Chilton Atlas hardware at the National Museums Scotland.

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Contents.

Acknowledgements. Several former Atlas people have helped with technical details. Particular mention should be made of Bob Hopgood, Ted Doubtfire and Yao Chen, all of whom worked on the Chilton Atlas.

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Chilton Atlas hardware at the National Museums Scotland.

Summary.
In 1962 the British-designed Ferranti Atlas supercomputer was, briefly, the world's most powerful computing system. In 1973 Dr A G Thomson, Keeper of the Department of Technology at the Royal Scottish Museum, asked the Science Research Council to donate some representative sections of a redundant Atlas for preservation and eventual display. In October 1974 the Royal Scottish Museum took delivery of a considerable amount of Atlas hardware from the Chilton site. These artefacts are now in the Granton storage facility of the National Museums Scotland in Edinburgh.

As far as can be ascertained, the acquisition of the Atlas artefacts in 1974 was not accompanied by much in the way of manuals or other documentation. The purpose of this present Report is to assist museum staff and interested enquirers by

- outlining the origins of the Atlas project and its historical context;
- explaining the longer-term significance of the computer;
- describing the function of the Atlas artefacts stored in Edinburgh in relation to the original computer to which they belonged;
- and finally listing sources of surviving original technical documentation that will aid the further understanding of the artefacts stored at Edinburgh.

(a)

(b)

Figure 1: Some of the Atlas hardware in storage at NMS Granton. (a): five logic cabinets, each containing between three and five bays; (b) two 4K word units from the Atlas Fixed Store (ROM).

1. Origins: Atlas in its historical context.
In the mid-1950s, scientists working on the civil and military applications of nuclear energy were demanding huge increases in computing resources. There was a strategic requirement for speeds and storage capacities of about two orders of magnitude greater than the performance of existing high-end machines such as the IBM 704 (first delivered in 1955) and the Ferranti Mercury (first delivered in 1957). In the USA, contracts were accordingly placed by the atomic energy research establishments for what became known for the first time as *Supercomputers.* In particular, in 1956 the Atomic Energy Commission's Los Alamos Laboratory placed a contract with IBM for a machine known as STRETCH (aka IBM 7030). STRETCH was the front-runner amongst American designs at the time. By 1957 IBM was reported to be spending $28m annually on developing the STRETCH supercomputer and to be deploying 300 graduates on the project. The first STRETCH was delivered to Los Alamos in April 1961; it cost $13.5m (or about £6m in 1961 and equivalent to about £120m in 2013).

In contrast, in 1957 the UK's Atomic Energy Authority found itself unable to sponsor a supercomputer. Furthermore, British computer manufacturers had little interest in rising to the American challenge. Nevertheless, the UK's National Research Development Corporation (NRDC), together with other interested parties such as the UKAEA, decided to promote a British supercomputer project. Writing retrospectively in 1958 Lord Halsbury, NRDC's Director, said: "Were we [the UK] strong enough to compete [with STRETCH]? Ought we to try? Could we afford not to? Could any such proposal be established on a commercial basis? During the last two years I have unsuccessfully wrestled with divided counsels on all these issues." After several abortive initiatives, NRDC decided in the spring of 1959 to sponsor the high-speed computer hopes of two British computer manufacturers: Ferranti Ltd. (with £300K) and EMI (with £250K). The EMI project came to nought.

By the spring of 1959 Ferranti Ltd. had in fact already decided to collaborate with Professor Tom Kilburn's group at Manchester University, where research into high-performance computing hardware had been going on for two years. Kilburn's high-performance MUSE project had a target speed of a microsecond per instruction: MUSE was short for *Musecond Engine.* MUSE developments had initially been funded by the University to the tune of £50K. When Ferranti became involved from 1959, the project was re-named Atlas and Ferranti increased the budget tenfold. The design team swelled to 27 people (45% academics and 55% from industry) under the leadership of Tom Kilburn.

A prototype, reduced-facility, Atlas was completed at Manchester University by early 1961. Meanwhile, production units were being manufactured at Ferranti's West Gorton factory about 3km away. The West Gorton facility, opened in 1956, was the largest computer plant in Europe at that time. Delivery of finished Atlas units to the University commenced in the summer of 1961, by which time the design team numbered 42 (28% academic, 72% industrial). The first production Atlas computer was officially unveiled at a ceremony on 7th December 1962 – see Figure 2.

The launch in December 1962 was marked by the release of a Central Office of Information film, which confidently announced that Atlas had "doubled the computer capability in Britain". Whilst not quite numerically true, the advent of Atlas certainly produced a very significant increase in scientific computing resources – as demonstrated in section 3 below.

Figure 2. Sir John Cockcroft *(seated)* **formally switches on Atlas at Manchester University on 7th December 1962. Sebastian de Ferranti** *(left)* **and Tom Kilburn** *(right)* **look on.**

2. Atlas in the market-place.

Depending upon configuration, each Ferranti Atlas cost between £2m and £3m (equivalent to about £50m each in 2012). Ferranti made strenuous efforts to market Atlas in America (principally to Atomic Energy establishments), in Australia (principally to CSIRO) and in Europe (principally to CERN). In the end, only three Atlas 1 computers were delivered: to the University of Manchester, to a joint BP/London University consortium, and to the Science Research Council's laboratory at Chilton, near Harwell. It is from this last, and largest, installation that the Atlas artefacts stored at the National Museums Scotland (NMS) come – as described later.

In conjunction with Cambridge University, Ferranti developed a simpler and cheaper version called Atlas 2. Three of these cut-down machines were installed, respectively at Cambridge University (where the machine was known as Titan); at the Atomic Weapons Research Establishment at Aldermaston; and at the government's Computer Aided Design Centre at Cambridge. The Atlas 2 at the Computer Aided Design Centre was the longest-lived, finally being switched off in December 1976.

IBM only sold seven STRETCH computers between 1961 and 1963, at an initial cost of \$13.5m each (finally reduced to \$7.78m each). Therefore in commercial terms, neither Atlas nor STRETCH was particularly successful. The main reason: by 1964 a new supercomputer manufacturer had appeared in America, the Control Data Corporation. The CDC 6600, which benefited from advances in silicon transistors, was at least three times faster than both the IBM STRETCH and Atlas.

3. Relative performance, then and now.

The Table below shows how the instruction-speeds of Atlas compared with other high-performance computers of the time.

Instruction	*IBM 704 (1955)*	*Ferranti Mercury (1957)*	*IBM 7090 (1959)*	*IBM STRETCH (1961)*	*Ferranti ATLAS (1962)*	*CDC 6600 (1964)*
FXPT ADD	24	60	4.8	1.5	1.59	?
FLPT ADD	84	180	16.8	1.38 – 1.5	1.61 – 2.61	0.3
FLPT MPY	204	300 (360)	16.8 – 40.8	2.48 – 2.7	4.97	1
FLPT DIV	216	5,000 (by software)	43.2	9.0 – 9.9	10.66 – 29.8	3.4

Table 1. Instruction times in microseconds for four American and two British computers that were first installed between 1955 and 1964.

Using modern terminology, Atlas had a computing speed of approximately half a million floating-point operations ('flops') per second – ie, 0.5Megaflops. Fifty years later, in 2012 a modern lap top computer could achieve about 20 Gigaflops, which is about forty thousand times faster than Atlas. Scarier still, the fastest Supercomputer in 2012 could achieve about 20 Petaflops, which is about a million times faster than a lap-top. Such a modern Supercomputer typically consumes about 10 Megawatts of electrical power and occupies a floor area roughly the same size as a football pitch – figures that might appear unbelievable to the humble lap-top user in 2012. Perhaps in a somewhat similar manner, the speed of Atlas in 1962 might have appeared unbelievable to the humble user of a small 1950s computer straining to achieve ten flops per second. Then, as now, scientists and engineers are seemingly insatiable in their demands for higher computing speeds.

Raw computing speed, however, is only part of the story. Of increasing interest in the 1960s was the power of a computer to process, automatically and quickly, a given workload consisting of many separate user-programs. Hugh Devonald, who headed Ferranti's Software Division, said in 1962: *"Atlas is in fact claimed to be the world's most powerful computing system. By such a claim it is meant that, if Atlas and any of its rivals were presented simultaneously with similar large sets of representative computing jobs, Atlas should complete its set ahead of all other computers."*

The power of a computer, in the above sense of work-rate, is naturally dependent upon software as well as hardware. The Atlas Operating System, called the *Supervisor,* was far more advanced than its rivals. Indeed, no other contemporary computer even had what we would now understand as an Operating System. Hugh Devonald said: *"The 'Supervisor' is the most ambitious attempt ever made to control automatically the flow of work through a computer. Its ability to handle the varied workloads that a machine of this size tackles will influence the future design of all computers".* He was right: see section 9.

As far as is known, the workload capabilities of Atlas and STRETCH were never measured accurately side-by-side. The best we can do is to quote Bob Hopgood, who wrote compilers for both STRETCH and Atlas and implemented a large Quantum Chemistry package (MIDIAT) on both computers. Hopgood said recently: *"STRETCH could run extremely fast if you had the code set up just right and it remained in core memory. It had some terrible deficiencies as well. It made guesses as to which way a conditional jump* *would go and if you got it wrong it had to backup all the computation it had done. So the same conditional jump could be as much as a factor of 16 different in time between guessing right and wrong. The STRETCH nuclear weapon codes at AWRE Aldermaston probably outperformed Atlas by quite a bit. On the other hand Atlas ran some large number theory and matrix manipulation calculations much faster than STRETCH. My codes were pretty similar in performance but on large calculations where intermediate results had to be stored on magnetic tape, Atlas was significantly faster due to the Ampex tape decks. I think on an untuned general purpose workload Atlas was faster and if the code was tuned to STRETCH it would be faster. In conclusion, I would say that in 1962 'Atlas was reckoned to be the world's most powerful general-purpose computer'".*

4. The Atlas Computer Laboratory at Chilton, Berkshire.

The artefacts in storage at the National Museums Scotland (NMS) come from the Atlas computer installed at a site that has variously been referred to as NIRNS, Harwell, Chilton or the Atlas Computer Laboratory (ACL), so a word of explanation is helpful. The National Institute for Research in Nuclear Science (NIRNS) was formed in 1957 to operate the Rutherford High Energy Laboratory as an open-access nuclear research facility, located just outside the perimeter fence of the United Kingdom Atomic Energy Authority's (UKAEA's) restricted-access laboratory at Harwell. NIRNS itself lay between the villages of Chilton and Harwell, so 'Chilton' became the informal name for NIRNS. It is convenient to refer to the NMS artefacts as coming from the *Chilton Atlas.*

Not surprisingly, the Atomic Energy Research Establishment at Harwell had been interested in purchasing an Atlas as early as 1959. Subsequently, the Government's CURE Working Party (Combined Use of Expensive Research Equipment) agreed in November 1960 that an Atlas should be purchased and owned by NIRNS and that it should be used by Harwell, Rutherford and the Universities. In the summer of 1961 an order was placed with Ferranti for an Atlas computer costing £3.1m.

NIRNS agreed to set up a new Laboratory physically in between the Rutherford Lab and AERE Harwell called the Atlas Computer Laboratory to run the machine. The Atlas Computer Laboratory (ACL) was run by NIRNS until the end of 1964. When the Science Research Council came into existence late in 1964/early 1965, SRC took over responsibility for the ACL. (The Research Council's central computing facilities have, since 2007, been run by the Science and Technology Facilities Council (STFC)).

The original intention had been for the Chilton Atlas to be used in equal proportions by Harwell, Rutherford and the Universities. However, by 1964 both Rutherford and Harwell had acquired their own IBM facilities so the Chilton Atlas was mainly used by the universities and other government departments, such as the Meteorological Office and the Natural Environment Research Council (NERC).

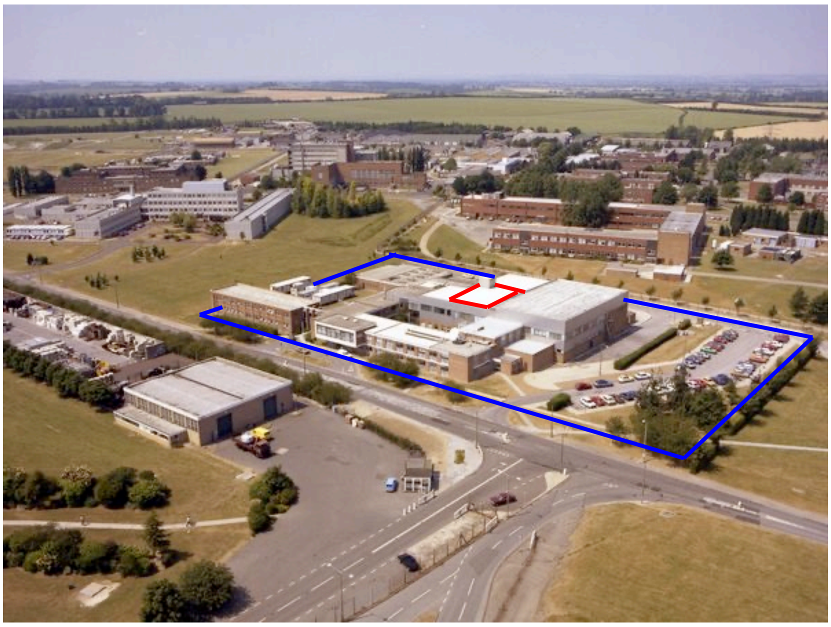


Figure 3. The Atlas Computer Laboratory at Chilton, as extended by about 1981, is shown ringed in blue. The area formerly occupied by the main units of the Atlas computer from 1964 - 1973, on two floors, is shown outlined in red. This is explained in section 6.

At Chilton, a special Atlas Computer Laboratory (ACL) was designed and built to meet the needs of a large national computing service. In 1961 Jack Howlett was appointed Director of the Atlas Laboratory. The new building was ready for occupation in January 1964 and the Atlas was installed during May and June of that year. In October 1964 a regular 'at risk' service was started, consisting of one 8-hour shift per day. The remainder of the time was spent on software development and engineering maintenance. 'Software development' included the implementation of *Hartran*, an Atlas Fortran compiler and its associated programming system. *Hartran* was designed to ease the transition of Harwell's computing work from their current IBM computers to the new Atlas. In May 1965 the Atlas formal hand-over and acceptance period began, leading to full three-shift operation and final acceptance by May 1966.

By 1966 the Atlas Computer Laboratory was processing an impressive number of programs each day. The Director, Jack Howlett, was able to write in his annual Report: "In a typical week we run 2,500 jobs, input 800,000 cards and 30 miles of paper tape, print 1.8 million lines of output, punch 50,000 cards, handle 1,200 reels of magnetic tape. We have 250 projects on our books from university users and are usually doing work on 100 of these…. Our experience over the past year has shown that the Atlas central processor, with the Supervisor which is an integral part of the system, is an exceedingly powerful and flexible device which deals smoothly and efficiently with a heavy load of very varied work".

At the Chilton Atlas close-down ceremony on 30th March 1973 the Director, Jack Howlett, was able to report as follows. Of the 44,500 scheduled hours of computing time during the period May 1965 to March 1973, 43,000 hours had actually been usable – yielding an Atlas availability of 97%. The central processor usage statistics during this period were:

User programs:	82% of CPU time;
Supervisor activity:	12% of CPU time;
Idle time:	6% of CPU time.

From May 1965 to March 1973, 863,000 jobs had been handled by Atlas, with a total market value of computing time of £10.8m. Approximately 85% of available computing time had been devoted to UK universities, during which 2,300 research projects had been supported. The remaining 15% of computing time was used by government departments for applications such as weather forecasting and space research. About 70% of all programs used Fortran, with the average run-time for a job being about 150 seconds of Atlas CPU time.

Over the years, the Chilton staff found that there were certain academic areas where the needs of most users could be met by general programs, which staff then provided - either writing them or acquiring (and adapting) them from other sources. Amongst such area were:

Crystallography: Determination of crystal structures by interpretation of x-ray diffraction patterns. Equipment was added to Atlas that scanned the films and produced the digital information needed as input to the analysis suite.

Computational Chemistry: several program suites were implemented and supported to calculate the structures and properties of molecules and solids .

Finite-element analysis: Mostly for the design of engineering structures.

Time-series analysis: Used to detect patterns or variations in recorded phenomena such as temperatures, river flows, power flows in the national electricity grid system, elecro-encephalograph recordings, etc.

Text analysis: Investigation of quantitative features of natural-language texts, such as word count, vocabulary, frequency distribution of word use, word length and sentence length.

Survey analysis: Operations such as counting, classifying and correlating the information gathered in surveys. Applications included the study of medical or social questions, such as the incidence or spread of some disease in a particular industry or geographical region.

Overall, the Chilton Atlas was judged to have provided a highly-valued service to the UK's scientific base for about nine years. Atlas was in due course replaced by other high-performance computers at Chilton and some reorganisation took place. The Rutherford High Energy Laboratory merged with the Atlas Computer Laboratory in 1975, to become the Rutherford Laboratory. In 1979 this was in turn merged with the Appleton Radio and Space Research Laboratory, to form the Rutherford Appleton Laboratory (RAL) at Chilton.

The Atlas Computer Laboratory (ACL) and its successor, RAL, became a strong influence on the government's evolving policy for UK academic computing resources. In particular, ACL and RAL embodied the concept of a large computer centre as the analogy of a large library, where scholars could come and use facilities that were far superior to those affordable by their separate institutions. In 1966 the government accepted the recommendations of the Flowers Report that there should be three large regional computing centres, at the Universities of London, Manchester and Edinburgh, and that there should be a Computer Board to allocate resources.

The need to access these regional supercomputers remotely became a driving force for the establishment of national digital networks. Building on experience gained at the National Physical Laboratory and at various universities, a Joint Network Team (JNT) of the Computer Board and the Research Councils was set up in 1979. JNT staff were housed at RAL, Chilton. JNT was transformed into UKERNA (the United Kingdom Education and Research Networking Association) in 1994.

5. Technical details of the Chilton Atlas.

The Chilton Atlas was the largest of the three Atlas 1 installations. Here is the state of play in November 1966:

	Manchester Atlas	***London Atlas***	***Chilton Atlas***
Core store (48-bit words) (cycle-time = 2 microseconds)	16K (in two pairs of stacks, 4-way interleaved)	32K (in four pairs of stacks, 4-way interleaved)	48K (in six pairs of stacks, 4-way interleaved)
Ampex TM2 one-inch magnetic tape decks (transfer-rate = 90K characters per second).	8 decks (8 channels)	14 decks (8 channels with four 2x8 switching units)	16 decks (8 channels with one 2x8 switching unit)
IBM-compatible half-inch magnetic tape decks	-	2 Potter type MT-120 decks	2 IBM type 729 decks

Table 2. Storage capacities, in terms of 48-bit words, of the three Atlas 1 installations.

Each of the above computers in Table 2 also had the following units of storage:

B store (eg index registers):	128 half-words (24 bits), cycle-time = 0.7 microseconds.
Fixed store (ROM):	8K words, access-time = 0.3 microseconds.
Supervisor Working Store:	1K words, cycle-time = 2 microseconds.
Drum store:	4 drums, each 24K words. (rev. time = 12.67 milliseconds; transfer-time = 2 milliseconds per block of 512 words).

In addition, a large file disk (a Data Products model 5045, of capacity 16.8 million 48-bit words with two independent read-write mechanisms) was added to the Manchester Atlas (in October 1967) and to the Chilton Atlas (in February 1968). The addition of a file disk also necessitated the addition of more Supervisor Working Store at Manchester and Chilton.

The three Atlas 1 computers also had slight differences in their conventional input/output equipment, reflecting not only local work-patterns but also estimated user-preferences for punched paper tape or punched cards – which in turn were influenced by local choice of computer language. The heavy use of Fortran at Chilton led to a high use of punched card equipment. Table 3 gives the state in November 1966. The right-hand column in the Table shows the maximum number of devices of each type that could be accommodated by an Atlas system.

	Manchester	*London*	*Chilton*	*Max number permitted*
Fast paper-tape readers (1,000 chars/sec.)	1	-	1	4
Slow paper tape readers (300 chars/sec.)	4	5	3	8
Fast paper tape punches (300 chars/sec.):	1	-	-	4
Slow paper tape punches (110 chars/sec.):	4	3	3	8
Card readers (600 cards/min.):	1	2	2	4
Card punches (100 cards/min.):	1	1	2	2
Lineprinters (1,000 lines/min.):	2	2	2	4
Slow teleprinters (10 chars/sec.)	2	4	3	4

Table 3. Conventional input/output facilities for the three Atlas 1 installations.

In due course, each of the above Atlas sites established a limited number of dedicated connections *(Datalinks)* via rented telephone lines to other organisations. When compared with today's Internet, these connections were primitive and slow; at the time they were very cost-effective. Over the years a number of specialist peripherals were also attached to the Chilton Atlas. Amongst these was a D-MAC graphical input table, an Opscan Optical Character Recognition device, an Optronics Microdensitometer and a Stromberg Carlson SC4020 Microfilm Recorder. The SC4020 at Chilton was seen predominantly as a general purpose peripheral, since its capabilities far exceeded the output rates achievable via lineprinters. Thus, bulk lineprinter output and bulk graphical output went to the SC4020, as did all film and microfilm output. Interactive graphics was introduced at Chilton in 1970 by connecting a PDP15 computer with a VT15 display to Atlas.

During the life of the Chilton Atlas, users' expectations gradually changed. Encouraged by news of experiments in multi-access timesharing facilities being conducted in America at MIT, the emphasis of computer designers was slowly moving away from efficient use of *mainframe hardware* and towards efficient use of *programmer's time*. By 1966 the Atlas Computer Laboratory was considering how to improve the human-machine interface. In 1968 Chilton staff provided two improvements: (a) better file-manipulation, and (b) time-sharing via a number of interactive terminals. This required two major pieces of hardware to be connected to Atlas: the large file disk and a satellite computer. The Atlas Supervisor proved robust and flexible enough to take these enhancements in its stride. The large disk store, added in February 1968, was a Data Products model 5045, of capacity 16.8 million words with two independent read-write mechanisms. These gave dual access from both Atlas and the satellite computer, an SDS Sigma-2 (marketed in the UK by GEC under the name S-2). Initially there were six ASR 35 online Teletype consoles, VDUs not being available at that time. Eventually there were 32 online terminals, all of which were Cossor DIDS 402 VDUs. Of the 32 terminals, up to eight could be active, four of which could be remote from the Chilton site.

6. Physical details of equipment layout at Chilton.

The Atlas Computer Laboratory at Chilton (see Figure 3) was a large complex, housing offices, communal facilities including a library, support services and ancillary equipment (eg air conditioning) as well as the actual Atlas computer. The building went through three constructional phases during the life of Atlas. More offices were added to the original 1964 premises in 1967 and then in 1971 further offices, a lecture theatre and a second computer block (ready to house an ICL 1906A computer) were added. The enlarged building is shown in Figure 3. The main functional units of Atlas were installed in two rooms, one on the ground floor and the other immediately above it on the first floor – (in the area outlined in red in Figure 3). The two-deck arrangement is demonstrated in principle by an Atlas scale model, made for sales demonstration purposes by Ferranti in 1963 and shown in Figure 4.

Figure 4. Scale model of a large Atlas installation, showing equipment on two levels. Broadly speaking, the upper floor holds input/output equipment whilst the central processor and memory system occupy the lower floor.

Each of the ground-floor and first-floor rooms housing the main Atlas functional units measured about 50 ft. by 70 ft. (15m x 21m). These are shown in plan view in Figure 5 *(see next page)* and as photographs in Figures 6 to 8. The identity of the equipment is explained later.

Generally-speaking, only trained maintenance engineers entered the ground-floor machine room shown in Figures 6 and 7. Generally-speaking, only staff trained in how to operate the input/output equipment entered the first-floor room in Figure 8. End-users prepared their programs on punched paper tape or punched cards on *data-preparation equipment* elsewhere in the building and then submitted their jobs to the staff – who ran the jobs on Atlas on behalf of the users. Printed results were then returned to the user, along with the original punched paper tape or cards employed for input. This mode of Atlas usage, typical of a large computing service of the 1960s, was enhanced at Chilton in due course as remote data-links and on-line terminals gradually came into operation at the Atlas Computer Laboratory.

Figure 5. Part of the ground-floor plan *(left)* and first-floor plan *(right)* of the Atlas Computer Laboratory. The areas in red, each measuring roughly 50 ft. by 70 ft. (15m x 21m), housed the main functional units of Atlas.

(a)

(b)

Figure 6 (a) and (b). These two views of an engineer sitting at the console of the Chilton Atlas give an idea of the size of the machine room on the ground floor. Input/output equipment was in the room directly above – (see Fig. 8).

(a) **(b)**

Figure 7(a). Two engineers testing core store packages at Chilton. It is likely that the logic bay to the right of the photo is bay 20 or 21 or 22 of cabinet 5(a) in Figure 11. The folder of logic diagrams being held above the oscilloscope is similar to a folder described in Appendix B, Table B2, item *CS/Atlas/1.*

Figure 7(b). The far corner of the machine room at Chilton, showing *(left foreground)* **the Data Products file disk which was added in 1968 and** *(right foreground)* **the Mag Tape Exchange. Cabinet 5(b) of Figure 11 is just visible in the background on the extreme right.**

Figure 8. The Atlas input/output equipment on the first floor at Chilton, in about 1968. The Ampex one-inch magnetic tape decks are shown in the background along the wall to the right.

7. The Atlas artefacts in store at the National Museums Scotland.
The idea for Edinburgh to acquire the Chilton Atlas probably came from Bill Watson, at that time the Director of the Edinburgh Regional Computing Centre, in a letter to Alan Simpson dated 22nd May 1973. Alan was a curator at the Royal Scottish Museum and an avid collector of computer artefacts. Bill Watson's letter prompted Alan's boss Dr A G Thomson, the Keeper of the Department of Technology at the Royal Scottish Museum, to write on 1st June 1973 to Dr Jack Howlett, Director of the Atlas Computer Laboratory at Chilton. Thomson explained that he was "*setting up a collection of computers as a major preservational exercise within the framework of the British National Collection*". He went on to say: *"The Atlas of course has particular significance in any survey of British computing and I feel it is important that it be well represented if at all possible. The units that incorporate the aspects that seem the most worthy of attention, and around which a selection of representative units might be made, are:*

A page address register bay;
A fixed store bay;
A main accumulator bay;
The engineers' console;
A drum unit;
A tape deck;
Input/output peripheral co-ordinator;
5 and 7 column tape readers.

"Our knowledge of the hardware is necessarily limited and I should welcome your advice on how we might adapt and expand this list to include for example a more complete coverage of the supervisor's function".

With the exception of the engineers' console, all the above units and more were donated to the Museum. They were transported at the Museum's expense, arriving in Edinburgh on 10th October 1974. They are currently in the NMS Granton storage facility in a suburb of Edinburgh, as described in more detail below. Note that the drum cabinet at NMS originally contained four drums but one of these was donated to the Science Museum Group (formerly known as the National Museum of Science & Industry) in London. It is now in the museum's storage facility at Wroughton, Wiltshire.

The Chilton engineer's console was retained by the Atlas Computing Laboratory. It was kept on display until about 2005 when it was moved into temporary storage. At the time of writing its exact whereabouts have not been determined; enquiries are continuing.

As far as can be determined, no supporting documentation came with the October 1974 delivery. However, Bob Hopgood and others from RAL passed several Chilton Atlas manuals to the Computer Museum in Boston, Massachusetts, in 1979. It is understood that this material was then transferred to the Computer History Museum (CHM) in Mountain View, California. A list of relevant items, extracted from the CHM's online catalogue, is given in Appendices A and B.

The main Chilton items now in storage at NMS Granton are listed the Table below:

NMS Accession Number	*Description*	*Dimensions, H x L x W, In millimetres*	*Identification in Figure 11 or 12*
T.2004.650.1	Ampex TM2 one-inch magnetic tape deck	1825 x 555 x 1000	TA
T.2004.650.2	Drum cabinet: electronics plus three Bryant drums.	2200 x 2550 x 675	Cabinet 4
T.2004.650.3	Core store stacks 0 to 5	2200 x 3830 x 675	Cabinet 5(a)
T.2004.650.4	Fixed Store	1800 x 2580 x 625	Cabinet 1
T.2004.650.5	CPU	2200 x 3200 x 675	Cabinet 2
T.2004.650.6	Core Store Co-ordinator, including Page Address Registers (PARs)	2200 x 3200 x 675	Cabinet 3
T.2004.650.7	Peripheral Co-ordinator, Drum Co-ordinator, 1Kwords Working Store.	2200 x 3200 x 675	Cabinet 6

Table 4. Accession-list of the main Atlas artefacts in storage at the National Museums Scotland. Several smaller pieces of Atlas input/output equipment were also acquired by NMS.

The five units labelled T.2004.650.2/3/5/6/7 in Table 4 are currently stored at Granton in a long line, as shown in Figure 1(a). Unit T.2004.650.1 is stored opposite this line (see Figure 9(a)). Unit T.2004.650.4 is stored opposite in three parts: firstly, the empty outer cabinet (see Figure 9(b), and then the two units that normally live in this cabinet (see Figure 1(b)).

(a)

(b)

Figure 9 (a) an Atlas magnetic tape deck. (b) the cabinet for the Atlas Fixed Store.

Precise identification of the cabinets shown at Granton in Figure 1 is not straightforward, since the original Chilton engineers' drawings have not yet come to light. Using evidence from a surviving set of logic diagrams for the Manchester Atlas (see Appendix B), and the memories of two former Atlas engineers (Yao Chen and Ted Doubtfire), the identification and functionality shown diagrammatically in Figure 10 is believed to be correct.

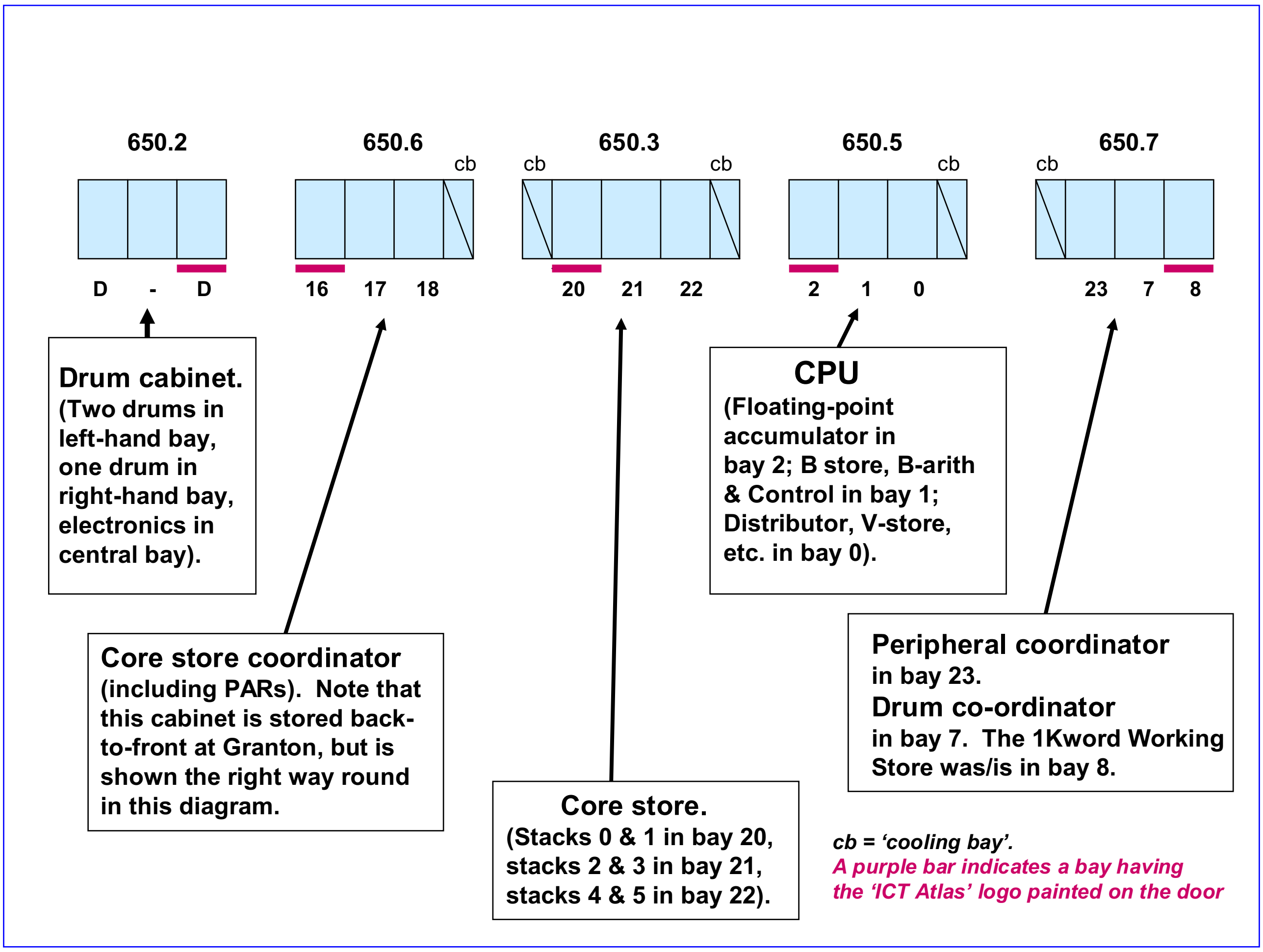


Figure 10. The location, identification and functionality of five Atlas logic cabinets in storage at NMS Granton and pictured in Figure 1.

The correspondence between the cabinets stored at Granton and logic cabinets as positioned in the original Atlas machine room at Chilton can be deduced with certainty. The original ground-floor machine room layout at Chilton is shown in Figure 11 *(see next page)*. Referring back to the photographs given earlier, the cabinet shown in the right-foreground of Figure 6(a) is the end of the Fixed Store cabinet (cabinet 1 in Figure 11). The one shown in the left-foreground of Figure 6(b) is the end of the cabinet housing core store stacks 6 – 11 (cabinet 5b in Figure 11). The original spacing between cabinets may be judged from the floor tiles in the photographs: each tile measures 2 ft x 2 ft (approximately 600mm x 600mm). These removable tiles formed a suspended false floor, with a void about 9 inches (230mm) beneath. Cabling for interconnecting the logic cabinets was situated in this under-floor void.

The Atlas magnetic tape deck, unit T.2004.650.1 in Table 4, is one of sixteen identical units whose original position on the first floor at Chilton is shown in Figure 12.

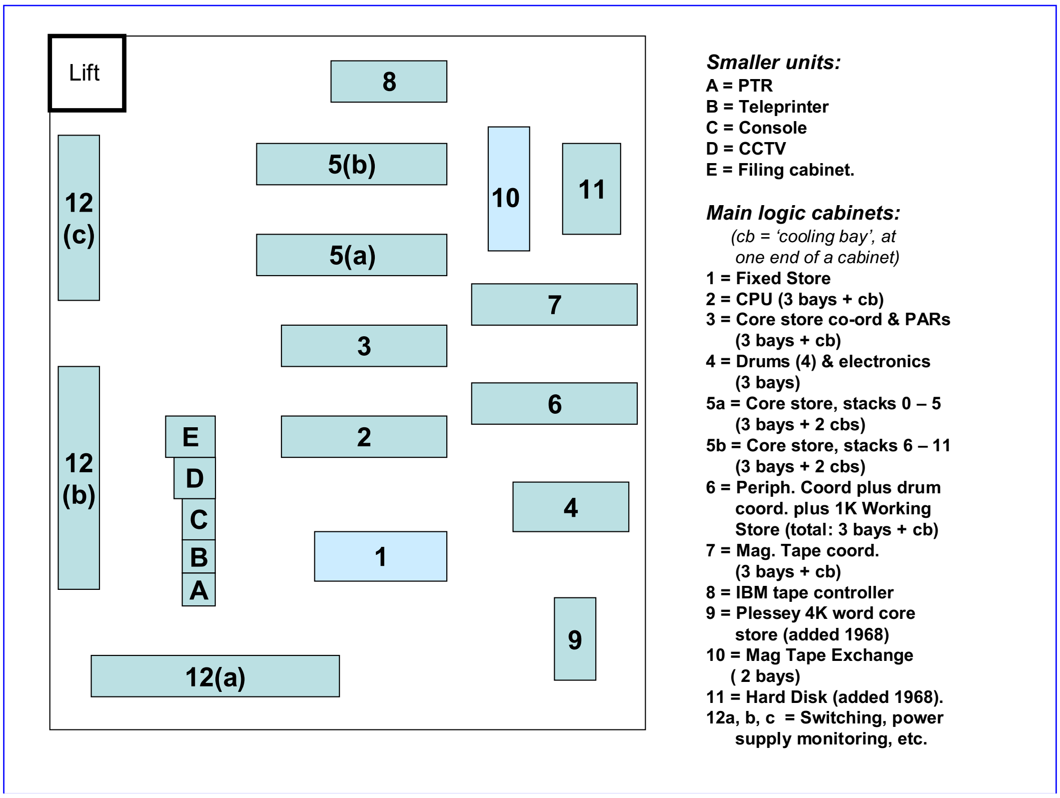


Figure 11. The original positioning and functionality of Atlas logic cabinets on the ground floor at Chilton.

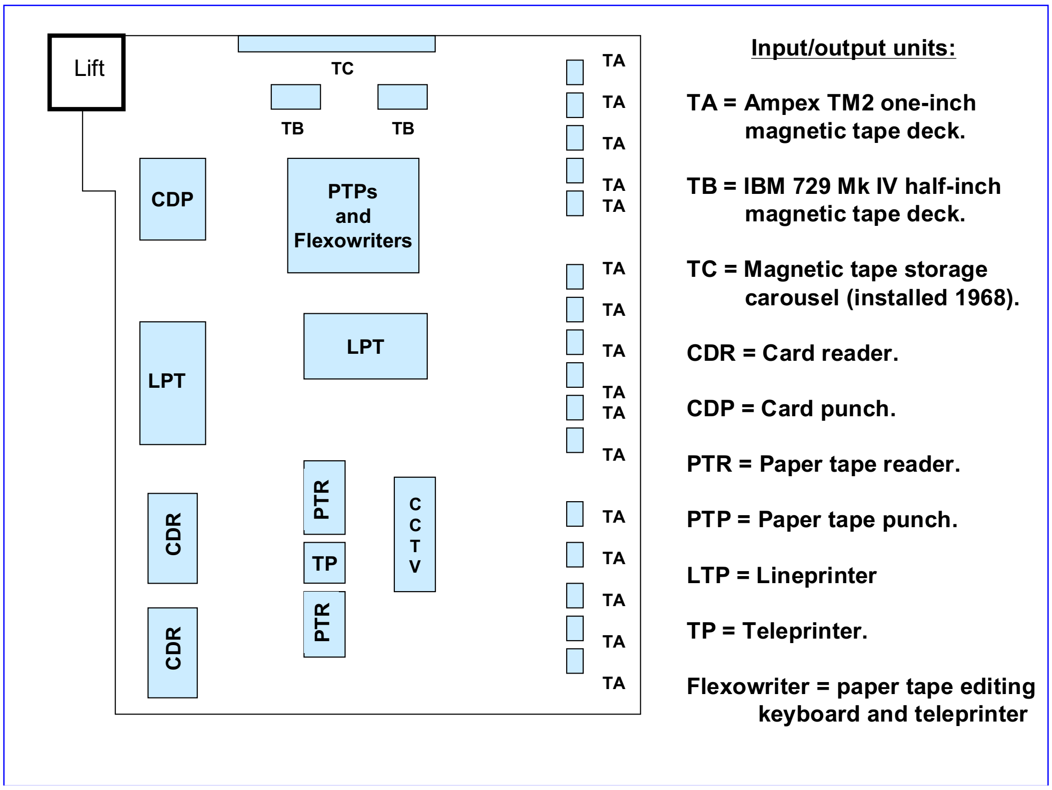


Figure 12. Original layout of the input/output equipment on the first floor at Chilton.

The original logical and physical connections between the cabinets shown in Figures 10 to 12 is complex. Figure 13 gives an overall schematic view of how the main units relate to each other. The box labelled *V Store* in Figure 13 is actually the collection of all the various control and data registers necessary to deal with information flow to/from the slower peripheral equipment such as paper tape readers and lineprinters. All registers concerned with error and monitoring, such as *arithmetic overflow,* are also considered to be part of the V Store and are allocated addresses in the V Store.

The box labelled *One-level store* in Figure 13 is noteworthy. Atlas programmers had available a large range of addresses: 2^{20} 48-bit words, equivalent to about 6 Megabytes in modern terminology. This large *Virtual* address-space was mapped onto the available *Real* memory which, in the Chilton Atlas, consisted of 48K words of fast core storage backed by 96K words of slower drum secondary storage. The movement of a user's information between the faster and slower sections (ie core and drum) was organised automatically in Atlas, by a combination of special hardware and system software. Users were presented with a *One-level store*, within which their currently-active information was available in the fast section. See also section 9.

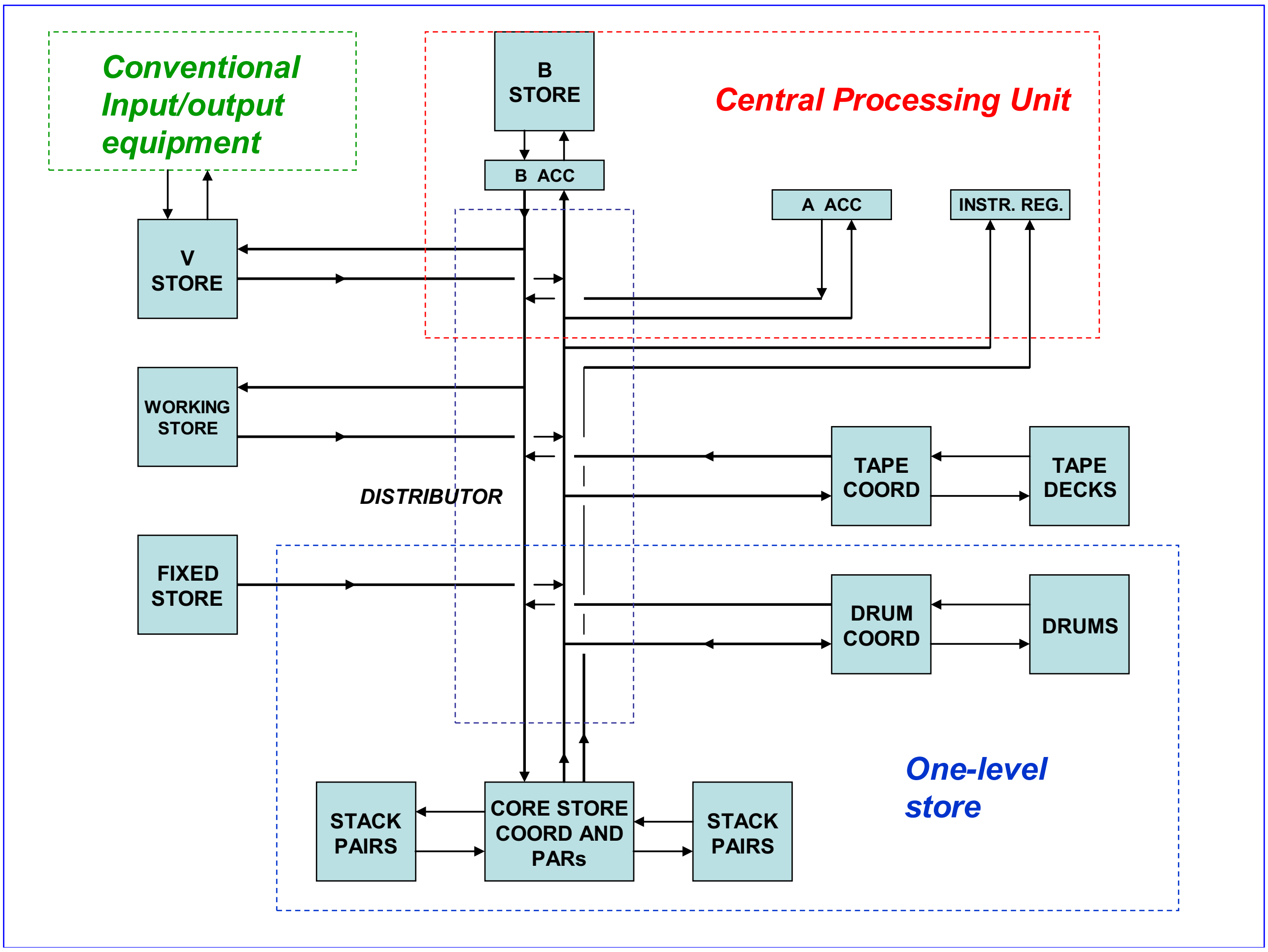


Figure 13. An overall schematic of the logical connections between the various Atlas units shown diagrammatically in Figures 10, 11 and 12.

8. Condition of the units in the NMS Granton store.
Although one of the four magnetic drums is missing from unit T.2004.650.2, the condition of the Atlas artefacts in storage is judged to be generally good. Each logic bay in each cabinet has a maximum of 480 printed-circuit boards or ‘logic packages’. Spot checks on 17th July 2013 suggested that, although there may be a very few packages missing, on the whole each cabinet contains all of its original complement of electronics. It was particularly interesting to see that bay 2 of the CPU cabinet appears to contain all the special printed-circuit boards used in the design of the main arithmetic unit and its control logic. Furthermore, on removing the protective outer panel, the meshes in the Fixed Store appeared to be populated and ‘as good as new’ – (see Figure 17(a)).

As demonstrated in Appendix A, very little has survived of the two other Atlas 1 computers and the three Atlas 2 computers. Since the units at NMS come from the largest and arguably the most successful of all the six Atlas installations, NMS is indeed fortunate to possess such a valuable and comprehensive collection of artefacts in such good condition.

A word of explanation is needed for bay 8 of unit T.2004.650.7, which should contain the original 1Kword Working Store. It may be observed that the lower front half of bay 8 at NMS is covered by a grey metal blanking-panel. This is believed to have been the usual case for bay 8, so the blanking panel does not indicate that any of the original printed-circuit boards are missing. In 1968 the Chilton Atlas was equipped with a new 4Kword Working Store when the new file disk was added. The old 1K Working Store is possibly still in place at the rear in bay 8 – though there has been no opportunity lately to examine the rear of bay 8 to check that the core stack is still in place. The 1Kword stack would have looked very similar to the stack shown in Figure 16 (b), except that the Working Store had two fewer male sockets than the number shown in Figure 16 (b).

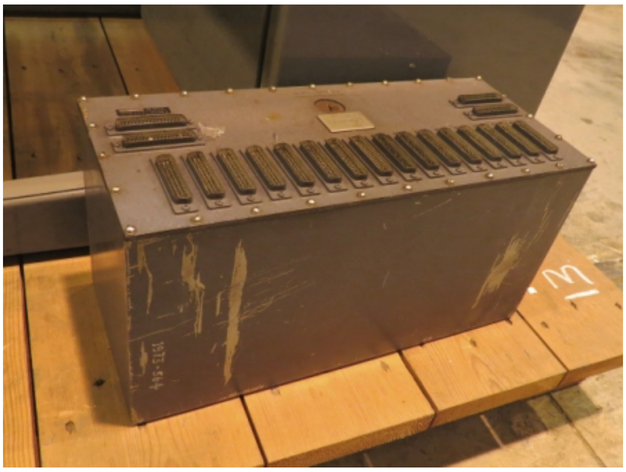
Many photographs were taken on 16th and 17th July, to confirm identification and to aid future research. A small selection of these is shown in Figures 14 to 16. Due to lack of time and suitable equipment, the set of 12 close-up photographs of Atlas printed-circuit boards (pcbs) needs to be re-taken by a specialist photographer. This is especially true of the photographs of type 812, 813 and 814 pcbs, these being the technically-advanced set of packages crucial to the operation of the high-speed adder – (see Figure 14).

Figure 14. The front and back of three sample Atlas printed-circuit boards from bay 2 of the CPU cabinet. *(From left-to-right):* **type 812 (adder carry), type 813 (adder input) and type 814 (adder output).**

(a) (b)

Figure 15 (a). Bay 1 of the CPU cabinet at NMS, with the front door open. This bay contains the B-store (at the top), the B arithmetic unit and some control logic. There are ten boxes in this bay, each box containing up to 48 printed-circuit boards.

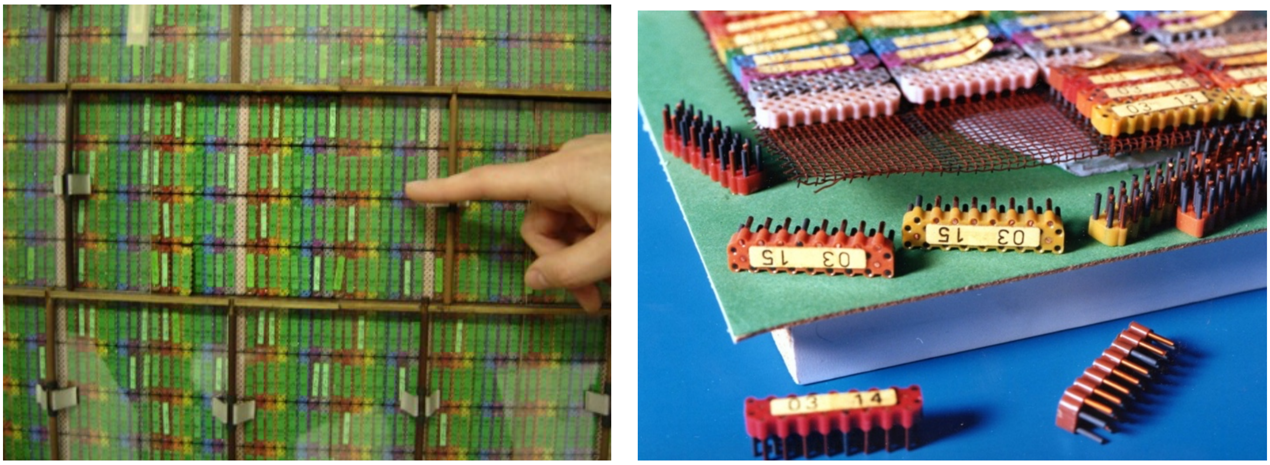
Figure 15 (b). Oblique close-up of the top left front of bay 18 of the Core Store Co-ordinator, showing *(at the left)* **the arrangement for performing +7.5v margin-testing.**



(a) (b)

Figure 16 (a). Part of the rear of Core Store bay 20 at NMS, showing a 4K word stack of ferrite core memory.

Figure 16 (b). A 4K word stack from the London Atlas core store. A similar stack is positioned behind and just above the panel of switches, within the central area of Figure 16(a). Several aluminium-topped connectors can be seen in Figure 16 (a) that engage with the sockets shown in Figure 16 (b).



(a) **(b)**

Figure 17 (a). Close-up of part of the Fixed Store mesh, populated with many small modules measuring 27mm x 5mm and each containing a pre-determined pattern of thin ferrite and copper rods representing binary 1s and 0s.

Figure 17 (b). Close-up of Fixed Store modules and a section of mesh, removed from the Manchester Atlas.

9. The historical significance of Atlas.

At the time of its inauguration in 1962, the Atlas hardware was very advanced and in particular the performance of the arithmetic unit and the Fixed Store (ROM) were exceptional. However the continued and rapid rate of improvements in digital technology had rendered Atlas hardware obsolescent within a dozen years. Of much more lasting significance are some of the key features of Atlas systems software and memory-management strategy. Three Atlas developments have stood the test of time.

(a). **The Compiler Compiler**. This was a novel software tool which, when given a formal description of a computer language and a computer's low-level instruction set, would automatically produce a compiler for that language. The Compiler Compiler has been described by Professor George Coulouris, who used it in the 1960s, as *"A quite amazing achievement in terms of the innovations that it contained and the effectiveness of its design and implementation".* The Compiler Compiler later inspired a series of parser-generator systems, which basically parse an input language into trees and provide routines to interpret what they mean. These routines can be replaced by compiled versions for efficiency. This is essentially how XSLT, the XML transformation language, works. XSLT currently drives the world wide web.

At the time of writing (2013) a Computer Conservation Society project led by Dik Leatherdale and Iain MacCallum is in progress to attempt a re-compilation and simulation of the Compiler Compiler using original listings – (see also Appendix B) – and an Atlas emulator available at https://www.leatherdale.net/atlas.htm (b). **The Atlas Supervisor**. This was the first multi-tasking, multi-user operating system. It provided for the automatic management of computer time and space and peripheral equipment. Per Brinch Hanson, author of the book ‘Classic Operating Systems’, has called the Atlas Supervisor *“The most significant breakthrough in the history of operating systems”.* Incredible as it now seems, the Atlas Compiler group at Manchester never numbered more than six full-time programmers and the Supervisor group never more than seven.

(c). **Virtual memory**. Atlas automated the transfer of information between primary and secondary memory (ie core and drum) in an efficient manner, by a combination of hardware Page-Address Registers and software Supervisor routines (particularly the *drum learning program*). By these means, a user’s (large) virtual address-space was mapped onto a (smaller) real address-space. In Atlas, this was called the *One-level store,* as is shown diagrammatically in Figure 13, thus implementing the concept of Virtual Memory. Robin Kerr, a member of the Atlas compiler-writing team at Manchester from 1959 to 1964 who subsequently worked for a number of American computing corporations, has said: *“The Atlas project produced the patents for Virtual Memory. I would claim that Virtual Memory is the most significant computer design development in the last 50 years. Certainly it is the most widely used”.*

In conclusion, the Ferranti Atlas was an influential project within the world-wide history of Computer Science. At national level, Atlas could with some justification be called the *Greatest British Supercomputer* because, to date, no other British-designed supercomputer has yet managed to achieve, if only briefly, the title of ‘world’s most powerful’. At Manchester University, Tom Kilburn’s research team built a successor to Atlas, called MU5 *(see footnote).* MU5 started working in mid 1974. At that time the fastest supercomputer in the world was reckoned to be the CDC7600, which was about ten times faster than its predecessor, the CDC 6600. The CDC7600 proved to be about four times faster than MU5 when running Fortran benchmark programs but MU5 was slightly faster than the 7600 when running Algol benchmark programs.

As is demonstrated in Appendix A *(see next page)*, the Atlas artefacts currently in storage in Edinburgh represent by far the most extensive assemblage of surviving Atlas equipment. The NMS collection therefore represents an important and tangible historical resource. It is unfortunate that, as far as can be determined, NMS did not acquire supporting Chilton Atlas documentation in 1974. Appendix B lists other sources of original Atlas technical literature that will help scholars interpret the NMS artefacts. However, only one document – item CS/Atlas/1 in Table B2 – is of any real help when attempting to understand the detailed functionality of the hardware units preserved at NMS. At the time of writing (2013) there is on-going Computer Conservation Society activity to explain in an accessible way the original Atlas hardware functionality.

The MU5 computer system. Derrick Morris and Roland N Ibbett. Published by Macmillan, 1979. ISBN: 0-333-25749-9.

Appendix A: Surviving Atlas hardware at other museums.

In the mid-1970s, at the time of de-commissioning the three Atlas 1 and three Atlas 2 installations, computer history was not such a hot topic as it is today. Museums generally were not keen to accept large pieces of computer hardware. In the 1970s the Atlas organisations, facing the task of clearing out obsolete hardware, generally took the pragmatic step of selling this hardware for scrap, since scrap dealers were glad to recover the gold and other metals from the equipment. Although a few individual printed-circuit boards were kept as souvenirs and a few technical manuals survived in attics, most Atlas-related artefacts soon disappeared from each of the six Atlas sites as soon as more modern computers were installed.

Of the three smaller Atlas 2 installations, it is believed that the only significant unit to have survived is the CAD Centre's engineers' console which is currently stored in the Birmingham Science Museum. Other Atlas 2 artefacts specific to the Cambridge Titan (the prototype Atlas 2) are held at the University of Cambridge Computer Laboratory.

Surviving artefacts from the three (larger) Atlas 1 installations are now listed.

London Atlas 1: apart from a handful of souvenir printed-circuit boards, now scattered, it is believed that only the three artefacts shown in Table A1 (below) have been preserved from the London Atlas. These are held in storage by the Science Museum Group (formerly known as the National Museum of Science & Industry, London) – (see: https://collection.sciencemuseumgroup.org.uk/).

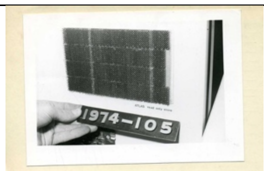
Catalogue Number	***Description as per the Museum's catalogue***	***Comment***
1974-105	Piece of Fixed Store mesh (from the Manchester University Atlas)	 *(Compare Figure 17 (b)).*
1973-564	Piece from London University Atlas: block of core store	This is a 4Kword stack from the main core store. See also the enlarged view in Figure 16 (b). 
1973-563	Piece from London University Atlas: Engineers' console.	
1974-409	Storage drum from ATLAS computer.	This is the Bryant drum, removed from the Chilton Atlas drum cabinet now in storage at the National Museums Scotland – (see section 7 above):

Table A1: Three units of the London Atlas and one unit from the Chilton Atlas. All four are currently held in the Science Museum Group's storage facility at Wroughton, Wiltshire.

Manchester Atlas: The University of Manchester's School of Computer Science has a collection of historic computer artefacts on display in the Kilburn Building. In addition to two or three individual printed-circuit boards, the main units of Atlas hardware on display are shown in Table A2 (overleaf). Furthermore, it is believed that a complete TM2 Ampex magnetic tape deck from the Chilton Atlas is held in private storage by Chris Burton of the Computer Conservation Society.

Chris Burton also has a Supervisor magnetic tape from the Manchester Atlas, dated 23rd February 1967 and therefore a few months before the large 16Mword file disc was added to this computer. This tape was passed to him by Frank Sumner, a key member of the Atlas design team. The tape is believed to contain the following items:

(a) the full code of the Supervisor (ie about 35,000 machine instructions including the approx 6K that normally resided in the Fixed Store) as at February 1967. Whenever the Supervisor was restarted, the main part of this code was transferred to the one-level store.
(b) the Compiler Compiler and about 24 other compilers, assemblers and loaders;
(c) logging, testing and diagnostic systems.

Chilton Atlas.
The majority of Chilton Atlas artefacts are in storage at NMS Granton, as described earlier in this Report. Additional units stored elsewhere are: (a) the engineers' console, believed to be stored somewhere within premises owned by the UK's Science and Technology Facilities Council (STFC); (b) the Bryant drum shown in Table A1 above; (c) small pieces of equipment stored in the Computer History Museum, Mountain View, California, as now explained.

… *(Table A2 overleaf)*

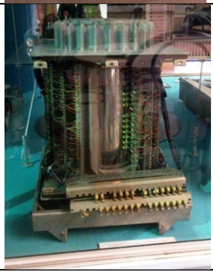
Item and comments.	***Photo***
Page Address Register bay from the core store co-ordinator. The outer cabinet has been removed to reveal all of the central steel frame that holds the boxes of printed-circuit boards.	
Prototype Fixed Store bay, with outer cabinet removed. It is believed that this unit comes from a pre-production installation – possibly the Atlas Pilot Model that was in operation at the University of Manchester in 1960.	
The engineers' console. The handkeys have been set in the standard positions to facilitate a diagnostic sequence, used when a machine error occurred that required investigation. The desk-top contains relevant contemporary Atlas engineers' fact-sheets with annotations, so that the whole display has the 'look and feel' of a working Atlas console.	
A Bryant drum with covers removed. Drums manufactured by Bryant Computer Products of Vermont USA (later Excello Corporation) replaced the original Ferranti MD5 drums on all Atlas 1 installations from about 1964 onwards.	

Table A2. Atlas units on display in the Kilburn Building, University of Manchester.

After the main Chilton Atlas units went to Edinburgh in 1974, F R A Hopgood was responsible at the Rutherford Appleton Lab for passing the few Atlas artefacts that remained to the Computer Museum in Boston, Massachusetts, in 1979. This was at the request of Gwen Bell, wife of Gordon Bell of the Digital Equipment Corporation, who took an active interest in preserving historic computer equipment. When the Boston collection was subsequently wound up, the Chilton material was transferred to the Computer History Museum (CHM) in California. The CHM online catalogue – see http://www.computerhistory.org/collections/search/ - lists eight small items in all. Eliminating duplicate pcbs, the five Chilton artefacts of interest are shown in Table A3 (overleaf).

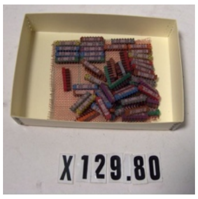
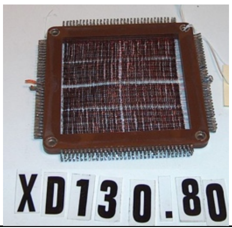
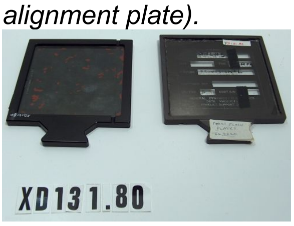
ID.	***SHL's brief description of item***	***CHM Accession number***	***Donor***	***comments***
A2	822 pcb	XD128.80	F R A Hopgood	The Atlas 822 printed-circuit board contains six flip-flops.
A3	Fixed Store bits	XD129.80	R A Lab	Some 'toothbrushes' from the Fixed Store:  *(Compare Figure 16 (b)).*
A4	Core plane	XD130.80	F R A Hopgood	Catalogue says: "Core Memory 'The Supervisor'". This is taken to mean a core plane from the original 1Kword Working Store, which was reserved for Supervisor use only. (The Supervisor was the name given to the Atlas Operating System). Another (identical) ferrite core plane from the Chilton Atlas' Working Store is currently held by Jim Austin's Computer Collection in Yorkshire: (http://www.computermuseum.org.uk/) According to Dai Edwards, it is possible that these might have been spare or non-functional planes, rather than pieces removed from a functional Working Store. 
A6	832 pcb (?)	XD2.74	?	Catalogue simply says 'Atlas digits' (without photo) but quotes a Ferranti serial number consistent with 832 pcbs. The Atlas 832 printed-circuit board contains four flip-flops.
A8	Form flash plates	XD131.80	Ruth. Appleton Lab	SC-4020 (Stromberg-Carlson film recorder) Alignment Test Slide 280002-793 SHT 2 OF 2. *(FRAH adds: Objects A8 were film flash unit backgrounds. The SC4020 drew the image on a charactron tube and a camera would take a photograph of it very quickly. For standard backgrounds, you could put a special plate in the camera path. There were some standard plates like a map outline of the UK. There was also an alignment plate that helped the SC4020 engineer, set up the machine. The one on the left looks like the alignment plate).* 

Table A3: Chilton Atlas artefacts in storage at the Computer History Museum (CHM) in California.

Appendix B
Bibliography and other sources of Atlas information.

The wider Atlas story is recounted in an illustrated booklet issued in 2012 to mark the computer's 50th Anniversary. This booklet, plus several other interesting reminiscences written by former Atlas people, can be down-loaded from the 50th Anniversary website: http://curation.cs.manchester.ac.uk/atlas/ An illustrated history of the Atlas Computer Laboratory at Chilton, plus copies of many original supporting documents, will be found at: http://www.chilton-computing.org.uk/acl/technology/atlas/overview.htm The specifications and delivery-lists of Atlas and most of the pre-1960 British-designed computers will be found at: www.ourcomputerheritage.org/

Between October 1957 and February 1962 Tom Kilburn's Atlas team filed 15 patents. About 25 Atlas papers were published in scientific journals in the period 1959 to 1968. A list of the more important papers is given in Table B1 below.

The overall Atlas systems architecture and Virtual Memory:

(a). Kilburn, T, Edwards, D B G, Lanigan, M J and Sumner, F H, *One level storage system.* IRE Trans on Electronic Computers, Vol. EC-11, No. 2, April 1962, pages 223 – 235. (See: atlas-r67.pdf (1.0Mb)).
(b). Sumner, F H, Haley, G and Chen, E C Y, *The central control unit of the Atlas computer.* Proc. IFIP Congress, 1962, pages 657 – 663.

The Atlas fixed store (ROM):

Kilburn, T and Grimsdale, R L, *A digital computer store with very short read time.* Proc. IEE, Vol. 107, Part B, No. 36, Nov. 1960, pages 567 – 572.

Atlas arithmetic unit details:

Kilburn, T, Edwards, D B G and Aspinall, D, *A parallel arithmetic unit using a saturated transistor fast-carry circuit.* Proc. IEE, Vol. 107, Part B, No. 36, Nov. 1960, pages 573 –584.

Atlas Supervisor details:

(a). Kilburn, T, Howarth, D J, Payne, R B and Sumner, F H, *The Manchester University Atlas operating system: Part 1, internal organisation.* Computer Journal, Vol. 4, No. 3, 1961, pages 222 – 225. *Part 2, users description.* Computer Journal, Vol. 4, No. 3, 1961, pages 226 – 229.
(b). Howarth, D J, Jones, P D and Wyld, M T, *The Atlas Scheduling System.* Computer Journal, Vol. 5 No. 3, November 1962, pages 238 – 244.

Atlas Compilers and languages:

(a). Brooker R A , MacCallum I R, Morris D and Rohl J S, *The Compiler Compiler.* Annual Review of Automatic Programming Vol 3, 1963, page 229. Published by Pergamon, London.
(b). Morris, D and Rohl, J S, *The Atlas compiler system.* Computer Journal, Vol. 10, 1967, pages 227 – 230.
(c). Brooker, R A, Rohl, J S and Clark, S R, *The main features of the Atlas Autocode.* Computer Journal, Vol. 8, 1965, pages 303 – 310.

Titan/Atlas 2 timesharing operating system:

Hartley, D. F., and Needham, R. M. *Operation experience with the Cambridge multiaccess system.* IEE Conference Publication No. 55, 255-260, 1969.

Chilton Atlas timesharing operating system:

J Baldwin and E Thomas, *Multi-access on the Chilton Atlas.* Computer Journal vol. 14, issue 2, 1971, pages 119 – 122.

Table B1: a selection of original Atlas papers in contemporary scientific journals

At the time of writing, there are two Atlas emulators/simulators available, developed respectively by Dik Leatherdale and Roland Ibbett. They significantly aid an understanding of the machine:

- To run Atlas code: https://www.leatherdale.net/atlas.htm
- To observe systems behaviour at the register level: http://www.icsa.inf.ed.ac.uk/research/groups/hase/models/atlas/

As mentioned above, the organisational history of the Chilton Atlas is well-covered at this website: http://www.chilton-computing.org.uk/acl/technology/atlas/overview.htm To underpin the wider Atlas story, the locations of original Atlas technical manuals and documents, including letters and internal company reports, reside in collections such as the following:

(a). The Computer History Museum, Mountain View, California [CHM in the Table below];
(b). The Ferranti Archive, located at the Museum of Science and Industry, Castlefields, Manchester [MOSI in the Table below];
(c). The ICL Archive, located at the Wroughton, Wiltshire, storage facility of the Science Museum Group (formerly known as the National Museum of Science & Industry, London) [ICL in the Table below];
(d). The National Archive for the History of Computing, John Rylands University Library, Manchester [NAHC];
(e). The School of Computer Science, Kilburn building, University of Manchester [C.Sc.];
(f). The Computer Laboratory, University of Cambridge [CL];
(g). Private collections, such as those of Chris Burton, David Hartley, Simon Lavington, Brian Spoor and other members of the Computer Conservation Society [CCS].

An illustrative selection of Atlas documents from some of the above sources is given in Table B2. The selection in Table B2 focuses on documents of relevance to the understanding of the hardware in storage at NMS and its system software.

Where	***Title of document; date (where given)***	***Collection catalogue number***	***Comment (eg URL if currently downloadable)***
CHM	Features of the Ferranti Atlas computer. May 1961. CS 272B	102640711	cs272b.pdf (1.1Mb)
CHM	Ferranti Atlas computer: extracode functions. 1962	102640696	
CHM	ICT Atlas Computer - Supervisor and Fixed Store Routine Specifications. Vol. 1, 1962.	102649984	
CHM	ICT Atlas Computer - Supervisor and Fixed Store Routine Specifications. Vol. 2, 1962. #400 - 599	102649986	
CHM	ICT Atlas Computer - Supervisor and Fixed Store Routine Specifications. Vol. 1, 1962. #600 onwards.	102649985	
CHM	ICT Atlas Computer - Supervisor and Fixed Store Routine. Specifications, General Description. 1962.	102649989	
CHM	ICT Atlas I - Preparing a Complete Program. 1966	102649990	
CHM	ICT Atlas 1 Operator's Manual - Part One - Central Machine and Supervisor. 2nd Edition. 1965	102649992	
MOSI	Volume of correspondence with the National Research Development Corporation about the development and history of the Atlas Computer. 1958-1963.	A1996.10/1/7/414	
MOSI	Ferranti Limited Computer Department. Ferranti Atlas Computer. Atlas magnetic Tape. List CS 298A. 1963.	A1996.10/6/6/20	
ICL	Boxfile of Ferranti / ICT papers, including:	38/60	

	a) The Atlas Drum System, provisional description; b) The Atlas Core Store & Working Store, provisional description.		
NAHC	"Draft Report on the Manchester Electronic Computer Project" by C. Strachey, J. Howlett, D. Wheeler and E.H. CookeYarborough (1958), and associated letters	MUC/B5	
NAHC	MUSE/ATLAS: Folder of Tom Kilburn's Design Notes and Internal Ferranti memos., 1959-60.	MUC/C18	
NAHC	Folder marked "Fixed Store. Print Output AB", 1963.	MUC/C21	
NAHC	Minutes and Reports, NRDC Sub-Committee on Electronic Computers, 1957-59	NRDC/C2/2	
NAHC	High Speed Computers, Ferranti, Atlas Project Contract". Reports 1959-60.	NRDC/C32/2	
NAHC	Five typescripts marked "ATLAS Computer Project Progress Reports", 1961/2.	FER/C20a	
NAHC	Folder marked "ATLAS block and logic diagrams" , inc. overall block diagram (1963), page address registers. (1962/3).	FER/21	
C.Sc.	Stiff-backed folder containing about 240 Atlas engineers' logic diagrams, each approximately 40 cms by 20 cms.	CS/Atlas/1	Formerly owned by Eric Sunderland, a maintenance engineer on the Manchester Atlas. A folder of this type is shown in Figure 7(a) in this Report.
C.Sc.	Box containing material relevant to the Compiler Compiler, including: (a) Compiler Compiler Flow Charts; (b) Compiler Compiler Index (types and indices); (c) Part III code listing; (d) Folder of various papers and listings relevant to CC Titan (Cambrigde); (e) Folder of CC Tapes showing changes from Atlas 1 -> 2; (f) Listings marked 'Cambridge CC', 'Original CC documentation', 'Titan installation', etc.	CS/Atlas/2	Formerly owned by R B E (Brian) Napper, who worked with Tony Brooker.
CCS	Atlas System Description. A stiff-backed, thick, clip-in blue foolscap folder containing updatable technical information on MUSE/Atlas, issued from 19/6/1959 onwards and known at Manchester as *The Atlas Bible.* Contains 14 sections with the following titles: Notation; general description; the function code; details of the basic function codes; the main store including arrangement of drum transfers; the operating system; input languages; magnetic tap; the peripheral equipments; instruction times; engineering facilities; details of the Atlas computer installations; interrupts; layout of V-store.	SHL/1	This copy, formerly owned by Iain MacCallum, has been updated to 1st July 1963. Dik Leatherdale and other members of the CCS are currently scanning this document so as to make it accessible online.
CCS	Compiler Compiler listings. A stiff-backed, thick, clip-in red foolscap folder containing listings from a three-stage compilation (Octal/Assembler/Phrase Structure Language). The outputs are dated 22nd December 1963.	SHL/2	This folder was formerly owned by Iain MacCallum. Iain and Dik have scanned the listings and are currently part-way through running the resulting code on an Atlas emulator. The intention is to re-create the Compiler Compiler.

CCS	The ICT ATLAS 1 Computer Programming Manual for ATLAS Basic Language (ABL). List CS 348A, January 1965. Contains approximately 300 pages.	SHL/3	cs348a.pdf (17.1Mb)

Table B2: A selection of the Atlas source documents, available in various museums and collections and relevant to an understanding of the NMS artefacts.

Many photographs of Atlas installations exist, particularly in the collections at:
(a) The Ferranti Archive, located at the Museum of Science and Industry, Castlefields, Manchester;
(b) The Science and Technology Facilities Council (the successor to the Rutherford Appleton Laboratory);
(c) The School of Computer Science, Kilburn building, University of Manchester;
(d) Private collections, such as those of Chris Burton, Dai Edwards, Simon Lavington and other members of the Computer Conservation Society (CCS).

No film or video of the Chilton Atlas itself has yet been discovered. The Chilton Atlas was, however, used with the Stromberg-Carlson film recorder to create several pioneering animated films. Many of these animated films are held at the Computer History Museum, California.

Three contemporary films, described in Table B3, have been located that feature the Manchester Atlas installation in its early days.

Date	***Title***	***Duration; B/W or colour?***	***Originating organisation; comments***
1961	**Ferranti Atlas at Manchester**	8 mins, colour	Ferranti Film Unit. Now held by the Science Museum: ICL Archives reference AR4. Style of the film: technical documentary. Shows manufacture of production Atlas in Ferranti's West Gorton factory, followed by the delivery of the first of five production cabinets to Manchester University.
1962	This week in Britain: No. 192, ***Atlas computer***.	2 mins. 45 secs. B/W	Central Office of Information. The COI was wound up in January 2012. COI films are now owned by the British Film Institute. Style of the film: contemporary newsreel item, with a reporter describing the inauguration of the Ferranti computer at Manchester University.
1963	Look at Life, number 16: ***Figure it out***.	9 mins, Colour.	J Arthur Rank. This film is now owned by ITV Studios and ITN. Style of the film: public information feature, giving a general overview of computers and their uses in the early 1960s. Includes shots of various Ferranti, Elliott and IBM computers and their everyday applications. The Atlas sequence only lasts a few seconds.

Table B3: contemporary films featuring the Manchester Atlas computer.