The Development of Computers and their History

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The kind invitation that I received from the organisers of this conference to contribute a paper surveying the history of present-day computers (the title suggested was "The Emerging Computer Industry - Technology") immediately put me in mind of an earlier invitation. This was one that I received in 1990, out of the blue, from Professor I.B. Cohen, Harvard University's very eminent historian of science.

His letter to me started with the splendid news that the Harvard University Press was planning a second edition of the book "A Computer Perspective" [Eames and Eames 1973]. For those, I hope few, of you who do not know this book I should explain that it is essentially the printed record of an exhibition designed for IBM by the late Charles and Ray Eames. The book is a superb, lavishly illustrated and remarkably accurate, account of the history of computing up to about 1950, and of the backgrounds against which the various technical developments occurred. The book was first published in 1973, but sadly had soon gone out of print.

Professor Cohen was for many years historical consultant to IBM, including on this exhibition and book. His letter to me explained that the long-lost photographic plates of the book had recently been found, so making a new edition possible at last. Economics dictated that the main body of the text, with all its illustrations, remain unchanged in the new edition, but Professor Cohen was planning on rewriting his original Introduction.

The original (rather unsatisfactory) anonymous Epilogue had summarised computer developments, in particular those by IBM, in the period 1950-1970. Professor Cohen invited me to provide a complete replacement for this Epilogue. However, the replacement was to cover the period 1950-1990, yet still fit within just four printed pages.

Though, as with the case of the invitation that has resulted in my presence here, I was flattered to receive such an letter, I was also surprised. This was because, despite Professor Cohen's statement that he had admired a paper of mine that he thought would provide a good basis for such an Epilogue, I was sure that I had not written any such paper - indeed, with the exception of two papers on software engineering and programming developments, virtually all my historical writings had, like the main body of the Eames book, concerned just the origins of digital computers. On being told this, Professor Cohen, after looking unsuccessfully for the paper he was referring to, wrote again saying that he had decided that he must have heard me lecture on post-1950 computer developments. This I also denied, but by this time was becoming intrigued by the challenge of fitting a summary of forty year's development of an industry that was growing at an exponential rate into the space that had previously been used for a description of just its first twenty years.

With the help of a number of colleagues, who patiently read my numerous drafts, I did in the end produce a replacement epilogue, in fact structured into five main sections, one for each of the four decades covered, and one discussing the future [Randell 1990]. One of the things I have done in preparation for writing this present paper is in fact to look back on this now eight-year old survey paper. (This was a chastening experience, particularly re-reading the section on the future.)

However, I soon decided not just to follow the simple path of producing an expanded version of my overly-compressed general survey of computer developments. This was because there are now a number of excellent books on the history of computing, a well-established scholarly journal, and several conference series, so that producing yet-another paper-length general historical summary of computer developments did not seem appropriate.

Instead, I have been idiosyncratically selective in my choice of topics to expand on. Indeed, given my interest in the origins of computers, one or two of the topics I have decided to discuss in fact concern an earlier period than the organisers had in mind. Moreover, I will also indulge in computer historiography rather than just computer history, since I wish to make some remarks that relate to the history of computing as a specialist topic area within the general subject of the history of science and technology. Hence the title I have chosen for this paper.

An Initial Apology

First some comments on my personal credentials, or rather lack thereof, for such a paper. My latent amateur interest in the history of computers became an active one in the late 1960s when I was preparing the text for my inaugural lecture at the University of Newcastle upon Tyne, where I had just been appointed to a professorship. I happened, while looking up some references related to Charles Babbage and Lady Lovelace, to stumble across a little-known paper by a Percy Ludgate [Ludgate 1914]. To my great surprise, I found that this 1914 survey paper contained a brief mention that he had worked on designing an analytical engine.

Out of curiosity, I set about trying to find out more about Ludgate, and the technological background against which he was working. I obtained the more detailed earlier paper that he referred to in his survey [Ludgate 1909]. Its place of publication implied that Ludgate was probably Irish or at least working in Ireland. With the help of a considerable number of Irish librarians and archivists, though having, at the time, no knowledge of even standard genealogical techniques I eventually found out a little about his family background and career, and indeed located an elderly lady who was his only known living relative. I also collected material about work by various other people on computing devices during the early decades of this century - a period about which virtually all the then-existing accounts of the history of computing were quite silent.

I wrote up my researches on Ludgate, but had quite a lot of material left over. Finding how little was generally known about the origins of our subject, I felt that something had to be done about this - the main result of my ensuing efforts was the book "The Origins of Digital Computers: Selected Papers" [Randell 1973], which was published a few years later, roughly contemporaneously with the two other early books on the history of computing, "A Computer Perspective", and Herman Goldstine's "The Computer from Pascal to von Neumann" [Goldstine 1972] .

Initially, my justification (to myself) of the time and effort I was putting into studying the history of computing, despite having no training or expertise in history - aside from high school classes which had done much to turn me off the subject - was merely the fact that I found the subject fascinating. Very quickly, however, I became so impressed by what I was learning about the

achievements of the early pioneers that I started to regard my efforts as an act of homage.

A gratifying number of people started to show an interest in what I and others were discovering and making available - but I remained painfully aware of my lack of training as a historian. Luckily, I came across an extremely helpful summary account of "how to do history properly" in the book "Bibliography and Research Manual on the History of Mathematics" by Kenneth O. May [May 1973]. (Some years later I was to make very extensive use of the indexing method that he described, during my investigation into the Colossus - a topic that I will return to shortly.)

Given that my knowledge of the general historical background to the work of the pioneers was to my mind so inadequate, I took refuge in confining my efforts to producing what I later learned was termed an "internalist" account of the origins of computing. However, I subsequently took much comfort from a remark made to me by Kenneth May, who I got to know in 1976 when I spent a sabbatical at the University of Toronto, where he was Director of the Institute for the History and Philosophy of the History of Science. This was to the effect that there was as much bad history of science produced by historians who did not understand science as there was by scientists who did not understand history. This, I fear, is the strongest defence I can offer of my historical writings and indeed for my choice of subject matter here.

A Colossus Revealed

In collecting papers and manuscripts for, and planning the structure of, my "Origins" book, I initially considered and discarded the idea of including material related to Alan Turing. His 1936 "Entscheidungsproblem" paper [Turing 1936]. This of course was the paper in which he introduced the concept that we now know as a Turing machine - a paper that did not seem appropriate for a collection that I had decided would concentrate on the design and construction of actual machines. Moreover, the Pilot ACE machine, built at NPL following Turing's earlier post-World War II work there, was slightly too late for my chosen time frame [Turing 1945].

However, a colleague, Professor Fritz Bauer of Munich if I recall correctly, on seeing my draft contents list for "Origins" urged me to look further at Turing's war-time activities. I contacted various people who had worked with Turing and eventually pieced together a few fragmentary bits of information about his

having been involved in the development of computers or computer-like devices at Bletchley Park, the wartime centre of Britain's code-breaking activities. I had great fun writing a blow by blow account of my investigation [Randell 1972] - though it owed much more to the guarded assistance of a few people in the know, my persistence, and to excellent secretarial support, than to any significant acquisition of historian's skills on my part. One interesting by-product, though, was that for several years I possessed what I believe was the only unclassified official document that admitted that Britain had developed an electronic computer during World War II. This was a letter denying my request to have this work declassified, signed by the then Prime Minister, Edward Heath.

A few years later, information started to surface in public about Bletchley Park's contribution to the Allied war effort. In particular there was the book "The Ultra Secret" by Winterbotham [Winterbotham 1974] , which created a great deal of interest. A second attempt to get the wartime computer developments was to my surprised delight partly successful, and I received official permission to interview a number of the people involved.

The investigation I then undertook was the first, and perhaps the only, really serious and sustained activity of mine that I feel justified in claiming as constituting a proper historical investigation - though this claim rests almost entirely on what I had learnt and put into serious practice from the Kenneth May book I mentioned earlier.

I corresponded with, and in many cases interviewed, a considerable number of the people who had been involved in developing or using Bletchley Park's electronic code-breaking devices - in particular the Colossus. I was asking them to remember what they had kept absolutely secret even from their families, and been deliberately trying to forget, for over thirty years. They could not refer to documentary sources. And during the war, their work had been highly compartmentalised, so that none of them had ever known much of the overall picture. Indeed, in some cases they did not know until my investigation that their work had been related to code-breaking, leave alone that it had contributed to the Allies obtaining huge amounts of strategically vital intelligence from supposedly unbreakable German teleprinter signals to and from Berlin.

Making sense of all the information I gathered, resolving the many inconsistencies, establishing a chronology, getting at least a vague

understanding of the computational powers of the Colossus, etc., was greatly facilitated by the simple yet sophisticated indexing system that I had learned from the May book. I used cards rather than a computer - in fact (un)punched 80-column cards rather than index cards, some two thousand in number by the end. Perhaps there are convenient PC-based database systems, intended specifically for historians, available now which would be much better. But when a few years ago I investigated the literature on how historians were and should be using computers, it was not evident to me that this was the case. I have as a result become quite interested in computer aids to historical research, but that is another issue, which I will not dwell on further here.

At the time I presented my account of the Colossus [Randell 1980] , in fact at the 1976 Los Alamos Conference on the History of Twentieth Century Computing, it seemed possible - even likely - that nothing further would ever be revealed. In fact, the secrecy surrounding Bletchley Park has greatly diminished since my investigation, in particular recently. First of all, starting in 1979, a multi-volume official history of Special Intelligence in World War II was published. This described what information was obtained at Bletchley Park by breaking various ciphers, in particular Enigma (work to which Alan Turing contributed greatly) and the teleprinter ("Fish") ciphers, and analysed the consequential impact on the Allies' conduct of the war. This official history provided little further information on the code-breaking techniques and machines themselves. However, in 1983, Tommy Flowers, the designer of the Colossus, was at last allowed to provide some additional details about the architecture of the Colossus in a paper for the Annals of the History of Computing, very usefully adding to the picture I had managed to assemble [Flowers 1983].

But now the situation is, I'm delighted to say, totally different. At Bletchley Park, in one of the actual huts that housed a Colossus computer over fifty years ago, Tony Sale and a small band of volunteer helpers have created an amazingly authentic working replica of one. He calculated its exact dimensions from detailed study of the few extant photographs, used his own expert knowledge of early electronics, located supplies of authentic components, and managed to obtain help from various official sources - all while battling to save the site from being redeveloped.

To my mind his resulting achievement stands alongside that of the Science Museum's magnificent full-scale construction of a complete Difference Engine from Charles Babbage's 1847-49 drawings. Moreover, albeit thanks to the

workings of the US Freedom of Information Act rather than any change of heart on the part of the UK Government, remarkably full technical details about how the Colossus was used - in effect programmed - are now available. (These are to be found in a lengthy report, written in 1945 by an American who had been working with the team at Bletchley Park [Anon. 1945]. This report gives the full details of the cryptanalytic techniques they had developed and used against the Fish ciphers.)

Thus a truly remarkable chapter in the pre-history of the modern electronic digital computer can now be properly appreciated by future generations. Needless to say, I feel highly privileged to have played a small part in bringing it to light, and count myself very lucky to have met and got to know some of the pioneers who were responsible. I also count it as a privilege to have had some involvement in Newcastle University's award of an Honorary Doctorate to Tommy Flowers, chief designer of the Colossus, and thus in helping to make the public aware of his tremendous contribution.

The 1960s Revisited

Of the four decades, starting in 1950, that I surveyed in my Epilogue for the Eames book, let me now concentrate briefly on the 1960s, and in particular on software matters. The very condensed summary I produced read in part as follows:

"The term "software" came into use, though as yet systems software was usually provided "free" with the hardware by the manufacturer, and applications software was normally designed specially for particular clients and particular computers. It was perhaps only when, in 1969, IBM "unbundled" its software by pricing it separately from its hardware that software became a commodity. Memory capacities increased, and the first time-sharing systems were brought into use, starting with MIT's CTSS in 1963. They were largely motivated by a wish to improve programmers' and users' ability to interact with their computers, though batch-processing systems remained the more common.

Increasingly ambitious applications and systems software projects were being undertaken, and organisations found themselves becoming much more dependent on large and complex computer systems than had previously been the case. Although there were some major success stories, one result was a growing concern about software cost and software project schedule over-runs,

and about failures, some quite spectacular, to achieve performance and reliability goals. The term "software crisis" was used by some to describe the situation, and "software engineering" to describe the hoped-for solution."

I had in fact written at some length about this period and topic earlier. This was for a paper on "Software Engineering in 1968", that I had been asked to give at the 1978 Software Engineering Conference [Randell 1979]. The preparation of this paper did involve quite a bit of historical investigation, but of a much different character, and level of seriousness, than that involved in my earlier Colossus study.

For a start, I was telling about very recent activities and incidents, quite a few of which I'd taken some part in. I had extensive files, especially of software-related papers from all manner of journals and conferences. (There had been a period of some years when it had seemed feasible to attempt to make a personal collection of all such papers relating in any way to my interests.) However, I was surprised and amused to find that the popular articles and advertisements, especially in journals such as Datamation, were much more helpful to me in recreating the mood of the times than any of the computer science journals.

I was also, again perhaps naively, somewhat surprised by how much one could add through the use of personal reminiscences, where these are available, to even apparently well-recorded events such as the 1968 Software Engineering Conference. (I have read an official history of the events leading up the formation of Newcastle University that was of necessity written almost entirely from official minutes of various formal committee meetings. Though using such material is undoubtedly better than relying just on reminiscences I am sure from my present experience of university meetings and their minutes that the account provides a less than adequate picture of what was really happening.)

Another way in which my - and I believe many other authors' - writings on post-1950 computer history differ from most writings on the origins of computers is that they are much more subjective and explicitly judgmental. This was especially the case in the subsequent more general account of programming developments that I published in 1994 [Randell 1994]. Indeed, I concluded this paper by arguing that the two most important events in the history of programming were the development of Fortran, and the introduction of the personal computer. These are two propositions that I am

still prepared to defend (though not here and now), even among all the present excitement about Java and the Web - but there is of course no question of providing a historical proof of their validity.

The 1980s Reviewed

Let me now fast forward to the 1980s, which I summarised in the Eames Epilogue in the following terms:

"The 1980s saw the personal computer market grow explosively. This was made possible by continuing technological developments, but also was fuelled partly by IBM entering the market in 1981 with their PC, and by the rapidly growing strength of the Japanese and other Far-Eastern manufacturers. Somewhat higher performance was provided by personal workstations, which were usually networked together and running the UNIX operating system, though the distinction between personal computers and personal workstations seemed likely to disappear. Towards the other end of the market, the decade saw the move towards the use of various forms of parallel processing in order to gain increased performance over and above that provided by technology improvements. Some of these were fairly conventional, others demanded quite novel programming techniques. However the major development was the vastly increased amount of packaged software produced, almost entirely for the more popular types of personal computer, for very sophisticated applications as well as a vast range of computer games.

This development led to the introduction of a myriad of specialist application packages, intended for use by all sorts of organisations and individuals, many of whom regarded their computers not as general purpose computers but as specialist devices - used for example solely for document preparation or standard financial calculations. Indeed many computers were being used quite unknowingly, being embedded into all sorts of devices and machines, such as central heating systems, dishwashers, automobiles and cameras. An interesting analogy can therefore be drawn to the electric motor - originally very large and expensive, used to power complete factories, it has been developed to the point where typical households have no idea how many electric motors they possess. Similarly, they now can no longer accurately count their digital computers."

What is most noticeable to me now, rereading this summary, is the complete lack of any specific mention of Microsoft. In contrast to the above summary,

just about all the full-length histories of this period, whose number illustrates the public interest in how computing got to be how it now is, are almost entirely accounts of the various personalities and companies involved, rather than technical histories. Some indeed are very significant contributions to business and or social history - though many are popularisations, which mainly serve to promulgate myths and over-simplifications. But even these help fuel general interest in how our computer world got to be the way it is, so have some merit.

Back to the Future

Let me move on and quote one final extract from my Eames Epilogue. I had the temerity to include a section in it giving my views as to likely future developments. One of my motivations was to distance myself from what I regard as some of the more inept attempts at predicting the future of computing. This section therefore ended as follows:

"In fact it is as hard to predict what the next forty years of computing will bring as it would have been to foresee the developments of the past forty years in 1950. It is one thing to estimate how processing speeds and costs will change, and perhaps how our ability to design and implement comparatively well-understood applications will improve. It is quite another to predict what new, and perhaps revolutionary, application programs will be thought up (e. g. the next decade's equivalent of the spreadsheet program). Equally difficult is the prediction of when and how various existing limits to our knowledge of how to solve various very challenging design problems will be breached, and various long term goals, for example in artificial intelligence, achieved. Failure to understand these difficulties has led to some dramatic, and dubious, predictions whose fulfilment will require innovative breakthroughs rather than foreseeable improvements in technology.

Predicting the impact of computer developments on society is even harder. The indirect effects of most radical inventions are more significant than their direct effects. The world of computers will surely continue to be technically highly innovative for years to come. The problem is ensuring that the consequences of all this innovation will be adequately beneficial to mankind, and to mankind as a whole, rather than just to a technological elite."

However, though the section as a whole still, I venture to suggest, reads reasonably well, one omission is already very striking. This is the lack of any

mention of the possible impact of what many would now argue is the most important current development in the computing scene, namely the Internet. The growth and impact of the Internet was of course greatly fuelled in recent years by exactly the sort of revolutionary new ("killer") application, namely the World Wide Web, that I had in mind but whose form I, needless to say, could not predict.

Such are the perils of prediction - and it is as unwise to forget them as it is to forget the past, or, to quote (albeit perhaps a little inaccurately) yet again one of my favourite sayings, that by George Santayana: "He who forgets the past is forced to relive it".

In fact it would seem to me that the Web, for all its success, is an illustration of Santayana's aphorism. The design of the initial Web protocols ignored all manner of well-established techniques for constructing dependable distributed computing systems. Now many of these are being belatedly investigated, or even reinvented. (This situation is reminiscent of the way in which computer architecture lessons, such as the importance of providing storage protection, were for years ignored by microprocessor designers so that, for example, the proliferation of so called "computer viruses" was encouraged.) It would be nice to think that articles and lectures on computer history would help to reduce the amount of such re-invention that goes on. But the computer field is developing so rapidly, over such a broad front, that all manner of parallel activity is occurring (often masked by the use of differing jargon). As a result many computer developers, and also computer science students, if they read the formal computer literature at all, seem to assume that anything written more than a few years ago is bound to be out of date and irrelevant.

Concluding Remarks

Let me conclude by turning again from computer history to computer historiography. Over the years since I first became involved in it, the subject and the practice of computer history has developed and matured considerably. One still encounters accounts of various events and activities that are amateurish in the extreme. But there is also a growing body of papers and books that are splendid contributions to the history of science literature, from both a historical and a scientific point of view, and there are now important well-organised historical archives and museum collections devoted to the subject. However, what I find most satisfying is the increase in the general

public's appreciation of the tremendous achievements of at least some of the computer pioneers who created our subject.

I very much doubt that we will ever reach the level of public interest and knowledge of the history of computers that there is, for example, in the UK in maritime history around the turn of the 18th century - the subject of an immense literature, both factual and fictional - but who knows? Many claim that we are living through a revolution, perhaps as important as the industrial revolution. So perhaps a century on, depending of course on how well and how wisely the world has used the new-found powers provided by the information revolution, the names of the main computer pioneers will even more widely known and respected than they are now. I certainly hope so.

One final comment - I cannot resist returning to the subject of my replacement Epilogue for the Eames book. The second edition was at the printers when I had the pleasure of dining with Professor Cohen during a brief visit I paid to Boston. He confessed that he had at last found the paper that he had had in mind when he wrote inviting me to produce a replacement Epilogue. It was by Maurice Wilkes!

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