Timeline of the MUSE/Atlas project at Manchester University, 1955 – 1971.

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Acknowledgements.
The reminiscences of many former Atlas pioneers have contributed to the compiling of these notes. Particular thanks are due to Dave Aspinall, Tony Brooker, Yao Chen, Eric Dunstan, Dai Edwards, Iain MacCallum and Robin Kerr.

1954, spring The new Dover Street building is occupied by the University's Department of Electrical Engineering. Soon afterwards, the Ferranti Mark I is moved from the Coupland Street building to *Computing Machine Room 1* on the third floor of the Dover Street Building. Meg (the prototype Mercury) is moved to *Computing Machine Room 2.* After re-commissioning and elimination of interference from radar being tested to destruction from a nearby Manchester location, local users were running programs on Meg by early 1955. Meg was also used by a visitor from the Norwegian Atomic Energy Organisation for about 6 months. The Norwegians then purchased the first production Ferranti Mercury, which was based on Meg.

1955, autumn The computer research group within Electrical Engineering, led by Tom Kilburn, started to investigate the possibilities of higher speed transistor logic circuits and faster memory systems of improved capacity. This work was intended to focus thoughts for the development of a new high-speed computer but there was no specific intent to build or even to specify a machine at this time. There was, however, the thought that transfers between the primary memory (probably ferrite cores) and backing store (probably a magnetic drum) could be automated by hardware so as to relieve users of this task. Tony Brooker had achieved some software support for this process on the Ferranti Mark I computer, within the Mark I Autocode system. No firm strategy for hardware memory management had yet been devised for a new machine.

1956 Feb Ferranti's computer department moves into new premises at West Gorton, Manchester.

1956 Dec. The design objectives for the Univac LARC and the IBM STRETCH computers are presented at the Eastern Joint Computer Conference in the USA.

1957 Jan. Jack Howlett (AERE Harwell) and J Corner (AWRE) produce for the UKAEA a report entitled *The case for a big computer*, stating that 'by 1960 the AEA would need a computer comparable to LARC and STRETCH'. In response to the Howlett/Corner report, the National Research Development Corporation (NRDC) Computer Sub-

Committee asks Lord Halsbury to review and compare US and UK scientific computer development activity. From about this time, the word ‘supercomputer’ starts to be used by NRDC. See references [1 to 4] for the background to the NRDC’s interactions with the MUSE/Atlas project at Manchester. The references are listed at the end of this document.

1957 early: A decision was made within the research group led by Tom Kilburn to design and build a fast computer with a target speed of a microsecond per instruction. The project was called MUSE, short for *Musecond Engine.* This would be a completely parallel machine and would have to use the latest high-speed germanium junction transistors then just becoming available. Dai Edwards would be responsible for the engineering aspects and Tony Brooker for the software. To support the project, a sum of £50K was made available from the Department’s own research fund. This fund had been accumulating since 1951, as an agreed percentage of the University’s overall *Computer Earnings Fund.*

1957 March Dick Grimsdale begins work on a fast fixed store (ROM) system and Yao Chen on fast RAM storage. For the latter, the possibilities of smaller core sizes and using two cores per bit and/or partial flux switching were examined, to see what speed improvements were possible.

1957 30th April John Cockcroft calls a meeting of UK computer users and designers at UKAEA to discuss technical problems and requirements for a high-speed computer. The meeting was attended by seven people from AERE, representatives from several other government establishments, and Kilburn from Manchester, Wilkes from Cambridge and Strachey from NRDC. The meeting made reference to UKAEA’s need for 10^5 mesh-operations per second on a 3-d mesh for reactor calculations – (a paper entitled *The Three-dimensional Computer* had been distributed by AERE). Amongst advanced technologies discussed were thin magnetic films and diode-capacitance stores, and the need to develop much faster transistor circuits and much faster input/output. At the meeting, UKAEA found itself in disagreement with NRDC’s proposal that NRDC itself (in practice, meaning Christopher Strachey) would design the machine.

1957 26th June NRDC agrees to put ‘not less than £1 million’ into a high-speed computer project. At this point, NRDC felt that the development would be beyond the capabilities of any one single UK manufacturer. Accordingly, NRDC proposed a joint project which would (a) have contributions from all the UK’s centres of expertise, and (b) would give NRDC an opportunity to gain some return on its investments. In the event, it proved impossible for NRDC to satisfy (a) and (b) together. (Note that by this time, IBM was said to be spending $28m annually on STRETCH and to be deploying 300 graduates on the project).

1957, late autumn Ferranti Mercury computer is installed in *Computing Machine Room 2* on the third floor of the Dover Street building. Mercury had passed its acceptance tests by 5th February 1958.

1957, late: Dave Aspinall, seeking a project for his Ph.D., decides not to work on thin magnetic films for Pete Hoffmann but to join the MUSE team and start work on the fast parallel adder. Test circuits were built using the latest American germanium 2N501 and SB240 high-speed transistors – each costing about £35 and therefore much too expensive for all but the time-critical carry-path. With its better symmetry and lower saturation voltage, the SB240 proved more satisfactory for the carry-path. Cost considerations and supplier-availability caused Kilburn's group to select Mullard OC170 transistors for the main MUSE logic. These graded base transistors were fast if operated with a significant voltage between emitter and collector at all times but could not be allowed to saturate without significant loss of speed. A non-saturating, defined-current, circuit was devised for MUSE, with clamping diodes limiting the output voltage levels. The cable driver and cable receiver circuits used on MUSE for inter-unit connection were also interesting. 8 milliamps was pumped through the standard OC170 circuit down a piece of miniature co-axial cable and regenerated into a standard signal at the other end.

1958 27th Feb. Meeting (later known as the *Second Harwell Computer Conference)* between NRDC and representatives from AERE, RRE, NPL, MOS and the Universities of Cambridge and Manchester. This meeting was initiated by Sir Owen Wansborough-Jones, then Chief Scientific Adviser to the government. A specification based on general requirements for a high-speed computer was circulated by Cooke-Yarborough (AERE). The meeting recommended the development of two computers: (a) a shorter-term project, having a fast store of 10^5 numbers and 10^5 mesh-operations per second, to be available commercially in five years' time; (b) a longer-term project involving new components and new techniques, for which the design would not start for another 3 to 5 years. The meeting recommended that a Working Party consisting of Kilburn, Wheeler, Strachey, Howlett and Cooke-Yarborough be set up to check the suitability of MUSE for (a), the short-term project, and to report in a months' time. Kilburn contributed to the Working Party's discussions but, for obvious reasons, did not participate in the writing of the final Report. On a visit to Manchester, which took place on 17th March, the Working Party were shown the MUSE developments, which by then included about 500 words of the MUSE fixed store with an access-time of 0.2 microseconds, one word of a two-core-per bit RAM with a cycle time of 2.5 microseconds, and two single-bit experimental adders using different types of transistor. (There was an extreme shortage of suitable transistors at that time and they were very expensive).

The Working Party noted that the Manchester project "aimed at producing within three or four years a computer with times for basic arithmetical operations of a few microseconds using components already in existence … It should be pointed out that the information quoted here has been disclosed at a much earlier stage than Dr Kilburn would have wished had he not been specifically asked".

Amongst the conclusions in the Working Party's final Report were the following points:

(i) "Dr Kilburn has in existence at Manchester a very lively team of experienced computer circuit engineers. They have close and easy relations with Ferranti Ltd. … [However] we doubt whether even this combination has the strength and breadth needed for execution of the stage 1 project unaided".

(ii) "The speeds of the proposed machine [MUSE] fall somewhat below the target originally suggested [of 10^5 mesh operations per second], but this is not a very serious matter".

(iii) "The proposed machine [MUSE] falls short of the minimum requirements for the stage (a) project in respect of storage capacity facilities and provision for peripheral equipment. The concept as it stands might be scaled up, but this would not provide a machine of the type we [particularly the UKAEA] require and one which is suitable for commercial manufacture. A fresh logical design would be necessary".

(iv) “Dr Kilburn made it quite clear that the present University project was not dependent upon support from NRDC and would be completed without it”.

(v) “Dr Kilburn further made it clear that he would only accept [responsibility for building] the [stage (a)] project on the condition that he was to be the final arbiter on all questions of engineering and logical design, although he would be willing to listen to suggestions from other people during the first 18 months”.

(vi) “Taking the above points into consideration … we cannot recommend that the Manchester University Project should be the sole basis for the Stage (a) computer”.

(vii) “We therefore recommend that the full meeting [ie between NRDC and representatives from AERE, RRE, NPL, MOS and the Universities of Cambridge and Manchester] be reconvened to consider whether it would be possible to combine the Manchester work with that of other organisations [for example RRE] or individuals or, failing this, what other course should be adopted”.

1958 Oct. After various meetings and conflicting advice, NRDC renewed its approaches to EMI, English Electric and Ferranti in an attempt to inject funds into a company that would undertake a British supercomputer project. English Electric responded negatively, and EMI positively, over the terms of NRDC’s loan. An EMI pilot project was eventually given NRDC support but it came to nothing. Ferranti did not agree with the terms of NRDC’s offer of a loan.

1958 Oct. During the summer period, Tom Kilburn had had private discussions with Sir Vincent de Ferranti. It is deduced that these talks were fruitful. In October Ferranti decided to go ahead independently of NRDC with a cooperative project with Manchester University that thereupon changed its name from MUSE to Atlas. This decision was confirmed in January 1959. (The slight uncertainty about informal versus formal agreement may have arisen because Brian Pollard resigned as Manager of Ferranti’s Computer Department and Peter Hall took over in December 1958).

1958 24th Dec.: Ferranti Mark I shut down. It was dismantled in June 1959 and the bits given to Ferranti Ltd. Once cleared, *Computing Machine Room 1* was assigned to house the so-called *Pilot Model* of the MUSE/Atlas project.

1959 Jan Issue 2 of the document *Provisional users’ code for the Manchester University computer, MUSE* is circulated.

1959 Feb. (a). The first paper describing the Atlas parallel adder is presented at the Institution of Electrical Engineers, London [ref. 5]. (b). Strachey files a patent for ‘time-sharing in large computers’ (British Patent 924672, granted in 1963). In 1959, ‘time-sharing’ was the term used in the UK for what we would now call ‘multiprogramming’. Strachey’s patent appears to make 57 claims, specifying a director (supervisor) in fixed store, a memory-protection mechanism and an interrupt priority structure. Note that Kilburn’s group at Manchester University filed 15 Atlas patents between October 1957 and February 1962 through NRDC, on subjects including arithmetic units, magnetic recording, storage systems and memory management - (see also below under March 1960).

1959 May NRDC loaned Ferranti £300K towards the cost of Atlas development, to be recovered from sales. Ferranti had paid off their loan by March 1963, according to [ref. 4].

1959 15th/20th June: IFIP UNESCO Computer Conference in Paris: separate papers on high-performance computers are presented by Kilburn and by Strachey – see [ref. 6 and 7]. The appearance of Strachey's paper was a complete surprise to the Manchester team who, by contractual agreement, had always discussed their computer research as early as possible with NRDC to ensure that it was covered by patents. With the benefit of hindsight, it seems that some of the ideas in Strachey's paper could be said to have been inspired by – or shared by – the MUSE/Atlas project. These include: the precise speed and use of a Fixed Store; the use of private RAM for the 'Director' [Supervisor] working area; the arithmetic instruction speeds; the use of fixed-block magnetic tapes; the need for some kind of job control language. Two of Strachey's ideas that were definitely not in MUSE/Atlas include: the provision of two extra consoles (one for maintenance engineers, the other for program testing) – these were in addition to the main operator's console; the use of datum/limit registers for memory management.

A great many papers on the hardware and software of the Atlas system then appeared in the period 1960 to 1967. The main ones are listed as [refs 8 to 21] at the end of this document. It is believed that Christopher Strachey published no further papers on computer architecture. For an account of his other work, see [ref. 22].

1959 19th June: Date on which Ferranti starts to issue copies of the massive manual known locally as the *Atlas Bible.* This was a foolscap spring binder for containing confidential technical information, arranged in 13 sections. Ben Cooper of Ferranti was in charge of organising the circulation and periodic updating**.** The preface describes the manual as "a description of the [Atlas] system from the viewpoint of a knowledgeable programmer, and is intended for the use of persons concerned with the design of the system". Updates to various pages were issued periodically until at least 13th July 1963. By this time the manual was over an inch thick.

1959 autumn: Towards the end of this year, Dexion frames had been assembled in the old Ferranti Mark I room on the top floor of Dover Street and all the Pilot Model developments transferred to this room. During 1959 the MUSE/Atlas team started to lay out printed circuit boards, to be manufactured by Ferranti at West Gorton ready to go into the Pilot Model racks and into the final production ATLAS logic racks.

1959, 9th Nov. On this date, formal Atlas hardware progress meetings started at Ferranti's West Gorton site. The meetings were chaired by Peter Hall. Keith Lonsdale, Gordon Scarrott and others attended on behalf of Ferranti. Tom Kilburn and Dai Edwards attended on behalf of the University. These meetings continued thereafter to be held on the second Monday in the month. At the first meeting it was formally decided that MUSE should be the Pilot Model for Atlas and that any further MUSE design should as far as possible be part of the final design for the production Atlas. It was agreed that some of the drum, magnetic tape and fixed store equipment would be attached to the Pilot Model but that in general the Atlas team would not be expected to work on peripheral equipment. Keith Lonsdale said that the design of peripheral equipment would be carried out by Ferranti's Orion team and the designs made available to the Atlas team. Subsequently there proved to be significant exceptions to Lonsdale's statement, particularly in relation to the magnetic tape and magnetic drum equipment. For example, higher drum transfer rates were needed for Atlas so the Orion revolution time was doubled for Atlas and new forms of read/write head were devised (see also the note below for May 1960 and Appendix 2).

1959, end On the software side, Tony Brooker, Derrick Morris, Robin Kerr and Jeff Rohl were planning the writing of high-level language compilers for Atlas. For this work, Brooker conceived the Compiler Compiler [ref. 18].

1960, January. The decision was made to sub-contract work on the B store and RAM main store design and manufacture to Plessey Ltd. This entailed a significant amount of work by Plessey. It was considered that the B store would probably use two cores per bit and be partially flux-switched for speed, and that the main RAM would probably use one core per bit and be constructed in units (*stacks*) of 4K words of 50 bits each (48 data plus two parity).

1960, 30th Jan.: The complete 24-bit B unit parallel adder was the first major section of MUSE/Atlas Pilot Model to be successfully tested on this day. The paper describing this [ref. 12] was received by the IEE on 28th January and published in November 1960.

1960, Spring Various meeting at which Tom Kilburn and Peter Hall (Ferranti) assigned formal responsibilities for progressing particular sub-sections of Atlas. Rather than list names/tasks here, and because the design and development team expanded over the next couple of years, a full list of names, dates and responsibilities is given at the end, in Appendix 1.

1960 March. Three Atlas hardware papers (storage and ALU technologies) were presented by the Manchester University team at the IEE meeting in London on 1st March 1960 – see [refs. 9, 10, 12]. The papers subsequently appeared in the November 1960 issue of the IEE Proceedings. Of the three Atlas patents that laid the foundation for what became known as Virtual Memory, one was filed on 16th March 1960 ('address translation'), and two on 20th April 1960 ('block transfers' and 'replacement algorithms').

1960 May Problems with the mechanical design of the (Orion) drums became evident. The Atlas team at the University became involved in the design of the read/write electronics, since Gordon Scarrott (of the Ferranti Orion team) said that there was no spare effort for this at West Gorton. Also at this time the Lancashire Dynamo company was commissioned to build the power supply and switching system for the production Atlas.

1960 August Confirmation that designers at Ferranti's Edinburgh factory were to organise and supply the magnetic tape decks. They chose the Ampex company as a likely source. The first Ampex deck (type FR300) that was received proved unacceptable because the acceleration time to operating speed was too slow by a factor of three. A new Ampex deck, the TM2, was ordered but the quoted delivery-time was one year. Only the basic Ampex TM2 decks were to be purchased: Ferranti Edinburgh were to design and supply the read/write electronics and fit them to the decks for both the Orion and Atlas projects.

1960 30th Sept. By this date, the outline design of all nine Atlas sub-units had been completed and the detailed logical design of 80% of these units had been finished. At this stage there are 49 types of printed-circuit board (pcb) in production or ready for production at Ferranti's West Gorton factory; there are 9 types for which the design is still incomplete. The package-count for 60% of the computer had been completed and the backwiring schedules for 20% of the computer had been produced – see [ref. 23]. The nine sub-units that are distinguished in [ref. 23] are:

1	CPU:	B arith and B store
2	CPU:	A arith
3	CPU:	Distributor
4		Core store control
5		Drum control
6		Peripheral Coordinator
7		Tape coordinator
8		Fixed store
9		Working store control plus the bought-in store unit.

By 30th Sept. the Pilot Model has the following sub-units in working order: (1), part of (3), a pilot version of (8), loaded with 850 words of information. A Creed Paper Tape Punch was connected to the Pilot Model at this stage. The Plessey 1K word store was delivered in August but not yet tested. Simple test programs have been run on the Pilot Model.

1960, 10th Oct. At the monthly progress meeting it was stated that successful operation of the B-store, the 1K working store and the fixed store had occurred.

1961, end-January. The Dexion Pilot Model of Atlas was dismantled and re-assembled at West Gorton, where it was used for further development and, in due course, the training of maintenance engineers. At the University, work began on refurbishing the *Computing Machine Room 1* at Dover Street with a false floor, air conditioning ducting, etc.

1961 February Ferranti Edinburgh stated that they are short of people to design the read/write electronics for the magnetic tape decks, though they had the capacity to manufacture and test. They asked for help, in order to complete the design and thus to deliver the deck systems on schedule. Two of the Atlas team, Dai Edwards and David Aspinall, agreed to help. They promptly went to Edinburgh and completed the necessary design work in one week. Sam Alexander (Ferranti) accepted the design work and confirmed that the resulting systems would also be suitable for Orion.

1961, March. Work was advancing at West Gorton on the construction of the logic cabinets for the first production Atlas – destined for the University of Manchester. At Dover Street the refurbishment of *Computing Machine Room 1* continued.

1961, early summer: detailed design of the Atlas Tape Coordinator handed over by Dave Aspinall to West Gorton for production. Dave Aspinall then took time off to write up his Ph.D. (awarded December 1961). By about this time, Kilburn's informal estimates [ref.24] of the constituent parts of the final Atlas appear to be as follows:

Unit	***Packages***	***Boxes***	***Racks***
Central computer (ie A, B&C, D)	1200	30	3
Tape coordinator	350	9	2
Drum cabinet	200	?	2

Drum coordinator	120	3	1
Core **store** coordinator	385	8	1
Core store	50 x 4		
Working store	50	1	1
Periph coordinator	266	7	1
Fixed store	334	non-std	2

1961, June. The first Atlas production cabinet, containing the A, B&C and D units, is delivered to Dover Street and installed in the refurbished *Computing Machine Room 1.*

1961, 30th Sept.: By this time, the total number of pcbs in Atlas had increased to 4,403, of which 1200 had been completed and tested, 1,000 awaited testing and the rest were still in manufacture [ref.23]. More completed cabinets had been delivered to Dover Street. The final board-count (including I/O peripherals and special online devices such as the X-ray Diffractometer and the Speech Converter) had risen to 5,257 by 1965 [ref. 25]. This reference also gives a rough estimate of the total number of transistors (60,000) and diodes (300,000).

1961 November: By now the manufacture of the NIRNS/Chilton Atlas had begun at West Gorton [ref. 26]. This probably implies that, by November, most cabinets of the Manchester Atlas had been delivered to the University. The power supplies were delivered to Dover Street by Lancashire Dynamo.

1962, 29th January. The cabinet containing the Tape Coordinator was delivered from West Gorton to Dover Street.

1962 February: On 16th February 1962 Kilburn reported [ref. 26] that*: "some components of the Manchester Atlas were now being tested, and it was already clear that the speed of the arithmetical processor was equal to expectations".*

1962, March: The detailed logical design of Atlas was declared to be 'complete' by this time [ref. 23]. 4,065 pcbs had been delivered to the University. The first half of the fixed store was working and had been loaded with information. The delivery of the first drum unit was expected by early April. Iain MacCallum, then an M.Sc. student working on the Compiler Compiler, remembers "the great excitement when the first 'extracodes' were tested on the fixed store memory. We wondered: was this the fastest executed programs ever?" [ref. 27].

1962 early June The Compiler Compiler becomes available. As far as Atlas software is concerned, the first language to which the Compiler Compiler is fully applied is Extended Mercury Autocode, EMA. By about the end of July EMA became available to end-users such as Kodak (see below). This helped users in the transition from Mercury to Atlas.

1962 July: On 6th July Kilburn reported [ref. 26] that: "*the central computer continued in use for the development of programmes for the Supervisor. Operating times were proving to be remarkably close to those predicted. Both halves of the core store had passed their acceptance tests at Plessey's. The core store, the drum store and one tape unit would be linked into the central computer via their respective co-ordinators during the* *coming fortnight, and the Atlas should be in full operation on internal programming work during August".*

1962 summer: By the summer of 1962 there were several of Ferranti's Computing Service customers who were anxious to begin running their applications programs on Atlas. Companies with urgent projects, such as Kodak and Royal Dutch Shell, were invited to use the Manchester Atlas on an 'at risk' basis whilst the Supervisor was still being developed. Furthermore, these 'apps programmers' were asked if they would like to help iron out bugs in the Supervisor. Ann Moffatt from Kodak, who used the Manchester Atlas from about July to December 1962, remembers that: *"We were given fairly detailed talks on how the Supervisor was supposed to work. I was given the 'drum learning program' to test and debug. Other customer programmers took other bits to test and debug. The programmers who had been sent by their companies to help get Atlas working were the best their companies could find. We had a healthy respect for each other and worked well together, excited to be working on the most powerful computer in the world at that time… We could use the machine between 11:00pm and 6:00am. I was writing my application programs in Mercury Autocode."*

1962 Sept. Internal course on programming in Atlas Autocode held for staff and research students in Lecture Theatre A, Dover Street.

1962, autumn: Commissioning of Atlas progresses at Dover Street. David Aspinall remembers that: *"At one stage, when Ferranti were having problems with the drum, one tape deck was programmed to emulate the drum store. Eventually, by December 1962, all eight magnetic tape channels were commissioned".* Also, it was reported [ref. 26] on 27th November that some work had been done on an experimental data link between Manchester and Edinburgh. At this stage the links were *off-line,* requiring paper tape input/output at both ends and good human communication to ensure satisfactory operation. On-line data links did not become available until about 1965. Also at the same meeting, Anelex lineprinters were described as *newly-available* – (see also under March 1963).

1962 Oct. Iain MacCallum and John Clegg joined Robin Kerr to start work on the Atlas Algol compiler.

1962, 7th December: Sir John Cockcroft officially inaugurates the Ferranti Atlas in the Dover Street building, accompanied by press coverage and demonstrations of the computer.

1963 Jan. The Mercury computer is moved out of Dover Street and thence to Sheffield University, by prior arrangement. The Mercury room, *Computing Machine Room 2*, is then used for Atlas data preparation equipment and for the online X-ray Diffractometer – (see below). From January 1963 the University of Manchester's Computing Service is run on Atlas. See below (June 1963) for the final form of the Agreement which gave the University half the available time on Atlas.

1963 February First bound copies of the *Atlas Autocode Programming Manual* issued. Authors: R A Brooker and J S Rohl.

1963, March: An Anelex 1,000 lines/minute lineprinter, a Creed 3000 paper tape punch (300 chars/sec.) and a TR7 paper tape reader (1,000 chars/sec.) were added to Atlas to complement the existing slower I/O peripherals. The lineprinter replaced an experimental graphical output device. At some time before November 1966 a second Anelex lineprinter had been added.

1963, spring: On 29th May meeting at NIRNS [ref. 2] Kilburn reported that: *"with the qualifications concerning the drum store which had already been discussed, the Manchester University Atlas was complete and maintenance was now in the hands of the Ferranti engineers. The Mercury Autocode [compiler] was finished; the Atlas Autocode [compiler] was in use but he would expect some faults to be found in it for a few weeks"*.

June 1963: By letter dated 3rd June 1963 to R A Rainsford (the University of Manchester's Bursar) from Peter Hall (Manager of Ferranti's Computer Department), the final agreement regarding the ownership and operation of the first production Atlas at Manchester University is as follows:

(a) The Atlas computer is owned by Ferranti Ltd.
(b) This Agreement is for 8 years, starting 1st Jan 1963.
(c) The University guarantees Ferrranti unrestricted access to the machine.
(d) Ferranti will maintain the machine for at least the equivalent of one shift without charge, and intends to maintain the machine on a three-shift basis.
(e) Ferranti will make available to Manchester University (MU), without charge, half the capacity of the computer after deduction of (i) time wasted due to system failures; (ii) engineering maintenance time.
(f) Ferranti will provide the operating team.
(g) Ferranti will pay MU £10K per annum for use of building, power, etc.
(h) Ferranti will pay MU £100K in consideration of MU's technical assistance with the Atlas project. Additionally, Ferranti will pay MU 5% of the invoice value of Ferranti Alas Computing Service external jobs executed during the period of the agreement.

This Agreement was approved by the University Council in July 1963.

1963 26th Sept. ICT acquires Ferranti's mainframe computer interests. Shortly afterwards, Atlas hardware and literature start to carry the ICT logo.

1963, Oct. Tony Brooker returns from a year spent at IBM's Yorktown Heights Research Laboratory, New York. He wrote a conventional compiler for Atlas Autocode in the Autumn term of '63 as a back up for Jeff Rohl's Compiler Compiler version *"in case for whatever reason it proved too slow. In fact both versions were used but I was able to twig mine to provide statistics about the relative usage of different statements".* [ref. 28].

1963, 11th December Bart Fossey and Bob Hopgood from Harwell visit the two Algol teams at Manchester – the main (ICT) one led by Robin Kerr/John Clegg and a second (University) project led by Derrick Morris.

1963, end-December The first version of the Algol compiler was in use and the design of the second version was complete. This second design required a new feature in the Compiler Compiler, which Derrick Morris completed early in 1964. Iain MacCallum left the Algol team at the end of 1963 [ref. 27].

1964, January: The full Supervisor becomes available.

1964, spring: The on-line X-ray Diffractometer becomes operational. The enhanced version of this, which was implemented for a PDP8 computer, is described in [ref. 29].

1964, May The second version of the Algol compiler is completed.

1964, spring: On 5th May it was reported [ref. 26] that tests on the NIRNS/Chilton Atlas at West Gorton *"indicated that computing times were within those specified with the exception of the time for division which ranged from 10 - 30 microsecs with an average of 25.6 compared with a specified average of 17.9 microsecs. Professor Kilburn said that this was due to a recognised logical error in the divider which he had decided not to rectify because the time taken to do so would have been considerable whereas the effect on the overall speed of the machine was small. The overall speed originally expected had been 60 - 80 times that of Mercury and the overall speed now found was 70 - 80 times that of Mercury".*

July 1964 Robin Kerr departs for the USA, leaving John Clegg in charge of Algol developments. During 1964 the Harwell Algol group collaborated with John Clegg's team.

1964 Tom Kilburn's group splits off from Electrical Engineering to form a separate Department of Computer Science, initially still located in Dover Street. The initial complement is 12 academic staff.

1964, December The *Speech Converter* comes into operation. This is an on-line 8-bit analogue/digital/analogue converter with 20KHz bandwidth, used primarily for research into speech analysis/synthesis and into automatic speech recognition see [ref. 30]. It is also used for other signal analysis applications.

1964, end: By now the Computing Service within the Department of Computer Science was staffed by one 'lecturer-grade' person plus about 14 people of technician/secretarial grade. About 40 to 50 University Departments or Departmental-groups were catered for, plus about 15 outside (academic) users. It is estimated that the computing needs of the University of Manchester, including UMIST, will exceed the time available on Atlas by 1967 [ref. 31]. Hence a proposal is put forward for a new building to house both the Department of Computer Science and the University's Computing Service, together with provision of a new 'Service' computer costing about £2m.

1965, early: The on-line data link becomes operational – [ref. 32].

1965, 1st March: Date of issue of an Atlas Autocode Reference Manual (authors listed as R A Brooker and J S Rohl).

1965, June: From time to time the Computing Service re-adjusts the charging formula used to assign costs (and hence resource-allocations) for outside users running programs on Atlas. On 18th June the charging is calculated as follows. The total cost (in pence) of a job is given by the following formula, which has four components:

Computing = A/10(1+n/100)
Input = 36B + 25.5C
Output = 0.5D + 2E + 60F
Mag tape = J/40 + nT/10 + m(240 + 2T + A/100)

Where:

A = instruction Count
B = PTR input (blocks)
C = CDR input (blocks)
D = LPT output (records)
E = CDP output (records)
F = PTP output (blocks)
n = requested store (blocks)
J = mag tape transfers (blocks)
T = mag tape half time (secs)
m = number of mag tape decks used
G = number of drum transfers.

Also, the computing time in secs = 0.006144A OR 0.011G (whichever is the greater), + 90 if n>100.

Note: the above cost is full rate; academics (from other institutions) are charged 20% of this rate.

1965, autumn The Department of Computer Science moves into temporary accommodation in Coupland Street, leaving the Computing Service in Dover Street.

1965 October The Department of Computer Science accepts its first intake of undergraduates into a three-year honours degree course.

1966 Tom Kilburn's research group within the Department of Computer Science starts plans for a new high-speed computer, targeted at being about twenty times faster than Atlas. The machine was later called MU5.

1967, 1st October: A 16M word Data Products type 5048 disk store with two independent read-write mechanisms, recently added to Atlas, comes into service on this day as a file store. The disk in situated in *Computing Machine Room 2.*

1968, July: A Computing Service analysis of the use by academics of Atlas during the period July 1967 to July 1968 [ref. 31] finds that 109,200 programs have been run, with the following statistics:

User group	***no of Depts***	***Equiv. cost of computing (£)***	***Total time (hrs)***	***no. of jobs***
Manchester Univ.	43	478,700	2,880	69.900
UMIST	18	251,100	1,640	37,600
Other Univs	8	4,400	20	500
Research Orgs	6	14,200	110	1,200
Totals	75	748,400	4,650	109,200

(Of course, the figures for the Ferranti Computing Service and commercial customers are excluded from the above analysis).

1968 Oct: ICT merged with English Electric Computers to become ICL (International Computers Limited).

1968 The Science Research Council (SRC) awards Tom Kilburn's research group a five-year grant of £630,446 for the MU5 project [ref. 33]. ICL West Gorton agrees to give significant help with production facilities. A further SRC grant of £130,000 for MU5 was received in 1973.

1969 autumn The Department's Computing Service section is taken over by the government-funded *University of Manchester Regional Computing Centre* (UMRCC). Gordon Black is appointed as the first UMRCC Director. The Centre is temporarily located at UMIST and an ICL 1905F is chosen as an interim facility. Meanwhile, a new Computer Building is designed to house both the academic and the service sections.

Spring 1970: UMRCC starts running an interim computing service, based on an ICL 1905F computer installed in the Maths Department at UMIST.

1971: By now, UMRCC had selected a CDC 7600 computer front-ended by an ICL 1906A as their main service facility. The two machines are first installed and tested at West Gorton, since the University's new Computer Building is not yet complete. By now, the MU5 design team numbered 16 Computer Science staff backed by about 25 research students and 19 engineers seconded from ICL West Gorton.

1971, 30th Sept.: The Manchester Atlas is switched off. The console, an Ampex tape deck, a small section of the Fixed Store and the logic bay containing the Page Address Registers are preserved for display in the Department of Computer Science. Miscellaneous documentation, including a copy of the Atlas Bible and a mag tape containing the Supervisor, is preserved. The remaining equipment is sold for scrap.

Postscript.

1972 autumn A new Computer Building, subsequently to be known as the *Kilburn Building,* is opened. UMRCC occupies the ground floor and the Department of Computer Science occupies the rest. UMRCC installs a CDC7600 computer front-ended by an ICL 1906A. UMRCC initially provided services for a group of universities which included Salford, Liverpool, Keele and Lancaster. UMRCC equipment was then

	updated over the years. For example a Cyber 205 vector supercomputer was commissioned in the mid-1980s, to be followed in due course by a Fujitsu VP1200 and VPX 24/10. The number of universities served expanded so that it became a national service. The name changed from UMRCC to Manchester Computer Centre (MCC) and finally to just Manchester Computing (MC) when it was wound down in the mid-2000s, by which time each UK university was making its own provisions. The University of Manchester's current Directorate of IT Services was established in 2005 just after the merger with UMIST. At the time of writing, the Directorate still operates from the ground floor of the Kilburn Building and with IT teams right across the campus.
1974 October	ICL announces a new range of computers called the *2900 Series*. The architecture of the 2900 Series owes much to and has a great deal in common with MU5. By October 1974 MU5 was running Algol and Fortran benchmarks and the assessment of hardware and software performance had begun.
1975	By now the Department of Computer Science numbers 32 full-time academic staff, including four Professors (Tom Kilburn, Dai Edwards, Frank Sumner and Derrick Morris).

Appendix 1: List of the principal people from Manchester University and Ferranti Ltd. who were involved in the design and implementation of hardware and software for the Manchester Atlas.

The following list is presented in alphabetical order. Efforts have been made to include all relevant people but it is likely that a few names have inadvertently been omitted. The date information (column 3) clearly requires more research. Comments are welcomed.

Name	***Dates at Manchester University for computer design purposes***	***Dates as Ferranti employee***	***Number of Atlas patents on which named***
David Aspinall	1955 – 1970		2
Don Atkinson		before 1961 – ??	
K F (Keith) Bowden	1958 – 1967		
A R (Tony) Brooker	1951 – 1967		
John Buckle		1962 – 1975	
E C Y (Yao) Chen	1957 – 1959; 1964 - 1968	1959 – 1964	1
C R (Reg) Claber		before 1961 – ??	
John Clegg		before 1961 – ??	
A B (Ben) Cooper		before 1961 – ??	
Jim Doughty		before 1961 – ??	
Peter Duncanson		before 1961 – ??	
Eric Dunstan	1953 – 1964?		
D B G (Dai) Edwards	1948 – 1988		9
R L (Dick) Grimsdale	1951 – 1961		
Gordon Haley		before 1961 – ??	
P D (Peter) Hall		before 1950 – ??	
Brian Hardisty		1961 – 1977	
Douglas Hogg		before 1961 – ??	
D J (David) Howarth		1960 – 1970	
J K (Keith) Howker		1959 - ??	
Peter Jones		1961 – 1963	
R H (Robin) Kerr	1956 – 1959	1959 – 1964	
Tom Kilburn	1946 – 1981		14
P I (Peter) King		before 1961 – ??	
D J (Dave) Kinniment	1962 – 1979		
Ron Lane		before 1961 – ??	
M J (Mike) Lanigan	1955 – 1962		2
S H (Simon) Lavington	1962 – 1986		
Keith Lonsdale		before 1950 – ??	
I R (Iain) MacCallum	1961 – 1962	1962 – 1963	
Frank McAulay		before 1960 – ??	
J J Moore		before 1961 – ??	
Derrick Morris	1958 – 1980 ?		
Peter Mumford		before 1961 – ??	
R B (Brian) Napper	1960 – 1997		
S P (Phil) Patience	1958 – 1960	1960 – 1963	
R B (Bruce) Payne	1956 – 1964		
A J (Paddy) Podesta		before 1960 – ??	
A A (Alec) Robinson	1948 - 1950	1950 – 1963 ??	
J S (Jeff) Rohl	1960 – 1967 ?		
Dave Smith		before 1961 – ??	
John Standeven	1961 – 1970 ?		
F H (Frank) Sumner	1957 – 2000 ?		2
Eric Sunderland		1963 - ??	
Gareth Thomas		1956 – ??	
E T (Ianto) Warburton		before 1950 – ??	
Peter Warn		before 1961 – ??	
P B (Pete) Whitehead		1963 - ??	
M T (Mike) Wyld		before 1961 – ??	

Appendix 2. Difficulties with the original MD5 magnetic drums.
This information is based on comments provided by Eric Dunstan, in an e-mail to Simon Lavington dated 25/10/2012. Eric worked on the Atlas drums and the drum co-ordinator from about 1957 onwards. Eric writes:

"The MD 5 drum proposed for Atlas was an upgrade of a Ferranti MD 4 drum built for Orion but running at [as I remember 5000 rpm] which would yield a rev time of 12 milliseconds or an average access time of 6 milliseconds. The drum was designed at Ferranti and consisted of a cylinder with a single web in the middle rotated by a motor on top. I can't remember whether it was a DC motor or an AC motor running on a higher frequency AC supply to get 5000 rpm.

"The outer shell [the rigid container housing the drum] had multiple slots which received Block Heads with 16 + spares? per block. These were mounted to the shell using spring clips and referenced to the shell via 3 'V' blocks mounted to the shell and 3 "differential" screws with spherical hardened surfaces. The screws had LHS and RHS thread arrangement with different thread pitches to give a "fine" adjustment. The actual system required 25 heads in parallel (I seem to remember that it was 1/2 an Atlas word -- 25bits) which required spreading the heads over more than 1 block. Since the system was a fixed head system operating about .001" from the surface, there was a measurement system consisting of 3 "pitot" tubes adjacent to the screws. The tubes were connected to three manometer tubes which recorded the back pressure and as they were calibrated gave a reading of the head media separation. There was a complication caused by the two lower tubes being necessarily off axis and therefore suffered increased pressure on the approach side and lowered back pressure on the retreating side of the vertical axis. This had to be "allowed for' in the calibration.

"The whole arrangement had to be air conditioned for thermal stability and cleanliness. The drum surface was sprayed with oxide at Ferranti but the arrangement was very fragile and Phil Patience and I spent many nights adjusting and readjusting the separation -- sometimes the head touched the surface which we detected by a nasty smell coming out of the drumshell. Part of the problem was the fact that the web in the middle caused the cylinder to become "conical' because of unequal centrifugal expansion. Ferranti also had a problem with quality control of the primer / oxide coating and I remember getting a call one night from someone on the shift and they asked whether the surface of the drum was supposed to be silver or brown -- it turned out that there was a problem with the primer adherence and the whole coating had come off and was lying on the floor of the drumshell!

"At this point, it was decided to turn to a drum manufactured. in the US by Bryant Computer Products in Vermont USA, later Excello Corporation. This was a plated drum which was tapered and fitted with an "autolift" system which raised the whole spinning drum. Because of the taper [narrowing to the top], the drum surface approached the pre-adjusted individual "flying" heads which then flew at the required separation. When the drum was "shut down" the mechanism [rather like a flyball governor] lowered whilst the heads were still flying so that there was never head media contact. I went to the US with Douglas Hogg to run acceptance tests on the drums, four of which were installed in the Manchester Atlas".

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25. D B G Edwards, undated handwritten sheet of package-count calculations. The details of peripheral equipment imply a date of this document as 1964 or 1965. See also e-mail from DBGE to SHL dated 19th October 2012.

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12th November 2012.