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ENIAC versus Colossus and the early presentation of electronic computers

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It is undeniable that, however valuable or otherwise, there is a constant debate in design history about authenticity, originality and the nature of 'firsts'. Given that my specialism lies in the area of electronic computing, I am frequently asked 'Which was the first computer?' This is not a straightforward question to ask, and people are often frustrated by the answer, 'Well, it depends on how one defines a computer.' Given enough adjectives, such as 'general purpose', 'programmable', or 'stored program' one can make an argument for almost any of the early electronic computers as being the 'first' – just look at any entries on Wikipedia for examples of how people manipulate dates and facts to suit their argument.

The basis of this paper is not to debate such claims, but is firstly to discuss the context and particular circumstances surrounding the development of the electronic computer, which took place during the second world war on both sides of the Atlantic at almost exactly the same time but for very different military reasons, and secondly to explore the impact that these different contexts had on the later presentation of computers to the general public.

Development of ENIAC

By the 1930s, warfare had become increasingly technological, to such an extent that the U.S. Army created a Ballistic Research Laboratory at the Aberdeen Proving Ground in Maryland. Among its many assignments was calculating artillery shell firing tables. For every new ballistics weapon that was developed, there was a requirement for associated information to target the weapon in the form of a book of firing tables. Without such firing tables, the weapon was virtually useless. Each book contained numerous trajectories for that particular weapon for different angles of elevation, and distances to target under standard conditions, as well as the different corrections that had to be made to any particular setting to determine the point of impact under actual conditions, taking into account variables such as air density and wind speed. One single trajectory took a human computer (the word computer originally referring to an individual mathematician) about 12 hours to calculate, and each firing table required hundreds of trajectories to be calculated.

In the book *Turing's Cathedral*, George Dyson wrote:

> As the US prepared to enter the war, there was a shortage of human computers at the Aberdeen Proving Ground, and an auxiliary computing section was established at the Moore School of Electrical Engineering at the University of Pennsylvania, where human computers could be

recruited among the student population, augmented as needed from neighboring colleges and schools.[1]

The calculations performed by these human computers were originally performed on analogue mechanical calculators, and later by more advanced mechanical computers called Differential Analysers – devices which had been in development since the mid 19th Century, but which became widely practical with a design by the celebrated engineer and inventor Vannevar Bush with Harold Locke Hazen between 1928 and 1931 at MIT. Electromechanical differential analysers were built at the Ballistic Research Laboratory in Maryland and in the basement of the Moore School of Electrical Engineering at the University of Pennsylvania in 1935, and at the time were the largest mechanical computers ever built.

Even with advanced machines, the Army's 'human computers' couldn't keep up with the mushrooming demand for artillery calculations created by the onset of war. The electromechanical differential analyser reduced the time to calculate a trajectory down from 12 hours to around ten to 20 minutes, but this still meant that it took 750 hours of continuous operation to complete one firing table, which even with double shifts and the assistance of the analyser at the Moore School of Engineering, meant a full table took around three months to deliver. The 200 human computers at Aberdeen Proving ground quickly fell behind, as requests for the preparation of new tables were arriving at the rate of six per day.[2]

John Mauchly, a physicist at directly involved in the production of these tables, proposed the building of an electronic digital computer to speed up and improve the process, based on decimal counting circuits built from vacuum tubes. Mauchly conceived and designed the Electronic Numerical Integrator and Computer (ENIAC) with significant help from a graduate student, John Presper Eckert, who worked out the necessary electrical engineering required. Both men worked at the University of Pennsylvania, and the ENIAC was built at the university's Moore School of Electrical Engineering. Despite concerns over the feasibility of the project, funds were sourced and the project began in July 1943 and took just under three years and $500,000 to complete.

The ENIAC contained almost 18,000 vacuum tubes, weighed 30 tons and covered a floor area of around 65 square metres. The concerns over the feasibility of the ENAIC were based around the known lifespan and reliability of vacuum tubes, or valves. Trying to prevent the valves from breaking down, Eckert and Mauchly ran the ENIAC on lower operating voltages which cut the breakages down to only two or three times in a week.[3] However, with repair times, this meant that the computer was still only functioning for 50% of the time. The ENIAC's longest continuous period in full operation was only five days.

Development of Colossus

The Government Code and Cypher School based at Bletchley Park, Buckinghamshire had significant experience in decrypting secret German messages, including those sent using the famed Enigma cipher machine. The Enigma machine used an ingenious rotor system to scramble each letter of a message individually so that even if the same letter were keyed in twice in a row, the coded letters produced would be different. The sequence of the letters generated was dependent on the initial position of three rotors, enabling billions of possible initial positions, and making the code extremely difficult (but not impossible) to break. Polish cryptographers developed a mechanical calculator (known as a Bombe) that broke the Enigma code as early as 1932, but at that point, the initial position of the Enigma machine was only changed every few months. With the outbreak of war, the machine's settings were changed at least once every day, and the Polish machine could not decode the messages quickly enough for the information to be of any use. The Poles informed the British in July 1939 that they could no longer break the code.[4]

At Bletchley Park in 1940, the celebrated mathematician Alan Turing developed the Polish machine into a much faster electromechanical calculator, which could check the thousands of possible variations and successfully decode Enigma messages within a few hours. The electromechanical bombes were operated by Wrens and ran 24 fours a day, but there was still an increasing backlog of unbroken codes. The situation grew worse in 1942, when a higher-level code generated by a 10-rotor machine called the Lorenz cipher began to appear, used for top-level strategic communications by German U-Boats. The number of possible variations of initial settings within the Lorenz cipher was far too great for the relay-based Bombe machines to tackle.

Bletchley Park mathematician Max Newman (Turing's tutor at Cambridge) asked the Telecommunications Research Establishment at Malvern to produce an electronic machine to automate the method of finding initial code settings. The machine (nicknamed Heath Robinson by its operators), was built at the Post Office Research Station at Dollis Hill, London, and used two paper tapes which ran at speeds of 1,000 characters per second – one containing potential rotor settings and one containing the coded message. The Robinson machine worked well enough to prove the concept, but the paper tapes could not easily be kept synchronised when running at the speeds necessary to decode a message within a reasonable timeframe. The spiked wheels the tape ran on kept breaking the paper. Another considerable problem was that the answer produced by the Robinson machine depended on an unreliable mechanical counter, and often, the answers given for the same message were different. Because of these problems, Newman proposed an electronic computer to decipher Lorenz messages, but it was deemed unworkable. Because the Robinson machine was made almost completely from telephone switching components, Tommy Flowers, an electrical engineer at Dollis Hill who had impressed Turing during his work on developing the Bombe, was brought in to look at the problem. He said 'I very soon came to the conclusion that it would never work. … the paper wouldn't stand up to it.'[5] Flowers realised that the problem was similar to one he had addressed before the war in designing automatic telephone exchanges. What was required was at its most basic level an enormous collection of very fast switches. Flowers knew

that electronic valves were capable of switching about a thousand times more quickly than mechanical relays. He had also discovered that the widely known unreliability of valves disappeared as long as they were never turned off. Flowers' main contribution was to suggest that one of the synchronised paper tapes in the Heath Robinson machine could be replaced by a pattern generated electronically by valves, removing the synchronisation problem and enabling reliable high-speed operation.

The officials at Bletchley Park were sceptical and would not back the development work. But Flowers was so convinced of its potential that he spent £1000 of his own money and 10 months designing and building the Colossus electronic code breaking computer. It contained 1,500 thermionic valves – more than any other electronic device of the time – and was delivered to Bletchley Park at the end of 1943. In its first test it successfully decoded a real coded message so quickly that a total of 10 improved machines were ordered. The Mk II Colossi built in 1944 contained 2,400 valves each and were five times faster.

Postwar Developments

There is a useful argument to be had here about the difference in outcome between innovations produced as a result of governmental imperatives, national patriotism, funded by the state and with no egos involved or patents to be protected, and the development of innovations funded by corporations, backed by shareholders and within the strictures of patents and commercial priorities. Some have argued[6] that all the major significant developments, including space exploration and the internet, in recent times have been produced through the former route rather than the latter.

Both ENIAC and the Colossus were created as the result of backlogs or bottlenecks in the generation of military information: ENIAC to calculate ballistics trajectories and Colossus to decipher encrypted enemy messages. They were each designed specifically to solve a single given problem, not as general-purpose computers. The fact that they were designed and built in secret as one-off experimental machines rather than ever being intended for large scale production significantly affected their design and construction, with the appearance of the machine, its use or even its understanding by others of no concern whatsoever.

Such concerns only emerged with respect to the electronic computer when it was first presented to the public immediately following the war. Although the ENIAC was not the only large-scale computer in operation at the time, 'it represents a unique marker in the public consciousness due to the dramatic way in which it was unveiled' at a press conference on Valentine's Day in 1946. One historian of technology has labelled this launch as 'The Press Conference That Shook the World', stating that the headlines that resulted from it 'were a major factor in the public perception of computers for decades to come'.[7]

The ENIAC press conference was considered by the team that developed the computer to be of vital importance. Despite massive funding, the machine was not completed in time to be of any use in the war itself, not finally being completed until November 1945 (in fact, its first real use was for the Cold War, being used for calculations required to build the H-Bomb). Many high profile scientists (including Vannevar Bush, whose Differential Analysers were used prior to ENIAC, and Howard Aiken, the man behind the Harvard Mark 1 – an electro-mechanical precursor of ENIAC) were being outspoken about ENIAC being a foolish endeavour and a waste of taxpayer's money. A high profile, dramatic public launch was a way to garner public support for more money to continue research and development on the ENIAC's successor, the EDVAC.

In preparing for the press conference, it was decided that the huge technological leaps made during the building of ENIAC were, in themselves, not impressive enough for public consumption. The team felt that an additional 'visual display' of the computing processes being performed was required. Film footage of the press launch shows how this was achieved, with the commentary explaining:

> Here we see John Mauchly standing before a wall of blinking lights that illuminates as ENIAC comes up with its answers to a calculation. The lights themselves, however, had no real purpose, except showmanship….
> As the engineers 60 years ago prepared for the debut of the new machine, they noticed the ENIAC's 18,000 vacuum tubes were not visible on the film they were making. So, even when the computer was working to solve a computation, there was little sign of anything happening. So they came up with an idea. A simplistic, almost humorous idea, but one that came to symbolize the very concept of a computer in the minds of the American public….
> The engineers put large light bulbs on the machine and painted numbers on them. Now the film was able to capture the impressive bank of blinking lights, populations and changing totals that the new machine produced.[8]

The display of flashing lights certainly had the desired effect. The following morning, the event 'was hailed in newspapers all over the U.S. and Europe',[9] with some of bold headlines even making direct reference to the lights on ENIAC:

> Blinkin' ENIAC a Blinkin' Whiz; Electronic Calculator Operating at Penn Does Work of 20,000 persons –*Philadelphia Record*
> Electronic Computer Flashes Answers, May Speed Engineering –*New York Times*[10]

The ENIAC Press releases generated so much interest that they were soon joined by reports of other, earlier computing devices that had been developed in similar secret circumstances to support the war effort; among them the Differential Analysers developed by Vannevar Bush at MIT and the Mark 1 developed by Howard Aiken at Harvard University. Such coverage ensured that the public was repeatedly presented with stories of 'man built', 'magic' or 'mechanical brains', which promised huge leaps forward in man's ability to solve problems ever more quickly.

IBM was quick to respond to the obvious public appetite for anything to do with computers. Despite huge interest, the ENIAC could not be seen by the public as following the press conference at the Moore School of Engineering it was installed at Aberdeen Proving Ground, so the President of IBM, Thomas Watson, instructed his engineers to build the biggest and fastest computer they could. The resulting computer, the IBM Selective Sequence Electronic Calculator (SSEC), was built in only eight months.

> Trying to make sure the SSEC would get as much public attention as the ENIAC, Dad had it installed in our showroom on the ground floor of IBM headquarters in Manhattan, in full view of the sidewalk. Passersby on Fifty-seventh Street could look in the window and watch the SSEC work. It was an amazing sight to come upon in the middle of the city – three long walls filled with electrical consoles and panels, all studded with dials, switches, meters, and little neon indicator lights that flashed whenever calculations were going on. Hundreds of people stopped to watch it every day, and for years it was the image that popped into people's minds when they heard the word 'computer.'[11]

The amount of publicity IBM received from putting a large computer on such public display was enormous. Newspapers widely reproduced an airbrushed image of the SSEC following the presentation ceremony on January 28, 1948, and the exposure of the machine 'did a great deal to enhance IBM's reputation as a leader in computer technology'[12]

In the UK, the development of computing technology embodied in Colossus was largely uncapitalized upon because of the Official Secrets Act. At the end of the war, Flowers was ordered to burn all plans and the Colossi themselves were dismantled, 'as was all hint that the world's first programmable electronic computer had ever existed'[13] (apart, that is, from two of the machines, which are rumoured to have ended up at the Government Communications Headquarters (GCHQ) in Cheltenham. The Colossus did, however, indirectly lead to other projects: Alan Turing worked at the National Physical Laboratory in 1945 where he worked on the Pilot ACE, and later at Manchester University, where the Small Scale Experimental machine (or 'Manchester Baby'), was constructed in 1948. This was developed into the Manchester Mark 1, and in turn, into the first commercial computer, the Ferranti Mark 1. The Ferranti computer was first widely presented to the public in a modified form at the Festival of Britain in 1951 as 'Nimrod': a computer against which the public could play an electronic version of the old strategy game 'Nim'. As with the ENIAC, Nimrod employed a series of flashing lights as a display to communicate the past moves, current stage of the game, and the process by which the computer was calculating its next move – again, giving an illusion of contemplative machine intelligence.

In the US, after refusing to give patent rights to University of Pennysylvania, Eckert and Mauchly set up on their own and developed the UNIVAC (Universal Automatic Computer). A key technological development at this point was the addition of memory drives using magnetic tapes. Rather than being hidden away, these were presented prominently, behind curved glass covers. Reportedly, observers commented that the sight of the reels moving back and forwards as

the computer searched for stored pieces of data gave the impression that the machine was 'thinking' and furthered the idea of the computer as a 'mechanical brain'. Their round shape also found a role in the anthropomorphication of the computer as they were consistently depicted as the 'eyes' of hybrid computer/robot machines. The UNIVAC became widely seen as a prescient technological intelligence when it was used on national television during the US presidential elections in 1952, when in contrast to expert political opinion that anticipated a dead heat, it correctly predicted a landslide victory in favour of Eisenhower.[14]

The precedent set by IBM with their showroom display inspired other corporations when computers first became commercial products in the early 1950s. Understandably, companies were keen to promote the fact that they had invested so heavily in expensive computer systems and were at the technological cutting edge of business practice. They had strong reasons for displaying their computer systems to clients and customers, which left them with a dilemma. Early mainframe computer systems were highly temperamental and required an amount of isolation to provide constant temperature, humidity and a secure power supply, as well as to limit access to the computer to authorised personnel. These criteria led to the development of the 'glass house' – a glass walled, secure area where both the environment and access could be controlled while simultaneously allowing the computer system to be seen by visitors.[15] The 'glass house' computer room become such a widespread phenomenon that it not only spawned a whole series of subsidiary industries, but also computer manufacturers started to take the fact that their systems would be on public display into account in their physical design. The introduction of colour was one aspect, with early systems having components in different colours so that accompanying brochures could explain easily to visitors what each part did, and with different colour schemes eventually becoming part of different corporations' brand identities. There are also examples showing that the superfluous flashing lights that became associated with electronic computation after the ENIAC press conference were employed for many years to come to impress viewers:

> As the one time World Head Of Design at IBM, Tom Hardy, relates, the fact that while the majority of the myriad rapidly flashing lights on the console of the IBM System 370, for example, 'could provide some basic indications to operators and service personnel, they mostly served as a dynamic "light show" that visually expressed a complex system processing large amounts of data at a rapid pace'[16]

Conclusions

Prior to the development of the electronic computer, the public's exposure to calculating technology was limited to mechanical mathematical devices, which in principle were little different to those proposed by Charles Babbage in the mid 19th Century. No matter how limited the mathematical understanding of the viewer, these at least presented a physical display of cogs, pinions, levers and counters moving as evidence of the calculating process taking place. Even later

developments such as electro-mechanical computers consisted of electrical relay switches which provided observers with hundreds of bouncing contacts accompanied by a clicking sound like 'a roomful of ladies knitting'. With the application of electronic valves to act as extremely fast switches, the physicality of the computing process itself disappeared. The press conference of the ENIAC solved the problem with the application of a technical unnecessary display of lights, which became associated with electronic computers thereafter. The lights represented an intangible aspect of computing technology, which many interpreted as evidence of the machine 'thinking', and furthered the interpretation of electronic computers as artificial intelligences. It was an aspect of electronic computers that was readily picked up and even exaggerated in media representations of computers in mainstream films such as *Desk Set* (1957), *Billion Dollar Brain* (1967) and especially *2001: A Space Odyssey* (1968).

I would argue that such media representations directly influenced the public's expectation of the capability of electronic computers. In terms of the Social Construction of Technology this is important, as once a set of expectations is present in the minds of a relevant social group, it becomes a deciding factor in the acceptance of various forms of computers and therefore a driving force in the actual technological development of computers themselves. Once the idea of artificial intelligence represented by flashing lights became embedded in the public psyche, it became a difficult notion to remove, and arguably the inevitability of artificial intelligence became an expectation of the future of computing technology.

[1] Dyson, G. *Turing's Cathedral*, (London, Penguin, 2012) p. 69.

[2] Rhodes, R. (Ed.) *Visions of Technology: A Century of Vital Debate about Machines Systems and the Human World*, (New York, Simon & Schuster, 2000) p. 179.

[3] Martin Campbell-Kelly, *The Computer Age* (East Sussex, 1978), p. 54.

[4] Smith, M. 'The History of Bletchley Park', in *The Secrets of Bletchley Park*, (Bletchley Park, 2001), p. 3.

[5] Tommy Flowers quoted in Smith, *Station X,* (London, Pan, 2004) p. 156.

[6] See, for example, Mazzucato, M., *The Entrepreneurial State: Debunking Public Vs. Private Sector Myths*, (London, Anthem Press, 2013)

[7] Martin, C. D., (1995) ENIAC: The Press Conference That Shook the World, *IEEE Technology and Society Magazine*, Dec 1995.

[8] Newsreel video, 'ENIAC: The Public's first glimpse of a computer', http://www.zdnet.com/videos/eniac-the-publics-first-glimpse-of-a-computer/155156 . Last accessed 13 August 2014.

[9] Martin, C. D., (1993) The Myth of the Awesome Thinking Machine, *Communications of the ACM*, Vol. 36, No. 4, p. 124.

[10] Ibid., p. 125, 127.

[11] Watson Jr., T. J. & Petre, P., *Father, Son & Co.: My life at IBM and beyond*, (New York, Bantam Books, 1990) p. 191.

[12] Campbell-Kelly, M, and Aspray, *Computer: A History of the Information Machine*. (New York: Basic Books, 1996), p. 116.

[13] Smith, *Station X*, p. 206.

[14] Martin, C. D. (1993), p. 130.
[15] Atkinson, P, Room with a VDU, *Interiors*, Vol. 5 No. 1, pp. 89-116.
[16] Ibid., p. 101.