

# Ferranti Atlas 2 computers at AWRE Aldermaston and at the CAD Centre.

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## 1. Introduction.

The Ferranti Atlas 2 computer (see ref. [1]) was a development of the larger Atlas 1 machine. Atlas 2 was based on research carried out at the University of Cambridge on a prototype called Titan, which was in operation at the University from 1964 to 1973. The aim of the Titan/Atlas 2 project, with Ferranti's blessing, was to produce a cheaper – but still very effective – high-performance computer. The design authority for the joint Ferranti/Cambridge team was David Wheeler of the University's Mathematical Laboratory.

The basic Atlas design had originated some years earlier at the University of Manchester in a project called Muse; Muse was further developed in the period 1959 – 1962 by a joint University/Ferranti team led by Tom Kilburn. The history of the Muse and Titan projects is recounted in references [2] and [3], which were written for a website celebrating the 50<sup>th</sup> Anniversary of Atlas in 2012 – see: <http://curation.cs.manchester.ac.uk/atlas/>. This present article pulls together similar retrospective and anecdotal sources, with the objective of paying tribute to Atlas 2.

Only two production Atlas 2 computers were sold by Ferranti Ltd. The first went to the Atomic Weapons Research Establishment (AWRE) at Aldermaston in 1964; the other went to the Ministry of Technology's Computer Aided Design (CAD) Centre at Cambridge in 1967. In this

article the technical history of these two installations is described up to the shut-down of their Atlas 2s in, respectively, 1971 and 1976. The mainframe interests of Ferranti Ltd., and in particular Ferranti's computer manufacturing site at West Gorton, Manchester, were taken over by ICT in September 1963. In turn, ICT became ICL in 1968. Thus, Atlas brochures and manuals carried the successive imprints of Ferranti, ICT and ICL.

By way of introduction, we start in section 2 with a user's view of the production Atlas 1 and Atlas 2 computers and a comparison with their rivals in the market place such as the IBM 7090 and the IBM 7030 (STRETCH). Then in sections 3 and 4 the build-up of the AWRE and CAD Centre facilities is described. Clearly the uses to which the AWRE Atlas 2 was put are still subject to the Official Secrets Act. Fortunately, more details of the CAD Centre are available and this story in section 4 can be linked to the present-day CAD company Aveva, which is thriving on the same site at High Cross, Madingley Road, Cambridge. References are listed in section 6, which is followed by a technical Appendix giving hardware details to explain the internal differences between Atlas 1 and Atlas 2.

## 2. What sort of beast was Atlas 2?

Atlas 2 grew out of Atlas 1. Whereas the cost of an Atlas 1 installation lay in the range £2m to £3.5m (equivalent to over £50m in 2014), depending upon configuration, an Atlas 2 typically cost about £1.5m. The hardware differences between the two machines are explained in Appendix 1. There were also changes to the Atlas Operating System (called the *Supervisor*), as indicated below. Atlas 2 was certainly a relatively powerful machine in its day. Since 'all virtue is by comparison', we need to take a look at its competitors to get an idea of the relative power of Atlas 2.

In the late 1950s the nuclear research sector was setting the requirements for high-performance computing facilities. IBM and UNIVAC were the principal American companies responding to the challenge, with IBM's STRETCH computer (aka the IBM 7030) emerging as an early leader. The UK's computer manufacturers were slower to respond, for various reasons described in ref. [5], but the Ferranti Atlas 1 eventually emerged as the UK's prime candidate in the *Supercomputer* race. Table 1 summarises the hardware properties of the main competitors. The raw speed of an Atlas 2 was similar to that of Atlas 1, dependent upon the Atlas 2 storage options that were installed; detailed figures are given in Appendix 1. In the mid-1960s Atlas 2 was rated as rather less powerful than Atlas 1 in terms of general job-shop work throughput. This was due to its lack of a *one-level store* (now called *Virtual Memory*) and other changes explained in Appendix 1.

<i>Instruction</i>	<i>IBM 704 (1955)</i>	<i>IBM 7090 (1959)</i>	<i>IBM STRETCH (1961)</i>	<i>Ferranti ATLAS (1962)</i>	<i>CDC 6600 (1964)</i>
FXPT ADD	24	4.8	1.5	1.59	0.3
FLPT ADD	84	16.8	1.38 – 1.5	1.61 – 2.61	0.3
FLPT MPY	204	16.8 – 40.8	2.48 – 2.7	4.97	1
FLPT DIV	216	43.2	9.0 – 9.9	10.66 – 29.8	3.4

**Table 1. Instruction times in microseconds for some American and British high-performance computers that were first delivered between 1955 and 1964.**

On the software side, the Atlas 1 Supervisor was a historical landmark, being the first multi-tasking Operating System. It managed time, space and resources (peripheral equipment) – thereby allowing several programs to be active at any one time. The Supervisor is briefly described in [ref. 6], which also cites the original journal papers. Changes were necessary for the Atlas 2 Supervisor, due to the hardware differences described in Appendix 1. In 1963 a joint Ferranti/Cambridge University team accordingly set about producing a multi-tasking Atlas 2 Supervisor ref. [7]. The Atlas 2 Supervisor team, which eventually grew to 21 members, included David Barron, David Hartley, Roger Needham, Chris Spooner and Barry Landy [ref. 3]. But then in 1965 the academics on the Titan team at Cambridge decided on a different approach: they embarked upon the design of a novel time-sharing system inspired by pioneering work at MIT in America. This required further hardware modifications, described in Appendix 1. Meanwhile, a team of about a dozen people based at Ferranti's Lily Hill offices near Bracknell, continued on the original Atlas 2 Supervisor. The Lily Hill team is believed to have included John Chilvers, Richard Jennings, Bernard Pearson, Tim Wood and Arthur Trice. We'll meet John Chilvers again in the CAD Centre (section 4), where he emerged as one of the key software people with experience of all three Atlas 2/Titan installations.

The result was two rather different Operating Systems for Atlas 2. Both were multi-tasking, and both were variously described in contemporary literature as *time-sharing* or *multi-programming* but only the Titan version provided users with what we would now recognise as multi-access on-line working via terminals. The Supervisor installed on Atlas 2 at Aldermaston was of the batch-processing, job-shop, variety; the interface with both users and operators was very similar to that of the Atlas 1 Supervisor. Titan's time-sharing system, called the *Cambridge Multiple Access System* [ref. 8], became available on a trial basis at Cambridge University in October 1966 and then generally available from March 1967. The same multi-access system was installed on the CAD Centre Atlas 2, where it gave users the type of online interactive working more suited to CAD applications.

Before launching into a description of the two Atlas 2 installations, it is worth mentioning that just three production Atlas 1s were also delivered [ref. 6]. The Atlas 1 sites were:

Manchester University:	inaugurated December 1962; closed down 1971;
London University:	delivered 1963; closed down 1972;
Chilton, near Harwell:	delivered 1964; closed down 1973.

### **3. Atlas 2 at AWRE Aldermaston.**

#### **3.1. Computational background.**

Initial UK post-war research into atomic weapons was carried out at Fort Halstead, near Sevenoaks in Kent. Then in 1949 the Atomic Weapons Research Establishment was found a new home at a former RAF airfield near the village of Aldermaston in Berkshire. In 1987 the name *AWRE* was changed to *AWE*. Aldermaston is still very much alive today.

The UK's atomic weapons programme clearly needed world-class computing facilities in the period of the Cold War and government funding was usually forthcoming to secure AWRE's competitive position. Prior to 1953, AWRE staff used the computing facilities of other organisations, for example those of Manchester University. Thereafter AWRE was itself provided with leading-edge equipment. Table 2 lists the main electronic stored-program digital computers that were installed at Aldermaston from the 1950s to the 1970s, generally with newer IBM arrivals replacing existing IBM equipment [ref. 9]. Atlas 2 and STRETCH ran alongside each other for several years.

<b><i>Approx. date of installation</i></b>	<b><i>Computer</i></b>	<b><i>Comment</i></b>
Sept. 1953	Ferranti Mark I*	384 words of RAM and 16K words of drum.
Sept. 1956	English Electric DEUCE	402 words of serial delay line and 8K words of drum.
Feb 1957	IBM 704	Initially with 8K words (later 32K words) of RAM, 16K words of drum storage and 10 magnetic tape decks.
July 1959	IBM 709	32K words of RAM and 12 magnetic tape decks
Oct. 1960	IBM 7090	32K words of RAM and 12 magnetic tape decks
May 1962	IBM STRETCH	96K words of RAM, 2M words of disk and 16 magnetic tape decks
End-1964	Atlas 2	128K words of RAM, 4M words of disk and 14 magnetic tape decks
1971	IBM 360/75	
1972	IBM 360/165	
1974	IBM 360/168	
1979	Cray 1A	
. . . etc.	. . . etc.	(New equipment continues to be acquired)

**Table 2. The principal computers installed at AWRE in the period 1953 to 1979.** (Other, smaller, computers were also present. For example, in 1966 AWRE had an IBM 1460 and an IBM 360/30).

*(... continued on next page)*



**Figure 1. The IBM STRETCH computer at AWRE Aldermaston.** Notice that the photo has been edited, to obscure the faces of AWRE personnel. *Photo © Crown copyright 1962, MOD.*

### **3.2. The acquisition of an Atlas 2.**

In January 1961 AWRE placed an order with IBM for the rental of a STRETCH computer, at that time the fastest in the world. At this point, the production Atlas 1 was not yet working and Ferranti as yet had no plans for an Atlas 2. When STRETCH arrived at AWRE in the summer of 1962, there was an intention to hire the machine for three years. The machine's Fortran compiler was judged not fit for purpose, so Alick Glennie of AWRE wrote the first of two Fortran compilers for STRETCH – (see below). Practically all of AWRE's important nuclear programs were transferred from the IBM 7090 to STRETCH during 1963, a major effort that took almost a year [ref. 11].

It had been previously noted that the continued operation of STRETCH beyond 1965 and particularly for more than one shift “will be more expensive than the purchase of an Atlas” [ref. 10]. As things turned out AWRE eventually concluded a Lease/Purchase agreement with IBM, whereby AWRE leased STRETCH for a sufficient number of years until the purchase price had reduced to a relatively small sum. After purchase, STRETCH was finally removed from AWRE in 1971. Prior to all this, the possibility of AWRE also acquiring an Atlas 2 was being seriously considered in 1963 [ref. 11]. By November 1963 a letter of intent had indeed been sent to ICT for the purchase of an Atlas 2 [ref. 12]. The eventual price was £1.6m.

The Atlas 2 intended for AWRE was commissioned at Ferranti's West Gorton factory, with the expectation that the hardware would be moved from West Gorton to Aldermaston at the end of October 1964. The contracted delivery date for hardware and software was 31<sup>st</sup> December 1964 [ref.13]. The *Financial Times* of 8<sup>th</sup> August 1965 stated that "the Aldermaston Atlas 2, a £1.5m complex, has been installed and the finishing touches are being put to operating procedures". In April 1966 ICT was able to report that: "for about 10 months, the hardware at Aldermaston has been satisfactory. At the beginning of the year, both hardware and software went into test and these tests have proved successful. Acceptance has been back-dated to early January [1966]" [ref. 14]. An AWRE brochure confirms that the Atlas 2 was formally accepted in January 1966 [ref. 9].

Atlas 2 was finally switched off some time between 1<sup>st</sup> and 31<sup>st</sup> December 1971 [ref. 15]. An IBM 360/165 came on stream in mid-October 1971, thereby replacing an interim IBM360/75 and by that time both the STRETCH and Atlas 2 had effectively ceased to operate as the main AWRE computing resource.



**Figure 2. The Atlas 2 computer at AWRE Aldermaston. . Photo © Crown copyright 1964, MOD.**

The Atlas 2 configuration at Aldermaston was as follows [ref. 9], where the unit of storage is a 48-bit word:

Main core store:	128K words
Disc:	Data Products 4M word disc file.
Magnetic tape decks:	12 Potter one-inch decks and two IBM-compatible half-inch (7-track) decks.
Peripheral units:	2 card readers (each 600 cards/minute) 1 card punch (100 cards/minute) 2 lineprinters (800 lines/minute) 2 Creed 75 printers (10 characters/second) 2 TRG paper tape readers (300 chars/sec; 5-, 7- or 8-track) 2 paper tape punches (100 characters/second).

In addition, off-line graphical output was provided in 1963 by a Stromberg-Carlson SC4020 Microfilm recorder. This took data from an IBM-compatible magnetic tape and either acted as a very fast printer (up to 7,000 lines/minute) or as a graph plotter. The output appeared either on 35mm film or on a roll of photo-sensitive paper. Bob Hopgood [ref. 11] has added: "The SC4020 was replaced by a more modern and faster SC4060 around 1966/68. The SC4060 produced sheets of paper directly. The paper was photo-sensitive to create the image and then dried by heat. At the time the anecdote was that it was the only computer output device that produced a fire and then fed paper at it to keep it going!"

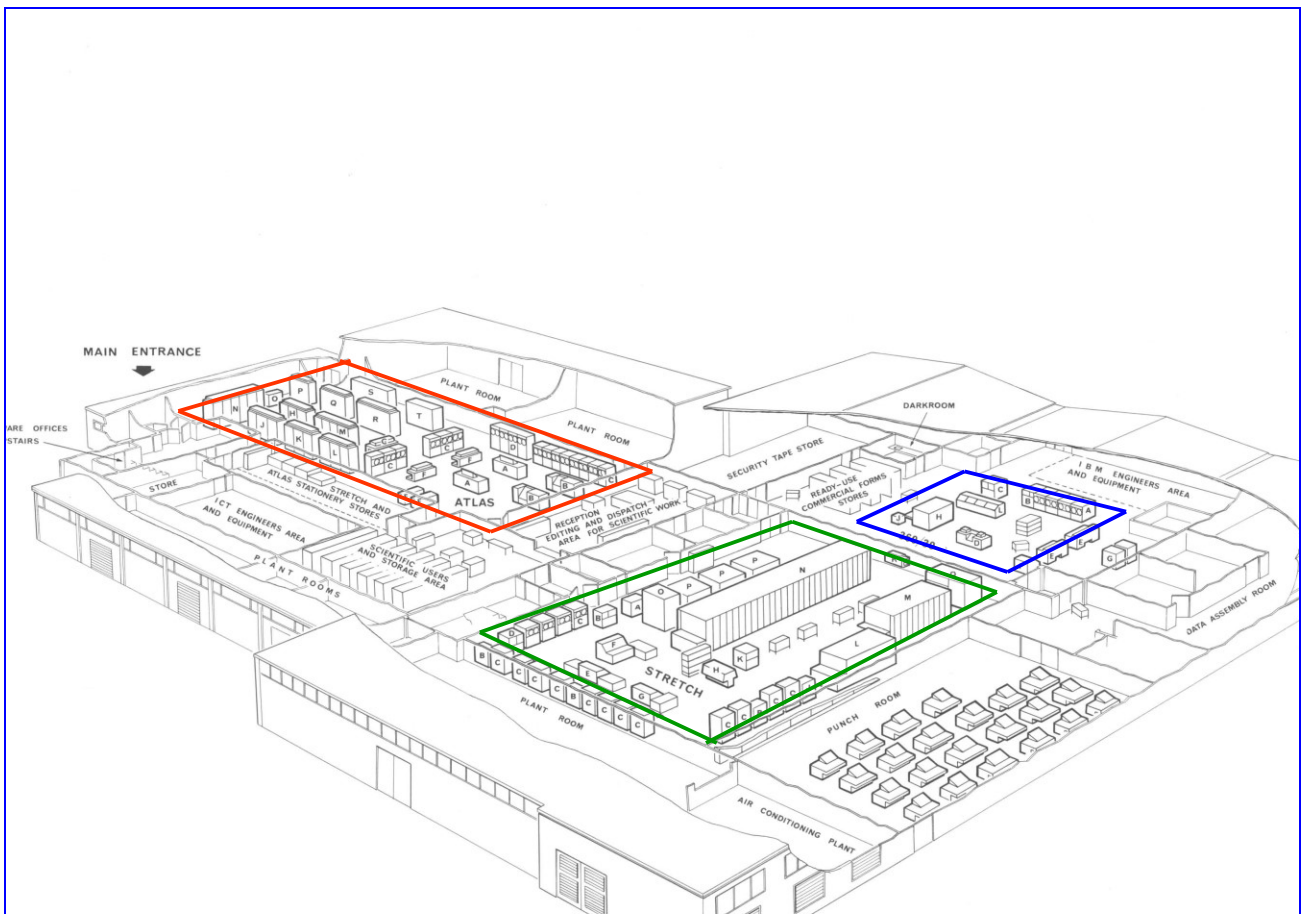


**Figure 3.** A Stromber-Carlson SC4020 Microfilm recorder at the Atlas Computer Laboratory, Chilton (close to Harwell), in 1967. Similar equipment was installed at AWRE Aldermaston in 1963 and later upgraded to a SC4060.

Co-operation naturally existed between Aldermaston and other sites related to the UK's Atomic Energy Authority (UKAEA). Indeed, ref [9] indicates that in 1966 about one third of Aldermaston's computing resources were being used to process selected work from AEA establishments at Harwell, Culham, Winfrith and Risley. Punched cards and/or magnetic tapes would normally be transported by car or aeroplane between AEA sites.

Around 1963/1964, Harwell had installed an IBM Workstation to provide electronic access to AWRE. In the bad winter of 1963 with snow from January to March, Bob Hopgood [ref. 11] remembers that actually: “the main link was a taxi that departed from Harwell around 08:00 and returned around 17:00. I know as I spent from January to April with the driver digging it out of snow drifts. I was seconded to AWRE but living in Abingdon so the taxi driver picked me up on the way to AWRE and dropped me off on the way back. There was also another run per day if I remember correctly in the middle of the day”.

In December 1965 an ICT Data Link was installed between Aldermaston and UKAEA Foulness, providing transmissions over 'phone lines at 100 characters/second between 8-track paper tape equipment at either end of the link.



**Figure 4. Layout of the Computer Building at AWRE Aldermaston in 1966.** The area outlined in red is the Atlas 2 computer; that outlined in green is the IBM STRETCH; that outlined in blue is the IBM 360/30. *Image © Crown copyright 1966, MOD.*



### 3.3. Software activity at AWRE.

Early programming at AWRE had been carried out in Assembler or in machine code. Fortran 2 became the norm in 1961 and from thenceforth the quality of Fortran compilers became an important issue for programming staff at Aldermaston. A E (Alick) Glennie led the compiler group. The names of most of the other staff have faded from memory, though amongst the AWRE computer operations staff, Mary Thomas and Florence Rigg are remembered [ref. 11]. One of the main IBM people involved with the STRETCH installation was John Nash from IBM's UK headquarters at Hursley – (see also below). Brian Chapman was a leading light in the team from Ferranti/ICT that provided software support for Atlas 2 at Aldermaston and Gordon Haley led the Ferranti/ICT engineering team that carried out the hardware installation.

Alick Glennie's software experience had started on the Ferranti Mark I computer at Manchester University where, in 1952, he developed a private *Autocode* system which is considered by many historians to be the first (albeit primitive) high-level language. In 1958 Alick worked on the ABC language, which generalised the SAP symbolic code for writing programs for the IBM 704.



**Figure 5. A E (Alick) Glennie, pictured at a NATO Software Engineering Conference in 1968. Alick died in 2003.**

In 1962, realising that IBM was behind schedule in developing a satisfactory Fortran compiler for STRETCH, Glennie's group developed their S1 Fortran compiler which accepted a dialect of Fortran 2. The S1 compiler was updated in 1963 to S2 for STRETCH, so as to give much faster compile-times. The S2 manual is available at [ref. 16c], from which it is deduced that the S2 team under Alick Glennie consisted of Mary Thomas, Barry Blythe and Colin Hart from AWRE; Bob Hopgood from AERE and Peter Ellis, John Nash and John Pether from IBM (UK) Ltd. Bob Hopgood recalls [ref. 11] that: "The main IBM people I remember were John Nash, Peter Ellis and John Pether from Hursley who all worked on the S1 and S2 compilers. John

Nash worked with Alick on the optimisation, Peter Ellis was mainly on the machine dependent parts”.

Later still, Glennie developed the S3 Fortran compiler for both STRETCH and Atlas 2, which provided the same user facilities as S2. S3 was embedded into the Hartran system, which was ported from the Atlas 1 at Chilton by Brian Chapman. Hartran (literally *Harwell's Fortran*) allowed for sub-programs [ref. 16], an important feature for nuclear applications where certain modules of code were often highly optimised and re-used. By means of S3, Fortran programmers at Aldermaston could switch painlessly between Atlas 2 (which was preferred for program development) and STRETCH (which was preferred for long production runs). At the time S3 was regarded as a state-of-the-art high-quality compiler, giving fast compile-times and efficient object code with full subroutine optimisation and innovative loop unwinding.

Before Brian Chapman finally left Ferranti/ICT at the end of 1966 he took the Aldermaston Hartran system (which included the S3 Fortran compiler) and installed it on the Cambridge Titan (aka Atlas 2) [ref. 17]. Later Hartran was also used at Cambridge in conjunction with a Fortran compiler (T3) written by John Larmouth.

Back at Aldermaston, ref [9] states that: “research in compilers will continue so that new needs may be satisfied. The *APL New System* for compiling machine tool control programs has been implemented during 1966”.

For obvious reasons, software activity at Aldermaston was, and still is, classified as *secret*. Bob Hopgood [ref. 11] remembers “the elaborate security at AWRE. You had to show your photo ID at the main gate and also at the [computer] building itself. I would have my bag searched each time I entered. One day the guard was quite amazed to find I was reading a biography of Leon Trotsky. It took quite a while to convince him that it was actually anti-communist and I was not a spy! ... When repairs were made to the toilets in the computer building, you had another two pass displays each time you went to the toilet in the next building”.

No details of post-1966 software projects at Aldermaston have yet come to light. However, it is intriguing to note that the Atlas 1 Compiler Compiler from Manchester was modified and ported to the Aldermaston Atlas 2 by Derrick Morris and John Clegg, shortly before John left ICT in July 1966 [ref. 18]. It is possible that ICT was contracted to provide Fortran IV and/or Algol compilers via the Compiler Compiler for the Aldermaston Atlas 2. Ref [9] states that: “In addition to the S2 and S3 compilers for Fortran 2, a Fortran IV compiler written by IBM is available on STRETCH. Compilers for other languages may be added as they become available from outside sources”. Bob Hopgood [ref. 11] has commented that the IBM Fortran IV compiler for STRETCH “[was notoriously slow and](#) [was abandoned by Aldermaston](#)”. It therefore seems likely that Fortran 2 was the standard at AWRE for several more years.

## 4. Atlas 2 at the CAD Centre, Cambridge.

### 4.1. Background and birth.

In 1963 the pioneering *Sketchpad* project of Ivan Sutherland at MIT [ref. 20] was opening up exciting possibilities for on-line graphics. Design engineers were intrigued by the thought that their drawings might one day be displayed, stored and manipulated by computer – thereby greatly assisting all stages of a manufacturing process. Within a few years the possibilities for *Computer-Aided Design* (CAD) were becoming apparent to perceptive administrators and managers.

However, the more perceptive computer gurus of the 1960s also knew that four facilities would have to exist before CAD systems could be put to use by industry:

- (a). Operating Systems that supported human-computer interactions;
- (b). on-line terminal devices that supported good-quality graphics;
- (c). computer hardware fast enough to support real-time graphical manipulations;
- (d). CAD software applications packages that were portable and user-friendly.

It would be some years before these four computing facilities became available in the market place – and indeed it was to be many years before CAD became commonplace in manufacturing.

In July 1966 Tony Benn became the UK's new Minister of Technology. Both he and the Prime Minister, Harold Wilson, were keen for the government to assist industry in adopting new technology. In early 1966, a Ministry of Technology *Working Party on Computer-Aided Design* had been established and by the autumn the government agreed that a *Mintech Atlas Centre for Computer-Aided Design* should be set up, to be owned and managed by the Ministry. The establishment's name was soon shortened, becoming known simply as the *CAD Centre*.

Many assumed that the new CAD Centre should be located in the nation's industrial heartland – for example in Manchester or Birmingham. In the event Cambridge was chosen, for the very good reason that the University already had an active CAD research group founded by Charles Lang in 1965 [ref. 21]. There was another factor influencing the choice of Cambridge. The Ministry of Technology was keen to support the UK's computer manufacturers and ICT had a spare Atlas 2 that was proving difficult to sell. The Ministry decided to buy this machine. Staff at Cambridge University knew all about Atlas 2 and how it could be made to run an operating system that supported human-computer interactions. Given that CAD applications required a high-performance, multi-access, computational platform, it seemed sensible for the government to install the last remaining Atlas 2 in the new CAD Centre. This decision must have brought relief to ICT, since this particular machine had been sitting on the factory floor at West Gorton 'in mothballs' since mid-1965.

The chosen location and the chosen computer caused some controversy at the time [22]. In particular, Atlas 2 was obsolescent by 1967 and was incompatible with ICT's emerging 1900 range of computers. Atlas was, however, not the only computer to be installed at the CAD Centre and the total equipment configuration, described below in section 4.2, turned out to work well.

A suitable site for the new Centre was acquired at High Cross, on the Madingley Road north-west of Cambridge, in an area owned by the University. Planning started in the spring of 1967 but the site was not ready until towards the end of the year. The existing building at High Cross had been used by the aircraft manufacturer Short Brothers for repairing flying-boat fuselages during the war and a considerable amount of refurbishment was necessary. In July 1968 it was announced in the House of Commons that the government planned to support the CAD Centre to the tune of £2.5m, of which £0.58m had already been spent [ref. 23].

On the Atlas 2 installation side, an early recruit was Graham Penning, who had joined ICT in June 1967. He transferred to the CAD Centre in December 1967, where he remained until 1973. Graham recalls [ref. 24]: “I attended an initial meeting at the *Three Horseshoes* at Madingley with various managers present. At this time the Madingley Road site was not yet ready for occupation. There was work going on to remove radioactive material discovered in the floor of the old rear corridor, near where I was to work! When work was going on to prepare the front car park, a stout electricity cable sprang up out of the ground. It was live. No service drawing of any kind existed for the site...Initial meetings were held at the CAD Centre, and engineers of which I was one first met up as a group. An Atlas commissioning team arrived headed by Denis Ashmore from West Gorton. His team included Dave Blain, Frank McCrystal, Mike Bane plus one other I can't remember. Commissioning was to take a year! Our engineering support team was headed up by George Hammond from Manchester Atlas. Dave Beckett and Bill Toombs arrived from London Atlas. John Martins and Bob Cheesman came from the Harwell [Chilton] Atlas, and Norman Wharton who was a roving support man from the Aldermaston Atlas. I also remember in those first meetings, Frank Hodson and Peter (?) representing the system support side. There was an on site wizened security guy called Pop who had no teeth”.

ICT absorbed the other UK mainframe companies in 1968 and, with government support, became ICL. Unusually, the government had asked ICL to manage and staff the CAD Centre. Thus was formed a unique partnership, whereby Mintech provided direction and financial control but day-to-day management and technical expertise were provided by ICL through its Dataskill Division. The company appointed Bernard Pearson as Deputy Director and the first batch of 12 operations staff moved to Cambridge in 1968 [ref.25]. Installation of computer equipment progressed by degrees. Recruitment of engineering design consultants and computer specialists started early in 1969 [ref. 22].

The first Director was Arthur Llewelyn, who took up his post on 8<sup>th</sup> September 1969. He had distinguished himself during the war whilst working on radar and had later become involved in computing projects related to aircraft and missiles. He had joined the Ministry of Technology in 1965 and had headed the Ministry's Computer Advisory Service. Arthur proved to be a skillful negotiator in the no-man's land between the Civil Service and the CAD specialists, being well-respected by both sides. He died in May 2006.

By the autumn of 1970 the CAD Centre was employing a total of about 50 people. Amongst these, the specialists were structured into two main groups: *Computers and Networks* (about a dozen staff led by John Chilvers) and *Applications* (about eight staff led by Brian Gott). John Chilvers remembers [ref. 26] that “inevitably there was cross-fertilisation. So far as I can

remember, the main applications groups were Mechanical Engineering, Civil Engineering and Electronics”.

Mike Williamson recalls [ref. 27]: “I joined CadCentre in October 1970. Dick Newell, Martin Newell and Tom Sancha were already there. Also there was the operating system team comprising Peter Gooding, Frank Hodson, Andrew Chandler and someone else whose name escapes me. I think Hugh Fingland was also there and Celia Bland. I was interviewed by John Chilvers and someone whose name also escapes me [could this have been John Ambrose?]”.



**Figure 6. Arthur Llewelyn, the first Director of the CAD Centre. This photo was taken at a NATO Software Engineering Conference in 1968. Arthur died in 2006.**



**(a)**



**(b)**

**Figure 7. (a) Brian Gott; (b) John Chilvers. Photos taken at the CAD Centre reunion in Cambridge in 2006.**

As recounted in [ref. 22], the CAD Centre had three initial aims:

- (a). to provide a means whereby new developments could be carried out with the minimum of investment and risk to the originators and with the maximum assistance from the CAD Centre;
- (b). to encourage an interchange of ideas and expertise in the development of CAD systems by setting up collaborative groups;
- (c). to provide a bureau service on Atlas – to be used both by industry and academia.

Atlas 2 acceptance trials were completed by March 1969. Soon the media was able to report that: “Up to 100 jobs can be handled at one time by the Ministry of Technology’s Atlas Centre for Computer Aided Design at Cambridge, now fully operational” [ref. 28]. By early 1970 the CAD Centre was providing a bureau service to 30 users and a consultancy service to many more.

#### 4.2. Equipment and facilities.

The Atlas 2 installed at Madingley Road is believed to have initially had 128K words of core store, though the cycle-time of this store has yet to be verified. It would probably have been either 2.5 or 5.0 microseconds. More core is thought to have been added later on in the life of the CAD Atlas 2, so that its final configuration is thought to have been as in Table 3. For comparison, the final configuration of Titan is also shown.

	<i>Cambridge Titan</i>	<i>CAD Centre Atlas 2</i>
<i>Main core store size (48-bit words) and cycle-time</i>	128K; 5 microseconds.	256K; ?? microseconds
<i>File disk</i>	Two, each 16m words	One, 27m words
<i>Operating system</i>	Titan multi-access	Titan multi-access
<i>Number of tape decks</i>	6?	6

**Table 3. Final configuration of the Cambridge Titan and the CAD Centre Atlas 2.**

(... continued on next page)



(a)



(b)

**Figure 8 (a) & (b).** Two views of the Atlas 2 machine room at the CAD Centre. In photo (a) five of the six one-inch Potter magnetic tape decks can be seen in the middle distance, with Costas Aretakis holding a reel of tape. CPU cabinets can be seen in the background. The two people in the foreground of photo (b) are John Chilvers and Celia Bland.

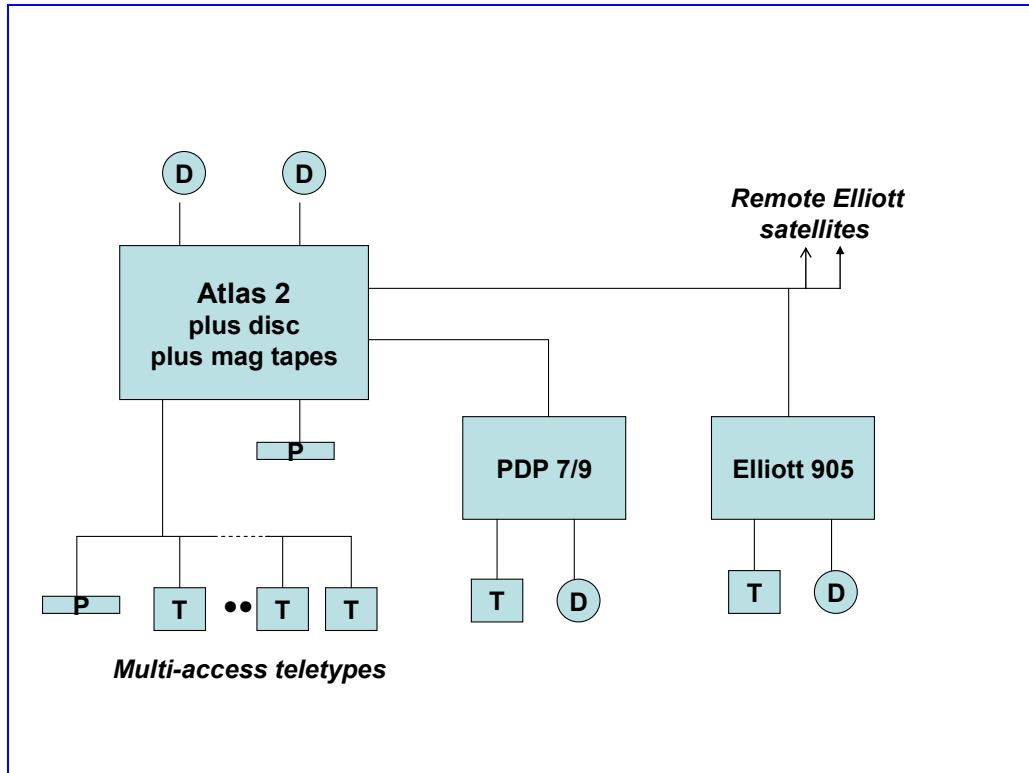


**Figure 9.** Motor-alternator sets and power distribution cabinets alongside the main Atlas 2 machine room at the CAD Centre.

From the start, specialist equipment was connected to Atlas 2 for visualisation and graphical input/output, along with conventional ASR33 teletypes and the larger ASR35s for general on-line program development. Over the years, the CAD Centre acquired a number of smaller satellite computers, some of which were directly connected to Atlas 2. An early acquisition was a Digital Equipment (DEC) PDP-9 computer with a large circular display and light pen. Other hardware within the Atlas time-frame (ie up to the end of 1976) included an Elliott 905

computer with a model 928 display with light pen, a CTL Modular One computer with a half-inch magnetic tape system, a PDP-11 and some Prime computers (see also below).

By way of illustration, the CAD Centre's early, and still very successful, 3D software graphics package GINO was described in 1971 as running at Madingley Road with the hardware facilities shown in Figure 10 – which is taken from [ref. 21b].



**Figure 10. The CAD Centre configuration in 1971, as used for the GINO 3D graphics package.** T = teletype terminals; D = display screens or storage tubes; P = plotters. At this stage the Elliott 905 had 16K words of storage and the PDP 7/9 had 8K words of storage. The PDP 7/9 was connected to Atlas via a 20K baud high-speed channel, whereas the Elliott 905 was connected via a 4.8K baud channel.

GINO had originated with the CAD research group in the Mathematical Laboratory at Cambridge University [ref. 21] and some of the researchers from this group had migrated across to the CAD Centre – illustrating the close and fruitful links that existed (and continued to exist) between academia and Madingley Road. Besides people, software also migrated from the Mathematical Laboratory to Madingley Road, particularly the CAD Centre's Fortran compiler, the Atlas-dependent *Systems Assembly Language (SAL)* in which GINO was implemented and the Atlas Compiler Compiler (which was used to create and support SAL) [ref. 21]. This initial software compatibility is also illustrated by the fact that the CAD Centre's Atlas 2 ran the University's Computing Service 'transparently' for a short time while Titan was being moved from one building to another in 1969.



Some of the early CAD facilities at Madingley Road were unsophisticated. Pictures from screens were taken with a polaroid camera attached to a huge black cardboard pyramid. Alan Clarke, who joined the Centre in September 1972, remembers [ref. 29] that: “Early 3D animations were made by strapping a Bolex ciné camera to an aluminium rod, and strapping that to a Tektronix 4010 storage tube, then covering everything in blackout curtain and setting it off after everyone went home.. When the frame had been drawn, an ASCII character was sent to some electronics, this triggered a solenoid, which pushed the end of a single-shot cable release on the Bolex. Sometimes, the solenoid didn’t have enough oomph, sometimes the curtain fell down and sometimes the night guard switched the lights on and ruined everything!”

Between 1972 and 1974 CAD sub-centres were set up in London and at St Helens, Lancashire [ref. 22]. By 1974 the CAD Centre at Cambridge had established its pioneering *Star Network*, providing links with the following four other sites:

- National Engineering Laboratory, East Kilbride, Scotland (UNIVAC 1108)
- SCICON Computer Services Ltd., Milton Keynes (UNIVAC 1108)
- SIA Ltd., Lower Belgrave Street, London (CDC 6600 and CDC Cyber 72)
- CAD Centre, St Helens, Lancashire (ICL 1904A).

The Star Network was implemented by the CAD Centre Systems Group under John Ambrose. Members of the team included Peter Simms, Mike France, Colin Hewitt, Martin Scutt and, for a period, Nigel Topham. Peter Simms remembers [ref. 30]: “The Network was pretty ground breaking at the time – as far as I recall there was nothing similar in existence. We created a set of protocols for file transfer (now common as ftp) and the model we developed predated later ISO protocols, and provided some feed in to the development of those protocols”.

The Star Network was organised over ‘high-speed’ asynchronous lines leased from the Post Office to a twin PDP/11 20 processor at the Cambridge CAD Centre. A contemporary brochure [ref. 31] says that: “*over 300 CAD software packages are available on various computers on the Star network*”. By this time the equipment attached to Atlas 2 includes teletypes, Tektronix terminals such as the T4010, a Calcomp 663 drum plotter and a Kongsberg Kingmatic 1215 precision flatbed drafting machine. A half-inch magnetic tape system was available via the CTL Modular One front-end processor. Modem lines were available at 110/110 bits/sec., 300/300 bits/sec., and 1200/75 bits/sec.

The Star Network gave users a wide range of specialist graphical input/output equipment and access to the latest applications software. Packages originating from the CAD Centre at Cambridge included:

TORVAP	(torsional vibration analysis)
DYLOAD	(dynamic loading on bearings)
GNC, POLYSURF	(design & production of NC tapes and drawings)
PCB1	(generating artwork for printed circuit boards and thin-film processes)
FAULT	(interactive evaluation of fault levels in power systems)

LENS	(design of electro-magnetic and electrostatic lenses)
FULLSIM	(full simulation of avalanche diodes)
MEDALS	(drafting of circuit and logic diagrams and schematics)
CONCEPT	(comprehensive flow-sheet simulation system)
MULTICOL	(distillation column simulation)
SYMBOL	(quick mass balancing system)
ECONOMIST	(cost estimation and financial analysis)
PRESBEAM	(interactive design of pre-stressing cables in concrete beams)
MEDALS	(drafting system for architects and civil engineers)
TUBES	(provides perspective and isometric views of intersecting tubes)
FINITE ELEMENT GRAPHICS	(prototype 2D mesh generation)
ASME8	(pressure vessel design).
GINO-F	(graphical design). By 1978 there were over 1,000 GINO users world-wide on 20 different types of computer, from 8-bit micros to supercomputers.
PDMS	(plant design management system). PDMS went on to become one of the world's most successful process and marine plant design systems, still in use at the time of writing.

Software packages originated by the other sites on the Star Network included:

STEP	(heat-exchanger program)
STEM	(mechanical design package)
DOMINO	(printed-circuit board routing program)
THINGS and HIDDEN LINES	(3D graphical packages)
GPSS, SIMSCRIPT	(discrete event simulation)
PERT, OPTIMA, PCM	(project evaluation, costing and monitoring)
SCICONIC	(linear programming system)
SCIPAC	(statistical analysis).
GENESYS, STRUDL	(structure analysis)
ENVPLAN, TFA, CIDER, COMPACT, COBA, HUD	(transportation planning)
BIPS, HOPS, MOSS, GRIP, HIGRAPH	(highway design)
CONCEPT	(chemical process design)
HTFS	(heat transfer fluid flow)
HOCUS, SIMULA, SIMSCRIPT, MIMIC	(discrete and continuous systems modelling)
APT, PROMO	(for NC tools)
SSI/100	(process simulation for chemical engineering)
PIPESTRESS	(static and dynamic analysis of pipework).
AUTOCON	(aerospace/automotive system for 3D shape and surface representation).

The number of client companies using the CAD Centre's facilities grew. Many accessed Atlas via serial lines (often as slow as 110 baud) and each company typically had an ASR33 installed on their premises, with either an early GPO modem or an acoustic coupler. From the above list of available software packages, it is clear that by 1974 the CAD Centre was providing a valuable service to all sectors of British industry.

Alan Clarke recalls [ref. 29] that: “Amongst the client organisations using Atlas were the following:

- Pye Telecommunications Ltd., a thriving Cambridge electronics company;
- De La Rue, who designed the complicated mathematical patterns for banknotes;
- Ricardo, an engineering consultancy, who used the CAD Centre for thermodynamic calculations for car engines;
- the Transport and Road Research Laboratory (TRRL) designing road signs and producing 3-D visualisations of approaches to junctions, roundabouts etc.
- Applied Research of Cambridge (ARC), doing work on modular hospital design.
- Whessoe doing pipework design for chemical plants.
- The Admiralty Underwater Weapons Establishment;
- GCHQ.

The Centre at Madingley Road continued to expand, acquiring more equipment which included one Prime 200 computer, three Prime 300s and three DEC PDP11/20 computers. The role of Atlas itself was gradually reducing in importance. The Atlas 2 service was formally closed down in December 1976, the occasion being recorded by the 9<sup>th</sup> December edition of the Cambridge Evening News – see Figure 11. The final switch-off was on 21<sup>st</sup> December.



**Figure 11.** Grouped round the Atlas 2’s console in December 1976 are (*left-to-right*): Chris Fell, Frank Cullen, Frank Hodson, Costas Aretakis, Celia Bland, and Graham Penning pointing.

By 1976 the emphasis was turning to the cluster of front-end and satellite computers at Madingley Road, chief amongst which was a Prime 300 computer with 128K words of 600 nanosecond memory and 6 Mbytes of local disc (3 fixed, 3 removable). This had been acquired by the CAD Centre in 1974. Produced by an American company strongly influenced by the Multics project at MIT, the Prime was a 16-bit word computer with hardware support

for Virtual Memory and floating-point arithmetic. The large (256K word) Prime address space and the VM operating system placed the machine well ahead of contemporary competitors such as the PDP-11.

Prime computers proved popular at the CAD Centre. It was soon realised that it was much cheaper to buy multiple Primes (and later VAXes) than a single monolithic machine to replace the Atlas 2. As an example, the earliest programming for the Plant Design Management System (PDMS) was done on Atlas 2 but soon moved to Primes at Madingley Road. By the late 1970s it also became economically feasible for CAD Centre clients to install their own Prime and run CAD Centre software locally rather than via a slow serial line [ref. 29].

#### **4.3. The CAD Centre legacy.**

One of the things that characterized the CAD Centre was its emphasis on outreach: serving and encouraging a wide circle of UK clients. Of all the other Atlas 1 and Atlas 2 sites, the Atlas 1 installation at Chilton was probably nearest in outlook to the CAD Centre. (This, of course, is aside from the obvious technical and physical proximity between Titan and the Atlas 2 at Madingley Road). Before exploring any link between Chilton and the CAD Centre, it is relevant to reveal the origins of the Chilton Atlas.

The Chilton site was originally called the National Institute for Research in Nuclear Science (NIRNS), deliberately positioned just outside the perimeter fence of the UKAEA's restricted-access laboratory at Harwell. It was NIRNS that set up the Atlas Computer Laboratory (ACL) to run the Atlas 1. The ACL operated under NIRNS until the Science Research Council came into existence late in 1964. SRC then took over responsibility for the ACL and it was thereafter run as a large national computing service. The service flourished and developed over the years, as new hardware was added. Since 2007 the Research Council's central computing facilities, successors to ACL, have been run by the Science and Technology Facilities Council (STFC).

So: were there any formal links between the CAD Centre and the Atlas Computer Laboratory? Bob Hopgood, who worked for many years at ACL, remembers [ref. 11] that "We didn't have a lot to do with the CAD Centre although with both of us interested in graphics we got to know the Newell brothers and Tom Sancha. In 1975 when the future of the ACL was under discussion, there was an attempt to create a National Computer Laboratory at the CAD Centre with ACL staff moving there. I remember having discussions with Arthur Llewelyn but he was not really interested and as a result nothing came of it". Brian Gott remembers [ref. 33] that "1975 was the beginning of a period of great uncertainty about the future of the CAD Centre, with all sorts of proposals flying around and competing for acceptance".

In the event, SRC's Engineering Board set up an Interactive Computing Facility (ICF) which, amongst other facilities, ported GINO onto Prime and GEC computers. The Atlas Computer Laboratory (ACL) and its successors became a strong influence on the government's evolving policy for UK academic computing resources – including networking. A Joint Network Team (JNT) of the Computer Board and the Research Councils was set up in 1979 and JNT staff were housed at Chilton. JNT was transformed into UKERNA (the United

Kingdom Education and Research Networking Association). All this 'national' activity had little initial impact upon the on-going specialised work of the CAD Centre

The need for continued specialist activity and outreach at Madingley Road was certainly apparent to those in the CAD Centre itself. In 1974 a report [ref. 34] had noted that: "A clear understanding of what is needed to adopt CAD methods is still beyond the grasp of most designers".

By 1980 the CAD Centre had certainly achieved its original aims, but at a cost to the public purse of up to £5M per annum, against fee receipts of, at best, half that amount. By 1982/3 the CAD Centre was in receipt of about £2m per year of Department of Industry money and almost half of this was recovered through sales of software and services [ref. 22]. By 1983 Margaret Thatcher had begun her second term as Prime Minister and privatization was in full swing. On 1<sup>st</sup> June 1983 a new company, CADCentre Ltd., came into being, owned by a consortium headed by ICL and including SIA, W S Atkins and Cambridge University. At this time, the staff of about 125 people was seamlessly transferred from ICL [ref. 22]. CADCentre Ltd. became a publicly-quoted company in 1996 and changed its name to AVEVA plc in 2001. At the time of writing, AVEVA is thriving.

The CAD Centre, together with the Cambridge Science Park (founded in 1970), have been the two seminal contributors to the growth of the town of Cambridge as a major centre for advanced technology and innovation – the region sometimes being known as *Silicon Fen*. Alan Clarke believes [ref. 29] that: "the CADCentre's true legacy lies in the huge part it had to play in the *Cambridge phenomenon* via spin-offs. One of the most important of these was Cambridge Interactive Systems (CIS) started in 1976 [or 1977?] by Dick Newell, Tom Sancha, Mike Williamson and John Chilvers. It was eventually sold to Computervision in the mid-80s for \$200 million (Prime and Computervision engaged in a bidding war)". John Chilvers [ref. 26] remembers Dick, Tom and Mike as "computing wizards" – an epithet that could be applied to Dick's brother Martin Newell and to several other staff who, over the years, helped to build the CAD Centre's international reputation.

Pictures of many former CAD Centre staff may be found in a 2006 reunion photo-gallery at: <http://www.flickr.com/photos/alanrclarke/sets/72057594140269676/> AVEVA Solutions Ltd, inheritors of the CAD Centre's mantle, has recently commissioned a full history of the CAD organisation since its foundation at the Madingley Road site in 1967. The plan is to produce a book and a catalogued archive in time for 50th anniversary in 2017. At the moment, Roger Annett and Bridget Langridge have started work on the project.

## **5. Acknowledgements and photo credits.**

Many former Atlas 2 people have contributed information about the Aldermaston and CAD Centre installations; their names are mentioned in the list of references below. The assistance of the Ministry of Defence is also acknowledged.

Picture credits are as follows:

Cambridge Evening News  
Alan Clarke:  
Computer Laboratory, University of Cambridge:  
Ministry of Defence:  
Brian Randell:  
STFC Rutherford Appleton Laboratory:

Figure 11.  
Figures 7(a), 7(b), 8(a), 8(b) and 9.  
Figures A1 and A2.  
Figures 1, 2 and 4  
Figures 5 and 6.  
Figure 3.

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23. *House of Commons Debate, 18 July 1968 vol 768 cc279-80W*. See Hansard: [https://hansard.parliament.uk/Commons/1968-07-18/debates/482d482d-b60d-412a-ae61-24b563bf5b25/ComputerIndustry\(GovernmentSupport\)](https://hansard.parliament.uk/Commons/1968-07-18/debates/482d482d-b60d-412a-ae61-24b563bf5b25/ComputerIndustry(GovernmentSupport))

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25. Colin Hewett, e-mail to Simon Lavington, 29<sup>th</sup> August 2012.

26. John Chilvers, e-mail to Simon Lavington, September 2012.

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33. Brian Gott, e-mail to Simon Lavington, July 2014.



34. J S W Chilvers and B Gott , *Computer Aided Design. Report CADC R1/74* issued by the Computer Aided Design Centre, Madingley Road, Cambridge, on 11<sup>th</sup> January 1974. 13 typed pages, including diagrams.

## **Appendix 1: The hardware differences between Atlas 1 and Atlas 2.**

### **A1.1. Basic functional units.**

In terms of cabinets of electronics, a typical Atlas 2 installation contained about 50% of the same hardware that was to be found in a typical Atlas 1 installation. For example, Atlas 1 and Atlas 2 used identical circuits for the ALU (Arithmetic and Logic Unit) and Control logic.

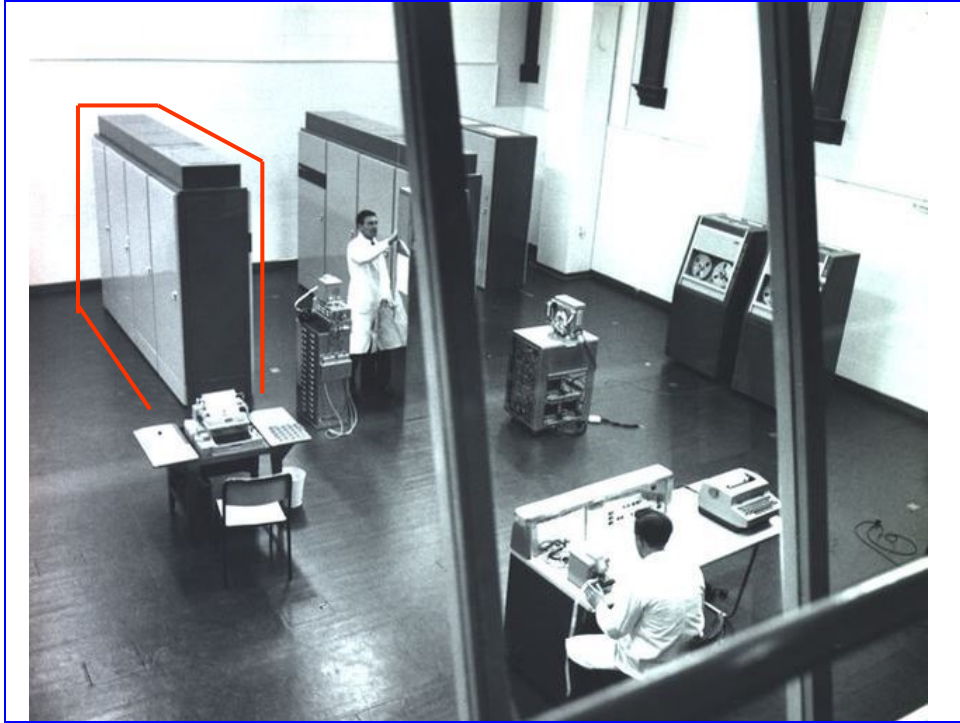
The main differences between the two machines was that Atlas 2 did not have the *One-level Store* hardware that provided what we would now recognise as Virtual Memory nor did it have the fast read-only memory (the *Fixed Store*) containing extracodes. So an Atlas 2 did not contain the following hardware units:

- Page Address Registers (giving associative look-up);
- Drum co-ordinator, four magnetic drums and their electronics;
- Fixed Store (containing extracodes, Supervisor routines, etc.);
- 1K working store, for Supervisor use.

These units took up about ten bays of electronics, out of an Atlas 1's full complement of about 24 bays – (the precise figure depended upon size of core store, etc.). The consequences of Atlas 2's lack of Virtual Memory are touched on below.

Some idea of the physical size of the standard Atlas bays and cabinets may be gained from Figure A1 (overleaf) which shows Titan at an early stage in its development. Each standard bay contained ten boxes (or rows) of printed-circuit boards (PCBs), each box having slots for 48 PCBs. Each PCB measured approximately 20 cms x 13 cms and typically included about ten transistors.

(... continued on next page)



**Figure A1: The Cambridge Titan at an early stage in its development.** The hardware cabinet outlined in red, consisting of three logic bays plus a narrower cooling bay, contained what may be roughly described as the *central processing unit*. Specifically, the cabinet contained the floating-point ALU in bay 2, the B store and B ALU in bay 1 and the Distributor, V-store and other control logic in bay 0.

The Atlas 2 design as planned by David Wheeler and his team at Cambridge also made certain simplifications to two more of the Atlas 1's standard units, namely the magnetic tape co-ordinator and the peripheral co-ordinator. This implied that Atlas 2 did not have quite the flexibility of an Atlas 1 when it came to the allowable variety of attached peripheral devices. However the Titan/Atlas 2 peripheral co-ordinator did provide direct access to fixed main memory locations, and so did not require running an (albeit optimised) interrupt-driven subroutine per I/O character [ref. 32]. The numbers and types of Atlas 1's allowable devices are listed in [ref. 6]. Importantly, Atlas 2 had a multiplexor that allowed up to 64 teletype-like devices to be connected – thereby exploiting the full user-benefit of the Cambridge Multi-Access Operating System.

As a suitable alternative to the original *One-Level Store*, Wheeler equipped Atlas 2 with a relatively large primary memory of optionally slower (and hence cheaper) ferrite cores together with two fast caches and some memory-protection hardware. The memory-protection hardware consisted of a single pair of conventional Datum/Limit registers and two other registers to lock peripheral transfers [ref. 3]. The major drawback was that the memory allocated to one program on Atlas 2 had to be contiguous in real memory – (but see also below).

The fast caches, implemented via tunnel diodes, came as two distinct units: the *Fast Operand Registers*, which buffered the contents of users' addresses 0 – 7. The second unit, called the *Slave Store*, was a 32-line instruction buffer (transparent to the user) intended for loops of 32 or less instructions.

Operational experience with the tunnel diode caches was mixed. Here are some comments from Titan team-member David Hartley [ref. 19], based on conversations with David Prince who was involved with David Wheeler in the design and implementation of the Titan slave store: "Both the Fast Operand Registers and the Slave Store were designed by David Wheeler and constructed from tunnel diodes by Neil Wiseman (then the Maths Lab's Chief Engineer). David Wheeler measured a performance improvement of 80% when the Slave Store was working. But the Slave Store proved unreliable and frequently crashed the machine, each time requiring a hardware restart. This was unacceptable for a service machine and so was eventually abandoned. The Fast Operand Registers were reliable and we believe they remained switched on for the life of the machine [ie Titan]. I don't know anything about the AWRE machine but it seems likely that the story was the same. We suspect that ICL didn't bother to put a slave store in the CAD Centre machine because it was built so much later". Bob Hopgood agreed [ref. 11] that he "could find no evidence that AWRE had actually got the slave store". Keith Howker, who was a member of Gordon Haleys' team at Aldermaston, adds [ref. 32]: "I don't recall there being any tunnel diode slave store at AWRE. Regarding reliability, I think it was Neil Wiseman who asked if anyone wanted a few hundred strain gauges!"

Table A1, which is taken from a 1963 Ferranti sales brochure [ref. 1] gives the estimated times for specimen Atlas 2 operations. Two choices of primary core store are quoted: (a) with a cycle-time of 2.5 microseconds and (b) with a cycle-time of 5 microseconds. (Note that a standard Atlas 1's core store had a cycle-time of 2 microseconds). In the Table, the times for the floating-point divide instruction are dependent upon the operand values, so a range of times is quoted. For the other operations, a pair of times is given: the first figure assumes use of the Atlas 2 slave store *and* fast operand registers; the second figure assumes *neither* cache has been used. Times are given in microseconds.

<b>Operation</b>	<b>With 2.5 <math>\mu</math>sec. core store</b>		<b>With 5<math>\mu</math>sec. core store</b>	
Single instructions: repeated FLPT ADD	2.0	2.8	2.0	4.6
Single instructions: repeated FLPT MULT	5.0	5.0	5.0	5.5
Single instructions: repeated FLPT DIVIDE	from 10.7 to 29.8		from 10.7 to 29.8	
Simple loop: scalar product of two n-vectors	11.9n	15.0n	14.3n	25.9n
Simple loop: sum polynomial to n terms	7.4n	9.2n	8.3n	13.7n

**Table A1. Times in microseconds for Atlas 2 operations, with and without the tunnel diode caches.**

### **A1.2. Hardware alterations for the multi-access system.**

When, in 1965, the Titan team decided on a multi-access operating system certain changes were required at the hardware level. These changes were implemented on Titan and on the production Atlas 2 that eventually went to the CAD Centre, but were mostly not implemented on the Aldermaston Atlas 2. The changes comprise three things: (a) an additional memory-protection register; (b) a terminal multiplexor; (c) large file disc – also implemented on the other Atlas 1 and Atlas 2 installations. The extra memory-protection register allowed for a common shared area of workspace [ref. 3]. The multiplexor enabled 64 devices of the teletype variety to be connected to an Atlas 2. The first file disc to be connected (to Titan in 1965) was a Data Products 16M word device.



**Figure A2. The final Titan configuration in its new machine room, some time after 1969.**

As has been indicated, the CAD Centre Atlas 2 was very similar to the final version of the Cambridge Titan. However, it is thought that there was one hardware difference: the CAD Centre Atlas 2 may have had page translation tables so that the memory allocated to a program did not need to be contiguous in absolute memory addresses [ref. 3].