

# A History of the Electronic Digital Computer (part 2)

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## Abstract

This paper is a slightly modified version of an article originally published in the February 1997 issue of *Phasor* (pp. 2–7), a computer journal (in PDF) for the computer user group MACRO, which was defunct in mid-1997, IIRC. I was the editor of the journal during its very short run.

## Part 2: 1900 – 1946

### *EARLY USES OF COMPUTERS*

Taking a lesson from the governmental use of the Hollerith machine, big business followed the same path, especially insurance companies, public utilities, and railroads. Hollerith's machine was redesigned to do basic cost accounting and sales analysis, and, although primitive by today's standard, it was a vast improvement over "analysis by hand."

In 1905, Percival Lowell began the search for a planet which lies farther out in the solar system than the planet Neptune. To help him calculate the probable path of the planet, he bought the "Millionaire" calculating machine. Lowell worked until 1914 to finish his calculation on "Planet X," which might have taken less than a day using a modern PC.

Weather forecasting in the early part of the twentieth century was fraught with three major problems: The first was the need for even a crude theoretical model of weather development; the second was to be able to amass lots of weather data from a large area adjacent to the area chosen for prediction; and the third was to be able to analyze this data. The first resolution was in the theoretical work of the Norwegian physicist Vilhelm Bjerkner, and later refined by Lewis Fry Richardson in WW1.

The second problem was aided by the ubiquitous placement of telegraph lines, from which local weather data could be telegraphed to a central collection point for synthesis and prediction of weather. But the third problem was so challenging to the computational machines of the time that good predictions based on theoretical work would not be available until the invention of the

ENIAC computer in 1946 (calculation first made in 1950), of which we'll have more to say later on.

### *FEEDBACK*

As our machines became more powerful, the need for guidance and control to keep them working properly grew evermore important a subject in its own right. In a very meaningful sense, the notions of power and accuracy do not blend well together. One early example where power and control came together was in the aiming of torpedoes after their launch. Torpedoes are large and fast-moving machines, but a slight deviation from the original aim can send it off target.

One highly successful devise used to control the steering of torpedoes is the gyroscope. The gyroscope works by setting a metal object spinning about some axis in a relatively frictionless mounting. This axis will remain unchanged regardless of the motion of the torpedo through the water, providing a reference for course correction. A typical course-correction scenario is as follows: a deviation from correct course causes a stress (feedback) on the stability mechanism, which in turn attempts to relieve the stress by using a servo-motor to adjust the steering mechanism until the correct course is re-established. One notable person in the early use of gyroscopic-feedback steering was Elmer Sperry, who, in 1910, affixed such a device to an airplane and demonstrated its astonishing stability.

### *THE ASSEMBLY LINE*

Henry Ford is often credited with inventing the assembly line, but this is not so. Its history in America goes back into American history at least to Thomas Jefferson. And Jefferson got the idea from a French inventor. But Ford did prove the usefulness of the assembly line to produce low-cost machines for the masses. The importance for our story, though, is that the assembly process was reduced to a series (or a parallel set of series) of simple tasks. From this set of series of steps one could even then envision a set of machines taking over the job of assembly, and the concept of automation follows quickly.

The assembly-line concept was initially very good for the workforce. After all, it could be used to produce a "complicated" machine, only requiring each worker to learn a minimal skill set to accomplish his or her task. The assembly-line concept was also good for management in the beginning, because the machines were still relatively simple and quantity was the ultimate goal of production. This state of affairs was to continue until the 1970s, when the Japanese, who had been following the Demming system of Quality production, finally saw the fruits of their philosophy and hard work. The US corporations have been playing catch-up ever since, with some success.

The assembly line has been relegated to simple product lines in successful organizations. In these organizations, especially the large ones, automation has replaced the perfunctory assembly tasks, reducing the unskilled work force and requiring those that remain to tend the machines and design the process to be

more skilled than ever. And in the really successful companies, the concept of micro management from the top has become a dirty word. Automation has brought the robot onto the production-line floor. The robot is one of two main types of automatons: the humanlike and non-human-like machine. The former is called an *android*.

## *AI*

In 1920, the engineer Leonard Torres demonstrated his electromechanical “arithmometer” which would take-in an arithmetic problem, typed in at a typewriter, and then type out the answer to the same typewriter. He even suggested that more than one typewriter could be attached to the machine, introducing the concept of time sharing. In this concept is the dumb terminal attached to a smart computing machine. But was Torres’s machine the first modern computer?

In 1915, Torres revealed his end-game playing chess machine. The machine was capable of mating an enemy king using only its own king and a rook – not a big deal for a human, but for a machine, it evoked the sense that the machine was doing some sort of thinking. This should provoke us to ask whether human thought is extraordinary at all. Today, chess machines can beat even grandmasters of the game. Either we must redefine what human thought is, or claim that chess machines can think, or claim that chess grandmasters can’t!

Torres built a number of machines to find roots to polynomials. Ironically, Torres admitted that his “algebra machine” knew more math than he did.

In 1919, Karl Pearson (the “Father of Applied Statistics”) wrote a pamphlet called “Tracts for Computers” to teach “computers” (i.e., humans, as the term meant at the time) how to use a calculator. In the 1920s, British astronomer L.J. Comrie got the scientific community interested in computing machines after he used them to produce an accurate nautical almanac. He then used the National-Ellis 300 and Burroughs Class 16 machines as a difference engine to produce nautical tables. It was in this machine that Babbage’s concept of a “difference engine” was finally realized almost a hundred years after its conception.

In 1926, Comrie used his machine to calculate the periodic positions of the moon from 1935 to the year 2000. He used half a million Hollerith cards in the process. It’s easy to see why IBM found that it was their punch cards and not the computers themselves that was the big profit engine for them. But this would someday change, in spite of IBM’s lack of initiative to foresee it.<sup>1</sup>

## *EDUCATIONAL STATISTICS*

In 1928, educational statistician Thomas J. Watson persuaded IBM to lend Columbia University three truckloads of equipment for educational statistics research. The research group came to be known as the Columbia Statistics Bureau. While Ben D. Wood worked as a staff at Columbia University Statistics Bureau, he initiated the use of technology in education reform. IBM helped

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<sup>1</sup>The history of business teaches us that companies that stay competitive over the long term have adopted the “always room for improvement” mentality.

Woods research into large-scale testing by creating a machine called the Packard.

On March 1, 1928, the New York World published an article entitled “Super Computing Machines Shown.” So, the hype over “Super Computing” machines is nothing new. In the early 1930s, Harold Black was trying to improve telephone line transmission. His problem to solve was the distortion caused by necessary amplification of the signal as it moves over large distances. This effect increases the noise on the line and decreased the number of simultaneous calls on it. Black hit upon the idea of negative feedback to contain the distortion. By negative feedback some output energy goes back into the circuit.

IBM makes another blip on the innovation screen again in the late 1930s to facilitate the US Social Security office to collate its data. For this purpose, they introduced the IBM 077. The computer has always been a machine in search of a new application. In the 1930s, John Wilbur of M.I.T. built a Simultaneous Equation Solver, which economist Wassily Leontief used to model economic impacts of events on a system as a whole. The input-output scheme was modeled as a set of simultaneous differential equations to solve.

In 1933, an assistant astronomer named Wallace T. Eckert was out to establish his lab as a “scientific laboratory of a revolutionary nature.” Eckert’s first claim to fame is that he used his IBM 601 machine and E.W. Brown’s tables on lunar motion to predict that the earth’s own motion had a previously undetected wobble to it. The second was just how Eckert connected his machines together—networked in some sense—to arrive at his “mechanical programmer.”

In 1930, Vannevar Bush built a machine to solve differential equations to aid in the analysis of power networks. Bush called it a “differential analyzer.”

Then in 1933, the British physicist Douglas R. Hartree used Bush’s differential analyzer to solve for approximate solutions to problems in quantum mechanics. A year later, he joined with Arthur Porter to build a “full scale” differential analyzer.

In 1936, in Berlin Konrad Zane began building one large calculating machine after another, and all in the family living room of his parent’s apartment. By the end of the war he had developed binary arithmetic, floating decimal point, program control, and a primitive programming language, called “plan calculus.” Only, Berlin was not the best place to invent technology on your own. Zane’s computer was destroyed by the bombing of Berlin during the war.

The theoretical groundwork for switching calculating machines from mechanical gears to electrical circuits was laid in 1937 by M.I.T. engineering graduate student Claude E. Shannon in his master’s thesis. His idea for the paper came from his part-time job operating a Bush differential analyzer.

In 1937, Harvard graduate student Howard H. Aiken worked with IBM to produce the so-called “Harvard Calculator,” which was capable of aiding calculations in physics, economics, and other fields. Inspired by the Harvard Calculator, IBM set off to build an even better machine, which was completed in 1944 and called the “Mark 1,” the world’s first automatic special-purpose digital computer.

During WW2, robotically controlled anti-aircraft guns were used to shoot down German V1 missiles over England, and with a very high success rate. It

used an electronic device called an operational amplifier, which used vacuum tubes.

### *THE PROBLEM OF ENIAC*

Generally considered to be the first general-purpose digital computer was the ENIAC (Electronic Numerical Integrator and Computer), started in 1943 and completed in 1946. One early task for ENIAC—and the reason it was funded by the government—was to produce ballistics tables for the armed services. This is quite a humble beginning for the machine that was to start off the computer revolution. The ENIAC is the central point of focus for the history of the electronic digital general-purpose computer. There were many electronic digital computers made before ENIAC, but they were special-purpose machines, not able to be programmed to do virtually anything. This is what makes ENIAC so important.<sup>2</sup>

So, let's take a moment to review the activities of the key players involved. It will be fraught with contradictory claims by those involved, and the motives of many of them have to be seriously questioned. In the end only the reader can decide for him or herself.

The start of the controversy goes back to the claims of one Ames, Iowa mathematician named John Vincent Atanasoff and his work to build an electronic digital special-purpose computer (using vacuum tubes). Evidently, he had succeeded in creating something that worked like a computer—he had at least the right ideas in place. Then, just before America got into the Second World War, he attended a lecture given by John Mauchly, a physics professor from Ursinus College, Collegeville, Pennsylvania. His lecture was on using analog computers to aid in the prediction of weather.

At the end of the lecture Atanasoff introduced himself to Mauchly and told him of his work in digital computing. Supposedly, Mauchly had been working on digital computing but he didn't let Atanasoff know that. Anyway, Atanasoff invited Mauchly to Ames to see his work, and Mauchly went. According to Mauchly, his trip to see Atanasoff's work was a waste of time since it was no more developed than his own work.

Mauchly then left to the respected Moore School to attend a class in electronics—a class he couldn't get at Ursinus. The class was prompted by the impending war about to engulf the U.S. For Mauchly, the only important thing to come of this summer class in 1941 was his meeting the lab instructor J. Presper Eckert, Jr (not to be confused with Wallace Eckert we spoke of earlier). They found their interests in the computer compatible and they agreed to work together on building the next-generation computer.

Mauchly and Eckert found themselves at the right place and right time to get support for their project. The Army needed to develop ballistics tables for the coming war. The methods available at the time were too time consuming, either for humans or for analog machines then available. The problem was that each

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<sup>2</sup>Yes, ENIAC could be reconfigured for different purposes, but this was a laborious physical task involving rewiring the multitude connections in the giant machine.

big gun has its own personality which must be factored into the computations. This part was determined at the ballistics range at Aberdeen. When America entered the war, the mathematician Herman Goldstine enlisted and became a first lieutenant, working at Aberdeen. He pushed for better computers to be developed.

Then Mauchly wrote a memo to his head administrator at the Moore School (John Grist Brainerd) about his desire to build an electronic computer. The memo was supposed to be distributed to various members of the faculty, but it was misplaced before anyone else read it (an unfortunate similar fate had occurred to the mathematician Galois more than a century earlier).

Mauchly met Goldstine at the Moore School and tried to sell him on his idea of an electronic computer. Goldstine was interested and asked for Mauchly to write a memo on it. Mauchly told him to see Brainerd about that, but when the memo couldn't be found, Mauchly had the secretary make up another one from her notes. Goldstine was impressed enough to take their proposal to his superiors and argue for its funding. This was done, and they accepted. The U.S. Army would be in charge of building the first general-purpose electronic digital computer. Only, the twist was that the project was classified SECRET. (The importance of this fact will be made clear soon.)

On 17 May 1943, the project to build ENIAC was officially begun. The chief participants were Goldstine as technical advisor, Brainerd as Project head, Eckert as chief engineer, and Mauchly as principal consultant. Brainerd worked only as an administrator for the project. One of the major criticisms leveled against the ENIAC project was that it could never work, because it used thousands of vacuum tubes, and they would all have to work simultaneously for the machine to work. But vacuum tubes of that day were highly unreliable. Eckert knew the solution, though. He designed the circuits so that the tubes would be run at a small fraction of their rated current capacity, thus greatly increasing the reliability of the tubes. Another source of unreliability is the measuring of current in a given tube. To measure the current precisely would be undoable. But to measure whether the current was on or off was doable. So, the binary (on or off) use of the tubes was designed into the machine. Furthermore, the entire machine was conceived as a collection of 30 modules. Very modern in its design. Goldstine would later credit Eckert's fastidious engineering standards laid on the team as the real reason for the success of ENIAC.

When finished in 1946, ENIAC used 17,468 vacuum tubes and took up 1,800 square feet. It was the world's first general-purpose electronic digital computer. It used IBM punch cards to encode computer information. But even before the ENIAC project was finished, the group was planning an even better computer, called the Electronic Discrete Variable Automatic Computer, or EDVAC. Of course, Mauchly and Eckert wanted to gain the credit for the work and vision they put into the ENIAC project, which is only right. But what happened next depended a great deal on the Wartime nature of the project, on a range of conflicting interests, the non-profit views of the Moore School, and on a chance visit to the facility by a world-renown mathematician some months earlier.

So, let's go back a bit to the chance visit of the famous mathematician

John von Neumann (pronounced fon-NOYmahn). John von Neumann was born in Budapest, Hungary in 1903. From his earliest years, he was interested in mathematics. In 1931, he emigrated to the United States and the following year took a permanent job at Princeton University.

In 1944, he was working on the Manhattan Project, doing calculations on implausible explosions as a means to detonating an atom bomb. The complications of his calculations naturally led him into the area of electronic calculation. Then, while von Neumann was visiting Aberdeen, he had a chance meeting with Goldstine, who promptly told him all about the ENIAC project. After von Neumann got clearance to visit the facility, he did so in September of 1944. He was later signed on as a consultant on EDVAC project.

Now we come to the really controversial part of the ENIAC matter: Who came up with the idea of memory-stored programming? (I really don't see the significance of this matter, since it seems all too obvious a need. Without it the computer will never be as fast as it needs to be.) I will take the position that Mauchly and Eckert were working on memory and memory-stored programming before von Neumann entered the act. All the hard evidence supports this view (but, admittedly, I'm not an expert on this matter).

Whether for right or wrong, Mauchly and Eckert wanted to pursue patents on ENIAC and EDVAC. This allegedly infuriated von Neumann, who wanted the machines in the public domain—supposedly. But I have my doubts as to the sincerity of this claim. The questions to ask in judging von Neumann's sincerity in all this are: Did von Neumann initiate due credit to Mauchly and Eckert for their intellectual labors? Did he violate security clearances in his rush to publish on EDVAC? Did he allow others to credit him with the invention of ENIAC without setting the record straight? In June of 1945, von Neumann distributed a "First Draft" of his now-famous paper on the theoretical ideas of the EDVAC machine, including the idea of computer memory-stored programming. The paper did not credit Mauchly or Eckert for any of their contributions to the field.

Goldstine distributed the paper to the researchers at the Moore School. When Mauchly and Eckert read the paper they were rightfully infuriated. It violated security—it was, after all, a secret Army wartime project. (Apparently von Neumann and Goldstine took it upon themselves to decide to "de-classify" the project.)

Another reason M & E were angry was because this paper undermined their claim to having invented the idea of the mechanisms that made their computer successful. The "First-Draft" paper made no mention of M & E, and this hurt their chances of obtaining the patent rights on their inventions. ENIAC was delivered to the Army in May 1945, and it was unveiled to the public in February 1946, after its secrecy status was dropped.

Moore School administrators did not like M & E pursuing patents, so they gave them the ultimatum to drop their patents pursuit on ENIAC and EDVAC. They refused and were eventually fired for it. The Moore School had started out as the center of modern computer development only to end up in the backwash of computer history. In the history of the computer there are only those that

see its potential and seize it, and those that miss that crucial opportunity that comes so rarely. (Nevertheless, there's always the possibility of a misstep along the way to undermine all you've accomplished.)

This brings us back to our central controversial figure of the story, “Johnny-come-lately” von Neumann. Whatever his motive was for purloining the credit from M & E, he was perhaps this century's most ardent advancer of computer technology. He became a prophet of the “computer age.” He foresaw its future, but he couldn't keep the future from making its own judgments on his own behavior in the matter.<sup>3</sup>

Goldstine's account of the Mauchly-Atanasoff original meeting at Atanasoff's home was that the basic ideas of the ENIAC and EDVAC designs were already known to Atanasoff, and Mauchly was just stealing them from Atanasoff. (Goldstine, 148). But if this is true, then what becomes of von Neumann's claim to have invented the idea of memory-stored programming? Goldstine is not shy in revealing his admiration of von Neumann, and it is perhaps an indirect apologetic for von Neumann's omission of M & E's name on the “First Draft” when he says (Goldstine, 200): “All this must make clear that the fall of 1944 was perhaps the most eventful time in the intellectual history of the computer. All evidence from the correspondence of the period certainly bears this out. It also helps reinforce the comments in the previous section about the general impossibility and impracticability of sorting out authorship of ideas.”

As a summary of the contentions held between M & E and von Neumann and Goldstine, Goldstine wrote (p. 223): “As we mentioned above, when the discussions leading up to von Neumann's First Draft had taken place it had been against a background of complete mutual openness and desire to produce to best possible ideas. Later it turned out that Eckert and Mauchly viewed themselves as the inventors or discoverers of all the ideas and concepts underlying the EDVAC. This view was strenuously opposed by von Neumann and me...” Von Neumann contributed substantially to the ENIAC/EDVAC projects—this is indisputable. But his resistance to give M & E their due credit, as a debt to historical truth and a courtesy to his fellow human beings, was probably responsible for their over-reactionary claims.

The upshot of M & E's effort to obtain patent rights was that the lawyers determined that the publication of the First Draft by von Neumann had legally placed the potential EDVAC patents into the public domain. M & E lost their bid for its patents. The reason why M & E hadn't published before von Neumann was because the project was classified ‘secret’ at the time that von Neumann published, which seemed a point lost on Goldstine and von Neumann. More people know about von Neumann than Mauchly and Eckert. In fact, the modern computer is often referred to as a “von Neumann machine.” Perhaps people refuse to see the character flaws of their idols. But I have to wonder if all this adulation towards von Neumann would have occurred if Mauchly and Eckert had been renown mathematicians just like von Neumann.

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<sup>3</sup>Personally, I'm a fan of the intellectual accomplishments of von Neumann. I'm also a fan, as apparently he was, of placing inventions in the public domain. But we must be careful not to arrogate to ourselves too much, because people in the private domain have rights, too.

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