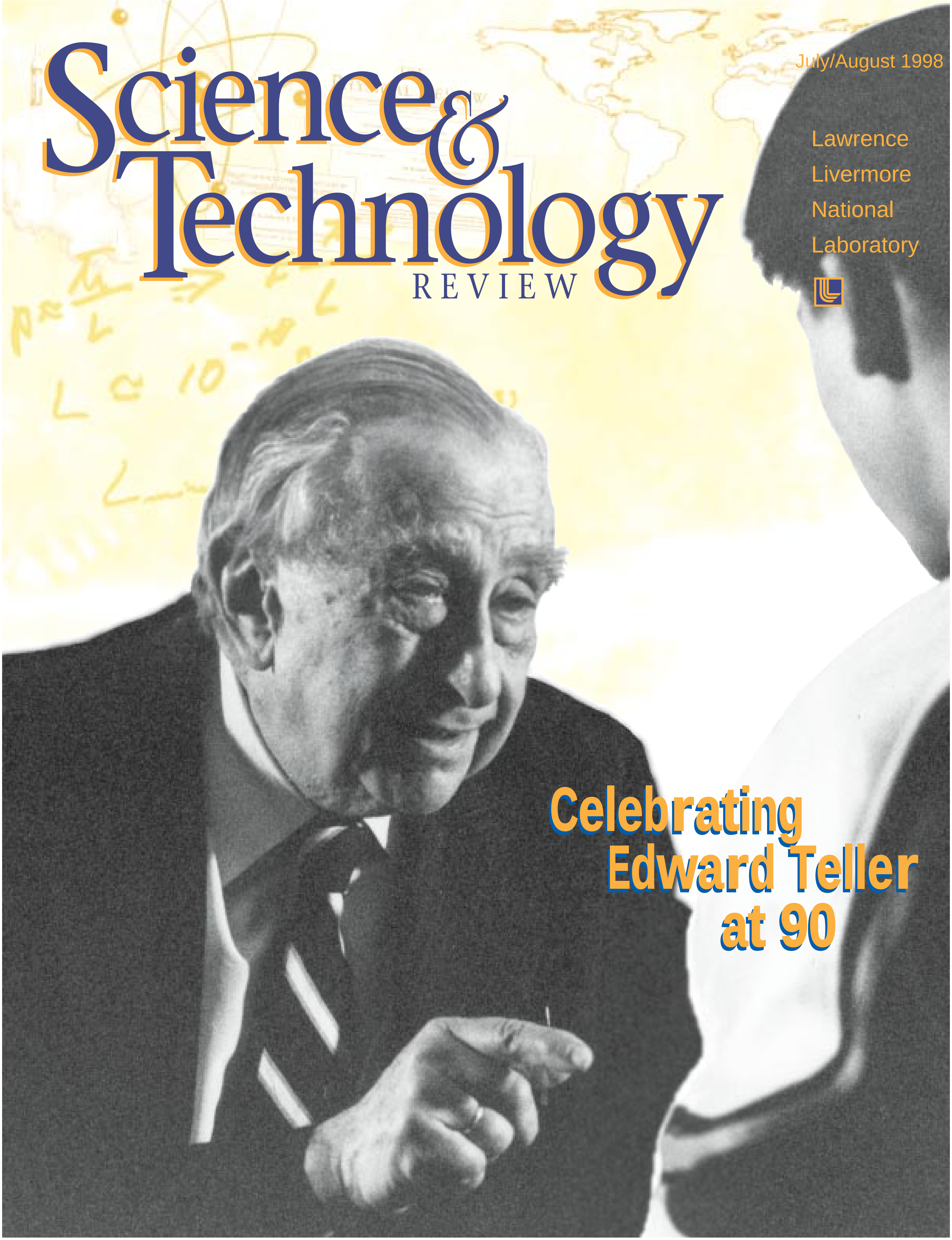
Science & Technology REVIEW

July/August 1998

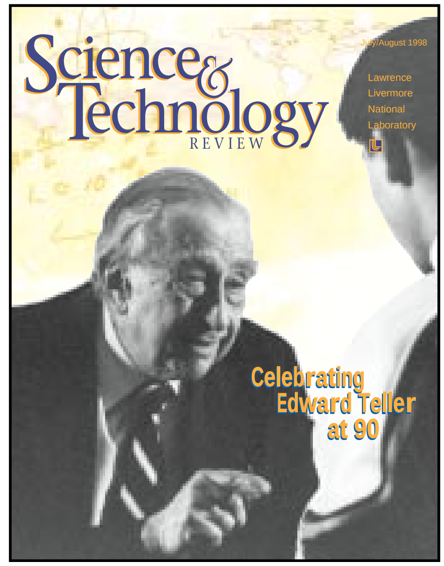
Lawrence
Livermore
National
Laboratory



Celebrating Edward Teller at 90

About the Cover

On the occasion of Edward Teller's 90th birthday, *S&TR* has the pleasure of honoring Lawrence Livermore's co-founder and most influential scientist. Teller is known for his inventive work in physics, his concepts leading to thermonuclear explosions, and his strong stands on such issues as science education, the nation's strategic defense, the needs for science in the future, and sharing scientific information. The articles in this issue also show him, as always, tirelessly moving forward with his new and changing interests.



About the Review

Lawrence Livermore National Laboratory is operated by the University of California for the Department of Energy. At Livermore, we focus science and technology on assuring our nation's security. We also apply that expertise to solve other important national problems in energy, bioscience, and the environment. *Science & Technology Review* is published ten times a year to communicate, to a broad audience, the Laboratory's scientific and technological accomplishments in fulfilling its primary missions. The publication's goal is to help readers understand these accomplishments and appreciate their value to the individual citizen, the nation, and the world.

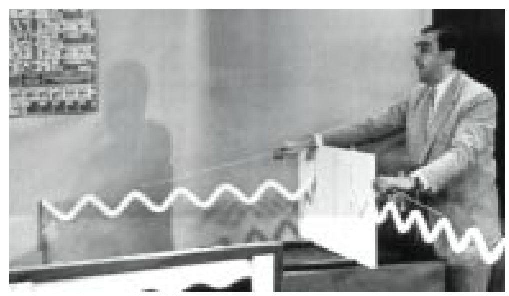
Please address any correspondence (including name and address changes) to *S&TR*, Mail Stop L-664, Lawrence Livermore National Laboratory, P.O. Box 808, Livermore, California 94551, or telephone (925) 422-8961. Our electronic mail address is *hunter6@llnl.gov*.

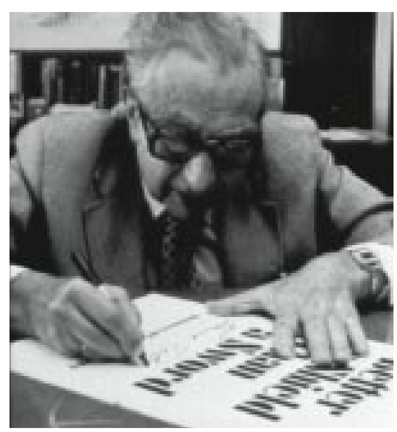
Prepared by **LLNL** under contract
No. W-7405-Eng-48

Science & Technology REVIEW

July/August 1998

Lawrence
Livermore
National
Laboratory





S&TR Staff

Scientific Editor
J. Smart

Managing Editor
Sam Hunter

Publication Editor
Sue Stull

Writers
Bart Hacker, Arnie Heller, Gina Kaiper, Sue Stull, Katie Walter, and Gloria Wilt

Art Director and Designer
Kitty Tinsley

Internet Designer
Kitty Tinsley

Compositor
Louisa Cardoza

Proofreader
Al Miguel

S&TR is a Director's Office publication, produced by the Technical Information Department, under the direction of the Office of Policy, Planning, and Special Studies.

Printed in the United States of America

Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161

UCRL-52000-98-7/8
Distribution Category UC-700
July/August 1998

Happy Birthday, Edward!

WHEN we began making plans to celebrate Edward Teller's 90th birthday, I asked him if he would give a talk to the Laboratory. We discussed it and agreed he would give two talks, the first to a small group at lunch, and then an address in the auditorium that would also be televised throughout the Laboratory. These events would be followed by a dinner and remarks the next evening at the Stanford University Faculty Club, near the Hoover Institution, where he now spends the other half of his professional life. All of us who participated in this sequence of activities will remember and cherish them as remarkable for a scientist of any age, but simply astonishing for someone entering his tenth decade.

At his birthday lunch, Dr. Teller reflected on the nature of scientific inquiry, as contrasted with artistic value or moral purpose. It was a particularly interesting talk because he illustrated it with anecdotes from his student days, including a memorable conversation with Niels Bohr. As he has so often in his life, he concluded by arguing strongly that knowledge be pursued as vigorously as possible, its applications sought, and both the knowledge and applications described to everyone so that decisions could then be made about their use.

In his speech to the Laboratory, "More Science in Livermore," Dr. Teller reflected on the Laboratory and on what it might do in the future. After remarking, "The Laboratory is the one thing in my life I am completely happy about," he briefly described three specific contributions of the Laboratory that had really major importance.

The first contribution was the introduction of very large computers into the scientific enterprise and our leadership in this area for many years (and again today, I'm happy to say). The second was the development of nuclear weapons that could be carried by submarines—a very difficult technical achievement, and one that changed the calculus of the Cold War because it effectively negated the advantage of a first strike (by either side). Finally, there was the work on strategic defense, which he (and many others) believe led to the collapse of the Soviet Union and the end of the Cold War.

Looking to the future, Dr. Teller enthralled the audience by describing in some detail a particular area of research that should be possible with the National Ignition Facility currently under construction. Specifically, we should be able to create matter at very high pressures and (relatively) low temperatures, leading to an entirely new domain for laboratory physics as well as exploring much of planetary and astrophysics.

These two talks and their main themes are indicative of the intensity and diversity of Dr. Teller's extraordinary contributions as a scientist. At his birthday dinner at Stanford, I said the best gift we could offer him was to continue to pursue knowledge and its applications as vigorously as possible at the Laboratory and to focus on the future, not the past. The one tangible gift is this issue of *Science and Technology Review*, not as a memorial, but as a guide to the life of one of the most original and important figures of the 20th century.

Happy Birthday, Edward.

■ Bruce Tarter is the Director of Lawrence Livermore National Laboratory.

THE WHITE HOUSE

WASHINGTON

January 14, 1998

Dr. Edward Teller
433 Gerona Road
Stanford, California 94305

Dear Dr. Teller:

I am pleased to join your family, friends, and colleagues in wishing you a very happy 90th birthday.

As you celebrate this milestone, you can reflect with pride on a life and career dedicated to science, public service, and education. From your pathbreaking work on the Manhattan Project to your pivotal role in the creation of the Lawrence Livermore National Laboratory, you have brought together many disciplines and some of the world's finest scientific minds to confront and overcome the great challenges facing our nation in this century.

In your emphasis on the importance of advanced computations, you helped usher in the era of supercomputing and the technology of the information age. As an educator and mentor of a new generation of scientists, you have shown how we can engage the young minds that will shape America in the next century.

On behalf of your fellow Americans, I thank you for your extraordinary contributions to the security and success of our nation. Best wishes for a wonderful birthday celebration and every happiness in the years to come.

Sincerely,

Bill Clinton

Glimpses of an Exceptional Man

REACHING one's 90th birthday is in itself an achievement. Edward Teller came to that milestone with much more—important accomplishments, great honor, public recognition. For sure, the way has sometimes been rough; controversies have surrounded a good part of his life. But Teller not only endures, he has prevailed. Still actively pursuing new scientific ideas, still a leader in foreseeing problems in need of solution, Teller is irrepressible and influential. We had better take seriously his wishes for his 100th birthday, among them, "excellent predictions—calculations and experiments—about the interiors of the planets" that he wants Lawrence Livermore's scientists to give him.

If there was a foreshadow of his career, it was late in appearing. Born in Budapest, Hungary, in 1908, little Ede Teller did not utter a word until he was three years old. His grandfather was afraid he might be retarded. But in a case of all or nothing, when at last the child began to speak, it was in complete sentences. Shortly thereafter, he was inventing mathematical games to amuse himself. At the family dinner table with father Max, mother Ilona, and older sister Emmi, he would sometimes ask to be left alone because he had a "problem"—that is, he was pondering a mathematics question. At an early age, he read and understood Euler's text on algebra. Mathematics professors consulted by Papa Teller regarded Edward as exceptional in the subject.

Certainly, Teller's early educational ambitions were to study mathematics at the university. He was deterred in this by a father who, concerned about Edward's professional future, bade him to study chemical engineering. For two years Teller did this, but he was pulled away by the excitement over quantum mechanics, a new theory of physics that was changing the way scientists viewed atoms and molecules. Teller joined the fray and went to the University of Leipzig, where he studied under Werner Heisenberg.

Just before he entered Leipzig, tragedy struck: Teller, absentmindedly missing his trolley stop, jumped off the vehicle after it had restarted and fell under its tracks. He lost a foot to the accident and has since then depended on a prosthesis. The accident prevented him from engaging in many athletic activities, but his competitive spirit and determination allowed him to excel in one—Ping-Pong. Teller has said that he was not greatly afflicted by the loss of his foot; Werner Heisenberg has said that it was the hardiness of Teller's

Born in Budapest, Hungary, the son of Max and Ilona Teller.

1908

1910

Begins to talk late, but in complete sentences.

1912

spirit, rather than stoicism, that allowed him to cope so well with the accident.

Teller met his wife, nicknamed Mici (for Augusta Maria), through his friendship with Edward “Suki” Harkanyi, her older brother. They married in February 1934, after a long courtship punctuated with separations caused by his university studies and appointments and a break of two years caused by a quarrel over Mici’s decision to study at the University of Pittsburgh without first discussing any commitment to Edward. But their life together was foreordained. For over 60 years, Mici Teller has been an integral part of Edward’s life at locales in Europe and across the United States. Early one year, Mici was uprooted from their home of three months and moved several times, from the Virginia suburbs to New York City, then to Berkeley, and, just as she found herself pregnant, on to Chicago and finally to Los Alamos. Paul, their first child, was born during the first summer at Los Alamos, and Wendy followed two years later.

Some scientists live only for their work. Teller, who greatly loves science, nevertheless has many other interests and pursuits. Among them is music. He is an accomplished pianist with an extensive classical repertoire. When relaxing at the piano with Mozart, he is unhappy about being interrupted, as happened one day when Leo Szilard phoned. Fortunately for Szilard, the reason for the call—confirming the fundamental basis for nuclear bombs, that neutrons bombarding elements could cause the release of more neutrons—was interesting enough to displace Mozart.

If Teller likes to have his Steinway (the “monster” purchased at a hotel auction in Chicago) moved to wherever he lives, he also likes to be surrounded by scientific colleagues and continually share ideas. Essential to Teller’s scientific method are free exchanges that stimulate thought or check irrationalities. It is no surprise that he feels strongly about scientific exchanges or that he expresses himself well and is a natural teacher.

In his youth, Teller and his family experienced repression and persecution at the hands of the Communists after Bela Kun seized power in Hungary. One war later, they were persecuted by Nazis. After 1938, they were afraid to visit family and friends in Hungary lest they be detained by the instruments of Nazi power. Teller never saw his father again, and he was not to be reunited with his mother and older sister Emmi until 1959. Emmi’s husband was lost to the Nazis, as was Mici’s brother.

The political events that so affected Teller’s life also affected his scientific career. His own inclination was to pursue pure science; war turned him into an applied scientist who used his expertise to develop weapons in the service of the United States. His work on the hydrogen bomb was an important accomplishment, especially when we found out that the Soviets were developing their own H-bomb. That work also made possible an invulnerable submarine-based nuclear deterrent. But somehow the confluence of Teller’s achievement with the scientific debate over nuclear weapons in McCarthy-era politics led to the Teller–Oppenheimer conflagration that damaged both scientists.

Teller has survived and gone on. Today, as emeritus director of Lawrence Livermore National Laboratory and senior research fellow at the Hoover Institution at Stanford University, he can look back on a very full life. But Teller, being Teller, mostly looks ahead.

— Gloria Wilt

Edward and Mici Teller have always enjoyed music. (Photo courtesy of Jon Brenneis.)

Attends Mellinger School in Budapest.

Enters the Minta School established by Moritz von Karmann.

1914 **1916** **1918**

Niels Bohr applies quantum theory to the movement of electrons around the atom.

Still Shaking Up Science Today

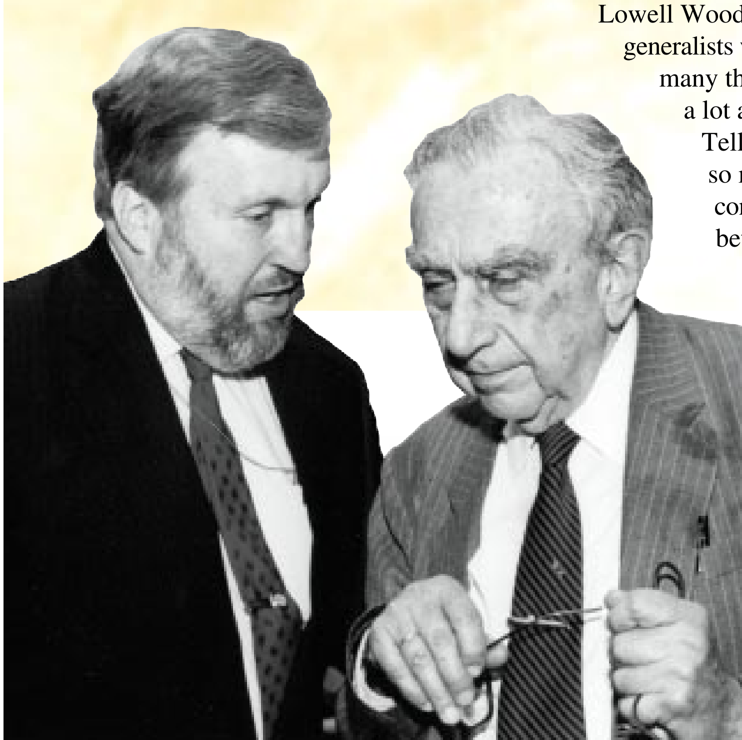
THERE is little doubt that Edward Teller is one of the towering figures of 20th-century physics. At 90, he is still one of the most influential men of science. Although his early training was in chemical physics and spectroscopy, Teller has made substantial contributions to such diverse fields as nuclear physics, plasma physics, astrophysics, and statistical mechanics. Lawrence Livermore physicist Mort Weiss, a close friend, has written: "His work has shaped the nature of nuclear physics research and has left an indelible impression on that field. His wide-ranging, questing, and tenacious approach to research, not only in nuclear physics but in many other fields as well, has inspired generations of nuclear physicists."

Although he officially retired from Lawrence Livermore in 1975, Teller remains extremely active. He currently divides his time between Livermore, where he is Director Emeritus, and Stanford University's Hoover Institution, where he is a senior research fellow. While at Livermore, Teller pursues amazingly diverse research interests with the gusto and curiosity of someone 40 years younger. "He has an inborn wide range of interests, and it seems every year his interests get broader," observes former Livermore Director John Nuckolls.

Longtime Livermore colleague Lowell Wood notes that there are many generalists who know a little about many things, but "Edward knows a lot about everything." Because Teller is expert in so many fields, he sees connections and relationships between disciplines. Says Wood, "Other scientists can be king of the hill for their narrow specialty, but Edward has the 'intellectual bandwidth' to be pretty good in a lot of areas and tops in any area he chooses." In that respect, says Wood, Teller is similar to other 20th-century greats like Enrico Fermi, Leo Szilard, and John von Neumann, who all made sizable contributions to more than one field (and who all at one time or another were close colleagues of Teller).

Livermore physicist Neal Snyderman attributes Teller's insatiable curiosity to the fact that he was present at the creation of quantum mechanics. "There was such excitement that you could finally understand matter. You finally had rules and then the great challenge of trying to understand everything."

Concerning Teller's famous assurance to the Navy in 1956 that Lawrence Livermore could produce a thermonuclear warhead small enough to be carried by a submarine, former Livermore Director Johnny Foster says that Teller had studied the technical challenges of miniaturizing warheads to



(left) Lowell Wood and Edward Teller have long worked physics challenges together. (right) From Hungarian Ambassador Pal Tar, Teller accepts the Middle Cross with the Star of the Order of Merit, one of the country's highest decorations. (Photo courtesy of Stanford University's Hoover Institution.)

1920

Socialists take over Hungary.

a greater degree than people at the time appreciated. "Actually, Teller does a lot more thinking than talking." If he has a motto, says Foster, it is that "you've got to probe the limits."

In attempting to explain Teller's mark in so many disciplines, Weiss cites his "fantastic ability to absorb information." What's more, he says, "Teller's a very intuitive thinker. He has a lot of ideas, and every now and then there's a real shaker that changes physics."

Plenty of "Shakers"

Teller is especially interested in the contributions to physics that will be possible with the National Ignition Facility, now under construction at Livermore. "All of planetary physics and much of astrophysics, like the explanation of magnetic fields in sunspots, may well depend on the findings of NIF," he declared recently. Such findings, he said, could be even more important than the Laboratory's contributions to national security.

While much of Teller's attention in the 1980s was directed to designing defensive systems to safeguard the nation against ballistic missile attack, his focus in the 1990s has expanded to protecting the planet from possible catastrophes. One particular concern is the possibility of catastrophic damage to the Earth from an asteroid or comet, similar to the one that probably triggered the demise of dinosaurs. Teller has collaborated with several Livermore physicists, including Dick More, on the issue of determining whether a collision by a giant asteroid would disrupt Earth's magnetic field.

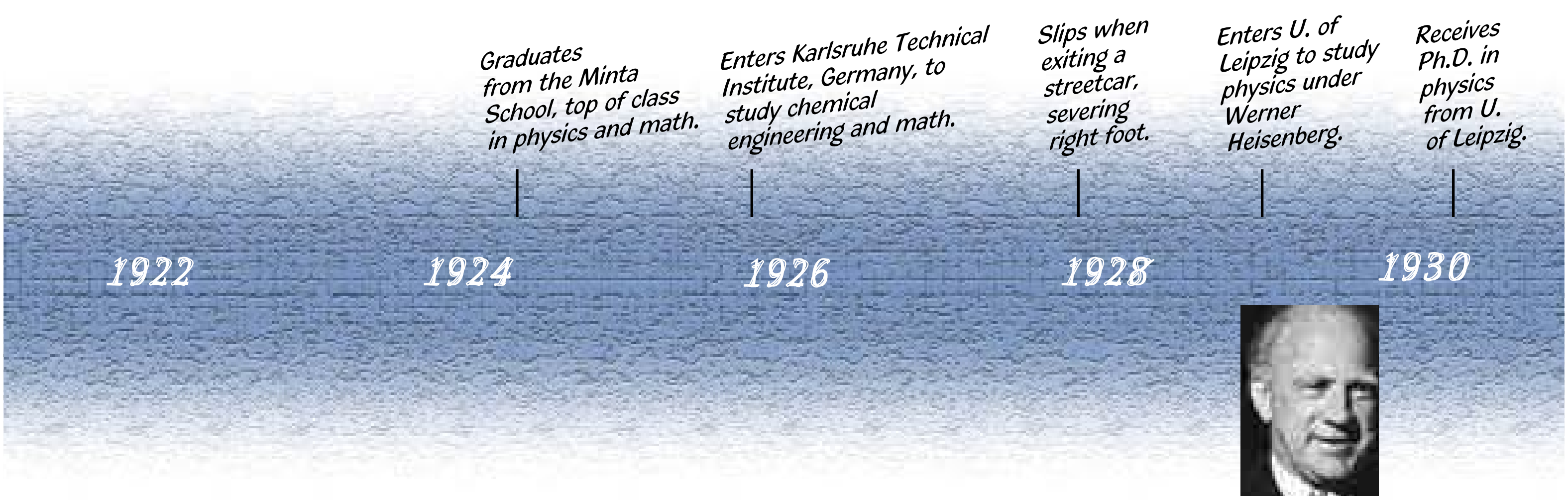
A 1995 workshop at Livermore on planetary defense drew more than 100 scientists from China, Russia, Europe, and the U.S. Teller emphasized to attendees the need for experiments to determine the composition and structure of comets and asteroids, and he discussed a strategy for mitigating hazardous objects so large as to be beyond the capabilities of nuclear explosives.

"Today, we know a meteorite killed 90% of all living things—dinosaurs and all kinds of other things. And that it was that meteorite that actually stimulated our own evolution. I have never been in favor of people dying out and a new world taking over. I would rather have evolution based on dreamed possibilities. So I advocate the building of telescopes, the prediction of collisions, and the deflection of objects, such as meteorites," Teller said.

The topic of asteroid collisions with Earth has recently caught the fancy of the public and moviemakers. The phenomenon illustrates the oft-repeated observation that Teller seems to anticipate society's needs for scientific and technological solutions, but more than that, he feels an overriding necessity to personally provide answers.

Over the past few years, Teller's concern for the planet has grown to devising ingenious fixes for possible environmental crises. He was the lead author of a paper presented at an international conference in Italy last year that outlined technological responses to drastic climate changes. He argued that current technology offers much more realistic options for addressing global warming than proposed drastic cutbacks in carbon dioxide emissions. One attractive approach, he suggested, involves diminishing by about 1% the amount of sunlight reaching the Earth's surface, to counteract any warming effect of greenhouse gases. In like manner, the paper discusses prospects for "physics-based modulation" of sudden plunges in temperatures, similar to those in the past that resulted in mini ice ages.

Strongly related to Teller's concern with planetary protection is his interest in the origin of life and the forces that have shaped evolution. Snyderman suggests Teller is interested in biology because it involves fundamental chemistry, one of



his first great interests, and because the origin of life presents "one of the great questions scientists are capable of answering but have not yet done so."

Safer Nuclear Power

If the industrial world's production of carbon dioxide is indeed causing global warming, then safe and affordable nuclear power, Teller believes, is a sure way to counteract that trend. His interest in safe fission reactors dates to the very beginnings of the atomic age. Shortly after its formation in June 1947, the Atomic Energy Commission established the Reactor Safeguard Committee, with Teller as its first chairman. Notes Snyderman, "Teller was involved from the very start of nuclear power more than 50 years ago. He believes it's the ultimate practical power source, but he also recognizes there's a public perception that must be overcome."

During the past decade, Teller has worked with Wood and other Livermore scientists on a new kind of nuclear fission reactor. The papers describe a nuclear reactor that has no moving parts and can operate without human intervention for three decades. Such a reactor, the authors state, "may be widely acceptable because its safety features are simple, inexpensive, and easily understood." If widely employed, the reactor could directly reduce present-day worldwide carbon dioxide emissions by twofold, thereby providing "a solution to all aspects of global warming."

The advanced reactor would be deployed 200 meters underground and capable of delivering electrical power up to 1,000 megawatts. It would be connected to the plant's electrical generator subsystems situated aboveground. The residual radioactivity would be sealed within the reactor's core and thereafter allowed to decay in place. Heat from the radioactivity would prevent water from reaching the system.

The novel concept has drawn interest from scientists from other national laboratories and even from Ukraine and Russia. Foster, who is familiar with the design, says that although much engineering work is required, the concept is sound and deserves further work. "What energy source are we going to leave our children?" he asks.

Teller also has a long-term interest in applying nuclear energy (both fusion and fission) to space exploration. Wood recalls working as a graduate student with Teller on designs for fission space propulsion engines in the 1960s and on more exotic, fusion-driven designs in the 1970s. Teller's current concept is a rocket engine, based on a uranium solution reactor, that would make possible travel from Earth to Mars in one day. As might be expected, Teller's interests in space range far beyond visiting the solar system, extending to the great questions of modern cosmology, including the physics of black holes and gamma-ray bursts.

Interest in Superconductors

Colleagues say Teller's enduring interest in magnetism is a natural extension of his early background in chemistry. One offshoot of that interest is his work with Livermore physicist Brian Wilson to advance the current theory of high-temperature superconducting materials. First discovered in 1986, these materials carry currents without the loss of any energy and in some cases generate immensely powerful magnetic fields. A satisfactory explanation for how high-temperature superconductors work still eludes scientists.

Superconductivity is also of interest to Teller because the promise of supercomputers is dependent on the use of materials through which current can

Research Associate at U. of Göttingen.

1932

Marries Augusta Maria ("Mici") Harkanyi.

Rockefeller Fellow at Niels Bohr's Copenhagen Institute for Theoretical Physics.

1934

flow with little or no resistance. Teller was among the first to see that the future of computers in science lay in creating models of physical events.

What accounts for Teller's fertile mind and extraordinary productivity even at age 90? "Physics must be the fountain of youth," says Snyderman. "He's incredibly sharp. I can't keep up with him." Snyderman, like Weiss, has for years met weekly with Teller to discuss whatever topic is on his mind that day. He admits that Teller has most of the original ideas. "He's always thinking about the future, and yet he keeps coming back to old problems. If he's not satisfied that a problem has been completely resolved, he keeps returning to find a practical and elegant solution. The only authority to Edward is logic."

Snyderman says that he usually emerges from discussions with Teller "in such an excited mood." Nuckolls finds Teller today much as he was when Nuckolls arrived at Livermore in the mid-1950s: "extremely creative and intuitive, with an insatiable curiosity." Citing Teller's "incredible intensity," Foster observes that Teller is "not happy if he isn't driving himself to exhaustion. Occasionally he oversteps it, and then he's in the hospital." Foster describes taking his son to visit Teller at Stanford Hospital. Wood was also visiting at the time, Foster recalls, and within 15 seconds, the three scientists (including a bedridden Teller), to the amazement of the younger Foster, were vigorously arguing physics, weapons systems, and ballistic-missile-defense issues.

At the same time, Foster describes a man who is "just so gentle." Friends and associates all say they wish the public could see the Teller they know, a man of warmth, humor, and playfulness. Indeed, Wood says the single most striking feature about Teller's life is the difference between the popular public image of the cold scientific genius and the reality of a very warm, concerned human being.

Taking a Stand

Teller continues to take strong, and occasionally unpopular, stands on issues involving science and technology. In 1995 he said, "We scientists are not responsible and should not be responsible for making decisions. But we scientists are uniquely and absolutely responsible for giving information. We must provide the decision makers with the data. On the basis of this, they will have the best chance to make the right decisions."

Teller never wavers from what he believes must be said, says Wood. "Politicians may not agree with him, but they know they are listening to the voice of integrity." He points out that Teller had already "shaped the course of men and nations" by the time he reached the age of 70 in 1978. And yet, Teller became a tireless advocate for strategic defense during the following decade, willingly enduring much personal criticism from both politicians and fellow scientists.

Foster says that Teller has thought through the proper relationship of scientist to society more carefully than anyone else he knows. "If there's a big national issue dealing with science and engineering, he'll address that issue, work hard, and make his contribution regardless of politics. . . . He'll go up against impossible odds. You'll tell him that he doesn't have a chance, but he'll say that he's a champion of lost causes."

"It's striking to see a person at the age of 90 interested in moving forward," says Wood. "It's a combination of physical strength and good genes, but more important, a strength of character and of purpose. Teller chooses to make the effort despite his failing physiology. I think that's quite remarkable."

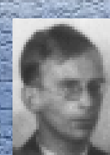
— Arnie Heller

Lecturer at U. of London.

With Mici, sails to the U.S.

Professor of physics at George Washington U.

1936



With George Gamow, establishes "thermonuclear energy" theme for annual Washington Conference on Theoretical Physics.

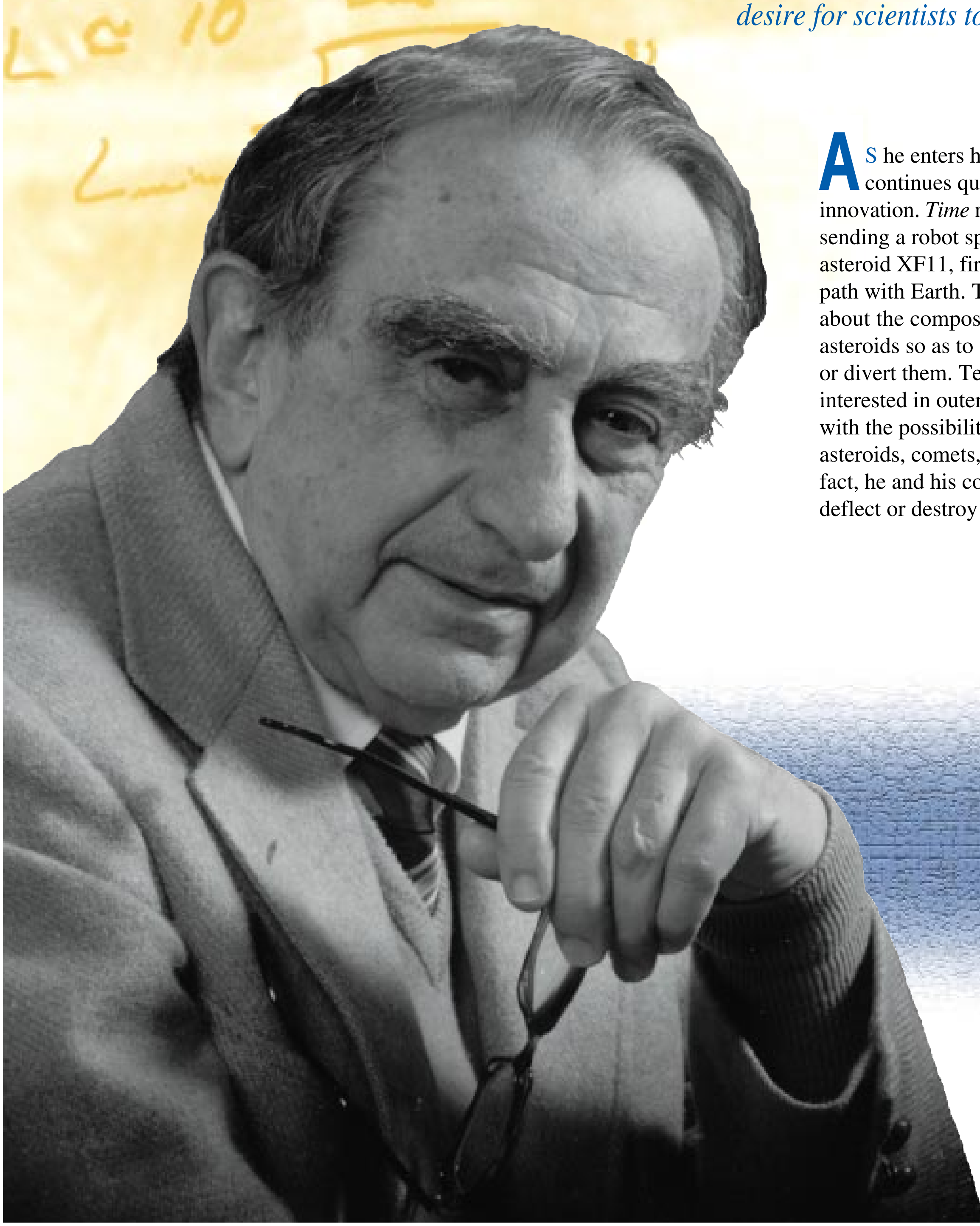
1938

Otto Hahn and Fritz Straussman, working in Germany, split uranium atom.

Leo Szilard verifies neutron production from fission of uranium.

Gifts of a Fertile Mind

It was a fertile decade to which Edward Teller was born: Planck's work in radiation and energy, the Wright brothers' first powered flight, and Einstein's theory of relativity. What Teller has accomplished is rooted in his continual quest for knowledge and the desire for scientists to share their findings.



As he enters his tenth decade, Edward Teller continues questing after knowledge and innovation. *Time* recently cited his suggestion of sending a robot spacecraft to rendezvous with asteroid XF11, first thought to be on a collision path with Earth. The idea was to get information about the composition and strength of passing asteroids so as to understand how best to destroy or divert them. Teller for some time has been interested in outer space and has been concerned with the possibility of catastrophes caused by asteroids, comets, or other near-Earth objects. In fact, he and his colleagues have studied ways to deflect or destroy such objects with nuclear

Drives Leo Szilard to Albert Einstein's summer cottage for him to sign letter to President Roosevelt about ". . . powerful bombs of a new type."

In 1957, the founders of the new Livermore branch of the University of California Radiation Laboratory are shown: E. O. Lawrence, Teller, and Herbert F. York, the first director.

explosions. Prolific in his ideas and determined in his pursuit of scientific truth, Teller has promoted scientific studies far ahead of their time, studies that often have profoundly affected the direction of science and technology.

While making notable contributions to science, Teller has also involved himself in myriad causes. He has promoted science education to develop strong scientists and engineers for the future; he has advocated openness in sharing scientific information; he has been at the forefront of developing safe nuclear energy for civilian use; and he has developed advanced technologies to defend U.S. national security.

That last cause has, of course, brought Teller both credit and controversy. It has endowed him with a larger-than-life presence in the scientific pantheon and has forever tagged him as the “father of the hydrogen bomb.” Nevertheless, it is not the sum of his work; a better symbol of his work is Lawrence Livermore National Laboratory, the institution Teller fought for and cites as his proudest achievement. Founded as a second weapons laboratory, it has also been, as Teller intended, a world-class science research institution that has made many scientific innovations while serving the nation’s security interests. The work at Livermore demonstrates just how comprehensive Teller science has been.

Doing Pure Science

Throughout his career, Teller has been a participant in the development of nuclear theory; he has helped shape the nature of nuclear physics research. Trained in chemical physics and spectroscopy, he cast his research net across a broad range of physics subfields. He began with atomic and molecular physics and broadened his expertise with nuclear physics, plasma physics, astrophysics, and statistical mechanics.

In 1925, when Teller graduated from gymnasium in Hungary and entered university in Germany, it was a time of revolution and extraordinary breakthroughs in physics. Einstein had turned the scientific world on its head with his theory of relativity. Then Niels Bohr came along and invented the early

Hears President Roosevelt address Pan American Scientific Conference & call to join in defending “our science, our culture, our American freedom, and our civilization” as a personal call to action.

Physics professor, Columbia U., working with Enrico Fermi & Leo Szilard on chain-reaction research.

Becomes naturalized U.S. citizen.

Physicist, U. of Chicago, working on chain-reaction research for U.S. Office of Scientific Research & Development.

1940

1942

Hitler invades Poland. Britain and France declare war on Germany. Germany works on atomic bomb.

Hitler invades Belgium, the Netherlands, & Luxembourg.

Japan bombs Pearl Harbor; U.S. declares war on Japan & Germany.

quantum theory—the radical insight that electrons circling atomic nuclei were jumping from orbit to orbit without heed to the space in between—and revolutionized the scientific understanding of atoms and molecules. Bohr's theory started to explain the stability of atoms, how combinations of neutral atoms could form chemical bonds, and why atoms of a particular element could form only limited numbers of bonds.

Teller, fascinated by quantum mechanics, changed from studying chemical engineering—which he was doing at the behest of his father—and went to the University of Leipzig to study physics under Werner Heisenberg, an important contributor to modern quantum mechanics theory. Heisenberg's uncertainty principle held that subatomic particles are governed not by causality but by probability.

As Heisenberg's student, Teller obtained his Ph.D. in 1930 in theoretical physics. The same year, he published his first paper, "Hydrogen Molecular Ion," the result of his application of quantum mechanics to the chemical bond of the positively charged hydrogen molecule. Teller exactly calculated the energy levels in an excited hydrogen molecular ion and thereby explained the properties and behavior of the hydrogen molecule. A mathematics prodigy, Teller was the right person for solving the involved mathematics problem of how one electron spins around two nuclei. That work was one of the earliest descriptions and still is a widely held view of the molecule today.

During the 1930s, Teller continued working on electron structure in molecular physics at the University of Göttingen. With Heisenberg in 1933, Teller wrote another significant paper, which extended the Franck–Condon principle to symmetry-breaking transitions among the nuclei in a polyatomic molecule. In 1939, this idea was applied to absorption spectra of benzene, explaining an anomalous band in the ultraviolet.

A series of collaborations with his students and colleagues led to a 1937 paper coauthored with Emil Jahn on the Jahn–Teller effect, a statement about the role of electron energy levels in determining the shape of molecules with more than two atoms. Although the proof was purely mathematical and its predictions were not verified experimentally until 1952, it remains one of Teller's most significant and enduring contributions. Because of the effect's value in spectroscopy, calculating chemical reactivity, and determining crystal structure, its significance extends through all of modern chemistry.

Teller had meanwhile fled Germany in 1933, going first to Copenhagen, then London. In 1935, he accepted a position at George Washington University, where he continued his work in chemical physics. His most significant result in the late 1930s centered on the theory of the physical adsorption of gases on surfaces. Named the BET theory after the initials of its creators Brunauer, Emmett, and Teller, it still plays a major role in calculations for such industrial processes as catalysis of chemical reactions.

At George Washington, Teller began a fruitful collaboration in nuclear physics and astrophysics with the distinguished physicist George Gamow. Their first publication appeared the same year Teller arrived and led to the definition of Gamow–Teller transitions, a still-important extension of the theory of beta decay. The beta decay theory describes the radioactive transformation of an atom as the nucleus emits or absorbs an electron or positron, changing

Physicist, Manhattan Engineer District, working at Los Alamos Scientific Laboratory.

1944

Physics professor, U. of Chicago, taking leaves for stints at Los Alamos.

1946

First full-scale controlled nuclear reaction is achieved, in a reactor built at University of Chicago.

President Roosevelt dies.

Germany surrenders.

Trinity test shot of atomic device, from New Mexico.

Atomic bomb is dropped on Hiroshima & Nagasaki; Japan surrenders.

its atomic number by one without altering its mass number. The Gamow–Teller theory provides rules for classifying subatomic particle behavior in radioactive decay.

With this work, Teller, who had been pondering the activity of the electron spinning around the atom, found himself delving into the very heart of the atom, the nucleus. Teller and others' prewar research in nuclear physics produced significant theoretical results on the forces holding nuclei together, the forces between nucleons, models of the atomic nucleus, and neutron scattering in molecular gases and crystal lattices.

Developing Nuclear Weapons

In 1939, at the Washington Conference on Theoretical Physics convened annually by George Gamow, attendees received some startling news: the German scientists Otto Hahn and Fritz Strassman had discovered fission. Bombarding uranium with neutrons, they had split the nucleus and released a great amount of energy.

That announcement was to be the opening salvo leading to the Manhattan Project and the development of the atomic bomb. Scientists at the conference wondered whether a splitting nucleus would release enough additional neutrons to start a fission chain reaction that would release a large amount of energy. Two months following the conference, Leo Szilard, a Hungarian colleague and friend of Teller's, confirmed the feasibility of such a chain reaction in his laboratory. A way had been found to make a bomb of great power out of a small amount of fissionable material, and Teller would play a role in it.

The following events are well recounted in history books: Szilard and Teller convinced Einstein to sign a letter to President Roosevelt about an atom-bomb-building project; America entered the war, which galvanized bomb research; the top-secret Manhattan Project enlisted an elite band of scientists to work on the bomb in the remote mountains of Los Alamos; and work culminated in 1945, with the explosion of the world's first atomic bomb.

Teller was present throughout the critical points in the development of the atomic bomb. He obtained initial federal funding for chain-reaction research, performing experiments by the fall of 1941 with Leo Szilard and Enrico Fermi at Columbia University. Their work led to the first controlled nuclear reaction.

Early in the war, atomic research intensified and was consolidated at the University of Chicago's Metallurgical Laboratory, where Teller was a part of the theoretical group and worked on the first nuclear reactor. There, the feasibility of releasing significant nuclear energy was confirmed. The Manhattan Project to produce the bomb began, and scientists took off for the mountains of New Mexico.

Once Teller had settled his family in Los Alamos in April 1943, one of his early responsibilities was to indoctrinate incoming scientists about the project. He also worked on implosion calculations, helping John von Neumann to develop ways to calculate the critical mass and nuclear efficiency of various bomb designs. He devised the implosion approach used in the first atomic bomb.

But even as he was involved with the work on the fission weapon, Teller, always thinking ahead, was pondering a fusion bomb, one that worked not by splitting heavy nuclei but by uniting light nuclei. The same process that powers the sun and the stars, fusion involves hydrogen, whose nuclei are the

Is appointed chairman of AEC's Advisory Committee on Nuclear Reactor Safeguards.

Becomes member of National Academy of Science.

Assistant Director of Los Alamos Scientific Laboratory.

1948

First Soviet fission device is detonated.

Mao Tse-Tung proclaims the People's Republic of China.

In 1952, the Los Alamos laboratory successfully tested “Mike,” the world’s first thermonuclear explosion, based on Edward Teller’s ideas. Subsequently, the Livermore Laboratory tested and developed the Polaris missile warheads.

simplest in nature and have the lowest electrical charge. Hydrogen nuclei also have the least repulsion of each other, so the nuclei fuse at lower temperatures. Scientists knew that fusion theoretically could release more energy per unit mass than fission.

With suggestions from Fermi, Teller had conceptualized a fusion weapon, in which a fission bomb would be used to heat a mass of deuterium (a heavy form of hydrogen) to start a fusion reaction. The concept stalled initially when Teller thought his calculations indicated the unlikelihood of a fission weapon producing the hundreds of millions of degrees of temperature needed to trigger significant fusion. But Manhattan Project colleague Emil Konopinski revisited these calculations with him, and they concluded that the concept probably would work. The thermonuclear superbomb became a secondary endeavor during the Manhattan Project.

The end of the war diminished the government’s interest in weapon development, so research work at Los Alamos shrank significantly, as did funds for nuclear testing and research. However, work on the “super” was revived upon the discovery that the Soviet Union, now an adversary of the U.S., had detonated an atomic bomb. A faction of the scientific community, including Teller, felt that it would only be a matter of time before the Soviets developed a hydrogen bomb. To maintain the balance of power, it was imperative for the U.S. to develop a hydrogen bomb first. A majority of the scientific community had doubts about the morality or the practicality of developing such a bomb, but pressure to build it mounted with the discovery that Manhattan Project scientist Klaus Fuchs had passed nuclear secrets—including concepts for a hydrogen bomb—to the Soviets. On January 31, 1950, President Truman gave the go-ahead to intensify the pursuit of the fusion hydrogen bomb. (See box, p. 16.)

Back at Los Alamos, scientists were trying to solve a critical problem of propagating a fusion reaction initiated by a fission bomb through a cylinder of liquid deuterium. The breakthrough came when Teller invented the radiation implosion concept, which was described by Teller and Los Alamos colleague Stanislaw Ulam in one of the most famous documents produced during 40 years of weapons research, but not widely read because of its security classification. In the radiation implosion concept, the fusion fuel is first compressed. This makes possible the

Conceives of radiation-imploded, high-yield H-bomb scheme.

Begins campaign for a second nuclear weapons laboratory.

1950

North Korea invades South Korea; People’s Republic of China sends forces in.

President Truman announces that U.S. will pursue development of hydrogen bomb.

U.S. “Greenhouse” test ignites first measurable thermonuclear burn.

ignition and effective burn of fusion fuel. Radiation is channeled from the exploding primary fission bomb to the secondary fusion device, causing it to implode and compress its fusion fuel.

The "Mike" thermonuclear device based on this radiation implosion concept was exploded on Eniwetok atoll on October 31, 1952. In this first test, cryogenic deuterium fuel was used. Later, solid lithium–deuterium fuel was used.

Building an Institution

What would become Lawrence Livermore National Laboratory was established just a few weeks before the Mike test, on September 2, 1952. It was the result of vigorous efforts by Teller, who believed that a friendly competitor of the Los Alamos laboratory would accelerate the development of thermonuclear weapons and fuel scientific accomplishment. Teller was greatly assisted by Ernest Lawrence, who also came up with a suitable site. The Livermore laboratory began life as a branch of the University of California Radiation Laboratory (now the Ernest Orlando Lawrence Berkeley National Laboratory).

At the Nevada Test Site, Teller and researchers inspect details of Operation Plumbbob, in which the U.S. conducted the first demonstration of a contained underground nuclear explosion. Teller was instrumental in this demonstration of underground testing without radioactive fallout.

Lawrence Livermore is stamped with Teller's vision and ideas. Throughout the 45 years of its existence, Teller has been its guiding presence.

Champion of Safe Reactors

Nuclear fission was discovered just before the beginning of World War II, which explains why its first application was as a weapon. But it has the potential for many civilian uses. Teller has long been a champion of nuclear energy for peaceful uses, particularly as an alternative to other sources of energy. To that end, he has made many fundamental contributions to the design of safe and reliable nuclear reactors for generating power.

In 1947, Edward Teller became the first chairman of the Atomic Energy Commission's Committee on Reactor Safeguards. The committee was originally formed to review, evaluate, and advise the AEC of the hazards of reactor

Visits Livermore with E. O. Lawrence; encouraged to think of this site for a second laboratory.

Consultant to Livermore branch of U. of California Radiation Laboratory.

Physics Professor, U. of California.

Associate Director of Livermore branch of the U. of California Radiation Laboratory.

1952

1954

National Security Council and AEC authorize a second nuclear weapons laboratory at Livermore.

U.S. "Mike" thermonuclear implosion device demonstrates feasibility of thermonuclear weapon.

First Soviet ignition of measurable thermonuclear burn.

First U.S. noncryogenic thermonuclear bomb tested.

Developing the H-Bomb

In the fall of 1941, Enrico Fermi suggested that a fission bomb be used to heat a mass of deuterium to a temperature where the thermonuclear fusion of two deuterium atoms will proceed rapidly. I came up with a counter argument: that the needed temperature would be so high that most energy will appear as useless radiation rather than usable kinetic energy of the nuclei. Fermi agreed to my objection.

A few months later, I attempted to finalize my argument on the deuterium-plus-deuterium reaction. We did not succeed. Emil Konopinski, my collaborator, suggested (correctly) that tritium in a deuterium-plus-tritium reaction might react much faster than deuterium-plus-deuterium. I, in turn, proposed that the thermonuclear reaction might proceed before a lot of radiation is emitted and an equilibrium with radiation is established.

During this work, Oppenheimer invited us to participate in a discussion at Berkeley about the problems of explosives using nuclear energy. Oppenheimer mentioned the possibility of a hydrogen bomb to Arthur Compton (head of the whole Chicago project), arguing that the fission and fusion bomb problems required a new laboratory, which was established in March 1943.

In Los Alamos, difficulties connected with the fission bomb soon required the whole available effort. But working with a small group, I could give continued attention to the hydrogen bomb. It turned out that it is quite difficult to postpone radiation equilibrium and obtain sufficient time for thermonuclear reactions. But it still seemed quite promising to obtain a hydrogen bomb in this manner.

With the end of the Second World War, strong feelings developed against continuing the work. I returned to pure physics in Chicago for the next few years, which personally I found more attractive.

In 1949, I returned as a visitor to Los Alamos with the main purpose to continue the improvement of the fission bomb. But in the summer, the Soviets exploded a copy of our fission bomb. The question arose whether work on the hydrogen bomb should be given new emphasis. This possibility was strongly supported by Ernest Lawrence. On the other hand, the Scientific Advisory Board (SAB) advised unanimously against such a project. In Los Alamos, Ulam and Everett made further calculations. They came up with results of improved quality, which, however, were negative on the feasibility of their approach to H-bombs.

By the end of 1950, I had the novel and positive answer. Because of the wartime work, we knew how to strongly compress the thermonuclear fuel, and, in the compressed fuel, radiation would be less important and would not inhibit the reaction. The Los Alamos administration discouraged new approaches, so for the time being I restricted myself to a few private discussions. One of these occurred between Ulam and myself in February 1951. Ulam suggested compression, for which I was fully prepared. I knew how to accomplish it, and I knew how it would help. I put all this down in a joint report, which Ulam signed but failed to support in subsequent discussions.

I took the opportunity of an SAB meeting (spring 1951) to present the plan for "an equilibrium hydrogen bomb," in which compressed fuel would be used. I gained the unanimous support of the SAB.

At that time, progress at Los Alamos had been assured, and I felt that it would be better for me to start work at an additional laboratory. This possibility materialized (with the essential help of Ernest Lawrence) in Livermore. In 1952, in the early days of Livermore, the first hydrogen bomb was successfully exploded. The detailed thermonuclear design was furnished by John Wheeler and collaborators.

An important application of the hydrogen bomb came through a plan for placing such explosives in rockets carried by submarines. This development made it impossible for the Soviets to attack the United States and prevent retaliation. Indeed, rocket-delivered explosives are hard to shoot down, and the submarines that carry them are hard to locate. The proposal I made succeeded because of the excellent work of John Foster at Livermore, who designed a small and efficient primary fission bomb, and Carl Haussmann, who designed a small and efficient secondary hydrogen bomb. The resulting nuclear explosives were more than ten times as powerful as those used during the Second World War, but the use of thermonuclear reactions made them flexible enough to become practical explosives carried by submarines.

— Edward Teller, June 1998

Is awarded Doctor of Science degree from Yale U., the first of 23 honorary degrees.

Serves on the General Advisory Committee to the AEC.

Instrumental in Operation Plumbbob, first U.S. demonstration of a contained underground nuclear explosion.

1956

First Soviet test of a genuine thermonuclear bomb.

At Project NOBSKA meeting, discussion of switch to solid propellant & Teller's compact weapon paves way for Polaris missile.

Atomic Energy Commission supports Teller's projection of compact warhead feasibility.

U.S. launches Atlas intercontinental ballistic missile.

U.S.–U.S.S.R. moratorium on nuclear testing begins.

In 1962, President Kennedy presents Edward Teller with the Enrico Fermi Award in recognition of "contributions to chemical and nuclear physics, for his leadership in thermonuclear research, and for his efforts to strengthen national security." (To the left is Glenn Seaborg, chairman of the Atomic Energy Commission; Teller's wife, Mici, is at the President's right.)

operations. The committee's charter was later expanded to include all aspects of reactor safety.

Teller, an engaging and energetic chairman, led the committee as it incorporated many improvements. The committee innovated such safety features as containment structures and methods for flooding the reactor in an emergency, promoted training of reactor operators while advocating system designs that lowered dependence on human factors, and devised systematic rules for reactor siting that took into account the nearby population and the reactor's power level.

In the early years of reactor technology, few techniques and little information existed for evaluating reactor safety. Probabilistic safety analysis techniques had not been developed, and human tolerances to radiation and ingestion of plutonium were not well known. Under Teller's guidance, the committee developed the concept of designing safety features into reactors to prevent the "worst possible accident." Over time, this concept evolved to today's "design basis accident," which considers accident probabilities in setting design safety standards.

U.S.S.R. successfully tests intercontinental ballistic missile; launches Sputnik I.

Becomes Director of Livermore Laboratory.

1958

U.S. launches Explorer I satellite.

Receives Albert Einstein Award for discoveries in atomic, nuclear, & solid-state physics.

Livermore Lab achieves breakthrough in tests of Polaris warhead prototypes.

E. O. Lawrence, Director of U. of California Radiation Laboratory, dies.

Strategic Defense Initiative: The Next Step

It is widely believed that the rapid development of weapons of mass destruction is the main danger humanity confronts. An extreme consequence of this belief is that new scientific knowledge is considered dangerous and must be limited.

I strongly believe that the main danger lies in human intentions and not in the ability to bring about mass destruction. An important example is the history of the wars of Genghis Khan—in particular, the destruction of Persia by the Mongols. More than half the population of the defeated country was killed, and Persia, the present-day Iran, has never recovered its great historic importance.

I believe that the most important part of the present danger is due to the situation that the world has become smaller and more interactive, and catastrophes may occur with unprecedented rapidity.

The United States, which is losing the remnants of its isolation, is a particularly important component in this change. The technical cause of this change lies primarily in the development and worldwide proliferation of missiles. They may carry weapons of mass destruction such as nuclear explosives or poisons (chemical or biological), but even if they carry no more than high explosives, they are already a terrible and sudden danger to stability.

My attempts to do something about this situation go back to the visit of Ronald Reagan, freshly elected governor of California, to the Livermore Laboratory. Reagan listened with an active interest to receive novel information of our attempts (in 1967) at missile defense. He asked a few relevant questions and then left without stating clearly whether and to what extent he agreed.

That answer came in 1983 when Reagan gave a remarkable after-dinner speech to a mixed audience of which I was a part. With a delay of sixteen years, he unambiguously stated that missile defense was possible, necessary, and urgent. In that regard, he gave the Livermore initiative his full support. But how to do it? Reagan suggested that defense, if ever possible, should not utilize nuclear explosives.

In this new situation, my good friend, Lowell Wood, took the strong initiative of advocating first x-ray lasers and later "Brilliant Pebbles." The latter (and final) proposal consisted in destroying the attacking missile by a direct collision with a small guided defensive object. The defensive object should actually be a satellite already in orbit. Lowell and others in our Laboratory continued to develop this concept. Having helped and supported this effort, I am convinced that it is realistic particularly with the continuing great advancement in computing capability. An important part of the development was and remains the specification that the aggressive missile should be destroyed soon after it has been launched. This necessitates continuing surveillance of our globe by satellites and an international understanding that unannounced missiles or missiles in unannounced orbits should be promptly destroyed. This, in turn, would make safety from rapid attack a worldwide benefit.

Such an effect has been strongly supported by Presidents Reagan and Bush. Unfortunately, efforts toward missile defense continue at present mostly in connection with defending our armed forces on their missions abroad. The American people (together with all other people in the world) should have such a defense that, indeed, necessitates defensive measures against dangerous launches even before it is obvious who will be attacked. We give priority to the defense of our armed forces, whose needs as an organization must obviously be satisfied. Unfortunately, the need to defend our homeland may, in political practice, be deemphasized by denying the possibility or, at any rate, the urgency of such a defense.

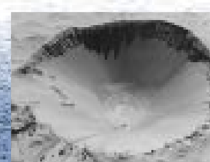
What has been stated here does not describe my only technical activity nor the only strongly needed technical-military development. It appears to me that it stands out as a matter that has been in the public eye for a couple of decades and where there seems to be a necessity for change in emphasis in the immediate future.

— Edward Teller, May 1998

Resigns as Livermore Laboratory Director; continues as Associate Director; assumes position of Professor-of-Physics-at-Large with U. of California.

1960

First Polaris system tests, far ahead of schedule; first Polaris submarine goes to sea.



Moratorium on nuclear testing ends with U.S.S.R. resumption of testing.

Receives AEC's Enrico Fermi Award for "contributions to chemical and nuclear physics . . . leadership in thermonuclear research . . . efforts to strengthen national security."

1962

In 1956, Teller led a study that culminated in the design of an inherently safe reactor. The TRIGA (Test, Research, Isotopes—General Atomics) reactor was invented that summer, the result of a Teller idea and his articulate advocacy of peaceful nuclear applications at the 1955 Conference on Peaceful Uses of Atomic Energy in Geneva. Some 60 TRIGA reactors were later built around the world.

Teller's study group developed a special reactor material system with an automatic mechanism to stabilize power output at a safe value and thus prevent dangerous overheating. The TRIGA design has led to many important and varied uses in nuclear education, research, and medicine.

Teller's concepts for nuclear reactor safety design were first used in the TRIGA reactors. The University of California at Berkeley used this TRIGA-3 reactor for research from 1965 to 1989.

Nuclear Power as Servant

When President Eisenhower gave the famous "Atoms for Peace" speech at the U.N., about adapting atomic-bomb technology to peaceful uses, the idea resonated with Teller. He took the theme further in a keynote speech to the Joint AEC Weapons Laboratory Symposium on Nonmilitary Uses of Nuclear and Thermonuclear Explosions, held in Livermore in February 1957, where he led an effort to stimulate new ideas in civilian nuclear applications. The conference led to the initiation of the Plowshare Program in June 1957 to explore the feasibility of using nuclear explosions for applications such as earth moving, power production, and breeding fissile materials such as plutonium.

Teller wholeheartedly endorsed the program and, through his writings and public talks, acquainted others with the range of Plowshare ideas and explained the physics and chemistry at their basis. Unfortunately, his enthusiasm for the project was at odds with the public's rising concerns about the environmental impact of nuclear power. Ultimately, Plowshare lost to such concerns. Even so, the program studies and experiments yielded many achievements, including:

- The first view of the phenomenology

Becomes Chairman of Department of Applied Science, U. of California at Davis, Livermore Campus; first class enters.

1964

Limited Nuclear Test Ban Treaty prohibits atmospheric testing of nuclear weapons.

1966

First U.S. combat troops are committed to Vietnam.

1968

U.S. Astronauts Armstrong & Aldrin land on the moon.

From the earliest days, Teller insisted that the Laboratory acquire the most advanced computers available. In 1960, Teller (left) discusses the newly installed Livermore Advanced Research Computer with Director Harold Brown (center) and Sidney Fernbach, head of the Computation Division (right).

of an underground nuclear explosion and subsequent information derived from it has proved useful for other underground investigations and nuclear tests.

- The most complete environmental study to date for excavating a small harbor at a remote site in Alaska with nuclear explosions. This work became a model for the modern environmental impact statement.
- Development of a family of nuclear excavation explosives that had TNT-equivalent yields from 1 kiloton to over 100 kilotons and that would release only a relatively low quantity of fission products into the atmosphere. These "clean" nuclear explosives would have been used to excavate a new Panama Canal, had that project gone forward.
- Demonstrations of fracturing low-permeability rocks with nuclear explosions and, later, the design of a special nuclear explosive for this purpose, leading to increased natural gas production.

Legacy of X-Ray Lasers

The Lawrence Livermore program to research nuclear-pumped x-ray laser systems accelerated after President Reagan's "Star Wars" speech to introduce the Strategic Defense Initiative (SDI) in 1983. Teller thought such a laser system would provide a shield for the United States against Soviet missiles. He championed the x-ray laser effort and numerous other R&D activities, including guided antimissile missiles called Brilliant Pebbles. (See box, p. 18).

Some experts believe the SDI helped to bring about major changes in world politics, including the end of the Cold War. The destruction of the Berlin Wall and the collapse of the Soviet Union changed defense priorities. The program for developing the x-ray laser into an antiballistic missile system was eliminated. But the SDI program produced a better understanding of the physics of x-ray lasers and new computer codes for modeling plasmas. It has also resulted in:

Named professor at U. of California.

1970

Is appointed to Foreign Intelligence Advisory Board by President Nixon.

1972

Is named to Nelson Rockefeller's Commission on Critical Choices for Americans.

Paris Peace Accord is signed for Vietnam conflict; cease-fire begins.

(left) Lawrence Livermore today. (right) Teller gives advice to attendees of his 90th birthday party.

- A laboratory x-ray laser for biological imaging. Coupling x-ray lasers with x-ray microscopes, Livermore scientists can create three-dimensional holograms of living organisms, which enable them to study how DNA is organized inside a sperm cell.
- Advanced materials such as aerogel and SEAgel. As a target for the x-ray laser, these materials can be doped with other materials. Their very low densities have spurred numerous commercial uses, such as thermal insulation and encapsulating material for timed-release medication.
- Radiographic diagnostic techniques to detect flaws in SDI components and spinoff methods for detecting flaws in artificial heart valves.

Good Luck Wish

During his 90th birthday celebration on January 15, 1998, Teller spoke about his latest science interests. He acknowledged that biology is the major field of opportunity for young, would-be scientists, although quantum mechanics is still the field he would choose for himself, “for things that are explainable.”

While x-ray lasers did not head his latest to-do list, he did bring up the larger issue of planetary defense and the future of physics. He said, “I see planetary defense as a very interesting contribution not to the preservation of life, but to the further understanding of the evolution of life.”

Speaking to an audience of 400 on his birthday, Teller strongly stated that he believes Livermore’s National Ignition Facility now under construction will succeed in achieving fusion energy, and a new branch of physics will develop in which ultrahigh pressures from lasers will be used to change electron structures.

“All of planetary physics and much of astrophysics may well depend on the findings of NIF,” he said. To his audience, many of whom will be instrumental in achieving the lofty goal, Teller said with a smile, “Good luck.”

— *Gloria Wilt, with Bart Hacker*

Officially retires; becomes Associate Director Emeritus of LLNL and University Professor Emeritus of the U. of California.

Becomes a senior research fellow at the Hoover Institution on War, Revolution, and Peace at Stanford University.

Is awarded Israel’s Harvey Prize for “. . . contribution to science and technology . . .”

1974

1976

For the Love of Science

BEST known as a scientist and proponent of sometimes controversial ideas, Edward Teller is also a self-confessed teaching addict. Among the less controversial of his opinions is that this country needs more intensive science education to develop scientists and engineers of the future. He has done everything he can personally to see that students of all ages learn about and appreciate science.

His belief in education and the exchange of information is so strong that since the 1940s, he has fought the secrecy that shrouds most defense-related scientific work by the government. He instead encourages openness and a sharing of ideas with the public and with other scientists around the world. By nature friendly and gregarious, Teller thrives on the free exchange of ideas and thoughts and believes that science as a whole thrives on openness. Moreover, he believes that while secrecy is not compatible with science, it is even less compatible with democratic procedure. His years in Europe, particularly Germany around 1930, perhaps demonstrated to him the importance of free speech.

Ever the Teacher

During an interview on the occasion of his 90th birthday, Teller was asked what scientists could do to help the public overcome their suspicions about new technology and science. “It is not up to the scientists,” Teller responded. “It is up to teachers. A good teacher does not have to be someone who deeply understands his subject. A good teacher is someone who can transfer the love he or she has for the subject to students.”

A teacher for over 60 years, Teller always hopes that his students will come to share his love for science. He has long been concerned that not enough young men and women are choosing science as a career, so he has made every effort to educate and inspire young scientists. His teaching career began at London City College in 1934 and continued at George Washington University in Washington, D.C., the University of Chicago, and several campuses of the University of California, where he holds the title of University Professor Emeritus.

From the first, Teller developed a reputation as an outstanding lecturer, always able to explain complex issues in simple terms and to synthesize myriad ideas. At the University of California at Berkeley, he taught a physics course to nonscience majors

1980

Teller loves to teach. At left, he answers a student’s questions after a talk; at right, he talks to rapt fourth graders from Lodi, California, in June 1990.

so popular that hundreds of students had to be turned away.

He recognized that an appreciation of science among nonscientists is as important as the creation of new scientists. In fact, science appreciation is so important to Teller that he devoted an entire chapter to the subject in his 1987 book, *Better a Shield than a Sword.*

In recent years, he has enjoyed reaching out to high school and elementary school students to stimulate their interest in science. In 1990, at 82, he taught a weekly class in physics to Livermore-area high school students and their teachers and parents. During the early 1990s, he continued to speak several times a year to area students. In 1996, his soft spot for youngsters interested in science was still apparent in an interview he granted to a seventh grader researching the Manhattan Project.

Creating a New Department

Teller began his career as a theoretical physicist interested in pure science. But after his work on the Manhattan Project during World War II, he was increasingly involved in its applications. Over the years, he grew concerned that our universities were strong in the pure sciences and engineering but not in the “gap” in between. After the establishment of Livermore Laboratory in 1952, he found that new employees were good scientists but often had little or no training in how science could be applied.

In 1960, Teller formally proposed establishing a Department of Applied Science as part of the University of California. The department would be located at Livermore and offer M.S. and Ph.D. candidates science instruction as well as hands-on experience with projects under way at Livermore.

This dream became reality when the first class entered in the fall of 1963. Organized as a unit of the College of Engineering at the University of California at Davis, the department, with Teller as its first chairman, offered M.S. and Ph.D. degrees in engineering. The program was designed to create an atmosphere where boundaries between science and engineering are subordinated, and engineering is fully integrated with mathematics, physics, and chemistry.

Hans Mark, the son of a colleague of Teller’s, has had a particularly close relationship with Teller and with the new department. In 1955, Teller convinced Hans Mark to join the Laboratory, where he became a division leader in experimental physics while also teaching at the Department of Applied Science and at Berkeley. He moved on to become the founding chairman of Berkeley’s Department of Nuclear Engineering and to serve in many prestigious technical positions across the country. Most recently, Mark was named director of Defense Research and Engineering for the Department of Defense.

Teller and Mark have served for years as members of the board of the Fannie and John Hertz Foundation, which has been instrumental in the growth of the Department of Applied Sciences at Livermore. In the late 1970s, the foundation and the University’s Science Fund made matching $500,000 donations that were used to build a permanent teaching facility at Livermore. The foundation sponsors a hundred fellowships a year at various university levels in the fields of mechanical and electrical engineering, as it has since its establishment in 1958.

Today, the Department of Applied Science offers a five-year Ph.D. program to a student body of 90. The majority of the students also work at Livermore while taking classes. Fourteen faculty

Serves on the White House Science Council.

1982

Is awarded National Medal of Science.

President Reagan announces Strategic Defense Initiative.

1984

Receives Sylvanus Thayer Award.

1986

Teller was the driving force behind establishing the University of California at Davis, Department of Applied Science. Shown here are the faculty in 1965: (left to right) Michael May, Harold Furth, Montgomery Johnson, Berni Alder, John Killeen, Roy Bainer, Teller (department chairman), Wilson Talley, Richard Borg, Al Kirschbaum, and Richard Post.

members hold joint appointments at UC Davis and Lawrence Livermore. Other than Lawrence Berkeley National Laboratory, Livermore is the only laboratory with such a close relationship to a university.

At the dedication of the permanent teaching facility at Livermore in 1977, Vice President Nelson Rockefeller commended Teller, saying that he had "spoken against the times when he suggested [establishing] an applied science school at one of the leading centers of high technology in the country, but to its credit, one of the world's leading institutions, the University of California, acted on the proposal."

The War against Secrecy

Not long after World War II, Teller, J. Robert Oppenheimer, Niels Bohr, and others protested continued classification of research. Many nuclear scientists even advocated sharing nuclear secrets with the Soviet Union, then our former ally and budding adversary, reasoning that openness on our part would allay the fears of the Soviets. Teller made the point that keeping scientific facts secret would hinder us but would hardly interfere with the work of a potential competitor, because scientific discoveries are almost always made by more than one researcher. However, the

Receives Presidential Citizens Medal from President Reagan.

Is conferred "Director Emeritus" by U. of California Regents.

Cowinner of first Sicilian Regional Science Peace Prize from Italy's Ettore Majorana-Erice- Scienza.

Receives Order of Banner with Rubies of the Republic of Hungary from its President.

1988

1990

Hungary officially declares itself an independent republic.

Berlin Wall is dismantled.

Operation Desert Storm is fought in Persian Gulf.

U.S. government rejected this and other overtures for openness.

Teller likened military secrets to industry's protection of engineering and production technologies. Industry limits access to a product until it reaches the market and researchers begin to produce the next generation. He saw no reason why military secrets could not be handled in a similar way, maintaining secrecy for a year to maintain the element of surprise and then sharing the new technology.

Teller also felt strongly that the country's citizenry should be as well informed about science as possible to allow rational discussion of public policy. Yet, as in the past, the public knows few hard facts about our country's defense systems or those of our adversaries, leaving decisions about our defense to the political winds.

But the classification tide is turning. In December 1993, then-Secretary of Energy Hazel O'Leary began to declassify many documents that had been kept at the secret level for decades. Teller played a key role in convincing O'Leary to declassify documents on laser fusion, pointing out that the secret classification of this work placed U.S. scientists at a disadvantage and impeded international cooperation. Because foreign governments did not restrict fusion research in their countries, the only victims of the secrecy were Americans.

Long-time colleagues and friends Hans Mark (left) and Edward Teller have shared a passion for experimental physics, intense interest in science education, and their excellent senses of humor.

A Way of Life

Edward Teller never stops fighting the good fight. During a speech at Lawrence Livermore National Laboratory's Special Guest Day in 1992, he reiterated his concern about

U.S.S.R. is disbanded.

1992

Is named to National Space Council's Advisory Board by Vice President Dan Quayle.

1994

Receives Middle Cross with the Star of the Order of Merit of the Republic of Hungary.

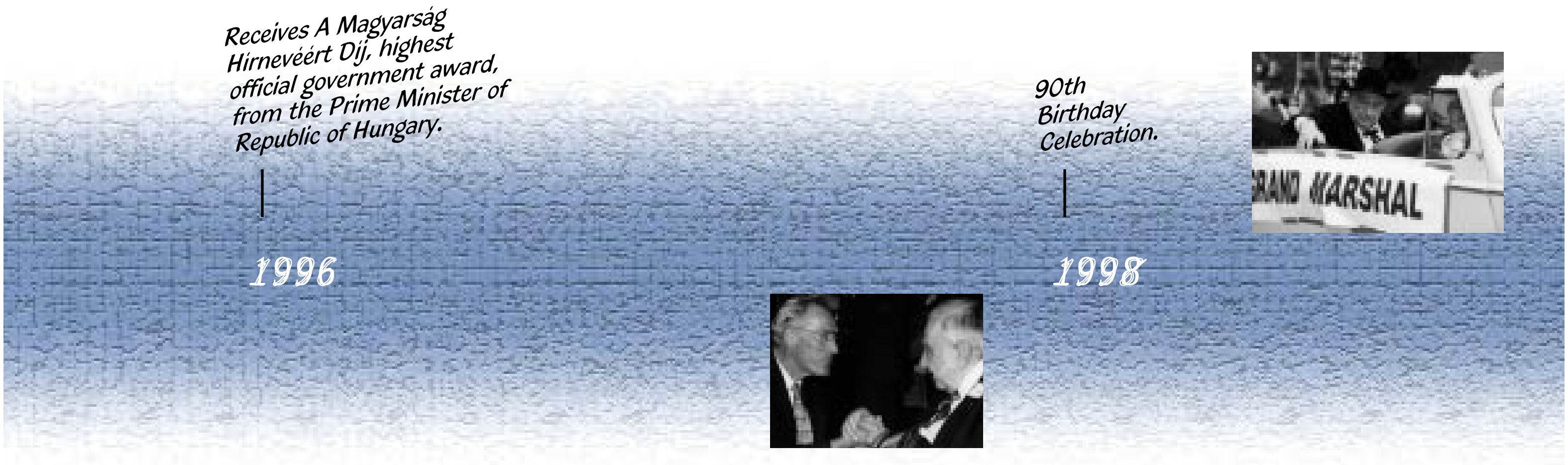
education in the hard sciences and engineering. His thesis was that the U.S. cannot maintain its world leadership position and standard of living unless we act now to rejuvenate our scientific community. He also restated his belief that every student should receive lectures that instill an appreciation of science and technology. According to Teller, possessing a scientific understanding of the universe is important because science "has an influence on all of us, affecting our ideas of space, time, and causality." And understanding technology is important "because we live in it."

He also continues to urge the government to change its classification policy to one that enforces secrecy in a practical manner, that limits the lifespan of secret information, and corresponds with the American ethos.

Teller, a naturalized American citizen, clearly loves his adopted country. Both efforts—for better science education and greater openness—are driven by his concern for maintaining the American way of life.

— Katie Walter

Edward Teller and then-Secretary of Energy Hazel O'Leary confer at a public forum on reshaping the Department of Energy's classification policy. Teller believes that such a policy should include not only less restrictive classification of new documents and declassification of old ones but also a proper explanation of declassified material. (Photo courtesy of AP/Wide World Photos.)



Edward Teller's Awards

1955	**Harrison Medal**, American Ordnance Association
1957	**Joseph Priestly Memorial**, Dickinson College
1958	**Albert Einstein Award**, Lewis and Rosa Strauss Memorial Fund
1959	**General Donovan Memorial Award**
1960	**Midwest Research Institute Award**
1960	**Research Institute of American Living History**
1961	**American Academy of Achievement Golden Plate**
1962	**Thomas E. White Award**
1962	**Enrico Fermi Award**, Atomic Energy Commission
1963	**Robins Award of America**
1974	**Leslie R. Groves Gold Medal**
1975	**Harvey Prize**, Technion Institute of Israel
1977	**Semmelweiss Medal**
1977	**Albert Einstein Award**, Technion Institute of Israel
1978	**Henry T. Heald Award**, Illinois Institute of Technology
1980	**American College of Nuclear Medicine Gold Medal**
1980	**Man of Science**, Achievement Rewards for College Scientists
1980	**Paul Harris Fellow**, Rotary
1980	**A. C. Eringen Award**, Society of Engineering Science, Inc.
1981	**Distinguished Scientist**, National Science Development Board
1981	**Distinguished Scientist**, Phil-American Academy of Science and Engineering
1982	**Lloyd Freeman Hunt Citizenship Award**, Heritage of Freedom Council
1982	**American Academy of Achievement Gold Medal**
1982	**Jerusalem College of Technology**
1983	**National Medal of Science for 1982**
1983	**Joseph Handleman Prize**, Jewish Academy of Arts and Sciences
1984	**National Security Award**, National Coordinating Council on Emergency Management
1985	**American Preparedness Award**, American Civil Defense Association
1986	**Sylvanus Thayer Award**, Association of Graduates, U.S. Military Academy, West Point
1987	**Strategic Defense Initiative Technical Achievement Award**, American Defense Preparedness Association
1988	**Shelby Cullom Davis Award,** Ethics and Public Policy
1988	**Fannie and John Hertz Foundation Award**
1989	**Presidential Citizens Medal**, President Reagan
1989	**DAR Americanism Medal**, National Society of the Daughters of the American Revolution
1990	**Ettore Majorana Erice Scienza Per La Pace**, Science Peace Prize, Ettore Majorana Centre for Scientific Culture, Erice, Sicily
1990	**Order of Banner with Rubies of the Republic of Hungary**, President of the Republic of Hungary, Foreign Minister of the Republic of Hungary
1994	**Middle Cross with the Star of the Order of Merit of the Republic of Hungary**
1998	**A Magyarság Hírnevéért Díj**, highest official Hungarian government award, Prime Minister of the Republic of Hungary

Edward Teller receives awards from (at left) General James Abrahamson and (at right) President Ronald Reagan.

Edward Teller's Honorary Degrees

Doctor of Science
1954 **Yale University**
1959 **University of Alaska**
1960 **Fordham University**
1960 **George Washington University**
1960 **University of Southern California**
1960 **St. Louis University**
1962 **Rochester Institute of Technology**
1964 **University of Detroit**
1966 **Clemson University**
1969 **Clarkson College of Technology**
1987 **Adelphi University**

Doctor of Law
1961 **Boston College**
1961 **Seattle University**
1962 **University of Cincinnati**
1963 **University of Pittsburgh**
1974 **Pepperdine University**
1977 **University of Maryland, Heidelberg**

Doctor of Humane Letters
1964 **Mount Mary College**

Doctor of Philosophy
1972 **Tel Aviv University**

Doctor of Natural Science
1981 **De La Salle University, Philippines**

Doctor of Medical Science, honoris causa
1983 **Medical University of South Carolina**

Doctor of Strategic Intelligence
1987 **Defense Intelligence College**

Honorary Professorship
1991 **Eotvos University, Budapest**

Edward Teller has received 23 honorary degrees since his Ph.D. in physics from the University of Leipzig in Germany.

Edward Teller's Books

Structure of Matter, Francis Owen Rice and Edward Teller, John Wiley and Sons, NY, 1949.

Our Nuclear Future, Edward Teller and Albert L. Latter, Criterion Books, NY, 1958.

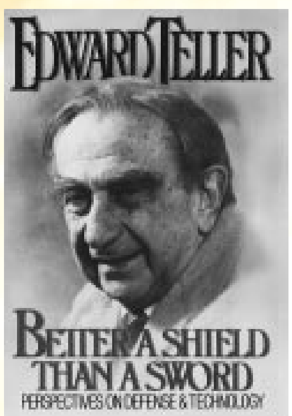
The Legacy of Hiroshima, Edward Teller with Allen Brown, Doubleday and Co., Garden City, NY, 1962.

The Reluctant Revolutionary, Edward Teller, University of Missouri Press, Columbia, MO, 1964.

The Constructive Uses of Nuclear Explosives, Edward Teller, Wilson K. Talley, and Gary H. Higgins, McGraw Hill, NY, 1968.

Great Men of Physics, Emilio G. Segrè, Joseph Kaplan, Leonard I. Schiff, and Edward Teller, Tinnon-Brown, Los Angeles, CA, 1969.

The Miracle of Freedom, Edward Teller, International Academic and Technical Publications, Boulder, CO, 1972.



Energy: A Plan for Action, Edward Teller, available from the Commission on Critical Choices for Americans, NY, 1975.

Critical Choices for Americans: Power and Security, Edward Teller, Hans Mark, and John S. Foster, Lexington Books, Lexington, MA, 1976.

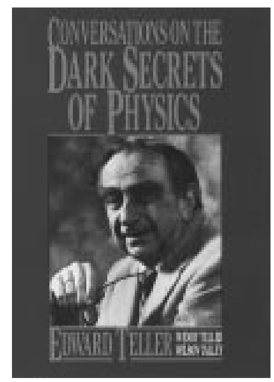
Nuclear Energy in the Developing World, Edward Teller, Mitre Corporation, Metrek Division, McLean, VA, 1977.

Energy from Heaven and Earth, Edward Teller, W. H. Freeman and Co., San Francisco, CA, 1979.

The Pursuit of Simplicity, Edward Teller, Pepperdine University Press, Los Angeles, CA, 1980.

Better a Shield Than a Sword, Edward Teller, Free Press/MacMillan, New York, NY, 1987.

Conversations on the Dark Secrets of Physics, Edward Teller, Wendy Teller, and Wilson Talley, Plenum Press, NY, 1991.



U.S. Government Printing Office: 1998/683-051-60049

University of California
Lawrence Livermore National Laboratory
Science & Technology Review
P.O. Box 808, L-664
Livermore, California 94551

Nonprofit Org.
U. S. Postage
PAID
Albuquerque, NM
Permit No. 853