Alan Turing recalled by Tom Vickers

Alan Turing at NPL 1945-47

Having been fortunate to get to know Alan Turing briefly at NPL from 1946 to 1947, it was suggested that I should commit my memories to paper. Sadly, memories fade with age; also I find that I would be repeating much that is now readily available in important books, particularly those by Hodges[1], Copeland[2] and Yates[3]. For much greater detail of this short period, I would strongly recommend the two accounts by J. H. (Jim) Wilkinson in his 1970 ACM Turing Award lecture[4], p243, and *A History of Computing in the 20th Century*[5], p101.

I will therefore try to present material which has not appeared elsewhere, plus some personal observations on the remarkable revolution in computing which took place during my stay at NPL from 1946 to 1977.

At the end of World War II, Jim and I were invited by E. T. (Chas) Goodwin to join the newly formed 'National Mathematics Lab' which was the Mathematics Division of the National Physical Laboratory (NPL) in Teddington. Earlier in the war, Goodwin had been a senior colleague of ours in the Maths Lab at Cambridge doing ballistics problems. (That lab was later to become the home of EDSAC.)

It was planned that Jim would share his time as an aide to Turing who was working on his own on the design of a computer (ACE or Automatic Computing Engine) and also work with Goodwin and Les Fox on the development of good numerical methods. It was also hoped that his plan to return to Cambridge to do further research would not materialise. I joined the Desk Computing Section headed by Goodwin and one of my briefs was to look out for better and faster desk machines. (Little did I realise what was to appear in a short time.) The whole Division was about 20 strong but it gradually increased to about 40. We were all very young (under 40). We were housed in a large house (Cromer House) and later in the adjacent Teddington Hall, both next to NPL. This is where the thinking about the Ace started.

Although Turing did not mix socially to any extent, I was very fortunate that I was regularly able to join him at lunch with my two senior colleagues, Goodwin and Fox and possibly others; here he clearly enjoyed their company and was most jovial. I was more the listener than a contributor in such exalted company! The subject of sport often arose because Fox was particularly good at both soccer and cricket. Any sports event between Oxford (Fox) and Cambridge (Goodwin), or cricket match between Yorkshire (Fox) and Middlesex (Goodwin) always caused a lot of rivalry, much to Turing's amusement as he knew very little about either cricket or soccer. However, he was always able to offer a new slant to the games such as 'If a pyramid of acrobats leapt up, could they save a potential 6 hit at cricket?' It struck me that Turing was particularly good at lateral thinking.

Mathematics did crop up at times, and the subject of build-up of rounding errors was a hot topic. It was clear that Turing took a more pessimistic view than Fox, leading at times to strong debates. Jim, with more limited experience at that time, tended to favour Fox and later on, with the arrival of the Pilot Ace, was able to do lots of experiments to provide evidence for his subsequent research in error analysis.

Turing frequently raised the subject of Machine Intelligence (this was in 1946, long before it became a fashionable subject). He also discussed the possible use of a computer to play chess.

This had obviously been a popular hobby during the war. He discussed the Bletchley 'Inter-hut' challenges when his colleagues had included the bulk of the British chess team. In revisiting Bowden's *Faster than Thought*[6] I see that the chapter on Game Playing was attributed to Turing and he discusses how chess might be played by computer. This classic book is probably not well known but it represents the state of computer activity in the UK in 1952, with description of machines and applications. I give further details in Appendix 1. I also provide details in Appendix 2 of a 1949 book by Hartree[9], a pre-war expert on the same subject.

Sadly, Turing did not stay to see the arrival of the Pilot Ace, his plans to concentrate on building the larger full-scale Ace having been delayed. However, he was pleased to see that it was a resounding success even though he had not been keen to see its development. He did not produce any problems to be solved, as his interests by then (not unusually for him) were far from the standard mathematical/engineering problems focused on at NPL. A return to academia was probably the right thing to do. He had left enough impetus to NPL in a stay of about 2 years.

The Impact of the Pilot Ace on the Parent Maths Division

By 1950, Maths Division had been in existence for 5 years and developed into a strong unit able to tackle a wide range of jobs for Government and Industry, mainly using desk calculators (of which we were able to acquire the best available) and Hollerith punched card machines. (Here, several had been converted for scientific rather than the usual commercial work. I have just been reminded that this included a modified tabulator redundant from Bletchley Park.) The smooth running cruise liner was about to be met by a gigantic tidal wave!

One of my jobs had been to seek improvements from the newer desk machines becoming available. Could I reduce the time to multiply 2 large numbers from 15 seconds by 10%, say? After exploiting a National Accounting machine with 6 registers modified to work in decimal rather than sterling, what could I do with 8 registers? Suddenly, the Pilot Ace appeared with a multiplication time of about 1/500 second and initially 250 registers. It is not surprising that I jumped at the opportunity to move, with the initial task of developing a junior section to be involved in operating and possibly programming. Ted York, who had been a member of the Punched Card team exploiting their modified equipment, also moved over to become a very experienced and enthusiastic programmer until recruited by RAE Farnborough when their Deuce (the commercial successor to the Pilot Ace) arrived. Significant changes of duties and organisation followed during the Ace era but I recall that these are discussed in detail by Mary Croarken in *Early Scientific Computing in Britain*[7] and I do not discuss them further here.

My chapter in Copeland[2], p265, presented at the Pilot Ace's 50th birthday conference, gives a summary of the overall impact of the Pilot Ace and I have little to add to it. I give details of the many jobs tackled and refer to the large number of guest workers who spent time with us and subsequently became leaders elsewhere, particularly in universities where they pioneered new courses in computing – E.S. Page, P. Samet, J. Ord-Smith and, very much later, Jean Bacon. We lost several staff by the same route – F. W. J. Olver (USA and still very active at Maryland), L. Fox (Oxford), C. W. Clenshaw (Lancaster) and S. Gill (London). Finally, I try to assess why it was such a success after a disappointing start and discuss some major offshoots such as the NAG (National Algorithms Group) Library which is now based in Wilkinson House, Oxford, and the Central Computing Agency.

Turing's Legacy to NPL

The ideas which he had developed with help from Jim Wilkinson, Mike Woodger and, later, Donald Davies and Gerald Alway (who sadly died at an early age in a car accident) were successfully used in building the Pilot Ace and it proved to be a greyhound among its UK rivals. In relation to EDSAC, for example, it was about 4 times faster, contained about a quarter the number of valves and had 33 copies made (the Deuce). The design of the Bendix G15 was based on it, over 400 were sold and it was arguably the world's first personal computer. For a detailed discussion of the speed of the Pilot Ace, see Martin Campbell-Kelly, in Copeland[2], p149. The most important impact was that his ideas persuaded three important members of the team to stay.

Jim Wilkinson had fully expected to return to academia but was inspired to stay and see a computer built. He then exploited its use and developed important research into error analysis of computer arithmetic, resulting in worldwide fame, a rise to the top position in the Scientific Civil Service and the award of FRS. He was able to inspire so many staff of all grades to get interested, whereas the shy Turing did not interact with junior staff.

Both Jim and Turing disliked some of the bureaucratic aspects of the Civil Service. Jim had a simple solution and that was to ignore it. To avoid a dull internal meeting, he would find a convenient hiding place to do some 'useful work'. (I recall that during his war-time work in the Cambridge Maths Lab he was found growing tomatoes on the top flat roof.) Many contributed to the success of the Pilot Ace but Jim was the undoubted leader who kept his light under a bushel. He was a real asset to NPL.

Mikc Woodger also stayed at NPL until retirement. An early very successful project of his, assisted by Brian Munday, was started on the Pilot Ace (when the magnetic drum was fitted) and finalised on the Deuce. This was a General Interpretive Program (GIP). A good description of it by R. A. Vowels appears in Copeland[2], p 319. Heavy use was made of it in handling matrices which often arise in engineering and aircraft design, although it did have wider applications. Indeed, this one program was sufficient to sell several Deuces to the then widespread aircraft industry. The firm of Bristol Engines developed a simplified form to deal with columns, rather like a modern spreadsheet.

Mike worked on language definitions including Algol and Ada. He was fortunately able to retrieve many important official documents which are now preserved in the Science Library. (My earlier attempts to archive important material were not encouraged: I was too early for the historian!)

Donald Davies had a long career in developing ideas in computing outside the main functions of Maths Division and these came under new regroupings eventually called Computer Science. David Yates, who was a colleague, gives full detail in his book[3]. Although a very important member of the Ace builders (particularly of the clever input-output arrangements), he did not get much involved with problem-solving as he acquired other duties, including a year in the USA. However, one of his first tasks on the Pilot Ace has not received much recognition so it is worth mentioning here. (I should add that when the Pilot Ace began to do jobs, any publicity was primarily up to the client. Further, there were not many appropriate journals available. That is why we got heavily involved in launching two new societies – the Institute of Mathematics and its Applications (IMA) and the British Computer Society (BCS).) Donald's problem came from the Road Research Lab - a sister establishment (and I believe a pre-war spin-off from NPL). It related to timing of traffic signals, both fixed, as they were then, and traffic-operated, which was under consideration. It must have been a very early use of computers in Operational Research involving the generation of random numbers. Four streams of traffic, represented by random digits (1=car, 0=gap) were timed through a junction. The streams could be seen on the output screen: when 2 of them stopped, the other 2 would start. The program was tiny, well under the 300 stores available. Hitherto, the use of random numbers taken from tables had not been widespread but it now became simple and the subject of OR blossomed from then on. Of his later work, mention should be made of the NPL network, which by 1976 connected about 30 various computers, 100 VDUs, several devices and services around NPL (a miniature World Wide Web). Two key features were the concept of packet-switching (as used in the Web) and a Standard Interface for connecting devices (like the USB on a modern laptop). At the time, its use was similar to the 3-point plug in the house. (It started as a 12-wire system, later extended to 18.) Like Turing and Wilkinson, Davies became FRS.

Thoughts on Post-War Computing at NPL

1. Little was known about the effort needed to build a computer, although from 1945 the key features were well established. The days of large special-purpose machines such as Colossus and ENIAC were over. (L. J. Comrie, the pre-war expert on computing - see Croarken[7] - had long disliked such machines.) A machine should be able to store both data and instructions in a common store, and these could be in binary form represented by pulses. The storage system needed to be specified and there were a number of options - delay lines (mercury, nickel, I believe Turing even suggested gin!), cathode ray tube, magnetic drum, but later to be replaced by magnetic core. Sir Charles Darwin, Director of NPL, felt that the best machine would be created by co-operation among the 3 main UK builders - NPL and the Universities of Cambridge and Manchester. However, original interest among the parties was lukewarm and it is clear that a Turing link with M.V. Wilkes would not have got very far. However, at the lower level, Wilkinson had very cordial relations with David Wheeler and Stan Gill (who had worked briefly for Jim) giving David a lot of unrecognised credit for the success of EDSAC. So, by 1951, three different machines were working in the UK with a potential greater than in the USA at that time. NPL had its links to English Electric Co. with the Deuce and other computers to come; Cambridge had the surprise link to J. Lyons, of Corner House fame, with the start of commercial computing, and also the development of micro-programming; Manchester had close links with Ferranti, later to produce Atlas etc. In addition, a line of computers for defence was coming from Elliot Bros. Thus the initial lack of joint activity produced widespread dividends later.

2. An early prediction (possibly by Hartree?) was made that 3 or 4 computers would satisfy the total national need! How many have we in a typical house now with its washing machine, phone, camera, laptop etc?

3. The newly-formed Nuclear Energy Authority of the late 1940s had big computing needs far beyond the desk machine but our Punched Card section proved to be effective for certain Monte-Carlo calculations, initially for Harwell and later for Aldermaston. (There was a very big difference. One was deadly secret and hush-hush whilst the other came under normal confidentiality. Yet the two problems were similar - in one the energy was captured (hopefully) for general use and in the other it was released with deadly results.) Later, a new problem was produced by Aldermaston which needed the skills of Wilkinson. It was processed on the Pilot Ace although we were not to know the details. The Nuclear Units were early buyers when large commercial computers became available from IBM and Ferranti, and lured several of our experienced punched card staff to run new computing sections in Harwell, Aldermaston and Culham, with enhanced salaries. (Our use of our card machines was likely to decline, so this was less of a problem to us.) Wilkinson was under tremendous pressure to go to Aldermaston, but he resisted. Having tried hard to leave secret Armament Research at the end of the war, he had no

desire to return to a similar regime.

4. Turing's proposal to "develop an electronic computer" which was presented to the NPL Executive Committee on 19 March 1946 did not, to my knowledge, surface until 1972, and then by chance! In going through the contents of a locked drawer for Confidential Information held by our deceased librarian, I came across the only copy held by the Division and this must have been deposited by J. R. Womersley when the proposal was first discussed. Jim Wilkinson was away, probably on one of his trips to the USA, so I showed it to Mike Woodger who had not met it. It was then published by Donald Davies as an NPL Report (see reference 138 in Yates[3]) and later by Carpenter and Doran[8]. Unfortunately, the original was not returned to me. It must be of immense value now, but at least we know the content. In it, Turing gives an interesting list of ten tasks which ought to be solvable by his proposal. These are listed in Yates[3], p21. Most would have been standard problems once the Pilot Ace was working, but for 3 of them his comments are more interesting.

a) Solution of linear simultaneous equations. "We cannot expect to solve more than 50 equations." In fact, in 1952 we solved 129 equations (and without the magnetic drum). See Copeland[2], p271.

b) Cut up a jigsaw into a number of whole squares. "Not a common problem but could have great military significance." This must be a reference to the huge manual task of Bill Tutte in cracking one of the codes at Bletchley as a preliminary to Turing's work, which featured in a recent TV documentary (see Hodges[1], p332). I wonder whether Turing or M. Newman ever gave thought to the impact of new computers on cryptography?

c) Comments on the ability of a computer to play good chess. I recall a much later writer (around 1970) saying that it could eventually beat the best players. I mentioned this to Michael Stein, a schoolboy Grandmaster who spent the summer with us prior to going to university and his comment was "nonsense". Some years later, I was very amused to read that Mike was the first Grandmaster to have been beaten by a computer.

5. How do ideas develop? From my experience at NPL, I found that lots of new ideas came about from chance discussions between scientists of different disciplines and there was plenty of scope for this at the three pioneering institutions. An extraordinary example is the original chat between M. V. Wilkes and J. Lyons to consider commercial computing. Innovation appears to be much more common than invention. However, in Turing's case he was much more the inventor than the innovator. He was always thinking way ahead of the current problem, and it needed a genius such as Jim Wilkinson to keep up with him. Hence his difficulty in communicating with others not on the same wavelength.

Tom Vickers, May 2012

Appendix 1

Faster than Thought edited by B. V. Bowden, published in 1953 and reprinted in paperback 1971.

This very interesting collection of papers on the state of the art in 1952 does not appear to have come to the attention of the modern historian. After a brief history of previous machines (eg Babbage) he then describes the electronics involved in a 1950 computer. This is followed by descriptions of current work in progress in the UK and the USA, mainly supplied by the relevant workers. It is interesting that for the Pilot Ace, the chapter is anonymous and "reprinted from ENGINEERING by kind permission of the editors". I assume that this refers to a Turing article, but I have no further reference. It is also of interest that, at the time of publication, Bowden was working for Ferranti and in close contact with Manchester University and Turing. The next section describes a range of applications, relying heavily on articles from Ferranti and Manchester University. As I have reported earlier, the article on game-playing is attributed to Turing, where he discusses chess, draughts and nim. There is no mention of applications at NPL but it could be that we had little published then. He had good contacts with us, as he was a buddy of our new director, E. C. Bullard. The final chapter on *Thought and Machine Processes*, which is written by the editor, includes a fascinating description of two mathematical prodigies of that time - Professor A. C. Aitken of Edinburgh University and Willy Klein of the Mathematisch Centrum in Amsterdam. I was very fortunate to have had impressive demonstrations from each of them. Their capabilities were similar, based on knowing their tables to 100 by 100 rather the 12 by 12, but their spare activities were rather different. Klein liked to learn logarithms of more numbers but Aitken, in his London demonstration, said that he was happy to look these up in tables and instead learnt all the piano works of Bach and Beethoven. Although he was teaching practical maths to students, I understand that his lab was poorly equipped with desk calculators as he expected his students to follow his methods! We always had close connections with the Dutch centre and Willy Klein (who was a humble operator) visited us for a couple of days. Apparently he would use a desk calculator when he was tired. I organised races with him using two of our popular demonstration programs - finding the smallest factor of a six-figure number and finding the day of a given date. He was quick! According to the article, he multiplied two ten-figure numbers to give a twenty-figure product in 64 seconds. In describing the Pilot Ace, I used to quote times for this as "by hand 15 minutes [Les Fox claimed he could do it faster but I am afraid he got the wrong answer], by desk machine 15 seconds and by computer 1/500 second". The article gives many examples of their amazing skills.

Bowden also quotes the skill of a Lakeland shepherd who, when retrieving and counting his flock of about 2000 sheep, will know not only how many are missing but which ones. What is incredible is that when I was a schoolboy I visited a farm in the foothills of the Pennines and helped to collect up the sheep. After more than one attempt we agreed a total and one was missing. Our illiterate farmer, who had very little school training, told us which one and where he last saw it!

Turing's Cathedral: The Origins of the Digital Universe by George Dyson (2012).

This substantial book has just been published and has received encouraging reviews from the main media. His father, Freeman, worked at Princeton and may have met Turing pre-war. I suspect that the post-war material relies heavily on some of the main books listed below. This is not surprising. Turing did such amazing things in a very short life but wrote and published very little and gave few interviews. We can expect many more similar books.

Appendix 2: References

1. Hodges, A. (1983). *Alan Turing: the enigma*. An epic biography dealing more with his life from schoolboy onwards and less with technical aspects of his work.

2. Copeland, J., ed. (2005). *Alan Turing's Automatic Computing Engine*. A very comprehensive technical account of his achievements. It includes not only the papers given at the two-day conference to celebrate the 50th birthday anniversary of the Pilot Ace but much other important material.

3. Yates, D. M. (1997). *Turing's Legacy*. A history of computing at NPL, 1945-1995. It relies on the Annual Reports of NPL. It is thin on the first few years when little was available but very complete on the later work of Donald Davies and others.

4. Wilkinson, J. H. (1971). *Some Comments from a Numerical Analyst*. ACM Turing Award Lecture, 1970. A significant part deals with the 1½ years he shared a room with Turing designing the Ace.

5. Wilkinson, J. H. (1980). His contribution to *A History of Computing in the 20th Century*. A collection of essays edited by N. Metropolis, J. Howlett and Gian-Carlo Rota, published by Academic Press. His article has a few bits in common with Wilkinson[4], but the book provides an excellent summary of activity up to 1980, similar to the way that Bowden[6] deals with 1952.

6. Bowden, B. V., ed. (1953, paperback 1971). *Faster than Thought*. See Appendix 1.

7. Croarken, M. (1990). *Early Scientific Computing in Britain*. A comprehensive account of how World War II changed the needs for computing from being very limited to the setting up of a centre at NPL (probably the most detailed account published) and the building of electronic computers.

8. Carpenter, B. J. and Doran R. W., eds. (1986). *A. M. Turing's ACE report of 1946 and other papers*, MIT Press. I have not seen this, but it provides the content of at least one historic document.

9. Hartree, D. R. (1950). *Calculating Instruments and Machines* (analogue and digital respectively to us). Hartree was a computing pioneer pre-war, initially in Manchester and later at Cambridge. He was involved in oversight of the new Maths Division at NPL. This is a rare book of lectures which he gave in late 1948 at Illinois and published by them. He begins by describing the Differential Analyser and its use, which he had built at Manchester, based on an original American design by Dr V. Bush. After a brief review of other "instruments" he refers to Babbage, ENIAC and the Harvard Mark I calculator in the belief that the latter two are outstanding steps in the way true computers are "likely to develop". He admits that developments in 1948 are very rapid. Finally, after summarising the electronic parts of machines under development in the UK, he suggests some mathematical problems for such machines. In total, a good review of the state of the art in 1948 to compare with 1980 (Wilkinson[5]) and 1952 (Bowden[6]).

10. Lavington, S., ed. (2012). *Alan Turing and his Contemporaries - Building the world's first computers*. This has just been published by the British Computer Society for the Computer Conservation Society to mark the centenary of his birth. Only 110 pages long, it concentrates on the period 1945-55 and relies heavily on material already published.