the future was obviously not going to be adequate. For me it was obviously necessary that we would have to go electronic. We had all that was necessary to go electronic and gain a factor of speed of about 1000 if we could get access to input data and instructions to build programs at the same rate that we could do the arithmetic, which was about 1000 operations a second.

We knew about counters and suchlike things from radar. We knew about using vacuum tubes as switches. And it was clear that Radiophysics – with its experience in radar design, building large instruments with vacuum tubes of the order of 100 each, with good experience in pulse technology (and what's more we had a first class electronic machine workshop) – was just right to get into the business of experimenting in electronic computation.

Photo: CSIRO archive

Trevor Pearcey in front of CSIR Mk 1 in Sydney. 5 November, 1952.

The problem which was really before us was what could we use for high-speed store?

We knew from Gold's work at Haslemere towards the end of World War II that he had been experimenting with mercury delay lines for cleaning up, as far as I know, radar traces and to improve signal/noise ratios. The development from that, I'm not quite sure how he handled it, but development of the idea of recirculation was necessary. This was absolutely essential if we were going to use the delay line developed into some form of storage.

So I went ahead and by 1947, on paper, I had a formal design of what eventually became the CSIR Mk 1 using Pitts and McCulloch's notation. Pitts and McCulloch were two physiologists, surprisingly enough. We got permission from the Chief of the Division of Radiophysics to develop components, and, of course, when you develop enough components you test them by shunting them all together. Late in 1949 the equipment we had developed and assembled performed its first loop program. From there on it was a matter of continuous accretion, and overcoming engineering tribulations.

You must remember that Australian industrial anarchy was rather rampant towards the end of the 1940s, and Australia was absolutely strapped for US dollars, so we couldn't get US communications equipment for input and output. There were inordinate delays in obtaining standard equipment for instance. Delivery times for paper tape gear for input and output, and punch card machines, ran into the order of two to three years. So we had to design our own input and output, after having been given by the Post Office an old teleprinter, which you will probably see later, which was recoded to make the least possible demands on whatever store we could get together. An old column by column card punch and reader was donated to us, but we had considerable trouble with that, and it was given up eventually as unreliable.

Maston Beard, who was responsible for the electronic design and construction, designed a 12-hole paper tape reader and corresponding punches. This was the origin of the 12-hole paper tape – it is in fact a long punch card.
I would like to give due credit (and perhaps more credit than to the programmers, who were myself and Geoff Hill), to the engineering staff. Considerable credit must go to Maston Beard, to Brian Cooper for the magnetic storage equipment, to Reg Ryan for designing the store, delay line circuitry, and for interleaving and doubling up the capacity of the store of each delay line.

From 1950 to 1955, I suppose, the machine was in continuing, somewhat irregular service, and performed really massive computations. For instance, weather analysis, analysis of flood data for the design of dams for assembling the Snowy Mountains Hydroelectric Authority (SMHA) at that time, for big problems in physical optics, and in the solution of problems in hydraulics and hydrodynamics, and so on.

I think that it is highly appropriate that the machine as it exists now should be considered a museum piece and appropriately housed. I hope you are able to achieve this and thank you for listening to me.

CSIRAC was on display at the Caulfield Institute of Technology from 1980 until 1992. Trevor Pearcey in front of CSIRAC in the early 1980's. He retired, Dean of Technology, from Caulfield in 1985

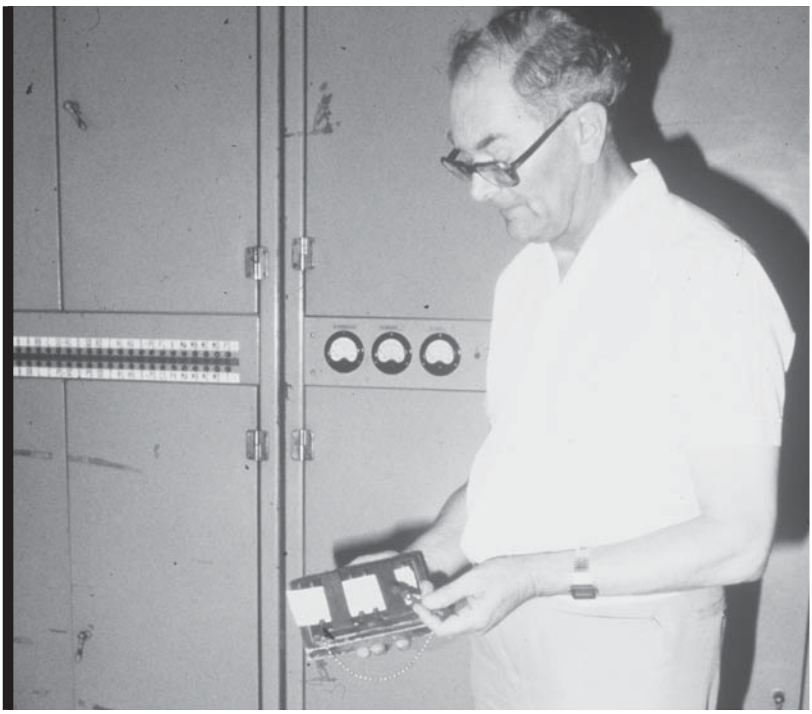


Photo: CSIRAC archive, the Universtity of Melbourne

Reflections on Pearcey's Achievement

John Bennett

I begin by pointing out that at no time was I directly associated with CSIRAC – neither at the development stage nor as a user. However, I had some early contacts with Trevor Pearcey before and during CSIRAC's development phase. And, when I returned to Australia at the beginning of 1956 after about a ten year absence in the UK, although we (i.e. CSIRAC and myself) overlapped for a few months on the Sydney campus, I was then too busy preparing for the launching of SILLIAC – which began regular operation on 4 July 1956 – to become involved.

Personal Background

To provide a background for my relevant early contacts with Trevor and CSIRAC, I must first give some personal details. I graduated in civil engineering from the University of Queensland at the beginning of 1942 and then became a radar trainee in the RAAF. My training included an excellent electronics course conducted under the auspices of Professor Victor Bailey in the University of Sydney School of Physics. This was followed by three years of active service including two years in the north. As I had been under 21 when I joined the RAAF, I was allowed to complete further degrees in electrical and mechanical engineering and in mathematics and physics, the latter being on a part-time basis while I was working with an electrical power company.

My First Contact With Automatic Computing:

As part of my electrical engineering training, I had been required to spend several months gaining what was described as 'practical experience'. Fortunately for me this time was spent in the CSIR (later CSIRO) Division of Electrotechnology headed by David Myers – later to become Vice-Chancellor of La Trobe University. Myers was interested in the development of computing devices, both analogue and digital. And my principle assignment at that time was to calibrate a ball-and-disc integrator inherited from the Australian Army artillery, where it was part of a gun-laying device. One member of the Division, Ross Blunden (who was to become Professor of Traffic Engineering at the University of NSW) was then experimenting with a scale-of-ten ring counter as a possible computer component.

Trevor Pearcey – First Contact

It was at that time that I met Trevor Pearcey, who had joined the CSIR Division of Radiophysics late in 1945. Trevor was using relaxation methods (by hand) to determine the shape of falling raindrops – and our common ground was Southwell's relaxation technique, which I had also been using to solve structural engineering problems.

Some Reminiscences

As this is a time for reminiscences, there are items from that time which I should mention. The first is that in 1979 the Sydney University Basser Department of Computer Science moved to what had been the CSIRO building in which I had worked in the summer of 1946-47 and the main Basser


Photo: CSIRO archive

CSIRO Radiophysics Staff 1952. |

office (including my room) took over what had been the office of the CSIRO Radiophysics Division – in which the opera singer Joan Sutherland once typed.

My second memory from that time concerns the Lalla Rookh Hotel – on City Road opposite the CSIRO building. The Lalla Rookh at the time functioned as a local social gathering place – watering hole, if you like – as it had done when as RAAF trainees we had slept under canvas on what had been the sports ground of the NSW Institute for Deaf and Blind Children sited next door to it. The name Lalla Rookh derives from oriental tales versified in 1817 by Thomas Moore. Truganini, the last full-blooded Tasmanian aboriginal (born 1812, died 1876) was also known as Lalla Rookh. There is a story that the immediate occasion which led to the naming of the hotel was the publicised sighting of a ship of that name by the then Governor of Victoria when he was with a group picnicking on St Kilda Beach. The University of Sydney Wentworth Building (which houses the Student Union) now occupies the site.

An Early CSIR – Computing Link

It should perhaps be pointed out that the first Australian commercially available calculating device was the totaliser designed and built by an Australian railway engineer, George (later Sir George) Julius – in 1913. Julius was one of the founders of CSIR and became its first Chairman.

Back In Brisbane

My 1947 work with the power company referred to above involved me in lengthy and tedious calculations relating to the distribution of electricity in the Brisbane River valley a decade ahead – and it was at that time that I heard an ABC radio programme concerning the UK National Physics Laboratory's plan to build ACE. I then decided that my future lay in automatic computing.

EDSAC

I was fortunate enough to win a scholarship which took me to Cambridge, where I was accepted by Maurice Wilkes as his first research student and spent my first year designing and building the main control and bootstrap units of EDSAC. EDSAC used a mercury delay line store, as had been suggested to Maurice Wilkes by Tommy Gold (later Director of the Centre for Radiophysics and Space Research at Cornell). Gold had worked on an echo-suppression device using mercury delay lines at the Admiralty Signals Establishment during the 1939-45 war.

It was at Cambridge in 1948 that I next contacted Trevor Pearcey when he visited the EDSAC group. My recollection of our discussions with him at the time is that he had thought through the architecture of what was to become CSIRAC and was concerned with the detailed design of the mercury tube memory. However details of the discussion, which took place nearly 50 years ago, tend to disappear into the 'Dreamtime'. When we were next in contact, CSIRAC had been carrying out computations on a service basis for over five years.

Concluding Comment

It is appropriate to conclude these remarks by paying a personal tribute to Trevor Pearcey and his fellow CSIRAC workers. To those of us from the early days of computers who have had the full support of our umbrella organisations it appeared that the successful completion and putting to work of CSIRAC was secondary to the main research thrusts of the CSIRO Division of Radiophysics. The most important projects, as seen by the Division Head, were radioastronomy and rainmaking. Trevor's project was at best subsidiary. For this reason the success of the CSIRAC group, despite what must have appeared at times to be a somewhat discouraging environment, is doubly significant.

CSIRAC's Role in Designing Multi-Storey Structures

Donald Beresford

In 1959 the part of the CSIRO Division of Building Research known as the Testing and Concrete Laboratory was under the direction Dr Lex Blakey, with a staff of some seven individuals, which included John Russell and myself. As always, new ideas for research projects were keenly sought in the general field of structural engineering and technology. As a small unit the emphasis was virtually a 'hit and run' approach – get the idea, and establish a presence in the area, before the larger research units get in and work the subject to death.

Lex was good at this and recognised the potential of the 'automatic computer' in the structural engineering field at this time, particularly having had some experience of the lengthy boring calculations prevailing in the aeronautical engineering field some years earlier and through his 'PR' relationships with consulting structural consultants in the capital cities – in effect, the idea nursery. Since Lex was a man of many responsibilities the CSIRAC involvement was delegated to John and me.

The design of the structural frameworks for buildings was a good target. Before the 1930s the design of even moderately sized buildings with a conventional rectangular grid of beams was calculated as WL/8 and a steel or concrete member capable of withstanding the moment selected. P/A determined the stress in the columns and the A adjusted to give the allowable stress.

However the analysts then pointed out that, with the junctions of the grid frame rigidly connected, bending moments were shared between columns and beams with a considerable reduction in the magnitude of the moment and also in the steel or concrete required. The calculation effort was at first prohibitive but alleviated by a method of 'moment distribution' devised by Professor Hardy Cross in the United States. With the multistorey structures gaining momentum in the late 1950s the analysis of, say, a plane framework 20 storeys high incorporating four columns, could be carried out in about a week by a qualified engineer. Unfortunately the remuneration of architects and engineers in the consulting professions was commonly derived as a percentage of the building cost so the material reduction was of dubious benefit to engineers, because one also had to compete on building costs. Hence there was a desire for rapid computation, as the popularity of multistorey structures took off.

After a grounding course on CSIRAC programming by Prof. Cherry a test assignment was sought and here Lex's previous association with aeronautical research provided a subject. At ARL (Aeronautical Research Laboratory) Stan Shaw, later Dean of Engineering at the University of NSW, had devised a relaxation method of determining shear distributions in metal sections, basically a solution of Laplace's equation under complex boundary conditions, and this provided a useful introductory exercise which was successfully undertaken by John, myself and also Terry Holden who attached himself to the team for this one, perhaps devoid of ideas in his own group.

Photo: CSIRO archive

Team from CSIRO Division of Building Research who used CSIRAC for various computations including thermal simulations of indoor temperature using climatic data, and analyses related to the design of structural frameworks for multistorey buildings. (L–R) Don Beresford (foreground), Roy Muncey, Bill Davern. 1958.

From there, the same procedures were applied to the multistorey frames, through the solution of the slope deflection equations applying to the individual members, the solution emerging as the rotation of each joint of the framework and the translation of each storey under vertical and lateral (wind) forces. John will no doubt enlarge on this area.

At that time one of the first of the new run of multistorey buildings in Melbourne had just been built, with the frames designed by Mr Harvey Brown, the chief structural engineer of Bates, Smart and McCutcheon, consulting architects and engineers. Harvey supplied the moment distribution calculations which provided a useful comparison to the CSIRAC computations. Subsequently consultants in the capital cities submitted their plans for analysis and it is fair to say that most of the multistorey structures built during the early 1960s had frames designed/ analysed by the CSIRAC program. The commercial trend in science was becoming evident and a fee based on computer time was charged. After CSIRO acquired their own computing facilities in the mid sixties the service continued over a decade or so using those machines until the commercial software companies produced sophisticated systems such as STARDYNE and STRESS.

In those early years CSIRAC's potential was becoming recognised in many areas and time on the machine was not easy to obtain. One way of gaining access was to use the less popular night-time hours while establishing paper tape punching facilities back at the Division.

The night shift was not without its amusing moments. The Physics Department was locked up at night and if one booking took over at, say, 1:00 a.m., the mode of entry was to throw small pebbles at the window of the computer room, attracting the attention of the incumbent who could then let you in from the inside. Unfortunately one incumbent whose name escapes me used a hearing aid, but preferred to concentrate on his work with the aid turned off. The answer was larger pebbles but fortunately no breakages resulted to my knowledge.

Then there was the steamy summer night when for some unknown reason the computer rooms became infested with mice, dozens of them running all over the equipment. I believe that there has been concern over spillage of mercury from the delay lines but no deleterious effect could be detected in these resident animals.

The security guard patrolling the campus was a regular visitor during the night watch, a boring loquacious fellow who succeeded in wasting valuable time, but no-one insults a security guard when your car is parked outside.

No doubt others will recall other episodes of the long nights spent at the CSIRAC console.

Don Beresford at keyboard control for tape punch. (L–R) Tape punch, cabinet with control circuitry, tape library, tape reader. 1958.

Photo: CSIRO archive

The Origin of the Stored Program Concept

Allan Bromley

Abstract

It has been traditional within the computer field to regard the "stored program concept" as a single idea that divides off the later "von Neumann machines" from its electronic and electro-mechanical predecessors. Some controversy, however, surrounds this approach. In particular, the precise role of von Neumann has been questioned.

In this paper the "stored program concept" itself is examined more closely and is found to be divisible into a number of distinct sub-concepts. Many of these sub-concepts can be attributed to separate inventors, sometimes with considerable clarity. We conclude that the stored program concept was not just the work of one person but must be seen as the accumulation of the work of many individuals.

Introduction

The mid 1940s was an important watershed in the development of digital computers. Although several important and large scale calculating machines were designed and developed before that time none would be considered as "computers" in the modern sense of the word. Most computing machines designed since, from thermionic value (tube) machines the size of a room to integrate circuit micro-processors no larger than a sugar cube, are all recognisably akin to one another – anyone skilled in the use and application of one could readily enough use any other.

The main characteristic which divides off modern computers from earlier calculating machines is the so called "stored program concept" – the idea that the instructions that control the computer are stored in the same memory as the data it manipulates and hence that the computer can, in principle at least, build or modify its own program of working instructions. Such computers are commonly called "von Neumann machines" after the mathematician, John von Neumann, whose work did so much to develop the stored program computer idea in the late 1940s.

Much controversy has surrounded the origin of the stored program concept. Its developer, whoever they may be, is commonly regarded as "the inventor of the computer" – surely one of the major accolades history will apply to a person of the twentieth century.

The controversy was fired and fuelled by patient litigation in 1971-1973 between Sperry Rand and Honeywell. In the case Sperry Rand, who had acquired the Eckert and Mauchly patent for the ENIAC, sued Honeywell for royalties claiming that the ENIAC patent covered techniques used in computers manufactured by Honeywell. Honeywell contested the validity of the ENIAC patent on a number of grounds including the prior existence of electronic digital computing techniques, particularly in the Atanasoff-Berry Computer.

The lengthy and detailed evidence assembled for the Sperry Rand/Honeywell case is a mine of information for historians. However, that evidence was presented and interpreted within the confines of the patent litigation. Although Judge Larson eventually ruled the ENIAC patent invalid on a number of grounds they were essentially technical legal decisions deriving from the Patent Law. The broader question of "who invented the computer" as historians might understand it, was not really answered by the legal judgement.

Since 1974 people have contributed to the debate, including a number of the principals involved. This has added some new evidence and altered the focus of attention on the past evidence. However the debate, particularly as abstracted in the popular press, has more often contributed heat than light. After all, the participants in such recent historical events are scarcely dispassionate observers nor can we be surprised if they occasionally write "with a glint of immortality in their eyes". The views of von Neumann, who died in 1957, have not been heard on the origin of the ideas now identified with his name and historians must form their own conclusions after weighing the evidence as best they can.

In this paper I will dissect into its component parts the "stored program concept" and other characteristics of different individuals to those parts. Not surprisingly, it turns out that many people made significant individual contributions to the concept of a computer as we know it.

1940's memory technology. CSIRAC's mercury delay line temperature controlled cabinet with thermometer on top. c.1956.

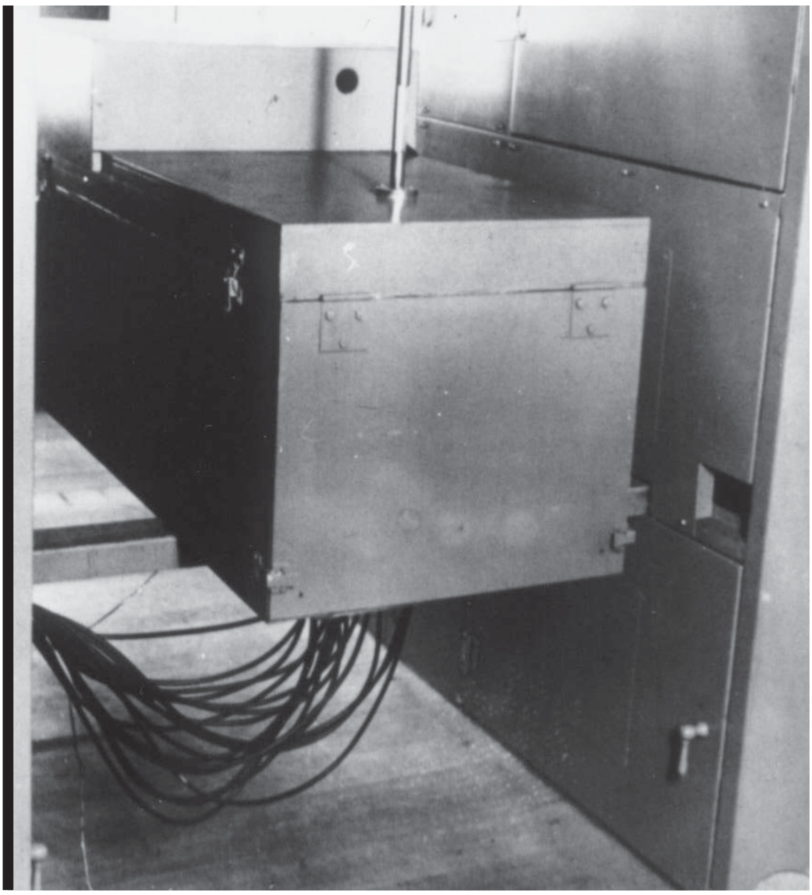


Photo: CSIRAC archive, the Universtity of Melbourne

The Stored Program Computer

Before going further it is best we make clear just what we do mean by a modern “computer”. The following features seem to me to be characteristic – probably essential.

A computer uses *electronic circuits* and its internal logical operations are therefore very fast. Number representations and arithmetic are usually binary or something closely related (such as binary coded decimal). The main storage is quite separate from the portion of the machine where arithmetic and logic operations are performed. I will use the terms “store” and “mill” to distinguish these two main portions in part to emphasise the primacy of Babbage’s development of these concepts and in part to avoid terminological squabbles in more recent machines. The mill generally contains a small amount of storage, sufficient only to its immediate requirements and minuscule compared with the capacity of the main store. The store contains not only the *data* on which calculations are performed but also the *instructions* which direct those calculations – the computer’s programs. Since the instructions are in the same memory as the data, programs may act on and *manipulate instructions* also. This is characteristically done by *loaders, assemblers* and *compilers* which build programs of instructions for a computer according to directions provided by the user in the form of programs written (generally) in higher level languages.

There are other features, such as the ability of an instruction to compute an instruction or data address in the store, and the linear addressing space of instructions and data. These characteristics are normally taken for granted in computers but have considerable historical significance.

Electronic Calculation

Judge Larson determined in the Sperry Rand/Honeywell case that:

> *“Eckert and Mauchly did not themselves first invent the automatic electronic digital computer, but instead derived that subject matter from one Dr. John Vincent Atanasoff.”*

Kathleen Mauchly has brought forward evidence that Mauchly had been actively experimenting with electronic counting circuits from about 1937-1938. Models of circuits from this time, which were intended for use in an electronic version of mechanical calculators but with more extensive storage, are still in existence.

When Mauchly visited Atanasoff in Iowa in June 1941 the Atanasoff-Berry Computer was well advanced in construction. Mauchly was struck, and greatly disappointed, by two aspects of the Atanasoff machine. That machine was intended only for a single special purpose application, the solution of simultaneous linear equations, and it was not fully electronic in design but used a rotating drum of capacitors (condensers) as the store. It was by this last means that Atanasoff had reduced the cost of storage to only $2 per digit, a cost that Mauchly could not approach with purely electronic circuits. This dichotomy, the economic pressure for different technologies for the store and mill of a computer, remained a feature of computer design until the development of cheap semiconductor memory chips in the late 1970s.

Two other features of the Atanasoff machine that are of considerable importance in retrospect are its use of binary arithmetic (organised to be carried out in a bit-wise serial manner) and the clear separation of the store and mill with all arithmetic capability concentrated in the mill. Neither aspect was clearly appreciated by Mauchly and neither appears in the ENIAC. Both are important features marking off later computers from the ENIAC.

The idea of digital electronic circuits arose well before the time of Atanasoff and Mauchly with the Eccles/Jordan flip-flop (1919) and the Wynn-Williams thyratron counter (1932). Although both were extensively applied in geiger counter and similar circuits in the 1930s neither had been developed in forms directly suited to computer uses – the emphasis had been on consistent rather than accurate reduction of high speed pulse signals. In their adaptations of electronic circuits to calculations the work of Atanasoff and Mauchly was independent of one another.

However, at the time of Mauchly's visit to Iowa Atanasoff's work was much further advanced. Not only had Atanasoff developed storage and counter circuits and logical circuits such as serial addition, but he had engineered these together into a single automatic system (the function of which was one step in the Gaussian elimination between simultaneous equations.) That these are far from trivial extensions is evident if we recall that the applications of Boolean algebra to relay switching circuits had only been made by Shannon in 1937 and had constituted a profound intellectual advance. It is unclear to what extent Mauchly appreciated the profundity of these aspects of Atanasoff's work. My impression is that his thoughts were initially dominated by shock at the manner which Atanasoff had achieved the $2 per digit storage and the limited special purpose nature of the machine. In view of the considerable further advanced state of Atanasoff's machine in 1941, Judge Larson's finding seems well enough justified.

But what really is the importance of electronic technology in digital computers? First, because of the two state nature of most digital circuits, it made binary systems of number representation and arithmetic natural and inevitable in all computer designs from von Neumann onwards. At best non-binary facilities in later computers are obtained by more or less complex binary coding schemes. Second, as stressed by Wilkes in the EDSAC design, electronic systems were so fast that speed could well be traded for simplicity. Thus sequential execution of logical steps was substituted for arrangements of parallel execution requiring additional hardware. The clear separation of the store and mill is a characteristic example. This trading of speed for simplicity has remained a characteristic of the design of all computers save those with the highest speed performance objectives. Both points were missed by the ENIAC designers. The ENIAC, in consequence, was ten times the size and complexity of any of its immediate successors.

The ENIAC achieved one momentous breakthrough however. It worked, and worked reliably. The ENIAC was an immensely complex system incorporating about 18,000 values (tubes) against the few hundred in the most complex radar and gunnery systems that preceded it. The success of the ENIAC is a tribute to the circuit design skills of Eckert based on highly conservative designs and meticulous quality control of components and circuits. The importance of the ENIAC to inspire confidence in subsequent computer designers cannot be overstated.

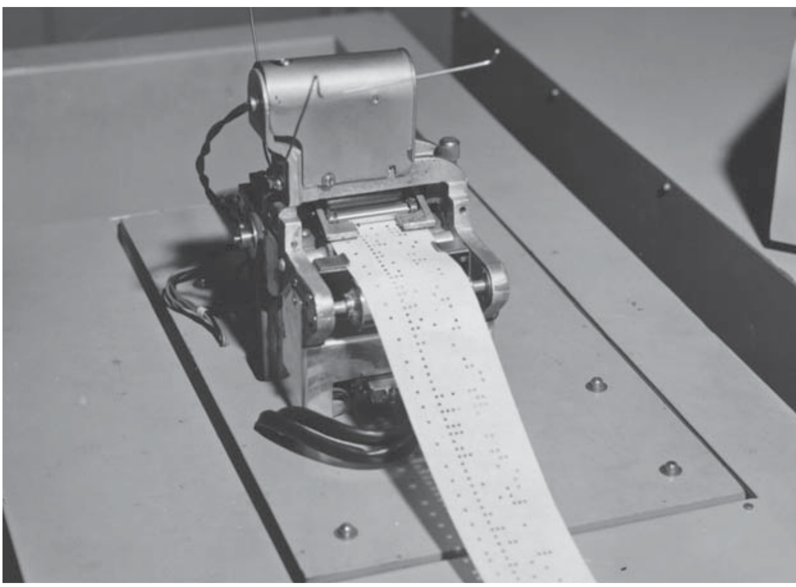
The Stored Program Concept

The ENIAC was developed with great speed under the press of wartime needs. It has many features that appear incongruous to modern eyes. These include the use of a decimal number system; the transition of numbers in a digit-wise parallel manner but in a unary-coded serial manner for each digit: the small amount of storage, all provided directly by electronic circuits; the association of arithmetic capability with every number store, so that each of the twenty number stores is also an accumulator; the high degree of functional parallelism so that several independent operations can take place concurrently; and the means of programming by independent sequencing units and very extensive hand plugged wiring.

Burks has suggested that ENIAC was designed as an electronic version of the mechanical Differential Analysers so that, for example, the digit trunks and plugged wiring of the ENIAC are analogues of the bus-shafting and interconnecting gearing of the Differential Analysers. This suggestion seems plausible in view of the historical context of the development of the ENIAC at the Moore School with the funding of the Ballistic Research Laboratory. Many internal details of the design support the idea. There is considerable evidence also of Mauchly's earlier ideas and, I feel, considerable resistance to, or lack of appreciation of, the ideas developed in Atanasoff's machine.

The ENIAC shows every evidence that the basic conceptual design, what we would now call the machine architecture, was very hastily done. The extensive and very thorough engineering development that followed did not alter what was basically a poor architecture. The very laborious and slow set up by hand-plugged wiring is a clear example of this.

There is evidence in the Sperry Rand/Honeywell case and the writings of several of the participants that members of the ENIAC group were dissatisfied with the basic design. John von Neumann became involved with the group as the ENIAC was nearing completion and joined actively in discussions on possible alternative architectures. It was from these discussions that the "First Draft Report on the EDVAC" emerged in 1945 over von Neumann's name. This report contains the genesis of the "Stored Program Concept" though, as we shall see, in an incomplete form. The report is without the cornerstone on which the modern idea of the computer was built. Much subsequent disputa-



12–hole paper tape reader used for loading programs (and data) into CSIRAC's memory. c.1956.

Photo: CSIRAC archive, the Universtity of Melbourne

tion has concerned how many of the ideas in the report were von Neumann's own or to what extent he merely reported ideas that emerged from others in the group. The spectrum runs from those who consider the report to be essentially von Neumann's own work to others who regard him as merely a plagiarist.

Distinctions in perceived values and aspirations between "academics", such as von Neumann, and "engineers", such as Eckert, are strong currents (among many) in the subsequent development and breakup of the ENIAC group. These questions are not germane to the history of ideas that I wish to consider here but have been carefully studied by authors such as Nancy Stern.

I will proceed by attempting to divide the stored program idea into smaller and, I believe, more fundamental pieces.

If a computer is to work at electronic speeds it is necessary that the commands that direct its action be available at those electronic speeds. Mechanisms such as the punched paper tapes or punched cards of the Harvard Mark I and similar relay calculating machines are simply too slow. The Atanasoff machine overcame the difficulty by being hardwired to carry out the single special purpose for which it was made. The ENIAC could be programmed by changing the hand plugged wiring by which it was controlled, but the set up was a lengthy process and the ENIAC was really only suited to tasks, such as ballistic calculations, where the same calculations had to be performed very many times with changes in only a few of the parameters.

A general purpose computer requires a readily changeable program accessible at electronic speeds – a program, therefore, held in a store similar in capabilities to that required for the data manipulation during calculation. It is a straightforward, but important, engineering simplification to build a single store, rather than two, part of which is used to hold data and part of the controlling program. Flexibility is gained by this stratagem; for a small program which manipulates a lot of data or a large program which manipulates a small amount of data can both effectively exploit the one machine to its maximum storage capacity.

This idea seems to have arisen before von Neumann joined the ENIAC group. There is a memo by Eckert cited by Lukoff, apparently dated January 1944 (the extant copy of which is from a year later), that suggests program instructions and data in the same store. The store, incidentally, is a drum, not unlike that employed by Atanasoff, that exploits a non-electronic storage technology.

The next major step comes in the EDVAC report where it is recognised that, since the program and data are in the same store, the instructions can be manipulated or modified by other instructions just as if they were data. This idea is greatly elaborated in several reports prepared by Burks and Goldstine with von Neumann after they had left the ENIAC group and gone to the Institute of Advanced Studies at Princeton to join Von Neumann in building the IAS machine. This series of reports includes the first substantial attempts at programming and the analysis of the ideas that arise therein. These have a surprisingly modern flavour and include, for example, the development of the idea of loop invariants and cover many areas other than numerical calculation, such as sorting.

For our purposes we note the programming idea developed rapidly in this era of the late 1940s. In all of this work von Neumann is involved. However, the only instances that occur of instruction modification are when a calculated address is used to replace the address field of an instruction. A program can carry out one operation but applied to different data locations in the store at each iteration. We have therefore, by having the computer calculate the addresses of data items, provided the capability of building and manipulating data structures in the store – the simplest such structure being the one dimensional vector or list of data items.

This idea, of the computer calculating the address of data item, now seems so natural that it is difficult to realise that the discovery of the variable address idea can have been a major breakthrough. But the idea was absent from all calculating machines before the EDVAC report. In the Analytical Engine, for example, it proved an unsurmounted obstacle to Babbage's attempts to design programs for solving sets of simultaneous equations where the same operations must be repeated over sets of equations and over the several coefficients in each equation. (It was, in fact, the study of Babbage's work which led me to appreciate the historical importance of the variable address idea). Similar difficulties in solving simultaneous equations would have occurred with the ENIAC, or the Harvard Mark I, and other early machines. The difficulty was masked for both of these machines by their limited size of store. However, both had fixed read-only data tables from which the concept might have been developed and the Harvard Mark I would have required only a very small change to the hardware but none, so far as I know, was ever made. The ENIAC, however, after its move to the Ballistics Research Laboratory, was permanently wired by pluggable patch cords to emulate a stored program machine – but the program was only in a read-only data table.

These examples show that the variable address idea was new to the EDVAC report and von Neumann's later work. I see no echo of it in earlier work by the ENIAC group nor in modern commentaries on the origin of the stored program concept. The variable address idea I therefore attribute to von Neumann himself. I regard this as the key concept in the structuring of data (and programs) and the key to the effectively "general purpose" nature of the modern digital computer.

I conjecture that the variable address idea may have arisen in the following way once data and program are held in the same store. When one command (instruction) is executed it is necessary to know where in the store the next is to be found. This can be (and in some cases has been) done by having each instruction specify the location of its successor. However it is both convenient and efficient to have a default successor – the instruction at the next place in store. The store locations are therefore not arbitrarily marked but are numbered ("successor" after all is the essential concept in the Peano axiomatisation of the integers) and these numbers must undergo an arithmetic operation, incrementation, when determining which instruction is to follow another. These numbered designations (of the store locations holding instructions) that are subject to arithmetic operations are now called addresses. Note that whilst earlier calculating devices had designations for the data items in the store that looked like numbers these were really just arbitrary designations since the "next" data locations had no functional meaning in the machine, nor was there any mechanism to indicate such a "next" location.

The numbering of program store locations brings with it not only the arithmetic idea but also a hardware register, now commonly called the "program counter", which was the embodiment of the program address and at least its incremental arithmetic capability. If now we extend the same idea to number the data locations in the store – a natural but by no means necessary extension – we have the addressing capability evidenced in the EDVAC report – data addresses in instructions and, by instruction modification, the capability to alter data (and program) addresses. By this process the simple linearly addressed space implied by the (default) successor to an instruction has become the (same) simple linearly addressed data space which many have regarded as characteristic of the "von Neumann machine".

It is difficult to know how far, if at all, the ENIAC group had moved along this path before von Neumann's arrival. The developments are subtle and by no means inevitable as the absence of the variable address concept in all earlier machines from Babbage onwards attests. (Babbage found the successor to an instruction as the next card in the string and did extend this idea to data also. Indeed this alternative model of the successor idea is very pervasive in the Analytical Engine). In the absence of evidence of prior developments in the ENIAC group I can only conclude that von Neumann's influence was of critical importance and that his authorship of the EDVAC report is warranted.

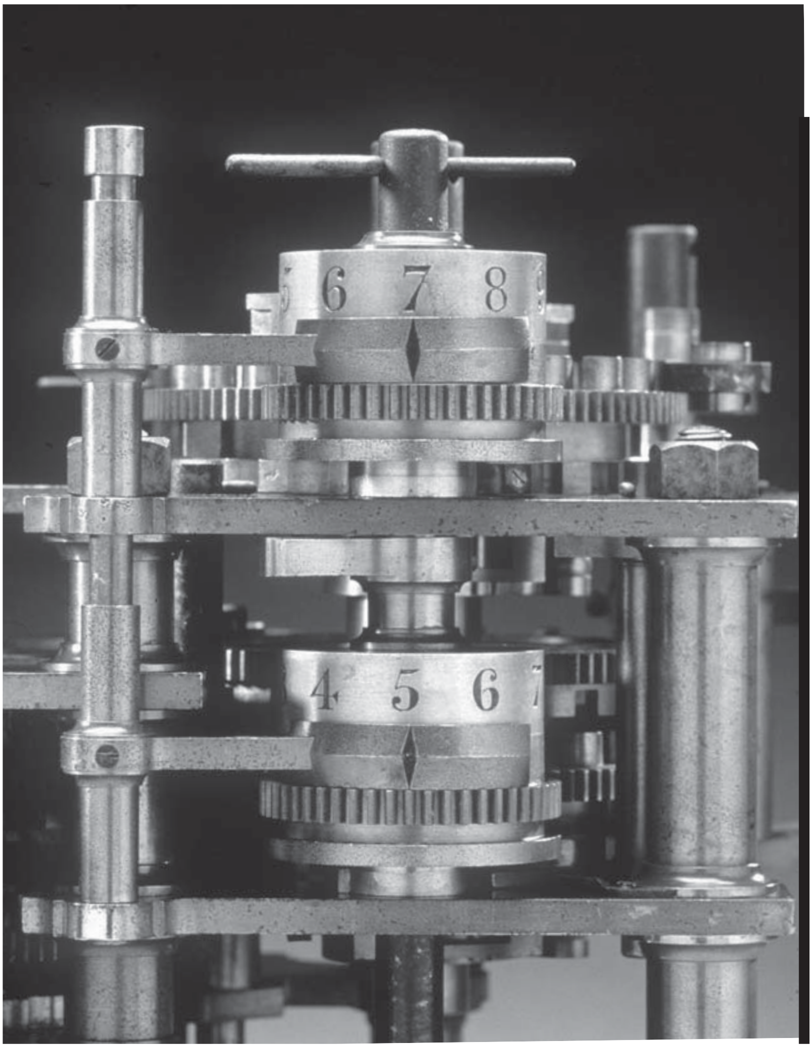
We should note that by this stage in the development of the stored program concept the separation of the store and mill had come about, as previously in the Analytical Engine and the Atanasoff machine. This probably arose in the ENIAC group before von Neumann's arrival. The separation is of importance mainly because it suggests that the store and mill might employ different electronic technologies. This was the key to obtaining low cost storage until quite recent times – indeed the early history of digital computers is very largely the history of memory technologies.

There is still more to the stored program concept than the variable address idea. Indeed instruction modification to vary data addresses is a rather poor mechanisation of the idea and is now totally superseded by developments of the index register idea which derived from the "B box" of the early Manchester computers. Although it is possible to generalise from address modification to instruction modification during program execution this is abhorrent in almost all computing circles. The reason is probably that we have not developed adequate analytical tools to understand the consequences of making such changes in a running program. However, the idea does occur in a somewhat disciplined form under a totally different intellectual veneer in some specialist areas of Artificial Intelligence. After all, the concepts of program and data are remarkably hard to distinguish (vide interpretation and emulation) and data modification has always been acceptable!

Instruction modification – in the highly disciplined form of instruction building – is an everyday occurrence in computer systems. It is the basic function performed by every loader, assembler and compiler. So common is this process that I regard is as an integral part of the stored program concept – the practical working out of the instruction modification idea. (Of course, it is not the running program's instructions that are changed, though even that distinction fades in the light of load-and-go compilers or any operating system that loads in new segments of itself).

The historical origin of this part, at least, of the stored program concept is clear. It arose in the system of initial orders for the EDSAC developed by Wilkes and Wheeler in Cambridge in 1949. From the first use of this, the first working stored program instruction computer, instructions were entered not in the machine code but via a rudimentary form of assembler. Instructions and addresses (for both instructions and data) were entered in a limited symbolic form and loader functions, including relocation, were carried out automatically from simple directives, as also were common debugging aids. The syntax was limited, even primitive, but the concept was fully developed at its first appearance. So far ahead of its time and other computers was this system that the curious consequence was to ossify further the development in this direction at Cambridge so the initiative was passed elsewhere.

Another important idea that is attributed to Wilkes is the modern discovery of micro-programming in 1952. This idea, that had been developed extensively by Babbage for the Analytical Engine, recognised that the instruction set of a computer could be obtained by "programming" a much simpler and lower level "micro-processor". The paradigm that this established, that the ideas of machines and programs could be extended in an hierarchical manner, is very widely used in modern computers, particularly by compilers and interpreters as well as at the micro-programming level.



Part of specimen piece of the Babbage Difference Engine No.1 – now owned by Powerhouse Museum, Sydney.

Photo: Powerhouse Museum

Conclusion

In summary, I see the origin of the stored program digital computer comprising a number of distinct stages or steps. The attribution of these to particular individuals and groups is tentative and might be changed by new historical information both on the work of individuals and on the channels of communication within the computer fraternity.

Paradigms for switching circuits: Shannon (boolean algebra), McCulloch and Pitts (neurones);

Electronic digital storage and arithmetic: Mauchly and Atanasoff independently;

Electronic binary arithmetic: Atanasoff;

Electronic logical control: Atanasoff;

Separation of Store and Mill: Babbage, Atanasoff, and von Neumann (all independently);

Proving electronic digital technology: ENIAC; Mauchly the catalyst; Eckert the engineering; logical design by Mauchly and others of the ENIAC group;

Common store for instructions and data: Eckert and ENIAC group;

Variable address idea: von Neumann, EDVAC report;

Programming: von Neumann, IAS group (Burks and Goldstine);

Subroutine library and instruction building (loaders, assemblers): Wilkes and Wheeler on EDSAC;

Hierarchical idea of machines and programs (micro-programming and interpreters): Wilkes and the EDSAC group.

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There is a rapidly growing body of historical writings in this area. In history, as distinct from science, frequent repetition may come to comprise "truth".

CSIRAC, Melbourne University and Digital – a long relationship.

Max Burnet

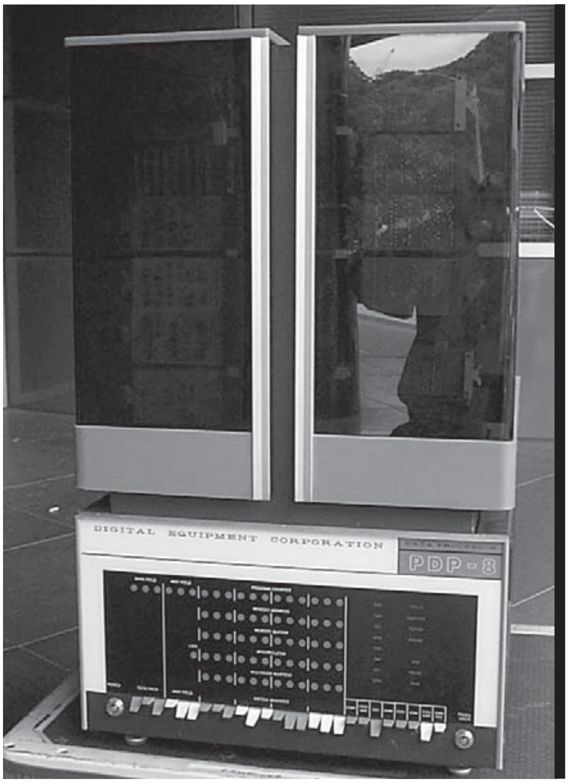


Photo: CSIRAC archive, the University of Melbourne

The University of Melbourne's first Digital PDP-8 minicomputer purchased in 1967.

At the age of 20, as a third year physics student at Melbourne in 1961, I attended a computing course on CSIRAC given by Dr Frank Hirst. I have to admit that I was not particularly fascinated by it!

After graduation I joined WRE at Salisbury, SA, and in 1964 took an IBM 360 programmming course, using punched cards, and that didn't fascinate me either. But in 1967 Digital Equipment Corporation (DEC) released the famous PDP-8 minicomputer and I was fascinated by the approachability of this little box. Thus began my 31 year career with Digital, and for most of those years I was involved in Digital's relationship with Melbourne University.

In 1967 I was hired to start Digital's Melbourne office, and on my first day I was taken to Melbourne University Physiology Department to see the very first PDP-8 sold into Australia. It was owned by Dr Dave Dewhurst. That machine is on display here today in the exhibition.

In 1968 I sold a PDP-8 to Dr Peter Thorne, with an interface to the University IBM mainframe. Delivery took many months, and Peter remembers travelling north on his holidays and stopping to make daily calls back to ascertain the delivery date. (Which was always a constant time from when he asked). To make matters worse, when it was delivered, Peter and I spent long hours making it work, as Digital had not sold many of them.

I also sold a PDP-8 to Dr Alan Head of CSIRO Tribophysics at Melbourne University. Alan is here today. Alan thought his spectrometer had discovered a new element, until we discovered that the “very fast” PDP-8 had nice harmonic square waves at multiples of 1.5 microseconds.

In addition, I also sold a PDP-9 to Dr Tony Klein of the Physics Department to control their Cyclotron. Tony thought he too had discovered a new element, until we found the orange paint of the PDP-9 was slightly luminescent, and therefore radioactive.

However, things settled down after that, and Melbourne University bought many PDP-11’s, VAX’s and Alpha’s over the years. A number of them were interfaced to supercomputers.

And although the usual love/hate relationship held between supplier and customer for 30 years, I trust that the net outcome was positive for the University. Certainly all the graduates that went out into the world trained on DEC gear, helped Digital.

Digital is thus delighted to be able to help sponsor this conference, and we trust our $5,000 donation will help assist the organisers. I have also arranged to have a CSIRAC poster made for the occasion. It features four original photos from the archives of CSIRO Radiophysics, Epping, and we thank them for providing them. Digital funded this too, but hopefully they won’t notice!

I happen to be NSW Vice President of the Australian Computer Museum Society Inc. The ACMS has also contributed $1000 towards this conference. As this represents one quarter of the entire meagre resources of the ACMS, you can see that the members are great admirers of CSIRAC and those who made it.

I would like to make one appeal.

The definitive journal of computer history is the IEEE Annals of the History of Computing. Those of us here at this conference, should attempt to produce a special issue devoted to CSIRAC. The Annals already recognises CSIRAC as the worlds fifth stored program computer, and the earliest intact one in the whole world.

Today, Melbourne University has one of the largest Alpha computers in Australia. It could do all the work CSIRAC did in a microsecond, but in the midst of such progress, we should remember the pioneers that got us to where we are today. We salute the designers, builders and users of CSIRAC.

Thank you.

‘Can We Afford Our Ancestors ?’ – Why we need an Oral History of Australian Science

Barry Butcher

If ever there was a need, and an opportunity, to save for posterity the stories of Australian scientists, then the fortieth anniversary of CSIRAC surely provides it. Very rarely do we have the opportunity to witness the birth of a new scientific discipline, and arguably, never before have we been blessed with such a rich resource base of memories upon which to create a historical perspective. For no other new science have we been fortunate enough to have the means to preserve the real voices of the founding fathers of a scientific and technical revolution unprecedented in the speed with which it has transformed and continues to transform, the global village. That Australia was in at the beginning of this revolution is surely reason enough to celebrate and in what better way could those celebrations be given a long term significance than in preserving the memories of those who helped make it possible.

Photo: CSIRAC archive, the University of Melbourne

Trevor Pearcey and Geoff Hill with staff of the Computation Laboratory at the University of Melbourne, (L–R) Trevor Pearcey, Ron Bowles, Kay Sullivan (Thorne), Jurij Semkiw, Geoff Hill, Frank Hirst. c.1960.

Writing the history of computing does not have to be a matter of dry facts; from these preserved memories we can experience awe at the achievements of the not too distant past and wonder at the possibilities that may lie ahead. More than that, the history of the computer in Australia may perhaps show how the concept of the ‘tyranny of distance’ has been vastly overblown and how the larrikin, anti-intellectual image of Australia is a historian’s artefact more than a cultural reality. Also, it might serve to demonstrate the power of science to bring together the otherwise culturally diverse individuals who engage in its pursuit. In 1997 George Dyson, son of the celebrated physicist Freeman Dyson, wrote an extraordinary book about the rise of computers from the time of Thomas Hobbes to the present day, tracing the development on through the writings of Leibnitz and Charles Babbage to the twentieth century giants von Neumann and Turing.[1] Dyson's is a deeply thoughtful book which ponders the philosophical issues associated with such issues as artificial life and intelligence and the origins of language and music, old concepts now brought before humanity with a power that only the sophisticated computer can conjure up. It is part of Dyson's argument that increasingly man and the machines he makes become less obviously separate creations; in a very real sense the power of the new machines, particularly computers, lies in their ability to extend the reach of the essential humanity of man. All the while, '*Nature, in her boundless affection for complexity, has begun to claim our own creations for her own*' (Dyson, p.13)

Whether such a book as Dyson's could be written in Australia, and whether, if so, anyone would read it, remains an unanswered question. But consider this; CSIRAC is without doubt one of the true pioneers on a new frontier, part of an original generation of machines that have for ever changed the world. And many of the men and women who made CSIRAC possible, and thereby committed Australia to participating in this changed world, remain with us, still maintaining that enthusiasm for science and technology and still, in an age wedded it seems to chronic pessimism, to a firm belief in the transforming power of science to bring about change for the better in the lives of human beings. This is why it is important to preserve the history of science in Australia; not for the delectation of the practitioner alone, but for the enrichment of those who by studying its past may be brought to see that the what, why, and how of scientific achievement are more than merely the products of curiosity. Trevor Pearcey, arguably the father of the computer in Australia and alas no longer with us, put the matter succinctly in his pioneering study of the development of Australian computing.

> *It is because of the phenomenal rate of change in our knowledge of computing and computing devices that it seems now to be worth attempting to give an account of how Australians contributed to our present new knowledge of computing, the design of computing machines and systems and their applications.* (Pearcey, p.1)[2]

Since those words were written the revolution has gone on apace and we have witnessed the arrival of the Internet, email, computer banking and shopping. Computers have revolutionised the industrial and financial worlds in Australia as elsewhere and Australian medicine has been transformed by what the new technology has brought to the fight for health.

The gathering together of so many of the original members of the 'CSIRAC team' in a reunion not only between themselves but with this justly

CSIRO Radiophysics research staff 1952.

(L–R) Standing:

M. Strohfeldt, C.A. Shain, G.A. Day, A.G. Little, S.F. Smerd, J.P. Wild, J.A. Warburton, F.F. Gardiner, D.E. Yabsley, R.X. McGee, H.L. Humphries, T. Pearcey, O.M. Phillips, M. Beard, J.W. Telford, R.D. Ryan, E.R. Hill, L.W. Davies, B.J. McHugh, G.W. Hill, R.D. Davies, Margaret A. Adamson, A.P. Mitra.

(L–R) Seated:

F.J. Kerr, W.N. Christiansen, B.F.C. Cooper, H.C. Minnett, J. Warner, L.L. McCready, E.G. Bowen (Chief of the Division), J.L. Pawsey (Assistant Chief), J.H. Piddington, P. Squires, R.N. Bracewell, E.E. Adderley, S. Twomey.

Absent:

J.G. Bolton, A.J. Higgs, N.R. Labrum, B.Y. Mills, E.J. Smith, R.S. Styles.

Photo: CSIRO archive

celebrated progenitor of today's computing machines is a good occasion then to engage in some reflective thoughts.

Every culture has its own version of ancestral worship and in Australia, deeply situated as it is in the European technoscientific worldview, such worship finds its greatest expression in the search for historical roots and precursors. The extraordinary development of the nation economically, politically and culturally in the last two hundred years is a reflection of the enterprise, courage and vision of pioneers in both the practical sense of that word and in the pursuit of practical solutions to the often extreme conditions in which such development in Australia has to take root. Australia's involvement in the scientific enterprise has not only been crucial to this internally within the borders of Australia, but quite extraordinary on the global stage given its small population and distance from the great centres of science in the Northern Hemisphere.

Why then one may ask have the busy and often vociferous band of professional Australian historians who have so assiduously fed our need to worship the ancestors been so silent about the triumphs of science and technology and the role of both in Australian history since European settlement? One must seek long and hard amongst the volumes of weighty prose churned out by this group to find anything that gives credit to researchers who have contributed to the growth of a viable agricultural and livestock industry for instance. Fond of referring to the fact that Australia has 'ridden on the sheep's back' they have not seen the need to inform their readers of just what made this possible. Equally, the mining booms that have acted to stimulate the growth of the economy for nearly a century and a half owe as much to those most practical of scientists, the geologists, as they do to political developments, yet once again few historians could name even one of these. Of the half dozen or so Nobel prize winners in science produced by Australia it is doubtful if the average Australian could name one; but then again, how many historians could do so? Science has indeed drawn a very short straw from the professional historian.

One consequence of this has been that until very recently science has been dependent for the preservation of its past on the enthusiasm of amateurs, invariably retired scientists themselves, the so-called practitioner historians. Their audience has often been drawn largely from fellow scientists; indeed the histories produced have often been official or semi-official institutional volumes, detailed chronological accounts of unswerving accuracy but all too often lacking the deeper socio-cultural context that embedding them in a more general history would provide. In recent times a more professional approach to the history of science in Australia has begun to emerge, led by university academics such as Rod Home at the University of Melbourne and Roy Macleod at Sydney University. Both have sought to bring science into prominence as a factor in Australian history through publications, teaching and the training of postgraduate researchers. Still it must be said that the work of this group is largely restricted by limited access to the local history journals and the continuing unwillingness of general historians to take science seriously.

In an attempt to counter some of this, Dr Linden Gillbank and Dr Doug McCann began to float the idea of setting up an oral history resource for Australian science which would preserve and make available for future generations the work and reminiscences of the nations scientific workers. Under the acronym VAST (Voices of Australian Science and Technology) the project got under way in 1996 when Drs Gillbank and McCann joined with the Centre for Sciences in Society at Deakin University to test the feasibility of long term funding from the scientific societies and institutions whose history it was seeking to document. For the next 18 months, with some assistance from the Australian Science Archives Project at the University of Melbourne and a goodly number of enthusiastic responses from many individuals, the project's founders, now joined by myself at Deakin University, sought to provide it with a viable base. The Centre was able to provide a small amount of money which made possible a visit to the Australian National Library in Canberra where discussions were held on the best way to get the project underway and how best to store recordings etc. Recording equipment was purchased and some preliminary interviews undertaken. A number of already existing valuable recordings were transcribed by Dr McCann with the help of a number of keen volunteers. Applications were made to both the Australian Research Council and the Myer Foundation for some initial funding, but unfortunately neither were successful. By the end of 1996 VAST seemed frustratingly stalled; I was myself away on sabbatical for the first half of 1997 and work commitments forced me to withdraw from the project, the burden of maintaining it falling almost entirely on the shoulders of Dr McCann.

In the midst of all this of course has come the CSIRAC celebration, raising once again hopes that a vigorous and thorough oral history of science in an Australian context can be instituted and sustained. As the cold winds of economic rationalism whistle through the corridors of academia, traditional historical disciplines are threatened and an important source of cultural knowledge thereby undermined. The bottom line is what dictates what gets preserved, taught and investigated. As the Vice-Chancellor of my own university told a reporter not long ago while explaining why the liberal arts was a not a priority at Deakin, 'History is a subject we may not be able to afford'. The only reasoned response that can be made to such a statement is that 'History is a subject we cannot afford to lose' – the response to the CSIRAC celebration shows us that not only does the history of science in Australia have an intrinsic intellectual interest generally, it serves to show how and why the bewildering changes in modern society that the computer has wrought, have come about. It gives us a tradition – of research, development, endeavour; it provides the occasion and grounds for analysing a significant innovation in science and technology. Not least, it recognises the achievements of a group of contributors to Australia's development – scientists – who to date have been largely excluded from recognition by the guardians of the nations ancestral heritage, the professional historians.

1 Dyson, George, *Darwin Among The Machines*, Allen Lane/The Penguin Press, London, 1997.

2 Pearcey, Trevor, *A History of Australian Computing*, Chisholm Institute of Technology, Melbourne, 1988.

Babbage's Difference Engine N^{o}.1

Matthew Connell

As curator of computing and mathematics at the Powerhouse Museum Sydney I am one of the custodians of our information technology collection. While I have some responsibility for telephones, typewriters, televisions, radios, gramophones, calculators, totalisators, robots, sliderules and various computational and communication devices my primary focus is computers. I have inherited a collection from previous curators but I am also charged with consolidating and building it up.

At the museum we collect various artifacts in the belief that those objects somehow embody the beliefs and values of the culture that made and used them and that through those objects, it is possible to gain access to those beliefs and to compare them with our own. We use them in exhibitions, public programs and publications to tell stories. One of the guiding principles in selecting artefacts for the collection is to find those with the potential to tell important stories.

In late September 1995, a Christie's catalogue for an auction of Fine Scientific Instruments was left on my desk with a yellow 'post-it note' sticking out of the side. I eventually got around to having a look at it, which I do more out of general interest than out of any expectation of finding anything for the collection, particularly as computers are unlikely to be found in such a catalogue.

On the 'post-it' one of my colleagues had written 'wouldn't you like to have this'. The page that it marked had a picture of a piece of machinery, an assembly of shafts, number wheels and cogs. The title announced 'Specimen Piece of Charles Babbage's Difference Number 1'. And in the text underneath 'assembled from original parts by Charles' son Henry Provost'.

At first I was surprised and excited that there was a piece of Babbage's Difference Engine not already in a museum collection and coming onto the market. My next thought was 'it will be expensive'. I looked for the estimated price and found 'refer to department' which means 'we're not entirely sure what its value is but we're sure it will be a lot'.

The curator who had left the note knew immediately that it would be expensive and assumed, as I did that we would be unlikely to be able to make a serious bid. But I felt that this was likely to be the last opportunity to purchase an item of such major significance, representing what is now the most celebrated period in the prehistory of computing. I decided I would put a proposal to our senior management that we have a go.

Unsure as to how it would be received I went to the director to see what he thought about it. Despite his concerns about the cost he recognised the significance of the piece and the desirability of having a piece of Babbage's machine in the collection, particularly as information technology had become a major focus for the museum. He told me to proceed with a proposal for the Board of Trustees. This report had to explain what it was, its significance, why we should get it, what condition it was in, the distribution of other pieces, the likelihood of us ever finding another, a suggested final bid and a bidding strategy.

I had four days in which to compile this information; gain official approval and organise someone to bid on our behalf in the UK. Fortunately, we were able to draw on the services of Associate Professor Allan Bromley from Sydney University, who is the world's foremost authority on Babbage's Engines. He also has considerable experience with the London auctions, particularly in relation to calculating devices. He was aware of the piece, other similar pieces and their locations, and parties likely to be interested and sufficiently wealthy to acquire the one going up for auction.

Allan developed our bidding strategy, which was subsequently agreed to by the Trust and our man in London received his final instructions. In the very early hours of October 6, I received a call from London saying that we had purchased the Engine for 160 000 pounds, our upper limit. It received a great deal of media attention locally and internationally with (very dubious) rumours circulating that Bill Gates had also been bidding for it. It was widely regarded as a coup for the museum.

So what is the significance of the Difference Engine?

In 1823 Charles Babbage then Lucasian Professor of Mathematics at Cambridge University started working on a machine that would automatically calculate and print tables of functions used at the time to facilitate calculations in many areas of science and commerce and particularly for navigation.

Babbage was distressed at the poor quality of the tables generated by human computers at that time. He felt that the method of finite differences, used to reduce the tabulation exercise to a series of simple additions, could be incorporated into a machine. The machine was to be fully automatic, able to be operated by a "dumb labourer". For eleven years from 1823 to 1833 he designed and tried to build the Difference Engine No1 – the first fully automatic calculator.

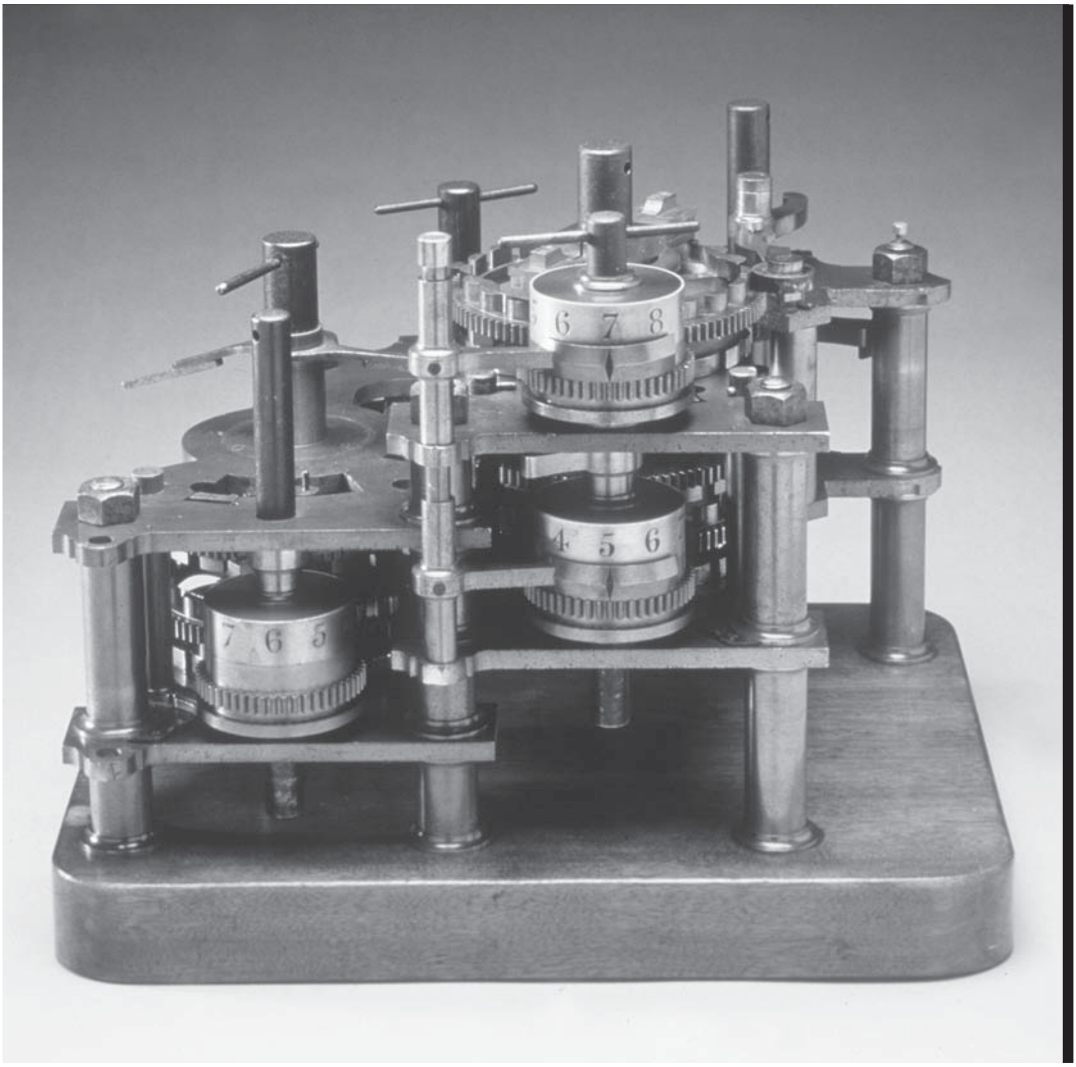
In 1823 there were no such things as standard machine parts, screws or tools. Everything had to be built from scratch. Babbage conducted a two-year appraisal of manufacturing techniques to determine how he might construct his engine. He needed to work to much higher tolerances than was usual in his day and had to hire the very best machinist available to carry out his task. As an engineering project it set new standards and established new techniques.

For a number of reasons the Difference Engine was never completed and a contributing factor to its failure was that Babbage became impatient with the lack of versatility of the Difference Engine. He started to devise another machine, which he eventually called the Analytical Engine. This new machine could be given instructions and data and operate in a number of different ways depending on these instructions. The analytical engine, also not completed, had essentially the same architecture as today's modern computer, anticipating the invention of the electronic computer by 100 years.

Babbage was tormented by the failure of his calculating engines for the rest of his life but he is now popularly regarded as the grandfather of modern computing. It is doubtful that any of the pioneers of the first electronic computers drew heavily on any of his ideas but we can't help being intrigued by someone who conceives of and starts building something so definitively modern so long ago and with the ‘wrong technology’. While the engines show that Babbage was a person of extraordinary intellect they also indicate that some of the social and cultural conditions for the conception of computing already existed in the nineteenth century.

From my point of view, interest in Babbage and his engines and other evidence (like this conference) suggest that the history of computers and computing is finally being taken seriously. In the past people often seemed to think that computers were too new to have a proper history but this is starting to change. It seems more people are starting to wonder what it really means for us to say we live in an information age and are examining the technology that is at the heart of that notion.

At the Powerhouse Museum we intend to provoke and encourage that speculation by creating a new exhibition which while providing access to new and exciting information technologies also allows visitors to see where they have come from and understand the decades of effort that brought them into being.



Specimen piece of the Babbage Difference Engine No.1. Owned by the Powerhouse Museum, Sydney. One of only six demonstration pieces assembled by Charles Babbage’s son Henry, after his father’s death, utilising parts manufactured for the original Difference Engine project.

Photo: Powerhouse Museum

Application of CSIRAC in Planning the Victorian Hydro-Thermal Generating System

Arthur Cope

Introduction

40 years ago when I was a young Engineer with the SECV (State Electricity Commission of Victoria) we had the task of planning the expansion and development of the Victorian generating and main transmission systems.

Over the 40 years since that time these systems have expanded tenfold from a system maximum demand of some 600 MW in the mid 1950s to a maximum demand of more than 6000 MW at present. During that time new generating units of varying types and size have been added to the system. Steam generating units have increased in size from 12.5 MW to 500 MW in the Latrobe Valley and Newport Power Stations with Hydro-electric units up to 250 MW in the Snowy Mountains. Similarly the main transmission voltages have increased from 110 kV to 500 kV. In addition, the Victorian system has been interconnected with Electricity Commission of NSW through the Snowy Scheme and also with ETSA. Investigations also have been carried out into the feasibility, cost and benefit of interconnection of the Victorian system with Tasmania.

From the above it can be seen that a power supply system is a dynamic entity and requires a continuing programme of new plant installation to meet the increasing load and to replace old or obsolete generating units. The problems concerned with system expansion still exist today but due to recent events, in a much more fragmented form and with differing parameters particularly in the political and environmental areas.

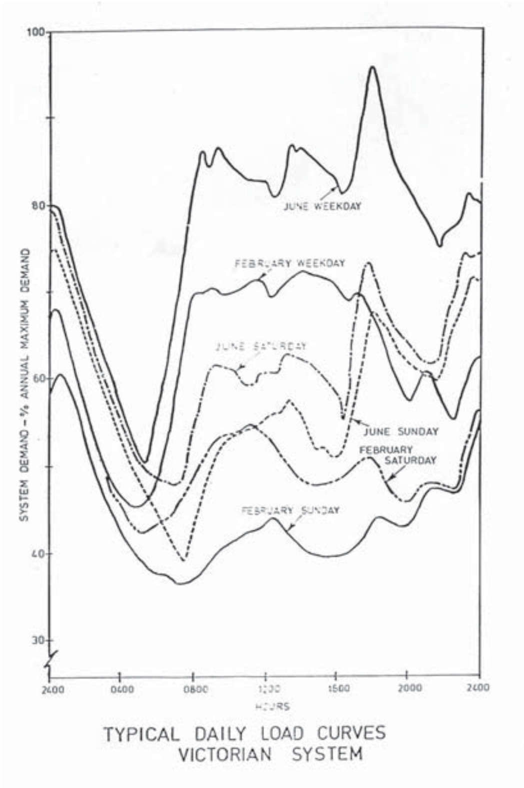
I am sure that very sophisticated and complex computer programmes exist worldwide for assisting in the solution of the problems associated with generating system planning, however, 40 years ago there were none. Neither was there any facility to attempt any form of programmed solution to any of the associated problems of system expansion – i.e., until CSIRAC was installed at the University of Melbourne.

CSIRAC was the beginning of electronic digital computer usage in solving the many engineering problems associated with the development of the Victorian power system over the past 40 years.

Computer Application

In planning of the expansion of the power system there is usually choice of site and type of plant which could be installed to meet growth in load for one or a number of years. Each plant type would have different costs associated with its operation in the system and when installed would also affect the operating costs of all other existing plants in the system. As total system costs are involved (rather than just costs of the new plant being added), the economic merits of the additional new units requires simulated operation of the whole system over a number of future years.

Comparison between alternative plants needs to be made by comparing total system costs when each plant is added to the system. Both systems need to be



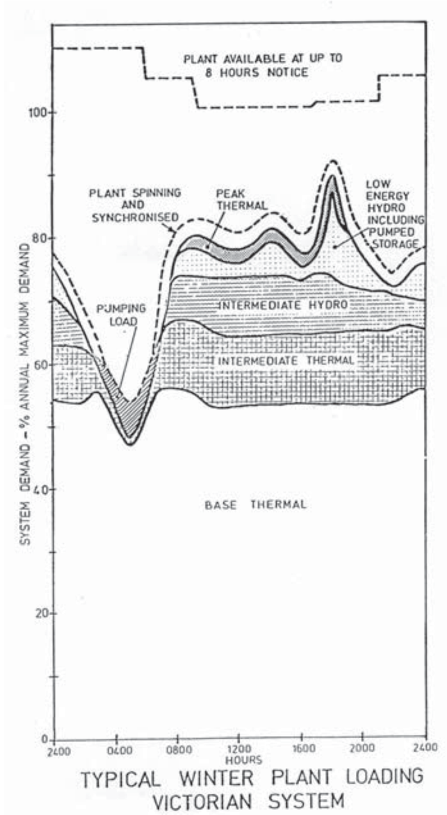


Figure 1 *(left) illustrates the hourly loading on the Victorian system over a variety of typical days, ranging from a week day in winter to a Sunday in summer.*

Figure 2 *(right) shows a typical winter week day plant loading for the Victorian system.*

operated over a sufficiently large sample of loads to enable allocation and fuel costs to be estimated for all stations in the systems.

The effect of changes in load growth, stream flow, fuel prices, labour costs and other variables which affect system operating costs can also be examined by simulating future operation under different assumed conditions. The complex operating methods for system loading, using desk electric calculators was very slow and tedious, if a representative sample of system loads was to be studied.

Short cut methods using load duration curves or average daily load curves reduced the arithmetic but could be inaccurate and misleading for all but minor changes in plant design, particularly if an analysis is being made of peak hydro plant in a predominantly thermal system. The simulation of system operation, however, is well suited for programming on electronic digital computers.

Planning Considerations

System Loading

Over a period of years the loading on a power system follows a general growth trend. In addition to this growth trend, cyclical variation of considerably greater magnitude occur in hourly load throughout the day and in maximum monthly demand during the year. Because a year corresponds to the longest complete load cycle it is convenient to divide long-term planning studies into yearly periods. Plant availability may then be assumed as constant over a yearly period subject, of course, to outages of maintenance and the annual increment of generating plant assumed to be added at the beginning of each year in order to meet load growth.

A suitable month to start each study year is April, as it would be the aim to have any new plant addition installed in the system and teething problems could be overcome before the winter peak. Figure 1 illustrates the hourly loading on the Victorian system over a variety of typical days.

Plant Cost Data
In order to estimate the annual plant cost in relation to plant output it is convenient to separate the components making up the plant cost into fixed, semi-variable and variable charges.

Fixed charges are made up of plant capital charges, transmission costs, insurance and all other items which do not vary with plant output.

Semi-variable charges comprise part of the operational and maintenance costs associated with the manning of the station, eg, 2 shifts, 5 days operation requires only half the manning for 3 shifts, 7 days continuous rosters. However, short term reductions in station rostering do not achieve a saving in semi-variable costs.

Fuel costs are the major variable charge which vary with output of thermal stations, although some maintenance charges are a direct function of output.

The approximate split of the above charges on all stations in the Victorian system have been 35% fixed, 25% semi-variable, and 40% variable. In this particular split some 10% of the energy was supplied by Hydro with negligible variable costs.

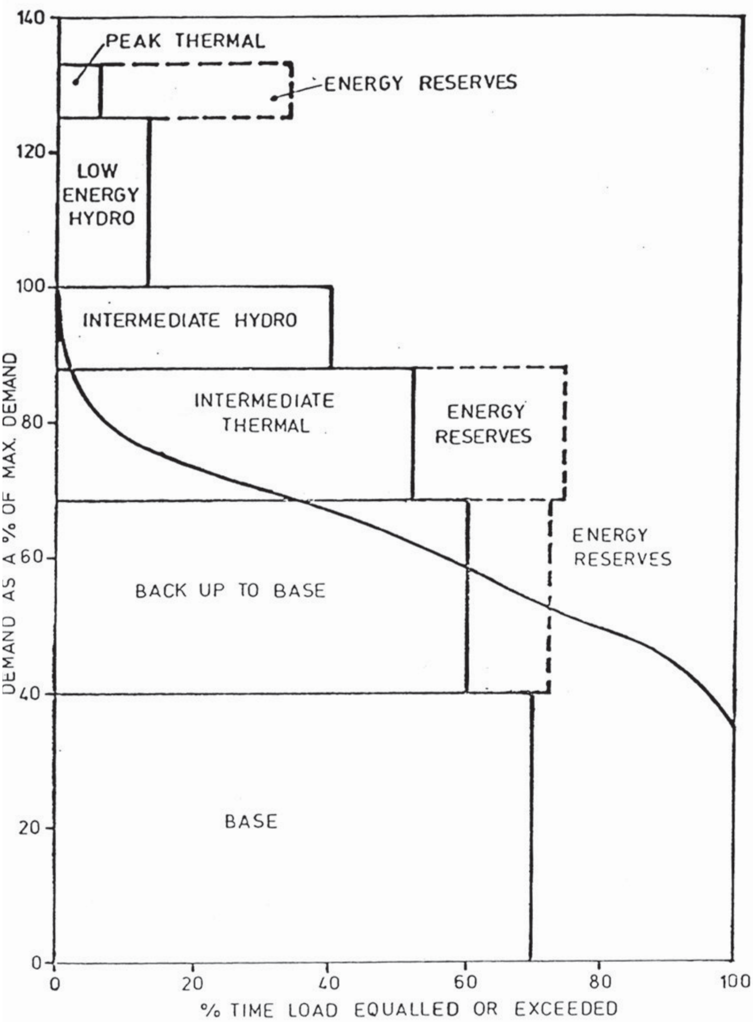
Plant Characteristics
Data concerning the fuel usage in relation to plant output must be collected in order to simulate future operation.

Fuel costs are involved in starting of units from cold or banked conditions while banked boilers alone can consume 1% to 2.5% of full load consumption, depending on furnace design. Minimum load running of thermal plant which is about 20% to 30% of full load rating may require 50% to 60% more fuel per kWhr sent out than the same unit at full load. Heat rate curves against output developed for the various thermal plants can be readily converted into fuel costs when calorific value and incremental fuel prices are applied for the particular station considered.

Economic System Loading
Economic loading of power plants in a system minimises the variable and semi-variable costs while still maintaining the required degree of reliability. Available thermal units can be brought into service in ascending order of variable costs until sufficient capacity is operating to meet the load with a required margin of running reserve.

Operating units with low variable costs are run fully loaded while higher cost units are run at minimum load solely to provide spinning reserve. Hydro plant has a practically infinitesimal variable cost, but except where spill is occurring in the head works has only a limited amount of water that can be turbined over a day or given period. In order to give Hydro plant a priority of operation in a Hydro-thermal system it is necessary to give Hydro output a value as a potential saver of variable charges at thermal stations.

Straight run of river Hydro without storage, of course, has the highest loading priority on the system.



ANNUAL PLANT CAPACITY FACTOR
VICTORIAN SYSTEM

Figure 3 *shows diagrammatically the distribution of annual station capacity factor determined on the computer for a future year of system operation. For reference purposes an annual load duration curve is also plotted on the diagram.*

Simulation of System Operation

For the purpose of carrying out economic studies of system expansion a programme was developed to simulate practical operation of the Victorian interconnected system on the CSIRAC digital computer at the University of Melbourne. The programme followed the economy loading principles applicable to the Victorian system and from the basic data relating plant variable cost and plant output, automatically determined the station and system variable costs.

Because of the characteristics of the Victorian system having low variable fuel cost plants in the Latrobe Valley and relative high fuel costs at metropolitan stations, plant loading priority could be simulated be using average sent out fuel cost per kWhr while plant characteristics could be represented by one or two steps in the incremental rate curves.

Computer time considerations and the need to examine a wide range of variable assumptions and loading conditions tended to rule out the use of very involved techniques such as linear programming for optimising plant loading. In preparing the computer programme, emphasis was, therefore, given to achieving a short time per iteration for each load interval, and for rapidly changing the basic data, even though this did mean a trial and error method of establishing the Hydro operating level and some preliminary work in pre-calculating the economic operating priority and monthly scheduled maintenance of plant.

System loading data used in the computer operations are based on a group of daily load curves shown in Figure 1.

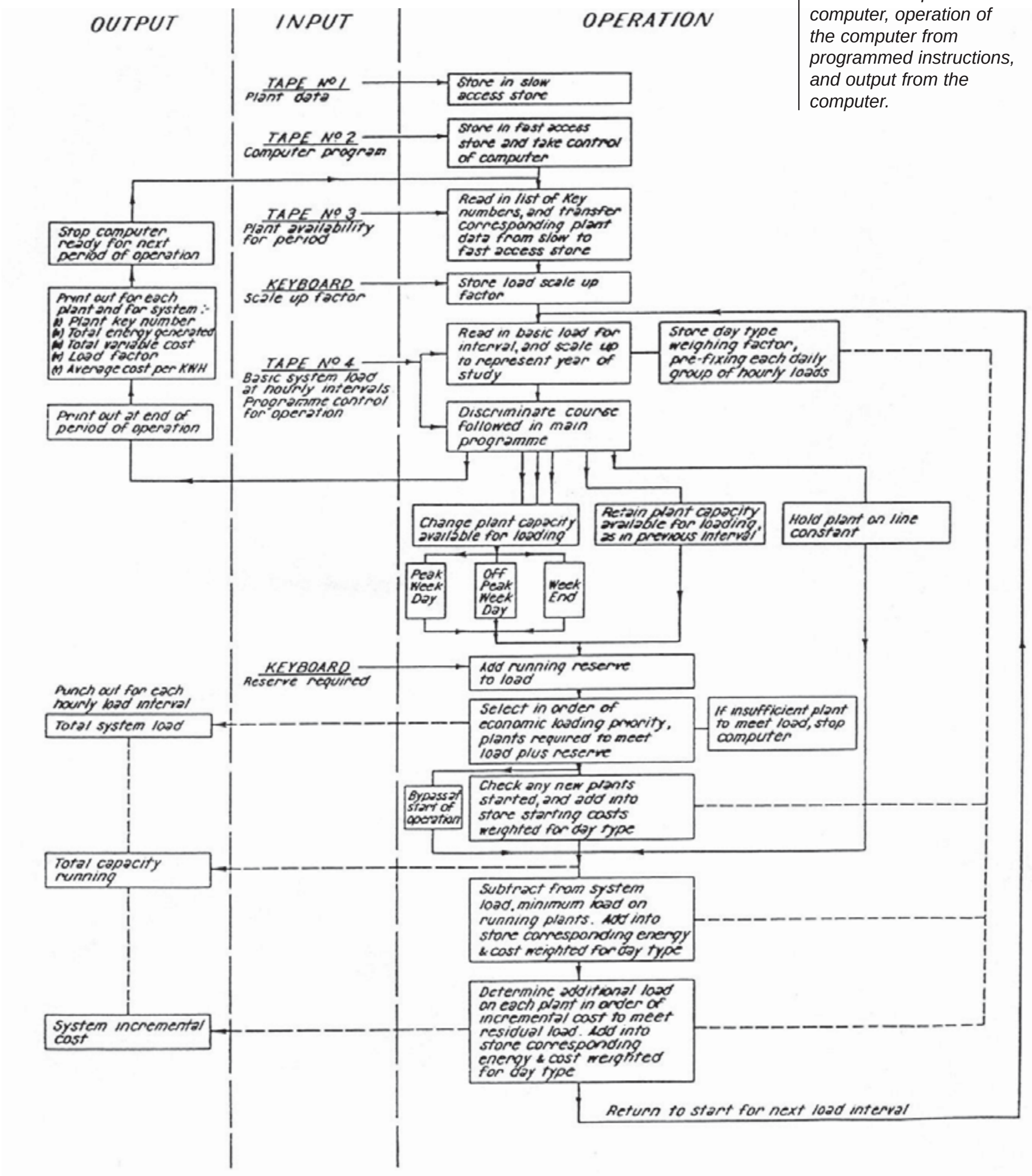
Each daily load curve is divided into 24 consecutive hours. Energy generated and variable costs at each plant are determined for each hourly interval and the cumulative totals printed out at the end of each period of operation being examined. The programme included provision for changing plant availability and loading procedure throughout the day to provide for such features as:

(a) Minimum area generation for supply security
(b) Reduced thermal plant availability due to routine maintenance off-peak and at weekends
(c) Holding surplus capacity on line during short duration load troughs to avoid start up costs, and
(d) Varying running reserve requirements

Tests run indicated that variations in system loading could be represented accurately by a sample of 5 daily load curves consisting of average, maximum and minimum envelope of hourly loading on week days and a maximum and minimum envelope of weekends and holidays; provision being made in the computer programme for weighting the energy and cost figures determined from each curve type to give the correct distribution of day types in the month and year being studied.

Computation time required was approximately 1 minute per daily load curve, which included punching out on tape for each 24 hourly interval of system load, generating capacity operating and system incremental production cost. Time to print out separate week day and weekend energy and cost figures for each station, up to a total of 32 required a further 6 minutes for each monthly period, so that a year's system operation with details of monthly energy and variable cost required about 2.5 hours.

Figure 4 *shows the CSIRAC programme of Victorian system operation divided into input into the computer, operation of the computer from programmed instructions, and output from the computer.*



Flow Diagram of Computer Operation.

CSIRAC and ICIANZ

Bill Glasson

The seminar on CSIRAC in 1996 stirred some memories which I mentioned briefly at the time but when Doug McCann asked me to write a page or two on recollections as a user of CSIRAC I sorted through old cartons of records at the bottom of the linen press for some prompts and pointers.

The first useful find was my office diary for 1959 with the following entries:

"30 June 1959 – *See Dr Hirst CSIRAC at University of Melbourne 2pm.*"

"1 July 1959 – *Write to Hirst giving particulars of job required. He is to send details of course (30 guineas and 3 weeks – programming). Machine costs 25 pounds/hour and they think they have a program which if slightly modified should do the job.*"

There were further references to "computer course" and "computer use" at intervals through the remainder of 1959.

By way of context, in 1959 I joined ICIANZ Limited (subsequently ICI Australia Limited, now Orica Limited) as a technical officer after two years in England. My main interest at the time was the measurement of the dynamic behaviour of processing units in chemical plants to help in the design of better control systems. The objectives then as now, were higher efficiencies, increased output and improved product quality – all of which add value.

One way of finding the key characteristics of dynamic behaviour was to calculate auto and cross correlation coefficients from time series of linked variables taken from normal operating records of the chemical plant being studied. Calculation by hand was tedious on a small scale and impractical on a large scale. As CSIRAC was the only computing bureau available in Melbourne at the time, I learnt the basics of programming, wrote a program, used it to process plant data and wrote a report on the method and results.

I can recall two images from that time. The first is of Trevor Pearcey lecturing with restrained precision while the class – certainly in my case – struggled with scale of 32 (5-bit) binary representation. The second is of Frank Hirst at the console of CSIRAC flicking switches to set registers with speed and confidence.

CSIRAC held a small library of subroutines for frequently used functions and because of storage limitations they had to be as short as possible. There was a story at the time, which others will be better placed to confirm, deny or correct, involving Professor Cherry who was of course a key figure in CSIRAC's period at the University of Melbourne. It was said that he pared down the subroutine for taking a square root to 17 instructions and when he could go no further developed a proof that this was the theoretical minimum.

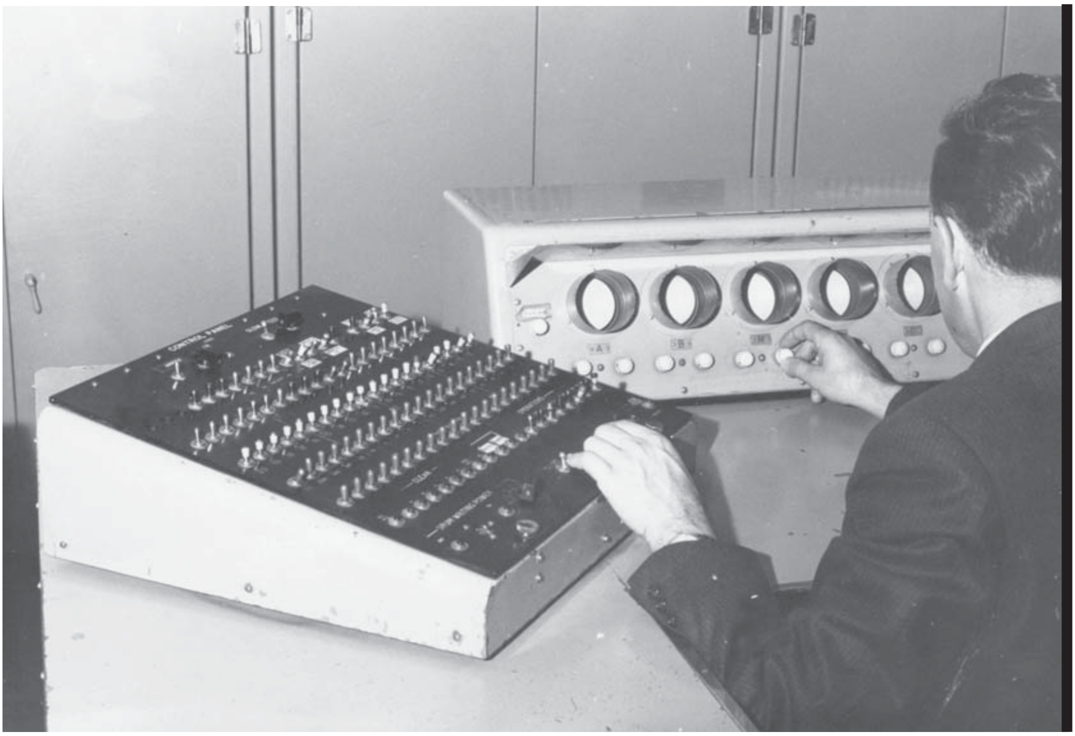


Photo: CSIRAC archive
the University of Melbourne

Jurij Semkiw at CSIRAC operating console. 1964.

While in England during 1957 and 1958 and working in the same field there was a need to solve sets of linear differential equations by way of matrix inversion. I recall travelling to London from the ICI Central Instrument Laboratory at Pangbourne to use an English Electric machine housed in a showroom fronting onto The Strand in the evening when rates were lower. I may have used CSIRAC for similar purposes but have no memory or record to support this. If so, it would have been run with a program prepared by someone else.

The association with CSIRAC was brief as other bureaus were set up and ICIANZ moved its computing inhouse. In May 1960 I attended the first Australian Computer Conference with Ron Bainbridge and George Rogerson who were colleagues at ICIANZ. To quote from a report written by Ron Bainbridge "in a hotel room one evening the idea of a small technical computer for ICIANZ was conceived". In February 1961 a proposal to buy a Ferranti SIRIUS computer was approved. It was installed in February 1962 and the rest as they say is history. I had little to do with computers in ICIANZ after I moved to operations in Sydney in 1963.

Some Echoes of CSIRAC: Using CSIRAC for Scientific Computation

Alan Head

I first met CSIRAC in late 1949 or early 1950. I was at the Aeronautical Research Laboratories (ARL) who had a large program on fatigue of metals and in particular fatigue of metals in aircraft. Fluctuating stresses can cause a small crack to form sooner or later and this grows until it is large enough to cause a catastrophic failure. Fatigue failure of the pressure cabin of the Comet is still remembered but there were Australian problems also. There was interest in the possible use of ultrasonics to detect cracks and the only local place that was working in ultrasonics was the Radiophysics Division of CSIRO. So I went to Sydney to look at what they were doing and found it was for the ultrasonic delay lines of CSIRAC. I was shown round CSIRAC and had a demonstration of, I think, adding two numbers set up on switches and showing the result on lights. CSIRAC was working in some sense but was far from complete.

I next met CSIRAC in 1955 and it was by then really working. Around this time, Radiophysics was investigating the possibilities for a large radiotelescope that finally led to the well-known large parabolic dish at Parkes. The many problems that were involved are well related in [1]. On the structural side there was the requirement that this large structure, which had to rotate to point to different areas of the sky, must not then sag out of its parabolic shape under the changing forces of its own weight. This requirement for a stiff but lightweight structure had much in common with aircraft design and ARL did studies of the problem (see [1]).

On talking with some of the ARL people involved, it struck me that some of their problems would go away if there were a large dish that did not have to move. And if it did not move but had to be able look in all directions then it had to be the same shape in all directions so it had to be a sphere not a parabola. But a sphere only gives an approximate focus, not the point focus of a parabola. So there had to be a second mirror, small and near the approximate focus of a sphere, that would move to use various areas of the sphere to look in various directions and be of a shape that would turn the approximate focus of the sphere into an exact point focus.

This idea was of interest to Radiophysics [1] and led to a report [2] that examined many aspects. The first designs were in terms of geometric optics and Trevor Pearcey extended this to account for diffraction. The initial numbers that I had calculated by hand were not sufficient and Trevor arranged for CSIRAC to compute the numbers which were needed for the design graphs in [2]. An account of this and a picture of a model built by ARL are given in [3].

In the end Parkes was a parabola and a very good one that has given yeoman service to radioastronomy and Australian science. The "Head" telescope was never built in Australia but several were built in USA, not for radioastronomy but as a radar antenna that was large but could scan fast to track distant fast moving targets (perhaps intercontinental ballistic missiles?) [4,5,6]. Many years later it was found that a large such antenna had been built in the USSR and was now being used for radioastronomy at the All Union Radiophysics

Measurement Research Institute near Yerevan, Armenia. But the days of a single large dish were drawing to an end as it could never compete with the resolving power of an interferometer with a number of widely spaced and interconnected smaller dishes.

In the late 1950s CSIRAC came down to the University of Melbourne and I moved to the CSIRO Division of Tribophysics on the campus of the university and it was then that I started using CSIRAC myself.

At that stage all programming was in basic machine language which used its own special 12-hole tape for feeding into CSIRAC. But FORTRAN was spreading rapidly as a higher language that made writing scientific programming so much easier for ordinary mortals. Geoff Hill wrote INTERPROGRAM for CSIRAC (on the lines of FORTRAN) and this rapidly became the language most used for CSIRAC programs and this used the commercial 5-hole tape equipment that had been added to CSIRAC. Running an INTERPROGRAM was now a mixture. To startup CSIRAC one needed the special 12-hole tape called the "primary" and then changed to 5-hole tape for the INTERPROGRAM. After some false starts I produced a 5-hole startup tape that just managed to work by exploiting various quirks of CSIRAC. It was long and slow but there were obvious possibilities for improving it. Geoff Hill took it and streamlined it and made it the standard for INTERPROGRAM and arranged the INTERPROGRAM compiler to punch out this startup leader first on the tape containing the compiled program. So an INTERPROGRAM user had only one length of 5-hole tape to use that combined primary and his program.

The original 12-hole primary tape is well documented in the CSIRAC literature but I do not think there is any documentation on the later 5-hole primary. And I think that anyone trying to work out how it operated by looking at an INTERPROGRAM tape would be rather puzzled. I do not know exactly what Geoff Hill's primary is in detail (as he had many alternatives to choose from) but here are the essential clues.

The original 12-hole bootup procedure was that CSIRAC had a special bootup mode. When this was switched on then it would read in 12-hole tape and put the 10 bits of each tape row into consecutive memory locations starting from location 0,0. CSIRAC had 20 bit words for memory and registers and those 10 bits read from tape would go to the lower half of a memory location, the upper half being set to zero. It was possible to write a program in which the instructions used only those lower 10 bits and this was the "primary" that could be forcefed in bootup mode and then used to read in real program tapes.

If the same thing was done with 5-hole tape then what would result would be that each 5-bit tape row would be written to the lowest 5 bits of consecutive memory locations. The result would be useless as a program as every instruction had the top 15 bits zero, which says that the source for every instruction was memory location 0,0.

But there was a quirk of CSIRAC. There was a set of 20 switches on the control panel called Input and any number set on these would be added to each tape row read in. So if this was set to 0,0,1,0 then force feeding a 5-hole tape gives a string of memory locations with that extra bit set and correspond to instructions that all have Input as the source.

Now set that Input switch back to zero and set 0,0,3,0 on the NA switches and start CSIRAC to DO these instructions and suppose these started

I → A
I → PK
I → 30
I → PA
....

The first instruction reads 5 bits to register A. At the second instruction it reads in 28 and PK adds this to the next instruction so for the third instruction it does NA → PK instead of I → 30. This results in 0,0,3,0 being added to the next instruction so it does A → PA instead of I → PA. As a result the contents of A have been doubled, left shifted by one place.

It would continue by doing 4 more of these left shifts, doing I → PA to add 5 more bits into A, 5 left shifts, I → PA, 5 left shifts and I → PA. A now contains a full 20 bit word that you now want to write to some memory location say m,n. First move A to register C by

I → PK
I → 30
I → C

Now a duplicate of the previous code reads in tape to build up in A the number m,n,13,0 followed by

I → PK
I → 30
I → PK
I → 0

This last instruction becomes m,n,C,M which is the instruction to write the number in C to memory location m,n.

Finally

I → T	Stop the computer if tape row is nonzero
I → S	Else a zero tape row jumps to program start to continue reading tape and building up contents of memory.

This would work but it is impractical as it has taken about 40 tape rows, most of which were 28s, to put one 20 bit word into memory. The streamlined version by Geoff Hill for INTERPROGRAM was vastly better than that but worked on the same general principle.

I used CSIRAC for many scientific calculations, most of which were one-off jobs but there was one in particular where the program has had a long life. It started in machine code, moved to INTERPROGRAM and then later became a FORTRAN subroutine called ANCALC (and I will refer to it by this name, which stands for 'anisotropic calculation').

Most crystals have physical properties that are different in different directions in the crystal. In particular for the elastic properties there will be stiff directions and soft directions. The usual theory of elasticity assumes that a material is isotropic, that the elastic properties are the same in all directions. But this is a bad approximation for many metal crystals where the ratio of stiff to soft is about 3 for many common metals, 8 for some types of brass and 20 for some alloys. So the theory of anisotropic elasticity is necessary and ANCALC produces the 30 or 40 numbers that are needed to use this theory. The program starts with the elastic constants of the crystal and a direction, calculates a sixth degree polynomial from these, finds the roots of the polynomial and from these calculates those 30 or 40 numbers. It took CSIRAC about 20 minutes to do such a calculation. Nowadays this takes milliseconds on a PC which is some improvement. But this difference is trivial compared with the original contrast between CSIRAC's 20 minutes and the daunting alternative of doing it by hand.

There is a well known formula for the roots of a quadratic polynomial and similar formula were found in the sixteenth century for the roots of third and fourth degree polynomials. There was much effort for the next three hundred years to extend this to higher degree polynomials until in 1826 Abel proved that there could not be a general formula for higher degree polynomials. Some of them can have explicit solutions but many cannot. One day I noticed in the output from CSIRAC a number something like 0.333341 and I wondered if it was really 1/3. It was and CSIRAC had turned up an important practical case where anisotropic elasticity was quite simple [7]. But a high precision (29 digit) version of ANCALC was later used to prove that there were no more such cases and that approximate numerical finding of the roots was necessary [8].

In 1967 ANCALC was in the centre of a valuable advance in the understanding of what is seen when an electron microscope looks through metals. The electrons are diffracted by the atoms of the metal crystal and the amount of diffraction depends on the elastic fields that are present. In a sense it is a two dimensional picture of the three dimensional elastic fields and any intuitive interpretation is not simple. So a computer program [9] started with ANCALC calculating the elastic fields and then differential equations followed the passage of the electrons through to the two dimensional image. It quickly became apparent that there was so much detailed information in the image that it should be presented as a picture but the only hardware of the time was the lineprinter. So the output was a lineprinter picture, a page of 60 lines of 120 characters that were chosen from those available for a range of blackness from a "." up to a "B" overprinted with a "%". Viewed from a distance this becomes a halftone picture and if reduced photographically to postage stamp size was very realistic.

There followed great activity at Tribophysics with a deluge of publications and requests from round the world for the program. A program needs instructions and what started as just that became a 400 page monograph [10]. Chapter 10 was the FORTRAN source code, including ANCALC of course. The program and its variants have become a standard that can run on a PC if required. The source code in the monograph for ANCALC has been much used in other situations where elastic anisotropy is involved. ANCALC is still essentially that CSIRAC program from long ago and comes echoing down the corridors of time, alive and well today.

Thank you CSIRAC and all who sailed with you.

[1] P. Robertson, "Beyond Southern Skies. Radio astronomy and the Parkes telescope", 1992 (Cambridge University Press).

[2] "Interim report on feasibility of the 'Head' radio telescope". Radiophysics internal report with contributions by J. L. Pawsey, A. K. Head, W. N. Christiansen, T. Pearcey and R. X. McGee.

[3] A. K. Head, "A new form for a giant radio telescope", *Nature*, v. 179 (1957) 692.

[4] Letter from S. Kownacki, Lockheed Missiles and Space Company to A. K. Head, 6 Nov 1961

[5] F. O'Nians, "Spherical Reflecting Antenna Systems", *Report WDL-P-172*. Philco Western Development Laboratories, 1 Oct 1961

[6] F. S. Holt and E. L. Bouche, "A Gregorian corrector for spherical reflectors", *Report AFCRL-62-163*, Electronic Research Directorate, Air Force Cambridge Research Laboratories, April 1962

[7] A. K. Head, "The [111] dislocation in a cubic crystal, *physica status solidi*, v. 6 (1964) 461.

[8] A. K. Head, "The Galois unsolvability of the sextic equation of anisotropic elasticity", *J. Elasticity*, v. 9 (1979) 9.

[9] A. K. Head, "The computer generation of electron microscope images of dislocations", *Aust. J. Physics*, v. 20 (1967) 557.

[10] A. K. Head, P. Humble, L. M. Clarebrough, A. J. Morton and C. T. Forwood, "Computed electron micrographs and defect identification", 1973 (North-Holland).

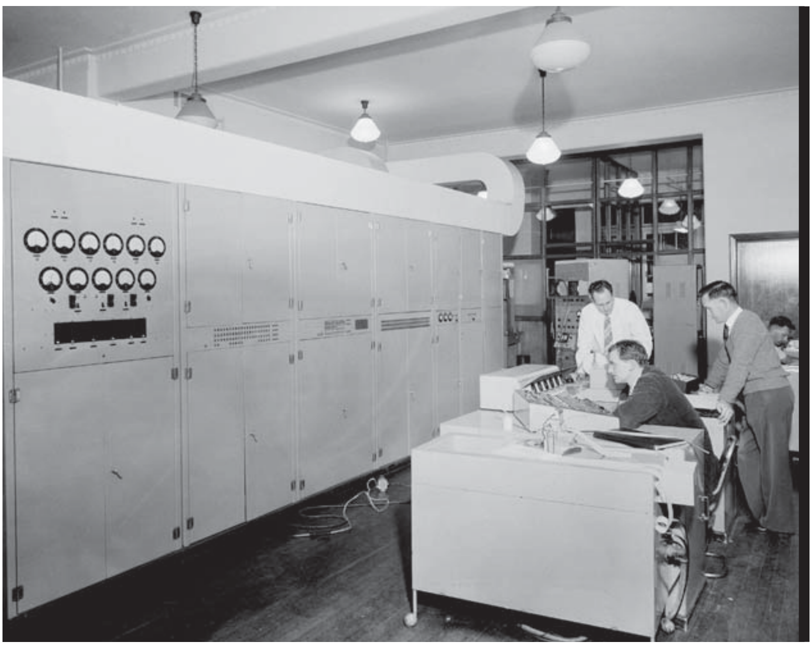
Using CSIRAC to Process Scientific Data

Terry Holden

In 1957 I was Research Officer at the CSIRO Division of Building Research in Highett. I had spent most of that year calculating varying temperatures inside model buildings from observed external data, to check against measured inside temperatures. The calculation methodology, devised by Roy Muncey (from ideas of van Gorcum), consisted of analysing the variable temperatures into their Fourier components, calculating the complex thermal admittance of each heat path into the building for each of the Fourier frequency, multiplying the corresponding terms together, summing the result for each path for the frequency, and finally Fourier synthesising these back to the resultant inside temperature.

We had taken observations at hourly intervals for four days and nights on three model dwellings, so had 96 data points to yield sine and cosine components at 48 frequencies. I used a Marchant desk calculator, five figure tables of squares and trig functions, and a Fuller cylindrical slide ruler. With these I could do one Fourier transform using short cut methods (due to Runge) in about two days, or was it four?

Some time before I was ready to start syntheses, we heard about the possible availability to us of the wonder of the age – CSIRAC. So cap in hand we approached the guru – Geoff Hill – who wrote us a Fourier Syntheses program. In October that year (1957) we ran the syntheses, and found the predicted inside temperature led in phase and had larger magnitude swings than the outside data. ‘Oh’ said Roy, ‘that happened to me once before – I think we have a sign wrong somewhere in the multiplication process.’ A little



Team from CSIRO Division of Building research using CSIRAC. (L–R) Roy Muncey, Terry Holden (at console), Bill Davern. 1958.

Photo: CSIRO archive

analysis showed that this was indeed the case – the product of two complex numbers (x+jy) by one whose real part is ($\alpha \cos \theta + \beta \sin \theta$) is not ($x\alpha - y\beta$)+-j($x\beta + y\alpha$) but ($x\alpha + y\beta$)+j($x\beta - y\alpha$). This of course is now burned into my brain – I was now faced with re-doing six months work. 'Please Mr (as he was then) Hill, can you write us a cross products program?' 'Sorry, I'm a bit busy at the moment – here's the manual – have a go yourselves!'

Roy wrote the cross products program. My first program was a Fourier Analysis based originally on Geoff's Synthesis program, but using some short cuts à la Runge. With "speedup" on CSIRAC, the best I could do for 96 ordinates was about 2 minutes per analysis (or Synthesis). Later both CSIRO and the RMIT acquired Elliot 803's, and with the Autocode the time was comparable to CSIRAC, but it took 4 minutes on the same machine with Algol 60. Later in Canberra on the Control Data 160A (which was in effect a 6600 Peripheral Processor used by Stats to load card data onto tape in preparation for the arrival of the CD3600 in June 1964), using Fortran (what a language after Algol 60!) an analysis took 20 minutes! God knows what the machine was doing. On the 3600 it took seconds, and on the Cyber 76 in the late 70s seemed to be finished before it started.

My next major venture was to automate the data recording. We built a "Multipoint Digital Temperature Recorder with Punched Tape Output." I will spend a little time talking about this machine, as it illustrates the

Terry Holden demonstrating the multi point digital temperature recorder. c.1958

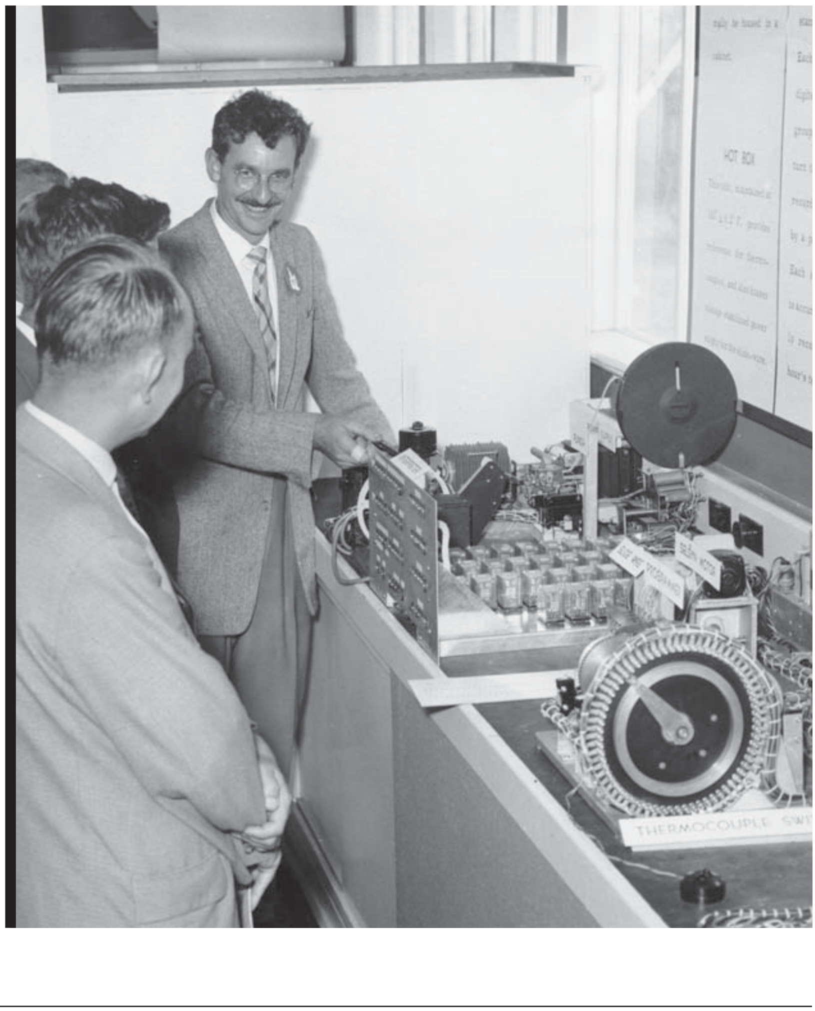


Photo: Terry Holden

environment of the time. Yes, we had heard of transistors but the technology seemed inaccessible to us. We could have used valves like CSIRAC, but for reasons which escape be we decided to use relays! The machine had about 40 of the brutes, but plug in and interchangeable.

The machine sampled 64 copper constantin thermocouples. The temperature measuring mechanism was simply that of a commercial ("Speedomax") recorder – slidewire – selsyn motor, amplifier etc. The 8-bit digitiser comprised cyclic "Grey Coded" cams and microswitches. The relay logic converted this to binary, and this was punched four bits plus a fifth parity bit onto 5-hole punched paper tape. At the end of the recording cycle, an extra checksum code was generated and punched, followed by time and date data. All done by relays, motors, solenoids and microswitches. Unfortunately, I believe the carcass has been disposed of, although a former colleague admits he still has the power supply.

Other details – the reference junction was embedded in a block of metal in an insulated box kept at 160 ± 0.2 deg F with a heater and stem-type bimetallic thermostat, readings were taken every 5 seconds, and the digitiser was calibrated in 0.5 deg F steps. The paper tape punch was a telegraphic reperforator, modified to accept parallel instead of serial data. The paper was spooled ingeniously onto a 35mm film spool driven through a slipping clutch by a 78 rpm gramophone motor. These motors were being thrown out everywhere as 45 and 33.3 came in. As an aside-managing paper tape was an art in itself – do you remember being careful never to lift you feet with the stuff in festoons all around you on the floor? The Building Research slipping clutch could be adjusted not to tug the tape (which caused punching errors), and we made half a dozen or so of these tape winders for various applications, scrounging old gramophone motors from all and sundry.

Of course we had programs to process this paper tape data. Access to CSIRAC for a reasonable stint was only available late at night, so homecomings in the wee small hours were a way of life. Not that my wife enjoyed this very much, especially the odd phone call from a colleague with a problem at 3:00 in the morning who thought you might be able to help… I was once pulled up for speeding down St Kilda in the dead of night, and got off with a caution by explaining to the magistrate that I was returning from the University having been using a computer – Ian Langlands my Chief of Division wanted to know what that had to do with anything, and I explained that whatever the relevance, the strategy had worked!

To embark on a session at CSIRAC one had to be suitably equipped. First there was the "CSIRAC box", with compartments for your standard programs. Elsewhere in the box was, of course, the 12-hole unipunch, for correcting minor programming errors by the addition of holes. To remove a hole, of course you had the piece of stainless steel with pre cut strips of coloured (and therefore opaque) sticky tape, and not forgetting the scalpel to cut the tape, or pick it off and place it.

Five hole paper tape data on spools were transported separately in a cylindrical carrier of the right diameter specially constructed for the purpose – "the billy can" – unfortunately this has since disappeared (probably to a barbecue).

Finally, a few anecdotes. Others have mentioned Geoff Hill's INTERPROGRAM – an interpreter for CSIRAC. Geoff produced an elegant manual for this language, and decorated the front cover with silhouetted paper tape. Of course, being Geoff, the tape was not garbage but to the cognoscenti spelt out "Waffle for the front page of the INTERPROGRAM Manual".

It has been mentioned that some of the first computer music was played on CSIRAC. I recall a bassoon solo – Early in the Morning I think it was, chosen by Prof Tom Cherry because the noise CSIRAC produced sounded like a bassoon. I remember Frank Hirst telling me with glee that the "program allowed for rallentando." I have in fact found a copy of the instructions for the music program, including such gems as "if transposition beyond these limits is attempted, the computer will be asked for notes that are not in its repertoire and will go berserk."

In preparing this talk I found a "List of CSIRAC idiosyncrasies" eg., "Input commands must not have an address" and another long discussion of the idiosyncrasies of the left shift command, how it did different things when the machine was in different "Modes", and how to program around these. All very esoteric to modern eyes.

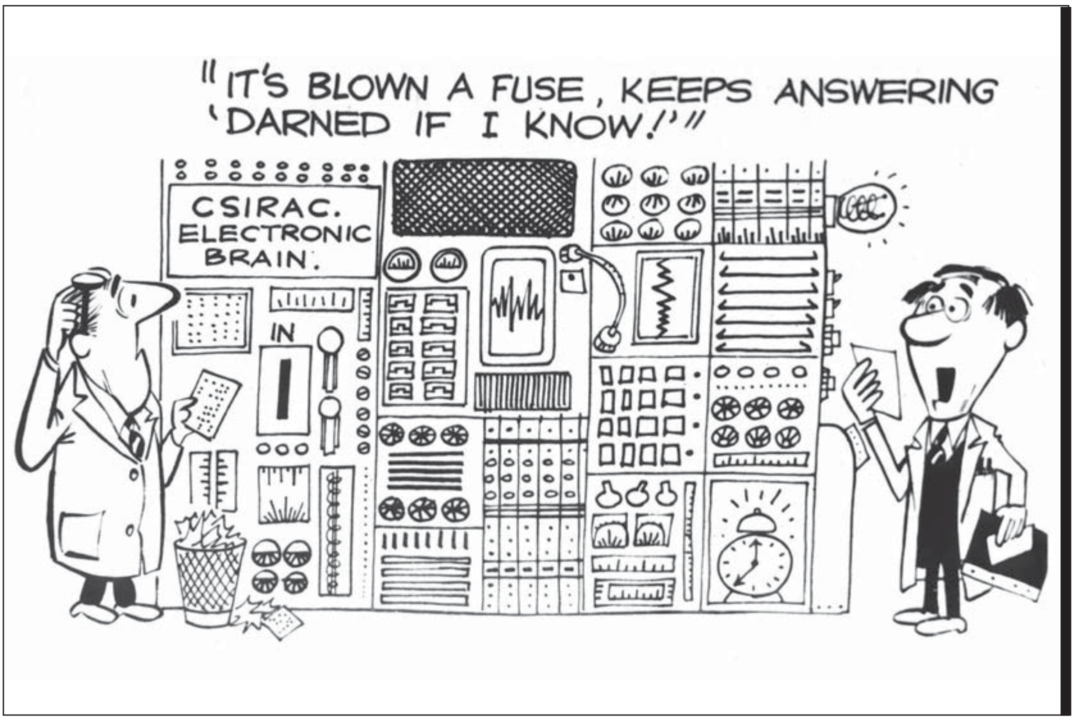
Establishing the CSIRAC Document Archive

Christopher Jack

The principal mission of the Australian Science Archives Project (ASAP) is the recovery of the records of Australian science, technology and medicine. The involvement of ASAP in the records of CSIRAC dates from an initial contact, in late 1994, between ASAP Director Gavan McCarthy and Associate Professor Peter Thorne of the University of Melbourne Department of Computer Science. This led to ASAP undertaking the processing of the CSIRAC collection, which was begun in October 1995.

At the time it was estimated that the collection comprised approximately 200 items. Although not a large collection of records, it contained a variety of material relating to the design, programming and operation of the CSIRAC computer, the transfer of the computer to the University of Melbourne and the establishment of the University's computer project at the Computation Laboratory. The records also contain material relating to computational developments in Australia during the 1950s. The processing project was to include the creation of a searchable database containing detailed descriptions of all record items and of contextual information (Series and Provenance descriptions) relating to those records. This would enable the creation of an on-line searchable guide or finding aid with links to both pictorial material from the collection and to other related information available on the World Wide Web.

WEG cartoon from Herald (Melb). 16 June, 1956.



Courtesy W.E.Green

After processing was begun more records, including a large number of photographs, were given to the collection by Jurij Semkiw, one of the people who had worked on the CSIRAC project at the University of Melbourne. He was also able to provide important background information, including identification of the subjects of many of the photographs.

As part of the project to preserve the history of CSIRAC, Peter Thorne was keen to include an oral history based on interviews with the principal people who designed and built the CSIRAC computer as well as with those who established its operation at the University of Melbourne. This led to the involvement of Doug McCann and Voices of Australian Science and Technology (VAST).

ASAP's work with CSIRAC will continue as another group of records relating to CSIRAC has been located and brought to Computer Sciences. These records include some of the original paper tape programs, electronic circuits and diagrams. Once the documentation of these additional records is completed, the Guide on the ASAP Web will be updated to include the new material. A similar thing will be done with the oral histories recorded by VAST. The magnetic tapes will be listed in the ADS as CSIRAC records and can then be recorded digitally. Once they are in digital format they can be put on a server or on CD ROM and linked to the Inventory in the ADS.

The ASAP Web Site hosts the published guides to various collections and "Bright Sparcs" a biographical listing of prominent figures of Australian science. It also has links to numerous other scientific and archival sites. The address for the CSIRAC guide is:

http://www.asap.unimelb.edu.au/pubs/guides/csirac/

Technology and Social Context: The Many Faces of CSIRAC

Doug McCann

Introduction

Any technology, or item of technology, exists within a social context. Technology is not just a material entity per se, its status can change depending on the uses to which the technology is put, or the attitude of the people who build the technology or upon whom the technology impacts. So it is with the computer CSIRAC.

Historians, philosophers and sociologist of science (and others) have in the past debated, and continue to debate, the significance of the relative autonomy of the technology itself versus the human or social factors. Computer technology is a case in point. Was its development inevitable? Could its present form have been different? What are the social influences and consequences? What are the political influences and consequences? These and a myriad of other questions immediately arise soon as one begins to think even cursorily about the enormity of a technology that is present in almost all aspects of our lives.

Like the harnessing of electricity before it, computer technology is similarly ubiquitous. Like biotechnology it has penetrated our very being and even challenges traditional notions of what it is to be human. These developments in electronic computer technology have only taken place over the past half century or so. Of course, developments in electronic computing have a prehistory stretching back to the development of other technologies, for example, valves, radar, ballistics, and mechanical calculators and so on, as well as to developments in theoretical physics and mathematics. These technologies, in turn, can be seen to hearken back to still earlier technoscientific developments. One could adopt an evolutionary model. But which model one choses and where one starts is arbitrary.

However, no matter where one starts the same sorts of questions arise. What were the intellectual, material and social conditions that gave rise to these developments? These are big questions. I do not intend here to attempt to tackle these bigger issues. They are the stuff of much larger studies. What I will briefly look at here is the way in which one item of technology, i.e., CSIRAC, owes its significance to attitudes in the society in which it is embedded. CSIRAC's very existence depended and, indeed, still depends, on a favourable attitude towards it from those who are in a position to affect its status, be it administrators, builders, users, curators, or members of the public at large. These attitudes can change markedly over time. CSIRAC's status has undergone dramatic transformations over the years since its original incarnation and possibly will continue to do so.

The Vicissitudes of a New Machine

In the early stages of organising the CSIRAC conference I was occasionally asked "Why bother?" The questioners indicated that they thought it was more important to concentrate on the future than to look back to the past. After all, CSIRAC is no longer functional and it seems unlikely that it will ever operate again. It was, in effect, as one commentator described it, “a dinosaur” whose only value was as a curiosity. There are currently so many exciting new things going on in the world of computing that it seems to be a bit of a waste of time to give such an ancient, superseded, cumbersome contrivance like CSIRAC more than passing consideration.

From one perspective they are right. CSIRAC was less powerful than the cheapest of today’s pocket calculators and had less memory than my digital wristwatch. It can be seen merely as a technological evolutionary stepping stone towards the next generation of computers – although the termination of the CSIRAC project (or CSIR Mk1 as it was known then) in the mid 1950s makes that step a little unclear. CSIRAC had no direct successors. As a technology it seems – to use an evolutionary metaphor – to have resulted in more or less in a local extinction event (although it could be argued that some subsequent Australian computers eg the CIRRUS drew upon CSIRAC).

That challenge stimulated my thinking. What value is there in reconstructing the past? Well, it is sometimes difficult for someone like myself who is immersed in the study of history to bring to consciousness reasons for my attraction to it. One could trot out all the usual justifications, e.g., George Santayana’s observation that “if we don’t learn from the past we are condemned to repeat it”, et cetera. However, apart from the utilitarian value of studying history (and in my case in particular the history of science and technology), there are also intellectual, emotional and aesthetic reasons for doing so. It is a fascinating and worthy activity in its own right. Nevertheless, the more I thought about it, and the more I learnt about CSIRAC, the more I realised that there are many edifying lessons that can be learned from the story behind the development and subsequent demise of this venerable Australian artefact.

For instance, how did it happen that a small, relatively isolated group of Australian scientists came to develop such an advanced high-tech machine (for its day)? But, why did this state-of-the-art project not really advance beyond the prototype stage? Was the fact that it didn’t directly lead to an Australian-based computer manufacturing industry just a chance circumstance or bad luck, or are there many similar examples of other Australian innovations that have withered on the vine? Is it still happening today to any great extent? These are interesting questions, but as I said above, what I will address here is the changing status of CSIRAC over time in an effort to emphasise how essentially the same piece of technology can be interpreted in dramatically different ways in different settings at different times. In the case of CSIRAC (perhaps even more so than many other later developments in computing) it is abundantly clear that social considerations (as well as technical ones) loomed large in its operation and continuing existence.

CSIRAC as a nonhuman ‘actor’ has played a number of roles in different settings at different times, listed below are just some of the ways these roles could be interpreted.

A Prototype Research Machine

CSIRAC began life as an experimental electronic automatic calculating device. It was designed and built “as a logical follow-on to experimental studies in design of electronic logical components” (Pearcey, 1988, p.616). By the end of 1947 Pearcey had assembled “a more or less complete logical design for a possible electronic, internally programmed automatic computing system" (Pearcey, 1994, p.18). As Pearcey states, the CSIR Division of Radiophysics then:

> *…agreed to proceed with engineering development of the major components required by any electronic computing system such as pulse generators, scaling and waveform generators, pulse distribution circuitry, coding and decoding devices, static/dynamic converters, shifting registers and logic gates (Pearcey, 1994, p.18).*

As Frank Hirst (who later managed the machine in Melbourne) makes clear:

> *When construction commenced, the main role envisaged for CSIRAC was as a research computer, in order that investigation into programming techniques and electronic computer circuitry could be undertaken. In the first instance, no consideration was given to building a machine expressly for processing computational projects (Hirst, 1965, p.11).*

CSIRAC's co-inventor Maston Beard (1957, p.1) has also emphasised that the "initial intention was to design and construct a very simple computer to illustrate principles of design but not to provide a computer for general use." The plan was to "then follow this with a computer which could form the basis of a useful computing service." The machine was designated the Mark 1 (Mk1). As Pearcey later remarked, there were no subsequent versions or Marks. "Perhaps that name expressed the team's hopes for the future." (Pearcey, 1984, p.106).

Following the initial design stage and the construction of individual major components Pearcey (1994, p.18) later observed:

> *It soon became clear that a project to produce the variety of special units for automatic electronic computing would eventually require those to be tested in a coordinated way and assembled into a more or less complete computer. The outcome was the first automatic electronic computer in Australia and one of the earliest in the world – the CSIR Mark 1, later known as CSIRAC.*

A General Computing Service for CSIRO

Although initially at the Division of Radiophysics the Mk1 was basically "used as a research instrument to develop programming techniques" (Pearcey, 1994, p.26) it came to play a much wider role and was "used at the division in part to assist in the cloud-physics and radio-astronomy projects" (Pearcey, 1984, p.113) and in "providing a computing service to scientists in other divisions of CSIRO, universities, and other government and research, design, and engineering bodies."

Beard (1957, p.1) also relates that while the Mk1 retained "many features of the simple computer" it was "very flexible and of sufficient capacity to serve as a useful computer for scientific and other calculations." He goes on to say:

> *The computer was used almost continuously during 1953 and 1954 for solving problems both for the Radiophysics Laboratory and for outside organizations.*

At this stage the Mk1 was "the only working electronic digital computer in Australia." , although it should be emphasized that "its operation was very low key." (Pearcey, 1994, p.27). Pearcey went so far as to assert:

In fact public knowledge of its existence and use seemed to be discouraged by Radiophysics management whose main concerns continued to focus on the increasingly successful radioastronomy studies, cloud physics and the practical objective of stimulating rain over the inland. Far less interest was shown in the digital computing side of things.

This alleged indifference apparently made continued progress very difficult for the small staff involved and accordingly, in 1954, Radiophysics management decided to terminate the Mk1 project. In 1955 the computer was dismantled and transferred to the University of Melbourne. However, while at CSIRO, the Mk1 had played a very valuable pioneering role as an experimental prototype and later as a more general computing service.

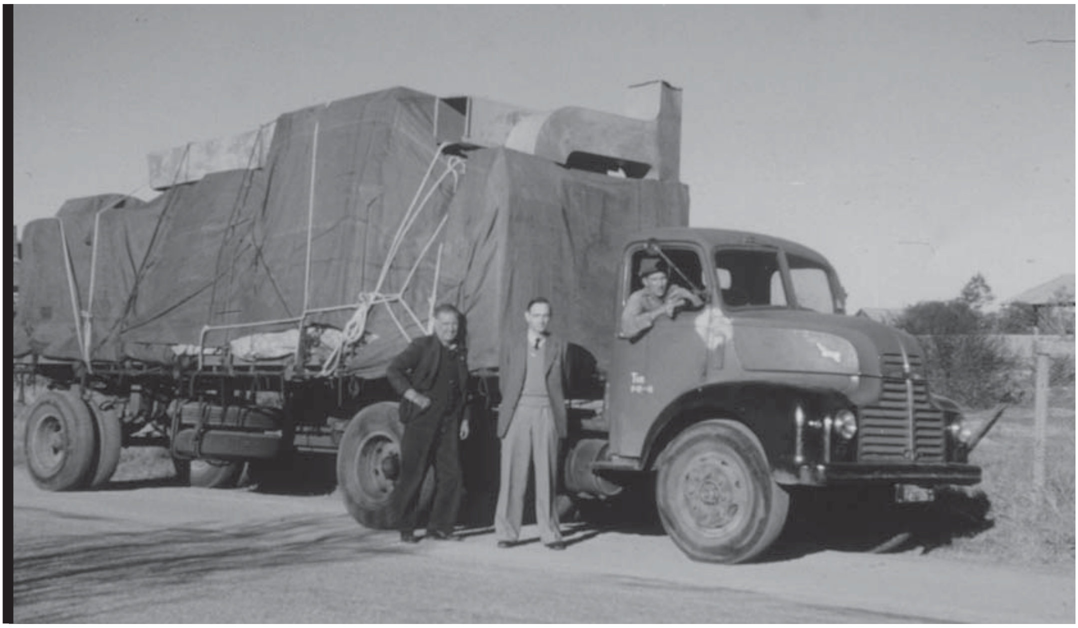


Photo: CSIRAC archive the University of Melbourne

CSIRAC on semi-trailer at northern outskirts of Benalla, Victoria, on Hume Highway. Maston Beard standing in centre of photo with the driver and his assistant. June 1955.

A Computer for a New Computation Department

On 14 June 1956 the Mk1 was recommissioned and renamed CSIRAC and the new Computation Laboratory at the University of Melbourne was officially opened. The computer was further upgraded and operated as a free open-shop computing service for scientists and others in CSIRO, academia and elsewhere. It was in Melbourne that CSIRAC came into its own as a general computing workhorse. In Melbourne, from June 1956 to June 1964, over 700 computing projects were processed. As Pearcey (1984, p.113) has pointed out:

> *During the eight years of its life in Melbourne, it handsomely repaid to Australian science many times its development cost.*

CSIRAC was the centrepiece of the University of Melbourne Computation Laboratory, later to be split into two sections comprising the Computer Centre and what is now the Department of Computer Science as a separate entity.

A Proud Artefact

On its retirement in June 1964 CSIRAC was donated to the Museum of Victoria where it was intended that it be placed on display, but it was not exhibited. By the time of CSIRAC's decommissioning most, if not all, of the world's first generation computers had ceased operation and nearly all had also been dismantled and scrapped. CSIRAC was fortunate in that respect because, since it was probably the last to remain in operation, there was already some degree of recognition by its users that it was a fairly historically significant machine. Nevertheless, over the next 16 years the computer remained disassembled in a Museum store in Abbotsford and was generally forgotten.

However, in 1980, as a tribute to Trevor Pearcey, who now worked there, the Caulfield Institute of Technology (now Monash University, Caulfield Campus) arranged for the transfer of CSIRAC from the Museum store to Caulfield to be placed on public display. It remained on display until late 1992 when it was returned to the Museum of Victoria, this time to a Scienceworks store in Maribyrnong.

A Forgotten Artefact

From the time of its retirement in 1964 CSIRAC gradually faded from public consciousness. Even in its heyday CSIRAC was never a household name. It was a specialised item of technology whose existence and operation was known and appreciated only by a relatively limited audience. Despite the fact that it had once been the centrepiece of computing in Victoria, and Australia, by the time of its return from Caulfield to the Museum in the early 1990s, most of the younger generation of computer enthusiasts would have had no inkling that CSIRAC ever existed. CSIRAC was now a virtual 'non-entity'.

Dismantled sections of CSIRAC being moved from Caulfield campus for storage at the Museum of Victoria. 1992.

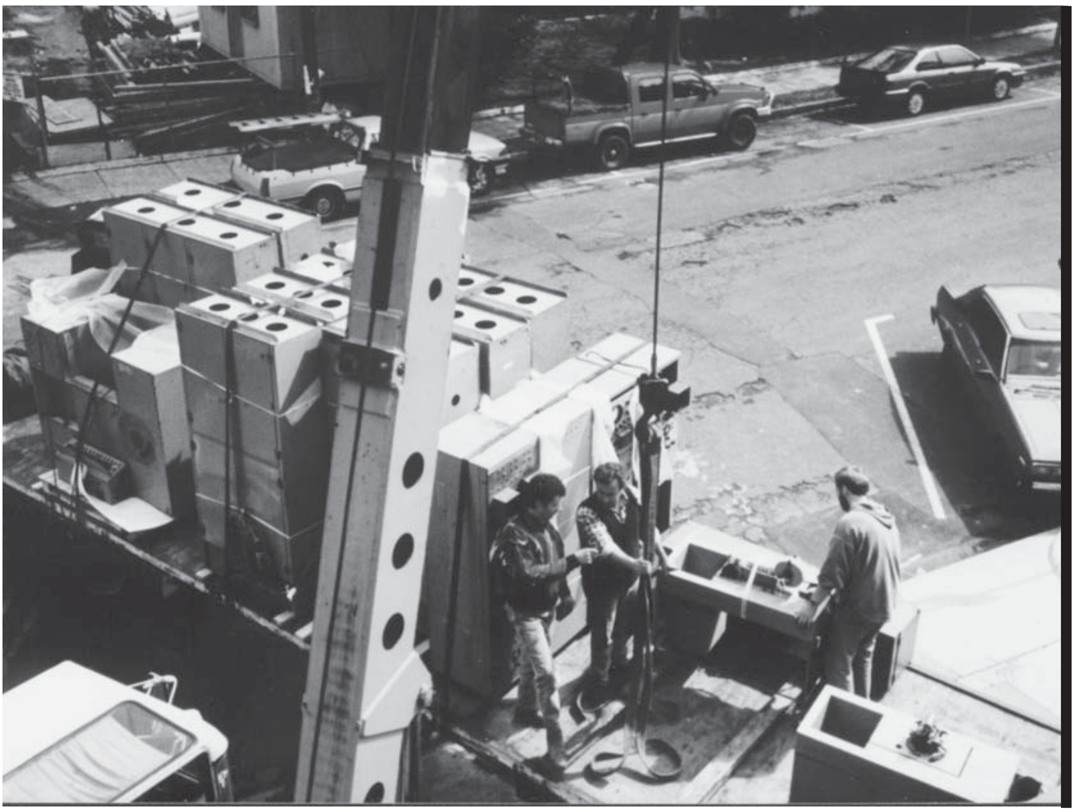


Photo: Museum Victoria

The Monster From the Vault

When moves were made to resurrect CSIRAC in early 1996 in preparation for a celebration and conference, the computer was sitting in storage in a Museum warehouse in Maribyrnong dismantled, in sections, and somewhat dispersed. It is questionable whether anyone other than the original builders or maintenance engineers could have fully reconstructed it. Fortunately, the two principal maintenance engineers, Ron Bowles and George Semkiw were available, and willing, to try to figure out the details. The recovery of the original circuit diagrams also greatly assisted this process. Science journalist Wilson da Silva captured the some of the atmosphere of CSIRAC and its museum surroundings when he wrote the following in a Melbourne newspaper 'The Age' (4 June 1996, p.C3) in an article titled "The Monster from the Vault":

> *Tucked away in the dusty corner of a Melbourne warehouse is a little-known piece of world computing history. It weighs seven tonnes and took up most of a room when it was operating… Now almost 32 years after the vacuum-tubed computer was put into mothballs and largely forgotten, it is coming out again to reclaim it place in history… Its name conjures images of a prop from a 1950s science-fiction classic like* ***Forbidden Planet****. And it looks the part, too. There is row after row of grey metal cabinets with dials and switches and gauges. Colored lights are dotted in rows along its panels and its innards is a jumble of thick wiring, mercury switches and vacuum tubes – 2000 of them.*

As mentioned, at that time CSIRAC was still in pieces, but even in that condition its imposing presence still commanded awe and respect. For someone who had never seen it, and was viewing it for the first time, it really did seem to be a metaphorical technological equivalent of a monster or dinosaur. A monster that possibly could be returned to life.

An Important Technological Artefact

Now that CSIRAC has been reconstructed and some of the background historical research has commenced it is clear that CSIRAC is indeed a very significant Australian technological artefact. Just how significant will become clearer after further historical research. Unfortunately CSIRAC will probably never actually operate again due to aging of its electronic components, and even if these components could be replaced the sheer cost and effort in running and maintaining the computer would simply be prohibitive under present economic circumstances. How important CSIRAC is seen to be is again a human and social judgement, in a sense it has little to do with the nuts and bolts (or wiring) of the technology itself. Assessments, conscious or unconscious, of CSIRAC's importance will almost certainly change over time, as they so obviously have done already.

A National Icon

Because CSIRAC was Australia's first computer, because it was one of the world's first, and because it is still extant, CSIRAC is, and deserves to be recognized as such, one of Australia's technological icons. The 1996 CSIRAC Celebration is a first step in raising awareness of its importance. Australians have been at the forefront of many scientific and technological innovations and developments of world significance, and CSIRAC would rank with the best of them, especially in the light of the computer revolution that followed.

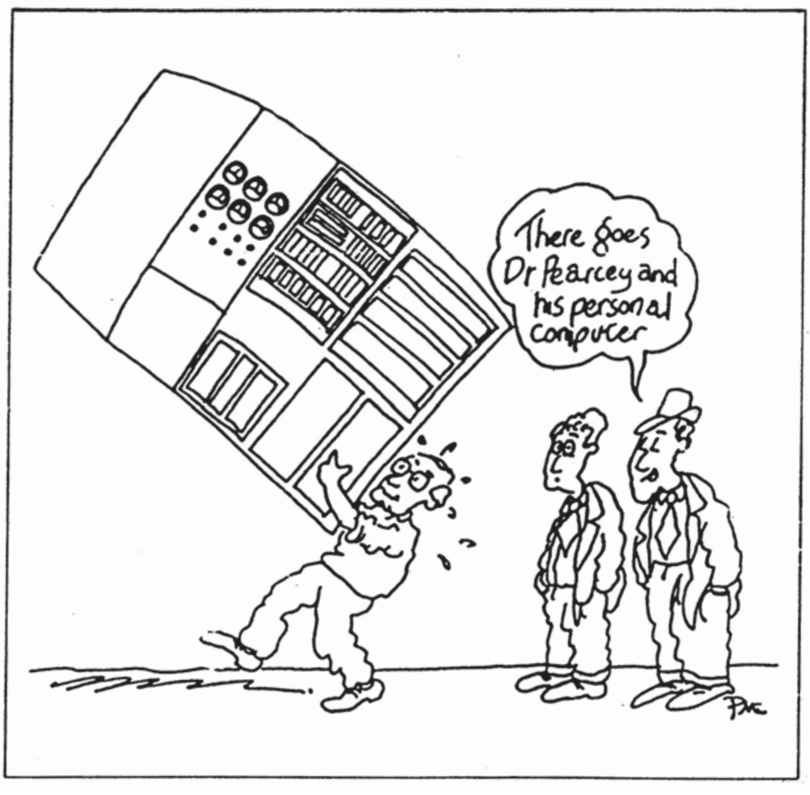
If the computer revolution had not happened CSIRAC's status would be much more problematic.

An Internationally Recognised Item of Computer History

Finally, CSIRAC is a reasonably significant item of technology internationally. It was, after all, one of the world's first electronic stored-program computers. Although it did not directly lead to a computer industry in Australia or to any important further lasting innovations in computer hardware or software, it still nevertheless was part of the general revolution in computer technology and programming. Where CSIRAC is special, however, is that it is probably "the only complete first-generation machine still in existence." (Pearcey, 1984, p.113). If that is the case then it is truly unique. It should be preserved at all costs. With time, and with proper conservation and promotion, it will one day become an internationally recognised item of computer history. That process has already begun.

Conclusion

I have attempted to show that, in addition to technical considerations, an item of technology, ie., CSIRAC, can also be strongly socially determined. CSIRAC has played a number of roles throughout its existence, from research machine, to computer workhorse, to redundant technology, to forgotten artefact, to treasured artefact and now possibly national icon. Because it is essentially the same piece of hardware (or only sightly modified) then it follows that the computer's sometimes radical changes in status are mainly due to other causes. These changes of status are strongly associated with different institutional, professional and societal settings.



Cartoon of CSIRAC and Trevor Pearcey on the return of CSIRAC from Caulfield Institute to the Museum of Victoria. 1992.

ACS Victorian Bulletin, Nov. 1992

From what I have said above it also follows that now and into the future there will probably be further changes in status in store for CSIRAC. For those who value this unique and historically significant item of Australian technology let us hope that we do not have a radical change for the worse, i.e., let us hope it is not forgotten again or more radical still, scrapped completely, as have many other historically important items of technology.

In order to address some of the larger questions alluded to at the beginning of this paper it is necessary to document the causes as to why things happened the way they did, if possible. It is fortunate that we still have the original machine available for examination which will greatly assist in this task. A number of the original players are still able to make a contribution to this documentation process, but as time goes by this becomes more difficult. We have already seen the illness or death of some of the key figures involved in the development of this technology. Time is of the essence.

Finally, to answer the question mentioned at the beginning of this paper, ie., "Why bother?", in general terms it is to contribute to the process of answering the larger questions about the nature and development of technology which is now so ubiquitous, so universal, so vital and so intrusive in our lives today. But if I was to answer that question from a personal point of view, I would say "all of the above" but mainly because "like Everest, it is there".

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CSIRAC and the Atomic Structure of Metal Surfaces

Alan Moore

In the late 50's Erwin Muller at Pennsylvannia State University invented the field ion microscope and produced some remarkable pictures of the arrangements of atoms on metal surfaces. His specimens were typically a thin metal wire with a very sharp spherical point. The diameter of the point was usually about 500 interatomic distances. The curvature of the point was so great that always there would be some atoms which protruded from the average surface of the tip.

Muller's pictures consisted of thousands of spots arranged in groups of concentric circles and the groups of circles were arranged in a pattern in the same symmetry as that of the arrangement of the atoms in the metal crystals. (Fig 1). It appeared that the spots corresponded to atoms which protruded from the spherical surface.

In the CSIRO Division of Tribophysics (at that time on the campus of the University of Melbourne) we already had published work which described methods which determined the arrangement of atoms on flat metal surfaces and we thought that we could perhaps simulate Muller's pictures by extending our ideas to crystals with spherical surfaces. In 1961 Geoff Hill wrote for CSIRAC an interpretive program (INTERPROGRAM) and programs could

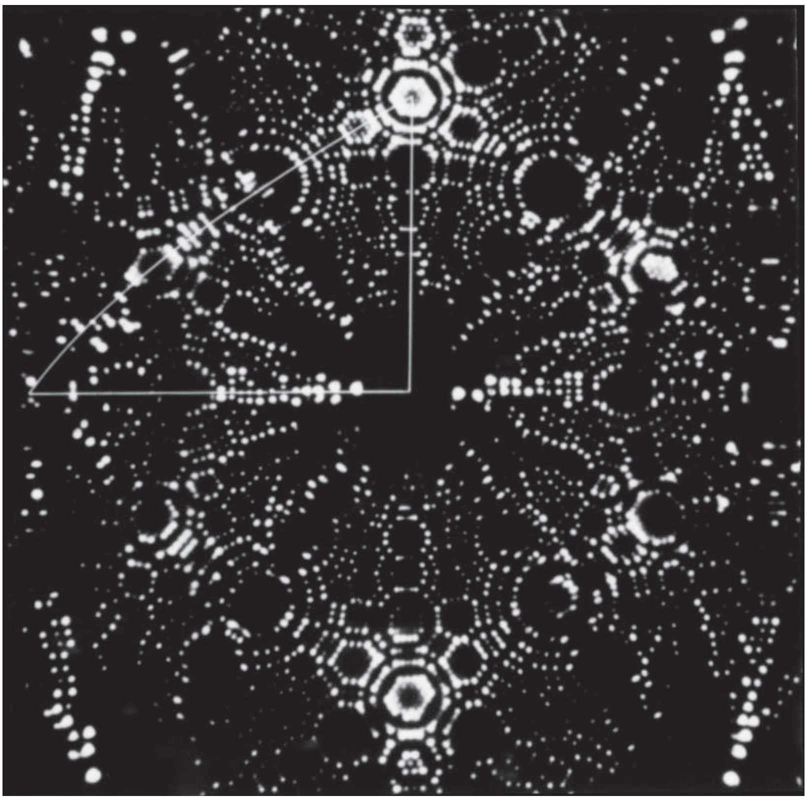

Figure 1. *A field ion micrograph of a very sharp tip of tungsten, a body centered crystal. The white spots indicate the positions of single atoms. The image has the same symmetry as the crystal and is made up of repeated reflections of the marked triangular area.*

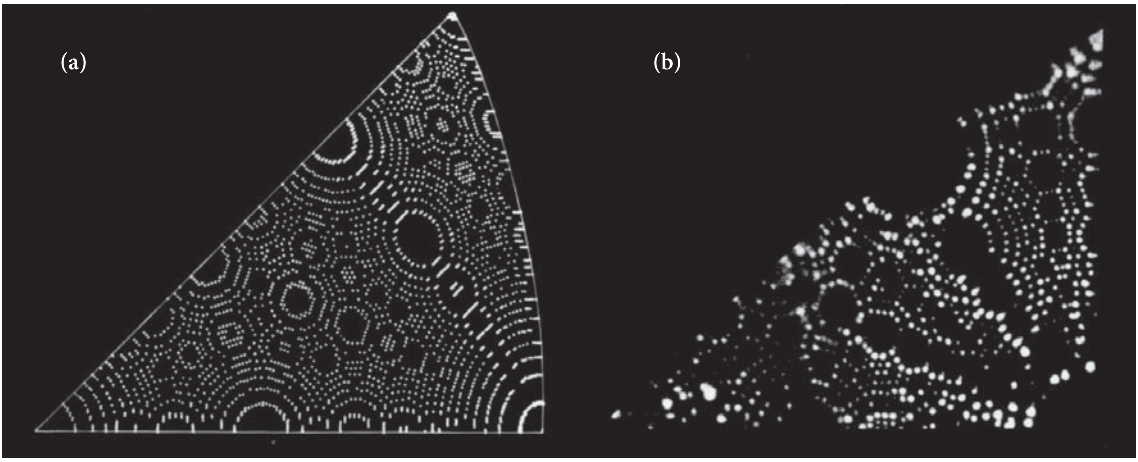

Figure 2. *A CSIRAC computer simulated pattern for a face centered cubic crystal (a). compared with the corresponding area of a field ion micrograph of tungsten (b).*

then be written in a language similar to earlier forms of BASIC. CSIRAC was no longer a mystery and we could calculate the positions of all the atoms on the surface of a spherical metal crystal.

For our calculations we imagined that the surface of the sphere had a radius of 350 times the distance between adjacent atoms in the metal crystal. We assumed that we had to calculate the XYZ coordinates of all atoms which were close to the surface of the sphere and also the distance of the atoms from the surface of the sphere. The origin of the coordinates was at the centre of the sphere and a separate computation was required for each atom.

On CSIRAC this involved a simple calculation involving:

- 3 multiplications of real numbers.
- 1 division of real numbers.
- 2 multiplications of integers.
- 2 square roots
- 6 numbers (including the XYZ coordinates of the atom and its distance from the surface of the sphere).

These were punched on paper tape.

For each atom the calculation took 7 seconds and every few minutes the tape had to be taken to a teletype for a printout. Most of the work was done overnight (often until one of the multitude of electronic valves burnt out). For each pattern I manually plotted about 2000 points on a large sheet of graph paper and the simulated pattern slowly appeared.

After several trials we concluded that the atoms which were closer than about 0.05 interatomic distances to the surface of the sphere corresponded to the spots which appeared in the FIM patterns and that our simulation should contain only those atoms. Our first simulations were of two crystal structures (fcc and bcc) and were a good match to Muller's pictures for platinum and tungsten which were typical examples of the two structures. (Figs 2 and 3). We could therefore estimate the maximum distance that an atom could be from the average surface and be included in a field ion micrograph.

I reported our results to a Field Emission symposium in the USA in 1962. There was considerable interest. In fact one person contacted his laboratory

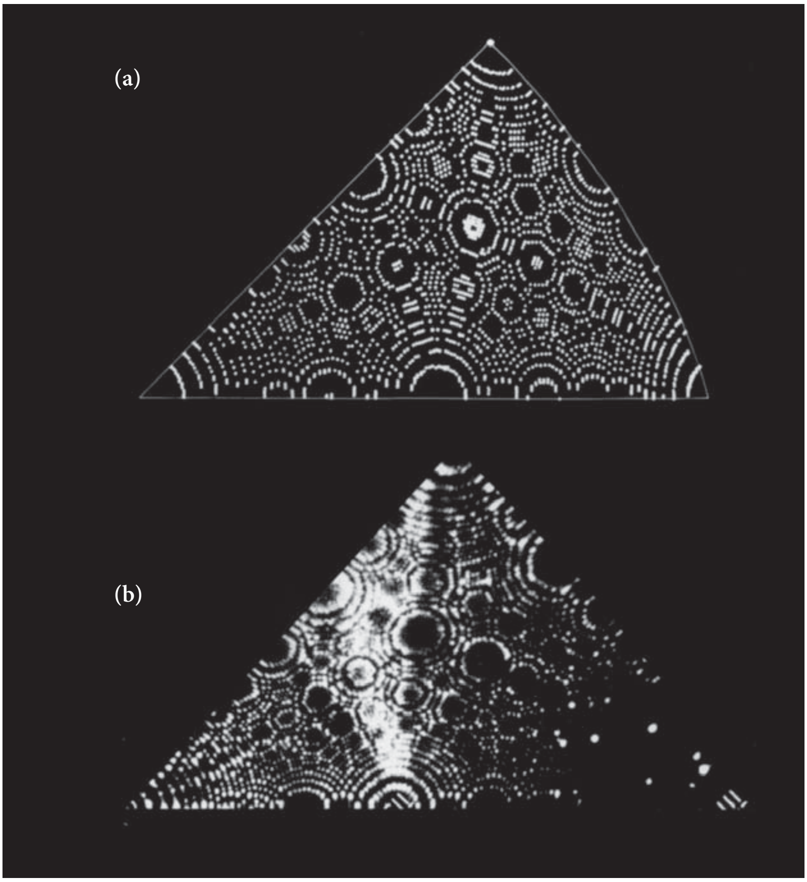

Figure 3. *A CSIRAC computer simulated pattern for a face centered cubic crystal (a) compared with the corresponding area of a field ion micrograph of platinum which is a face centered cubic crystal (b).*

and a new simulation appeared before the end of the conference. Several people regretted that the computer in their institution did not have the open policy that we enjoyed with CSIRAC. However in a short time they found ways to use their local computers, which were much later models than CSIRAC, and FIM simulations became well established. CSIRAC put our publication date about a year ahead of other work.

A short time later, the CSIRO Control Data computers became available and simulations could be calculated and plotted in a few seconds. We extended our work to several related topics such as simulations of field on patterns of alloys or to simulations which showed how single atoms evaporate from the spherical tip.

CSIRAC was very valuable to us as it was the starting point for about eighteen years of our activity in Field Ion Microscopy.

CSIRAC, Mass Spectroscopy and the Fast Fourier Transform

Jim Morrison

In the late 1950s, as a young mass spectrometrist working in the then Chemical Physics Section of CSIRO, I had been troubled by a problem common to many experimentalists, in that the phenomenon which I was trying to measure, an ionization efficiency curve, was smeared out by the limited resolving power of my apparatus, due to the spread in energies of the ionizing electron beam, making it difficult to distinguish fine details in the experimental curves.

Mathematically, what is observed is the convolution of the true data with an apparatus or smearing function. Largely due to my prior experience as an X-ray crystallographer, I had devised a mathematical method for unfolding the convolution integral, which I termed 'Deconvolution'. This involved taking the sampled Fourier transform of the experimental data, and dividing it by the sampled Fourier transform of the apparatus function, then taking the inverse Fourier transform of the result.

To carry out this computation, I used Beevers Lipson strips, used by X-ray crystallographers for X-ray structure analysis, little pieces of paper, on which were printed cosine and sine values sampled at 6 degree intervals for a set of harmonically related functions, and multiplied by amplitude factors. One selected a number of these, set them up in a frame, then added up columns using a Sundstrand adding machine, to obtain Fourier summations. One could calculate only limited sets of values, and it was hard on the eyesight and was tedious in the extreme, but it gave some promise of being a useful technique.

At this stage, I discussed my problem with Eric Hercus, an old friend, formerly a professor of Physics at Melbourne, who on his retirement had joined the staff looking after CSIRAC. He induced me to try out my problem on CSIRAC, and in fact wrote the programs necessary to achieve it for me, using a language which looked like Turing quadruples, and aided in typing in my data on to paper tape using what I think was called a Flexowriter. To get it into the limited memory of CSIRAC, we had to take advantage of every symmetry and antisymmetry and factorization possible, ending up with something very similar to the Fast Fourier Transforms of later days.

Nothing that has happened in the whole of computing since has impressed me so much as the result then. The results of the computation appeared in a minute or so, as compared with the painful hours of hand computation, and were most promising. Over the next few months using CSIRAC, I was able to explore the possibilities of this method of deconvolution, and to determine the precise limits set by the presence of random scatter in the experimental data, by the form of the apparatus function, and the effect of inaccurate knowledge of the apparatus function.

I spoke about my results at a Solvay Conference in Brussels in 1962. To my great surprise, I encountered not a little amount of difficulty in getting acceptance of my results. Some claimed that I was breaking the Second Law of Thermodynamics, by trying to get something for nothing. Slowly, the method gained acceptance, and the words Fourier Transform, almost unheard of in those days, are by now almost household words, in fact one can buy inexpensive specialized chips to carry out Fast Fourier Transforms.

CSIRAC made me a dedicated user of computers, from CSIRAC to the early IBM machine which we used to have to travel to down St Kilda Road, through various Elliot 503, 803, Sirius, CDC machines to the elegant desk computers of today, and through a whole range of assembly codes, autocodes and higher languages.

CSIRAC perforce taught one to write efficient code, a habit which I have tried to maintain up to the present day. I am somewhat dismayed by much of the commercial software available today. With megabytes of memory and gigabytes of fast storage to play with, efficiency in programming seems of little object. When I think that we were able in the 1970s to write quite respectable artificial intelligence programmes in chemistry using 16K of total memory, a lot of the present day efforts seem rather pathetic by comparison.

I owe not only a special debt to CSIRAC, for having introduced me to the power of computing, but also to several of its creators in the CSIRO Divisions of Radiophysics and Electrotechnology, Drs Pearcey, Beard, Hollway and others, who by their expertize in digital valve circuitry and their helpful advice stimulated me to build small dedicated controllers for my own apparatus. CSIRAC in its time was a great achievement, and a landmark in the history of computing.

Early Commercial Computing and CSIRAC

Peter Murton

I first met CSIRAC late in 1956 when I attended a programming course run by Frank Hirst in the department of Physics at Melbourne University.

Having started my working life with the PMG's Department in 1952 at the Central Research Laboratories and read how a programmable machine could help me with some of the lengthy calculations with which I struggled to determine electrical induction between power and telephone lines, I tried to talk my department head into acquiring a computer, but, in those days, the expenditure was too great for the budget.

When Colonial Mutual advertised in 1954 for someone to run their computer, I took the job only to find out that the machine had been ordered from the drawing board and four years would elapse before the machine would be delivered. I put this somewhat lengthy gestation period to good use, as I was responsible for Planning and Mechanisation in the office, and I was also able to study the rather scarce literature on computing. In mid 1956, I spoke at the annual conference of the Australian Institute of Management, explaining how computers were going to take over much of the routine record keeping in commerce and industry – however, I think I lost my audience when I started to explain binary arithmetic and thermionic valve theory to demonstrate how a computer would work.

At that conference I met many people interested in computing – one was Gordon Pearson from the ANZ Bank who discussed with me the possibility of direct information exchange between our companies. Our policyholders could pay their premiums by direct debit from their respective bank accounts. The banks would each forward these amounts to our account and then we would enter each amount received back onto the policyholder's renewal record. Gordon and I agreed that if Colonial Mutual would initiate this action by giving the banks a pack of punched cards, or better still a magnetic tape, the banks could automatically deduct the premiums from the respective accounts and the main part of the task would be completed. Needless to say it took some time to work out all the timing and legal implications, how to handle dishonours and to get the support of all life offices and banks. The system took off and so direct debit was born – later I worked on its extension to Electronic Funds Transfer as we know it today.

Reading that Melbourne University were starting programming courses I applied to attend and so joined the second course in about September 1956. Working at a financial institution, I chose a loan repayment schedule as my project, but the word length was not sufficient to give me a useful result and I was too lazy to re-do the whole program all over again in double length arithmetic. One trick I used to get a good result was to calculate the outstanding balance after each payment, subtract that from the previous balance to determine the capital paid, and subtract the capital paid from the instalment to find the interest paid – this technique ensured that the sum of all the capital payments was exactly equal to the original loan.

"My" computer eventually arrived in April 1958 and yet was still the first one to be installed in Australia in commerce or industry – the second I believe was an IBM 650 at the AMP some 4 or 5 months later. The computer came with an engineer to install it and a prewritten program which was meant to handle the company's work. After that I set about composing a programming course for my colleagues at Colonial as I did not wish to be confined to programming for the rest of the computer's active life.

My experience with CSIRAC not only helped me understand programming but enabled me to meet many interesting people who were directly involved with CSIRAC, namely Frank Hirst, Tom Cherry, Geoff Hill and Trevor Pearcey. All of these people came back into my life through the Victorian & Australian Computer Societies – Frank Hirst called a meeting early in 1961 to consider forming a Victorian Computer Society, Tom Cherry became its first President, Trevor Pearcey Vice-President, Frank the Honorary Secretary and I was a humble committee member. Geoff Hill became the first convener of the Australian Computer Society's course accreditation committee in 1972 when I was still on the ACS National Council.

Another colleague from that Australian Institute of Management conference in 1956 was Lawrie Griffiths from Felt and Textiles, who in 1963 was elected to the Victorian Computer Society committee and also became secretary of ANCCAC (Australian National Committee on Computation and Automatic Control) which ran the national computer conference in Melbourne that year. Lawrie stayed on the Computer Society Victorian Committee until 1968 when I was its Chairman and he saw the final winding up of ANCCAC in March 1969 when its functions were handed over to ACS.

Building Structure Analysis and CSIRAC

John Russell

Synopsis

This paper offers a brief review of some engineering calculations carried out on CSIRAC in the late 1950s and early 1960s. The numerical methods used are outlined. The programs described were mainly those developed at the Division of Building Research for the solution of various structural problems which came to its attention during that period.

Introduction

The principal tools available for stress calculations early in the twentieth century were long-hand methods assisted by logarithms and the slide rule. Shortly afterwards the hand desk calculator came into being and this was followed by the electrically-operated desk machine. Other methods of solution were graphical analysis and model analysis, which still enjoyed some vogue in the latter 1950s.

Even with the electrically-operated desk calculators of that time the solution of stresses for statically indeterminate structures was a laborious task. The necessarily tedious calculations and unfamiliarity with methods of analysis undoubtedly delayed the development of this type of structure until the revolution in structural design concepts brought about by Hardy Cross, whose methods were readily adaptable for computer analysis, offering both speed and accuracy to solutions of some structural problems.

Most problems in indeterminate structures may be reduced to the solution of a set of simultaneous equations, which may be developed from structural theory; for example, in analysis of rigid frames these equations may arise from the slope-deflection theory, or they may be developed from the finite difference expression for a differential equation at a number of discrete points.

Contemporary solutions of structural engineering problems outlined in [1] and [2] were roughly parallel to the approach adopted at the Division of Building Research, where the author and colleagues were employed at the time. The advantages of a computer in structural engineering calculations were recognised in a general way by engineers, but it is fair to say that they were hardly in general use. Some examples of areas in which the computer CSIRAC was used in various problems of structural design are outlined here. Much of the information herein has previously been reported [3],[4],[5],[6], the present paper essentially summarising them. In what follows most comments relate to the scene in the latter 1950s and the early 1960s and they are undoubtedly of little more than historical interest now.

Structural Problems

Some problems are readily adaptable to solution by computer. These are quite often simple ones which require very simple types of programs. Until programming methods were improved to get more directly from the problem to its machine solution, the time for program development and hence the cost were bound to offset to some degree the advantage in using computers. It might be mentioned that the frequency of use of a particular program was able to reduce the disparity in cost.

The problems dealt with here will fall into three major areas, namely relaxation, iteration, and direct computation, with some overlap in the methods of solution used for each. CSIRAC's limitations in capacity mandated iterative solutions of simultaneous linear equations – invariably a "well-behaved" set (an empirical observation rather than a rigorous proof) – arising from rigid frame theory.

Examples of engineering calculations programmed by the author and other officers of the then CSIRO Division of Building Research are given below:

Rigid Frames
In the 1950s there came to be an increasing number of multi- storey buildings erected in Australia and structural engineers were being more frequently confronted with the analysis of these structures. The ordinary longhand moment distribution methods then used in analysis were impossibly tedious unless drastic approximations were introduced.

Standard programs [5], based on solution by successive approximation of the slope-deflection equations for each structural frame, were developed on CSIRAC for analysis of this type of structure. Separate analyses were carried out for each of the vertical and horizontal loading conditions.

For a direct vertical load system with no lateral loads, the end moment of any member *ij* for any joint *i* may be expressed as:

$$M_{ij} = 2E\kappa_{ij} (2\theta_i + \theta_j) + FM_{ij} \qquad (1)$$

where M = moment
E = Young's Modulus
$\kappa_{ij} = (I/L)_{ij}$ where I = moment of inertia
L = length
θ_i , θ_j = rotation of joints i, j
FM_{ij} = fixed end moment at ij

The slope-deflection equation may then be shown to be:

$$\sum K'_{ij} + 2\theta'_i + \theta'_j = 0 \qquad (2)$$

where $K_{ij}' = K_{ij} / \sum K_{ij}$
K_{ij} = sum of stiffnesses of all members entering joint i
$\theta_i' = \sum FM_{ij} / 2E \sum K_{ij}$

Under a lateral loading system two further equations are required.
These are:

$$\sum C_{im} (\theta_i + \theta_m) - 2\delta + \delta' = 0 \qquad (3)$$

$$\theta_i' = -3 (\kappa_{im}'\delta_m + \kappa_{im}'\delta_{im}) \qquad (4)$$

where m = number of columns in the frame
$C_{im} = (I/L)_{im} / \sum(I/L)_{im}$
θ_i , θ_m = joint rotations at each end of the storey member
δ = deflection / length = unit translation of storey
$\delta' = HL / 6E \sum (I/L)_{im}$
and H = cumulative lateral load applied at each storey

Out-of-balance shear forces result from non-symmetrical loads, or non-symmetrical frames, or both, under a direct vertical load system. These forces were calculated in the analysis under this loading system and were introduced as data under the lateral load analysis.

Programs were written to solve the series of simultaneous equations shown above by relaxation methods, that is, certain values were assumed originally for all qs and ds, the residual of each equation was calculated and either q or d then adjusted so that this residual became equal to zero. When all residuals became simultaneously equal to zero (actually a prescribed low value), the system of equations was solved. Over-relaxation was used to advantage, a value of 1.7 times the residual being often used to correct q and d; this reduced the time required for the computation of typical frames to about half that for standard modifiers.

At CSIRAC's capacity, any frame could be analysed with up to 200 joints for the vertical load or 150 joints for the horizontal load, for example, a 25-storey building with six vertical columns. The calculation times were not greatly dependent on the size of frame and were about 20 minutes for lateral load and about 5 minutes for vertical load.

The programs required only the right-hand and lower member stiffnesses, and the fixed-end moments for each joint, and the incremental lateral load and the height for each storey.

Standard forms on which these data may be tabulated were made available from the Division of Building Research. Results were presented in the form of joint rotations, storey translations, and end moments of each member. These programs were used extensively by structural engineers. The number of frames analysed varied from building to building – in some cases only one or two frames were presented for analysis, in others about twenty, with both vertical and horizontal loading modes and the resultant out-of-balance shear mode all to be taken into consideration.

For one multi-storey building the frames were actually designed by testing and modifying the beam and column stiffnesses until optimum design, as analysed by the rigid frame program, was achieved.

The programs proved so popular among consulting engineers that on the demise of CSIRAC they were reprogrammed for an Elliott 803 and later for CSIRO's Control Data machines.

Multi-storey Frame containing Shear Walls
An extension of the lateral load rigid frame analysis was made to include an estimate of the effects of shear walls.

The method used is described by Benjamin and Williams [7]. The adjustment required is to modify equation (3) to:

$$\sum C_{im} (\theta_i + \theta_m) - \delta\{2 + L_{im} / 6E \sum (I/L)_{im} / (1/AG + L_{im}^2 / 3E_w I_w)\} = 0 \quad \ldots (5)$$

where A = plan area)
G = shear modulus)
E_w = Young's Modulus) of shear wall
I_w = moment of inertia)

This method was used for optimum design in analysing one frame tested by the rigid frame programs.

Grid Frames

An extension of the rigid frame analysis for plane frames is the grid frame analysis of flat slabs and plates, in which a slab is regarded as a rectangular grid of members equivalent in stiffness to the portion of the slab they represent, and loads and column reactions are regarded as point loads applied at the intersections of the members. The basic variables involved are d_i, the deflection of the lattice point i normal to the frame and q_i and f_i, the rotations of the lattice point in two orthogonal directions.

For a rectangular lattice three equations may be evolved for each lattice point. These are:

$$P' - \delta_i + \sum K_{ij}'' \{\delta_j - 1/2\ (\theta_i + \theta_j)\} = 0 \quad \text{.......(6)}$$

$$2\theta_i' + K_{im}' \{\theta_m' + 3\ (\delta_i - \delta_{-m})\} + K_{i,-m}' \{\theta_{-m}' + 3\ (\delta_i - \delta_m)\} = 0 \quad \text{.......(7)}$$

$$2\varphi_i' + K_{ij}' \{\varphi_j' + 3\ (\delta_i - \delta_j)\} + K_{i,-j}' \{\varphi_{-j}' + 3\ (\delta_i - \delta_{-j})\} = 0 \quad \text{.......(8)}$$

where θ_i' = rotation in direction of abscissa
φ_i' = rotation in direction of ordinate
$P' = P/12E \sum(I/L)_{ij}$
$K_{ij}'' = (I/L^3)_{ij} / \sum(I/L^3)_{ij}$
$K_{ij}' = (I/L)_{ij} / \{(I/L)_{ij} + (I/L)_{i,-j}\}$
P = load)
E = Young's Modulus)
I = moment of inertia) of grid member
L = length)

Programs were devised to solve grid frames of up to 100 lattice points by relaxation of the above expressions. The rather involved constants were calculated from the basic slab data by a separate program and the end moments in the lattice members were produced from the δ, θ, and φ solutions by another program.

Torsional moments were allowed for in a separate program but this reduced the maximum number of lattice points to 75. A further program for uneven lattice spacing was also developed.

There is a much slower convergence resulting from these equations than where the slope deflection equations are applied to the analysis of rigid frames, the time taken for solution being about 30 minutes for a plate on 16 columns.

The major use of these programs was in conjunction with experimental investigations of flat plate structures then being undertaken at the Division of Building Research. The applications for commercial use were doubtful, except that deflections at all node points were supplied.

Simultaneous Equations

It was found possible to generalize some of the previous programs to provide a method for solving simultaneous linear equations, this method being sometimes more rapid than those based on more conventional mathematics (e.g. matrix inversion). The greater speed is obtained only if the system is rapidly convergent, and as the rate of convergence varies with the type of problem it is difficult to give an accurate estimate of the time required for solving a particular problem.

This method finds its most convenient use in solving a set of equations in which the system of unknowns appears as a band matrix when the problem is formulated systematically. One virtue of the method is that the zero coefficients need not be punched as data, and greater speed is achieved in the calculation because time is not wasted, as in conventional mathematical methods, by carrying out arithmetical operations with zero coefficients.

Using this program a complete set of seven simultaneous equations arising from a multi-bay portal frame was solved in less than one minute, and a banded set of 35 equations each containing eleven variables was solved in fifteen minutes. The latter set resulted from the finite difference equations for an irregularly shaped slab.

By comparison with later computers these speeds were very slow, but at the time they were sufficiently fast for further refinement and speed to be of little value for most structural engineering purposes.

Portal Frames

Slope deflection equations were used to formulate the elastic analysis of a 4-bay, pin-based portal frame. This required the solution of 19 simultaneous equations, and the total time to produce moments and deflections was about 10 minutes.

Some attempts were made to investigate the problem of multi-bay portal frames using plastic theory, but little success was achieved on CSIRAC. It is interesting to note that, shortly afterwards, the problem was found to be amenable to linear programming techniques [8].

Flat Slabs and Plates

Where optimum behaviour of a flat plate structure in the sense of minimum deflection and cracking is required, the reinforcement should be distributed in proportion to the elastic moments M_x and M_y at every point. If the structure is prestressed, this distribution will also satisfy the criterion of zero deflection at every point at a particular load. It can also be shown that this optimum distribution can be introduced without introducing additional reinforcement.

One method of determining the moments is by introducing a substitute problem with identical loads and boundary conditions, but an additional function which represents an auxiliary elastic foundation must be introduced into the governing equation.

The columns for flat slab construction are generally laid out on a rectangular grid with a specified ratio of sides, for example, 1:1 (square grid), $1{:}1^1/_2$, 1:2 and so on, or if L is the column spacing in the direction of the abscissa, and pL the spacing in the direction of the ordinate, then the ratio of sides will be p:1.

The general analytical method used requires the calculation, for a point load P of:

$$M_x = \sum_{y=b}^{\infty} (M_t \sin^2 \theta + M_r \cos^2 \theta) \quad \text{...(10)}$$

and $$M_y = \sum_{y=b}^{\infty} (M_t \cos^2 \theta + M_r \sin^2 \theta) \quad \text{...(11)}$$

where M_r (= P m_r) = radial moment caused by a single load or reaction
M_t (= P m_t) = tangential moment caused by a single load or reaction
θ = angular polar coordinate, measured from the positive x-axis
b = radius of column head)
x = radial polar coordinate), these in terms of abscissa column spacing

The values of m_t and m_r are obtained from the solution of the modified biharmonic equation $D\nabla^4 w + \xi w = q$, with appropriate boundary conditions and are:

$$m_t = -\frac{1}{2\pi x}\,\text{kei}'\,x$$

and $m_r = \frac{1}{2\pi}$ (kei' x + ker x) , which are dependent on x alone.

D and q have their usual meanings, and ξ is a term of small magnitude.

For the ring moments due to the column heads, two expressions for M_x and M_y similar to (10) and (11) may be derived.

The geometry of the centre of each column head in the plate, with reference to the point at which M_x and M_y are required, is given by:

$$\bar{x} = \sqrt{\{(n\,p\,l +/- x_0 \sin\theta_0)^2 + (m\,L +/- x_0 \cos\theta_0)^2\}} \quad \text{.............................(12)}$$

$$\sin\theta_0 = \{npl \pm x_0 \sin\theta_0\}/\,\bar{x} \quad \text{..(13)}$$

where

x_0, θ_0 are the radial polar coordinates of the centre of the nearest column head

2m, 2n are an integral number of columns in the abscissa and ordinate directions respectively, and the +/- signs in (12) and (13) are used in the appropriate quadrants.

The moment functions m_t and m_r may be calculated at discrete intervals from tables of the Bessel-Kelvin functions kei'x and ker x , as the generation of the infinite series for the latter function was, at the speed of CSIRAC, prohibitive in terms of time. For the argument range (0,2.50), however, each infinite series could be replaced by the first six terms with no significant loss of accuracy.

For the argument range above 2.50 a method of curve fitting devised by Holden [9] and requiring the calculation of zeros of Chebyschev polynomials was used.

One calculation (plate geometry plus moment calculations) required approximately two hours. The moment behaviour was calculated and graphed by producing the above calculations for sufficient points in the central section of the mesh. One quadrant of this section was considered sufficient to illustrate the moment behaviour for a single panel, and by taking the values of L = 1 and p = 2/3 and 1, and using the principle of superposition, the moment behaviour for a wide range of panels was investigated.

These programs were used constantly to produce the required design data for the distribution of reinforcement in flat plates.

Construction Loads in Multi-storey Slab

Of some interest in building constructions is the case of multi-storey structures in which a series of poured-in-situ floors have to be supported while the concrete is at an early age It is customary for each floor to be supported by the floor beneath it and as the concrete in the lower floors gains sufficient strength the supporting formwork is removed.

Precise knowledge of the least time necessary to keep the formwork in place is of value in reducing costs, both in saving formwork and in allowing the floor area to be clear for subsequent building operations.

An analysis of this type of problem involved the calculation of a large number of relatively complicated parameters, which for any one case resulted in a large amount of tedious computation. These parameters were then used to determine the relative loads carried on each floor as a multiple of the dead weight. The CSIRAC interpretive language Interprogram was used for this work, each calculation being handled in a few minutes from the basic slab dimensions, the formwork constants, and the concrete data.

The calculations were correlated with site measurements.

Conclusion

The particular problems referred to here as being solved by using CSIRAC were by no means unique to it or even necessarily to computers. A major objective was been made to draw the attention of design engineers to some computer services then available, acquainting them with the way standard methods could be modified to become amenable to computer processing, and to illustrate the speed with which routine computations may be carried out with these machines – naturally at the time with particular reference to CSIRAC. Other programs for engineering calculations were available even then on other computers, and later integrated engineering packages enjoyed some vogue.

The programs referred to here were only those with which the author had direct association, in some cases the programs were devised by others and in others the author collaborated extensively with colleagues.

Acknowledgments

F A Blakey and F D Beresford were major collaborative workers on the rigid-frame problems. J F Brotchie was responsible for the theoretical basis of the flat plate analyses. W L Gamble collaborated with the author on the 'plastic hinge' solution of portal frames. All were at the time officers of the CSIRO Division of Building Research.

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CSIRAC as an Aid for the Production of Solar Position and Radiation Tables

John Spencer

The major project for which I used CSIRAC was the production of Solar Position and Radiation Tables for the Australian capital cities. The direction of the sun relative to horizontal and to vertical surfaces facing 36 different directions at 10 degree intervals was tabulated for hourly intervals on a selected day of each month, chosen to include the summer and winter extreme values. Estimates of direct and diffuse solar radiation incident on the same surfaces under clear sky conditions were also tabulated. Tables of sun-rise and sunset times and of sun arrival and departure times on the vertical surfaces were also provided, the final publication for each location running to about 80 pages.

John Spencer began work with the CSIRO Division of Building Research in 1959 and used CSIRAC until it was dismantled in 1964 for computations associated with the measurement of solar radiation and the calaculation of radiation tables. Here he is shown in a later photograph at CSIRO (Highett, Melbourne) adjusting the shade ring on solar radiation measuring equipment.

Preliminary work involved fitting power series to establish empirical relations between the sun's height above the horizon and measured radiation data. It was found necessary to write an inverse sine routine to extend the capability of the existing CSIRAC library routine, and to write routines for outputting angles in the formats required in the publication.

Certain intermediate results which depended only on the place for which the tables were to be calculated were checked and then punched on 12-hole tape. These were then stored on the drum. With the drum writing power

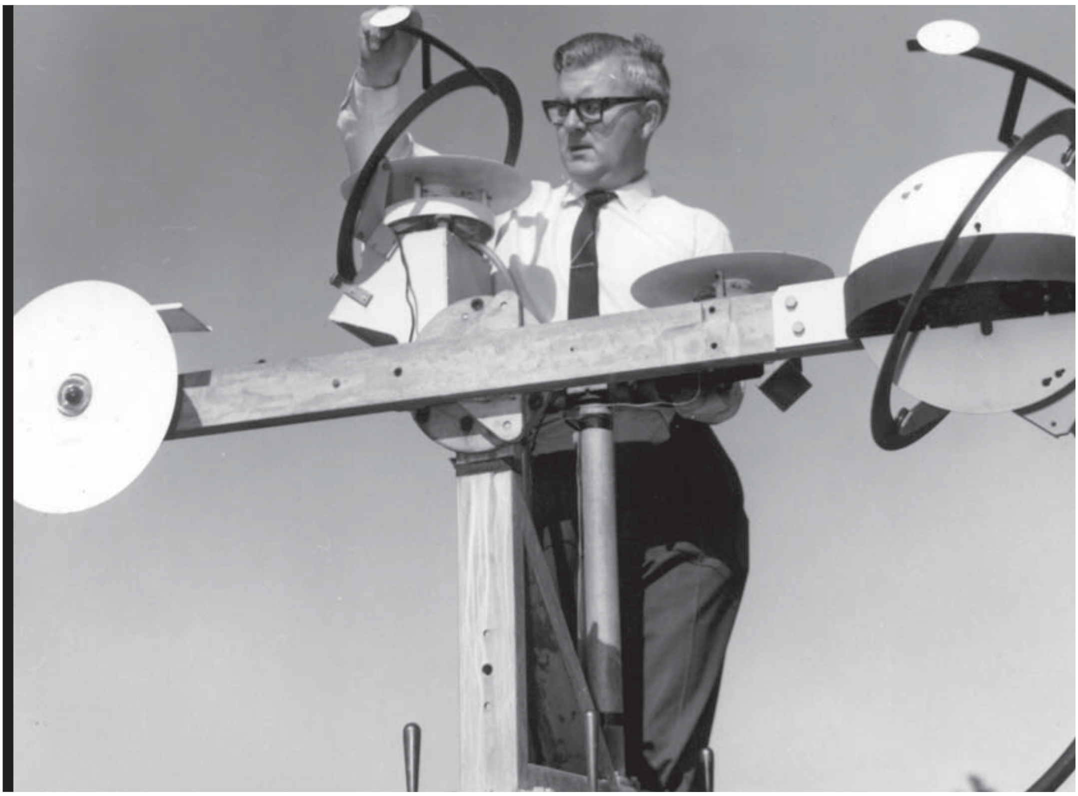

Photo: John Spencer

turned off, these results would remain secure as long as needed. Further calculations for the same place could then be carried out on subsequent occasions just by reading in this data tape again.

To maintain the integrity of the program a "cross-product" check which used the content of each cell containing the program in a continued multiplication with overcarry and yielded a unique result which changed if the content of any of the cells changed was used. The correct result was punched on the program tape and checked whenever the program was input, and subsequently at intervals of about half an hour. The program was arranged to halt if the check was not satisfied, and results obtained since the last correct check (which were suspect) could be discarded. On occasions, the program would halt with an illegal instruction displayed on the lights. One could then record the value in the sequence register, and by comparing with the program listing ascertain whether digits were gained or lost at that location. This information, recorded in the log, could later assist the engineers in locating the fault. It was generally felt that if the digits were being lost that the situation might be improved by increasing the voltage setting with the panel control, and conversely if digits were being gained by decreasing the voltage. I have known occasions when this approach seemed to work, so there may have been something in it. However there were many occasions when it did not help, but at least you felt that you were trying to do something!

Each individual result to be output was calculated, stored, and then recalculated. If the two results agreed, the result was output to the punch. If the two results did not agree a short hoot on the speaker was given, and the process was repeated until successive calculations gave the same result.
This placed me in a very good position to assess how the machine was performing – a single hoot about once an hour could generally be disregarded, frequent multiple hoots usually meant that one might as well pack up and go home! However there were many occasions when the machine operated faultlessly for six hours or more.

It was found that even taking the above precautions was not sufficient to ensure error-free output – for example they did not check for errors in the paper tape punch and in printing from the tape on the Flexowriter. The final step was to carry out the whole process twice and compare the printed results over a light box. It was usually easily possible to decide which was correct if there were minor discrepancies, but on the rare occasions when this was not possible a third calculation of the offending part was used to settle the matter.

The amount of input required for the program was so small that it was normally entered in the NB register via the console switches. The result, converted to decimal, was then printed on the console teletype, and the program paused so that the values could be checked and if necessary corrected. My 32-scale arithmetic was not always perfect!

The output however was another matter. It soon became evident that reeling up large quantities of paper tape from the bin, which was tolerable occasionally, was a very onerous task. We found that 16mm film spools held the 5-hole tape perfectly, and a supply of these was obtained. An old 78rpm gramophone motor, mounted in a wooden box, provided with a slipping clutch and adapted to take the 16mm film reels proved to be an ideal solution. This was used on most occasions, but in the interests of higher production it was

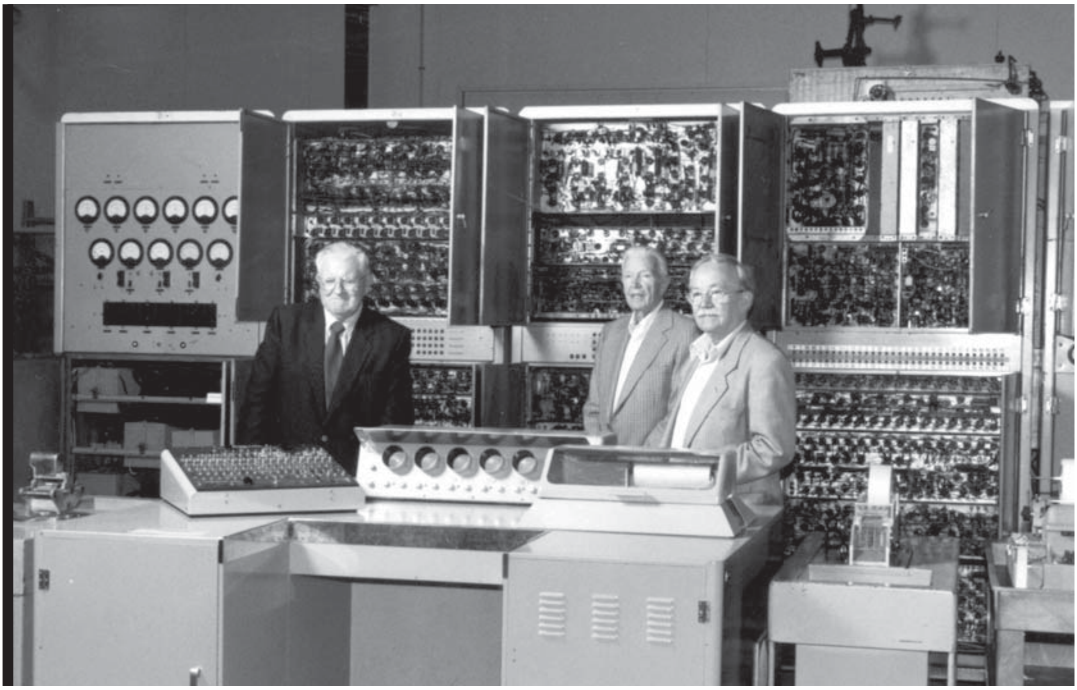

Photo: Museum Victoria

John Spencer (left) in front of CSIRAC at Museum Victoria. In 1998 John wrote an emulator for CSIRAC to run on a modern personal computer and used it to simulate CSIRAC programs. He played a major part in recreating music first generated on CSIRAC in the early 1950s and collaborated with Paul Doornbusch to simulate the early "sounds of CSIRAC". (L–R) John Spencer, Ron Bowles, Jurij Semkiw. 26 November, 1999.

sometimes possible to drag the Flexowriter round to near the punch and lead the output tape directly to it. Good for production, but very noisy!

My times of operation were normally 8.00pm to midnight or midnight to 4.00am, though these could easily be extended if there was no-one to follow. Generally four or five hours of production was enough, though the boredom could sometimes be alleviated thanks to the library of Astounding Science Fiction which often helped. Long sessions were usually undertaken when program testing, as the urge to get rid of the last bug overcame tiredness. I remember one mammoth session when I started at 8.00pm, farewelled the staff at about 8.30pm, and was still hard at it at 10.00am the following day when they arrived back.

CSIRAC was completely a "hands-on" operation – if the machine was off when you arrived it was necessary to power it up; during running one had to reload tape in the punch, empty the chad container, and occasionally replace the burnt out globes in the tape readers. If no-one was following when you had had enough you powered the machine off before going home.

After CSIRAC was decommissioned in 1964 there followed a period of 15 years or more where one rarely saw the computer one was programming, let alone operate it. It was of great delight to me when PCs were developed to the stage when programs of mine that had run on the large CSIRO computers in Melbourne and Canberra could be run on one's own desk-top machine. "Hands-on" operation again, thank goodness!

The Australian Computer Museum Society: The role of multidisciplinary voluntary organisations in modern industrial and socio-technical history

Marcus Wigan

Abstract

Computers and information processing have, in the course of two generations, moved from being a highly specialised and largely secret technology to powering a fundamental empowerment of the broad community. This has been a shift from a few highly specialised installations to where the average new home computer configuration has now become more powerful than the average computer bought by business.

The first generation from roughly 1945-1970 saw the establishment of government and business data processing, but the generation covering the period from 1970 to date has seen the democratisation of information and information processing power and a substantial shift from calculation to communications and symbolic processing. This social sea change has been signalled by a small number of early adopters, largely amateurs and voluntary organisations.

Computing is a very fragile technology in historical terms, as the hardware on its own is largely symbolic of the history, and the major importance lies not in the engineering but in the combination of software and hardware that was required to realise the systems as a whole. The shift from hardware to software comprising the major contributions in computing has not been matched by the capture of the software, and the ability to deploy it depends on what is now historical hardware. The enthusiasm and competence to enable the old hardware to run the software written for it, and to ensure that the old hardware can actually be operated successfully to do so, is a major mission for voluntary organisations such as ACMS.

While the formal recognition of the need to capture hardware, software and oral history of the computer and software era is being slowly recognised, a major part of the knowledge and expertise lies with voluntary organisations. The ACMS is working to ensure that hardware, software and the expertise to capture and document computer history is undertaken in time, and before the fragile magnetic media fades.

A WWW site has been set up for Virtual Curators to make common cause to be made with modern historians and sociologists, with the disciplines of computer science and engineering, information science and software engineering. The enthusiasm, expertise and communications competences that can be marshalled through voluntary societies such as the ACMS has a major catalytic and action role which complements the celebrations of the start of Australian computer history.

Context

- The rate of change has been very rapid
- Machine-dependent records
- Records require operating old computers
- The hardware and software are vanishing
- People are a key component of conservation
- Modern history includes social impact
- How do we capture the essence?

Computing software and hardware have maintained a very high compound rate of growth for many decades. The earliest systems such as CSIRAC and SILLIAC (and even the next generation of early systems) were comparatively few in number, and the written and printed records are very limited. Although the curve hit the hundreds of thousands in the early 1980s, this growth has left much of the software and hardware in the disposal bin.

The software required to operate these systems was tied to a large extent to the hardware itself, until standards began to emerge in the form of magnetic tapes and 8" and 5" format floppy discs. Much of this software and documents, created using software held on these and other formats, was not transferred to storage media formats readable by the successor generation of systems.

The importance of the people and the software in the creation and use of computing equipment is often ignored. However, there existed an entire culture which involved the application and communication of the skills that made computers actually operate and solve problems. The memories of the people involved are a vanishing but major aspect of computing – and a major conservation issue to be addressed in modern industrial history.

Computers in context

- Initially rare, expensive, secured and centralised (Mainframes)
- Next, widely available at Departmental level (Minis)
- Then, the personal computer as a technical hobby (Altair, S-100)
- Latterly, personal computing as information power and control (TRS80 to Mac/IBM PC)

Computers have changed their role as they have improved in capability and reliability, and increased in number. The public perception steadily altered as this process proceeded. The CSIRAC period was one of inaccessible computing and a numerical calculation orientation. The users were as a result mainly the engineers, mathematicians and scientists who could obtain direct access. Few of these machines have remained, CSIRAC was one of them.

Although this changed as financial and business applications expanded, but the next major general change was to accessible smaller ('mini') computers when more than one computer in an organisation become common. The personal computer emerged at about the same time (Altair, etc), but was the province of the technical and electronically skilled users, thereby recapitulating much of the early mainframe history. The first electronic bulletin boards emerged as the purely technical aspects of these machines were mastered, the first in the southern hemisphere being constructed by the Micro Computer Club of Melbourne (MICOM) in the early 1980s.

After several partly-successful starts (Apple II, TRS-80, Commodore Pet, etc) IBM and Apple made machines that established a totally new market of broad-band truly personal computers. The broad access to personal information and control is still mediating social change, and is already in a second wave through easy many-to-many communication through the Internet.

Computer museum roles

- Obtain and conserve hardware
- Obtain and conserve documentation
- Obtain software and make it workable
- Integrate hardware, software to function
- Bring together the hardware, software and knowledge to recreate the experience
- Place the capacities and capabilities in their social context

A computer museum cannot be a simple collection of pieces of hardware. A computer is a combination of hardware, software and programs – and has little significance without some understanding of the problems to which they were applied, and the context in which they were used and viewed.

A museum should therefore aim to secure hardware, software and documentation – and make the whole system work. This requires storage systems to be functional, and the storage media to be functioning.

This is a demanding set of goals, and the tasks to be addressed to make a functional computer museum are well defined. An acquisition policy is needed, and the necessary materials located and secured. Storage must be secured. The equipment must be restored or otherwise made complete and functional, and the system brought into operation so that it can access its own machine-specific software and execute programs.

The roles of museums that are less obvious to the public at large are the function of recording and integrating the social context in which the computers were operated and contributed (or not, as the case might be).

The construction of displays for educational or public display requires all these tasks to be undertaken, although it is not usual (at present) to have the display containing functioning older computers, for the practical reasons of maintenance and security – and the equally problematic issue of manning such displays for interchange with the interested public.

Tasks

- Acquisition
- Storage
- Restoration
- Bring into operation
- Record and integrate social context
- Communicate this to the community

The tasks to be addressed to make a functional computer museum are well defined. An acquisition policy is needed, and the necessary materials located and secured. Storage must be secured, the equipment must be restored otherwise made complete and functional, and the system brought into operation so that it can access its own machine-specific software and execute programs.

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Who has a role in creative conservation?

- Official conservation bodies
- The computer and software industries
- Official educational bodies
- Voluntary organisations
- Individuals

The tasks and goals for a computer museum are demanding, and knowledge intensive. Who should take up these roles and tasks? Are there any groups or organisations able and willing to share in these tasks?

Official conservation bodies do exist – but tend to look towards conservation of the physical aspects of the computers. This is a valuable, but incomplete role. Museums such as Powerhouse and Scienceworks tend towards this model, due to storage, display space and curator resource limitations.

The computer industry itself has not proved to be very responsible conservationists, with major individual exceptions such as Digital (who have an official Museum Curator in Max Burnet: another of the founder members of the ACMS).

Educational bodies have generally not taken the initiative, although individuals have been active sporadically. The future seems most likely to be secure in the hands of voluntary societies and of individuals, complementing the formal museums. Many individuals have collections of equipment and software, and the skills to operate any of these machines, and the ACMS is a voluntary society aimed at filling these emerging gaps.

Information access and control

- CSIRAC etc for computation and cryptography
- Leo etc for financial management
- Burroughs for high level languages
- Unix (AT&T) for communications
- IMS etc (IBM) for databases
- Personal computing for personal information access, management and control

There are many different ways of organising and selecting significant computing systems. It is important to note that some of the major conservation needs are for significant pieces of software, only some of which can realistically be conserved in a functioning form due to both systems and copyright issues.

One possible axis is the progress from pure computation and cryptography (CSIRAC is in this category), through broader-band microcoded business-oriented machines such as the Leo, on to machines with high level languages as the basic structure (such as the Burroughs series of machines).

This perspective then shifts to a software orientation, with Unix and large scale databases becoming more important than the machines on which they run, and then on to a recapitulation of the process as personal computers progressed through the same cycle again at a vastly accelerated pace and a far wider penetration into the community. At each stage the impacts are different, and affect a progressively wider and wider community.

Many other perspectives are equally appropriate, but this illustrates the diversity of display and themes possible once a software+hardware+social view is taken.

Virtual curators

- http:4/10/99/www.csirac.edu.au
- Virtual Curator requirements to be met
    - house and make operative a specific system
    - prepare a web page to describe and display it
    - to pursue relevant contextual information
    - to communicate and support others with the same types of system

The combination of voluntary and formal organisations offers a positive and creative series of opportunities. The most significant is the possibility of a Virtual Curator, who will usually be an individual with a strong interest in a particular historical machine, keeping it operative with software and knowledge.

A Virtual Curator is a concept which directly addresses the problems faced by formal museums. It ensures that the physical storage problem is alleviated, the scarce human resources of the museums are complemented by individuals with the interest and skills required, and also creates a basis for a clearinghouse to ensure that old machines are not simply stored and forgotten.

An essential component of a Virtual Curator process is a networked communication required to ensure access, display and discussion on the exhibits. The ACMS in Victoria has been donated a Sun3 on the La Trobe University backbone by the Department of Computer Science and Engineering to host a World Wide Web site for Virtual Curator members of the ACMS and its affiliates to install their displays, handle communications with interested parties, and provide a basis for the clearinghouse for interested individuals to participate in the curation, communication and conservation processes.

Qualitative research

- Working systems are only part of the story
- Conservation, archiving and recovery of records on obsolete media
- Development of educational material
- Interviews and other records of social and personal contexts of such systems
- Cooperation with archivists, librarians, sociologists and historians

The role of a curator is ideally considerably more than that of a storage clerk and cataloguer. Bringing up working and documented systems is only the first step in effective curation of such community assets.

Archivists and librarians are increasingly encountering very real problems of lack of access and storage integrity to some of their master records held on computer readable media. Access to these materials – often unavailable in any other form – requires computing systems capable of driving the obsolete or obsolescent storage devices, and running the software required to retrieve the information. In areas of data storage there are now many key numerical data sources held in such totally inaccessible formats as compressed SPSS system files written by the offbeat CDC Cyber series with their peculiar character and word representation conventions. These are typical of historical master archives rendered useless by the passage of working systems and software. Operating systems and software typical of the period reveals a great deal about the era in which the systems were used, and is a basic component of the educational and historical record. Only an active museum society can hope to keep a wide range of such skills in currency. The rising roles of historians, cliometricians, industrial economists and sociologists in interpreting recent history also stimulates a need for a major and active involvement in such associations, and participation and support of such qualitative and quantitative research is becoming a prime (yet still currently largely ignored) function of a modern computer museum or society.

Partnership

- Virtual Curators bring expertise and storage
- WWW provides a communication nexus
- The WWW offers a complete display capacity for text, film clips, pictures etc.
- The modern history and the science and social historians that lends such depth and value to this activity can be brought together through this framework

The framework of Virtual Curators and the WWW communication and display policy provides a constructive and highly effective method to address some of the current problems of formal museums when dealing with information technology.

The skills of display and information assembly on line can be combined through the WWW to realise an active partnership with the museums. The community concerned with the fragility of computing records and history are not limited to technical, business and scientific people: sociologists and historians are also becoming actively involved. Modern history has a high and increasing dependence on computer records, and the impacts of computing systems over the last half century have become pervasive and fundamental. The development of these impacts and changes, and the roles of individuals in both the technical and the usage of computers and software to manage information as well as computation is moving inexorably to centre stage in modern history.

However, given the problems of researching the more active model of a museum, which requires substantial expert manpower, the active model is probably increasingly beyond the reach of most museums, and even most specialist collections. The key resource is the knowledge and expertise to keep the combination of hardware and software actually operating. Clearly a new model is needed for a fully functioning computer museum.

The ACMS sees an expanding partnership between museums, industry, education, voluntary organisations and individuals – and the Virtual Curator and WWW communications support will be a major contribution towards making the efforts of all more effective.

CSIR Mk1 in Radiophysics Laboratory, Sydney. (L–R) Geoff Hill and Trevor Pearcey. 6 June, 1952.

About the Contributors

John Bennett

John Bennett graduated in civil engineering, then after four years in RAAF ground radar, graduated in mechanical and electrical engineering, then BSc, from the University of Queensland. He later completed a PhD in the UK. He entered the field of computing in 1947 as a member of the team which built the Cambridge EDSAC. From 1950-1955 he worked for Ferranti Limited, initially in Manchester then London. In 1956 he joined Harry Messel in the School of Physics at Sydney University to head operations of the computer SILLIAC. He was appointed Professor of Computing Science at Sydney University and played a major role in the development of computing in Australia. He was foundation Chairman of ANCCAC, President of the New South Wales Computer Society, foundation President of ACS, Vice-President of IFIP and Secretary General of ICCC. Author of many papers and reports on computing he retired in 1986 and is currently Emeritus Professor and Honorary Associate of the University of Sydney.

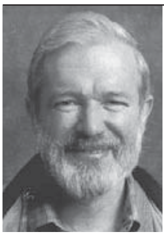
Don Beresford

Don Beresford holds a Fellowship Diploma in Applied Physics from the Melbourne Technical College (later RMIT), is a Chartered Professional Engineer (MIE Aust) and a member of the Institute of Concrete Technology, UK. He is a life member of the Concrete Institute of Australia. He retired in 1988 after 37 years with the Building Research Division of CSIRO holding the rank of Principal Experimental Scientist. Interests included instrumentation, structural engineering and materials technology. The power of CSIRAC to cope with the protracted design and analysis of structural frameworks was recognised as the tall building boom developed in Australia from 1960 onwards. Beresford, in conjunction with John Russell, wrote programs which were utilised in some dozens of these structures during the sixties throughout the major capitals of Australia.

Ron Bowles

Ron Bowles had four years service with the RAAF during WWII in the radar section and afterwards studied at the Melbourne Technical College (later RMIT) under the Commonwealth Reconstruction Training Scheme, graduating with a Diploma in Radio Engineering in 1950. In May 1951 he joined the CSIRO Division of Radiophysics in Sydney and worked on research projects using radar equipment before joining the Computation group in 1954 as Chief Maintenance Engineer of the Mk1 computer. The following year he was part of the team involved in its transfer to the University of Melbourne. After the official handover of CSIRAC to the University of Melbourne in June 1956 he transferred to their staff to continue as chief maintenance engineer of CSIRAC until its replacement in 1964 with an IBM 7044/1401 configuration. He stayed with the Computer Centre as operations manager and deputy operations manager until retiring in 1982. He was a foundation member of the Victorian Computer Society and is a Senior Member of the Institute of Radio and Electrical Engineers.

Allan Bromley



Allan Bromley was born in Windsor, NSW, and educated at Freemans Reach Public School (a classic country single teacher school) and Richmond High School. He studied Physics at the University of Sydney, taking a BSc with First Class Honours in 1968, and a PhD in Theoretical Astrophysics in 1972. He then joined the Basser Department of Computer Science and worked in Computer Architecture and Digital Systems Design. In 1979 he took study leave at the Science Museum, London, where he developed a strong interest in the design of mechanical digital computers, the Difference Engine and Analytical Engine, by Charles Babbage in the mid-nineteenth century. He initiated the project to build Babbage's Difference Engine No.2 to commemorate the bicentenary of Babbage's birth in 1990. He has also worked on the Antikythera Mechanism, a geared calendrical calculator from about 50 BC. He has taught and researched widely in the history of digital and analog computers. His hobbies include collecting (just about everything), books, electronics, painting, and jogging.

Max Burnet

Max Burnet graduated with a BSc(Hons) in Electronics from the University of Melbourne in 1962, then worked at the Weapons Research Establishment in Adelaide for 4 years before joining Digital Equipment Corporation in 1967. He started Digital's Melbourne and Perth offices and was Australian Managing Director from 1975 to 1982. He was Digital's longest serving employee and ensured that the company was a good citizen in Australia by achieving local content and export credits. For 23 years from 1971 Max managed Digital's liaison with DECUS, their user society, which became Australia's most successful user society with over 4000 members. He organised a museum of all early DEC computers and earned the nickname "Museum Max". In July 1993 he was one of 15 pioneers featured in Computerworld's "Pioneers of Australian Computing". He retired from Digital in March 1998 just prior to the Compaq takeover. He is currently using his industry knowledge and contacts to help Australian technology companies with their strategy and marketing. He has also formed BACK (Burnet Antique Computer Knowhow), with the aim of keeping old computer systems alive, and offering media transfer and update services.

Barry Butcher

Barry Butcher is an historian of science and technology and completed a doctoral thesis at the University of Melbourne in 1992 on the reception and impact of Darwinism in Australia. He has taught at Deakin University, Geelong, Victoria since 1984. He has presented papers and published a number of articles on the history of science in Australia and is currently engaged in writing a history of the CSIRO Animal Health Laboratory at Parkville which is based largely on oral history sources.

Matthew Connell

Matthew Connell was educated at Pimlico State High School, Townsville, North Queensland and graduated B App Sc from The Queensland Institute of Technology, Brisbane in physics in 1980. He worked initially in exploration seismology for a geophysical exploration company, followed by microelectronics research at RMIT in the Microelectronics Technology Centre from 1983-1986. He then worked as a computer systems manager at the University of Technology in Sydney. In 1991 he was appointed curator of computing and mathematics at the Powerhouse Museum and is currently building a longterm exhibition around the topic of information technology with an emphasis on what it means to live in the information age.

Arthur Cope

Arthur Cope served with the RAAF during WWII and graduated in 1949 from RMIT with a Fellowship Diploma in civil engineering. After initial employment with the SR&WSC and the CRB on the design of water supply and road works he joined the Victorian SEC. He worked on the investigation and development of major brown coal open cuts and thermal power stations in the Latrobe Valley and hydroelectric works in the Kiewa Valley and Snowy Mountains. The selection of the optimum plant mix for expansion of the Victorian generating system also involved investigation of system interconnection with NSW, SA and Tasmania. To determine the type of plant best suited for expansion of the generating system, a program for loading of the system was developed using CSIRAC. These studies later served to develop more advanced programs for system simulation in line with the capacity of computers available. He has been associated with papers on Power System Planning and related subjects published by IE(Aust), IEEE, Power and Apparatus and Eighth World Energy Conference. He retired in 1984 as Principal Planning Engineer of the Victorian Generating System.

John Deane

John Deane graduated from Macquarie University with a BA in mathematics. After working as a commercial programmer for Tooth & Co from 1972-1974 he joined CSIRO Radiophysics as a system programmer making use of a PDP-15. He worked on radio astronomy projects for the Narrabri Heliograph, Epping 4m Telescope and Parkes 64m Telescope using microcomputers, PDP-11s, VAXes and SUNs. In 1980 he co-authored two computing books for Dick Smith Electronics and in 1984 wrote ‘A Picture History of Radiophysics’ after accidentally learning about CSIRAC. He joined CSIRO’s Australia Telescope project in 1985 and developed its Antenna Control Computers. Since 1991 he has worked in the telecommunications group. In 1996 he became a member of the Australia Computer Museum Society and wrote ‘CSIRAC – Australia’s first computer’. He next wrote ‘BABY – the first modern computer’ and was one of four runners-up in the University of Manchester’s 50th Anniversary of Computing BABY programming competition.

Bill Glasson

Bill Glasson graduated from the University of Adelaide in 1954 with a Bachelors degree in Electrical Engineering. After further work to gain a Masters degree and two years with ICI Central Instrument Laboratory at Pangbourne in England he joined ICIANZ in 1959. In the same year he began a brief association with CSIRAC when he used it to calculate the dynamic behaviour of processing units in a chemical plant. Like many other clients of that time he learnt the basics of programming on CSIRAC, wrote a program, used it to process data and wrote a report on the methods and results. He was a founding member of the Victorian Computer Society. He retired in 1995 after a career which evolved through research, operations, management and corporate planning.

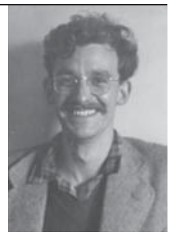
Alan Head

Alan Head was educated at Ballarat CEGS and Scotch College and graduated with a BA in mathematics and physics from the University of Melbourne and a PhD from Bristol University. He has worked as a Research Scientist in various Divisions of CSIRO starting with the Division of Aeronautics in 1947 and retiring from the Division of Materials Science in 1990. His major work was in solid state physics and applied mathematics. After a brief acquaintance with CSIRAC around 1950, and again in 1955, he became a regular user in the late 1950s. Since retiring from CSIRO, he has continued the association as an Honorary Research Fellow. He is also a Fellow of the Royal Society of London, Australian Academy of Science, International Congress on Fracture and Australian Institute of Physics. His current computer interests are mainly computer algebra systems and their applications in physics and applied mathematics, particularly Lie symmetry analysis of differential equations.

Frank Hirst

Frank Hirst was educated at Ivanhoe Grammar School and Melbourne University, graduating in chemistry and physics. After war service in the RAAF he completed a MSc and a PhD in nuclear physics. From 1952-54 he worked as a nuclear physicist at AERE in Harwell, England. On returning to Australia he was appointed Senior Lecturer, then Officer in Charge, of the Computation Department at the University of Melbourne from 1955-1969. His association with CSIRAC began when he supervised the dismantling of the computer in the Radiophysics Laboratory in Sydney in 1955 and had it transported to the University of Melbourne. He subsequently supervised the operation of CSIRAC until its decommissioning in 1964. In 1970 he became Reader in Charge of the Department of Information Science (now Department of Computer Science) at the University of Melbourne. In 1972 he was appointed Professor of Computing Science at the University of Adelaide and retired Professor Emeritus in 1984.

Terry Holden



Terry Holden has a BSc in physics and radiophysics from the University of Melbourne. He joined CSIRO Lubricants and Bearings Section in 1945, and moved to CSIRO Division of Building Research in 1946. After a research project on the effect of the floor on foot comfort, he worked on various aspects of heat transfer in houses. This involved experimental work and mathematical modelling, and the search for efficient methods of handling the relevant data led to using the CSIRAC computer at the University of Melbourne, and subsequently to the design and construction of a digital data logger. During this period he also lectured part-time in mathematics and Algol programming at RMIT. He was a foundation member of the Victorian Computer Society and he is a Fellow of the Australian Computer Society. In 1964 he moved to Canberra to the CSIRO Division of Computing Research (later CSIRONET) and worked firstly on operating system development, then on design and management of the computing network, and later become Assistant Chief. He retired from CSIRO in 1984 and entered the private sector and from 1987 became an independent computing consultant.

Christopher Jack

Christopher Jack graduated with a BA and Dip Ed from La Trobe University and a Graduate Diploma of Archives & Records from Monash University. He has worked as an archivist with the Australian Science Archives Project (ASAP) since early 1995. He has documented the records collections of Australian scientists as well as managing larger projects to document the records of organisations such as hospitals, medical research institutions and power stations. The project work he undertakes deals with mixed media as well as paper records and artefacts. Increasingly his work as an archivist and records systems specialist is shaped by the general up-take of electronic systems for the management of information transactions. As a member of ASAP, he has an on-going role in the documentation of the CSIRAC Project.

Doug McCann

Doug McCann graduated with a Diploma of Applied Chemistry from the Bendigo Institute of Technology in 1972. After work experience in the research laboratories at Kodak (Aust) he completed a Dip Ed and taught in technical schools for several years. During this time he also completed a Graduate Diploma in Librarianship at RMIT and subsequently worked at the State Library of Victoria from 1976-1980. He returned to teaching and worked as an education officer at the Museum of Victoria while completing a Master of Environmental Science at Monash University. This was followed by a PhD in History and Philosophy of Science at the University of Melbourne. He is currently working on several projects in the history of science and technology including the CSIRAC project.

Alan Moore

Alan Moore joined the Lubricants and Bearings Section of CSIR in 1941 and was involved in the technology for making the high precision bearings used in aircraft engines. This led to investigations on the mechanisms of friction and wear, and after the war he received a PhD from Cambridge. Back at the renamed CSIRO Division of Tribophysics his studies on the atomic structure of metal surfaces led to the work on CSIRAC in 1961. He was at the Carnegie Institute of Technology in Pittsburgh for a year and returned to build and use a Field Ion Microscope at CSIRO. He retired in 1982 and had two years at the Department of Material Science at Oxford where computer simulations of FIM patterns were extensively used.

James Morrison

James Morrison was educated at Lenzie Academy and completed a PhD at the University of Glasgow specialising in Xray crystallography. He was Professor of Chemistry at La Trobe University from 1967 and Adjunct Professor of Chemistry at the University of Utah from 1975. In the late 1950s while carrying out research in mass spectrometry in the Chemical Physics Section of CSIRO he used CSIRAC to assist his mathematical work involving Fourier transforms and achieved impressive results. After the presentation of his results at a conference in Brussels in 1962 his method slowly gained universal acceptance. Following his success with CSIRAC he thereafter enlisted electronic computers as an indispensable aid for his research programs utilising all the major developments in computing from the CSIRAC era to the present day. He became Professor Emeritus in Australia in 1989, and is still an active teacher of chemometrics at the University of Utah.

Peter Murton

Peter Murton was educated at Geelong Grammar School and graduated in Electrical Engineering from the University of Melbourne. After graduating, he joined the Post-Master General's Department (now Telstra), Research Laboratories, where he first read about computing. Later he joined Colonial Mutual Life to prepare for the computer they had on order. He learnt programming on CSIRAC in the latter half of 1956 and took delivery of the Colonial Mutual computer early in 1958. He was a founding member of the Victorian Computer Society, Vice-Chairman of ACS, Victorian Branch 1966-67, Chairman 1968 and the third President of ACS 1968-70. He was elected Hon. Secretary of ACS Victorian Branch, a position he held for twenty years. Peter remained at Colonial and became the executive in charge of Computers & Communications, retiring in 1991. He is now a Director of Drummond Street Relationship Centre Inc. and Hon. Secretary, Littlewood Charities Club Inc.

Trevor Pearcey

Trevor Pearcey graduated in physics from Imperial College, London in 1940. He joined a radar research group in the UK and worked on the theory of microwave optics for the design of antennas, shaped disks, waveguide structures, scattering of targets, and other similar projects. Many of these studies required large scale calculations and in early 1945 he discussed the possibility of using electronics for fast computation with Douglas Hartree. In late 1945 he joined CSIR Radiophysics in Sydney and in 1947 he collaborated with Maston Beard in the design, construction and operation of the CSIR Mk1 computer (later renamed CSIRAC). Following the termination of the Mk1 project he returned to the UK but in 1959 came back to Australia and worked on the CIRRUS computer and the development of CSIRONET. In 1972, after a period as a consultant with Control Data Corporation, he joined Caulfield Institute of Technology as Head of the Electronic Data Processing Department and retired as Dean of Technology in 1985.

John Russell

John Russell commenced work at the CSIRO Division of Building Research in 1946, working on problems of heat transfer in buildings. Graduating BSc at the University of Melbourne he for some years investigated physical and structural properties of cast and lightweight gypsum plasters. On CSIRAC he used numerical techniques for building structure investigations. In 1964 he became Officer-in-Charge of the Melbourne Branch of (what was to become) CSIRONET and in 1968 was appointed its Director of Technical Services. A foundation member of the Victorian Computer Society, he was in 1969 elected Fellow of the Australian Computer Society. Retiring from CSIRO administration in 1985, his latter career included a period as Manager for CSIRO Scientific Data Systems. He has since engaged intermittently in independent consultancy.

Jurij Semkiw

Jurij (George) Semkiw arrived in Melbourne from Ukraine via Germany in 1949 having completed his matriculation in Bayreuth the previous year. He completed a Diploma of Radio Engineering at Melbourne Technical College (now RMIT) in 1956, then commenced work at the University of Melbourne Computation Laboratory and assisted in reassembling and testing of CSIRAC which had arrived from Radiophysics in Sydney a few months prior. He worked with Ron Bowles as second maintenance engineer on CSIRAC until it ceased operation in 1964. He designed and built the first transistorised circuitry for CSIRAC, doubling the drum capacity. Other projects include work on the PDP8 where he developed various interfaces and a disc controller for a large capacity disc. He developed interfaces and controllers for the Interdata systems including the first hardware for the Department's computer music project. He also developed the hardware for the multigate project (Ethernet to Appletalk communication system) which sold around the world. He was a Foundation member of the ACS, and graduate member of Institute of Engineers Australia. In 1994 he ceased full-time work and is currently an associate with the Department of Computer Science.

John Spencer

John Spencer was educated at Mildura High School and the University of Melbourne, graduating BSc with a major in chemistry in 1949. He commenced work at the CSIRO Division of Building Research, working initially on joint-sealing compounds, bitumens and bituminous roofing and later on thermal, optical and mechanical properties of various types of glazing. His association with CSIRAC started in 1959 and continued until its decommissioning in 1964. Its use facilitated work on the calculation of solar position and the measurement and estimation of solar radiation on building surfaces leading to the publication of tables for all Australian capital cities. Later, using various CSIRO computers after CSIRAC, he worked on the calculation of indoor temperatures, air conditioning loads and energy consumption in buildings, and building thermal modelling. He retired from CSIRO in 1994 and has since written an emulator for CSIRAC to run on a PC. Memberships of professional societies include FRACI, MACS, MIEAust.

Kay Thorne

Kay Thorne was educated in a number of schools in Australia and the UK and after matriculation in Victoria sought employment at the University of Melbourne where she worked for 17 years. She worked initially with CSIRAC and later the Department of Information Science. During this time she completed a BSc. She then took up employment with the Association of Independent Schools, completing a postgraduate diploma in Criminology at the University of Melbourne. Following this, she worked for several professional and industrial associations, and completed first a postgraduate diploma and subsequently a MA in Public Policy. In her employment she became increasingly aware of the miscommunication and culture differences between industry and government and the community generally. These interfaces became her major focus and she currently works as a consultant in those areas.

Peter Thorne

Peter Thorne was educated at University High School and the University of Melbourne. He worked with CSIRAC as a weekend maintenance engineer in the early 1960s while completing his BSc in Physics. He then undertook postgraduate work under the supervision of Frank Hirst leading to a PhD in Computation. His PhD topic had its origins in work undertaken by Hirst and Pearcey in the field of non-linear differential equations. He has played a major role in the development of computer education in the school, TAFE and university sectors and has consulted extensively to government and industry on IT related matters. He was appointed Reader in Computer Science and Associate Professor in 1988. He became Head of the Department of Computer Science in 1990. In 1996 he organised the CSIRAC celebration.

Marcus Wigan

Marcus Wigan graduated from Oxford University with a PhD in nuclear physics in 1967. He worked initially on operational research in the early 1960s, using the Algol on Elliot 803's and subsequently on realtime computing at Harwell as part of his nuclear physics doctorate. More recently he has been a visiting Professor of Management at Sydney University and is currently a senior Honorary Fellow in Geographical Information Systems (GIS) at Monash University and operates a transport and systems consultancy (Oxford Systematics). He specialises in GIS in planning, transportation, safety and human geography applications. His most recent consulting experience is on pricing, privacy and data ownership issues in spatial data, and on efficient techniques of engineering education using hypertext and problem based learning. In the 1980s he authored a monograph on expert systems on microcomputers and was President of MICOM, when it set up the first bulletin board in the southern hemisphere. He was a founding member of the ACMS in NSW.

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CSIRAC THE GIANT AUSTRALIAN BUILT COMPUTER THAT LAUNCHED THE NATION INTO THE DIGITAL AGE.

THIS IS THE STORY OF THIS REMARKABLE MACHINE AND OF THE INNOVATIVE PIONEERS WHO BUILT AND USED IT.

CSIRAC SURVIVES INTACT – THE LAST OF THE WORLD'S FIRST GENERATION COMPUTERS.

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