EVOLVING FROM CALCULATORS TO COMPUTERS

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Computers were people using desk calculators when Los Alamos began. By the end of the war, Los Alamos scientists were using the first electronic computer. **John von Neumann** was the primary agent of this change, which led to the Laboratory's strong program in computer science and technology, as well as making it possible to calculate the behavior of nuclear explosives.

Early calculations relating to the diffusion of neutrons in a critical assembly of uranium were made by Eldred Nelson and Stanley Frankel, who were members of Robert Serber's group in the Radiation Laboratory at the University of California, Berkeley, in 1942. When they came to Los Alamos in the spring of 1943, they ordered the same sorts of machines that they had used in California: Marchant and Friden desk calculators to make the calculations required in the design of nuclear weapons.

To perform some of these repetitive calculations, a group of scientists' wives were recruited to form a central computing pool. These "computers" included Stanley Frankel's wife, Mary; Josephine Elliott; Beatrice Langer; Mici Teller; Jean Bacher; and Betty Inglis. This became group T-5 under New York University mathematician Donald (Moll) Flanders when he arrived in the late summer of 1943.

The mechanical calculators tended to break down under heavy use by physicists and had to be shipped back to the manufacturer until physicists Richard Feynman of Princeton University and Nicholas Metropolis of the University of Chicago learned to repair them. Although Theoretical (T) Division Leader Hans Bethe at first objected that this was a waste of time, he relented when the number of working calculators diminished.

Dana Mitchell, whom Laboratory Director J. Robert Oppenheimer had recruited from Columbia University to oversee procurement for Los Alamos, recognized that the calculators were not adequate for the heavy computational chores and suggested the use of IBM punched-card machines. He had seen them used successfully by Wallace Eckert at Columbia to calculate the orbits of planets and persuaded Frankel and Nelson to order a complement of them.

In September 1943, von Neumann made the first of many visits to Los Alamos. A mathematician at the Institute for Advanced Study at Princeton, he had been asked by Oppenheimer to serve as a consultant in hydrodynamics, and during his visits he became aware of the work on implosion being conducted by Seth Neddermeyer and his group.

Von Neumann, who also was a consultant on explosives for the Army, pointed out that shaped charges could be used to produce a more uniform shock wave for this purpose. He subsequently developed Neddermeyer's one-dimensional theory of implosion with Edward Teller, the theoretical physicist from the Metallurgical Laboratory of the University of Chicago. When von Neumann had difficulty with the pure high-density incompressible phase of implosion, he suggested a test implosion to determine physical quantities that could not be calculated

analytically. He subsequently formulated another model for computation, and Teller set up a group in T Division devoted to the theory of implosion.

The new IBM punched-card machines were devoted to calculations to simulate implosion, and Metropolis and Feynman organized a race between them and the hand-computing group. "We set up a room with girls in it. Each one had a Marchant. But one was the multiplier, and another was the adder, and this one cubed, and all she did was cube this number and send it to the next one," said Feynmann. For one day, the hand computers kept up: "The only difference was that the IBM machines didn't get tired and could work three shifts. But the girls got tired after a while."

Feynmann worked out a technique to run several calculations in parallel on the punched-card machines that reduced the time required. "The problems consisted of a bunch of cards that had to go through a cycle. First add, then multiply, and so it went through the cycle of machines in this room - slowly - as it went around and around. So we figured a way to put a different colored set of cards through a cycle too, but out of phase. We'd do two or three problems at a time," explained Feynman. Three months were required for the first calculation, and Feynman's technique reduced it to two or three weeks.

The first implosion calculation showed that the fissile material would be strongly compressed and that a high yield would result from assembling a relatively small amount of fissile material if a spherically symmetrical implosion was produced. Although much work on explosives lenses, detonators and other components of the device was required to accomplish this, the Trinity test July 16, 1945, showed that the calculation was correct. About a dozen other calculations of implosion were done to refine it before the end of the war.

In the meantime, von Neumann brought news of computer developments elsewhere, such as Bell Laboratory's relay computer and Howard Aiken's Mark I electromechanical calculator at Harvard where Aiken was director of the Harvard Computation Laboratory. The Mark I was even used to run an unclassified version of one of the Los Alamos problems. Although it took several times as long as the Los Alamos machines, it computed to far greater precision.

Von Neumann saw that problems like those encountered at Los Alamos could be solved by electronic computers similar to the electronic numerical integrator and calculator (ENIAC) being developed at the University of Pennsylvania. In 1944 and 1945, he formulated ways to translate mathematical procedures into a language of instructions for such a machine. And he recommended to Teller, who had conceived of a thermonuclear or "super" bomb, that one of the computational problems associated with its design be used to test the ENIAC, because it would be much more demanding than the ballistic trajectories the Army had designed it to calculate. Metropolis and Frankel traveled to the University of Pennsylvania early in 1945 to discuss the problem with the developers of ENIAC, John Mauchly and J. Presper Eckert.

The calculations were run in December 1945 and January 1946. A half-million punched cards of data were transferred from Los Alamos to Philadelphia to run it, and mathematician Stan Ulam, who von Neumann had recruited to come to Los Alamos from Princeton, recalled "the spirit of exploration and of belief in the possibility of getting trustworthy answers in the future. This

partly because of the existence of computing machines that could perform much more detailed analysis and modeling of physical problems."

In the postwar era, von Neumann continued to arrange for access to the ENIAC for Los Alamos scientists and also built an improved version of the electronic computer at the Institute for Advanced Study at Princeton, where Oppenheimer became director. Inspired by his example, Los Alamos had Metropolis build the mathematical analyzer, numerical integrator and computer, or MANIAC, which was completed in 1952 and was responsible for the calculations of Mike, the first hydrogen bomb. It was followed by MANIAC II, the IBM-built STRETCH supercomputer and a series of commercial super computers that have made the Laboratory the world's largest scientific computing center.

Von Neumann also helped Ulam and Metropolis develop new means of computing on such machines, including the Monte Carlo method, which has found widespread application. His influence on the development of electronic computers was far-reaching, and he continued to foster their development at Los Alamos up to the time of his death in 1957 while serving on the Atomic Energy Commission.

The wartime work of the Laboratory created a need for computing that stimulated von Neumann, Metropolis, Ulam and others to reduce previously insoluble physical problems to a form in which they could be calculated automatically. The use of these techniques not only made possible the design of nuclear and thermonuclear weapons, but also the solution of many other scientific problems, ranging from aerodynamics to molecular biology. What began with a brief visit to the Laboratory by von Neumann in September 1943, has become a revolution in science and technology.

- Robert W. Seidel