The First Electronic Digital Computers in Australia

Los primeros computadores electrónicos digitales en Australia

The Seeds of Computer Graphics

In the initial period of electronic computing, it is important to recognise that most of the imaging was done by scientists for scientific purposes. These include data reduction and graphing and the visualisation of simulations made to ascertain that their theoretical work matched the results of their experiments. It is only because of the people who were more involved in computing at the computing level, for example programmers and mathematicians, that computer images in their own right began to be thought of as art. The interesting thing here is that many of the people involved in early computing were not simply doing a job but were very much enthusiasts spending large parts of their lives working with the machines. This could involve a large amount of their leisure time. Many of the odder manifestations of computing, for example the banners, calendars, and games, were the result of this use of time.[1]

The Beginnings of Graphical Display

Making images with computers is essentially a process of calculating, storing in memory, and displaying an image derived from some sort of application data. The constraints have always been how much data can you display in any one period (especially if making animations for example), and this depends on the storage capacity and speed of the memory and the characteristics of the display. After the Jacquard loom, used for weaving what were, in effect, still images from data stored in punched-cards,[2] the Williams-Kilburn tube electrostatic store or memory, which made the first stored-programme computer possible,[3] is perhaps the prime development of the production of graphics by computer.

The CRT (Cathode Ray Tube) store was the means of storage itself, but it was also possible to understand the CRT as a map of the states of the bits in memory. Since it is maintained in an enclosed metal box with a special detector across the face of the tube, the memory array cannot actually be seen; however, by tapping-off the memory regeneration circuits the map could be displayed on another CRT and used to monitor the state of the machine. This diagnostic function was, for a long time, the main use of the CRT displays that accompanied many of the early machines (and in particular the first machines in Australia).[4]

1. This was particularly the case with many of the students who were studying computer programming—specifically when the University of Sydney instituted programming courses for physics honours students. This was also the case in universities in the U.S., including the Massachusetts Institute of Technology, where the first computer game, Spacewar, was invented by students. Stewart Brand. *The Media Lab: Inventing the Future at MIT*. New York: Viking. 1987

2. Charles Babbage. *Passages from the Life of a Philosopher*. London: Longman, 1864. Herman H Goldstine. *The Computer from Pascal to von Neumann*. Princeton, New Jersey: Princeton University Press, 1972. Anthony Hyman. *Charles Babbage - Pioneer of the Computer*. Oxford: Oxford University Press, 1982. Doron Swade. *Charles Babbage and his Calculating Engines*, London: Science Museum, 1991.

3. Lavington, Simon (1998) History of Manchester Computers, Swindon, Wilts., UK: British Computer Society, p.17.

4. On these early machines programming was always done in the direct code of the hardware of the machine (no assemblers, compilers or high-level languages yet) and debugging a program involved the difficult process of ascertaining where the machine had stopped or whether it was stuck in a loop. The monitoring CRT could be very helpful in diagnosing the state ...

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However, it was also recognised that the CRT store could do "fun" things like make announcements in text characters running across it or play games, and it was eventually possible to use the CRT display dedicated to monitoring memory to produce actual useful displays of data results.

CSIRAC

Australia's first computer was the CSIR Mk1: built between 1947 and 1951 in the Division of Radiophysics of the CSIRO. It became known as CSIRAC (Commonwealth Scientific and Industrial Research Automatic Computer) after it was moved to the University of Melbourne in 1956 [Fig. 1]. Its development and structure are covered in the article in the footnote.[5] CRT displays and were an important part of CSIRAC's diagnostics.

Their use was extended when the switch panel used to start up the machine was incorporated into a proper desk console with six 2-inch (50 mm) diameter CRT displays offering monitoring of the arithmetic registers,[6] which are the current contents of memory.[7] It also had a "Flexowriter" character printer to print out program results.

There was very little use of the CRTs or of the "Flexowriter" line printer for Graphics at CSIRAC, but they could certainly produce images [Fig. 2]. In Ditmar (Dick) Jenssen's research work, we can see the results of at least one use in which the results of calculations were presented as 2-dimensional data such as a graph or a "map". It was done in a way that was as much an extension of graphing techniques in science as it was an extension of the computer printout.

… of the machine if a bug arose, which often happened (and may well have been either a hardware failure or a software problem). The beginnings of computer music lie in this diagnostic function as well. Many of the early machines had a speaker attached to the machine occupying some convenient memory address location so that a bit could be programmed to make a noise through the speaker. If the speaker then stopped you knew the program had stopped or if it went into a repeating loop of the same sequence of sound then the machine was in a loop in the program. This was also exploited by some early users to make sounds that were simply entertaining but based on the behaviour of the program while it was engaged in processing the data of their task, for example, Ditmar Jenssen's Barotropic Rock.

5.   Deane, John (1997) CSIRAC Australia's First Computer, Killara, NSW: The Australian Computer Museum Society; McCann, D. & Thorne P. (eds.) (2000) The Last of the First. CSIRAC: Australia's First Computer, Melbourne, Vic.: University of Melbourne, Dept of Computer Science and Software Engineering.

6.   It is difficult to know when this occurred but the CSIRO Annual Report for June 30, 1952 mentions the intention to build a control desk in the next year, 1952-53. It was probably later not earlier.

7.   CSIRAC was also provided with a speaker (the "hooter") so that it could alert the user to programmed events in the program sequence. The presence of the speaker encouraged some of the programmers (particularly Geoff Hill) to produce musical output. By instructing the computer to write to a particular destination register, to which the speaker was attached, at the finish of every calculation, for example, programmed loops could be made to run at a rate that produced pulses at an audible frequency. With careful setting up of the loops, many musical tones could be programmed and Geoff Hill is reported to have programmed a version of Colonel Bogey that was played to the delegates at the first Australian Conference on Automatic Computing Machines, held at the CSIRO Division of Radiophysics, March 1951. The machine was used for intermittently making music irregularly during its lifetime. Professor Tom Cherry, who was the head of the Department of Mathematics in Melbourne University, wrote a programme that would allow anyone to produce a musical sequence with CSIRAC by punching the appropriate codes into a "pianola tape" version of the usual punchtape input. The music was coded with a row of digits indicating pitch (5 digits), duration of the pitch (the next 5 digits), and a separate row of intensity values. Paul Doornbusch, The Music of CSIRAC, Common Ground Publishing, 2005.
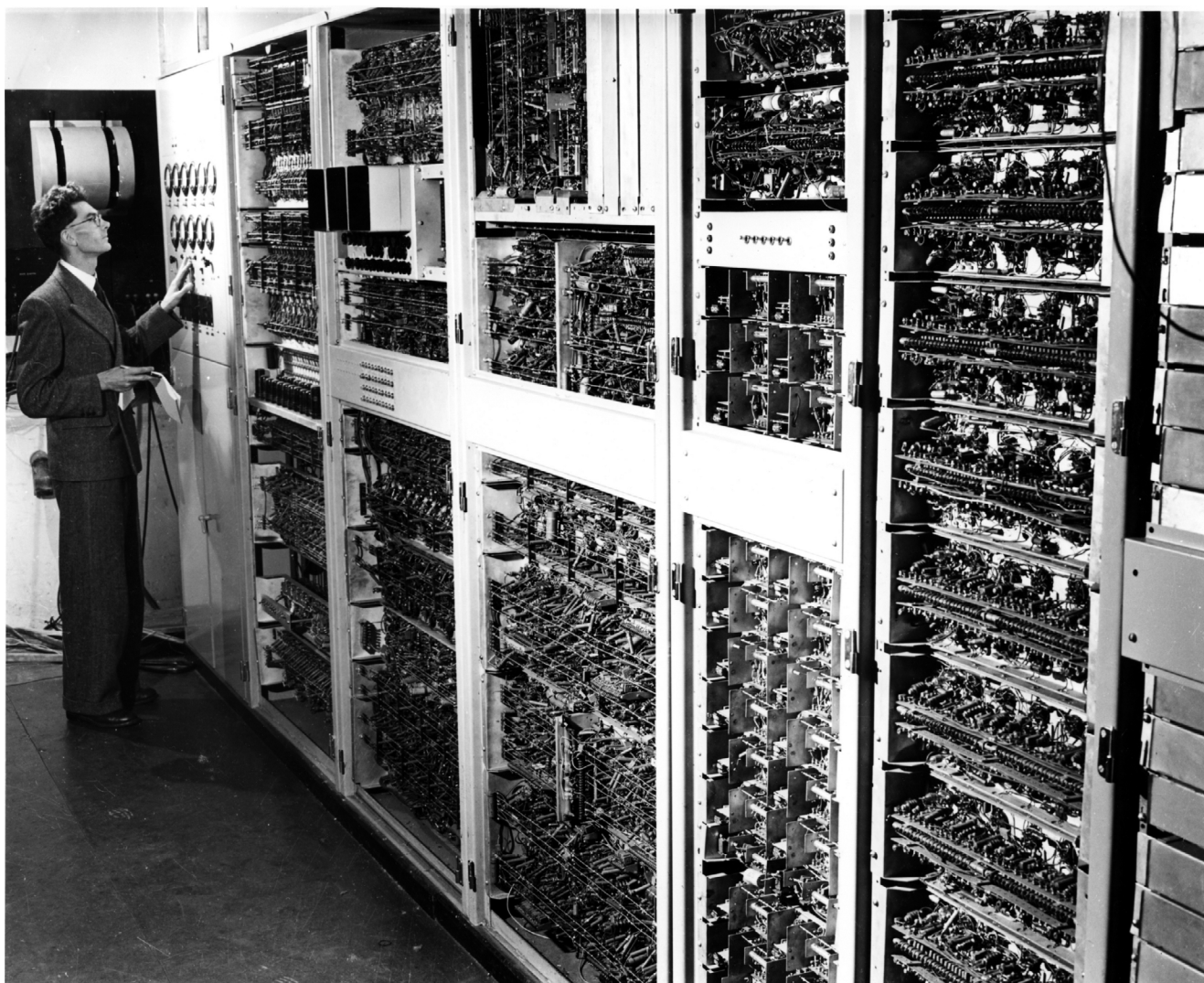
Figure 1. Originally called CSIR Mk 1, this huge computer was among the first five in the world and ran its first test program in 1949. Renamed CSIRAC, it was officially commissioned in 1951. It embodied many features novel at the time and was able to operate more than 1000 times faster than the best mechanical calculators. It was constructed by the Division of Radiophysics to the designs of Trevor Pearcey (pictured) and Maston Beard. Photo dated November 5 1952. Creative Commons License.

Figure 2: CSIRAC (Council for Scientific and Industrial Research Automatic Computer), Australia's first digital computer, and the fourth stored program computer in the world. First run in November 1949, it is the only intact first-generation computer in the world, and is on permanent display at the Melbourne Museum. CRTs in the center right. Photo by John O'Neill. Creative Commons License.

During public demonstrations, CSIRAC would play games that were programmed by Jenssen, which included a guessing game he called Telepathy, a Calendar game (which printed out the date you entered on the console switches),[8] and NIM (a "match-stick" game based on "pick-up-sticks"). [Fig. 3] Images had to be prepared directly from the results data, either by direct placement of bits into appropriate locations in memory if a CRT display was desired, or by direct placement of characters into the appropriate rows and columns of the printed page via the Flexowriter. Each of these activities would take large amounts of computer time which, in this era, was a rare and valuable commodity, so graphical use of the computer was usually discouraged.

CSIRAC was both a research and a teaching machine. As some of the students using it became more competent with it, night shifts were made available and it was during this time that it was used to do some of the first significant computer-generated graphic data visualisation in Australia. These resulted in Jenssen's investigation into numerical weather forecasting. He was first introduced to CSIRAC on a programming course at Melbourne University in December 1956 and completed his master's thesis in numerical weather forecasting. He then built a model to predict the weather 24 hours ahead of the current day's weather data. His early successful attempts to do numerical weather forecasting rated a mention in the *Sun*.[9] The calculations were made on CSIRAC, and the results were output to pun-
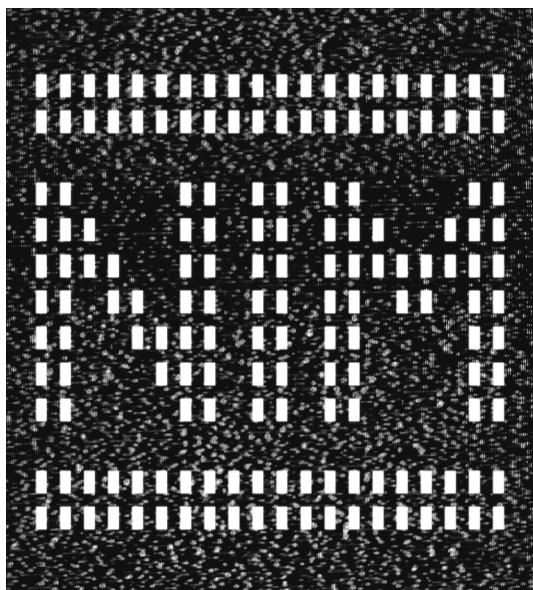

Figure 3: Reconstruction of the image emulation on the Memory CRT display of the opening image for the game NIM played on CSIRAC. The image comes from the emulations of the CSIRAC games written by Ditmar Jenssen. Reconstruction by Pierre Puentes.

ched paper-tape.[10] Then, again using CSIRAC, the results could either be displayed on the Memory CRT or printed out off-line on the Flexowriter.

In his master's thesis, there is a single composite photograph of the CRT screen[11] with an outline map of Australia superimposed on it. The image essentially shows alternating bands of atmospheric pressure as contours with each band covering a range of 10 millibars of pressure difference.[12] It shows a memory display of the initial pressure field, and the right image shows

8. The games for CSIRAC were programmed in 1957 by Ditmar Jenssen. He told me:
    "My games were essentially:
        1. the game of Nim,
        2. a game of "telepathy" of my own devising (essentially a binary-choice guessing game), and
        3. not really a game – a program to say what day of the week any date fell/falls on.
    "Nim" used the D-registers as a display for the "piles of matches" involved, and "Telepathy" used the front panel light display of CSIRAC. "Day of the week" was a simple teleprinter printout. [from an email from Jenssen dated 24 May 2001.] The electronic version of the game NIM was originally implemented as a popular demonstration of what computers were on a specially constructed machine at Ferranti in Manchester for the 1951 Festival of Britain. The idea for the machine was suggested by John Bennett, an Australian, who led the Ferranti Mark I* programming group. [see Bennett, J.M., "Autobiographical Snippets", p.55, in Bennett, et al, 1994.] Bennett returned to Australia in 1956 and is of fundamental importance to our story. [see the section on SILLIAC]

9. Lyell, Peter (1958) "We will never be sure" *The Sun*, Monday, September 22, 1958, p.6. Melbourne.

10. Jensen's work was prompted by a 1950 paper by Charney, Fjortoft and von Neumann [Charney, *et al*, 1950] which produced the first weather forecast from actual weather information. It included a printout of the barotropic contours (what we think of as "isobars") as filled-in blocks. The equations of barotropic vorticity (defined as the spin of an atmospheric element as seen by an observer on the Earth's surface) that Charney, *et al*, used were known to produce correct results in forecasting but nobody could prove why. Jensen showed *why* the barotropic model actually worked in his MSc thesis [Jenssen, 1959].

11. Ditmar Jenssen. *On Numerical Forecasting with the Barotropic Model*, MSc thesis: Meteorology Dept., Melbourne University, March, 1959.t

12. Jenssen, Ditmar (1963), *Application of Digital Computers to Weather Analysis and Forecasting and to Problems of the Antarctic Water Budget Conduction in Moving Ice Sheets*. PhD thesis: Meteorology Dept, Melbourne University, October, 1963.

the 24-hour forecast. The initial data are from a Weather Bureau 5000-millibar chart.[13] Alternating pressure bands are shown by "on" and "off".

The image was printed from a photograph of the D-register CRT.[14] The map was hand drawn onto the print and then re-photographed. The composite photos were made early in 1957 by Melbourne University Audio-Visual Services and are primitive bitmaps with the resolution limited to 20 dots by 16 lines by the size of the registers that held the data. Referring to [Fig. 3] the word NIM in the D-register of CSIRAC, we can see that it was also made up of 16 rows each of 20 bits with the appropriate bits turned on to make up the large characters (there are two blank rows above and one bank row below the characters). The programme to do this character display is the same as the one Jenssen used to show the barotropic data.

The barotropic CRT image was one of the first things Jenssen did on CSIRAC; it was simply a matter of placing a twenty bit number with appropriate bits set high or low into each of the 16 D-registers and was a very quick routine that functioned as a check to see that the data had been punched in correctly. He commented that the impetus for him to create the contours as bits on the D-register raster came from being dissatisfied with the detail that the Charney et al paper could provide.[15] The the resolution of the images made possible with CSIRAC's monitoring displays was not very good, but this is what the structure of the computer permitted. To achieve better resolution, the solution was to print out the results as an array of characters on a page of paper with the Flexowriter. Fig.5 shows the use of "full stop" characters placed at appropriate columns over the rows of printout to give an indication of the continuous lines representing the contour boundaries of atmospheric pressure. According to McCaughan, who, in an email to the author (27 March 2002), remembers that he

worked with them himself in 1960. "I have been reflecting on the fact that my 4th year project on Silliac would have had to include those maps that you found in Peter Poole's thesis. I would not have originated that idea which implies that it came from Crawford and/or Poole, and that it started in the late fifties." According to McCaughan, who, in an email to the author (27 March 2002), remembers that he worked with them himself in 1960. "I have been reflecting on the fact that my 4th year project on Silliac would have had to include those maps that you found in Peter Poole's thesis. I would not have originated that idea which implies that it came from Crawford and/or Poole, and that it started in the late fifties." The outline maps are hand drawn onto the printed contours.

As part of his PhD thesis, data were calculated on UTECOM (A "Supercomputer" built in England and later at the Kensington Institute of Technology, NSW; now the University of NSW) in 1960. The numbers were again output to punched paper-tape. Jenssen would then bring the paper-tapes back to Melbourne where the results could be checked. To make the contour map images, the punched-tapes were printed on the Flexowriter. Jensen commented that he created the images this way based on his desire to reproduce the published weather maps, which were drawn by hand from computer generated data.[16] In making the CRT images, CSIRAC was being used as an off-line graphics device rather than the calculator it was originally intended as; this foreshadows the direction that computing would take over the next decade as more and more tasks were distributed over a collection (soon to be a network) of machines. Jenssen acted both as the researcher of the meteorological data and the technical developer of the graphic displays, which he generalised into the game images. What he wrote for the CSIRAC was essentially a plotting program.

13. Jenssen, Ditmar, conversation with the author at Carnegie, Vic., 22 October, 2001.

14. One of CSIRAC's data registers (note: a register is effectively one location of memory but usually set up independently of the main machine memory).

15. Conversation with Jenssen at Carnegie, Vic., 18 January 2002.

16. ibid.

Jenssen also produced some computer music on UTECOM while doing the calculations for his barotropic forecasting model (on-and-off between 1959 and 1962). He arranged his programme so that the value from the data entered into each iteration of the calculation would send a related number of pulses to the computer's speaker as it ran through each cycle of the loops of varying length. These went into the calculation process and produced a sequence of tones that were determined by the data values used in calculating the barotropic contours. He called it "Barotropic Rock" and told me that the regular sound had quite a rhythmic effect.[17] Sadly there is no recording of it, but in the late 1950s that would have been very difficult.

Overall, CSIRAC did a lot of valuable work, but eventually it was just too old and too slow to be useful anymore.[18] In the meantime, two new computers had been established at universities in Sydney. One was the UTECOM, an English Electric Deuce machine at the then University of Technology (now UNSW),[19] and the other was the SILLIAC —established at the School of Physics in the University of Sydney— and a descendent of John von Neumann's Institute of Advanced Studies (Princeton) machine. As I have not been able to gather that much information on the UTECOM, I am not going to go in to much detail.[20] However it was supplied with a Tic-Tac-Toe programme, which set the play grid up on one of the pair of monitoring CRTs on its console.

SILLIAC was the site of what was an extraordinarily open and productive collaborative environment in the University of Sydney, where the computer industry began in Australia. The foundations of computer art and computer graphics in its many manifestations were centred on it.[21]

SILLIAC

SILLIAC's construction and early use has been discussed in Australia's First Computers: SILLIAC. It was the site of what was an extraordinarily open and productive collaborative environment in the University of Sydney which initiated the computer industry in Australia. Also the foundations of computer art and computer graphics in its many manifestations were laid around it.[22]

SILLIAC was also equipped with a CRT set up as a monitoring display which had a 40-way switch by which the operator could select one of the forty bits from each of the 1024 (1K) 40-bit words of (Williams-Kilburn tube electrostatic store) memory.[23] The monitoring CRT was mainly used to gauge the progress of a programme through the computer by watching for repetitive behaviour in the pattern displayed on a 32 x 32 dot "raster" (grid) of the CRT. The blinking of the dots on the display represented the contents of memory as it changed over the progress of the programme. Iterations would give regular repeating patterns on the screen —numbers (variables) could be seen to be growing or decaying— and "bugs"

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17. *ibid*. In this conversation Jenssen also mentioned other music from scientific data, including Charles Dodge's, The Earth's Magnetic Field [Nonesuch, 1970], made from the data provided by Bartel's diagrams. The diagrams produce a kind of histogram and Dodge used details of the heights of each column to set the tones for the sounds.

18. It was decommissioned on 24 Nov 1964, and donated to the Museum of Victoria at Spotswood [Bennett, Broomham, Murton, Pearcey and Rutledge, 1994, op cit, p.34]. It remains the only intact computer of its generation in the world and has recently been on display at the Museum of Melbourne.

19. Which was the descendant of Turing's NPL PilotACE [B.E. Carpenter and R.W. Doran, "The Other Turing Machine," Comp. J., vol. 20, no. 3, pp.269-279, 1977].

20. Deane, John (2006b) *UTECOM: A Turing Engine for the University of NSW.* Killara, NSW: Australian Computer Museum Society.

21. The detail on SILLIAC's development and history while glossed above can be further explored in [McCaughan, J.B.T. (1987) "The Era Begins", chapter 2 of Millar, D.D. (ed.) (1987) The Messel Era. The story of the School of Physics and its Science Foundation within the University of Sydney, 1952-1987, Sydney: Pergamon Press, for The Science Foundation, University of Sydney, and Pearcey, 1988, and Deane, 2003b, op cit, and Deane, John (2006a) *SILLIAC: Vacuum Tube Supercomputer*, Sydney, NSW.: Science Foundation for Physics, School of Physics, University of Sydney, in association with the Australian Computer Museum Society. [2nd edition, for the SILLIAC 50th Anniversary celebrations]].

22. The detail on SILLIAC's development and history while glossed above can be further explored in [McCaughan, 1987, op cit; Deane, 2003b, op cit, and Deane, John (2006a) *SILLIAC: Vacuum Tube Supercomputer*, Sydney, NSW.: Science Foundation for Physics, School of Physics, University of Sydney, in association with the Australian Computer Museum Society. [2nd edition, for the SILLIAC 50th Anniversary celebrations]].

23. Deane, 2003b, op cit, p.97.

could be noted when the pattern went into an unexpected repetition if the programme got "stuck in a loop". The CRT was also used for games and could display alphanumeric characters by stuffing high or low bits into the appropriate memory locations in the same way that Jenssen had been doing with the CSIRAC (also see the SILLIAC programme "Drawing Pictures on the CRT", below). Later in the 60s when the machine was made available to honours students, it was used for animations.

Along with the monitoring CRT, SILLIAC had a loudspeaker that was used to follow the progress of a programme but could also be used to play music. Several music programmes including "Happy Birthday" and "Yankee Doodle Dandy" came with the programme library received from the University of Illinois. Mc-Caughan describes them as sounding "vaguely like bagpipes".[24]

A number of other music programmes were written over its years of operation by Chris Wallace, Bob Donnelly, David Jacques, and Jenny Ed-Caughan, who was a tape-recording enthusiast, made a recording of the diagnostic programme "Leapfrog" running through its cycles in about 1964. He recalls: "It also had an engineering test routine called "leap frog" which played a sequence of notes through the loudspeaker that was repeated with variations that grew more complex. It was definitely harmonious, but rather eerie. TV viewers from the early 60s might remember a sci-fi series called A for Andromeda that had computer music for its theme not unlike that of SILLIAC."[25]

The machine also had a character-printer (Teletype) which was used for printing out the results of programmes and calculations. Mostly the data printed with the teletype was then taken out of the computation lab by the user and, if graphical results were needed they were hand plotted to graph paper. The machine could also be used to compile tables from which the teletype could print the results in formatted columns. There were a great range of applications for SILLIAC, though the important ones from the beginning were in nuclear physics and cosmic rays studies, followed by radio astronomy and crystallography.

Cosmic Ray Research

The Cosmic Ray Air Shower project was partly conducted by gathering data from an array of 92 Geiger Counters spread out in five rows, three meters apart, on the lawn behind the School of Physics building. The output of the counters was automatically recorded to punched paper-tape for input to SILLIAC.[26] One of the research projects using data from this array was to study the variations in the times that a shower would trigger the Geiger counters. Careful study of this data could then reveal the direction from which the core particle that triggered the shower had come.

Part of this work was presented in Peter Poole's Ph.D. Thesis[27] in which there is a series of printouts that show the Geiger counter array as a set of dots, numbers, and Xs in a grid over the page. This gives a direct visual description of where the triggering events, and the number of them per Geiger detector, had occurred in any one particular shower. Because they took up too much computer time to print directly, the line printer graphics were punched to paper-tape from the computer and then printed out "off-line" on the Flexowriter. This is a very early scientific visualisation of the data sources produced through the character-printer output technique of placing printer characters in the appropriate places on the page. The original versions of these printouts were probably made around 1959.[28]

24. McCaughan, 1987, op cit, pp.30-1.

25. *ibid*, p.31.

26. *ibid*, p.59.

27. Poole, P.C. *A Study of Variations in the Arrival Rates of Extensive Air Showers*, Ph.D thesis, The School of Physics, University of Sydney, 1963.

28. According to McCaughan, who, in an email to the author (27 March 2002), remembers that he worked with them himself in 1960. "I have been reflecting on the fact that my 4th year project on Silliac would have had to include those maps that you found in Peter Poole's thesis. I would not have originated that idea which implies that it came from Crawford and/or Poole, and that it started in the late fifties."

This technique to represent data as a graphical display is very similar to the technique of printing banners that became, for many people, for many people their first contact with what computers could do in general as well as in graphics. The procedure for printing banners is important and uses a similar technique to that which Jenssen employed in his weather forecast printouts from 1957 using CSIRAC as well as Poole's Geiger counter ma. A large character font printout can be made by printing a single character (often an "X") regularly across the columns of the page. When printed line-by-line down the page, these rows of characters would make up characters (read along the length of the page) or other graphical objects (including the university's coat-of-arms seen in the KDF9 banner) that take advantage of our ability to, at a distance, see patterns in things that when seen close up are a mass of detail.

Crystallography

Another of the major research areas in which SILLIAC was used was crystallography. These studies were initially run by Hans Freeman of the Chemistry Department at the University of Sydney and later by his students including John Lambert-Smith and Mitchell Guss. The main use of the computer in this work was in the calculations involved in the Fourier syntheses, which help determine where the atoms in a crystal plane lie on the basis of data gained from the diffraction, by electrons surrounding those atoms, or x-rays beamed at the crystal. These calculations generated much data and initially had to be hand-plotted to see the arrangement of atoms arrayed over the cleavage planes (the faces) of the crystal structure.[29] This suggested that the use of a computer to analyse the data would help greatly.

One of the first moves was to produce a graphical representation of the 2-dimensional array of X-ray intensities diffracted through one plane of the crystal. In 1963, a programme was written for SILLIAC that would represent the numbers produced as a 64 x 64 array of characters in a printout, with successive alphabetical characters representing the amplitudes of the intensity values gained from the x-rays deflected off the atoms in the crystal planes.[30] The program was used "to convert standard numerical output tapes into a coded alphabetical form." It yielded "a rectangular array of alphabetical characters, each number being represented by a single alphabetical character. The sequence of letters, A to Z, are equivalent to numerical values of decreasing amplitude" and produced an array of up to 64 characters per line, on a line-by-line basis.[31] Unfortunately there appear to be no extant examples of this kind of printout; however, the contour diagrams of electron density were developed from this kind of work. We can see that this type of printout foreshadows the need for a plotter to be utilised in the production of contour drawings of relative values of an array of data. Raster Contour Plotter was another programme written for the machine.[32] This program allowed the user to display, on the 32 x 32 spot raster (grid) of the monitoring CRT, a contour map of the comparative values of any set of data in two variables (ie, two dimensions) that might be entered into, or produced with, the machine.[33] The contour plot would be iterated

29. Freeman, Hans C. *The crystal Structure of biuret hydrate and X-ray crystal structure calculations on the 'Silliac' high-speed electronic digital computer*. PhD thesis, School of Chemistry, University of Sydney, 1957a.

Freeman, Hans C. "Crystallographic Calculations on the SILLIAC Electronic Digital Computer," Australian Journal of Chemistry, 10, no.2, (1957b): p.95.

Freeman, Hans C. "SILLIAC Computer Programs for X-Ray Crystal Structure Analysis." *Proc. Conf. on Data Processing and Automatic Computing Machine*s. Australian Defence Scientific Service, Department of Supply, (1957c): p.120-1.

30. Bennett has said [Bennett, J.M. (1971) "Computers and the Visual Arts" *Aust. Computer Jnl*, vol.3, no.4. (Nov. 1971) pp.171-177, p.172] that the use of printers for graphical output by judicious placement of characters on the page goes back to work by x-ray crystallographers at Cambridge University in 1950.

31. From the notes to the Program V26 in the possession of Hans Freeman. The program was V26 in the SILLIAC library, and the source of the numbers was program V7 (or V17) [SILLIAC Fourier summation programs].

32. SILLIAC Program Q5. I have not been able to discover when it was written except that it was sometime after the first of the four magnetic-tape stores became available around mid-1960. The remaining three became available after March, 1962. See Deane, 2003b, op cit, pp.70, 75 & 78.

33. The picture is produced by dividing the value of the number, z, in each location (x,y) by some number, Δz, that represents the spread of values the user might wish to see between contours. Obviously this depends on the overall range of z in all…

over a range of 20 values for the desired spread between contours so that the user could select the most satisfactory version for their purposes. Once the user had the best version of the contour pattern they could get from this process, they could print it out on the line printer using the, by-now, standard approach of letting characters represent points in the image. The print "routine will print out a pattern of zeros and spaces as printed by the teletype equipment, corresponding to any of the twenty patterns appearing on the raster. It does this by printing a zero where there was a dot on the monitor screen and a space where there was no dot."[34]

Program Q5 could have been very useful for crystallography in which a two-dimensional projection of the disposition of the atoms in any particular cleavage plane of the crystal could be displayed, however I do not know whether it was ever used by them. The other possibility is that it was written to help the Radio-astronomers but I haven't been able to find out whether they used it either. The Radio-astronomers in the School of Physics used the plotter to map their radio data onto photographs from optical telescopes so that they could identify the visible (or not) sources of their signals.

It was also possible to display large characters on the monitoring CRT as patterns of bright spots on the raster. This was done at the dedication ceremony in 1956, but, at present, I have no information on precisely how. Nevertheless, a good indication is available in the SILLIAC program "Drawing Pictures on the CRT" of 17th September 1963. The program description says:

> "This program draws a picture on the CRT given by the first 32 bits of the data words. The level at which the picture is to start and the relative level at which it is to end must be given as sexadecimal[35] digits."

Thus by inputting the appropriate number —in which the first 32 bits of the binary value of the number represents the spots that had to be "on" (bright)or "off" (dark)— into the machine in the order that they should appear down the raster, a picture or a character of the required height could be produced.[36]

...(x,y). The value of z at each (x,y) is divided by Δz and where the integer part of the quotient is even it places a dot at that (x,y) location on the 32 x 32 grid. Where the integer part of the quotient is odd it leaves a space. Thus, the image appears as alternating bands or surfaces of filled and empty regions. See the program description for further details: SILLIAC Code Q5 – Basser Computing Department. (This may be difficult to do. The author [SJ] has a photocopy of it in his archive.)

34. SILLIAC Code Q5, Basser Computing Department, p.11.

35. A slight variation on the Hexadecimal or base 16 numbers that program assembler codes use these days.

36. It is possible that this is the program that David Crawford converted into his animation routine.