70th Anniversary of the Trinity Test

1945 - 2015

Director's Round Table Discussion

The legacy of the Trinity Test and its enduring significance to national and global security.

July 16, 2015, 8:30 – 10:15 am
Domenici Auditorium

TRINITY TO TRINITY

Los Alamos
NATIONAL LABORATORY
EST. 1943

CHARLES F. MCMILLAN LABORATORY DIRECTOR

It is my pleasure to welcome you to this Director's Round Table. Today, we are marking the 70th anniversary of the Trinity Test—the first test of an atomic weapon—with a discussion we're calling:

TRINITY TO TRINITY

This journey from Trinity to Trinity begins with the New Mexico desert night sky turning instantly to day at 05:29 am on July 16, 1945. An eyewitness recalled,

> *"The effects could well be called unprecedented, magnificent, beautiful, stupendous, and terrifying. The lighting effects beggared description. The whole country was lighted by a searing light with the intensity many times that of the midday sun. It was golden, purple, violet, gray, and blue."*

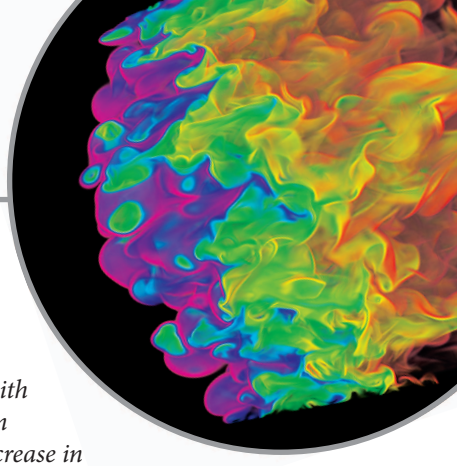
It was the Trinity Test: the world's first nuclear detonation. Trinity was the culmination of a fantastic effort of groundbreaking science and engineering by hundreds of men and women at Los Alamos National Laboratory (and other Manhattan Project sites). It took them less than two years to change the world.

This year, the Laboratory is marking the 70th anniversary of the Trinity Test because it not only ushered in the Nuclear Age, but with it the origin of today's advanced supercomputing. We live in the Age of Supercomputers due in large part to nuclear weapons science here at Los Alamos.

Nuclear weapons and computers go hand in hand. The evolution of computers is directly tied to the evolution of nuclear weapons. Simple computers were key to the design and development of the first nuclear bombs, like the one detonated during the Trinity Test. Throughout the Cold War, evermore-powerful computers were designed and built specifically to aid the design and build cycle that led to today's U.S. nuclear deterrent.

Just as it was 70-years ago, the key mission of Los Alamos is to provide the nation with a safe, secure, and effective nuclear deterrent. Today, how we carry out that mission has changed. From 1945 to 1992 we designed, tested, and built many different types of weapons creating a stockpile at the height of the cold war of more than 30,000 weapons. Today, we use our science and engineering capabilities to ensure that the few thousand of weapons that remain in the deterrent are safe, secure, and effective.

The weapons in the stockpile are built of thousands of components; some of these components are now beyond their expected lifespan. These aging components must be continuously evaluated, replaced, repaired, or redesigned—and then tested where possible. In the absence of full-scale testing, we tie together experimental data, world-class modeling and simulations, and the expert judgment of our scientists and engineers and report our findings to the President of the United States.



Without supercomputing, we couldn't do this. Today, the nation's most powerful supercomputers are designed and used primarily to steward aging nuclear weapons.

This brings our journey to the Trinity supercomputer, which is in the primary stage of becoming fully operational. At 40 petaflops (40 quadrillion [10^{15}] floating point operations per second!) and with 2 petabytes of memory, Trinity will be the second or third fastest computer in the world. Trinity is an essential step in the journey to advancing the technology of supercomputers towards a 1,000-fold increase in performance over today's systems.

But its speed is not as significant as what it will do with its speed and revolutionary new programming; Trinity will make complex, 3D simulations of nuclear detonations practical with increased fidelity and resolution. With Trinity, Los Alamos is blazing the path to the next plateau of computing power: exascale (10^{18} petaflops) computing.

Highly accurate 3D computing is a Holy Grail of the Stockpile Stewardship Program's supercomputing efforts. As the weapons age, 3D features tend to be introduced that require highly accurate 3D modeling to understand. This is a great challenge reminiscent of the one faced by the Manhattan Project. The challenge then was to build the first nuclear weapon that works. Now our challenge is to understand how and why a weapon works well enough to confidently predict its performance without requiring an additional nuclear test. Only time will tell if we are successful in this endeavor.

The Trinity Test of 1945 was the first full-scale, real-world test of a nuclear weapon; with the new Trinity supercomputer our goal is to do this virtually, in 3D.

It is important to realize that because stewarding these weapons depends on an in-depth understanding of mind-bogglingly complicated physics, which we are still unraveling, and because warhead components continue to age—and thus change their characteristics—there is no foreseeable end in sight to the challenges of stockpile stewardship. Highly accurate 3D computing is a critical part of this journey, but not its destination.

I hope what you learn from our speakers today helps you better understand why the nuclear deterrent is so important—it is used everyday to dissuade our adversaries while reassuring our allies—and that supercomputing is key to the Stockpile Stewardship Program's goals: ensuring the stockpile remains safe, secure, and effective.

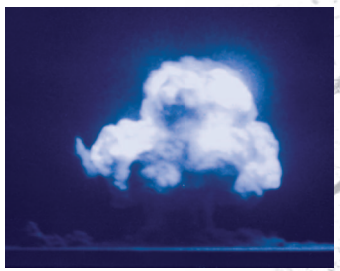
If you want to make a lasting contribution to the security of the United States while using world-class supercomputers, then consider what we do here at Los Alamos. This is where supercomputing began, and we keep pushing its frontiers.

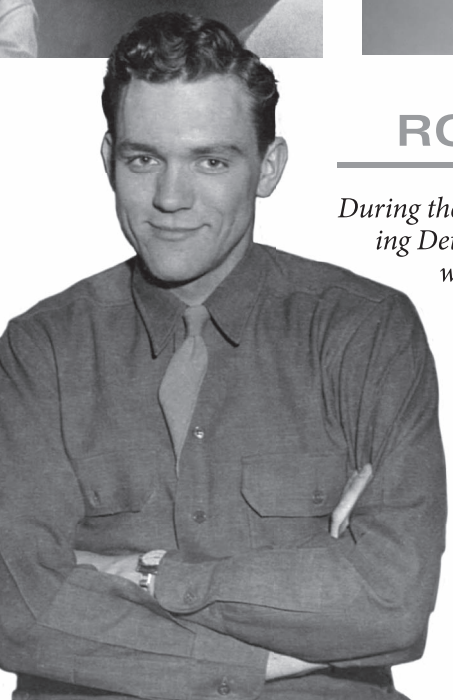
J. ROBERT OPPENHEIMER

The Laboratory's first director, J. Robert Oppenheimer, was born in 1904. Oppenheimer made the critical key decisions that led to the success of Los Alamos National Laboratory, including the key technical decisions related to the designs of both Little Boy and Fat Man.

After the war, Oppenheimer became the Director of the Institute for Advanced Study at Princeton University, which he built into an internationally recognized theoretical physics research center. In 1963, President Lyndon Johnson awarded the Atomic Energy Commission's Fermi Award to Oppenheimer in recognition of his contributions to the nation and to national security.

Very few individuals in the twentieth century had has much impact on the study of nuclear physics, World War II, and the United States as did J. Robert Oppenheimer.





ROGER RASMUSSEN

During the Manhattan Project, Roger Rasmussen was part of the U.S. Army's Special Engineering Detachment. On July 16, 1945, Rasmussen was a member of an evacuation team charged with clearing residents from a top secret area near White Sands, NM, and keeping it clear. In doing so, he witnessed the first atomic weapons test: Trinity.

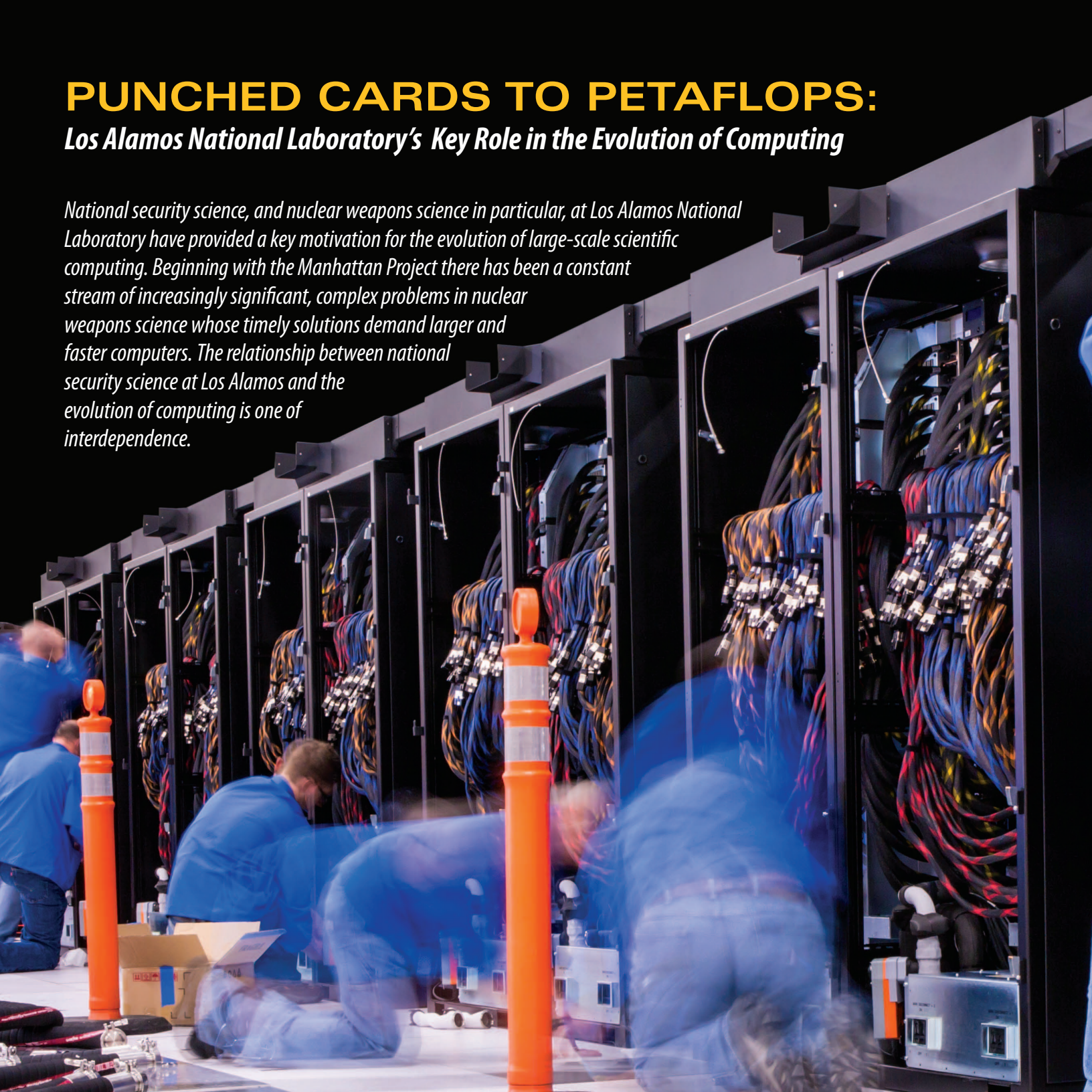
Rasmussen had enlisted in the Army in 1942. He had been pursuing a degree in physics when Pearl Harbor was attacked. It was only 20 days after his 21st birthday.

After the war, Rasmussen finished his education and returned to Los Alamos as a physicist. His career at Los Alamos spanned nearly 40 years. Rasmussen still lives in the town of Los Alamos.

PUNCHED CARDS TO PETAFLOPS:

Los Alamos National Laboratory's Key Role in the Evolution of Computing

National security science, and nuclear weapons science in particular, at Los Alamos National Laboratory have provided a key motivation for the evolution of large-scale scientific computing. Beginning with the Manhattan Project there has been a constant stream of increasingly significant, complex problems in nuclear weapons science whose timely solutions demand larger and faster computers. The relationship between national security science at Los Alamos and the evolution of computing is one of interdependence.



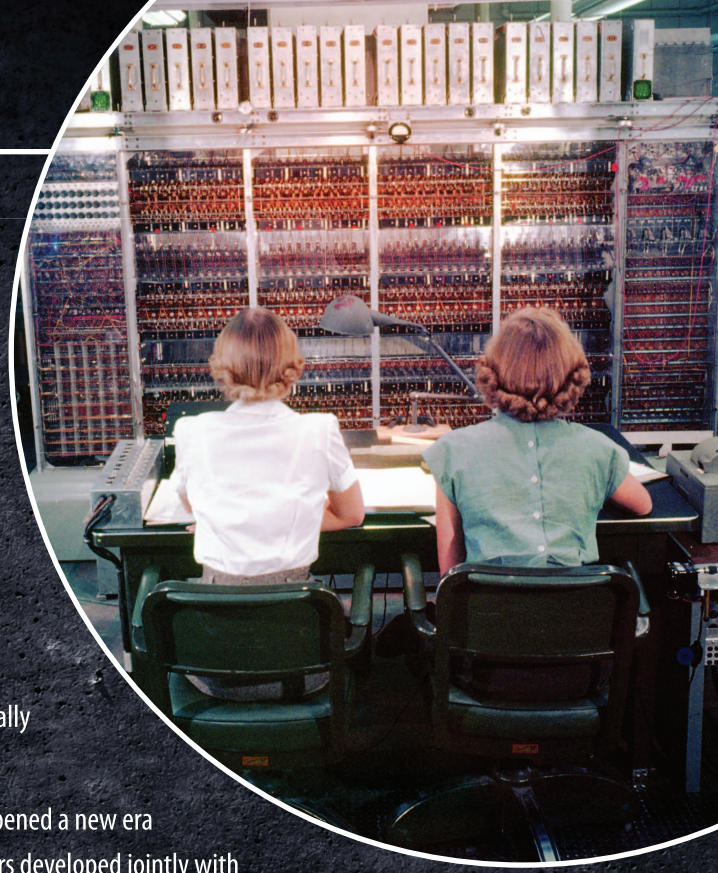
ANALOG ERA

For millennia, humans have needed calculating tools to perform, for example, basic arithmetic, records management, and timekeeping. By the 17th century, advanced analog computers like the slide rule and the first mechanical calculator had evolved. In the late 19th century computers capable of interpreting data, such as advanced punched-card machines (like the player piano), had evolved.

The Laboratory developed and built the first nuclear weapons using simple mechanical calculators, the most useful of which was the Marchant desktop calculator. The women who operated these calculators (often the wives of Los Alamos scientists) were called "computers." International Business Machines (IBM) punched-card machines were also used.

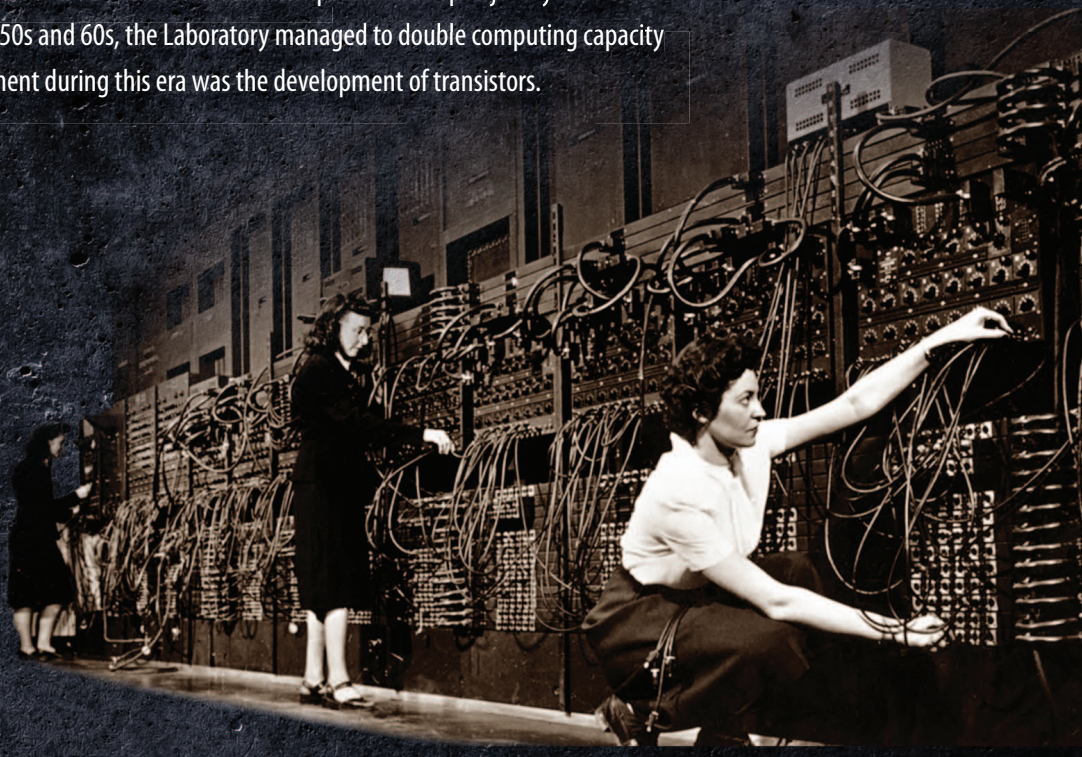
VACUUM TUBE ERA 1946–60

The eminent Hungarian mathematician, John von Neumann, introduced Los Alamos to the world's first electronic digital "computer," the ENIAC (Electronic Numerical Integrator And Computer). The ENIAC was designed to make calculations for the Army's artillery firing tables to help gunners improve accuracy. But first, the ENIAC's was used to perform calculations to design and build the hydrogen bomb. A revolutionary capability, conceived by von Neumann, was the ENIAC's use of programs stored electronically on the machine, which became the basis for all modern computing systems.



In the 1950s digital-electronic computing technology became less expensive, more reliable, and more powerful and commercially produced computers started to gradually displace ENIAC's custom handmade descendants.

The Laboratory purchased its first commercial computer, an IBM 701, in 1953. This opened a new era in Los Alamos computing, dominated by commercial machines and custom computers developed jointly with corporate partners. Throughout much of the 1950s and 60s, the Laboratory managed to double computing capacity every two years. The most significant advancement during this era was the development of transistors.

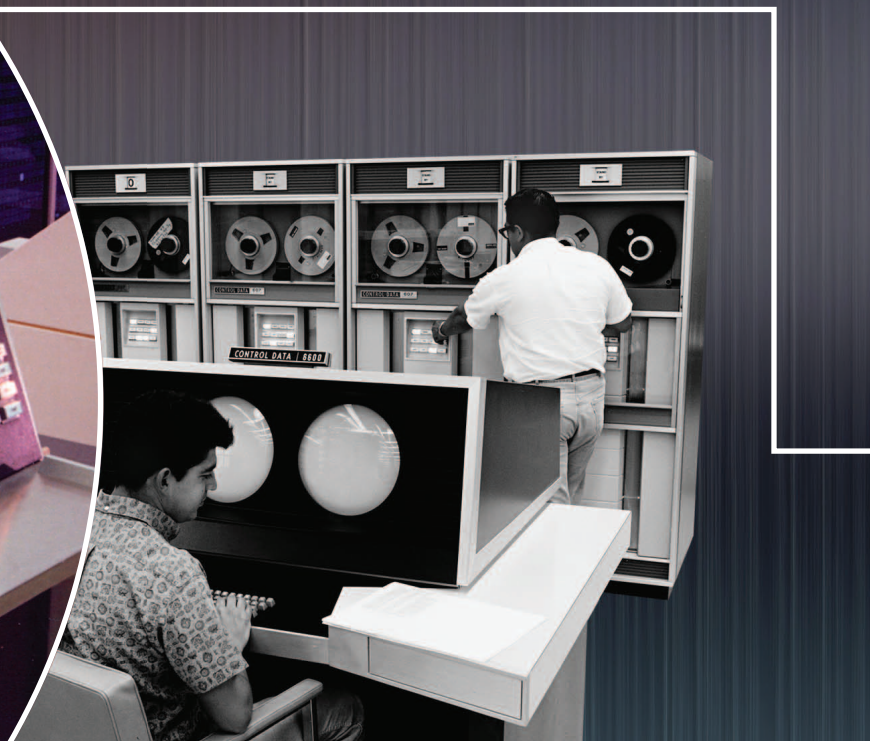


IBM ERA 1960–64

To meet the growing computing needs of the nuclear weapons program, the Laboratory jointly developed with IBM the Stretch, IBM's first transistorized computer. The Stretch, delivered in 1961, retained the title of world's fastest computer into the mid-1960s. Using this technology, IBM began to focus less on government contracts and more on building computers for thousands of commercial clients.

CONTROL DATA CORPORATION (CDC) ERA 1964–76

Needing a new partner, Los Alamos looked to CDC to develop evermore-powerful machines for doing increasingly complex weapon's calculations. CDC delivered by producing the world's first supercomputer, the model 6600. The 6600s were the first computers capable of performing a million floating-point operations per second (megaflops). The even faster CDC 7600 models soon supplemented them.



CRAY ERA 1976–1989

Seymour Cray, the CDC designer who led the development teams that produced the 6600 and 7600, left CDC to start his own company in 1972. Cray Research completed its first design, the revolutionary 160-megaflop Cray-1, in 1975 and delivered it to Los Alamos the following year.

The Cray-1 used integrated circuits and an innovative Freon cooling system to ensure the giant machines did not overheat. Cray also used revolutionary "vector" processing that enabled the Cray-1 to process information far more efficiently than any other computer of its day. During the 1980s, the Laboratory purchased additional Cray computers, most notably the X-MP. The X-MP, which used multiple "vector" processors, reigned as the world's fastest computer from 1982 to 1985.

STOCKPILE STEWARDSHIP ERA 1989–PRESENT

As the 1980s drew to a close, Los Alamos continued to drive the evolution of supercomputing. The Lab partnered with Thinking Machines Corporation (an IBM company) to develop the massively-parallel Connection Machine series that focused on quantity over quality: using thousands of microprocessors (not more powerful ones) to perform numerous calculations simultaneously. This took Lab computing into the gigaflop zone (one billion floating-point operations per second) by 1990.

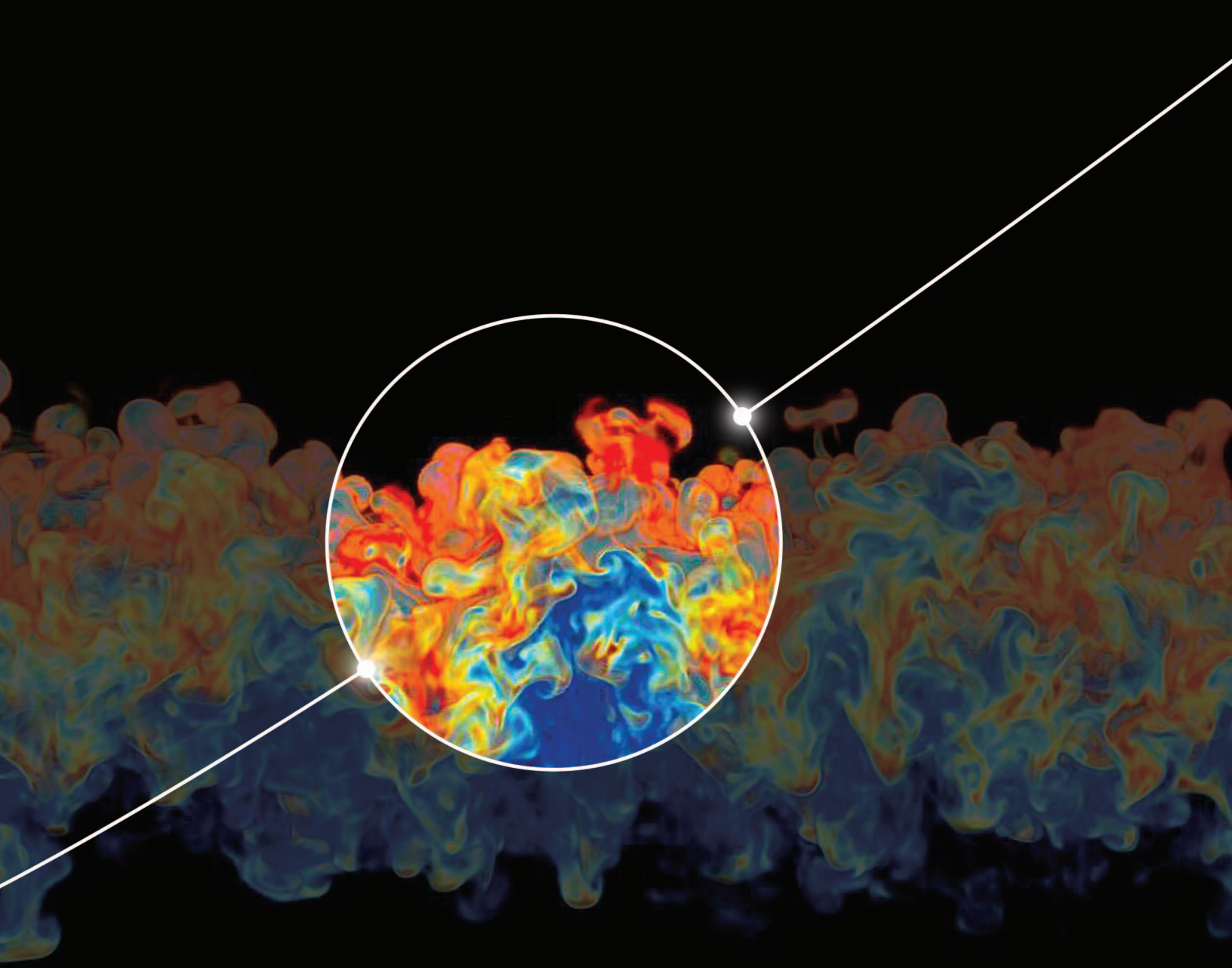
But then the Cold War came to an abrupt end in 1991 and nuclear weapons testing ceased in 1992. To ensure the continued safety, security, and reliability of the nation's nuclear deterrent, President Bill Clinton and the Congress created the Stockpile Stewardship Program in 1994. In lieu of underground nuclear weapons testing, this law called for "an increased level of effort for advanced computational capabilities to enhance the simulation and modeling capabilities of the United States with respect to the detonation of nuclear weapons."

Suddenly, it was necessary to rapidly develop supercomputers powerful enough to replace real-world nuclear testing with virtual testing. This meant eventually being able to create simulations in 3D. Speed was important, but to be useful 3D simulations, resolution and accuracy were even more important. To achieve high-fidelity 3D simulations, computing would need to make incredible technological leaps from gigaflops to teraflops (trillions, in 1999) to petaflops (quadrillions, in 2008) to exaflops (quintillions, coming soon).

TRINITY: SUPERCOMPUTING INTO THE FUTURE

The nation's supercomputing capabilities have evolved in response to needs of the Lab's nuclear weapons program delivering a safe, secure, and effective nuclear deterrent. Today, as the anniversary of the Trinity Test turns 70, the need for 3D simulations has brought the Trinity supercomputer to Los Alamos. Trinity—expected to be the second or third fastest supercomputer in the world—will make complex 3D simulations of nuclear detonations practical, with increased fidelity and resolution. The first phase of Trinity's installation began in June.

WELCOME TO TRINITY AND THE DAWNING OF EXASCALE SUPERCOMPUTING



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National Nuclear Security Administration

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