Andrew D Booth - Britain's Other "Fourth Man"

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Abstract. Andrew Donald Booth (1918-2009) was the leader of a team of computer pioneers at Birkbeck College in the University of London, UK. Booth worked with limited resources, both human and financial, and concentrated on building smaller machines. This paper presents an outline of his career in the UK which, the author believes, has not received the attention it deserves in comparison to a number of his UK contemporaries.

Keywords. Andrew Booth, Kathleen Booth, Norman Kitz, computer pioneer, Booth multiplier, magnetic drum, natural language translation, desktop computer.

1. Introduction

Andrew Donald Booth, (born Feb 11th 1918 and died Nov 29th 2009), was the leader of a team of computer pioneers at Birkbeck College in the University of London. This paper presents an outline of his career in the UK (he left for Canada in 1962) which, the author believes, has not received the attention it deserves in comparison to a number of his UK contemporaries.

Following the end of World War 2, four groups in the UK were looking at building digital computers. The best known were at Manchester (associated with Freddie Williams and Tom Kilburn) and at Cambridge (led by Maurice Wilkes). The third group was at the National Physical Laboratory, Teddington (led by Jim Wilkinson and Ted Newman using a design by Alan Turing). The fourth group was that of Andrew Booth at Birkbeck College, London University. He worked with limited resources, both human and financial, and concentrated on building smaller machines. He had a radical ambition for that time of building a computer that was cheap enough that each university could own one! This was at a time when the NPL ACE was being talked of (at least at NPL) as sufficient for the whole of the UK's needs!

This paper highlights Booth's unusual combination of skills – a first class mathematical mind capable of working on the complexities needed to handle the mathematics of X-ray crystallography for a PhD combined with a natural gift for practical engineering which enabled him to design and build innovative relay and electronic computers.

2. Relay Computers

Andrew Booth first met the challenge of solving complex sets of equations while working on the X-ray structure of explosives during World War 2. In 1975 in an interview with Christopher Evans for the Science Museum, London [1] he related how during the war he managed a small team of girls doing these calculations and

> being by temperament a mathematician I don't like arithmetic. …. I didn't think much of the methods they were using and I tried to do two things. In the first place. I devised some better mathematical methods … but I also made one or two small hand calculators.

His father was a marine engineer and part time inventor. Consequently it was perhaps not surprising that Andrew Booth developed mechanical devices to reduce the need for laborious calculation by hand of solutions to sets of equations for their many observations.

It was this latter interest that brought him to the attention of the great crystallographer J D Bernal. Returning to Birkbeck College in the University of London at the end of WW2, Bernal started building a new research group to study crystallography. He

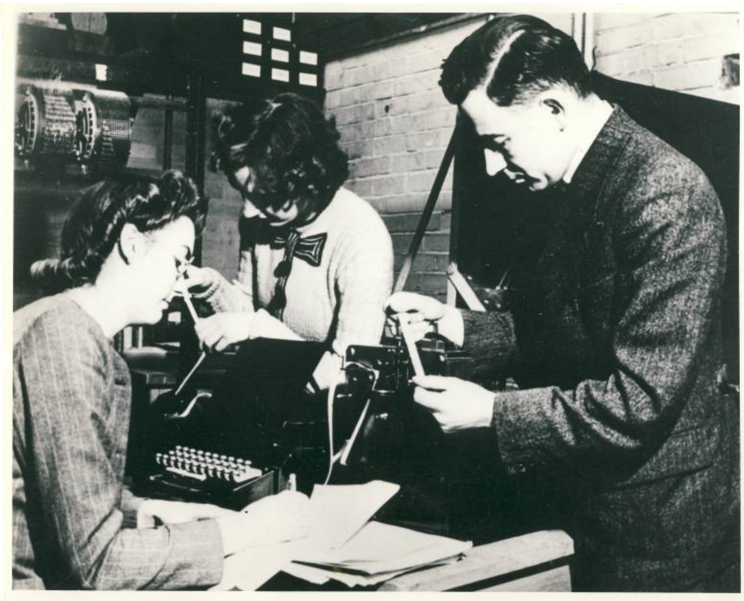


Figure 1 Kathleen Britten, Xenia Sweeting and Andrew Booth working on ARC in December 1946

decided to appoint four assistants, one of whom was to lead on mathematical methods. He appointed Andrew Booth who had completed a PhD on crystal structures of explosives at Birmingham in 1944. Andrew Booth started by building analogue devices and exploiting other mechanical devices as he outlined in his first book [2].

Shortly after his arrival at Birkbeck he started to build his first electromechanical calculator, the Automatic Relay Calculator (ARC)**,** shown in Figure 1. Due to a lack of space at Birkbeck the calculator was built at the British Rubber Producers Research Association in Welwyn Garden City where he had been briefly employed between Birmingham University and Birkbeck.

In 1946 Bernal obtained funding from the Rockefeller Foundation for Andrew Booth to visit US researchers working on computers. Andrew Booth reported that only von Neumann (a friend of Bernal) at Princeton gave him any time. In 1947 Andrew Booth undertook a 6 month US tour, again funded by the Rockefeller Foundation, based at the Institute of Advanced Studies at Princeton with John von Neumann and accompanied by his research assistant, Kathleen H V Britten, who was soon to become his wife.

3. Building a Memory

One major result of the 1947 visit was the redesign of the original ARC to give it a “von Neumann” architecture (the resulting design being usually referred to as ARC2). Andrew and Kathleen Booth set out the technological options for each of the components of a computer using a “von Neumann” architecture in a paper which circulated among the growing community of computer pioneers. Such was the interest, they produced a second edition [3].

The heart of the “von Neumann” architecture was the memory. In the paper they evaluated all of the physical properties including heat, light, sound and magnetism and concluded that magnetism offered the best prospects because of its persistence.

Andrew Booth was interested in building a low cost computer and so needed low cost components. On his trip around the USA he had seen a simple recording device sold for use in commercial offices which allowed managers to record letters on to magnetic oxide coated paper discs for typing by their secretarial staff. However, in order to achieve the performance needed to act as the memory of a computer he had to rotate the paper disc much faster than for simple voice recording. At this higher speeds it proved impossible to keep the disc flat and so he had to abandon this first attempt at a floppy disc.

Andrew Booth’s next attempt used a metal drum. The first drum was mounted horizontally and about the size of a cotton reel, being 2 inches in diameter with a modest packing density of just 10 bits per inch. The drum was made of brass with a nickel coating. Thus it was that Andrew Booth built the world’s first rotating electronic storage device albeit a drum rather than the now ubiquitous disc. This drum, shown in Figure 2, is now on display in the Science Museum, London.

Figure 2 Booth's First Drum
Photo Courtesy of NMSI. London

The drums were built by his father and together they created a small company called Wharf Engineering Ltd which manufactured small discs and other computer peripherals.

During the 1947 visit Andrew Booth met Warren Weaver, Natural Sciences Division Director of the Rockefeller Foundation, who had funded the trip. Andrew Booth asked if the Foundation would fund a computer for London University. Weaver said that the Foundation could not fund a computer for mathematical calculations but that he had begun to think about using a computer to carry out natural language translation and that the Foundation probably could fund a computer for research in that area.

These events gave rise to the first official reference to computing at Birkbeck, in the 1947-8 College Annual Report, which says:

> An ambitious scheme is in progress for the construction of an Electronic Computer, which will serve the needs of crystallographic research at 21-22 Torrington Square; it will also provide a means of relieving many other fields of research in Chemistry and Physics of the almost crushing weight of arithmetic work, which they involve. [4]

Notwithstanding the Rockefeller Foundation’s funding of a machine expressly for natural language processing, readers will note the College’s emphasis on the “unfunded” mathematical calculations although, in fairness, Birkbeck became for the next fifteen years a leading centre for natural language research. Initially the tiny memory on computers meant it was very difficult to do any serious natural language processing but Andrew Booth and his research students developed techniques for parsing text and also for building dictionaries. Numerous papers and several books were published as a result and this work is discussed further in section 6.

Andrew Booth, even in the days of cumbersome early machines, wrote about making computers available as widely as possible. Nonetheless the following extract from the College report for 1949-50 under the unpromising heading of “Desk Calculating Machines” seems well ahead of its time:

> The Committee of the Privy Council for Scientific and Industrial Research have made a grant for a programme of research on desk calculating machines to be carried out over the next two to three years on behalf of the National Physical Laboratory by the Electronic Computer Laboratory at Torrington Square. [5}

This project seems to have ended prematurely without a full prototype being built but a copy of Andrew Booth’s report from 1950 has recently been found in the Science Museum archives [6]. In it Andrew Booth evaluates the technical options for putting computers on, if not the desktop, at least the laboratory bench. The design used dekatron valves which operated on a decimal basis and thus provided simple counting devices. Booth lacked any simple way to display digits electronically and proposed to use the position of the lighted cathode as a counter in a manner similar to reading an analogue clockface. Andrew Booth observes in the report that this feature had been regarded as a serious shortcoming by reviewers from the National Physical laboratory although Booth predicts correctly that a technical solution would soon become available.

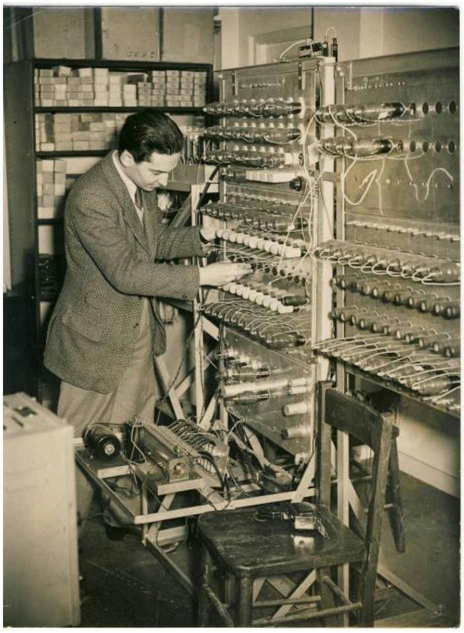


Figure 3 Norman Kitz working on SEC, December 1949.
The larger drum in the forefront of the picture is now in the Science Museum, London

Around 1948/49, Andrew Booth redesigned the ARC2 as an entirely electronic machine which he called Simple Electronic Computer (SEC). This was built by Norman Kitz (formerly Norbert Kitz), see Figure 3, and is written up in his 1951 MSc (Eng) dissertation [7].

An interesting historical footnote is that Norman Kitz left Birkbeck to work for English Electric at NPL on the DEUCE computer. From there he moved to Bell Punch and designed the world's first electronic desktop calculator, called ANITA. So although Andrew Booth never completed a desktop calculator at Birkbeck, it seems likely that he inspired one of his students to do so.

Figure 4 APE(X)C Computer in 1956

Andrew Booth moved swiftly on to create his best known computers, the All-Purpose Electronic Computers (APEC). The 1951/52 College Annual Report proudly records that "*The APEXC calculator operated successfully for the first time on 2nd May 1952*". A year later the 1952/3 College Annual Report records that:

> The second digital computer APEXC [SEC was the first] has been completed and is in use. It has shown the expected speed of about several hundred times as fast as mechanical methods but has exceeded expectation in its reliability and freedom from breakdown. An improved model is almost complete and will take its place as soon as the first is sent to its owners, the British Rayon Research Association. [8]

The Annual Reports are slightly confused with regard to the computers' names. It is possible the names changed over time. Andrew Booth subsequently refers to the Rayon Research machine as APE(R)C – R for Rayon - and the later APE(X)C – X for X-ray - was the Birkbeck crystallographers machine, see Figure 4.

4. Booth Multiplier

If the drum reflected Booth's engineering talent, then the Booth multiplier was a demonstration of his mathematical skill. A key component of any computer design is the arithmetic unit and to provide fast arithmetic it is necessary to have hardware multiplication and division. When Booth visited von Neumann in 1947 he obtained details of von Neumann's design for both a hardware multiplier and divider. Booth described them in his interview with Evans as "a beautiful divider" but the multiplier as "an abortion" [1]. When Booth asked von Neumann why he had not used a similar approach in his multiplier as in the divider, von Neumann assured him it was a theoretical impossibility and Booth accepted the great man's opinion. Booth told Evans that when he was designing the APEC computer he realised that von Neumann was wrong and Booth recollected how, over tea with his wife in a central London cafe, he designed a non-restoring binary multiplier which, with a subsequent minor modification by a colleague, is the Booth multiplier which is still in use today.

Basically the Booth multiplier follows the usual method for long multiplication of summing partial products. However it also uses a "trick" that to multiply by a string of 9s it is possible to left shift an appropriate number of places and subtract the multiplier from the result. This approach works even better in binary where it results in a simple rule:

- Examine each pair of digits in the multiplier creating the first pair by appending a dummy 0 at the least significant end, then
    i. If the pair is 01, add the multiplicand
    ii. If the pair is 10, subtract the multiplicand
    iii. Otherwise, do nothing
- Shift both the partial product and multiplier one place right and examine the next pair of digits
- Repeat as many times as there are digits in the multiplier.

This was submitted for publication in August 1950 and published the following year [9].

5. Commercial Success

Accommodation at bomb damaged Birkbeck was still at a premium throughout this period and so Andrew Booth built his APE(R)C and probably later computers in a barn in Fenny Compton, Warwickshire where his father lived.

It was to this barn in March 1951 that a three man team led by Dr Raymond "Dickie" Bird from British Tabulating Machines (BTM) came to visit. BTM were the UK's leading supplier of punch card systems and their management had decided that they needed a small computer to improve the calculating power and flexibility of their tabulators.

At the time that BTM joined forces with Andrew Booth there were, as already noted, three other electronic computer projects in the UK. However, strong links had developed between the EDSAC team at Cambridge and Lyons who were building their LEO (Lyons Electronic Office) computer. Manchester were forging links with Ferranti, who like NPL with Pilot Automatic Computing Engine (ACE), were building large and expensive scientific computers.

In just a few days Raymond Bird's team had copied Andrew Booth's circuitry. Returning to BTM's factory at Letchworth they added extra I/O interfaces and named

Figure 5 BTM HEC 1 Prototype in store at the Birmingham Museum

the resulting computer the Hollerith Electronic Computer (HEC), see Figure 5. This prototype computer is one of the world's earliest surviving electronic computers, unlike so many early machines which were dismantled when no longer needed, and is now in store in the Birmingham Museum.

BTM moved ahead rapidly getting HEC1 to work by the end of 1951. BTM management decreed that the HEC would go to the Business Efficiency Exhibition in October 1953 and so a new machine (HEC2) had to be built contained in a smart metal cabinet suitable for the public to see. Eight similar machines were sold as the HEC2M mainly for technical applications. The successor was the HEC4 which was a commercial data processing machine of which over 70 were sold in the UK and abroad. At the end of the 1950s this was the UK's best selling computer by volume. After BTM merged with Powers SAMAS to form ICT the HEC4 became the ICT 1200 range, see Figure 6. The technical details of the HEC4 form the majority of Raymond Bird's thesis [10].

Figure 6 ICT 1201 of 1956

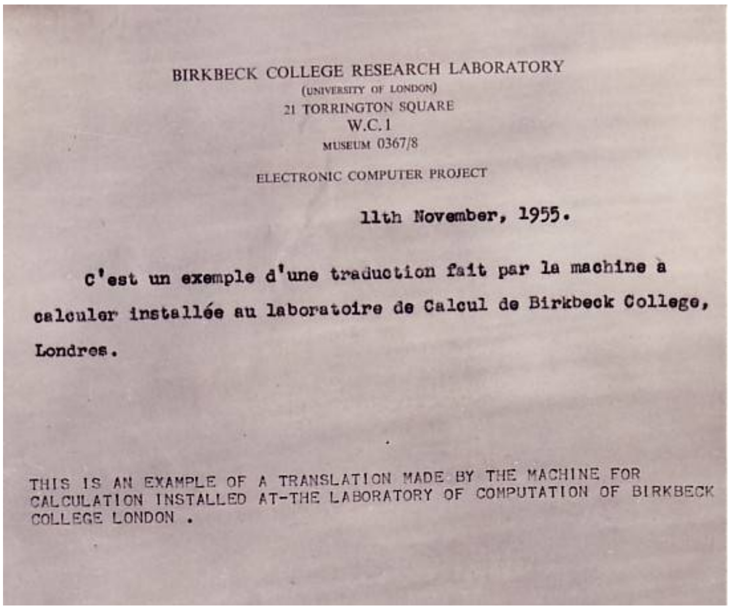
Booth continued to build new machines. After the APEC machines, came MAC (Magnetic Automatic Calculator). Three examples of a development of MAC named M.2 were built by Wharf Engineering Ltd. These were for University College London, Kings College London and Imperial College London. The Annual Report for 1957/58 notes

> The keynote of the M.2 is, as in previous machines, small size and simplicity, and an idea of what has been achieved is provided by the fact that M.2 occupies a space rather less than that of an office desk, consumes as much power as an electric fire, but has roughly the speed and capacity of the much larger commercial machines which are being provided for some of the smaller Universities. [11]

6. Natural Language Processing

The Booths with their research students published numerous books and papers on text processing including creating Braille output and natural language translation. A detailed assessment of Booth's early work in this area can be found in a paper by

Hutchins [12]. On November 11th 1955 the laboratory gave an early public demonstration of natural language machine translation, see Figure 7.



BIRKBECK COLLEGE RESEARCH LABORATORY
(UNIVERSITY OF LONDON)
21 TORRINGTON SQUARE
W.C.1
MUSEUM 0367/8

ELECTRONIC COMPUTER PROJECT

11th November, 1955.

C'est un exemple d'une traduction fait par la machine à calculer installée au laboratoire de Calcul de Birkbeck College, Londres.

THIS IS AN EXAMPLE OF A TRANSLATION MADE BY THE MACHINE FOR CALCULATION INSTALLED AT-THE LABORATORY OF COMPUTATION OF BIRKBECK COLLEGE LONDON .

Figure 7 Machine Translation of Natural Language 1955

The 1956/57 College Report reported that language processing work continued apace:

> Work on machine translation of languages has, however, continued at full speed and with the completion of the French programme for scientific texts attention has been transferred to German and to aspects of Platonic chronology. The laboratory was fortunate in having Dr Rais Ahmed, from the University of Aligarh, as a guest during part of his sabbatical leave and his presence gave considerable impact to the work on spoken word recognition. [13]

One of Birkbeck College's best known former students and now a College Fellow, Dame Steve Shirley who later founded a major UK software house that became Xansa, remembers as a student of mathematics and computing at that time:

> intoning "one, one, one .... two, two, two ...." into a tape recorder for some very early voice recognition research led by Andrew Booth [14]

Their wider contribution to this community has been assessed in the book by John Hutchins in his book *Early Years in Machine Translation* [15].

7. Other achievements

Andrew Booth was an innovator in many areas of his life. The College Annual Report for the 1956/57 records the Governors' resolution on July 18th 1957 that:

> From the beginning of the next session [October 1957] the Computer Laboratory be constituted as a separate Department under the Headship of Dr A D Booth [13]

The author has been told that the Department of Numerical Automation was the first academic department established to teach computing in a UK university and possibly worldwide, elsewhere the courses were still taught in computer laboratories. Also the department's M.Sc in Numerical Automation started in October 1957 was the first degree programme, many others, including at Birkbeck, having been Postgraduate Diplomas. These are difficult claims to verify and the author would welcome any information of earlier activity.

Outside the Department, Andrew Booth's played a key role through his appointment as chairman of a committee formed to set up a "National Computer Society". The 1956/57 Report notes that when it was formed in June 1957 he was elected to serve on the first Council of the British Computer Society, [13].

One notable landmark was Kathleen Booth's book on programming the APEC computers [16]. This was an early book on programming and unusual in having a female author. She did most of the programming while Andrew Booth built the computers.

The College Report of 1958/59, in a foretaste of much more recent work, reports Dr Kathleen Booth developing a program to simulate a neural network to investigate ways in which animals recognise patterns. The following year reports a neural network for character recognition.

The College Report for 1961/62 recorded that Andrew and Kathleen Booth resigned at the end of the 1961/62 academic year. Andrew Booth has given his account of the circumstances in two places [1, 17] attributing it to the College not conferring a Chair on him. In retrospect this was a massive loss to the College and, from today's perspective, totally incomprehensible given his key contributions to computer technology and his substantial research output. Andrew Booth moved to Canada where he continued his distinguished academic career initially at the University of Saskatchewan and subsequently as President of Lakehead University, Ontario.

8. Conclusions

There can be little doubt that Andrew Booth made a major contribution to the early development of computing. His two main technological contributions are the drum store and the Booth multiplier. A modified version of his multiplier is still used today in many processors. The design of his APE(X)C computer was used to provide the key components of the highly successful ICT 1200 computers, primarily used for commercial data processing. He built and sold low cost, smaller computers mainly for academic use. His M.2 series, built by his own company Wharf Engineering Ltd, were used successfully to teach programming in several London university colleges.

In the area of applications he devoted much time to the processing of X-ray crystallography data. As his academic independence increased he and his wife contributed to a number of fields notably the early development of natural language processing which is acknowledged in that community.

Andrew Booth is largely unknown outside the specialised world of the computer historian but the author believes that he deserves greater recognition by anyone whose computer writes to their hard disk or executes a multiplication instruction.

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