COMPUTING SCIENCE

A Turing Enigma

Brian Randell

TECHNICAL REPORT SERIES

No. CS-TR-1342 June 2012

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Printed and published by Newcastle University,
Computing Science, Claremont Tower, Claremont Road,
Newcastle upon Tyne, NE1 7RU, England.

Bibliographical details

RANDELL, B.

A Turing Enigma
[By] B. Randell

Newcastle upon Tyne: Newcastle University: Computing Science, 2012.

(Newcastle University, Computing Science, Technical Report Series, No. CS-TR-1342)

Added entries

NEWCASTLE UNIVERSITY
Computing Science. Technical Report Series. CS-TR-1342

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About the authors

Brian Randell graduated in Mathematics from Imperial College, London in 1957 and joined the English Electric Company where he led a team that implemented a number of compilers, including the Whetstone KDF9 Algol compiler. From 1964 to 1969 he was with IBM in the United States, mainly at the IBM T.J. Watson Research Center, working on operating systems, the design of ultra-high speed computers and computing system design methodology. He then became Professor of Computing Science at the University of Newcastle upon Tyne, where in 1971 he set up the project that initiated research into the possibility of software fault tolerance, and introduced the "recovery block" concept. Subsequent major developments included the Newcastle Connection, and the prototype Distributed Secure System. He has been Principal Investigator on a succession of research projects in reliability and security funded by the Science Research Council (now Engineering and Physical Sciences Research Council), the Ministry of Defence, and the European Strategic Programme of Research in Information Technology (ESPRIT), and now the European Information Society Technologies (IST) Programme. Most recently he has had the role of Project Director of CaberNet (the IST Network of Excellence on Distributed Computing Systems Architectures), and of two IST Research Projects, MAFTIA (Malicious- and Accidental-Fault Tolerance for Internet Applications) and DSoS (Dependable Systems of Systems). He has published nearly two hundred technical papers and reports, and is co-author or editor of seven books. He is now Emeritus Professor of Computing Science, and Senior Research Investigator, at the University of Newcastle upon Tyne.

Suggested keywords

ALAN TURING
TOMMY FLOWERS
ENIGMA
COLOSSUS
BLETCHLEY PARK

A Turing Enigma

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Keywords: Alan Turing, Tommy Flowers, Enigma, Colossus, Bletchley Park

1 Introduction

There are many who are far better equipped than I am to speak of the various aspects of the late great Alan Turing's scientific career that are of direct technical relevance to the CONCUR community. Instead, at the conference organisers' request, in this year in which the hundredth anniversary of his birth is being celebrated, I am going to tell you of a historical investigation that I undertook some forty years ago into the then complete mystery of what Alan Turing had worked on, in great secrecy, during World War II.

In about 1971 my growing interest in the history of computing led to my assembling, with a view to publishing in book form, a representative set of papers and reports documenting the many fascinating inventions and projects that eventually culminated in the development of the "modern" electronic computer,

I took Charles Babbage's work as my main starting point, and decided on a cut-off date of 1949, when the first practical stored program electronic computer became operational. So I planned on including material on ENIAC, EDVAC, the Manchester "Baby" machine, and the Cambridge EDSAC, but decided to leave coverage of all the many subsequent machines to other would-be computer historians.

I circulated a list of my planned set of documents to a number of colleagues for comment – one of the responses I received queried the absence of Alan Turing from my list. My excuse was that, to the best of my knowledge, Turing's work on computers at the National Physical Laboratory (NPL) had post-dated Manchester's and Cambridge's successful efforts, and that his pre-war work on computability, in which he described what we now call a Turing Machine, was purely theoretical, and so fell outside the chosen scope of my collection.

I had first become interested in computers in 1956 in my last year at Imperial College. There weren't many books on computers at that time – one was *Faster than Thought* [1]. My 1955 copy of this book was probably my first source of knowledge about both Babbage and Turing, and indeed about the work of the various early UK computer projects, though soon afterwards I had learned much more about Babbage, and his collaboration with Lady Lovelace, from the excellent Dover paperback *Charles Babbage and his Calculating Engines* [13]. In Bowden I had read:

> "The basic concepts and abstract principles of computation by a machine were formulated by Dr. A.M. Turing, F.R.S. in a paper read before the London Mathematical Society in 1936, but work on such machines in Britain was delayed by the war. In 1945, however, an examination of the problems was made at the National Physical Laboratory by Mr. J.R. Womersley, then Superintendent of the Mathematics Division of the Laboratory. He was joined by Dr. Turing and a small staff of specialists ... "

However, piqued by the query about my having omitted Turing from my envisaged collection, I set out to try to find out more about Turing's work during the interval 1936-1945. I obtained a copy of the 1959 biography by his mother, Mrs Sara Turing [26], to find that its only indication of what her son had done during World War II was the following:

> " ... immediately on the declaration of war he was taken on as a Temporary Civil Servant in the Foreign Office, in the Department of Communications ... At first even his whereabouts were kept secret, but later it was divulged that he was working at Bletchley Park, Bletchley. No hint was ever given of the nature of his secret work, nor has it ever been revealed."

In fact by this time I had learned somehow that his wartime work had related to code-breaking, though neither I nor any of my colleagues were familiar with the name Bletchley Park. On rechecking my copy of David Kahn's magnificent tome *The Codebreakers* [10] I found Kahn's statement that Bletchley Park was what the Foreign Office "euphemistically called its Department of Communications", i.e. was the centre of Britain's wartime code-breaking efforts. However Kahn gave little information about what was done at Bletchley Park, and made no mention of Turing.

At about this stage I came across the following statement by Lord Halsbury [6]:

> "One of the most important events in the evolution of the modern computer was a meeting of two minds which cross-fertilised one another at a critical epoch in the technological development which they exploited. I refer of course to the meeting of the late Doctors Turing and von Neumann during the war, and all that came thereof ... "

I wrote to Lord Halsbury, who in 1949 was Managing Director of the National Research Development Corporation, the UK government body that had provided financial support to several of the early UK computer projects. Unfortunately he could not recollect the source of his information, his response (quoted in [16]) to my query being:

> "I am afraid I cannot tell you more about the meeting between Turing and von Neumann except that they met and sparked one another off. Each had, as it were, half the picture in his head and the two halves came together during the course of their meeting. I believe both were working on the mathematics of the atomic bomb project."

Inquiries of those of Turing's colleagues who were still at NPL produced little, but Donald Davies, who was then Superintendent of the Division of Computing Science at NPL, arranged for me to visit Mrs Turing. She was very helpful and furnished me with several further leads, but was not really able to add much to the very brief, and unspecific, comments in her book.

Various other leads proved fruitless, and my enthusiasm for the search was beginning to wane. I eventually had the opportunity to inspect a copy of Turing's report giving detailed plans for the ACE [25]. This proved to postdate, and even contain a reference to, von Neumann's *First Draft of a Report on the EDVAC* [14] so I did not examine it as carefully as I later realised I should have. However, I did note that Turing's report alluded to the fact that he had obtained much experience of electronic circuits.

2 Secret Wartime Computers

But then my investigation took a dramatic turn.

I had written to a number of people, seeking to understand more fully whether and if so how Turing had contributed to the initial development of practical stored program computers. One of my enquiries — to Donald Michie — elicited the following response (quoted in [16]) :

> "I believe that Lord Halsbury is right about the von Neumann-Turing meeting ... . The implication of Newman's obituary notice, as you quote it[1], is quite misleading; but it depends a bit on what one means by: a 'computer'. If we restrict this to mean a stored-program digital machine, then Newman's implication is fair, because no-one conceived this device (apart from Babbage) until Eckert and Mauchly (sometimes attributed to von Neumann). But if one just means high-speed electronic digital computers, then Turing among others was thoroughly familiar during the war with such equipment, which predated ENIAC (itself not a stored-program machine) by a matter of years."

[1] The obituary notice for Turing [15], written by Professor M.H.A. Newman, who was associated with the post-war computer developments at Manchester University, stated that:

> "At the end of the war many circumstances combined to turn his attention to the new automatic computing machines. They were in principle realisations of the 'universal machine' which he had described in the 1937 paper for the purpose of a logical argument, though their designers did not yet know of Turing's work."

I then found that there had in fact already been several (rather obscure) references in the open literature to the work at Bletchley Park with which Turing was associated, of which the most startling was a paper by I.J. (Jack) Good [5]. This gave a listing of successive generations of general purpose computers, including:

> "Cryptanalytic (British): classified, electronic, calculated complicated Boolean functions involving up to about 100 symbols, binary circuitry, electronic clock, plugged and switched programs, punched paper tape for data input, typewriter output, pulse repetition frequency 10^5, about 1000 gas-filled tubes; 1943 (M.H.A. Newman, D. Michie, I.J. Good and M. Flowers. Newman was inspired by his knowledge of Turing's 1936 paper)." [(Tommy) Flowers' initials were in fact "T.H."]

Furthermore Good's paper went on to claim that there was a causal chain leading from Turing's 1936 paper [24] through the wartime cryptanalytic machine, to the first Manchester computers, although it states that the main influence was from von Neumann's plans for the IAS machine (at Princeton University's Institute for Advanced Study).

Further details of Turing's role, and the war-time code-breaking machines, were provided in a letter I received from Tommy Flowers (quoted in [16]):

> "In our war-time association, Turing and others provided the requirements for machines which were top secret and have never been declassified. What I can say about them is that they were electronic (which at that time was unique and anticipated the ENIAC), with electromechanical input and output. They were digital machines with wired programs. Wires on tags were used for semi-permanent memories, and thermionic valve bi-stable circuits for temporary memory. For one purpose we did in fact provide for variable programming by means of lever keys which controlled gates which could be connected in series and parallel as required, but of course the scope of the programming was very limited. The value of the work I am sure to engineers like myself and possibly to mathematicians like Alan Turing, was that we acquired a new understanding of and familiarity with logical switching and processing because of the enhanced possibilities brought about by electronic technologies which we ourselves developed. Thus when stored program computers became known to us we were able to go right ahead with their development. It was lack of funds which finally stopped us, not lack of know-how."

Another person whom I had contacted in an effort to check the story of the Turing/von Neumann meeting was Dr S. Frankel, who had known von Neumann whilst working at Los Alamos. Although unable to help in this matter, he provided further evidence of the influence of Turing's pre-war work (quoted in [16]):

> "I know that in or about 1943 or '44 von Neumann was well aware of the fundamental importance of Turing's paper of 1936 'On computable numbers … ' which describes in principle the 'Universal Computer' of which every modern computer (perhaps not ENIAC as first completed but certainly all later ones)

is a realization. Von Neumann introduced me to that paper and at his urging I studied it with care."

By now I realised that I was onto a very big story indeed, and that I had been very wrong to omit Turing's name from the list of pioneers whose work should be covered in my planned collection of documents on the origins of digital computers.

I prepared a confidential draft account of my investigation, which I sent to each of the people who I had quoted, for their comments and to obtain permission to publish what they had told me, and in the hope that my draft might prompt yet further revelations. This hope was fulfilled, when in response Donald Michie amplified his comments considerably. The information (quoted more fully in [16]) that he provided included:

> "Turing was not directly involved in the design of the Bletchley electronic machines, although he was in touch with what was going on. He was, however, concerned in the design of electromagnetic devices used for another cryptanalytic purpose; the Post Office engineer responsible for the hardware side of this work was Bill Chandler ... First machines: The 'Heath Robinson' was designed by Wynn Williams ... at the Telecommunications Research Establishment at Malvern, and installed in 1942/1943. All machines, whether 'Robinsons' or 'Colossi', were entirely automatic in operation, once started. They could only be stopped manually! Two five-channel paper tape loops, typically of more than 1000 characters length, were driven by pulley-drive (aluminium pulleys) at 2000 characters/sec. A rigid shaft, with two sprocket wheels, engaged the sprocket-holes of the two tapes, keeping the two in alignment. Second crop: The 'Colossi' were commissioned from the Post Office, and the first installation was made in December 1943 (the Mark 1). This was so successful that by great exertions the first of three more orders (for a Mark 2 version) was installed before D-day (June 6th 1944). The project was under the direction of T.H. Flowers, and on Flowers' promotion, A.W.M. Coombs took over the responsibility of coordinating the work. The design was jointly done by Flowers, Coombs, S.W. Broadbent and Chandler ... There was only one pulley-driven tape, the data tape. Any pre-set patterns which were to be stepped through these data were generated internally from stored component-patterns. These components were stored as ring registers made of thyrotrons and could be set manually by plug-in pins. The data tape was driven at 5000 characters/sec, but (for the Mark 2) by a combination of parallel operations with short-term memory an effective speed of 25,000/sec was obtained ... The total number of Colossi installed and on order was about a dozen by the end of the war, of which about 10 had actually been installed."

So now the names of these still-secret machines had become known to me, and it had become possible for me to attempt to assess the Colossi with respect to the modern digital computer. It seemed clear that their arithmetical, as opposed to logical, capabilities were minimal, involving only counting, rather than general addition or other operations. They did, however, have a certain amount of electronic storage, as well as paper-tape 'backing storage'. Although fully automatic, even to the extent of providing printed output, they were very much special purpose machines, but within their field of specialization the facilities provided by plug-boards and banks of switches afforded a considerable degree of flexibility, by at least a rudimentary form of programming. There seemed, however, no question of the Colossi being stored program computers, and the exact sequence of developments, and patterns of influence, that led to the first post-war British stored program computer projects remained very unclear.

At about this stage in my investigation I decided "nothing ventured nothing gained" and wrote directly to Mr Edward Heath, the Prime Minister, urging that the UK Government declassify Britain's wartime electronic computer developments. In January 1972 my request was regretfully denied but Mr Heath assured me that a detailed report on the project would be commissioned, though it would have to remain classified. (His reply to me was for some time the only unclassified official document I knew of that in effect admitted that Britain had built an electronic computer during World War II!)

The classified official history that the Prime Minister had commissioned following my request was, it turns out, compiled by one of the engineers involved with Colossus, Don Horwood [8]. Tony Sale recently described Horwood's report as having been "absolutely essential" to him when he set out in 1993 to recreate the Colossus [22].

3 The Stored Program Concept

The earliest suggestion that instructions be stored in the main computer memory, that I knew of, was contained in von Neumann's famous EDVAC report [14]. This describes the various purposes for which memory capacity was needed — intermediate results, instructions, tables of numerical constants — ending:

> "The device requires a considerable memory. While it appeared that various parts of this memory have to perform functions which differ somewhat in their nature and considerably in their purpose, it is nevertheless tempting to treat the entire memory as one organ, and to have its parts even as interchangeable as possible for the various functions enumerated above."

On the other hand, a later report by Eckert and Mauchly [4] claims that in early 1944, prior to von Neumann's association with the EDVAC project, they had designed a "magnetic calculating machine" in which the program would "be stored in exactly the same sort of memory device as that used for numbers".

These accounts imply that the idea of storing the program in the same memory as that used for numerical values arose from considerations of efficient resource utilization, and the need to fetch and decode instructions at a speed commensurate with that of the basic computer operations. The question of who first had the idea of, and an understanding of the fundamental importance of, the full stored program concept, that is of an extensive addressable internal memory, used for both instructions and numerical qualities, together with the ability to program the modification of stored instructions, has been for years a very vexed one. In particular there is no consensus regarding the relative contributions of Eckert, Mauchly, von Neumann and Goldstine – a controversy that I did not wish to enter into.

What was indisputable was that the various papers and reports emanating from the EDVAC group, from 1945 onwards, were a source of inspiration to computer designers in many different countries, and played a vital part in the rapid development of the modern computer. But Alan Turing's role remained obscure.

The initial major goals of my investigation, which were to check out the story of a decisive wartime meeting of von Neumann and Turing, and to establish whether Turing had played a direct role in the development of the stored program computer concept, had not been achieved. Instead, and perhaps more importantly, I had to my own surprise by this stage accumulated evidence that in 1943, two to three years before ENIAC, which hitherto had been generally accepted as having been the world's first electronic digital computer, became operational, a group of people directed by M.H.A. Newman and T.H. Flowers, and with which Alan Turing was associated, had built a working special purpose electronic digital computer, the Colossus.

I had established that this computer was developed at the Post Office's Dollis Hill Research Station, and installed at Bletchley Park. The Colossus, and its successors, were in at least a limited sense 'program-controlled'. Moreover, there were believable claims that Turing's classic pre-war paper on computability, a paper which is usually regarded as being of 'merely' theoretical importance, was a direct influence on the British machine's designers, and also on von Neumann, at a time when he was becoming involved in American computer developments.

Having obtained permission from all my informants to use the information that they had provided to me, I and Donald Michie were keen that a summary of my investigation [16] be placed in the public domain. The vehicle we chose was his *1972 Machine Intelligence Workshop*, the proceedings of which were published by Edinburgh University Press.

Afterwards, I managed to persuade Donald to contribute a two page summary of my findings, and thus at last some coverage of Turing, to my collection of historical computer documents – a collection that was published in 1973 by Springer-Verlag as *The Origins of Digital Computers: Selected Papers* [17].

4 Ultra Revelations

There things rested, and it seemed possible that it might be a long time before anything more would become public about Bletchley Park, Alan Turing's work there, or the Colossus Project.

But then in spring 1974 the official ban on any reference to Ultra, a code name for information obtained at Bletchley Park from decrypted German message traffic, was relaxed somewhat, and Frederick Winterbotham's book *The Ultra Secret* [27] was published. This was the "story of how, during World War II, the highest form of intelligence, obtained from the 'breaking' of the supposedly 'unbreakable' German machine cyphers, was 'processed' and distributed with complete security to President Roosevelt, Winston Churchill, and all the principal Chiefs of Staff and commanders in the field throughout the war". The book caused a sensation, and brought Bletchley Park, the Enigma cipher machine, and the impact on the war of the breaking of wartime Enigma traffic, to the general public's attention in a very big way.

The book's one reference to computers came in the statement, "It is no longer a secret that the backroom boys of Bletchley used the new science of electronics to help them ... I am not of the computer age nor do I attempt to understand them, but early in 1940 I was ushered with great solemnity into the shrine where stood a bronze coloured face, like some Eastern Goddess who was destined to become, the oracle of Bletchley". No mention was made of Alan Turing, or any of the others who I had learned were involved with Bletchley's code-breaking machines.

A further, even more sensational, book *Bodyguard of Lies* [3] then revealed more about how the Germans had been using Enigma cipher machines, and gave some information about the work of first the Polish cryptanalysts, and then of Turing and others at Bletchley Park on a machine called the "Bombe" that was devised for breaking Enigma codes. However it made no mention of computers and referred to electronics only in connection with radar and radio; its main topic was the immense impact of all this work on the Allies' conduct of the war.

Emboldened by what seemed to be a rather significant change in Government policy concerning discussion of Bletchley Park's activities, I made some enquiries as to whether another request to declassify the Colossus Project might now have a chance of being treated favourably. I was strongly urged not to write to the Prime Minister again – apparently my earlier request had caused considerable waves on both sides of the Atlantic. Instead, on the advice of David Kahn, I wrote on 4 Nov 1974 to Sir Leonard Hooper, who David Kahn described as being the former head of GCHQ, and who was by then an Under Secretary in the Cabinet Office, I believe with the title Co-ordinator for Intelligence and Security. After a brief exchange of correspondence, in a letter from Sir Leonard dated 22 May 1975 I received the welcome news that "approval had been given for the release of some information about the equipment", and that it was proposed to release some wartime photographs of Colossus to the Public Record Office. I was invited to come to London for discussions at the Cabinet Office. This visit occurred on 2 July 1975.

When I arrived, somewhat nervously, in the Cabinet Office building I was escorted to a panelled room where I met Sir Leonard Hooper, his personal assistant, and a Dr Ralph Benjamin. (I do not recall whether it was then, or later, that I learned that Dr Benjamin was GCHQ Chief Scientist.) I was shown the photographs, and we discussed in detail the wording of the explanatory document.

And then I was told that the Government were willing to facilitate my interviewing the people who had led the Colossus Project, after they had been briefed as to just what topics they were allowed to discuss with me. This was with a view to my being allowed to write a history of the project, providing that I would submit my account for approval prior to publication. Needless to say I agreed.

The photographs and explanatory document were made available at the Public Record Office (now The National Archives) on the 25th October 1975, and I had the pleasure of sending a letter (now on display in the Turing Exhibition at Bletchley Park) to Mrs Turing, informing her that "the Government have recently made an official release of information which contains an explicit recognition of the importance of your son's work to the development of the modern computer".

During the period October-December 1975 I interviewed the leading Colossus designers: Tommy Flowers (twice), Bill Chandler, Sidney Broadhurst, and Allen 'Doc' Coombs. I found all four of them to be delightful individuals, immensely impressive, and amazingly modest about their achievements. All were unfailingly pleasant and helpful as they tried to recollect happenings at Dollis Hill and Bletchley Park. I had the further pleasure of interviewing Max Newman and Donald Michie, and David Kahn kindly interviewed Jack Good for me at his home in Roanoke, Virginia. I also corresponded, in some cases quite intensively, with all these interviewees, and with a considerable number of other people, including several of the Americans who had been stationed at Bletchley Park.

Each interview was tape-recorded, and I had the tapes transcribed in full. The people I interviewed and corresponded with were being asked to recall happenings of thirty or so years earlier, and to do so without any opportunity of inspecting original files and documents. Secrecy considerations had been paramount and had given rise to a rigid compartmentalisation of activities. Few had any detailed knowledge of the work of people outside their own small group. Many of them had made conscious efforts to try and forget about their wartime work.

Piecing together all the information I thus obtained, and even establishing a reasonably accurate chronology, was therefore very difficult. I was greatly aided in this task by the advice I'd read in Kenneth May's magnificent *Bibliography and Research Manual on the History of Mathematics* [12]. For example, the techniques that he described for creating and using a set of correlated card indexes greatly helped me in sorting out a major chronological confusion amongst my interviewees concerning the development of the Robinson machines.

What became clear from my discussions with the Colossus designers was that their interactions with Turing had mainly occurred on projects that preceded Colossus. My investigation led me to summarize their and other's attitude to him as follows (quoted from [18]):

> "Turing, clearly, was viewed with considerable awe by most of his colleagues at Bletchley because of his evident intellect and the great originality and importance of his contributions, and by many with considerable discomfort because his personality was so outlandish. Many people found him incomprehensible, perhaps being intimidated by his reputation but more likely being put off by his character and mannerisms. But all of the Post Office engineers who worked with him say that they found him very easy to understand — Broadhurst characterised him as 'a born teacher — he could put any obscure point very well'. Their respect for him was immense, though as Chandler said 'the least said about him as an engineer the better'. This point is echoed by Michie who said 'he was intrigued by devices of every kind, whether abstract or concrete – his friends thought it would be better if he kept to the abstract devices but that didn't deter him'."

I submitted the draft of my paper on Colossus to Dr Benjamin on 12 April 1976. Subsequent correspondence and discussions with Dr Benjamin and Mr Horwood led to my incorporating a number of relatively small changes into the paper and its abstract, the main effect of which was to remove any explicit indication that the projects I was describing were in fact related to code-breaking. I was merely allowed to say that "The nature of the work that was undertaken at Bletchley Park during World War II is still officially secret but statements have been appearing in published works in recent years which strongly suggest that it included an important part of the British Government's cryptologic effort". This, and the fact I was allowed to retain references to books such as The Ultra Secret and Bodyguard of Lies, however meant that readers would be left in little doubt as to what Turing and his colleagues had been engaged in, and the purpose of the Robinson and Colossus machines.

5 The Outing of Colossus

The cleared paper was then submitted to the *International Conference on the History of Computing*, which was held in Los Alamos in June 1976. (No attempt is made to detail the contents of this 21,000-word paper here!)

Doc Coombs and his wife were planning to be on vacation in the States at about the time of the conference, so to my delight he suggested that he accompany me to the conference and I arranged for him to participate. It is fair to say that my presentation created a sensation – how could it not, given the material I had been allowed to gather?

I have recently found that Bob Bemer has reported[2] his impressions of the event:

> "I was there at a very dramatic moment of the invitational International Research Conference on the History of Computing, in Los Alamos … Among the many that I conversed with was a medium-sized Englishman named Dr. A.W.M. Coombs, who was so excited about something that he was literally bouncing up and down. Not being bashful I asked (and he didn't mind) about the cause of his excitement, and he replied 'You'll know tomorrow morning – you'll know'. Saturday morning we regathered in the Auditorium of the Physics Division. I sat third row from the front, a couple seats in from the right, to get a good view of all the famous attendees. To my left in the same row, three empty seats intervening, was the bouncy Englishman, all smiles and laughter. In front of him, two seats to his left, was Professor Konrad Zuse … In the fifth row, again to the left, was Dr. John Mauchly, of ENIAC fame. On stage came Prof. Brian Randell, asking if anyone had ever wondered what Alan Turing had done during World War II? He then showed slides of a place called Bletchley Park, home base of the British cryptographic services during that period. After a while he showed us a slide of a lune-shaped aperture device he had found in a drawer whilst rummaging around there[3]. Turned out it was part of a 5000-character-per-second (!) paper tape reader. From there he went on to tell the story of Colossus, the world's really first electronic computer … I looked at Mauchly, who had thought up until that moment that he was involved in inventing the world's first electronic computer. I have heard the expression

[2] `http://www.bobbemer.com/COLOSSUS.HTM` (checked 14 May 2012)

[3] In fact it was one of the Colossus team that found this aperture device, which is now on show with some other small Colossus artefacts at Newcastle University.

> many times about jaws dropping, but I had really never seen it happen before. And Zuse – with a facial expression that could have been anguish. I'll never know whether it was national, in that Germany lost the war in part because he was not permitted to build his electronic computer, or if it was professional, in that he could have taken first honors in the design of the world's most marvelous tool. But my English friend was the man doing the day-to-day running of Colossus. I saw then why he was so terribly excited. Just imagine the relief of a man who, a third of a century later, could at last answer his children on 'What did you do in the war, Daddy?'."

The conference organisers hurriedly organised an additional evening session, at which Doc Coombs and I fielded a barrage of questions from a packed audience. Doc Coombs' role at this session became that of adding detail to some of the events that my paper described rather guardedly, and mine became at least in part that of endeavouring to make sure that his splendidly ebullient character did not lead him to too many indiscretions. (Tommy Flowers had beforehand warned me that "in his natural exuberance [Doc Coombs] is likely to give away too much for the Foreign Office and you should be careful not to provoke him!")

My paper was promptly published and circulated widely as a Newcastle University Computing Laboratory Technical Report [18] - the proceedings of the Los Alamos conference did not appear until four years later [20]. In addition, a summary version of my paper, including all the Colossus photographs, was published in the *New Scientist* in February 1977 [19], after I had also cleared this with the authorities. This version was afterwards included in the third and final edition of my book *The Origins of Digital Computers* [21] in place of the earlier two-page account by Michie.

Some time in early 1976, I believe, I became aware that BBC Television were planning the *Secret War* series, and that the sixth, and originally last, episode (entitled *Still Secret*) was going to be about Enigma. I met with the producer of this episode, Dominic Flessati, told him — very guardedly — about the Colossus, and showed him the Colossus photographs, at which he became very excited.

The result of this meeting was that Flessati revised his plans for the sixth episode in *The Secret War* series, so as to cover Colossus as well as Enigma. The BBC brought their formidable research resources to bear on the making of this episode. The Enigma section of the episode gave extensive details of the work of the Polish cryptanalysts who originally broke Enigma, how the Enigma worked, and how Bletchley Park made use of a large number of machines, the so-called "bombes", designed by Alan Turing and Gordon Welchman to break Enigma traffic on an industrial scale. It also took the Colossus story on somewhat further than I had managed. For the Colossus section of *Still Secret* they interviewed Tommy Flowers, Gordon Welchman, Max Newman, and Jack Good, mainly on camera, and filmed a number of scenes at Dollis Hill and Bletchley Park, as well as showing the official Colossus photographs.

Whereas I had had to be very guarded in my paper regarding the purpose of the Colossus, *Still Secret* made it abundantly clear that Colossus was used to help break high-level German messages sent in a telegraphic code, via a machine that it said was called a Geheimschreiber ("secret writer"). However the machine that it described, and whose workings it showed, was a teleprinter-based device made by Siemens & Halske.

It was in fact a number of years before this inaccurate identification of the target of the Colossus project was corrected and it became known that the Colossus was in fact used to help break teleprinter messages that were enciphered using a separate ciphering device (the SZ40/42 made by Lorenz AG) to which an ordinary teleprinter was connected, rather than an enciphering teleprinter.

6 The Aftermath

The TV series was very successful when it was broadcast in early 1977. Undoubtedly it, and the accompanying book [9] by the overall editor of the series, did much to bring Bletchley Park, Alan Turing, the Enigma and the Colossus to public attention, though it was some years before there was a general awareness that Colossus was not used against Enigma, and one still occasionally sees confusion over this point.

My original query, concerning the story of a wartime meeting between Turing and von Neumann at which the seeds of the modern computer were planted remained — and remains — unanswered. The present general consensus, with which I tend to agree, dismisses this as a legend. However I should mention that after my account was published one senior US computer scientist, well-connected with the relevant authorities there, did hint to me rather strongly that it would be worth my continuing my quest! But nothing ever came of this, I'm afraid.

I did feel that my investigations had cleared up some of the more important misconceptions and misattributions regarding the stored program computer concept, not least exactly what the concept involved. However, my investigation of Turing's postwar work at NPL did not match the thoroughness with which Carpenter & Doran [2] analyzed his 1945 design for ACE. Their comparison of the fully-developed stored program facilities that Turing proposed in 1945 for the ACE against the rather rudimentary ones in the EDVAC report that slightly predated it [14], and which he cited, indicate to me that I really should have included at least some of Turing's 1945 Report, in my collection of selected papers.

There was one very amusing aftermath, as far as I was concerned, of my involvement with the BBC television programme. I had been asked by Domenic Flessati to tell him the next time I would be in London after the TV series had been broadcast, so that we could have a celebratory dinner. This I did, and we met on the front steps of Bush House, where he introduced me to Sue Bennett, his researcher for *Still Secret*, in the following terms "Miss Bennett, I'd like you to meet Professor Randell, the 'Deep Throat' of the *Secret War* series." I'm rarely left speechless, but this was one of the occasions!

One final happening in 1977 needs to be mentioned – the conferment on Tommy Flowers of an Honorary Doctorate by Newcastle University, an event that was reported prominently by The Times the next day [23]. I take great pride in the fact that I played a role in arranging this very belated public recognition for his tremendous achievement.

7 Concluding Remarks

By way of a Conclusion, one further Newcastle-related incident is worth reporting. At my invitation Professor Harry Hinsley, a Bletchley Park veteran and senior author of the multi-volume official history *British Intelligence in the Second World War* [7], gave a Public Lecture at Newcastle University, soon after the first volume was published in 1979. His lecture was on the subject of the impact of Bletchley Park's activities on the war. One of the questions he received after his lecture was "If this work was so significant, why didn't it shorten the War?" His reply was short and to the point: "It did, by about two years!"

As I indicated earlier, the request that I devote this lecture to my investigation into Turing's wartime work was motivated by the overall relevance of his career to the CONCUR community. Interestingly, there is a link between my 1970s historical investigation and my own most recent computer science research, which in fact is directly related to your topic of concurrency. This research concerns a new formalism, based on occurrence nets, for representing the activity of a complex evolving system [11]. One of the potential applications of this research is to the design of software for supporting large-scale crime and accident investigations.

I have in this lecture described the problems that I had in piecing together a coherent account of the work at Bletchley Park from a large amount of fragmentary evidence, e.g. even the basic problem of establishing an overall chronology of events. I have mentioned that I had been greatly helped in overcoming these problems by the use of Kenneth May's card index system. I now realise how much more useful to me might have been the sort of (criminal) investigation support system that is now one focus of my current research – but that is another story, for another time.

References

1. Bowden, B.V.: Faster Than Thought. Pitman, London (1953)
2. Carpenter, B., Doran, R.: The other Turing machine. Comp. J. 20(3), 269–279 (1977)
3. Cave Brown, A.: Bodyguard of Lies: The vital role of deceptive strategy in World War II. Harper and Row, New York (1975)
4. Eckert, J.: Disclosure of a magnetic calculating machine. Tech. rep., Unpublished Typescript (1945), reprinted in J.P. Eckert. The ENIAC, in: A History of Computing in the Twentieth Century, pp. 525-539, New York, Academic Press, 1980.
5. Good, I.: Some future social repercussions of computors. Int. J. of Environmental Studies 1(1), 67–79 (1970)
6. Halsbury, L.: Ten years of computer development. Comp. J. 1, 153–159 (1959)
7. Hinsley, F., Thomas, E., Ransom, C., Knight, R.: British Intelligence in the Second World War (5 vols.). Her Majesty's Stationery Office, London (1979 et seq)
8. Horwood, D.: A technical description of Colossus I. Tech. Rep. Report P/0921/8103/16, Government Code and Cypher School (August 1973), National Archives HW 25/24
9. Johnson, B.: The Secret War. British Broadcasting Corporation, London (1978)
10. Kahn, D.: The Codebreakers. MacMillan, New York (1967)
11. Koutny, M., Randell, B.: Structured occurrence nets: A formalism for aiding system failure prevention and analysis techniques. Fundamenta Informaticae 97(1-2), 41–91 (2009)
12. May, K.: Bibliography and Research Manual on the History of Mathematics. University of Toronto Press (1973)
13. Morrison, P., Morrison, E.: Charles Babbage and his Calculating Engines. Dover Publications Inc., New York (1961)

14. von Neumann, J.: First draft of a report on the EDVAC. contract no. w-670-ord-4926. Tech. rep., Moore School of Electrical Engineering, University of Pennsylvania, Philadelphia, PA (1945), extracts reprinted in Origins of Digital Computers: Selected Papers (ed. B. Randell) Springer-Verlag, 1973.
15. Newman, M.: Alan Mathison Turing 1912-1954. Biographical Memoirs of Fellows of the Royal Society 1, 253–263 (1955)
16. Randell, B.: On Alan Turing and the origins of digital computers. In: Meltzer, B., Michie, D. (eds.) Machine Intelligence 7, pp. 3–20. Edinburgh Univ. Press (1972)
17. Randell, B.: The Origins of Digital Computers: Selected Papers. Springer-Verlag, Heidelberg (1973)
18. Randell, B.: The Colossus. Tech. Rep. 90, Computing Laboratory (1976)
19. Randell, B.: Colossus: Godfather of the computer. New Scientist 73(1038), 346–348 (1977), reprinted in Origins of Digital Computers: Selected Papers (ed. B. Randell), 3rd. ed. Springer-Verlag, 1982.
20. Randell, B.: The Colossus. In: Metropolis, N., Howlett, J., Rota, G. (eds.) A History of Computing in the Twentieth Century, pp. 47–92. Academic Press, New York (1980), Proceedings of the 1976 Los Alamos Conference on the History of Computing.
21. Randell, B.: The Origins of Digital Computers: Selected Papers (3rd ed.). Springer-Verlag, Heidelberg (1982)
22. Swade, D.: Pre-electronic computing. In: Jones, C.B., Lloyd, J.L. (eds.) Dependable and Historic Computing, pp. 58–83. Springer, Heidelberg (2011)
23. Times: Computer pioneer: Mr. Thomas Flowers. The Times p. 16 (1977), 14 May 1977; Gale CS270237870
24. Turing, A.: On computable numbers, with an application to the Entscheidungsproblem. Proc. London Math. Soc. (2) 42, 230–267 (1936)
25. Turing, A.: Proposals for the development in the Mathematics Division of an Automatic Computing Engine (ACE). Tech. Rep. Report E882, National Physical Laboratory (1945), reprinted with foreword by D.W. Davies, NPL Report Comm. Sci. 57, April 1972.
26. Turing, S.: Alan M. Turing. W. Heffer and Sons, Cambridge (1959)
27. Winterbotham, F.: The Ultra Secret. Weidenfeld and Nicolson, London (1974)