
Douglas Hartree


Max Newman


Alan Turing


Maurice Wilkes

British Computer Pioneers

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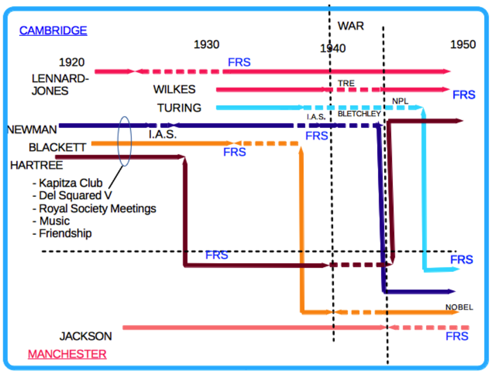
Britain's early success in computing was remarkable, especially since most of the pre-1945 groundwork had been done by the Americans. This talk is about British computer developments between 1944 and the early 1950s, with emphasis on these four pioneers.

The five sections of this talk start with the pre-1944 background, then deal in turn with the Colossus, EDSAC, ACE, and Manchester computers, and explain the parts played by our four pioneers.

You will certainly have heard of Alan Turing. Everyone has heard of Turing, and knows his iconic status. Public perception has been strongly influenced by the film "The Imitation Game" and by biographies whose content tends to be selective. As a result there is widespread belief that the computer developments of the late 1940s were driven by desire to implement Turing's ideas. There are many experts who rail against this such as Thomas Haigh in a thoughtful appraisal "Actually, Turing Did Not Invent the Computer." Turing is a highly important figure, but there are others who deserve comparable acclaim. Maurice Wilkes you may have heard of. But Max Newman and Douglas Hartree are hardly known by the public despite the fact that they are equally worthy of national recognition., as I will explain. Newman's name did surface just a few years ago when the Turing-Newman Collaboration Collection was purchased for the Bletchley Park Trust at a cost of over £300,000.

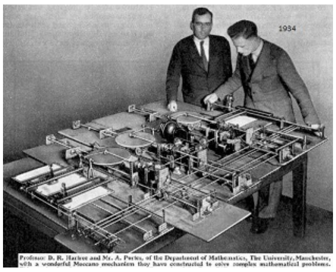
The Background



It all goes back to Cambridge in the 1920s and 30s. The assembly of talent there was remarkable. Close and lifelong personal connections were established and career moves were made which strongly influenced the way in which British computing developed. There are seven people on this chart who play important parts in the story. All became Fellows of the Royal Society at an early age, and all except Turing became Professors. Blackett is important to the story even though you can't call him a computer pioneer in the technical sense. That's Patrick Blackett, P.M.S. Blackett, Nobel Prize physicist. He was a political operator . When Harold Wilson later made his 'white heat of technology' speech, Blackett was beside him.

The chart shows their career paths between 1920 and 1950, including the war years. Several spent part of their career at Cambridge in the upper part of this chart, and part at Manchester - below the dotted line. Newman, Hartree and Blackett were particularly linked. They and other famous names were bound together by their 'clubs' and the Royal Society. And there was music. Newman was an excellent pianist and also played the harpsichord. The Hartrees were passionate about music and were splendid hosts, not only to Cambridge and Manchester colleagues, but also to famous visitors - such as Heisenberg (of the Uncertainty Principle) , another notable pianist.

There was personal friendship between the Blacketts and the Hartrees, and the Blacketts and the Newmans. And it was Hartree, Blackett, and then Newman who took Chairs at Manchester with great success. Newman also had strong connections with the Institute of Advanced Study at Princeton, New Jersey, and that too forms part of the story. Hartree too had strong American connections.



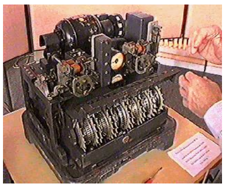
So let me expand on the lives of the pioneers pre-war and Before Colossus. Douglas Hartree was a renowned mathematical physicist, born 1897. His PhD and early work at Cambridge applied mathematics to quantum theory and in 1929 he became Professor of Applied Mathematics at Manchester. He sought better means of mechanical calculation, and in 1934 he used Meccano to build a differential analyser - a general purpose analogue computer. The successors of this machine, and Hartree's influence, soon launched Maurice Wilkes on his long career in computing.

Maxwell Newman was also born in 1897. His first post-graduate work in the early 1920s was on the use of symbolic machines in physics, his earliest thoughts on mechanical calculation - thoughts which would be further developed at Cambridge and during periods spent at the Institute for Advanced Studies Princeton, which was the home of some of the finest minds in the emerging 'Computer Science' - von Neumann, Alonzo Church, Godel and others. At Princeton Newman made important personal connections and at Cambridge his lectures inspired Alan Turing, and he arranged for Turing to go to Princeton for his doctorate.

Alan Turing and Maurice Wilkes both gained 1st class honours degrees in mathematics at Cambridge in 1934 and were almost the same age. Both remained for post-graduate work. Turing then went to Princeton and then returned to Bletchley Park. Wilkes remained at Cambridge except for a period at TRE Malvern during the war - gaining experience which would stand him in good stead.

Let's now look at the places which cradled British Computing. Britain's early electronic computing began at four locations - Bletchley Park, Cambridge, NPL Teddington, and Manchester. Douglas Hartree was linked to the work at three locations, and Max Newman at two of them.

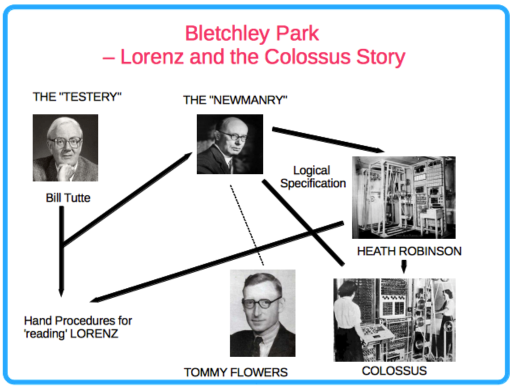
Colossus



I'll first talk about Bletchley Park and Colossus - the work of Max Newman and Tommy Flowers . There has been great interest in the intriguing drama of Bletchley and Enigma and Colossus, and the colourful life of Alan Turing. But it is difficult to pick out the true facts from persistent contradictory, and often incorrect assertions. Turing's famous work applied to the Enigma cyphers in the period up to 1942. The "Imitation Game" seems to attribute every collective achievement at Bletchley to Turing alone - and that of course is total nonsense!

German 'Lorenz' messages were first intercepted in 1940. This was a much more advanced communication system than the older 'Enigma' and was used by the German Command (including Hitler himself). The Germans must have had absolute faith in the security of the encryption which was much more complicated than Enigma!

In August 1941 Bletchley Park had a bit of luck! A careless German operator repeated a message in a slightly offset form, but using the same cypher settings. So the two related transmissions could be logically compared. And then it needed a genius to exploit this fragment of information! The genius was not Turing; it was Bill Tutte, another Cambridge mathematician. After many months he had deduced the logic of the Lorenz machine and by the middle of 1942 the team of cryptanalysts in the unit called the 'Testery' had devised ways of reading the messages (Roy Jenkins was among those involved). These decoded messages were of great intelligence value - far more so than those from Enigma. But decoding took time - using paper and pencil methods, leading to the setting up of an emulated Lorenz machine on a rack of relays - the so-called 'Tunny' machines.



Bletchley work was of course all very secret and compartmented - it was the "Ultra Secret". The small number of outsiders who knew about the work included Patrick Blackett, then a senior scientific adviser to government. In July 1942 Blackett visited Bletchley, and on return wrote a personal 'recruiting' letter to his friend Max Newman who was still at Cambridge. Max Newman soon joined the 'Testery' team. He perceived that parts of the tedious hand decoding process could be mechanised, and he was very soon in charge of the 'Newmanry', responsible for providing this machine-support. He interpreted Bill Tutte's methods for part of the Lorenz decoding process, turned them into a logical specification, and conceived a machine based on logical comparison of data from rapidly spinning loops of paper tape. He realised that the electronic 'scale-of-two' counters previously devised at Cambridge by Charles Wynn-Williams could be used, and he recruited Wynn-Williams to work with Post Office Engineers on building 'Heath Robinson'. This worked, but because it relied on rapidly moving fragile paper tapes it was rather unreliable, and early in 1943 this prompted Tommy Flowers of the Post Office Research Station to propose the building of an electronic equivalent using radio valves. Not unreasonably the Bletchley management were nervous, and insisted that continuing improvements to 'Heath Robinson' had to have top priority. However Newman provided the logical description for Flowers to work on, including a requirement for programmability and Tommy Flowers continued with his hardware development at Dollis Hill. He installed the first Colossus at Bletchley in early 1944. Don Horwood, father of Martin Horwood (well-known as previous M.P. for Cheltenham), was involved in the installation. Another account has said that Flowers, not a man to be overwhelmed by the importance of events, noted in his diary: **"Colossus did its first job. Car broke down on way home."**

Colossus was five times as fast as a Robinson, much more reliable and far more versatile. The design was further improved and 11 more were built and used by the 'Newmanry' in the final year of the war. It is reasonable to share the credit for Colossus between Max Newman and Tommy Flowers. (There is popular perception that Flowers was the sole inventor, unhelped by Bletchley Park and never adequately rewarded, but this is entirely unfair to Newman)

The Newmanry became an industrial-scale data-processing operation. By 1945 there were some 40 machines including the Colossi, Robinsons and Tunnies and some 300 staff including the large number of Wrens trained as machine operators. Colossus was certainly a programmable electronic digital computer, But it was not a 'stored program' computer since there was no memory system. That was also true of ENIAC in America, and in fact ENIAC was not even a 'digital' computer.

Turing took no part in the development of Colossus or its predecessors the Robinsons. (Both Newman and Flowers were insistent about that). Turing was in the U.S.A. between November 1942 and March 1943, and on return he moved away from cryptanalytic work onto developing a system of speech encryption (Delilah). He was of course still in touch with Bletchley Park, and the success of Colossus convinced both Newman and Turing that electronic stored program computers could be built.

EDSAC

But now I'll go back to Hartree and Wilkes and the evolution of computing at Cambridge. I'll be coming back to Newman's work at Manchester.

At Cambridge, the foundations for huge successes in computing were laid in the 1930s.   The early development of computing at Cambridge was user-driven, much influenced by Professor Lennard-Jones, a notable chemist. Lennard-Jones, appointed in 1932, was the prime mover in the case made for a Mathematical Laboratory.

Douglas Hartree , then a Professor at Manchester, played a significant part in the evolution of this project. In 1935, with guidance from Hartree,   the first of several differential analysers was constructed at Cambridge. In 1936, invited by the Cambridge Philosophical Society, Hartree gave a lecture on the applications of his Manchester differential analyser. Maurice Wilkes was in the audience and immediately recognised that the differential analyser could help him to solve equations he was encountering in his own research into radio propagation. Later that year Wilkes took over responsibility for the Cambridge machine and in 1937 he was appointed as 'demonstrator' in the new mathematical laboratory, whose first Director was Lennard-Jones. Wilkes visited Professor Hartree for the first time in Manchester and later described this visit: **" .. Professor Hartree became my close counsellor and friend in later years. ... I sensed that here was a level of professionalism in computing far beyond anything I had encountered up to that time."**

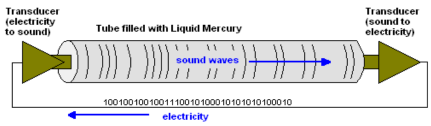
Maurice Wilkes spent much of the war period working on radar at the Telecommunications Research Establishment (TRE) Malvern and there he acquired the knowledge of electronics, practical skills and pragmatism which would mark his approach to computing. At Cambridge the Mathematical Laboratory got back in business after the war, and Maurice Wilkes, back from wartime radar work, became Director in 1946. And at about that time Douglas Hartree was appointed Plummer Professor of Mathematical Physics.

During the war, Hartree, attached to the Ministry of Supply, had a wide-ranging remit, including practical mathematical work on subjects such as the design of magnetrons, ballistics, gun control etc. His differential analysers were involved with a wide range of war-related computational work, including work for the atomic-bomb programme which earned him high regard from the Americans. He chaired inter-departmental committees. His wartime advisory experience, coupled with his understanding of practical computation, meant that he was ideally placed to play a major role in the development and application of electronic computers in the United Kingdom. In addition, his position in the Ministry of Supply, his reputation, and his contacts allowed him privileged access to, and knowledge of electronic computing developments in the United States.

In April 1944 a committee was set up to consider the setting up of large-scale, government-sponsored centralized computing facilities. Douglas Hartree was an influential member.

In May 1945 he went on a two-month tour of computing installations in the USA, including visiting ENIAC (still not complete). He saw the draft of von Neumann's famous and influential EDVAC report on the design of a stored program computer. Hartree's report on the visit contained technical detail and understanding, and stressed the problem of internal memory - a problem which would beset the early computer projects - British and American.   In particular it would influence the relative progress of Newman, Wilkes and Turing in the building of the first British machines. And it would considerably delay the first proper American computers, including EDVAC itself, and John von Neumann's own IAS machine.

Hartree (and others of course) realised that a 'large' random access store for digital data and programs was required, In 1945 there were just two possibilities.   Both seem rather strange now.   Recirculating mercury acoustic delay lines would certainly work, having already been proved in radar.   But they were not random access; their action was like a Ferris wheel where at any moment only one of the many compartments is available for loading and unloading.   Max Newman said ***"its programming was like catching mice just as they were entering a hole in the wall."***



The second possibility was electrostatic storage based on the 'iconoscope', This would be random access, but had not yet been made to work.

Hartree visited America again in 1946, there by invitation. ENIAC was working, and Hartree programmed it to perform calculations on fluid flow.   On return he encouraged Wilkes to visit ENIAC in the summer. "Nature" also published his paper **"The ENIAC: The World's First Electronic Digital Computer"**   which was the first public description anywhere of the so-called 'first' electronic computer. (Hartree probably knew about Colossus at that time, but his lips were sealed!)

Wilkes returned from his visit, determined to build a stored program computer along the lines set out by von Neumann. Hartree was also involved in facilitating arrangements for Max Newman to make a visit to IAS, home of the emerging von Neumann machine.   Hartree was now in his new Chair at Cambridge. His Inaugural Lecure included his expectation that **"it may well be that the high-speed digital computer will have as great an influence on civilization as the advent of nuclear power".**

At about the same time, in a radio broadcast, he said **" Computers can also be used in many problems of modern statistics, problems which are of importance in economics, public health and sociology..."**

He was now energetically involved in the launching of electronic computing projects, not only at Cambridge. but also at Manchester and NPL - as I will be describing.

Wilkes got EDSAC under way - helped by two pieces of good fortune. Firstly, at just this time, the forward-looking company of J. Lyons, of teashop fame, heard about computers, actually realised their commercial potential, and sent two people to America on a fact-finding mission. And it was suggested there that they should talk to Professor Hartree. They soon provided Wilkes with a helpful grant of £3000, the start of a continuing partnership. which was particularly nurtured by Hartree.

The second bit of luck for Wilkes was the return of Tommy Gold to Cambridge. Gold was a close associate of Hoyle and Bondi, later to become known as the Cambridge Cosmologists. But Gold had been working on naval radar and was an expert on mercury delay lines. It was easy for him to give Wilkes a memory design which actually worked!

EDSAC's further advantage was that Wilkes was very practical and far-seeing. He says in his memoirs that he believed that it would only be a matter of time before mercury memories would drop out and be replaced by truly random access memories . Hence he did not divert effort into developing short-term techniques for addressing the idiosyncracies of the mercury memory. The priority for him was that the machine should work, albeit slowly, that it should not be difficult to program and that it would have a future when better memory technologies came along.

EDSAC had got off to a good start., running its first program in May 1949 Wilkes had created a computer that was accessible and practical, rather than pushing the boundaries of technology - a machine used by a wide range of researchers in the university not just ‘acolytes’. It led on to the Leo series of computers and also to EDSAC 2 . Magnetic core memory arrived on the scene in 1953 and Wilkes was able to adapt the design and abandon the clumsy Mercury delay-lines.

Douglas Hartree made large personal contributions to EDSAC, and Wilkes later wrote a glowing tribute to Hartree. **" ..... his experience of computing, of a most practical kind, qualified him to play a major role ... He could work with those much younger than homself ..... It was in no small measure due to Hartree that computer applications at Cambridge got off to a good start ".**

The Lyons Company also recognised Hartree's contributions to their computers by naming the LEO headquarters "Hartree House".

ACE

The April 1944 committee on which Hartree sat recommended that a new section should be set up at the National Physical Laboratory, one function being to investigate electronic computing devices suitable for rapid computing. Soon afterwards Douglas Hartree was on the panel which selected John Womersley as the Superintendent of the new section. John Womersley persuaded Turing to join NPL. Hartree himself joined the NPL Executive Committee early in 1945.

Turing then began to plan the NPL computer, known as the 'ACE' - Automatic Computing Engine. This was the first British computer project to get under way, early in 1946. It started with Turing's paper proposal which was a remarkable document for it's time. Womersley in seeking the Director's approval wrote of **"combining electrical apparatus already well developed"** and stressing that **"in the use of the apparatus we will be far more resourceful and cunning than the Americans"**. So it went ahead, and in March 1946 an optimistic Tommy Flowers considered that the delay-line store could be built by June 1st and a 'minimal ACE' could be working by August/September 1946. Turing estimated the cost of the machine to be £11,200. How wrong they all were!

There was blind faith in Turing's ability to see it through. And the belief that Turing could do no wrong persists today. Professor Jack Copeland's article "Alan Turing : Father of the Modern Computer" used the derogatory and largely unjustified phrase **"Woolly-minded administrators wasted the brilliant technological achievements of Turing and his group."** The truth was rather different.

Turing had his own 'agenda' which can't have helped. In a 1946 letter to Ross Ashby (who was designing a synthetic brain called the Homeostat) he wrote **"In working on the ACE I am more interested in the possibility of producing models of the application of the brain than in the practical applications to computing".** This was clearly inconsistent with the stated aims of providing a practical computing service for Government Departments, Industry and Universities.

Like Wilkes and others, Turing chose the mercury delay line as the storage medium. But he wanted speed. He welcomed the intellectual challenge of using the delay line efficiently. That led to his unconventional and difficult system of 'optimum programming' using program-memory locations which were not necessarily consecutive and instructions which each contained the address of the next instruction. And that locked the ACE - and its successor, the DEUCE, into the delay-line technology which would soon become obsolescent.

And the relationship with Dollis Hill was in difficulties. Dr Coombs of Dollis Hill remembered that at every meeting **"the last idea, the one that they produced last week was old-hat and they'd got quite a different one and we couldn't get a consolidated idea at all"** . And Dollis Hill had plenty of work on telephone modernisation.

Douglas Hartree on the Executive Committee made several attempts to get ACE back on track. He tried to facilitate collaboration between Wilkes and Turing. In April 1946 Wilkes made his first abortive attempt to cooperate with NPL, His plans for EDSAC were already under way six months later when he was prompted by Hartree to make further contact with the struggling NPL. Correspondence continued from November 1946 until April 1947. Very early on, Turing judged that Wilkes ideas were **"much more in the American tradition of solving ones difficulties by means of much equipment rather than thought".**

Wilkes, on his part, found Turing very opinionated, with ideas that were widely at variance with what the mainstream of computing was going to be. He thought that some of Turing's ideas were bizarre. Wilkes pressed for a firm answer from NPL in January 1947, but Womersley only replied in April, rejecting the collaboration and citing **"one or two little difficulties".** Rather pathetically - after all the time they had already spent - he said they had decided they must do **"..... a certain amount of experimenting to become familiar with the kind of hardware ....".** This rejection freed Wilkes to devote all his efforts to building EDSAC .

Hartree's other initiative in support of NPL, a more successful one, was to facilitate the one-year attachment to NPL of an experienced American computer scientist, Harry Huskey. Huskey wrote a report in March 1947. He concluded that **"the logical development at NPL was far ahead of practical results, that the plans had led to more and more complicated machines, and that there was a "battle of principles"** He proposed the building of a test bed (which Turing opposed). Hartree visited at the time, backing Huskey, and concluding that **"further planning of a theoretical nature for such a large machine would be unwise ...".**

This, and Huskey's report triggered the departure of Turing for a sabbatical year at Cambridge, never to return to NPL. Once Turing had gone, the new team got the 'Pilot Ace' working in 1950, one year behind Wilkes. It was later described as 'based on an earlier design by Dr A.M.Turing'.

Manchester

We now go back to the Manchester story. In early 1945 with peace in the offing, Professor Patrick Blackett was transferring his attention back to Manchester University. He was determined that Manchester should build a computer. And as with his Bletchley recruiting, he knew that his friend Max Newman was the man and that a Mathematics Professorship at Manchester would be tempting! Newman's wife, Lyn, was very reluctant, preferring family life in "Cross Farm", their much-loved Cambridgeshire farmhouse, to exile in the "perpetual gloom of Manchester". But the Blacketts visited the Newmans at Cross Farm and eventually persuaded Lyn that a dutiful wife must see that Max's career was the most important thing.

So Max Newman was appointed to the Fielden Chair of Mathematics at Manchester in 1945. He was determined to have a computer, and he acquired dismantled Colossus equipment as 'War Surplus' - which was taken to Manchester in December 1945. He needed funds to build the computer and applied to the Royal Society in late 1945. That included provision of £800 p.a. for a full-time electronic engineer.

The Royal Society sought the views of Hartree and of the Director of NPL, Sir Charles Darwin (grandson of the Charles Darwin). Darwin's own view was that a Manchester project would compete for resources - and wasn't necessary. He had already expressed the short-sighted view (even then) that **"…...In view of its rapidity of action, and of the ease with which it can be switched over from one type of problem to another it is very probable that one machine would suffice to solve all the problems that are demanded of it from the whole country........."** And he consulted Womersley - who smelt a rat. He was sure that Newman had Flowers in mind for the engineer - who else?

So while Hartree supported the application, Darwin strongly opposed it. Hartree won the day, helped by pressure from Blackett, and Newman was funded. That was the start of the 'Royal Society Computing Machine Laboratory'.

Max Newman wanted a computer as quickly as reasonably possible. In early 1946 he contacted John von Neumann himself at Princeton. where the "IAS Machine", prototype of the generalised "von Neumann Machine" and forerunner of the IBM 701, was well under way and Newman based his ideas on this. Newman never considered 'delay-line storage', and fairly soon recognised two 'iconoscope' options. To start with, it seemed more likely that the American 'Selectron' would provide the answer but this encountered prolonged problems. However Newman was also aware of the work being done at TRE Malvern by Freddie Williams. Freddie Williams had made outstanding contributions to radar at TRE, and in 1946 he had started work on electronic data-storage using 'iconoscope' methods.

That gave Newman a second option. Manchester needed to fill the post of Professor of Electrotechnics. Newman, and of course his friend Patrick Blackett, aware of the importance of Williams's work, both played an important part in the appointment of Williams. NPL also tried to recruit Williams when their association with Flowers was failing, but the Manchester post was more attractive - and it has also been said that Williams did not relish the idea of working with Turing.

By autumn 1947, Williams, with Tom Kilburn, had produced a working 'Williams Tube', and adopted this as the storage method in the Manchester Small-scale Experimental Machine (Manchester Baby) which was running in mid 1948. Julian Bigelow from Princeton, who was building the IAS machine visited then, and adopted the 'Williams Tube' instead of the Selectron. The IBM 701 commercial machine was later produced using 72 Williams Tubes.

And Blackett had vision and ambition. He made contact with Sir Ben Lockspeiser of the DSIR and that soon led to £100,000 defence funding and the involvement of Ferranti. From then onwards the influence of Newman and the Royal Society Computing Laboratory rapidly declined.

However in 1948 Newman published his paper 'General principles of the design of all-purpose computing machines'. Newman also specified the first realistic program to be run on the Manchester Mark 1 in June 1949, and desribed it at the Cambridge Conference on High Speed Automatic Calculating Machines that month. He believed that it was the first routine for a problem with some intrinsic interest to have been run on a general-purpose machine.

Turing joined Newman's team in 1948 as 'deputy director' of the Royal Society Machine Laboratory. He wrote the Programmers' Manual for the Manchester Mark1 machine, a useful contribution, and developed early programming techniques. But his personal enthusiasm for practical computing was limited. In 1953 he said **"It was really quite difficult to find useful things to do on a machine partly because in pure mathematics there was no urgency in getting a solution and partly because some of the fun of it was lost when a machine was used."**

Turing became less involved with the Manchester/Ferranti machines, turning to his own interests in Artificial Intelligence and Morphogenesis. He wrote the important paper on Computing Machinery and Intelligence in 1950.

The Manchester Mark1 became the Ferranti Mark1. In 1951 it was referred to as a 'high-speed electronic computer built for the University Mathematics Department, and paid for by a Government grant - an improved version of a prototype developed by Professor F. C. Williams and Dr. T. Kilburn of the Electrical Engineering Department, and Professor M. A. Newman and Mr. A. Turing, of the Mathematics Department '.

When Turing died in 1954, Newman, mentor, supporter and friend of Turing for 18 years, wrote the biographical memoir for the Royal Society.

Conclusions

The early work I've described took place in Universities and Government Establishments. But things were rapidly changing. The 1951 Manchester Conference launched the Manchester Mark 1 which soon led to the line of Ferranti Computers . The NPL ACE became the English Electric DEUCE and English Electric later took over LEO from J. Lyons . And at the same time new technologies were arriving. Transistors began to replace valves from 1953 onwards. Magnetic cores provided a random access memory system which soon swept away the Williams Tube and the Mercury Delay Line.

So how does all this affect our view of the pioneers? Which ones provided the special spark which got it all going?

Was it **Alan Turing?** He is an important figure because of his contributions to the theory of computing, from the 1937 paper through to his later work on Artificial Intelligence and the 'Turing Test'. There is widespread belief that the "Turing Machine" was the main seed from which real computers progressively evolved. Actually this wasn't so. Turing's early paper was not much known before the 1960s. It was not a topic which came up in the early conferences, even though Turing himself was often a delegate. It was not included in early histories such as one in a Computer Engineering course I attended in the late 1950s. And both Wilkes and Newman discounted the idea that Turing's paper was seminal. (When asked what influence Turing's paper had in the early days of computer design, Newman replied: "I should say practically none at all.")

Turing was a truly brilliant mathematician and individualist who many found very difficult to work with. But he did not contribute much of lasting value to the early practical development of computers. His ACE design was radically different from any other contemporary - or subsequent - computer design. It was ingenious and fast and the DEUCE machines which followed were put to good use. But Wilkes was right in regarding it as an odd machine which did not influence main-stream development. Although spending time at Cambridge and Manchester, neither Turing nor his theories materially contributed to the design of either of those Universities' machines, which derived from the progression from early relay-based machines, such as Howard Aiken's 'Harvard Mark 1', through to ENIAC and the von Neuman report.

Maurice Wilkes (later Professor, and Sir Maurice Wilkes) led the world with EDSAC (1949) - the World's first operational stored program electronic digital computer , and was responsible for innovations such as microprogramming. He influenced computing for many more years and his Computing Laboratory led on to the many, and continuing achievements at Cambridge.

By 1940, **Douglas Hartree** and **Max Newman** were already distinguished mathematicians and Fellows of the Royal Society. However their areas of expertise were quite different. **Douglas Hartree** devoted his entire career to practical computation applied to Physics. **Max Newman** was a pure mathematician, expert in mathematical logic and topology.

Max Newman's close association with the development of computing lasted barely eight years. Yet he certainly deserves recognition. The ideas underlying 'Heath Robinson' and then Colossus were largely his. He fully deserves to share the credit for the 'World's first programmable electronic digital computer' with Tommy Flowers. As soon as the war ended, Newman swiftly and successfully launched the development of computing at Manchester and contributed significantly to the 'Manchester Baby' (1948) - first to contain all the elements of a modern digital computer.

Now there's **Professor Douglas Hartree**. In the development of electronic computers he was the 'father figure', but he was certainly not a mere figurehead. His background and his knowledge of the ENIAC and other U.S. developments gave him the standing to promote and assist in the first three computers in the UK. His experience in numerical analysis made him a leader in the use of computers for scientific problems. In the years between 1946 and 1953 he took the lead at several Conferences, including Australia's first Conference on Automatic Machines in 1951. He was the special guest at that conference and was referred to there as one of the world's leading figures in computing. He delivered four technical papers to that conference

He remained an important figure for several more years. He nurtured the partnership with J. Lyons which led to LEO (1951) - the World's first computer used for business applications. He was still actively involved with practical computing at Cambridge. Unfortunately he died from a heart attack in 1958. His large contribution was belatedly recognised by the naming of the supercomputing 'Hartree Centre' in 2012.

These four pioneers made very different contributions to the early history of `British computers. There were not many computer pioneers world-wide before 1950 and most of the others were in the U.S.A.. Douglas Hartree and Max Newman (less well-known to today's public than Turing and Wilkes) must not be forgotten! `