Australia's WREDAC – It *Was* Rocket Science

John Deane

Australia

Abstract. From 1950 Australia's *Long Range Weapons Establishment* took steps into an almost unknown future. Building on a tiny bit of experience John Ovenstone addressed a deepening problem with calculations and defined an *automatic computing machine*. Elliott Brothers used their electronics expertise and bent their efforts from developing their first commercial computer to fill Ovenstone's order. As LRWE became the *Weapons Research Establishment*, the *ELLIOTT 403* digital automatic computer became *WREDAC*, and Australia's second computer - just[1]. WRE's computer was special, it took input from locally built analogue to digital conversion of missile range data, processed this with locally written software, and produced performance reports, off-line, on Australia's first line printer and the world's first digital plotters. While this machine was a number cruncher, Ovenstone saw that it could be used for business applications - he programmed demonstration examples and told everyone who would listen that this was the way ahead. Like the other first generation computers *WREDAC* soon had competition from fast, reliable transistorised machines. Unlike the others *WREDAC* did not have a university environment to support it and its life was relatively short - but productive and inspiring.

Keywords: Weapons research, long range weapons, Woomera (Australia), ELLIOTT 403.

1   Vengeance Weapons and Woomera

Late in 1944, in the fifth year of World War 2, the German army started firing V-2 rockets at Paris, London and many Allied cities. It was understood that they were ballistic missiles carrying around 1 tonne of high explosives, but there was no known defence and the Allies couldn't duplicate the technology.

At the end of the war, and with the added knowledge of the US atomic bomb, the UK *Ministry of Supply* created a *Guided Weapons Directorate* to develop rocket based armaments. One of their first problems was to create a test site at least 800 km long. Europe was too densely populated and firing over water would limit the recovery of missiles. The best choice seemed to be either somewhere in Canada or Australia[2].
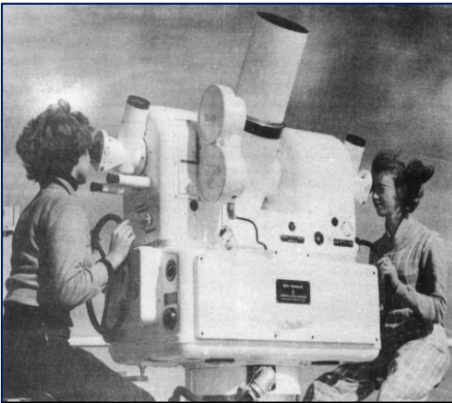
---

[1] Trevor Pearcey's CSIRAC first ran in November 1949, WREDAC in June 1956 (though it probably ran in the UK about August 1955), SILLIAC in July 1956 and UTECOM in September 1956 (and this English Electric DEUCE probably ran in the UK about April 1956).

[2] Peter Morton, 'Fire across the Desert' (Australian Government Publishing Service, 1989). Morton's large and impressive book has a detailed account of many matters associated with Woomera, and especially demonstrates the complexity of management as well as technical aspects.
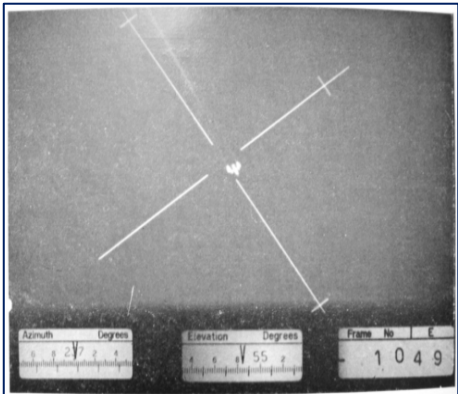
An Australian Army officer, William Coulson, stationed in London heard of this proposal and drew up a map with a suggested test range running from Mt Eba in South Australia, north-west for 1,800 km to the coast of Western Australia near Broome. This became the core of a proposal to the Australian Prime Minister, J.B. Chifley, in September 1945. This promised access to weapons information, technical development, and money – and the Australian Government rapidly agreed in principle[3]. A UK team surveyed the range in early 1946 and generated a substantial report. This resulted in the creation of the *Anglo-Australian Joint Project* at year's end, then with the arrival of the core UK scientific team, the *Long Range Weapons Establishment* (LRWE) on 1st April 1947[4].

The LRWE was housed in what had recently been a large munitions factory at Salisbury 20 km north of Adelaide, while the newly christened *Woomera*[5] rocket range started a further 500 km north-west[6].

Kinetheodolite tracking a missile on the Woomera Range (from "The Weapons Research Establishment and Rocket Range" pamphlet WRE 1956) Photo: Courtesy, Defence Science & Technology Organisation	One frame of kinetheodolite film (from WRE Annual Report 1967-1968) Photo: Courtesy, Defence Science & Technology Organisation

Their job was to evaluate rockets principally developed by the UK military contractors and provide detailed technical reports. Considerable equipment was installed on the range to do this. Initially:

---

[3] Peter Morton 1989 *ibid*. Morton has multiple references to William Coulson.

[4] Peter Morton 1989 *ibid*. Lt General John Evetts led the initial survey as well as the scientific team. His report which defined what the LRWE would do was known as *Evetts' Bible*.

[5] A 'woomera' is an Australian Indigenous invention to aid in launching a spear. The thrower uses a long grooved stick to increase the leverage of the throw and propel the spear with extra force.

[6] 'The Weapons Research Establishment and Rocket Range' (Commonwealth Department of Supply, 1956).

- a wide angle camera which took multiple exposures on a glass photographic plate – this was only useful at night,
- a film movie camera,
- a pair of kinetheodolites used to track the rocket manually - the telescope image and telescope bearing and elevation angles were recorded on movie film,
- radar provided bearing and range which were plotted to show the current position of the rocket and also recorded by movie camera,
- 12 geophones arrayed round the target position plus a multi-channel sound recorder,
- a precision timing source[7].

These were duplicated and extended throughout the life of the Range. Many rockets also transmitted internal state telemetry by radio which was displayed on a CRT screen and recorded by another movie camera.

Three "Computers" (from the film "WRE Maths Services", NAA D4994/CA7504/146 1953)

Photo: Courtesy, Defence Science & Technology Organisation

What was done with the recordings from these instruments varied according to the rocket developer's requirements, but there was a frequent request for the track in three dimensions, speed through the flight and rotation of the rocket body. After developing the photographic films, analysis started with labour intensive tabulation of data on a frame-by-frame basis. For the kinetheodolite record, the two angle values plus any offset of the rocket image from the centre of the frame were read on a film viewer and listed[8].

The initial planning for the Woomera range included 'Computers' to process this data. In 1946 this meant young women operating electro-mechanical desk calculators. The original estimate was that 6 *Computers* could analyse one rocket trial in a week.

2   Computers to a Computer

As trials got under way the team of *Computers* could transcribe 10,000 data points from film in 50 hours, calculate the 3-dimensional track in another 50 hours, and plot the results in 20 hours. In a particular trial in 1950 there was a discrepancy between the

---

7   Peter Morton 1989 *ibid*. The kinetheodolites were by Askania, radar was an anti-aircraft AA No.3 Mk.7 unit, position plotting tables were by EMI, the geophone recorder was by Miller, and the timing source was built by AWA.

8   Peter Morton 1989 *ibid*. This lists the many instruments used and how they changed over time plus many of the problems with using the recordings.

hand calculated track and that recorded by radar – 5 months later the analysis was 'almost complete'![9]

The LRWE managers were aware of overseas events and sent four representatives to the 'Conference on High Speed Automatic Computing Machines' held at the University of Cambridge in mid-1949. In their report they wrote:

The following remarks are made bearing in mind the possible requirement of a general purpose computer for Australian use.

1. A number of high speed digital computers are at present under development in England. Those actually operating are EDSAC ... [at] Cambridge; the Manchester University's computer[10]; and ACE ... at the National Physical Laboratory. All these are general purpose machines, and can be used to solve any problem capable of numerical solution to a high order of accuracy.

2. All the English machines have fundamental differences in conception and design. ... A thorough investigation of these and many other alternatives would be necessary before a choice of design could be made.

3. From informal discussions held during the conference, the capital outlay for such general purpose computers appears to be about £10,000 sterling. This compares favourably with the estimated cost of the Royal Aircraft Establishment's electronic differential analyser, £20,000, and with the annual hire charge for a complete punched-card installation – about £5,000. ...

4. An analysis of the time factor for the calculation of a certain problem ... has shown that the use of an electronic machine can reduce the computation time by hand methods by a factor of 500.

5. A detailed examination of EDSAC circuitry shows that all radio components are standard, and not subject to extreme tolerances. Many complete units, (e.g. teleprinters), would be available as war surplus. ...

   In conclusion it is felt that a high speed digital computer could be constructed in Australia without importing materials or labour for the project, but that much investigation would need to precede its design details. Whatever its form, LRWBE[11] should have sufficient suitable problems arising from missile and aircraft developments to keep such a machine economically occupied[12].

They were also aware of Trevor Pearcey's progress towards building an electronic computer for CSIRO and established good relations. Pearcey sent his circuit diagrams and LRWE's *Maths Services Section* assembled a proposal to construct the 'LRWE

---

[9] NAA Series D174/84 Item SA5145 Part 1 'Computation of trials results 15 May 1950'

[10] i.e. the 'Small Scale Experimental Machine' or *BABY*

[11] Long Range Weapons Base Establishment

[12] NAA Series D174/84 Item SA5145 Part 1 'Computation of trials results 27 July 1949'. The LRWE attendees were G.E.Barlow, B.S.Deegan, W.C.J.White and R.H.Whitten.

Electronic Digital Automatic Computer' – *LEDAC*. This "*should use standard components wherever possible, and should be built with ease of servicing in mind. The design should not concentrate on speed; reliability was more important*"[13].

Over 1950 they obtained punched card equipment as an interim measure to help the data processing task. At the end of the year a small group started work on *LEDAC's* mercury filled delay-line memory[14].

Nearly a year later the LRWE Board considered the electronic computer question, cancelled the *LEDAC* project and directed that a UK Ferranti *MARK 1* was to be purchased. In January 1952 Ferranti's price quadrupled to £195,000 and this was cancelled too.

Maths Services took a step back and realised that the punched card equipment was not delaying the overall processing as the initial data tabulation was so slow. They surveyed similar US establishments then bought new tape recorders, and movie film viewers with built in card punches[15].

However, they knew that the rate of rocket trials was going to increase sharply. Planning for 1955 and 1956 suggested that 400,000 position points, 6 million telemetry samples and 600 km of film would need to be processed, and around 200 lady Computers would be needed. They revisited the electronic computer question.

Back in 1950 a young Queensland mathematician, John Allen-Ovenstone[16], had joined Maths Services, then headed off to Cambridge to do a doctorate. He had used Pearcey's CSIRO computer then Cambridge's first computer *EDSAC*. When he returned to LRWE in 1953 he developed a broad specification for a computer and the various converters that would be required[17]. This document described input converters for rocket telemetry, the new doppler radar, and tracking radar. The converters were to re-code the data and write magnetic tapes suitable for the computer. Kinetheodolite film viewers were to be modified to punch paper tape rather than cards. There should also be output converters to accept a magnetic tape from the computer to print tabulated data and draw graphs. Clearly the computer itself had to handle a great deal of input-output, but Allen-Ovenstone's document did not specify great calculating power. All told these were very bold requirements!

The specification document was sent to British computer manufacturers, and Allen-Ovenstone with experienced engineer George Barlow travelled to the UK in early 1953. They visited English Electric who had just completed a prototype of their first commercial machine, the *DEUCE*. However, this didn't yet have software or any performance statistics. It also couldn't be delivered before mid-1955! The other

---

[13] Peter Morton 1989 *ibid*. LRWE's Frank O'Grady proposed the contact with Trevor Pearcey at CSIRO.

[14] Peter Goddard private communication Dec 2007.

[15] Peter Morton 1989 *ibid*. W.A.S.Butement, R.W.Boswell & R.P.Bonnell travelled through the USA. They recommended Ampex tape recorders and Benson-Lehner *Boscar* ballistic film analyser and recorders.

[16] He later dropped the hyphen.

[17] Peter Morton 1989 *ibid*. The document can be identified as 'J. Allen-Ovenstone, Notes on data processing at LRWE, 9 Oct 1953' (21pp) but this hasn't been located in Australian Defence archives, nor in UK computing archives.

available computer was Ferranti's *MARK 1*. They found this a 'neat' machine, but it was not constructed of plug-in units which they considered essential for servicing. In addition they suspected that its electrostatic memory would be sensitive to radio transmissions present at Salisbury[18].

A UK computer company they apparently didn't visit was Elliott Brothers. Elliotts had championed plug-in electronics for their WW2 Naval radar and continued this in their first significant computer, the *401*. At the same time as the UK visit, the University of Sydney requested information about this machine – and their London contact arranged for this, and sent a second copy to LRWE[19].

With the number of rocket trials rapidly increasing, and still no computer, Barlow and Allen-Ovenstone returned to the UK in mid-1954, and the head of Maths Services, Major Jacoby, travelled to New York for a demonstration of IBM's first large electronic computer, the *701* 'Defence Computer'. Jacoby was very impressed[20].

Barlow and Allen-Ovenstone returned to Ferranti for a preview of their new machine, the *PEGASUS*. They liked the design but thought it was more complicated than LRWE needed, and Ferranti was not interested in building the simpler machine Allen-Ovenstone wanted[21]. Then they followed up the *Elliott 401* brochure and received a much more encouraging response. Historian Simon Lavington wrote in *Moving Targets*:

> *Laurence Clarke believes that the basic design of ... [LRWE's computer] was carried out in the space of about a week after the initial visit of Ovenstone and Barlow ... Laurence was in North Wales on holiday visiting family and was called back ... because of the importance of the project[22].*

At this time Elliott Bros. were working on their first commercial computer, their *402*. In addition they had a series of small projects which might be related to the *402* and they administratively grouped these as project *403*. The preliminary work for LRWE was based on the same plug-in logic modules as the *402* and identified under the *403* odd jobs classification[23].

Back at LRWE the discussions must have been interesting. Jacoby recommended the *IBM 701* though it used similar electro-static memory to the rejected *Ferranti*

[18] Peter Morton 1989 *ibid*.

[19] National Archives of the History of Computing at John Rylands University Library, The University of Manchester: National Research Development Council records: NAHC/NRDC/C15/8 "Computer 401 Elliott Bros, Publicity". Correspondence 1953-55. 3 letters on 13 May, 1953, NRDC to Prof D.M.Myers, University of Sydney; NRDC to W.A.S.Butement, Dept. of Supply, Melbourne; and NRDC to W.R.Blunden, Military Board, Australia House, London.

[20] Peter Morton 1989 *ibid*. Jacoby was also involved in the *LEDAC* project.

[21] Bernard B Swann "The Ferranti Computer Department" (1974, unpublished manuscript in the John Bennett collection of the Australian Computer Museum Society)

[22] Simon Lavington "Moving Targets" (Springer 2011). Laurence Clarke became Technical Director of Elliotts.

[23] NAHC/NRDC/C13/3 'Electronic Computers, Elliott Bros Ltd, Development, File No 3'. Correspondence 1952-53. NRDC Internal Memo 27 August 1953. Has considerable detail about Project 403 but it is not what became the Elliott 403 / WREDAC.

MARK 1, while Barlow and Allen-Ovenstone had found the Elliotts people very responsive. The final choice for Elliotts may have owed more to their lower price than the technical arguments.

> *On 29 September 1954, the first manufacturing progress meeting for ... [LRWE's computer] was held at Elliott's Borehamwood Laboratories, 'amid a flurry of telexes querying and replying to minor details'. A crucial matter was the interface between the Woomera instrumentation's data-converters ... [and the computer]*[24].

But progress wasn't exactly rapid. An internal memo the following February, five months later, included:

> *... while I was at Borehamwood, I was shown the state of progress on the 402 and 403 machines. ... Adherence to this modular principle has enabled Elliott Brothers to design rapidly and easily the 403 machine which is the special machine to be delivered to the Long Range Weapons Establishment in Australia.*
> *The 403 will comprise sixteen cabinets ...*
> *Assembly of the 403 has not yet commenced ...* [25]

While 'Elliott 403' remained the official name, it was often referred to within Elliotts as *COBBER*. Then in January 1955 LRWE was amalgamated with two other research laboratories that had been created on the Salisbury site, and the new organisation was christened the *Weapons Research Establishment* - WRE - and from then on the computer was *WREDAC*[26]. The machine Elliotts was building was: [27]

Processor	Technology	Bit serial operation using vacuum-tube logic, 34 bit words, and 333 KHz clock	Constructed from 640 standard Elliott plug-in units incorporating about 1,600 tubes
	Instructions	2 per word, single address, with separate formats for arithmetic and input/output	48 instructions including **+ - × ÷** transfers, input/ output, indexing etc.
	Memory	512 words of magneto-strictive nickel delay-line fast access working store	(= 2 KBytes)
	Speed	average 600 microseconds per instruction	(= 1.6 KHz)

[24] Simon Lavington 2011 *ibid*. These quotations refer to the computer as 'WREDAC' which it wasn't then called.
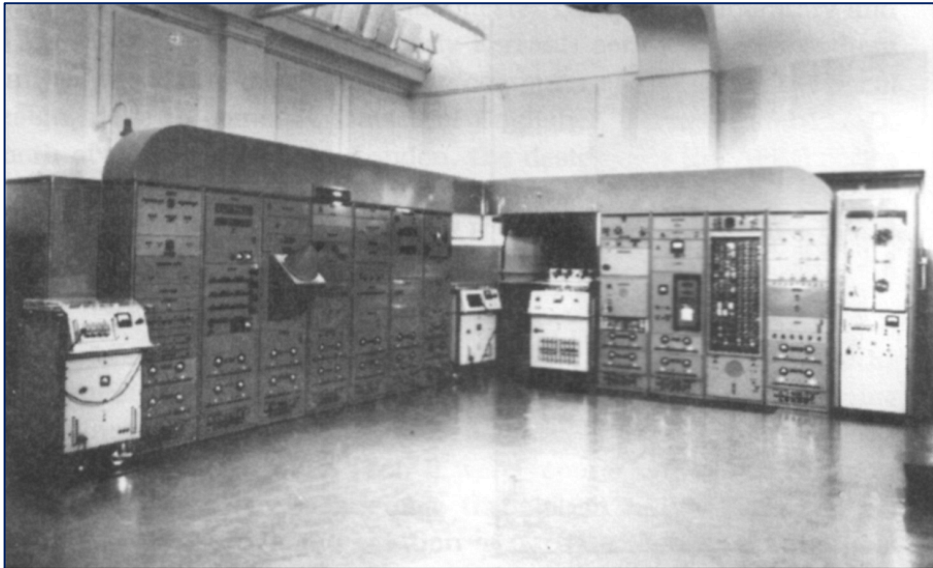
[25] NAHC/NRDC/C13/8 'Computers, Elliott Bros, Manufacturing Programme Contract No 3'. Correspondence 1953-65. NRDC Internal Memo 15th February, 1955.

[26] 'Weapons Research Establishment Digital Automatic Computer' of course.

[27] Digital Computer Newsletter Vol.7 No.4 Oct 1955 (Office of Naval Research, U.S. Navy). A. St.Johnston 'A Series of Computers using plug-in units' Proc. IEE Vol.103 Part B Supplement 2 Convention on Digital-Computer Techniques pp186-7, April 1956.

Program medium	Paper tape	5 channel teletype reader and punch		Instructions were punched in a symbolic form
I/O		Disk	46 cm diameter disk rotating at 2300 rpm with 80 read/write heads providing 16 K words of backing store	(= 68 KBytes)
		Magnetic Tape	2 units, 1/4 inch tape ancillary store written at 100 bits per inch & similar to EDSAC's	(a 2400 foot tape could hold about 250 KBytes)

This was just the processor, 16 cabinets nearly 2m tall and formed in a big 'U' shape about 6m wide with 3m arms. Plus power supplies and air-conditioning plant.

The *Elliott 403*'s Input Converters: Rocket Telemetry Converter (left) and Doppler Radar Converter (right) – from T. Pearcey 'A History of Australian Computing' – Chisholm Institute of Technology 1988)
Photo: Courtesy, Defence Science & Technology Organisation

Elliotts also developed an 'Output Converter' for WRE. This separate system had a third magnetic tape unit to read processor output, 7 large cabinets of vacuum-tube logic and 5 output devices. The largest was a line printer by Bull of Paris which could print 2 lines of characters per second. Then, remarkably, there were 4 graph plotters. These were *Mufax* facsimile machines, modified by Elliotts, for which the converter synthesised data streams at 4 lines of dots per second. Printer and plotters used treated paper which had to be developed by the *Dyeline* process[28][29].

---

[28] The result is not permanent and there seem to be no extant examples of either output system.

[29] 'Data Processing System - The Australian Weapons Research Establishment - Salisbury, S. Australia', Communications of the ACM. Vol.1 No.7 July 1958.

The third major part of the overall system was a pair of Input Converters developed by George Barlow, Leo Cohen and Fred Thonemann at WRE. Rocket telemetry tapes recorded at the range were read, processed by another 7 cabinets of logic and written to a magnetic tape compatible with *WREDAC*. The Doppler Radar Converter accepted the second type of range recording and via a further 4 cabinets processed this into a form *WREDAC* could use[30].

To keep track of Elliotts' work WRE engineer Jack Bowie stayed in the UK for some months up to mid-1955. Simon Lavington continued Laurence Clarke's recollections:

> Bowie was always threatening us with a *'crutching knife'* if the project ran late. This is a horrendous tool used by the sheep shearers! [31]

The *403* was due to be completed in June 1955, and it arrived by sea in Adelaide in September 1955 accompanied by three Elliotts technicians and a large kit of spares. But not the Output Converter, printer or plotters. The basic installation was completed during November, but there were problems. One type of tube kept failing in the memory electronics, and the cooling system did not really cope as temperatures passed 35ºC. [32]

The Output sub-system was shipped in May 1956 and by mid-year *WREDAC* passed its acceptance tests and was handed over to Allen-Ovenstone and his team.

The *Elliott 403*'s Output Converter in the UK in 1955: 4 Mufax plotters, Bull Line printer, Output processor, Magnetic Tape input (from the Elliott's archive at BAE Systems and Telent PLC UK)
Photo: Courtesy, Defence Science & Technology Organisation

---

[30] R.W.M. Boswell 'Guided Flight Trials' (J. Royal Aeronautical Society, Vol.62 June 1958).

[31] Simon Lavington 2011 *ibid*.

[32] Simon Lavington 2011 *ibid*. The tubes were '12AT7 twin triodes' operating too close to their design limits. This was never fixed but WRE engineers eventually screened new valves for the best performers.

3   Using WREDAC

Meanwhile, Allen-Ovenstone had written 'An Introduction to Programming for Automatic Digital Computers' which included detailed explanations of programming mathematical functions, and everything one needed to program 'the WRE DAC'.[33] He also wrote the basic system software which was a very compact symbolic program loader on the same principles as EDSAC's. [34]

It is likely he wrote the initial trials data processing programs, and by September an enthusiastic report was presented at a symposium 'Automation and Australia' at the NSW University of Technology[35] in Sydney. WRE's Principal Scientific Officer, Fred Thoneman discussed UK business computing then gave a very clear overview of WRE's activities:

> *... much experimentation, engineering work and engineering testing involves the making of a very large number of measurements and organising them into coherent and intelligible forms. ... It's the kind of job that data-processing automata are excellently fitted to do, if, and this is an important point, if there is enough data to justify the use of these automata. They cost a lot of money, at least they do at present. ...*
>
> *[We] have been almost obliged to take advantage of high-speed automatic processing. A large part of our work involved with guided weapons is what might be called the mass production of measurements, and the introduction of data-processing automata in this field was motivated by the desire to get our flight-trial results quickly into a clearly surveyable form. The sheer bulk of raw data generated at high rates, and very high rates these are, by elaborately instrumented guided weapons, requires that the system be fully automatic. If you leave a man, no matter how quick he is, actively engaged in the routine daily processing work, he must necessarily slow the entire system down to human rates, and the factor is somewhere about the order of 10 to 100,000 to 1. ...*
>
> *We will imagine that the observing instrument is in a missile. ... This is coupled in the missile to an electrical oscillator whose frequency it controls. It is necessary, of course, because the missile is inaccessible, to telemeter, by radio-link, the information of the out-put of that detecting device to ... a ground receiver. ... The telemetry system is time-shared, that is, the output from many observing instruments are sent sequentially along the same transmission channel, and ... we have to deal with many thousands of points or data a second. ...*
>
> *In the automatic system, the received data is recorded directly on magnetic tape ... The data is played back at a slower speed into a fully automatic measuring device which measures the data as it comes along, sample by sample, and codes those measurements in binary-digital*

---

[33] J. Allen-Ovenstone 'An Introduction to Programming for Automatic Digital Computers' WRE TM 50, 1955.

[34] Peter Main, private communication Dec 2007.

[35] Later the University of NSW.

code. ... the machine will work for hours, even days, at a time, and if it does break down the break-downs can be fairly easily repaired. These measurements, which are now recorded on magnetic tape in binary-digital code, are played into a high-speed electronic digital computer of the type of which this University has recently become the proud possessor[36]. That is where the calculations are done on this data, and the output of the computer is then recorded again on a third magnetic tape, and also, as willed, can be tabulated very rapidly using a fast printer ... or, by using another type of decoder, caused to plot graphs at very high speed on anything up to 12 simultaneous channels. ... The pay-off of this system can be expressed very simply and briefly. To process completely 10,000 data by relatively up-to-date manual methods required a total of 20 working hours. The automatic system does the entire job in a total time of fifteen minutes. Both systems are equally accurate. [37]

At the end of 1956 Allen-Ovenstone's Quarterly Report included:

For the first time since the range commenced operation there was no backlog of trial calculation over the Christmas period and, despite the shortage of skilled programming and maintenance staff, a reasonable service to the establishment was maintained. [38]

This was very positive, but there were reliability problems. They were keeping track of performance and the first period reported was from acceptance in July 1956 to March 1957: [39]

Average Total Time Available/Week	40 hrs	*- ie 1 shift operation*
Average Scheduled Maintenance/Week	10 hrs	*- 2 hrs at the start of each day*
Average Unscheduled Maintenance/Week	8 hrs	*- ie faults*
Average Effective Time/Week	20 hrs	
Average Standby Time/Week	2 hrs	*- time with no jobs to run*
Efficiency Factor = $\dfrac{\text{Effective Time}}{\text{Total Time}}$	50%	

That 'Effective Time' looks like a concern but the required work was being done.

One might think that the Maths Services Group had enough to do, but no. They could have been inspired by the 'Automation and Australia' symposium, or by the Cambridge *EDSAC* team's support of the Lyons Electric Office (*LEO*) business computing initiatives, but Allen-Ovenstone became the driving force behind planning

---

[36] 'UTECOM', an English Electric *DEUCE*.

[37] F. Thonemann 'Automatic High-speed Data Processing' in 'Automation and Australia - proceedings of Symposium at NSW University of Technology 11 & 12th September 1956' (NSW University of Technology)

[38] J. Allen-Ovenstone 'WREDAC quarterly report 1.10.56 to 20.12.56' SA5398/11/2, reproduced in Peter Morton 1989 *ibid.*

[39] 'Data Processing System - The Australian Weapons Research Establishment - Salisbury, S. Australia', Communications of the ACM. Vol.1 No.7 July 1958.

an international computing conference for mid-1957. A direct cause was given in the conference proceedings – WRE had been providing advice on computers "*on a consulting basis, with their application to office procedures for banks, insurance companies and general administration of large undertakings*". WRE gave three objectives for the conference:

(a) to tell the many interested people and organisations of our experiences and to show them our system and equipment and demonstrate our operations;

(b) to get intelligent and constructive criticism of our methods from those versed in the art with a view to improving our techniques and operations;

(c) to provide sound advice from our own staff, and the many renowned visiting delegates and lecturers, to those business and technical delegates interested in the use of such machines in their own spheres of activity. [40]

For the first of these objectives John Ovenstone[41] wrote two demonstration programs to run on WREDAC:

Stock and Inventory Control – to model a business producing 500 items manufactured from 1,000 catalogued components and to demonstrate tracking of stock levels, production changes and costs.

Hourly Payroll Calculations – which modelled a business with complex employee records, daily employee details updates, and weekly hours worked, then it produced pay lists and total wage details.

For each of these he considered many practical issues, such as the time required to prepare the basic records and the regular update procedures. He created a suite of sample records and documented the programs with flowcharts. Ovenstone also prepared a paper on computing for business accounting.[42]

The Conference was enormous, and it was split into three sections: *Programming and Mathematics*, *Engineering*, and *Business Applications*. There were talks by visitors from:

UK: Ferranti Ltd., EMI Electronics Ltd., National Cash Register Co., English Electric Co., British Tabulating Machines Co., University of London, Cambridge University, University of Manchester, University of Leeds, Royal Aircraft Establishment, Royal Radar Establishment, National Physical Laboratory,

USA: IBM Pty. Ltd., Burroughs Ltd., University of Michigan, RCA Patrick Air Force Base,

---

[40] H.J. Brown, 'Introduction' to 'Data Processing and Automatic Computing Machines, Proceedings of Conference held at Weapons Research Establishment, Salisbury, S.A. 3rd - 8th June 1957' (Commonwealth of Australia Department of Supply 1958).

[41] About this time he dropped the hyphenated surname.

[42] J.A. Ovenstone, 'Business and Accountancy Data Processing' and 'Demonstration Problems on the WREDAC System' in 'Data Processing and Automatic Computing Machines, Proceedings of Conference' 1957 *ibid.*

and locally: University of Adelaide, University of Sydney, NSW University of Technology, University of Melbourne, University of Tasmania, CSIRO, Snowy Mountains Hydroelectricity Authority, Kalamazoo Ltd., and WRE.

There were 8 talks involving WREDAC, 14 related to the other Australian computers (CSIRAC, UTECOM and SILLIAC), 8 on UK computers and another 8 'advertising' commercially available equipment. Plus 8 talks on the older analogue computing techniques and a collection more on various technical issues. Overall 68 papers were presented over the 6 days of the conference along with discussions and demonstrations.

Initial papers repeated the usefulness of WREDAC and its associated systems and added:

> Other applications of the WREDAC computer have been exploited outside the field of guided missiles. For example, it has already been applied to a variety of calculations arising in aerodynamics and aircraft structures, and now the possibility of its use for business calculations is under consideration. An officer of the Public Service Board has spent some time here studying the WREDAC in order to report to the Board on the possible applications of high speed digital computers in Government Departments. [43]

Clearly the conference was a great success, and with hindsight the proceedings provide a remarkable description of the start of British and Australian digital computing, along with papers that had surprising influences subsequently[44].

George Barlow, who was deeply involved in developing the WREDAC system, was fascinated by one presentation in particular. He wrote later:

> At the time we knew we were ahead of the British ... To my delight, I found that while RCA, who operated the [missile test] range at Cape Canaveral, had both Telemetry and Doppler Converters, neither worked. ... Bill Boswell was so pleased that he dispatched Bill Watson and myself to a conference in New York held by the Instrument Society of America, which had a session scheduled on Automatic Processing of Trials Data ... We were just in time to hear the chairman say, 'Well, we all agree that range data is a fruitful ground for automatic processing, but has anybody actually done it?' Bill nudged me, and I managed to stammer out that we had automatically processed telemetry data - in Australia. There was a stunned silence. [45]

Whether John Ovenstone was inspired by the conference, or frustrated by his programming experience, he had instigated a series of improvements to WREDAC by the end of 1957. The first was a much enlarged operator's console. The original was an array of switches and two modest display tubes built into a processor cabinet which had to be used while standing. The replacement was an imposing desk with

---

[43] B.G. Gates, 'Opening Address' in 'Data Processing and Automatic Computing Machines, Proceedings of Conference' 1957 *ibid.*

[44] eg. Charles Hamblin's description of *Reverse Polish Notation* which led to stack based computing and influenced the design of hand held calculators.

[45] G.E. Barlow quoted in Peter Morton 1989 *ibid.*

switches, dials and two television sized screens. This would certainly have provided a much more comfortable program debugging environment! [46] In addition he specified additions to the processor's logic. Three new instructions would be provided to modify the operation of existing instructions:

> 'Use B-lines' allowed for multiple groups of address modification, or indexing hardware, i.e. more complex handling of tabulated data,
>
> 'Use Logic' would support new hardware for floating-point arithmetic, and for business oriented character operations, and
>
> 'Use Units' would allow more magnetic tape drives to be installed, along with multiple paper tape readers and punches, without changing existing input/output instructions. [47]

Ovenstone's vision and ability to get things done did not go unnoticed. In 1958 he was promoted out of WRE to First Assistant Secretary for the Department of Defence where he worked at converting many administrative tasks to computer operation - but that's another story. [48]

As experience was gained WREDAC was used for many tasks beyond missile trials data analysis. Reported work included:

- CSIRO's *Division of Mathematical Statistics* had regular access to carry out a large-scale climate change study, up to the end of 1959. [49]
- WRE's *Systems Assessment* and *Aerodynamics* divisions had missile flight data reprocessed and converted to analogue form for further analysis on their simulator.[50]
- Another CSIRO Division, *Soils*, made notable use of WREDAC to process x-ray scattering data for the first stage of determining the atomic structure of mica. [51]
- In 1960 WRE's new *Theoretical Supersonics Group* programmed a simulation of missile wing behaviour. [52]
- University of Adelaide MSc student John Sanderson wrote a high-level language interpreter for WREDAC. [53]

In mid-1958 the Maths Services folk summarised WREDAC's performance:

> *... about 18 months and 30 man-years of effort were required before the automatic system completely replaced the corresponding manual processes. The total elapsed time between a trial and the presentation*

---

[46] The new console position is shown in WRE drawing MSK56 of 22 October 1957. Details of the consoles may be obtained from undated photos in Peter Morton 1989 *ibid* and J.M. Bennett et al 'Computing in Australia' Hale & Iremonger 1994.

[47] 'Data Processing System' CACM. Vol.1 No.7 July 1958 *ibid*.

[48] Peter Morton 1989 *ibid*.

[49] Research Review of the CSIRO 1960. Accessed through Google books February 2012.

[50] White, Overheu & Wheadon "A report on data processing at WRE", WRE TRD2, 1959 (reported in Peter Morton 1989 *ibid*).

[51] E.W. Radoslovich (CSIRO Div Soils) "The Structure of Muscovite" Acta Crystallography 13/919 1960 (reported in Peter Morton 1989 *ibid*).

[52] Y.Y. Chan "Theoretical pressure distributions on a series of supersonic wing-body combinations" WRE TM HSA 85-90 1960.

[53] J.G. Sanderson, "Automatic Programming for Digital Computers" University of Adelaide MSc Thesis, 1957.

WREDAC's new console about 1958
(from T. Pearcey "A History of Australian Computing" - Chisholm Institute of
Technology 1988)
Photo: Courtesy, Defence Science & Technology Organisation

of final results has been reduced to one-tenth of that required by the manual system, the cost of processing trials information has been reduced by a factor of at least 20. The peak load capacity of the automatic system is about 50 times that of the manual system, and the complete cost of the automatic system has been recovered in the first two years of operation. [54]

The report continued with figures showing increasing use and improving usefulness:

	July 1956 - March 1957	March 1957 - Dec. 1957	Dec. 1957 - March 1958
Average Total Time Available/Week	40 h	57 h	70 h
Average Scheduled Maintenance/Week	10 h	10 h	10 h
Average Unscheduled Maintenance/Week	8 h	6 h	8 h
Average Effective Time/Week	20 h	40 h	50 h
Average Standby Time/Week	2 h	1 h	2 h
Efficiency Factor = $\dfrac{\text{Effective Time}}{\text{Total Time}}$	50%	70%	72%

By late 1960 this last efficiency factor was 'above 80%'. [55]

4   WREDAC's End

WREDAC was performing well but new requirements were on the horizon. The UK was developing an intermediate range ballistic missile, the *Blue Streak*, which would be capable of carrying a nuclear weapon. It would be tested at *Woomera* and a great deal of new range equipment would be needed, possibly including as many as 50 high performance tracking cameras. A 1959 report stated:

new electronic digital computing facilities capable of coping with 100 times the 1958 computational load must be acquired urgently. [56]

This report went on to carefully justify this speed factor and then to give some benchmarks for available transistorised, i.e. reliable, computers:

Operating speed relative to WREDAC

Machine Calculation	WREDAC	IBM 7090	TRANSAC S-2000	EMIDEC 2400
Accepted Measure	1	68	27	21
Polynomial	1	74	60	20
Square Root	1	63	32	34
Table look-up	1	145	67	34
Scaling of number	1	76	64	21
Runge-Kutta	1	52	35	16

---

[54] "Data Processing System" CACM. Vol.1 No.7 July 1958 *ibid.*

[55] Peter Morton 1989 *ibid.* Trials superintendent J. Clegg reported WREDAC's reliability above 80%.

[56] White, Overheu & Wheadon "A report on data processing at WRE", WRE TRD2, 1959 (quoted in WRE TM TRD 35).

> *Clearly the above figures indicate ... that there is only one available machine able to cope with the expected computational load.*

The IBM 7090 promised a great deal of available software, and the new standardised FORTRAN language. In March 1960 the WRE Board of Management voted to hire the 7090 at US$330,000 a year.

Five weeks later the *Blue Streak* was cancelled.

However, missile trials continued. The IBM 7090 was delivered at the end of 1960 and handed over in February 1961. The two computers were run in parallel while the required suite of new programs was developed. Telemetry processing and missile range data conversion were updated and the 7090 took over trials analysis, as indicated in the following table. [57]

	Trajectory points calculated per day	Cost of each calculated point
1955-56 (pre WREDAC)	800	A$4.00
1956-57 (WREDAC)	1000	50c
1963-64 (IBM 7090)	3000	10c

WREDAC continued to be used too, with new programs ranging from analysis of wind tunnel tests of missiles, to statistics and mathematical work.[58] However, after only 7 years' use WREDAC still needed constant maintenance and looked very old next to the sleek transistorised IBM 7090.

At the end of 1962 WRE Principal Research Scientist George Barlow recommended that WREDAC should be disposed of, and that it might be offered free to the South Australian Institute of Technology. Peter Morton wrote:

> *Its ultimate fate is hazy. A few parts did go back to Britain as spares, but most of it probably ended as scrap. [59]*

The old machine wasn't missed, as Peter Morton continued:

> *The excellent reliability and much greater speed of the new IBM 7090 helped the growth of programming skills within WRE. ... The new computer played an important role in WRE's support of the American space programs, and it was vital to the success of the ambitious ELDO [European Launcher Development Organisation] firings of the mid-1960s. [60]*

---

[57] Peter Morton 1989 *ibid*.

[58] Knight, D. C. "Wredac programmes for the reduction of wind tunnel force-measurement data", Jul 1960 WRE-TRD-TM-53. Nicholls, L. A.; Phillips, A. D. "Some facilities on WREDAC for the analysis of stationary time series", Aug 1960 WRE-TRD-TM-52. Overheu, D. L. "Some programs for the conjugate gradient methods for the solution of linear simultaneous equations", Jul 1961 WRE-TRD-TM-57A.

[59] George Barlow biography from http://www.eoas.info/biogs/P003358b.htm (March 2012) and Peter Morton 1989 *ibid*.

[60] Peter Morton 1989 *ibid*.

Appendix 1 - Some of the People Associated with WREDAC

John Allen-Ovenstone	Born 1925 in Sydney. During WW2 John Allen-Ovenstone served with the AIF in S.E. Asia and then joined the NSW Police force. In 1948 he enrolled at the University of Sydney and obtained a BSc with 1st class honours in mathematics and physics. He also used the CSIRO's first computer (CSIRAC) being developed on the University site. Following graduation he joined LRWE and was sent to Cambridge to complete his maths studies. There he used their first computer, EDSAC, which had just been completed. He was awarded a PhD in 1953 and returned to WRE where he specified, supported and championed their first computer (WREDAC). He rose to the rank of Principal Scientific Officer responsible for missile test data processing. In 1958 he transferred to the Department of Defence where he introduced data processing and a vision of integrated, communicating systems. From 1964 he was foundation Professor of Computing Science at the University of Adelaide. In 1971 he became Managing Director of business consultants Inbucon (Australia). Following recovery from severe injuries in a car crash he had a series of government jobs up to retirement in 1983. He died in 1984. [61]
George Edgerton Barlow	Born 1924 in Melbourne. At Melbourne University he received a MSc in Physics in 1947 and joined LRWE. He received training in the UK then from 1949 worked solidly on computing related electronics. Initially this was analog processing, then LEDAC and WREDAC. He designed the important missile telemetry converter with Leo Cohen and Fred Thonemann in 1953. In 1968 he transfered to DSTO Canberra and from 1980 until his retirement in 1987 he was Deputy Chief Defence Scientist. He died in 2005. [62]
Robert William McGregor (Bill) Boswell	Born 1911 in Melbourne. For his 1935 MSc at Melbourne University he used radio direction finding to trace thunderstorms across southern Australia. He continued this with CSIRO, then joined the PMG which sent him to the UK for further study. During WW2 he joined the Navy and worked on radar. In 1946 he joined the Department of Civil Aviation as senior engineer. Then, in 1948 he became Principal Scientific Officer at LRWE and headed the electronics group. The next year he was put in charge of the test range. He joined the CSIRO Committee on Mathematical Instruments (ie computers), toured US and UK missile test ranges and in 1956 received an OBE. From 1958 he was Director of WRE and known as 'Mr Rocket Range'. In 1965 he left WRE to become Secretary to the Department of National Development and Chairman of the Snowy Mountains Council. Then in 1969 he was Deputy High Commissioner in London and returned to be Chairman of the Australian Atomic Energy Commission. He died in 1976. [63]

---

[61] Who's Who in Australia 1965 (Colorgravure Publications), Encyclopedia of Australian Science (http://www.eoas.info/biogs/P003832b.htm), "Outstanding scientist dies" The Australian 24 Jul 1984.

[62] Encyclopedia of Australian Science (http://www.eoas.info/biogs/P003358b.htm), "Developing the science to defend the nation" Sydney Morning Herald 25 Nov 2005.

[63] Australian Dictionary of Biography (http://adb.anu.edu.au/biography/boswell-robert-william-mcgregor-9547), Encyclopedia of Australian Science (http://www.eoas.info/biogs/P001605b.htm)

Appendix 2 - Summary of WREDAC's Instructions

This is a summary of 'An Introduction to Programming for Automatic Digital Computors' written about 'the WRE DAC' by John Allen-Ovenstone in 1955 as Technical Memorandum WRE TM50. This document is 73 pages long, so detail and extensive examples have been skipped.

Programming Notes:
- Instructions occupied half a memory word (17 bits), and the low order half ('even') was executed before the high ('odd') instruction.
- There were two instruction formats, 'arithmetic' (identified by its low order bit = 0) and 'transfer' (low order bit = 1).
- Run time addresses could be modified by adding the contents of a B-line register (or index) specified as α 0 i.e. no modification, β B-line 1, γ B-line 2, δ B-line 3. B-lines 1 to 3 occupied memory locations 1 to 3.
- Program tapes were punched in a 5 bit teletype code:

Code	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Letter	A B C D E F G H I J K L M N O P Q R S T U V W X Y Z α β γ δ φ
Number	1 2 3 4 5 6 7 8 9 / 0

  The program loader interpreted operation code field as letters and addresses as decimal numbers.
- Numbers were stored with values -2 to +2 in 34 bits as sign, unit, 32 bit fraction.

Arithmetic Instructions:

Operation	Address	B-line	Type
5 bits	9 bits	2 bits	'0'

Here *b* represents the B-line which may be α 0, β B-line 1, γ B-line 2, δ B-line 3.
A accumulator, R multiply register.
(addr) implies the contents of location addr.
addr may be modified, see under cues below.

As punched	Op	Description	As punched	Op	Description
CH *b*	0	Check, stop if the console 'Stop' key is depressed	CA *addr b*	16	Clear and add A = (addr)
GE addr b	1	Go to even addr	CS addr b	17	Clear and subtract A = - (addr)
PO addr b	2	If A positive go to addr odd	SW addr b	18	Swap A and (addr)
PE addr b	3	If A positive go to addr even	CL addr b	19	Clear to A, (addr) = A then clear A
NO addr b	4	If A negative go to addr odd	AD addr b	20	Add A = A + (addr)
NE addr b	5	If A negative go to addr even	SA addr b	21	Subtract A = A - (addr)
JO addr b	6	If B-line 1 ≠ 0 increment its address bits and jump odd	CT addr b	22	Collate A = A AND (addr)
JE addr b	7	ditto even	AS addr b	23	Add subtract A = (addr) - A
LD addr b	8	Long division A = A + R / (addr)	SB addr b	24	Set B-line, if addr>0 (1) = addr else (1)=512 - |addr|
SM addr b	9	Set multiplier R = (addr)	CO addr b	25	Clear to odd, (addr)odd = high A, clear A
MA b	10	Multiply and add A = A + A × R	CE addr b	26	Clear to even, (addr)even = high A, clear A
MS b	11	Multiply and subtract A = A - A × R	ST addr b	27	Store (addr) = A
SL addr b	12	Shift left (A) by addr places	AO addr b	28	Add odd, high A + (addr)odd

SR addr b	13	Shift right		SO addr b	29	Subtract odd, high A - (addr)odd
NM b	14	Normalise, shift A till |A| between 1 and 2, store count in B-line 1		AE addr b	30	Add even, high A + (addr)even
MD b	15	Modulus, A = |A|		SE addr b	31	Subtract even, high A - (addr)even

Transfer Instructions:

Tape unit	Operation	Memory block	Disc track	Type
1 bit	4 bits	3 bits	8 bits	'1'

Here there is no B-line modification and all transfer orders end with α. Block transfers are for 64 words.

As punched	Op	Description	As punched	Op	Description
	0	spare	R T d α	8	Read magnetic tape, one word from drive d to A
	1	spare	W T d α	9	Write magnetic tape, from A to drive d
I L α	2	Input paper tape to 5 low bits of A	B b T d α	10	Block to tape transfer, from main store block b to drive d
I M α	3	Input paper tape to most significant 5 bits of A	T d B b α	11	Tape to block transfer, from drive d to main store block b
O L α	4	Output from least significant 5 bits of A to paper tape	T d H α	12	Tape drive d halt
O M α	5	Output from most significant 5 bits of A to paper tape	T d G α	13	Tape drive d go
B b D t α	6	Block to disc transfer, from store block b to disc track t	T d F α	14	Tape drive d forward
D t B b α	7	Disc to block transfer, from disc track t to store block b	T d R α	15	Tape drive d reverse

Program Loader Cues:

As punched	Description
QA m α	Set next order address to m and store m in 7
QC α	Obey the following command as soon as it is assembled (especially 'QC α GE *startaddress* α' at the end)
QP m α	Place next order in word m as a parameter and continue storing whole words
QS α	Place next order in the address from the last QA
QN m α	Read next 7 characters as a binary fraction and store in m, repeat till 7th char is odd

The program loader (or initial orders) occupied 64 words and set a number of memory locations. It could modify an instruction's address to support standard subroutine loading by defining locations identified by A, D, G, H, K, M, N, S or U to be set to a load address. Then, instructions with this letter appended to their address field would be modified at load time, e.g.

QA 300 α   sets the load address to 300 and places 300 in load variable 'A'
CA 5 A α   is loaded into 300 with its address modified to 305.

Memory set by the loader:

1 to 3 (i.e. Bline 1 to 3) = 0	$6 = 1 \times 2^{-3} + 1 \times 2^{-16}$
$4 = 1 \times 2^{-32}$ round off	Load variables: 7 A, 8 D, 9 G, 10 H, 11 K, 12 M, 13 N, 14 S,
$5 = 1 \times 2^{-29}$ unit address	15 U

During 1958 WREDAC's processor was modified along the lines recommended by John Ovenstone. The new head of Mathematical Services, Don Overheu, then wrote 'An Introductory Coding Manual for the WRE Automatic Computer' (WRE TRD39). The following notes are based on the differences this shows from the preceding section.

Revised Arithmetic Instructions:

CH *addr b*	0	If *addr* ≠ 0 and A=0 goto addr odd	- Replacing the conditional halt.
LD *addr b*	8	Long division A = A + (addr) / R	- Inverting the sense of the division.
UL *spec* α	23	Use Logic as spec given by Mode, ABC:	- Replacing AS (Add subtract).
		Mode (3 bits) = 1 for Use B-line logic (the only Use-logic implemented) A (2 bits) specify which 2 B-lines are to be added before use as modifiers: 0 use indicated B-line, 1: 1+2, 2: 2+3, 3: 3+1 B (2 bits) specify which of the 4 sets of B-lines will be used: 0, 1, 2 or 3 C = specify the B-line for SB, JO, JE and NM, 0 none, 1, 2 or 3	

Also addresses may be written X / Y where X is the block (0 to 7) and Y the offset (0 to 63).

All Transfer Instructions Were Revised:

Operation	Block address	Sector address	Type
5 bits	3 bits	8 bits	'1'

Here there is no B-line modification and all transfer orders end with φ. Block transfers are for 64 words.

As punched	Op	Description	As punched	Op	Description
	0	spare	WT 0 φ	16	Write magnetic tape channel 0 from A
	1	spare	WT 10 φ	17	Write magnetic tape channel 1 from A
IL φ	2	Input paper tape and add to 5 low bits of upper A	BT 0 *b* φ	18	Block to tape transfer, channel 0 from main store block *b*
IM φ	3	Input paper tape and add to most significant 5 bits of A	BT 10 *b* φ	19	Block to tape transfer, channel 1 from main store block *b*
OL φ	4	Output least significant 5 bits of upper A to paper tape	RT 0 φ	20	Read magnetic tape, one word from channel 0 & add to A
OM φ	5	Output most significant 5 bits of A to paper tape	RT 10 φ	21	Read magnetic tape, one word from channel 1 & add to A
BD *b / s* φ	6	Block to disc transfer, from store block *b* to disc sector *s*	TB 0 *b* φ	22	Tape to block transfer, from channel 0 to store block *b*
DB *b / s* φ	7	Disc to block transfer, from disc sector *s* to store block *b*	TB 10 *b* φ	23	Tape to block transfer, from channel 1 to store block *b*
	8	spare	TF 0 φ	24	Tape channel 0 forward
	9	spare	TF 10 φ	25	Tape channel 1 forward
	10	spare	TR 0 φ	26	Tape channel 0 reverse
	11	spare	TR 10 φ	27	Tape channel 1 reverse
FG0 φ	12	Find gap channel 0 ie blank tape	TH 0 φ	28	Tape channel 0 halt
FG1 φ	13	Find gap channel 1 tape	TH 10 φ	29	Tape channel 1 halt
	14	spare	ET 0 φ	30	Erase tape channel 0
US *x / y* φ	15	Use control x, unit y	ET 10 φ	31	Erase tape channel 1

For the Use command, control equipment = 0 for paper tape reader, unit = 0 or 1

= 1 for paper tape punch, unit = 0 or 1

= 2 for magnetic tape channel 0, unit = 0 to 3