ENIAC U. S. Army

ENIAC: The Army-Sponsored Revolution

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Fifty years ago, the U.S. Army unveiled the Electronic Numerical Integrator and Computer (ENIAC) the world's first operational, general purpose, electronic digital computer, developed at the Moore School of Electrical Engineering, University of Pennsylvania. Of the scientific developments spurred by World War II, ENIAC ranks as one of the most influential and pervasive.

The origins of BRL lie in World War I, when pioneering work was done in the Office of the Chief of Ordnance, and especially the Ballistics Branch created within the Office in 1918. In 1938, the activity, known as the Research Division at Aberdeen Proving Ground (APG), Maryland, was renamed the Ballistic Research Laboratory. In 1985, BRL became part of LABCOM. In the transition to ARL, BRL formed the core of the Weapons Technology Directorate, with computer technology elements migrating to the Advanced Computational and Information Sciences Directorate (now Advanced Simulation and High-Performance Computing Directorate, ASHPC), and vulnerability analysis moving into the Survivability/Lethality Analysis Directorate (SLAD).

The need to speed the calculation and improve the accuracy of the firing and bombing tables constantly pushed the ballisticians at Aberdeen. As early as 1932, personnel in the Ballistic Section had investigated the possible use of a Bush differential analyzer. Finally, arrangements were made for construction, and a machine was installed in 1935 as a Depression-era "relief" project. Shortly thereafter, lab leadership became interested in the possibility of using electrical calculating machines, and members of the staff visited International Business Machines in 1938. Shortage of funds and other difficulties delayed acquisition until 1941, when a tabulator and a multiplier were delivered.

With the outbreak of the war, work began to pile up, and in June 1942, the Ordnance Department contracted with Moore School to operate its somewhat faster Bush differential analyzer exclusively for the Army. Captain Paul N. Gillon, then in charge of ballistic computations at BRL, requested that Lieutenant Herman H. Goldstine be assigned to duty at the Moore School as supervisor of the computational and training activities. This put Goldstine, a Ph.D. mathematician, and the BRL annex of firing table personnel in the middle of a very talented group of scientists and engineers, among them Dr. John W. Mauchly, a physicist, and J. Presper Eckert, Jr., an engineer.

Despite operating the computing branch with analyzer at APG and the sister branch and analyzer at Moore School, BRL could not keep up with new demands for tables, coming in at the rate of about six a day. Goldstine and the others searched for ways to improve the process. Mauchly had come to Penn shortly after his 1941 visit with John Vincent Atanasoff at Iowa State College to discuss the latter's work on an electronic computer. In the fall of 1942, Mauchly wrote a memorandum, sketching his concept of an electronic computer, developed in consultation with Eckert. Ensuing discussions impressed Goldstine that higher speeds could be achieved than with mechanical devices.

About this time, Captain Gillon had been assigned to the Office of the Chief of Ordnance as deputy chief of the Service Branch of the Technical Division, with responsibility for the research activities of the Department. Early in 1943, Goldstine and Professor John Grist Brainerd, Moore School's director of war research, took to Gillon an outline of the technical concepts underlying the design of an electronic computer. Mauchly, Eckert, Brainerd, Dr. Harold Pender (Dean of Moore School), and other members of the staff worked rapidly to develop a proposal presented to Colonel Leslie E. Simon, BRL Director, in April and immediately submitted to the Chief of Ordnance. A contract was signed in June.

The so-called "Project PX" was placed under the supervision of Brainerd, with Eckert as chief engineer and Mauchly as principal consultant. Goldstine was the resident supervisor for the Ordnance Department and contributed greatly to the mathematical side, as well. Three other principal designers worked closely on the project: Arthur W. Burks, Thomas Kite Sharpless, and Robert F. Shaw. Gillon provided crucial support at Department level.

The original agreement committed $61,700 in Ordnance funds. Supplements extended the work, increased the amount to a total of $486,804.22, and assigned technical supervision to BRL. Construction began in June 1944, with final assembly in the fall of 1945, and the formal dedication in February 1946.

The only mechanical elements in the final system were actually external to the calculator itself. These were an IBM card reader for input, a card punch for out-put, and the 1,500 associated relays. By today's standards, ENIAC was a monster with its 18,000 vacuum tubes, but ENIAC was the prototype from which most other modern computers evolved. Its impact on the generation of firing tables was obvious. A skilled person with a desk calculator could compute a 60 second trajectory in about 20 hours; the Bush differential analyzer produced the same result in 15 minutes; but the ENIAC required only 30 seconds, less than the flight time.

During World War II, a "computer" was a person who calculated artillery firing tables using a desk calculator. Six women "computers" were assigned to serve as ENIAC's original programming group. Although most were college graduates, the "girls" were told that only "men" could get professional ratings. Finally, in November 1946, many of the women received professional ratings.

ENIAC's first application was to solve an important problem for the Manhatten Project. Involved were Nicholas Metropolis and Stanley Frankel from the Los Alamos National Laboratory, who worked with Eckert, Mauchly, and the women programmers. Captain (Dr.) Goldstine and his wife, Adele, taught Metropolis and Frankel how to program the machine, and the "girls" would come in and set the switches according to the prepared program. In fact, the scheduled movement of ENIAC to APG was delayed so that the "test" could be completed before the machine was moved.

Late in 1946, ENIAC was dismantled, arriving in Aberdeen in January 1947. It was operational again in August 1947 and represented "the largest collection of interconnected electronic circuitry then in existence."

ENIAC as built was never copied, and its influence on the logic and circuitry of succeeding machines was not great. However, its development and the interactions among people associated with it critically impacted future generations of computers. Indeed, two activities generated by the BRL/Moore School programs, a paper and a series of lectures, profoundly influenced the direction of computer development for the next several years.

During the design and construction phases on the ENIAC, it had been necessary to freeze its engineering designs early on in order to develop the operational computer so urgently needed. At the same time, as construction proceeded and the staff could operate prototypes, it because obvious that it was both possible and desirable to design a computer that would be smaller and yet would have greater flexibility and better mathematical performance.

By late 1943 or early 1944, members of the team had begun to develop concepts to solve one of ENIAC's major shortcomings -- the lack of an internally stored program capability. That is, as originally designed, the program was set up manually by setting switches and cable connections. But in July 1944, the team agreed that, as work on ENIAC permitted, they would pursue development of a stored-program computer.

At this point, in August 1944, one of the most important and innovative (and influential) scientists of the 20th century joined the story. Dr. John L. von Neumann of the Institute of Advanced Studies (IAS) at Princeton was a member of BRL's Scientific Advisory Board. During the first week of August, Goldstine met von Neumann on the platform at the Aberdeen train station and told him about the ENIAC project. A few days later, Goldstine took von Neumann to see the machine. From this time on, von Neumann became a frequent visitor to the Moore School, eagerly joining discussions about the new and improved machine that would store its "instructions" in an internal memory system. In fact, von Neumann participated in the board meeting at Aberdeen on August 29 that recommended funding the Electronic Discrete Variable Computer (EDVAC).

In October 1944, the Ordnance Department approved $105,600 in funds for developing the new machine. In June 1945, von Neumann produced "First Draft of a Report on the EDVAC," a seminal document in computer history and a controversial one. It was intended as a first draft for circulation among the team; however, it was widely circulated, and other members of the team were annoyed to find little or no mention of their own contributions. This, combined with patent rights disputes, led to several confrontations and the later breakup of the team.

The second of the great influences was a series of 48 lectures given at the Moore School in July and August 1946, entitled "Theory and Techniques for the Design of Electronic Digital Computers." Eckert and Mauchly were both principal lecturers, even though they had left Moore School to form their own company. Other principals included Burks, Sharpless, and Chuan Chu. Officially, 28 people from both sides of the Atlantic attended, but many more attended at least one lecture.

Although most "students" expected the sessions to focus on ENIAC, many lecturers discussed designs and concepts for the new, improved machine, EDVAC. Together, von Neumann's paper and the Moore School lectures circulated enough information about EDVAC that its design became the basis for several machines. The most important of these were two British machines the EDSAC (Electronic Delay Storage Automatic Computer) built by Maurice V. Wilkes at the Mathematical Laboratory at Cambridge University and completed in 1949 and the Mark I developed by F. C. Williams (later joined by Alan M. Turing) at the University of Manchester and completed in 1951 in cooperation with Ferranti, Ltd.; and one U.S. machine, the Standards Automatic Computer (SEAC) developed at the National Bureau of Standards and completed in 1950.

Meanwhile, despite the breakup on the team, BRL still had a contract with the Moore School for construction of EDVAC. It was decided that Moore School would design and build a preliminary model, while IAS would undertake a program to develop a large-scale comprehensive computer. Basic construction of EDVAC was performed at Moore School, and beginning in August 1949, it was moved to its permanent home at APG.

Although EDVAC was reported as basically complete, it did not run its first application program until two years later, in October 1951. As one observer put it, "Of course, the EDVAC was always threatening to work." As constructed, EDVAC differed from the early von Neumann designs and suffered frequent redesigns and modifications. In fact, at BRL, even after it achieved reasonably routine operational status, it was largely overshadowed by the lab's new machine, the Ordnance Variable Automatic Computer (ORDVAC), installed in 1952. Interestingly, ORDVAC's basic logic was developed by von Neumann's group at IAS.

Meanwhile, in 1948 after reassembly at APG, ENIAC was converted into an internally stored-fixed program computer through the use of a converter code. In ensuing years, other improvements were made. An independent motor-electricity generator set was installed to provide steady, reliable power, along with a high-speed electronic shifter, and a 100-word static magnetic-core memory developed by Burroughs Corp.

During the period 1948-1955, when it was retired, ENIAC was operated successfully for a total of 80,223 hours of operation. In addition to ballistics, fields of application included weather prediction, atomic energy calculations, cosmic ray studies, thermal ignition, random-number studies, wind tunnel design, and other scientific uses.

Significantly, the Army also made ENIAC available to universities free of charge, and a number of problems were run under this arrangement, including studies of compressible laminar boundary layer flow (Cambridge, 1946), zero-pressure properties of diatomic gases (Penn, 1946), and reflection and refraction of plane shock waves (IAS, 1947).

The formal dedication and dinner were held on February 15, 1946 in Houston Hall on the Penn Campus. The Penn president presided, and the president of the National Academy of Sciences was the featured speaker. Major General Gladeon M. Barnes, Chief of Research and Development in the Office of the Chief of Ordnance, pressed the button that turned on ENIAC. To commemorate this event, on February 14, 1996, Penn, the Association for Computing Machinery (ACM), the City of Philadelphia, and others are sponsoring a "reactivation" ceremony and celebratory dinner. As part of the ACM convention, ARL will sponsor a session on Sunday, 18 February, to present the story of Army/BRL achievement. One of the speakers will be Dr. Herman H. Goldstine.

Considerable information, including pictures, is available on the World Wide Web. Visit the ARL homepage. For more information on the image archives, visit http://ftp.arl.army.mil/~mike/comphist/ and select the "Photographs of Historic Computers" entry.

Special thanks are due the ARL Technical Library at APG for access to historical materials in their "vault."