People of the Hill
The early days

Harris Mayer

Preface

In the first decade of its existence, 1943 to 1953, the Los Alamos Laboratory developed the fission weapon and the thermonuclear fusion weapon, popularly known as the atomic bomb and the hydrogen bomb. This memoir of that early period is one person's viewpoint, the view of a man now over 80 years old, looking back on a golden time when he first arrived in Los Alamos with his new bride in March 1947. It is my recall, seasoned with the knowledge of a lifetime, of a new town and a new laboratory.

Most of the scientists in this story were known to me personally. Others, I knew through the eyes of my young close friends. But my knowledge is only that of a student, blooming into scholarship in the presence of some of the master scientists of the era. That there is wonder and worship is no accident; these are my personal impressions, not the complete view of a skilled biographer. Of course, these people are far more complex than revealed to me by the professor-student relation. Also, I have stayed entirely within the period of that first decade, before the Oppenheimer security investigation, which polarized the scientific community and profoundly altered its relationships. I have not permitted that tragic affair to rewrite the sentiments of the earlier time.

So this account is not meant to be history's dispassionate catalog of events. On the contrary, it is an attempt to give my personal impassioned interpretation of events as I perceived them, played out by people as I have known them. In this process, I have tried to capture some of the essential spirit of the Laboratory at that time. Here is one play that I have written among the many that others could write. I have much enjoyed this scripting. I hope the reader will enjoy the production.

Part I: The Fission Weapons (1943–1946)

The Town, Security, the People

During the war, as a newly hired Los Alamos staff member, you checked in at 109 Palace Avenue, in Santa Fe, where Dorothy McKibben welcomed you warmly and processed your initial paperwork. You would still be unaware of what your job would be like. Then a no-nonsense WAC in a dusty Jeep drove you up a dirt mountain road, fit only for a wagon trail, that led to the top of a mesa shouldering the east slope of the Jemez mountain range. This range is the rim of the caldera formed over a million years ago when an ancient volcano blew its top. The result of the explosion was the Valle Grande, a beautiful meadowed valley measuring some 15 by 20 miles, a favorite visiting site of the Los Alamos residents.

Any arriving young city dweller was in for a culture shock. The streets were unpaved. They were a beaded string of mud puddles after a rain, a rutted obstacle course when dried out. The temporary huts and barracks that served as residences were scattered apparently randomly about the mesa top. That arrangement was one of the two great administrative accomplishments of J. Robert Oppenheimer, the Laboratory director. He had convinced General Groves, the leader of the entire Manhattan nuclear weapons project, to spare the pine trees that dotted the mesa. In typical military fashion, Groves had planned to bulldoze the area flat to facilitate construction. At Oppenheimer's urgent insistence, however, the new houses were not placed monotonously side by side along barren checkerboard streets but were angled higgledy-piggledy among the trees. Only the few houses once occupied by the faculty and owners of the Los Alamos Ranch School, which had been taken over by the Army, were substantial. The only houses that had bathtubs, they still stand today along the appropriately named Bathtub Row. Oppie, as every one called him, and his family occupied one of them. But all in all, what the newly hired saw was an ugly shanty town, mud in the streets, wash drying on the outside clothes lines, babies bawling in a place secluded, unknown to the outside world. Yet this was the town, under the startlingly clear air of the northern New Mexico mountains, where clear-eyed young men were busy discerning nature, defying technical difficulties, striving against time to alter a foreboding history.

At the center of town was Ashley Pond, about the size of a baseball field. Buildings from the Los Alamos Ranch School were retained to the north: Fuller Lodge with its dramatic big log construction; the Big House, also rustic; and of course, a few hundred yards farther along, the Bathtub Row homes. Also in this area, the Army had built a cafeteria and a commissary run by the military. In a time of war rationing, everyone could get great buys at the commissary, which was like a combined general store and small supermarket. This was one of many fringe benefits to ease the otherwise Spartan living conditions on The Hill. To the south and east, fronting on the pond, was an elbow of wood construction technical (tech) area buildings. On the reverse side of these buildings, an unpaved road ran, later named Trinity Drive after the site of the first test of a nuclear explosion. Two enclosed pedestrian bridges over Trinity formed convenient passageways to other similar office buildings and to Laboratory facilities. The tech area was isolated from the general town site by security fences. Military guards, pistols at hip, checked one's tech area badge at entrances on either side of Trinity Drive. Designed to be temporary, the buildings outlasted the war and eventually even their economic utility. Starting in 1956, as the new tech area was built on the adjacent mesa to the south of town, the old buildings were torn down. Around Ashley Pond today only Fuller Lodge remains, modernized with additions in keeping with its original style. Nowadays, the Los Alamos Inn stands on land cleared of the old Lab buildings. Musing there, one can sense the spirit of that dynamic, vibrant old tech area. The meandering winds seem to whisper in one's ear, recounting the wondrous secrets of the atomic bomb that they long ago overheard here.

This was the city on the mesa. But the people living there never called themselves mesa dwellers, hardly ever said, "I live in Los Alamos." Los Alamos was usually referred to as "The Hill.' If one visited Santa Fe, it was "I've got to get back up The Hill." A scheduled bus ran between Los Alamos and Santa Fe. It was considered inappropriate by security to miss the return trip. Underlying this reticence to mention Los Alamos was the pervading atmosphere of security. Round the clock, sentries manned guard gates on all approaches to the town. Official badges were inspected when people entered and left the area. Personal guests had to be approved by the security office merely to enter the town. Off-site, the famous scientists had pseudonyms to conceal their true identities. Neils Bohr was Nicholas Baker; Enrico Fermi was Earnest Farmer.

Everywhere the Army presence was apparent. Soldiers in uniform manned the guard posts and ran the motor pool and the communications facilities. The Army engineers did all the heavy construction. But the Army was also a valuable personnel resource for the Laboratory. Young scientists summoned for service by their local draft boards were diverted into the Special Engineering Detachment (SED), some ending up at Los Alamos. Although they were housed in barracks and sometimes mustered for parade, they worked on a par with their brother scientists inside the fences at the Lab.[1]

Newly hired Los Alamos staff arrived at Lamy, New Mexico.

At 109 Palace Avenue in Santa Fe, they signed in.

Once at the tech area in Los Alamos, they spent long hours applying the new concepts of nuclear physics to a usable weapon.

To the scientists working at the Lab, their quasi confinement was an understood security necessity. Besides, they were too busy working to be much concerned by the restrictions. But for wives who had no employment at the Lab, it was different. Some developed acute cases of "Hill fever," a condition usually not part of the medical lexicon and one not always appreciated by a husband mired in a resistant technical analysis. People were sometimes under stress, and release by drinking was a common indulgence. Although alcohol was off-limits on a military base, that was no barrier to the ingenuity of the staff. It was reliably reported that one

[1] After the war, some of the SEDs returned as staff members—for example, Jay Wechsler helped greatly in the engineering of the first hydrogen bomb test. In the Theoretical Division (T Division), Bill Lane was an SED holdover. He was the slender living memory of the group that had done detailed numerical calculations of the fission bomb using the most modern IBM equipment of the time. From the higher military ranks, Colonel Ralph Carlisle Smith, Smitty in his civilian reincarnation, was a welcome holdover. Although on the organization charts he headed the newly formed legal and document division, he was essentially the unofficial chief of staff of the new Laboratory director, Norris Bradbury, who had replaced Oppie.

of the well-known landmarks on The Hill was useful in giving directions as in “To get to the new cafeteria, go two blocks past the bootlegger’s and turn left.”

After he had saved the pines on the mesa from the general’s bulldozers, Oppenheimer achieved his second great administrative accomplishment: the particular security structure within the Laboratory, quite different from the standard need-to-know compartmentalization desired by General Groves. Oppie insisted that there be no security barriers within the Lab. Essentially, every staff member had “need to know.” Groves gave in; Oppie won out. It was a wise victory. It fostered an essential spirit of camaraderie, which resulted in cooperation even under the trying work conditions at the Lab and the daunting challenges of nature. All that made for a great laboratory.

To Build a Laboratory

How did the great laboratory that made the atomic bomb come into being on an isolated mesa on the eastern shoulder of New Mexico’s Jemez mountain range? From his early years of vacationing in the area, Robert Oppenheimer knew of the exclusive Los Alamos Ranch School on that mesa. In the site selection process, the Ranch School was probably his secret choice for his nuclear weapons laboratory. So on a brisk day in November 1942, Oppie himself, accompanied by Ed McMillan from Berkeley and Major John H. Dudley of the Manhattan Engineering District, visited the site incognito. The residents at the school wondered what these strange visitors were about. It was wartime; perhaps some of the faculty had a potent premonition. In fact, this visit meant that the days of the school were at an end. The school was to be taken over for the war effort.

Oppie made the decision. Here was the place. It was a felicitous choice. The sun sank slowly behind the Jemez range. The shadow of its ridge crept sedately eastward along the finger of the mesa, dulling first the base of the ponderosas while their crowns for a while longer remained enflamed in orange gold. In the years ahead, this daily ritual was to contribute much to the essential spirit of the Laboratory.

Oppie’s choice was ratified by General Groves. He arranged the purchase of the Ranch School for $440,000. A contract was drawn up with the University of California as the legal entity responsible for the Lab. Initially, it was a responsibility in name only, but as the years went on, the University became an important element in the workings of the Laboratory. The contract continues in force to this day.

The Ranch School was no more. Now it was time to build the Laboratory on the site. The first priority was to assemble the staff. Originally, Oppie thought he would need three hundred—he ended with about three thousand. With Groves’s inspired selection of J. Robert Oppenheimer as Laboratory director, staffing of the Laboratory clearly was to be successful. A sure accession was Edward Teller. He had been captivated by Oppie’s quick mind, one as fast as his own, and he even envied Oppie’s universal erudition, more varied than his. Teller hoped to be the leader of T Division at the Laboratory. He also hungered to continue exploration of the thermonuclear bomb, the Super. It was Teller who had brought that possibility to Oppenheimer’s attention during the 1942 summer study at Berkeley. There, Oppie and Hans Bethe had enthusiastically joined Teller in divining the initial concept of that weapon, so fascinating in its scientific complexity. Edward was to be disappointed in both these hopes.

The next and the essential convert was Bethe. He was at the Massachusetts Institute of Technology (MIT) Radiation Laboratory in Cambridge, working on the radar devices that had won the air war over Britain. Oppie’s magnetic aura captured Bethe. Other senior scientists were not so easy to recruit. Oppie’s great personal magnetism was not capable of catching the pragmatic experimentalist, Isador Isaac Rabi. That Columbia University Nobel laureate to be (1944) reasoned that the nuclear bomb would never be ready in time to be a factor in the war, whereas radar had already demonstrated its potential to make a meaningful difference. Rabi only consented to be a part-time consultant, an elder statesman to the younger master scientists, and a valuable representative of the Lab on the national scene. But many other people from the MIT Radiation Laboratory, particularly Victor Weisskopf, came to Los Alamos. Bethe and Weisskopf were to be leader and deputy of T Division.

With Bethe and Teller aboard, recruitment snowballed. Oppie could not discuss the nature of the project at Los Alamos, but he could promise association with those two scientists. It was wartime, and the enemy was real, powerful, perceived as evil, and threatening. Not only patriotism, but also concern for the concepts of civilization itself, motivated the scientists to accept without question the unrevealed and highly secret work. But they could not have dreamed of its eventual worldwide impact.

Personnel and equipment were gathered from the university campuses and industrial laboratories around the country. First to arrive at Los Alamos was Robert Wilson’s Princeton group because their project, the isotron for separating uranium isotopes, had been abandoned. Richard P. Feynman was one of the group. Feynman’s addition to the later formed T Division, with

Bethe and Weisskopf, made a remarkable triplet combination.

It was Churchill himself who approved the transfer of a star group of scientists from the British atomic project to the safety of the United States to aid in the Manhattan Project. They arrived in November 1943. The leader of the British mission was James Chadwick, that careful nuclear experimentalist who patiently pursued the neutron. For that discovery he had received the Nobel Prize in 1935.

The British mission included theorists Rudolf Peierls, Geoffrey Taylor, T. H. R. Skyrmes, and Klaus Fuchs. Peierls, a well-rounded theoretical physicist, was a Berliner, assistant to Heisenberg, working in England when Hitler expelled the Jews from the universities. Peierls wisely stayed in England. When the war came, he was eager to help his adopted country. Working on the British atomic bomb project, he had already correctly estimated the order of magnitude of the critical mass of uranium-235 for a fast fission weapon, which Heisenberg had very badly missed. That error from so capable a physicist and his associates passeth understanding. It precluded the possibility of success in the German atomic weapon program.

Geoffrey (G. I.) Taylor, the ace hydrodynamics professor, combined experimental experience, intuitive theory, and clever classical mathematics to achieve a more thorough understanding of this important aspect of weapon design than any of his Los Alamos colleagues. Klaus Fuchs, of course, was the perfect espionage agent of the scientific era—capable in his science, universal in his technical interest, and morally motivated to aid the communist cause. He became involved in every aspect of weapon design, the thermonuclear Super, as well as the two types of fission weapons. He was easily accepted as a valuable coworker, which of course he was; no one ever dreamed that he was a spy. Actually, the United States had accepted the U.K. security clearances for the British mission, and so made no independent investigations. It is doubtful, however, that they would have detected the potential spying of Klaus Fuchs.

Other experimentalists rounded out the British mission: William Penney, P. B. Moon, Egon Bretscher, Otto Frisch, and James Tuck, among others.[2] It was a year later that the Canadian group, George Plazek, Carson Mark, Bengt Carlson, and Max Goldstein appeared at Los Alamos. They arrived too late to take part in the main work on the fission bombs, but they stayed on after the war and made important contributions in neutronics and in the computational capability of the Laboratory.

In building up the Los Alamos staff, physicists and chemists mysteriously disappeared from their universities. Bewildered colleagues they had left behind sometimes later joined them on the mesa top. Some of the recruits were the following: from the Columbia University physics department, Norman Ramsey, Julian Askin, and Bernie Feld; from the University of California, Eldred Nelson, Robert Christy, and Robert Serber; from the University of Chicago, Nick Metropolis, Stan Frankel, Harold Agnew, and Harold Argo. Somewhat later, in 1944, after the pile under the stadium stands at Chicago had been operating satisfactorily, Enrico Fermi, with his exceptional assistant Herb Anderson, joined his European expatriates Bethe and Teller. From the University of Wisconsin, Stan Ulam, a first line Polish mathematician, was recruited by his friend and supporter Johnny von Neuman.

Initially, a gun device was deemed necessary for the assembly of a fission weapon. Therefore, early on, the Los Alamos Laboratory initiated an ordnance program. William S. (Deak) Parsons, a clever, inventive Navy captain, was chosen as head. He was aboard the B-29 aircraft that dropped the bombs over Japan. So was young Harold Agnew, who later became the third director of the Los Alamos Laboratory.

We may set the birthday of the Laboratory at April 1, 1943. Even before that date, construction started at the site. More important, top purchasing priorities for equipment, far more valuable than cash in wartime, were obtained. The university scientists and the Laboratory connived on the transfer of experimental equipment to the site, equipment paid for by the government, more to observe the legal niceties of our procurement system than as a condition of sale. So it was that the Harvard 36-inch cyclotron, disassembled in pieces and parts, arrived at Los Alamos in mid-April with Bob Wilson from the canceled Princeton project as its shepherd. By June, it was operating. The two University of Wisconsin Van de Graff generators were commandeered. The 4-million-volt "long tank" was brought online in May and the 2-million-volt "short tank," in June. Physics measurements could then be made, for example, on the crucial number of neutrons emitted per fast neutron fission. Only specks of uranium-235 and plutonium-239 were available for that measurement, but the experiment was successful. Apparently, nature loves a fission chain reaction, for that number was found to be considerably greater than 1, the theoretical minimum required.

[2] While the rest of the mission returned to England after the war, Tuck, after a brief sojourn in the mother country, came back to Los Alamos for the rest of his life. Tuck was a lively, outgoing person, worthy of his namesake, the cleric companion of Robin Hood. To him physics was a joyous adventure or it wasn't good physics. He started the controlled fusion program at Los Alamos, inevitably named the Sherwood Program.

The Master Scientists

To understand the contributions of theorists to the many-faceted work of the Los Alamos Laboratory, one must understand the relationships of four outstanding scientists: J. Robert Oppenheimer, Enrico Fermi, Hans Bethe, and Edward Teller. Though immensely talented and wise in physics beyond their years, they were still relatively young. Teller was born in 1908; Bethe, two years earlier; Oppenheimer, in 1904. Fermi was the oldest of the group, not only in age—he was born in 1901—but in the respect they rightly accorded him. He had already received his Nobel Prize in 1938. But to the youngsters in their twenties, the main workforce in the Lab, these four men were indeed the wise old souls, though only in their thirties and forties. Together at Los Alamos, almost from the starting date of the Laboratory in April 1943, these four men who had known each other for some years, who instinctively almost innately understood each other, now worked closely, enthusiastically toward the development of nuclear weapons—they were a family of scientific brothers. Much later, the tragic Oppenheimer affair in April 1954 ripped the family apart forever.

The lives of these scientists were sternly contoured by the great changes that occurred in the twentieth century. That was the time of a painful metamorphosis of Western civilization. Starting from the comfortable assurances of the Victorian era as a primarily agricultural society, the transition progressed uncertainly toward the promise and the perils of the new, predominantly industrial society. In the process, the two great world wars were fought, the outflingings of a culture trying almost everything to find a satisfactory accommodation. Bethe and Teller, too young to serve in the military of World War I, escaped the grinding up of a whole generation of men, but they nevertheless experienced real poverty, privations, and hunger in war's aftermath. Characteristically, Enrico Fermi, temperamentally of earthy Italian peasant stock, passed unaffected through that war.

But while the larger society was convulsing in this cultural transformation, the scientists' own smaller universe of physics was reveling in the scientific revolution caused by the two new central theories of the twentieth century, relativity and quantum mechanics. Whereas the scientists had been victims of the societal changes, they were joyous participants, indeed significant contributors to the new science. At different universities from 1926 to 1933, these young men, instructed by the grand old professors—Bohr, Pauli, Sommerfeld, and Born—used the new scientific disciplines to solve problems in atomic, molecular, and solid-state physics. By day they worked hard and ably at their craft. Compared with classical mechanics, quantum mechanics appeared abstract, nonintuitive. But so simple the premises of that new theory, so universal its application! One equation, the Schrödinger equation, contained almost everything needed. But that equation concealed remarkable subtleties. It took a newly developed nonclassical intuition to penetrate those subtleties. Then easily the new theory served up quantitative results on problems untouchable by classical theory.

These were young men, not yet married, still not settled down. Their whole lives were just opening up before them. They had that zest, that wild joy of living, only partly satisfied by their daytime scientific work. By night they gathered with colleagues and an occasional younger professor in groups where the traditional carousels of youth were overlaid with something deeper, more . . . the wonderment at the mysteries of their craft. Free, however, from the discipline of their daytime work, they would be expansive, philosophizing about the innate quality of Nature and their own place in her grand scheme. The ever pragmatic Enrico Fermi did not so indulge.

Although the young scholars did not fully recognize it, the dark shadow of Adolph Hitler was lengthening over Europe as the sun was setting on the Weimar Republic. On April 7, 1933, Hitler's captive Reichtag passed the "Law for the Restoration of the Civil Service." These mild appearing words meant simply that Jewish faculty members were to be expelled from the universities. The young scientists' bright dreams of fulfilling careers turned into nightmares. Edward Teller and his wife Mici were Jewish. Hans Bethe was brought up as a Protestant—German law defined him as Jewish. Fermi was a Catholic, but he married Laura Capon, a beautiful, spirited, intelligent young Jew. All three families realized that they had to escape from Europe while they had time. By different paths, at different times, with varied help, anxieties, luck, they all found places in America. When the Manhattan Project started, they were available and well prepared for its demands.

Of the four outstanding scientists, three—Teller, Bethe, and Fermi—were European refugees from dictatorships. They had felt the personal degradation and moral corruption of totalitarian regimes. Oppie was an American intellectual, but he had done postgraduate work under Max Born in Europe. All of these men were not merely great scientists; they were extremely complex individuals. Contrary to the popular stereotype of a scientist as an expert in his field but naïve in other disciplines, and particularly in practical matters, these remarkable men were multiphasic in their capabilities. Their stern and thorough training in science equipped them to analyze problems in other areas of their interests and, where appropriate, to apply quantitative methods of considerable sophistication in their solutions.

The three Europeans had been together at Columbia University since 1939, all living in Leonia, a pretty New Jersey suburb a few miles across the Hudson River from New York City. Among their friends and an essential part of their intellectual community were Joe and Maria Mayer and Harold Urey. Urey was the director of the Special Atomic Materials (SAM) Laboratory of the Manhattan Project, where the fundamental work was done on the separation of the uranium isotopes. He was already a Nobel laureate for his discovery of heavy water containing deuterium, the rare mass 2 isotope of hydrogen. Joe and Maria Mayer were well known to the three European scientists from prewar days. Later in 1963, Maria, aided to a significant extent by her good friends Teller and Fermi, was to get the Nobel Prize in physics for her work on the magic numbers of nuclear shell structure. The group often carpooled together, driving to Columbia University, where they would need only one parking space. When crossing the George Washington Bridge to New York from Leonia, their car contained four current or future Nobel Prize awardees.

Bethe and Teller arrived at Los Alamos almost at its beginning. Fermi followed in 1944, as soon as he finished his work on the nuclear pile at Chicago.

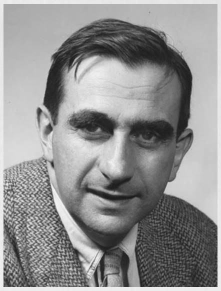
Oppenheimer and Groves. Oppie, of course, was the technical director, but General Leslie Groves was in overall charge of the Manhattan Project. General Groves was a capable no-nonsense engineer, but he was incapable of appreciating the scientists' method of probing the unknown territories leading to the realization of the fission device. He had a timetable driven by desperation, and he was determined to meet it. His skill was in known engineering projects, in programming to meet schedules and budgets. His recent practice was in military command, where orders were obeyed, not questioned, and well-paid contractors, who understood engineering schedules and budgets, were acquiescent to his will or sometimes even to his whim. He would have preferred to do without the scientists, the eggheads who could not seem to get on with the work. Oppie alone could not have moved the general to adopt the exploratory methods of the scientists in place of his proven procedures of getting a job, albeit a well-known one, done. But Oppie knew the power of his scientific associates. He trusted their capabilities. Skillfully, he used the necessity of accommodating to their methods to sway the general away from his accustomed path.

Rather than Groves channeling the scientists to his methods, it was the scientists, through Oppie, who channeled Groves's efforts for their support. Groves became not the project leader directing efforts, but the project enabler who helped the scientists do their job. Capable an engineer as he was, Groves never realized that he had been co-opted to the scientific task. To the end of his life he really believed that he had made the atomic bomb.

Enrico Fermi and Hans Bethe. By 1941, Fermi was already building a nuclear reactor pile in the basement of Pupin, the physics building at Columbia University. That pile could not achieve criticality because of the neutron-absorbing impurities in the graphite blocks then available. Fermi was the most complete physicist of the brothers, perhaps the most complete physicist of the century. He had a profound understanding of his subject. In theoretical physics, quantum mechanics was as natural to him as classical mechanics. He said that,

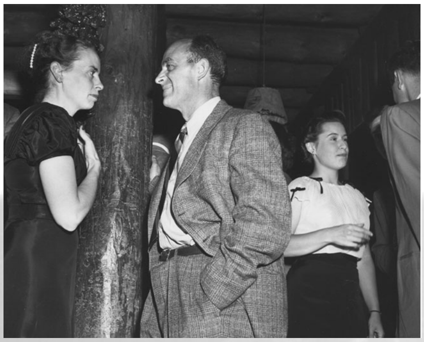

J. Robert Oppenheimer


Enrico Fermi


Edward Teller


Hans Bethe

after completing his *Reviews of Modern Physics* article on the quantum theory of radiation, he understood it so well that its extension to his theory of beta decay just sprung unbidden into his brain. Both an experimentalist and a theorist, he had the feel of physics in his hands. He was the supreme practical problem solver; for example, he developed the age theory of neutron slowdown enabling simple calculations of



Fermi socializes with coworkers and friends at a party.

nuclear reactor performance. At parties, he was the best riddle and puzzle solver of the crowd. The high sport at these events was to stump Fermi. Modestly, he explained his success, not as due to his particular skill or intellect, but simply to his practice at the art. After a while, he had seen most of the usual puzzles and had developed the knack of solving the various types.

Bethe was lecturing from his classic articles published in *Reviews of Modern Physics* (1936–1937), summarizing and systematizing all that was worthwhile knowing about nuclear physics at that time. If one knew what was in that "Bethe Bible," one need not bother reading any literature previously published. Most theorists, as well as the experimentalists, told Bethe about their work before it was published. His brain absorbed it all, refined the information, organized it, and stored it permanently, but with instant recall. In addition to having formidable manipulative technique, Bethe had a deep understanding of physics, accompanied by a unique knack of finding the simple way for analyzing a problem. He showed this quality in his 1946 work explaining the Lamb shift in the hydrogen atom 2s and 2p fine structure. By using a nonrelativistic approximation and by staring down some daunting infinities, he captured the essence of this quantum electrodynamic effect before anyone else did. Bethe was a genial father figure to his young associates. They could always find him a sympathetic listener to their troubles, personal or scientific.

Edward Teller. Edward Teller was the most convivial of the three Europeans. It seemed as if he did not work on physics—he talked out physics. He almost had to have a collaborator. For Fermi, physics was in his hand; for Teller, it was on his tongue. This story is told by one of Edward's students who knew Fermi as well. When the student first met both of them soon after they came to the United States, Fermi's English was so heavily disguised by his Italian accent that he was barely understandable. Teller, on the other hand, spoke well, although he sounded obviously quite Hungarian. Several years later, the student found that he could understand Fermi easily, but Teller's accent had improved not a bit. The student reasoned that Teller was always talking while Fermi really listened. When the student told this theory to Teller at a dinner party, forty years later, Teller could only laugh a huge Hungarian laugh.

Edward Teller was one of those scientists and human beings who are easy to be with but hard to classify. His outstanding scientific characteristic was his creativity. Before the war, he had already made significant contributions in molecular and solid-state physics. But it was his breadth of comprehension, rather than any specific contribution, that gave him his effectiveness. Putting diverse aspects together, Teller was able time and time again to hit upon the unusual synthesis; that was his creative mode. Even close colleagues, however, complained that he had too many ideas; they could not work on all of them. With the good ones, there were sure to be some poor ones to be filtered out. But the faint hearted, who never propose anything that turns out to be wrong, rarely propose anything significant. Edward Teller, even by his critics, was never assailed as being faint hearted.

Concealed behind his very clear physical insights was his full mathematical competence; he could, when he wished, work out in detail his inspirational concepts. However, as a teacher in his classroom, Teller would eschew the mathematical derivations and, instead, develop interesting physical reasoning to prove a point. As a trivial example, in his

At Fuller Lodge in Los Alamos, Teller talks with Julian Schwinger (left) while son Paul enjoys his favorite ride.

graduate lectures on mechanics, he obtained the resultant of two forces, which leads to the familiar parallelogram result not by the addition of the *x*- and *y*-components of the forces but by qualitative symmetry arguments that showed the inevitability of that conclusion.

But it was outside the classroom, in one-on-one or one-on-two conversations, that Edward excelled. With his peers, he would stimulate; with the fully developed young scientist, he would inspire; with the fresh student, he would educate. He helped them all.

Edward Teller was one of a group of Hungarians sometimes called the Martians because of their apparently unearthly intellectual abilities. They all came from a small neighborhood in Budapest: Leo Szilard, Teller, Theodor von Karman, John von Neuman, and Eugene Wigner. They knew each other from their youth. It was Szilard and Teller who approached Einstein to get his backing for the atomic bomb project and through him eventually to get President Roosevelt to approve it. The childhood acquaintance and later mature interactions of these "Martians" contributed greatly to their effectiveness during the Manhattan Project.

J. Robert Oppenheimer. Oppenheimer was the director of the Los Alamos Laboratory, chosen and championed by General Groves. With Oppenheimer rested the responsibility for the scientific and technical aspects of the project. For his authority he possessed, through the general, the key to unlimited funds and, what was more important in the wartime economy of scarcity, the highest priorities. But what authority over the minds of those European scientists did he have? Oppie, in his own right, had made significant contributions in physics. He was in part responsible for the Born-Oppenheimer adiabatic approximation of molecular and solid-state physics, which separated the treatment of the degrees of freedom of the rapid motion of the electrons from those describing the more stately motion of the massive nuclei. He also developed and then applied the Oppenheimer-Phillips process to the collisions of high-energy deuterons with complex nuclei. In that process, the proton in the deuteron could not penetrate the Coulomb barrier of the target, and so it sat by as a spectator particle, while its accompanying neutron engaged in the reaction. Two of the earliest papers on the theory of black holes were his. Had he not been diverted from his career as scientist by his service at Los Alamos, he might have gone very far in that field.

Oppie possessed a very quick and facile mind. He was able rapidly to absorb almost any subject, and since his interests extended far beyond science, he became learned as well in philosophy, literature, and language. His wide-ranging erudition surprised, even delighted, his colleagues but set him apart—he carried himself on a higher plane. His very quickness also enabled him to understand the varied work of the Laboratory staff; sometimes, he would comprehend even more than did the originators. That faculty made him extraordinarily well suited to direct work in the multidisciplinary problems of the Los Alamos program. Furthermore, with his vast command of technique, he could often integrate scattered work into a sophisticated and powerful mathematical formulation. Despite his mental gifts, in the judgment of the European trio, his accomplishments in science were not up to his potential, and they were competent to make such judgments. So, how could Oppie, as director of the Laboratory, make these men work together with him?


(Left to right) Dorothy McKibben, Oppie, and Victor Weisskopf at a party on Bathtub Row.

Consider the following: Before the war, Oppie was one of the intellectual elite in the company of his students and colleagues at Berkeley. He was harsh in his criticism of their work, to some extent belittling their efforts. After the war, as director of the Princeton Institute for Advanced Study, he continued the same elitist attitudes. But at Los Alamos, Oppie was different. He was obviously capable intellectually of recognizing that, in the Los Alamos setting, his attitude toward the technical staff must be different from that he showed to his students. Not only must he continue to be a leading scientist, but also he must be an effective administrator and much more. He remained above the staff but not distant from them. He would understand and kindly appreciate rather than criticize them, and they loved him. In the company of Fermi, Bethe, and Teller, he was in no position to denigrate their abilities. Recognizing this, Oppie became their facilitator—he provided the opportunity and the atmosphere for them to do their best work. And he could integrate their work into the overall Lab program. He was the coach and the strategist of his team of star physicists. Organizationally, he realized that it was inappropriate to place them all in one theoretical division with the resulting question of who worked under whom. To Bethe, he gave the name and position of head of T Division. Fermi had his own Division, "F" Division, of course. By temperament, Teller would not permanently be pigeonholed anywhere. He was permitted to float, nominally in T Division, but detachable for special assignment anywhere, either at his own selection or by Oppie's direction. Edward was a large man with many and large ideas. He would prove to be one of the most creative people at the Lab.

Role of the European Scientists. What did these three European scientists bring to the Laboratory during and after the war? Obviously, they brought their broad scientific knowledge and great scientific talent. They were also problem solvers, comfortable with entering new fields and venturing on untrodden grounds—just what was needed to develop the fission bomb, a device previously imagined only in science fiction. To their tasks, they brought the discipline of hard work and the habit of persistence, not the dogged persistence following a single path toward a destination, but the persistence to try path after path until a broad highway opened up to their goal. There was an enduring legacy these scientists left to Los Alamos. It was the love of science, the enthusiasm of working in science, and the confidence that science was the tool of choice for developing the new industries needed in peace as well as war—to serve the needs of humankind. Moreover, they could inspire others to have the same faith.

As no others, they knew their opponent—the two sides of Germany. They knew the background and the richness of the body of German science, and they knew the genius of Werner Heisenberg. They also knew at first hand the perversion of values that the Nazis had brought to their countries, and the power of an aroused and united nation whose imagination had been unfortunately captured by its persuasive but demoniac leader. Therefore, they worked with conviction spurred on by a terrible fear.

Inspiration of the Scientific Staff. To the more junior scientists (not necessarily the younger scientists) at the Lab, Oppie acted with regard, care, and understanding. He was their charismatic leader, and they all but deified him. His direction and their combined cooperation made for a great team. Together with the European science masters, they played above their individual capabilities. They succeeded. They made the fission bombs.

A unique spirit of cooperation and camaraderie among the young staff scientists pervaded the Laboratory. Oppie's leadership was a part of it, but there was more. These young people had left home and family behind. Joined in a great enterprise, they could not afford to dissipate their energies in divergent pursuits, nor did they have much opportunity to do so. They were isolated, confined on The Hill, restrained by security measures. The town was entirely dedicated to their work, no way to escape that fact. Their companions in the few hours off from work were usually coworkers. Such concentrated intimacy they had never known before. Actually, their coworkers were like an extended family. And what coworkers! Some scientists worked directly under the European masters, who here were not Professor Fermi, Dr. Teller—just Enrico and Edward.

The hours were long, and the work hard. Sometimes it was routine, but often it was science at the edge of their capabilities. They found that necessity had as brother, opportunity. Though the work had direct application, the work itself or the methods to be developed required good science, and the best scientists were close at hand to advise, to inspire, or just to listen. Here they were not students, working alone on a small, detailed topic in science leading to a doctorate. Here, for most of them for the first time, they were in large groups working together by using big science, big facilities—a brotherhood of effort, companions in accomplishment. But behind all the deadly seriousness of the task were a spur and a satisfaction. For most of the participants, the Los Alamos experience was the highlight of their lives. The work was well done.

At the Laboratory, the hours were long, and the work hard. The weekly colloquia, one of which is shown in this photo, were stimulating and intense. They are still remembered.

War Work at Los Alamos

When Los Alamos was founded in April 1943, fission bombs were already known to be feasible, at least in principle. Two avenues to their production were using the separated uranium-235 isotope to be produced by Oak Ridge or using plutonium-239 to be produced by the Hanford nuclear reactor. But all plans were largely on paper. Fermi's pile at Chicago had just demonstrated the first manmade neutron chain reaction in a critical assembly. Hanford and Oak Ridge were still "to be's." How to design a bomb with the constituents available in only small amounts and with some critical material and nuclear properties largely unknown? That was the Los Alamos problem. Getting the required plutonium and the separated uranium-235 isotope—that was the problem of the rest of the Manhattan Project.

Meanwhile, news from the battlefield gave a terrifying urgency to the tasks of the Laboratory. The Battle of Stalingrad, after terrible slaughter, had just ended in Soviet victory on February 2, 1943. It was not yet recognized as the real turning point of the European war. In the Pacific, the island-hopping campaign had barely begun. On the ground in North Africa, the U.S. troops were about to experience their first combat defeat at Kasserine Pass. How to proceed at the Laboratory? There was no time for the conventional wisdom. What was needed was a new wisdom chased by haste, built on scientific insight, ingenuity, and luck, helped by nature's guiding hands!

The building in which criticality experiments were carried out was called the kiva, a term borrowed from the Pueblo Indians. Here, the kiva is photographed from an Indian cave in the nearby wall of the Pajarito Canyon.

The goal of the Laboratory, the development of the fission bomb, was clear, and the basic scientific concepts were known. But the detailed implementing pathway was vague. Urgency dictated that almost everything be done at once. To General Groves, this process could only bring chaos—no firm priorities, no observed schedule, no PERT charts. He felt beset by more and more requests for strange pieces of apparatus and for usually unavailable materials. He did obtain them all; that was his genius.

But the scientists were on familiar ground. In their research, as usual, nature was in charge, but not always clear and apparent in her direction. In keeping with their background, the scientists organized in traditional academic manner, by topical disciplines. They created divisions in physics, chemistry, explosives, mathematics and computation, theory, and others as well. Senior professors headed each division, with younger persons, much like students, guided and taught by them. Not only was the staff expected to do specific jobs, although that was their primary responsibility, but they were encouraged to learn and also to innovate. Because at Oppie's insistence there was no security compartmentalization, the senior scientists knew, in some sense, all the work at the Laboratory. The junior scientists were also informed but to a lesser extent. Therefore, everyone could contribute ideas; everyone could join in their evaluation. Not altogether surprising therefore, creative contributions, out of the mainstream of their work, were made by Jim Tuck—a central idea in the high explosives of the plutonium weapon; by Seth Neddermeyer—in the assembly of the plutonium weapon; and by Bob Christy—for a crucial idea that rescued the plutonium weapon from potential disaster. Moreover, pure science too was cultivated if it had the possibility of mission application—for example, Walter Koski experimented with the collision of two high explosively driven jets to see what high temperatures could be achieved. Teller improved the theory of radiation transport at temperatures attained in nuclear weapon explosions. He developed a practical statistical treatment of the very many spectral lines in the transport medium under those conditions. This was an adaptation of Wigner's work on neutron transport in nuclear reactors, where many neutron absorption lines exist and must be considered.

New facilities were built, almost overnight, erupting from the chaos: a critical assembly building, plutonium-handling laboratory, high-explosive range, ordnance firing site, sheltered canyon location for a nuclear reactor, and another one for experiments with very high intensity radioactive sources. Finally, when necessary, the scientists seconded as engineers, and very capably too—there was no holdup or misunderstanding in transition as would occur in ordinary industrial practice.

The entire informal, almost slipshod-appearing organization fostered the nascent good feeling and cooperation of the staff. General Groves did not appreciate the character of this organization, but strangely, he had confidence in Robert Oppenheimer. Although to Groves Oppie appeared disorganized, actually Oppie could keep up with everything, understand everything—he had all the inputs in the data bank of his brain, and there he could organize them and, as necessary, rapidly reorganize them to take into account new facts of nature. Oppie worked magic with his people, and they worked their hearts out for him, performing way over their heads. That dedication was what made the Los Alamos Laboratory.

The scientists worked in a special type of mental denial. They knew the terrible destructive power of the nuclear explosive they were devising. They subconsciously could not call it a bomb. Instead, they called it, in general, the device, or the gun gadget (the uranium-235 bomb) and the Christy gadget (the plutonium bomb). The plutonium weapon was named after an Oppenheimer protégé, Bob Christy, who very late in the program, proposed an idea that rescued that device from apparent failure. The characteristic time scale of the explosion was never referred to in its scientific nomenclature, but was called a shake, obviously short for the flick of the lamb's tail. The characteristic cross section for the nuclear processes in the explosion was called a "barn," signifying that it was an easy target. Despite this levity, the scientists worked hard and happily at their mission, although at heart they were appalled at its potential for destruction. Also, they worked with a terrible urgency, for the famous European expatriates who worked at the Laboratory knew the capability of the German scientists they had left behind. They feared living in a world where Hitler would be the first to have the bomb.

The Equation of State: An Example. To illustrate the character of the work at the Laboratory, let's choose one problem of the many. The fissile material, initially of course in a subcritical configuration, is to be assembled by rather violent, explosively driven motions into a supercritical state. To calculate this motion, the equation of state of the various materials in the weapon was needed at pressures and densities starting from their normal state and increasing during the assembly of the weapons to conditions surpassing those at the center of the earth. Then, at the nuclear explosion, conditions would approach those at the center of the sun. Nicholas Metropolis was assigned to the problem.

The "sun" part was the easy one. Astrophysicists had already understood in principle how to calculate that equation of state. Under those conditions, all materials form highly ionized plasma, and the pressure is almost entirely due to the free electrons acting as a perfect gas. Guess the number of free electrons, guided by the astronomers' formula, and you have the answer to some reasonable approximation. Los Alamos is still improving this approximation almost 60 years after the work of Metropolis.

The highly compressed state just before the nuclear explosion was treated by Metropolis, with the help of Julius Askin, using the Thomas-Fermi model of the atom. Of course, molecular or crystal structure had been squeezed out of the material by this time. The model, designed for isolated atoms, had to be altered to account for the pressing presence of neighbors. So, the boundary condition on the electron density had to be changed from one vanishing at infinity to one that is continuous across the boundary to the next atom. Further tinkering was necessary to adapt the model designed for zero temperature to the very considerable temperature of interest.

At the low pressure end of the range of interest, one had experimental measurements by Percy Bridgeman at Harvard and some further data from Hugoniot measurements in material shocked by high explosives. The gap between these low-pressure points and the Thomas-Fermi results was forbidding. Someone, possibly Teller, suggested using data obtained by the behavior of seismic waves traveling through the earth's core. That expedient would give one intermediary point, valid of course only for iron-nickel alloys, not for uranium or plutonium, under pressures and densities like those at the center of the earth.

For plutonium, however, there was the additional difficulty that only microscopic amounts of that substance were available until too late in the project to make the Bridgeman-type measurements. Still, something had to be done. In wartime Los Alamos, pessimism was recognized as a word but not accepted as an attitude or even as an emotion. With the minute quantity of plutonium they had, the solid-state physicists and chemists did the best they could, and they did very well. They determined the crystal structure, as well as the density and even some alloying properties. All that did not help much in determining the desired equation of state.

The history of what actually happened thereafter is probably not available. At that time, records were not kept, and the people involved are no longer around. But we can imagine what might have occurred. Perhaps Oppie called a group together: Fermi, Teller, Segré, Metropolis. He asked them to make their best estimate of the values required. After some brilliant but disorganized discussion, Fermi said, "This is what we shall use; it will be good enough for our application. Let's get on with the job." Indeed that "Fermi feeling" was often the best, if not the only, method for many problems, one of the special resources of the Laboratory.

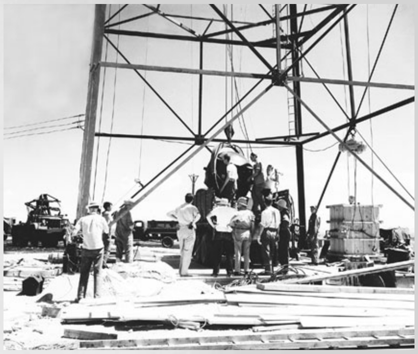
For this small problem, one of many in the design of the first nuclear weapon, one had to dip into the core of the earth and the center of the sun, assemble results from quantum theory applications and laboratory and high-explosive experiments, and patch all together in a hurry, with a feel for physics and a sprinkling of luck. That was typical work done in wartime Los Alamos.

Trinity: A Culmination and a Beginning

As the work of the Laboratory went on, unexpected successes alternated with heartbreaks. Finally, in the spring of 1945, the gun gadget was ready, its obvious simplicity apparently guaranteeing its performance. The plutonium device was much more complex, but no one really knew whether it would work. Therefore, a crucial nuclear test shot was planned. The test site near Alamogordo, in the southern New Mexico desert, was called Trinity by Oppenheimer. He never satisfactorily explained his choice of name.

In the predawn, dark silence of July 16, 1945, an explosive release of nuclear energy from the fission of plutonium-239 in the Christy gadget caused a supernal flash of light that illuminated the desert at the Trinity test site. The fission bomb was now a reality. Brighter than daylight this flash, with rich promises for the future; darker than midnight, with portents of fear. Observers wearing special dark glasses were able to see the initial flash and the early fireball, confirmation of the value of the time of striving, hope, and heartache in their work. Unprotected eyes looking at the test tower were blinded for minutes, a foretelling metaphor: In the coming age, to see without foresight was to lose sight. The first sensation felt by observers facing the test tower was the heat of the light pulse, a palpable force. It felt like simultaneous hard slaps on both cheeks. Still not a sound, only visible evidences of the shot. Then, the shock wave raced across the desert floor. When it hit, one could hear the first sharp crack, afterwards continued echoes and reverberations. Eventually, a cloud of bomb debris, desert dust, and atmospheric water droplets lifted off the desert floor and, rising slowly, formed the characteristic ominous mushroom shape of a nuclear burst.

The Trinity shot was the beginning of the nuclear testing procedure as a central feature of nuclear weapon development. Contrary to later test operations, however, Trinity was a nuclear explosion test almost entirely devoted to the needs of the scientists who designed the weapon. The military did not hand down requirements for the weapon yield, the nuclear materials, the safety, survivability, and performance specifications that have now become standard operating procedure. There was only one, but an overriding, requirement—the weapon must fit through the bomb bay doors of the B-29 Super Fortress. There was, however, a political desideratum—the test should be made in time to influence the upcoming Potsdam conference. But unknown to the United States, Stalin had considerable knowledge of our nuclear weapon progress through the espionage of his secret agents, most important among them, Klaus Fuchs. Stalin showed no surprise, although he must have laughed silently, inwardly, when Truman dropped a hint that we had a secret superweapon in the making. The July 16 date set for Trinity, which was the date of the commencement of the Potsdam conference, therefore had an urgency in the mind of General Groves that had nothing to do with the scientific purpose of the test.



The implosion "gadget" is hoisted to the top of the shot tower at Trinity site.

Further than the two requirements just discussed, the scientific aspects of the Trinity test were initiatives of the Los Alamos Laboratory, aided of course by the logistics support of the military. The site had been selected by Kenneth Bainbridge, the Harvard cyclotron expert chosen by Oppie as test director. Naturally, General Groves approved the choice of site. The diagnostic experiments were conceived, designed, and executed by the Laboratory. The bomb-firing electronics and even the operating protocols were Lab responsibilities. Academics, only a short time earlier familiar primarily with university laboratories, learned about field operations—operations in a somewhat uncontrolled environment with essentially no second-chance opportunities. The T-Division theorists too learned how to cooperate with the experimentalists, some even going to the field.

After the success of the Trinity shot, the realization that the fission weapon was a reality burst upon the consciousness of the staff. Before the Trinity event, the staff members were too busy with the everyday tasks necessary for the development of the weapon to dwell upon its consequences. They could strive to make it work, while fearing that it would. But after Trinity, the stark reality of success stared deep into their psyches. Each reacted in his own particular way. Learned Oppie, at Trinity, quoted from the Bhagavad-Gita, "Now I am become death, the destroyer of worlds." Bainbridge, characteristically a realist, said earthily, succinctly, "Now we are all sons of bitches." The rest of the scientists, back at the Lab, were jubilant but worried. They wondered whether the bomb should actually be dropped on Japan.

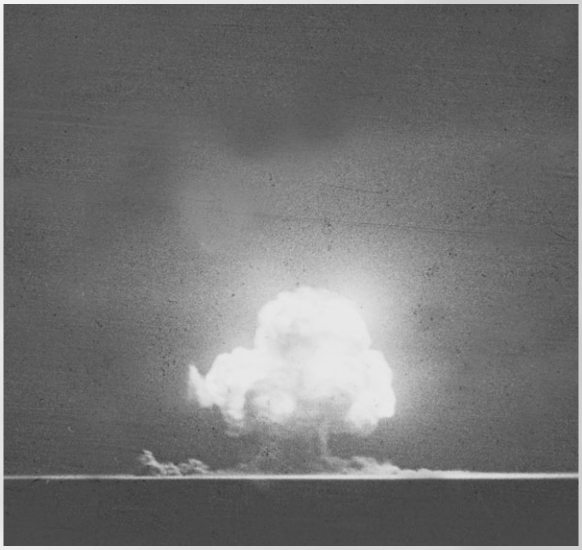
War's End: Devolution and Revival

Achievements. Two entirely different types of fission weapons were made, the uranium-235 gun type and the plutonium-239 implosion type. One success alone would have been an outstanding achievement. At Los Alamos, the scientists had developed an essentially new mode of operation, the intimate meshing of science with technology. From an idea, the nuclear bomb, and a single new fact of nature, the fission process, to the end use of the finished product—all the steps in between were coordinated by the same tightly knitted community of effort. True, this result was accomplished under the unusual urgency of an overriding national need. In the war effort, no obstacles were permitted. They were only problems to be understood—and once understood, to be solved.

What was understood?—The fission process itself, the processes of the chain reaction, the nature of the supercritical assembly, and the dynamics of the ensuing explosion. Along the path, one needed to understand the chemistry and metallurgy of the various weapon components and the engineering of the assembly of the parts. A critical element was the high explosive in a use for which precision never before achieved was absolutely necessary. Sometimes, a scientist would do engineering, and he was often very good at it—he might even like it. The engineers, for their part, had learned how to cooperate with the scientists, even though they did not always understand the science involved.

Dropping the Bombs. The United States dropped the bombs. Two Japanese cities were destroyed, their inhabitants killed. President Truman's hand had signed the executive order, but his hand was moved by currents he did not control. The debate going on among the Los Alamos scientists about the use of the nuclear weapons had been soul satisfying to them, but that long, hard, devastating war was over.

What would history be like if the bombs were not ready or if the United States refrained from using them? The bloody battle of Okinawa was a foretelling. The War Department estimated that, in the planned October invasion of the mainland, there would be a quarter of a million U.S. casualties and perhaps one to two million Japanese casualties. Could the wise, constructive peace that actually occurred in Japan be made under such brutal circumstances?



The fireball at Trinity site.

But the bombs were dropped. How much of the current dichotomy in viewpoint about nuclear energy—uneasy acceptance in the U.S. of its benefits and unreasoning fear of its dangers—is due to its first use in slaughter, however inevitable?

The people of Los Alamos had participated in a unique experience, one that would alter the prospects of the world both in warfare and in the pursuits of peace. When they heard about the two nuclear explosions that had obliterated Hiroshima and Nagasaki and their immediate aftermath in the surrender of Japan on the deck of the battleship Missouri, they realized the import of their work. They realized also that they themselves had been changed. All future experience and accomplishments would be measured in their own eyes against their Los Alamos achievements. The isolation from their families, the living on The Hill—the beautiful Jemez range in their back yard, the pinked peaks in the sunset of the Sangre de Cristo in their distant view, in contrast with the dust or mud of their unpaved streets and the insubstantial houses in which they sheltered their children—the camaraderie of friends who shared the same privations and delights, the heavy realization that two hundred thousand real human beings had been killed as a result of the microsecond duration of the explosions of the devices they had created: All this was past and prologue. Their future seemed as rosy as the sunset on the Sangres, but was it not incarnadined as well with the extinguished hopes of the Japanese victims? To the people of that strange city of the hill, their wartime experience had been a singular, slowly evolved epiphany. New sighted now, they were to see a new world.

Aftermath. In the autumn of 1945, after successful completion of its wartime mission, the Los Alamos Laboratory started to disband. Disbanding, however, conveys the wrong concept. It was a diaspora in which the departees formed a web to maintain the intimate relationships that had led to their wartime achievements. As they spread across the

In 1946, two implosion bombs, identical to the one tested at Trinity site and the one that had destroyed Nagasaki, were tested as part of Operation Crossroads in the Pacific.

nation, they were the missionaries of the new mode of doing science and technology—big science, but soundly based upon fundamental science, linked in a group effort with engineering development, all in support of pragmatic goals in the service of the common good. It was science for humanity's sake, but in an immediate sense, not as an eventual effect. The success of the atomic bomb project conveyed upon these scientists an aura of expertise, which however, outshone their real experience. The federal government placed them on numerous advisory boards and committees not solely restricted to the future development of nuclear weapons and nuclear energy. J. Robert Oppenheimer, for his leadership of Los Alamos, his amazing erudition, and quick understanding in diverse areas of science and human endeavors, was favored as the central member in many of these groups, even those with policy-making responsibilities. Because of this diaspora, the Manhattan Project, particularly the Los Alamos experience, was to illuminate the larger economy. Furthermore, the federal government, which had sponsored the wartime work, now continued to support big science—in government, in industry, and in universities as well. The former Los Alamos staff members were welcomed everywhere. Although the Los Alamos Scientific Laboratory (as it was named later) lost their service, the commonweal as a whole was well served by the dispersion of Laboratory personnel. With this acceptance in the larger world, the Laboratory itself was not to be abandoned. Some of the departees periodically returned to the Lab. It was possible for a staff member at home in Los Alamos in one afternoon to consult with all three visiting luminaries, Bethe, Teller, and Fermi.

After the war, the great effort that had developed and fielded the two nuclear weapons wound down, mission accomplished. Well done. The future roles of the Laboratory were in doubt. In the euphoria of victory and the passion to return home to resume normal life, most of the scientists were leaving Los Alamos. They believed that their work was done. Not realizing that the way science would be done in the future had forever changed, they were going home, but they were not going back. Though they left the Lab behind, the shell remaining was not destined to fade away. The Lab had demonstrated that a large organization with a mission of great national importance could do what no single university or combination of universities could accomplish. It was historically necessary that the Lab should live. The nation subconsciously recognized this inevitability, although individual scientists by and large did not.

As the Laboratory scientists appeared to evaporate, a stubborn residue remained. The seasoned academics were returning to their universities; other young people were going home to participate in the vibrant postwar economy. Hans Bethe had returned to Cornell, taking Dick Feynman with him. Teller joined Fermi at the University of Chicago. Of the whole group of talented young physicists only Rolf Landshof, Frederick Reines, and Bob Richtmyer remained. The Canadians, Carson Mark and Bengt Carlson, stayed on as a nucleus of mathematical talent, specializing in neutron transport methods.

Some people stayed because they loved the countryside; others stayed because the intense pressure of the wartime effort was relaxed and they could now pursue science leisurely but skillfully, using the fine facilities of the Lab still largely in place; some people simply had not yet found another place to go. It was slowly to dawn upon these few who remained—and also on the European masters and some others who had left—that the country had given the Laboratory an opportunity, no longer a designated mission, but an opportunity to create an institution using the new big science in the national interest. Los Alamos has been defining and refining this opportunity ever since.

Robert Oppenheimer was replaced by Norris Bradbury, an experimental physicist who had also served as a naval officer. Bradbury considered himself an interim director, a caretaker in the transition from wartime to peace. He planned to stay on but for a short period, less than a year, a matter of duty rather than desire. He deliberately kept a low profile. Events, not his hand, were now at the helm of the Laboratory ship. Contrary to his initial plan, he stayed at his post for 25 years.

Operation Crossroads. Faced with the diaspora, the remaining Lab core required some defining activity to ensure its success. The 1946 nuclear test operation in the Pacific provided one such focus. Counteracting the fragmenting forces tearing the Laboratory apart was the unifying effect of Operation Crossroads, the test explosion of two atomic bombs over Bikini Atoll in the western Pacific. This operation was much more a military show than a scientific test. The bombs were duplicates of Fat Man, the plutonium Christy gadget tested at Trinity site, the one that had destroyed Nagasaki. Tested, sure to work, their air burst explosion would give little new information about the bombs' internal operation. But some military equipment was exposed to the blasts to measure the effects of nuclear explosions on potential military targets. Thus, the area of nuclear weapon effects was born, albeit in a haphazard and nonquantitative fashion. That was to be remedied in future tests. From the Laboratory, Darol Froman was chosen as scientific test director. A combined Army-Navy force provided the logistic support for the operation—the progenitor of more sophisticated test programs under Joint Task Force Eight, a permanent military organization established for that purpose. Nuclear explosion testing was now established as a central feature of the Laboratory's mission.

Of course, the components of the bombs had to be manufactured, and the parts assembled. That was a job for the Engineering Division of the Laboratory. Here was a unifying task, although not a scientific one, focusing the efforts of a fragmented work force. In its own way, it was done with the same can-do spirit of the heady wartime developments. Moreover, it was symbolic of a continuing mission for Los Alamos. In fact, nuclear explosion testing was an essential for the rebuilding of the Laboratory. The scattered holdovers now had new hope for fulfilling careers. Darol Froman and Al Graves were role models for others who stayed on—Jerry Kellogg who headed the Physics Division, Eric Jette for chemistry, Max Roy explosives, and Bob Richtmyer for T Division. The renewed Lab could coalesce around these strong men, with Norris Bradbury as the unifying new Laboratory director.

From a weapons viewpoint, the successful explosion of four bombs of the same construction, all giving, so far as was known at the time, comparable yields, meant that the new bombs were a reliable basis for a future stockpile of nuclear weapons. The Laboratory then set about carefully, conservatively modifying and improving the designs of the weapons and systematizing their manufacture.

The Atomic Energy Commission. Meanwhile, on the national scene, Congress passed legislation establishing the Atomic Energy Commission (AEC), a decision that placed all nuclear energy programs, including weapons, firmly under civilian control. Furthermore, after some political posturing, Congress confirmed the enlightened and capable administrator, David Lilienthal, former chairman of the Tennessee Valley Authority, as chairman of the AEC.

In Los Alamos, the Army left the region, turning governance over to new civilian agencies. At the Laboratory, the military guards were replaced by AEC-employed civilians in new uniforms. They still rode horseback to patrol the extensive surrounding countryside. In place of the Army Corps of Engineers, the maintenance and support services for both Lab and town were taken over by the newly formed Zia Company, an offshoot of the McKee construction firm. The doctors in the hospital discarded their rarely donned military uniforms and provided the same skilled and caring medical services with the same stethoscopes and white coats they had habitually used. The same low, subsidized fees applied, but now the physicians were employees of the AEC. Laboratory personnel remained employees of the University of California as before, but somewhat more integrated into the University system, particularly for retirement benefits. Little regarded at the time by the youthful staff, retirement benefits eventually proved to be one of the attractions of the University relationship. New security badges were issued to Lab employees with numbers starting with the letter Z because the Zia Company had the only complete list of residents. The practice of designation by Z number prevails to this day. The town was still closed and resident passes were still needed to enter or leave. The Laboratory itself was still a fenced-in operation with the main technical area near Ashley Pond and varied outlying sites on adjoining mesas. As yet, there was no town government and apparently no need for one.

Budgets now came from Congress through the AEC. Although during the war the military provided essentially unlimited funds to the town and the Lab, the expenditures, while generous, were sometimes made at the wish or the whim of military commanders. But now the AEC effectively gave director Norris Bradbury one overall check to fund the Laboratory. It was always an amount larger than the Lab could sensibly use. The Lab could almost decide for itself what the funds would support. The Laboratory was now ready for a new mission—to use nuclear weapons to secure the peace as they had terminated the war.

Part II: The Dawn of the Thermonuclear Era (1946–1952)

Getting Ready

The development period from the formation of the Lab in April 1943 to the explosion of the plutonium fission bomb at the Trinity site on July 16, 1945, was the fission era. From Trinity to the Mike shot, detonated on November 1, 1952, on Enewetak Atoll in the Pacific, was the thermonuclear development era. More dramatically, these were the atomic bomb and the hydrogen bomb miracles. But when two apparent miracles occur together, there has been no miracle. A causal mechanism must be involved. Some essential culture at Los Alamos must be at work to make both developments possible. Of course, nature was also kind. In what follows, why this all came about will in some part be illuminated.

The fission bomb was made under wartime urgency, when a great nation girded for victory. The greatest nuclear physicists of the time were at Los Alamos, organized under their leader, Robert Oppenheimer, in his finest hour. T Division was led by Hans Bethe—immensely capable, precisely organized—with a brilliant supporting group. In contrast, the first hydrogen bomb was made in a peacetime America, relaxed, reaping the harvest of victory, albeit with the fear of the growing cold war. Norris Bradbury was the unassuming director of the Los Alamos Scientific Laboratory at that time.

Although Los Alamos under Oppie, with a star supporting cast, might well be expected to perform miracles, under Bradbury, with presumably the second team, it took a miracle to perform a miracle. Oppie opposed the development of the hydrogen bomb; Bethe, after the war, refused for some time to work on it. The principle of the fission bomb was "well understood" early on. Success was more an industrial than a scientific miracle, the gathering of scarce resources in a strained wartime economy to produce the fissile material for the bombs. But the true workings of the hydrogen bomb were involved and obscure. Initially, work was not in the most fruitful direction. How the hydrogen bomb was made was crucially dependent on how the Lab was reconstituted after its almost complete disbandment at the end of the war.

Chronology

There were two distinct phases in the development of the hydrogen bomb: the classical Super from 1942 to 1950 and the new and successful hydrogen bomb from 1950 to 1952. Thereafter, the hydrogen bomb was refined and exploited, and today it is the mainstay of the U.S. nuclear arsenal.

The Super, proposed by Edward Teller and Emil Konopinski at the 1942 Berkeley conference, was sidelined during the war, but not abandoned. From 1946 to 1949 with the tolerance but not the official support of the national authorities, the work continued at a low level because of its scientific interest. But the first Soviet explosion of a fission weapon on August 29, 1949, changed the relaxed attitude of the Laboratory. On January 31, 1950, President Truman directed the AEC to continue work on a thermonuclear weapon. Then the only candidate was the Super. Increased activity but little progress resulted because the basic problems of the Super were just too daunting. However, the Laboratory added personnel and accelerated use of computers. Nuclear tests at the Pacific range, particularly the George shot of Operation Greenhouse in April 1951, explored some of the principles of thermonuclear reactions.

The second phase was initiated with the new concept of a hydrogen bomb discovered in late 1950. It was so obviously sure to work that the total resources of the Laboratory could be focused on it. The concept was brilliantly verified by the Mike shot in the Pacific on November 1, 1952, and the hydrogen bomb was born. During this entire period, very important improvements were made in the performance of fission weapons, significant since they were essential to the operation of the hydrogen bomb.

Permanent Housing. By 1948, the rebuilding of the Los Alamos Scientific Laboratory was substantial. Although far from reaching its peak wartime status, the Lab in personnel was well staffed, in equipment even robustly furnished. More important than the actual level of competence of the Lab was the feeling of permanence and the promise of future accomplishments. The Army was gone, an inheritance of wisdom and folly left behind, part of the physical and intellectual capital of the town and the Laboratory. The energetic, but sometimes arbitrary, administration of the military was superseded by the distant and paternalistic oversight of the AEC, responsive to the needs of the Laboratory. But for the present, the Lab was on a solid foundation with an assured future. The town adjoining was also transformed into a permanent city, emphasizing the permanence of the Lab.

Beginning in July 1947, for the first time in Los Alamos, really permanent houses were built, initially in the western area. Those houses are still in use today, although some have been improved with extra rooms and upper levels: Small but comfortable homes, one story, 1000-square-foot well-designed floor plans, two or three bedrooms, one full bath with real bathtub, hardwood floors, beamed open wood ceiling and fireplace in the living room, full row of extra closets down the central hallway, natural gas cooking, heating, and hot water, one-car open carport with additional outdoor storage. Styling was definitely New Mexico, some fake adobe, single units or duplexes—all with the fresh-paint smell of newness.

Except for the upsloping hill to the far west impinging on the national forest, the western area had been meadow; so the land lacked the tall pines and small shrubs of the fringing woods. Small willows and olive trees were therefore planted. Today, some 50 years after, the area looks richly landscaped. The streets were set out on an interesting quasi-Cartesian grid with some cul-de-sacs for variety. With the open spaces included, each home site averaged half an acre, but there were no defined lot lines. In Los Alamos, as counterpoint to Robert Frost's memorable New England dictum, "null fences made good neighbors."

The physical isolation of The Hill and the fenced-in town site exaggerated further the feeling of isolation from one's family. Obviously, almost no grandparents and no sisters or cousins or aunts either, only coworkers—they were your family. But the comradeship of shared work and shared neighborhood formed bonds closer than kin. To the young scientists awakening in the morning, feeling the crisp clean air, viewing with 100-mile visibility mountain vistas and endless skies, it was like nirvana. When they arrived at the Lab, to the working scientists, it was indeed a nirvana, but with boundless opportunities. And there was that great feeling of comfort and cooperation with friends at work.

The First Soviet Nuclear Explosion. Joe 1, the first Soviet nuclear shot detonated on August 29, 1949, was a historical marker for the scientists at Los Alamos. It confirmed their conviction that there was no secret of the atomic bomb—that nature's book was impartially open to all and the Soviet scientists could read it. Although it was no surprise, it brought a shock of realism to their work and changed leisurely investigations into matters of great urgency. Now, additional people joined the Laboratory staff.

Accelerated Staffing. Among the senior scientists, John Wheeler and George Gamov were newcomers. The old masters of the wartime effort—Bethe, Teller, and Fermi—took leave from their universities and came back, generously giving part time. These mature physicists brought with them a new contingent of their students. From Princeton, as the Matterhorn Project for civilian applications of controlled thermonuclear burn phased down, Wheeler brought Ken Ford and John Toll. Burt Freeman and Joe Devaney added to his group—four young bachelors injected into a community mainly of young marrieds with children. This group was soon engaged in calculating the radiation transport for some of the nuclear test shots using new methods devised by Wheeler. Hans Bethe sent his students George Bell, Walter Goad, Carl Walske, and Albert Petschek, and then came himself. These men joined Conrad Longmire in the neutronics group, but they participated more widely in weapon design. Fermi reappeared with Dick Garwin—the equivalent of a whole laboratory capability in that couple, not a metaphor but a reality.

Guided by the old masters, these young men, along with the wartime holdovers, provided the muscle for the detailed calculations necessary for the design of improved fission weapons and, more important, a thermonuclear weapon. New computing machines were ready at their service. Actually, a new method of theoretical scientific work was in the making. No longer was progress made by advanced mathematical analysis, giving numerical results by slide-rule manipulation. Now, scientists programmed the computers, and instead of staying up all night baby-sitting experimental setups, they cradle-watched their computers at their allotted tasks.

The new method gave birth to a new breed. Two other newcomers typified them: Robert Thorne and Art Carson. These men would write their own codes, and nobody else knew precisely what was in them; nobody else could successfully run them. They were opaque to most, but like the mysterious prophesies of the Delphic oracles, the output stream of computer paper was believed to be utterances from the gods.

Finally, the Lab was up to strength to repeat for the hydrogen bomb the miracle that made the fission bomb during World War II.

Nuclear Testing

Primary among the tools of the nuclear weapon trade is the nuclear test. First used at Trinity site, the nuclear test is a vast expansion over traditional scientific experimentation. These tests are expensive. For the Pacific tests, the military of Joint Task Force Eight deployed ten thousand men and almost a thousand ships to Enewetak Atoll. The small cadre of scientists was almost lost in the human melee of army and construction personnel. Two entire Pacific atolls, Bikini and Enewetak, were commandeered, their population transplanted to other islands. A military tent-city was set up on Enewetak, the southern island of the atoll, which

View of the Enyu Island in the Bikini Atoll.

gave the atoll its name. A little to the north, on Parry Island, the quarters and laboratories of the scientists were constructed, an invisible security curtain separating that island from the more populous island to the south. Before the war, the islands were covered with coconut palms in cultivated rows. During the fighting in the Pacific, the plantations were destroyed. Twisted military equipment was the new flora, decaying as mementos of the campaigns. Now once again, the palms and the coral rock of the island were to be sacrificed, this time to the aims of the test program. The Mike shot, at 10 megatons, for example, consumed an entire island, Elugelab.

The magnitude of the effort required for nuclear test programs in the Pacific put a somewhat unwise discipline on the Laboratory. The dates for an operation were set long in advance, and the Lab research and development had to be focused on preparing shots in time for the operation. This method precluded some avenues of research considered too long term; in other cases, it resulted in a too-hurried preparation for a test series. To remedy this failing, the AEC opened up the Nevada test site. Whereas in the Pacific the program was "get ready for a test," eventually at Nevada the Lab's watchword became "test when ready."

Nuclear testing became a political, as well as a scientific, enterprise. International treaties regulated testing. International motivations resulted in test moratoriums, mutual or unilateral, and in the ending of such moratoriums. Nor was the number of tests or the nature of the tests free from political considerations. When the Soviet Union broke the moratorium in 1961, the United States responded by resuming its testing. At the cabinet meeting to decide on the test program, Harold Brown, the Defense Director for Research and Engineering, gave a detailed technical briefing on the scale of proposed tests. At the end of Brown's talk, President Kennedy turned to his brother Bobby, the Attorney General. He asked how many shots the Russians were planning. When Bobby answered, the President, disregarding all Brown's technical input, simply ordered that the United States should plan for the same number of shots in its test resumption series. The United States and the Russians have negotiated a comprehensive test ban treaty, which both countries now observe, but since the U.S. Senate so far has refused to ratify the treaty, it is not the law of the land. Since March 1992, however, the United States has not conducted any nuclear test.

Transport to the Pacific Atolls. To the Los Alamos scientists, working at the Pacific nuclear test range was a whole new cultural experience. It started at Hickam Field in Hawaii, the departure point for the military aircraft transport to the test area. Before takeoff, each civilian was given an equivalent military rank. There was company grade, corresponding to lieutenant and captain; field grade, corresponding to major and colonel; and general officer grade. Your quarters at Hickham were based on your rank. Quarters were important because the schedule of takeoff of the Military Aircraft Transport Service planes was rarely adhered to. The procedure was to assemble all travelers at the site ready to board the plane whenever it became available—that way, no time would be lost in rounding up the passengers from the presumed pleasure spots of Oahu. This was very efficient for the airplane, but it often meant sitting around for many hours waiting for your aircraft. And it was your assigned aircraft. If on final checkout for takeoff, some slight problem was found, you were not given another plane; you just waited for yours to be fixed. Often, the delay was just a few hours; sometimes, it was days. Then the level of comfort of your quarters would be important. Carson Mark, although he was of general officer rank, stayed with his T-Division scientists in their field grade quarters.

The C-54, the military version of the commercial Douglas DC-4, took off. This was a cargo carrier, with passengers only as a courtesy. Along each side of the aircraft was a long bench of canvas supported by aluminum tubing. These were the passenger seats. The center of the fuselage was filled with bulk cargo strapped down to lugs in the floor. The aircraft was not pressurized, so the top altitude in flight was limited to about 8000 feet. No problem flying over the Pacific. Once you passed the Hawaiian Islands, the elevation of the coral atolls of the Pacific was only a few feet above sea level. However, at those low altitudes, there was considerable weather that made for a bumpy ride. The C-54 is a rugged aircraft that could take more jolting and wind shear pummeling than the passengers' composure could accommodate.

Slow is this airplane, and large is the Ocean Pacific. Hours, slow hours in flight, fitful sleep sitting up, too hot, too cold; these aircraft have no sophisticated climate control. Bulky Mae West lifejackets on at all times bring comfort in being uncomfortable—one can last long if ditched into the warm Pacific. Then landfall, in the wide ocean that small oval lagoon, pearled with foam on the seaward rim, with deep blue water at its heart, so welcome, as our bird swoops in for a landing. Enewetak Island.

All is protocol as you leave the plane by grade when your name is called. First, the security check; then you are assigned sleeping quarters. An orderly, a lieutenant colonel, takes care of you, bringing your ration of duty-free spirits. Then, a quick wave-rocked ride in an LCM (short for landing craft man), and you arrive at Parry Island. Was this one of the boats used in the Enewetak campaign? Now you are on station.

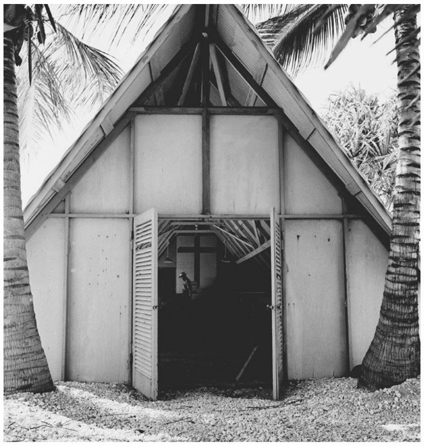
Life on the Atoll. The atoll is the top of a gigantic sea mound peeking out above the ocean's waves. Long, long ago a hot spot in the earth's upper mantle forced a flume through the thin Pacific tectonic plate. Over millions of years, molten rock under great pressure pushed through the flume, spread out upon the ocean floor, and piled up to form an underwater volcanic mountain. Eventually, from the benthic depths 5 kilometers below the surface, the mountain grew to pierce the waves, and thence 2, 3, 4 kilometers into the sky. In one or a series of cataclysmic explosions, the volcano blew its top, leaving a ringed caldera remnant. Slowly, moving only 100 kilometers in a million years, the tectonic ocean plate drifted northwesterly, leaving behind the volcano's source of fire. Now dying into new life phases, the rim of the caldera weathered down. Combined with the subsidence of the ocean floor depressed beneath its mass, the caldera disappeared below the surface of the ocean.

But then a billion billion little coral animalcules went to work. These small creatures can survive only in the narrow subsurface depth of about 20 meters. They built a coral crown atop the sinking volcanic rock. They could not invade the deep center of the caldera, which then formed the beautiful interior lagoon of the atoll. As the remnant mountain continued to subside, the lower parts of the coral reef died, crushing into limestone, while new live coral was added just below the surface. Wave action continually broke off small pieces of this coral and threw them up to form a ridge above the surface, the multi-islands of the atoll. The weathered coral formed the fine white sand of the islands and their beaches on the lagoon. These isles are evanescent. What the waves disgorge in great storms, they can devour again.

At high tide, the great ocean rollers come in and break at the atoll's outer rim. They spill over onto the tidal plain, perhaps 100 yards out. The water there is only 4 feet deep, more or less, depending on the tide. Rushing toward the shore, the breaker's water mass reforms into small waves, and they in turn make puny crests, which break and spill upon the island sand. As the tide recedes, it bares the black dead coral ridges of the plain. In thousands of little tidal pools, it traps the itinerant dogfish among the resident flora and the sea cucumbers that live in these puddles. The dogfish have sought shelter from the deep sea beyond the atoll rim, where the large predators, sharks and barracuda, play. But many times, the pools become isolated, the sun warms the waters, the dogfish have no room to maneuver, and they become prey to the shore birds. Humans leave them alone; they are not good to eat.

When the tide is out, the coral rock of the tidal plain is exposed. It has sharp ridges; the general surface is slippery with sea slime. A cut from the coral quickly becomes infected. Bacteria too enjoy the plenty of the tidal pools.

From the atoll rim, the water bottom, which is the edge of the sea mound, falls rapidly away to the sea floor, 5 kilometers below. The slope is about 20 degrees. As a result, the low-tide boundary is sharp, indented by old dead coral reefs at the surface, live coral heads a little way out below the surface. No one is crazy enough to try to swim off the atoll rim. The waves break sharp, the rocks are sharp, and the sharks patrol the border.



This chapel was built for the people involved in the tests on Parry Island (now known as Medren Island) in the Enewetak Atoll.

For the experimentalists, life on the atoll was a race against time, 12 hours a day, 7 days a week. Construction, installation of equipment, servicing, checkout, calibration—all done for a microsecond of data, with no second chance. In contrast, the scientists from T Division were on hand as experts in the details of weapon performance or, in some cases, for additional information on the theory of the experiments as required. For them, the hours were sometimes heavy with boredom, further weighted by the monotonous weather—air temperature 80 degrees Fahrenheit, water temperature 80 degrees, humidity 80 percent, the trade winds blowing 22 knots, all unchanging day or night.

But sometimes there was, for these island-bound theorists, the excitement of the scientific and technological environment itself. You climbed the test towers 100, 150, 200 feet into the sky to check the layout of experimental equipment because specifications and blueprints did not always contain the full information needed for a successful test measurement.

Modifications to equipment were sometimes made on the spot under a theorist's instruction. You would lift your eyes from the apparatus, and there you would stand atop the tower, with the constant trades cooling the lingering sweat from your climb, and the Pacific stretching to a horizon lost in the faint sea haze, which to your view might not exist at all, except as another theory.

On the atoll, the sea is ever present. The sound of the waves is a steady background, pleasant when you wish to listen, ignorable when you are involved. No matter how busy, you would take some time off to swim in the warm waters. No shock as you plunged in, just the warm wetness refreshing. Most of the men would swim out to the coral heads in the lagoon, facemask on, snorkle set. There the sea creatures that belong to the atoll play. No prior experience could prepare the invading mesa dwellers for the richness, the variety, the colors, the beauty, and the strangeness of these underwater gardens of the sea.

Humidity was an enemy. In the damp and the heat, electrical equipment deteriorated, metals corroded, catalyzed by the tiny salt crystals always present in the air. Experimentalists were readjusting, repairing, replacing. The theorists' Marchant calculators were almost unusable after an overnight exposure to the damp. To prevent this deterioration, you kept them, when not in use, in a locker heated by a 100-watt bulb, lit all the time. The same lockers also protected your clothes and particularly leather shoes, all of which otherwise became moldy almost overnight.

Food was one of the every day recreations on the islands. Holmes and Narver, the support contractor providing the general services, knew how to keep their construction workers happy: Give them lots of overtime and lots of food. The budget for food alone, in the 1950 era, was $5 per person per day. It was a bulk no-menu mess hall. You ate what was served. And what food! Choice meat sirloins or filets mignons were piled on great platters passed down the long tables, 20 workers sitting on benches on both sides filling up their plates. It was more than all you could eat. No worry about excess quantities prepared—the leftovers were the next day's stew, stew to shame French cuisine. On arrival, the new visitors watched with amazement as the old timers, competing with the construction contingent, heaped two or three steaks on their plates and sometimes asked for more. After a week, one joined the food orgy. But milk was that terrible tasting mixture made from powder, except when a freighter had just come in. Then there was fresh milk, the right stuff. Otherwise, no decent milk, but there was always plenty of ice cream. The burly construction workers were able to use up all that food, but some of the sedentary scientists stored the excess on their middles.

Transportation at the Atoll. Were it not for the support services, the scientists could not get their jobs done. Since the shot island itself and other northern islands with experimental sites were about 50 kilometers away from Parry Island, communication and transportation links were needed among them. The joint task force military personnel supplied both.

Water taxis and LCMs were the standard interisland carriers. The speedy water taxis were a traveler's adventure, if he were up to it. In any but the calmest seas, these taxis set up a spray that, but for the canvas-top protection of the rear two-thirds of the boat, would soak any passenger. You had the choice to sit under the canopy and inhale the exhaust fumes or to sit up front and feel the salt spray dashing on your face. Most of the young men enjoyed the ride, but Roy Reider, the safety engineer, whose job required him to visit the experimental stations often, was seasick susceptible and hated the transit. The LCMs were noisy and slow, an experience in the practical results of shock waves as the flat forward ramp in its up position smashed into the choppy sea.

For rapid transit, there were the Army's L-5s and L-13s, the small light observation planes. They could make 100 knots, and Parry to Eleleron took only 20 minutes. Operating in the trade winds, these aircraft were remarkable. Landing speed was as low as 25 knots. In the 25-knot trade winds, they could land on a dime. Actually, a passenger could jump off a landing plane before touchdown with but the care needed to step off the end of a moving passenger walkway at a modern airport. Not much of a runway was needed for takeoff either. These planes could take only one or two passengers, so it took a high priority to get a ride. Overcoming these superficial hardships was part of the culture of the test site.

The Pogo Planning Staff. The Pogo staff, the name borrowed from the famous comic strip, was the overall technical planning staff for the scientific operations. That group had done most of the stateside definition of the experiments. Now, they were on-site to help in the execution. Fred Reines, head of the Pogo staff, was on loan from T Division. Fred was a broad-range idea man; some of the experiments were his personal suggestions. He was dynamic—no boredom in his presence. Pogo staff meetings were almost continuous, monitoring every aspect of the tests. If there were no apparent problems, Reines might suggest something overlooked, or he might even improvise an additional small experiment. Fred always held an extra Pogo staff meeting at 8 p.m.—too early to go to sleep, so why not staff up a little more, nothing else to do on the islands. But there was something else in which Fred did not indulge: the 9 p.m. movie. Darol Froman, the associate director of the Lab and a former scientific test director himself, now out on the islands and a much-valued presence at the Pogo meetings, did like movies. So did Harris Mayer, theorist and very good personal friend of Fred's. Promptly at 8:55 p.m., Darol and Harris would stand up, deliberately disturbing the meeting, to show where the proper priorities were, and leave to go to the movies.

Fresh movies came in on the C-54 transports. When they were not available, old ones were reshown. The theater was open air, with rows of hard benches set out before a big screen, a small bright cutout on the dark sea supporting the lighter sky. Darol and Harris sat down close together because they knew what was coming: not the suspense on the screen, but the weather. Predictable, as were the trades, the rain would come in at 9:45 p.m. The two scientists were prepared; one poncho covered both of them. They sat together until the rain, as it sometimes would, came down in sheets so dense that the scattered light from the droplets overwhelmed the image on the screen. Except for these very dense showers, the rain was pleasant. It mattered little that you were wet on the outside of your clothing, when because of the humidity, moisture was always condensing on the inside.

Characteristically for those years, the tests were an all-male operation. Indeed, there were but few women scientists at the Lab—Jane Hall, Diz Graves, and Cerda Evans among them. It was understood that it was no denigration of their competence that they were excluded from the test operations. That's just the way things were. Times have changed, but then the camaraderie was a man thing, an enterprise of brothers.

But one got to know one's coworkers in a total living experience otherwise impossible, even in the close-knit Los Alamos town community. Overall, life on the islands was a comradeship in purpose, expressed in activity in test preparation, in sharing experimental results, in recreation, and in boredom.

The Path to the Hydrogen Bomb

The fission bomb was a reality. Nature had indeed been generous in her choice of nuclear cross sections and the number of neutrons released per fission, so that the task was daunting but doable. But nature had also generously provided for another much greater and more pervasive energy source—the thermonuclear furnace of the stars. There, in contrast to fission, where a heavy nucleus is split to release its energy, four light hydrogen nuclei are ultimately fused together to form a helium nucleus. In the process, the very high binding energy of helium is released. Scientists had been captivated by the fascinating complexity and excited by the potential of this thermonuclear fusion reaction even before the Los Alamos Laboratory was opened in April 1943. Here was the possibility to harness on earth this energy of the heavens. But instead of using hydrogen, the stellar reaction chain was to be short-circuited by starting with deuterium—deuterium nuclei in thermal agitation colliding with deuterium, a much more rapid process. Although nature had been generous with her margins in the physical parameters, as she had been in the case of the fission bomb, she was not nearly as transparent in revealing the proper physics to follow. In fact, the path to the hydrogen bomb was a tortuous one, with many interesting side branches to cause delays.

Clearly, the tremendous concentrated energy release in a fission device was the key to initiating the much greater energy release in a thermonuclear fusion assembly. It was time to start serious work on that possibility. Now, in a star the thermonuclear furnace is contained by the pressure generated by the gravitational effect of its huge mass. The reactions proceed slowly, majestically, on a grand scale, the overall cycle taking thousands of years. On earth, the problem would be the confinement of the exploding thermonuclear bomb. This necessarily precarious balance between explosive force and containment restraints depends upon the complex relations of the many physical processes involved.

The idea of a thermonuclear bomb powered by the deuterium-deuterium reaction was brought up in the pioneering Manhattan Project 1942 summer study at Berkeley by Edward Teller and Emil Konopinski. Oppenheimer, the leader of the study, and Hans Bethe, one of the "luminaries" involved, enthusiastically adopted the idea and focused the best efforts of the study on it. Oppie called the bomb the Super. During the war, however, the Laboratory could not fully indulge this intense interest of the scientists. But after the war, there was time to explore the concept of the Super.

Although the Super was not on the main line of the Laboratory's mission, the curiosity of the scientists could not be constrained. The everyday work of increasing the yield of fission bombs by small factors paled before the promise of the fusion bomb to increase yields by orders of magnitude. Understandably, volunteers were eager to work on it. In an informal arrangement characteristic of the organization of the Laboratory of that day, they started work on the Super—the measurement of the cross sections of thermonuclear fuel by Jim Tuck, the calculations of the equation of state and radiative transfer opacities by Harris Mayer, the development of computer codes by Marshall Rosenbluth, Art Carson, and Foster and Cerda Evans, while overall, Teller was dreaming, thinking, analyzing, inspiring the other scientists, and yes, educating, persuading, the administration of the Lab and the powers in Washington to advance the cause of the Super. On the action level, he drafted Enrico Fermi and Johnny von Neuman to engage in the concepts and the calculations, and he had Stan Ulam with his dedicated helper and tireless worker Cornelius Everett to carry them out. However, contrary to her transparency in the case of fission weapons, nature was more complex and subtle with the Super concept. She was not prepared to give up its secrets readily. Our understanding of the processes involved, our techniques and tools for diagnosing the device were not adequate for the job. Will it, won't it, will it work? Our results were discouraging.

Progress by grand concepts and giant steps was stalled. It was time to make haste slowly. Consequently, it was decided to place a small mass of thermonuclear fuel adjacent to a very large yield fission bomb. Such a small mass would not give enough energy to ignite the Super, but it would demonstrate at least that some external thermonuclear burn could actually be accomplished. So was born the idea of the George shot. Tested at Enewetak in Operation Greenhouse in April 1951, George was a complete success. The yield was about 225 kilotons, only a small part of which was the precious thermonuclear yield.

But George was much more important in the process of its conception than it was in the success of its testing. Because of its influence, George deserved its ranking as the nonpareil shot in nuclear testing. Although the scientists were involved full time in the details of the test, in the shadowy recesses of their brains, waiting to be brought to full consciousness, were all the physics and components of the hydrogen bomb. The daunting difficulties of the Super concept could be avoided by a new approach. Not obviously suggested by the planning for the George test, that approach required a new synthesis of all its elements. Consciously, the scientists worked in the usual combination of inspired conception followed by critical analysis—sometimes with both going on almost simultaneously within one mind. When both aspects clicked together, then an idea was born. Consciously, the scientists did not proceed by considering a logical extension of the elements of George or the principles of its action. They thought they were considering the problem anew. But in their subconscious, all the elements were there for the viewing; just the new synthesis had to be made. How very clever of the human mind to uncover the obvious when it was not obvious!

This new idea transformed the concept of the Super into the beautifully workable hydrogen bomb. Remarkably complex, and devilishly interesting was this new concept—and capable of great flexibility in applications. It led to the felicitous design of a considerable variety of thermonuclear weapons. A transparently workable design with many important details was worked out by the early days of 1951, even before the firing of the George shot. The shot itself was then an irrelevancy.

There has been a continuing discussion among scientists, historians, and the curious public about the contributions of Teller and Ulam to the concept of the thermonuclear bomb. The overriding fact is that the bomb is an actuality. The Soviet Union and the United States made thousands of them. China has some in its nuclear arsenal. So has the United Kingdom. Nature had provided generous margins in the properties of radiation flow and nuclear reactions that made this complex concoction challenging and intriguing but, ultimately, not excessively difficult to master. Teller, Ulam, Sakarov, or some unknown researchers in other countries—that is no longer important. All these men were talented, creative, worthy of respect, even if afflicted by some modicum of "Fame . . . that last infirmity of noble mind." At this late date, the distribution of fame or blame is a diversion from the stark reality. We now have the knowledge of the hydrogen bomb. Long ago, humanity took upon itself the knowledge of good and evil. What good and evil will we make of this?

The George Shot

The nonpareil thermonuclear shot, wittingly and unwittingly testing many principles of thermonuclear weapon design for the first time, was code-named George. It was one of four shots in the Greenhouse Operation of April 1951 on the small island Eleleron of Enewetak Atoll. George was a Teller initiative, with ideas and sweat contributed from all over the Laboratory. It was a test of the principle of a thermonuclear reaction, but it was not, by any means, designed as a complete thermonuclear bomb. A fission bomb provided the energy to start the burn reaction in a small mass of thermonuclear fuel. But to examine the reaction in detail, it was necessary to separate the fuel from the fission bomb. Therefore, the design tested had a separate implosion fission bomb with a hefty yield of about 225 kilotons. Energy from the bomb would ignite the fuel. The test device was placed atop a sturdy 200-foot-high tower. Many different instruments were arranged with a clear view of the external mass in order to diagnose its performance.

Two experimental stations were at the base of the tower. One, belonging to the University of California group under Herb York, was to measure the thermal x-rays from the hot fuel mass. The other station housed the electronics for the Naval Research Laboratory (NRL) experiments measuring the time dependence of the neutrons produced in the thermonuclear fuel. That group was headed by Ernst Krause. Their aims were the same, diagnosing the thermonuclear reaction, but the ethos of the two groups could not have been more different.

The NRL group under Ernie Krause was a well-practiced machine; the men had worked together for many years. Krause was careful, meticulous, well organized, a hard worker himself, and a hard driver of his men. Here was a team that knew by prior experience how to get the job done. On shot day, they were ready, their station buttoned up.

The University of California group under Herb York was a newly gathered assortment of smart, eager young men in their first field experience, many later to become stars in their own right. Besides York, who became head of the Advanced Research Projects Office in the Department of Defense and later Chancellor of the University of California at San Diego, there was Harold Brown, a future Secretary of Defense; Mike May, future director of Lawrence Radiation Laboratory (known as Lawrence Livermore National Laboratory since 1979); Robert Jastrow, Chief Scientist at NASA, Goddard; Hugh Bradner, undersea photographer and underwater equipment designer par excellence; and Bill Grassberger, who had a long, fruitful career at Livermore as a radiative transport expert. Under York's leadership, the team members worked with the enthusiasm of youth and the luck of the blessed. On shot night, they had an unexplained slow leak in their vacuum pipe—no way to treat it. If it continued, the experiment was lost. In the dead of night, miraculously, the leak stopped. At shot final countdown, the experiment was a "Go!"

Herb York's group later became the nucleus of the new Lawrence Livermore Laboratory, the second weapons laboratory of the United States.

The 14-MeV Neutrons. The experiments to measure the total number of thermonuclear neutrons from the external mass of the Greenhouse George shot were straightforward in concept, massive in practice. Louis Rosen's especially designed detectors consisted of nuclear-emulsion plates mounted in a massive concrete collimator aimed at the fuel mass. Emitted 14-million-electron-volt (MeV) neutrons passing through the collimator would cause recoil protons upon elastic scattering from the hydrogen atoms in the emulsion of the plate. The ionized track of the protons would be revealed when the plate was developed. The tracks could be measured and counted under a microscope. The collimator would not see the much more numerous fission neutrons from the multikiloton energy yield of the fission bomb itself. A strong 14-MeV neutron source placed on the tower at the fuel location was used for calibrating the entire setup before the shot.

In this experiment the really important problem was protecting the plate from the blast and shielding it from the gamma rays of the fallout. Heavy concrete shutters, released by explosive bolts fired synchronously with the detonation of the bomb, fell by gravity to tightly seal the detector. The concrete walls were sufficient shielding to attenuate the late-time gamma rays from fallout.

The George shot on Eleleron Isle, viewed from Parry Island base 15 miles away, was a terrifying sight. The fireball flashed, the cloud formed and rose, the characteristic mushroom shape developed—and rose and rose. One's head tilted up and up to follow it, the angle of view increasing. The radial expansion of the cloud and the distortion of perspective made it appear that the top of the cloud was marching with increasing velocity toward us at Parry Island, menacing the puny viewers. Shivers of latent feral fear crept along their spines. The great yield of the fission bomb had surely been achieved, but what of the thermonuclear fuel?

A quick water-taxi ride to the shot island. The recovery crew disembarked on a devastated wasteland: just coral sand left, the shot tower gone, and a crater in the coral rock left instead. The recovery crew had to wait for clearance from the radiation-safety monitors before going in to recover the precious plates. They had made a quick aerial survey of the radiation levels and plotted a reasonable approach path. The levels were variable, hot spots here and there, most not really dangerous but not trivial. There was caution in choosing a path among the hot spots, where dose rates reached 100 rad per hour. The crew was in no danger of getting a lethal dose; 500 rad was the so-called LD_{50}, meaning a 50 percent chance of dying as a result of exposure. The real fear was that one would accumulate the maximum permissible dose of 3 rad for the whole operation. That meant a quick ticket home.

To keep within safe limits, one needed a good entry and return path and a quick recovery at the detectors. When Louis Rosen and his recovery crew got to the massive concrete neutron cameras, they saw that the covering, protective layer of sand had been blown away by the blast. The great hunks of concrete had been tilted—of course, alignment now was irrelevant, but were the camera films all right? The opening of the concrete block cameras to extract the film was not going as it had been in the dry runs. Louis was working hard, but he was unhurried even in that radioactive environment. The plates came out intact.

With the precious nuclear-emulsion plates safely stowed in shielded recovery packets, the group took a quick trip by water taxi back to base camp on Parry Island. Strangely, the time on the return trip passed much more quickly than on the approach. Then, Louis Rosen went into the darkroom to develop the plates. After a wait that seemed longer than it really was, he came out and placed a nuclear-emulsion plate under his microscope. The T-Division contingent that had gathered to hear the results was waiting anxiously for his reaction. If the burn was a success, they thought it would be obvious, and Louis would say so in a minute or so. But Louis, face expressionless, said nothing at all. Not to disturb him, they started up a game of poker, Carson Mark, Frank Hoyt, Marshall Rosenbluth, and Harris Mayer, with Rod Spence and George Cowan from the radiochemistry group and Bill Ogle, deputy scientific test director. As the minutes passed with no signal from Louis, they thought in despair that he was anxiously seeking for a few, even one, true neutron track. The game got wilder, deuces and treys wild, then eights and jacks added—no one of the group knew the odds of the permissible fantastic combinations—and do five aces top a royal flush anyway? Yes. An hour and a quarter later, Rosen got up from his microscope, stretched, and said simply, "We got them." The careful scientist and the unforgivable miscreant had been counting and measuring proton recoil tracks from the 14-MeV neutrons, hundreds of them, for the whole time.

Louis Rosen

He had folded in the proper calibration, done a statistical analysis, and gathered the data in good shape. Yes, that small external mass was one hot thermonuclear source. No question, thermonuclear fusion was incontrovertibly demonstrated.

Mike—The New Hydrogen Bomb

The scientists returned from the Pacific proving grounds bearing rich treasures of experimental results. The Booster device, also tested in the Greenhouse Operation, worked well. The ignition of the small fuel mass in the George shot demonstrated a thermonuclear burn and supplemented the understanding achieved in the Booster. However, the success of George gave only vague moral support to the new concept of the thermonuclear weapon. The immediate importance of George was the proven performance of the sophisticated diagnostic tools used. Those instruments would be available for the diagnoses of future, much more complex, weapon designs.

The sun-tanned crew from the Pacific test range returned to a Laboratory that was about to be dramatically changed by the new thermonuclear weapon concept. Los Alamos was now committed to developing a concrete realization of the concept and testing it at the Pacific proving grounds.

Consider this recipe for disaster facing the Laboratory and discern how such a startling accomplishment could have come from it: A new technical idea proposed in March 1951 to be tested in only 19 months; the two leaders of the new program, Edward Teller and Marshall Hollaway, who cannot get along with each other; a Laboratory director, Norris Bradbury, who cannot make them cooperate and regretfully but decisively chooses Hollaway as project leader, causing Teller to resign; engineers under Hollaway who need to freeze the design in order to meet the test date; theorists, no longer the wartime stars, trying first to understand the applicable principles of the design to find the appropriate one and unable to come up with a final design. What organization could complete the task on time? An organization conceived in the value of each individual scientist, banded together as coworkers, friends, neighbors, in an enterprise of national significance, with a tradition and a will to succeed—that was the Los Alamos Scientific Laboratory of the 1950s.

Out on the Pacific test range on the island of Elugelab at the north end of Enewetak Atoll, the Mike device was set up. No tower for this 60-ton monster—it stood upright on the coral sand. A bewildering array of experimental equipment was placed on Elugelab and other islands up to 25 kilometers away to diagnose the shot. Ernie Krause's crew, veterans of the Greenhouse George shot, were there but with much more elaborate experimental equipment this time.

After the preparations on the islands had been completed and the northern end of the atoll evacuated, the center of activity shifted to the command ship, the Estes, stationed 50 kilometers south of the detonation point, presumably a safe distance. From the ship, the firing signal was sent by microwave transmission to Mike, the deserted monument to destruction.

At 7:00 a.m. on November 1, 1952, Mike exploded with a 10-megaton yield. The island of Elugelab vanished. A crater 1 kilometer in radius and 50 meters deep had been blown in the coral rock; a fraction of the missing material had been vaporized or shattered into dust, which was carried up in the mushroom cloud to pierce the tropopause, high though it is in the tropics. At about 15 kilometers altitude, the cloud entering the stable stratosphere was forced to spread out, forming a flat pancake, instead of the rounded top of the mushrooms from the smaller explosions of fission bombs. The stratospheric circulation would carry the radioactive cloud around the entire Northern Hemisphere. Once again, as it had done at Trinity with the fission bomb, the Lab succeeded spectacularly with the hydrogen bomb. The Mike shot of Operation Ivy went off only one year and seven months after the George explosion.

The Mike device is pictured just before it demonstrates the new thermonuclear concept.

Reaction to the Hydrogen Bomb. Why was there interest among the military and the Los Alamos scientists in a weapon that would produce a yield of 1, 10, or even 100 megatons? The Trinity bomb was 20 kilotons in yield; it obliterated a city and terminated a war. Immediately after the war, the Air Force generals—familiar with bombing missions of hundreds of airplanes, each carrying about 10 tons of high-explosive bombs, a total of only a few kilotons—regarded the fission bomb as the proper successor to the mass bomber raid. They had no experience with larger yields, and in that mindset, they had no requirements for them. Furthermore, because of secrecy, they had no knowledge base to understand that much higher yields were possible even with the infant fission weapon technology.

During the 1946–1950 period, the military were not involved in the workings of the Laboratory; they placed no requirements on the bomb yield because they had no vision of its utility. They wanted as many bombs as needed to load their aircraft. Their interest was in packaging and saving scarce fissile material. When approached with questions about bomb yields, they said 20 kilotons is fine, no need for more. But once the military were given the confidence that megaton yields would be available easily, they quickly changed their views about requirements. Now it was "no yield too high."

Why did Los Alamos leap so quickly into the development of the new hydrogen bomb? First, there was the scientific knowledge of its inevitability. The concept in Oppenheimer's word was "sweet." That concept indeed was "Nature's sweet and cunning hand laid on" (Shakespeare, *Twelfth Night*). But Oppie, in his years of government committee work since Trinity, had learned the wisdom of the laconic, short, and sweet. "Sweet" was his appropriate appraisal. He knew this idea for a thermonuclear weapon would work. No longer was this concept of the bomb a distant hope like the classical Super.

This was pregnant reality. For better or for worse, we had to fully understand this unborn thing. Surely too, the Soviets would know about it, and we had to understand what it would mean to them. The wisdom of the wide deployment as a weapons system could not be determined without an understanding of the characteristics of the hydrogen bomb. It had the potential of increasing the yield of nuclear weapons a hundredfold. At that time, the Lab was spending much effort in improving the fission weapons by what was considered great steps: up to a factor of 2. The near perspective was shadowed over by the great looming shape of the future.

When only the classical Super was the thermonuclear weapon candidate, Oppenheimer and Bethe particularly, but most of the other scientists as well, had an easy decision. There was in their view an abhorrence of the weapon they had created. Strongly, they held the position that the Super was an immoral weapon that should not be developed. Since the probability that the Super could be made was low because of the great technological problems, they could reinforce the moral position by the pragmatic one. Because the scarce commodity was scientific talent, why waste that on the

Super, which had only a slight chance of success and was unnecessary and immoral to boot?

But the new hydrogen bomb changed the conditions of the argument. Now, Oppie and Bethe and Rabi, with the scientific knowledge that they had, knew very well that nature would readily serve up the hydrogen bomb, leaving it to humankind to feast upon and digest. Now, morality must face up to reality, not to a remote possibility, as was the Super.

Mike's Role in Nuclear Weapons Development. Mike was designed with all the features of the new concept for the hydrogen bomb. As such, it was an integral demonstration of a practical weapon, even though it was much too heavy to be carried by aircraft. However, it was fielded as an experiment liberally instrumented to test specific features of the design and to learn about the behavior of the weapon if the yield was not as planned.

Fortunately, since the behavior was actually as planned, those measurements confirmed the methods used in several detailed features of the design, validating the methods for future applications in variations of the specific Mike configuration. Therefore, sufficient information was collected to allow the modifications required to reduce mass and even size so that a weaponized version could be made with confidence. The test also verified the procedure used in the design—understanding of the physics, idealization of the physics into models for the computer, and further idealizing the actual configuration to one that could be calculated with new computer codes on the supercomputers then available at the Laboratory.

Mike was designed as a test of feasibility, not as a fieldable nuclear weapon. But its success, a 10-megaton yield in line with projections, clearly meant that the thermonuclear weapon would take its place in the U.S. nuclear arsenal. By the time of the next test series—Castle, in 1954—several versions were available and were tested. Smaller, lighter, cheaper, more readily maintained in the field, new weapons appeared in the stockpile. However, the strategic requirements began to change as intercontinental missiles came into the force, complementing the great bombers. Since multimegaton yields were no longer optimum, the national laboratories developed submegaton weapons in a surprising variety of designs. The heritage of Mike had to be greatly modified. As a result, a healthy competition between Los Alamos and Livermore arose, both laboratories contributing to the new stockpile.

Afterword

An unusual circumstance, the wartime years. Los Alamos Laboratory was born for a single mission: Make the fission weapon and make it in time to defeat Nazi Germany. The legal framework, a contract with the University of California to operate the Laboratory, was merely a convenience. The University was a pass-through for funds, nothing more. In fact, the Army through General Groves and his appointed deputies ran the Laboratory in every detail. But there was wisdom beyond intent in this arrangement. An entirely new entity was created, a national laboratory, that in the ensuing years developed into an essential component of the body politic and the national economy. The legal convenience now supported a powerful reality.

We, the staff of the Los Alamos National Laboratory, essentially work for the U.S. government, but we are not part of it. Because of our unique legal structure, we can help our government objectively, we can provide our results to industry impartially, and we relate to academia as partners philosophically and intellectually. The years have proved the worth of such an institution, more efficient than a government arsenal, more creative for the commonweal than profit-oriented industry, and more focused on national needs than academic institutions. That being the present, what of the future?

In the next quarter century as never before, the riches of our planet may be spread out before us. We may waste them, or we may use them wisely. Perhaps, unforeseen events may foreclose our choices. Nevertheless, at Los Alamos National Laboratory, we have the opportunity to use science and technology for the benefit of humankind. In that use, we may hope that wisdom will prevail in our society. ■

Harris Mayer joined the Manhattan Project at Columbia University shortly after Pearl Harbor. Initially, he was with a small theoretical group acting as staff for professor Harold Urey, the Director of the SAM Laboratory at the University. His association with the Los Alamos Laboratory began in June 1944, when Edward Teller organized a group under Maria Mayer at Columbia to do opacity calculations for him. Both the opacity work and Harris have been connected with the Lab ever since. After the war, Teller adopted Harris as his graduate student at the University of Chicago to give him his doctorate for the opacity work. That degree was part of the University's donation to the war effort. Between 1947 and 1956, Harris was a group leader in the Theoretical Division (T Division). Thereafter, he broadened his perspective by a stint in private industry—4 years at the Institute for Defense Analyses in the Washington, D.C., environment and 14 years at the Aerospace Corporation in Los Angeles—all the while retaining close contact with the Lab as a consultant. From 1983 onward, he has spent the major part of his time at the Laboratory, working with T Division and the Applied Physics Division. He now lives in a beautiful home on Barranca Mesa, in Los Alamos.