NATIONAL ACADEMY OF SCIENCES

LUIS WALTER ALVAREZ
1911—1988

A Biographical Memoir by

W. PETER TROWER

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BY W. PETER TROWER

LUIE, AS HE WAS KNOWN TO ALL, arrived at Ernest Lawrence's Radiation Lab then located behind LeConte Hall on the University of California campus in the fall of 1936. Newly married, this freshly minted Ph.D. from the University of Chicago owed his job in those grim Depression days to nepotism; his sister, Gladys, was Lawrence's secretary. Tall, blond, blue-eyed, and gymnast-fit, Luie would later be described by Jane Wilson, the wife of another of Ernest's acolytes, as "a golden boy." Bereft of all things Hispanic and innocent of most things nuclear, Luie began his life's adventures.

Luie was no stranger to the Bay Area, having been born in San Francisco to a second-generation physician and a Stanford Medical School graduate physiologist. It was while spending time in his father's laboratory that he became fascinated with instrumentation. An accomplished but unexceptional student, Luie along with Bill Shockley was interviewed by Stanford psychologist Lewis Terman for his famous longitudinal study of the gifted. Neither was selected, nor would either have qualified for Mensa membership, but both received Nobel Prizes (which none of the 1,528 "Termites" did).

Luie's life changed radically when his father was recruited by the Mayo Clinic in rural Minnesota, after he demonstrated the association of gastric ulcers with psychological stress and in the process founded the field of electrogastroenterography. Later in life Dr. Alvarez became a syndicated medical columnist, a job that earned him the sobriquet, America's Physician. In Rochester, Luie wandered the countryside, climbed prohibited towers, and experimented with explosives—all activities typical of those who become physical scientists. He would attend the University of Chicago where his social life was that of a typical undergraduate—joining a fraternity, getting sick on bootleg gin, motoring on Lake Michigan, pursuing girls, and lettering in gymnastics. His academic life, however, was unusual, even for a physics major.

When learning of a new particle detector invented by Geiger, Luie set about mastering the highly problematic art of its construction having obtained dominion over the room in which Robert Millikan had conducted his famous oil-drop experiments. There Luie also began building telescopes—an activity that required spending countless hours walking in slow circles around an oil drum, a glass blank in hand and another attached with pitch to the drum, occasionally pausing to inspect how the grit was shaping his lenses. In contented solitude Luie discovered persistence, found the joy in making things, and fell in love with all things optical.

Graduate school changed little in Luie's life. He sampled and quickly abandoned a couple of courses for his far more interesting, self-selected lab-centered activities. When the recent Nobelist Arthur Holly Compton arrived at Chicago and learned of Luie's success with Geiger tubes, he proposed that they work together to determine the nature of the primary cosmic radiation. So with six of his tubes mounted one next to the other in a wheelbarrow, Luie found himself ensconced on the roof of a Mexico City hotel whose high altitude and low latitude were favorable to catching these solar cosmic rays. Using the Earth's field as a magnet and alternating the detector array to face east and then west, he demonstrated that the particles, later to be known as the solar wind, preferentially came from the west and so possessed positive electric charge, and thus were most likely protons. When not engaged with his wheelbarrow, Luie attempted to make contact with attractive local girls who proved to be unresponsive to his blandishments because of his nonexistent Spanish.

When Luie returned to Chicago, he became the first author of a major discovery paper in particle astrophysics, a subject he only returned to late in his career. Compton's generosity toward his graduate student was faithfully practiced by Luie throughout his life when handing out recognition to his collaborators and students.

Luie's detectors also flew on a record-setting stratosphere balloon, anticipating a later balloon-borne experiment of his that ended in disaster. He further exploited his Geiger tube expertise, building a detector that allowed a solitary cosmic ray to start the General Motors mock assembly line at their Century of Progress Exposition pavilion. Luie immediately invested his GM honorarium in flying lessons, a central activity in his life that lasted for exactly 50 years from the day he first soloed.

With no course requirements the Chicago doctoral physics program vetted Ph.D. candidates with comprehensive oral exams that had to be navigated before submitting a thesis. Intimidated, Luie reluctantly surrendered the key to "his lab," and for six months inhabited the physics library, attempting to learn all the physics that he had so successfully avoided. In his inquisition, Luie gave an adequate accounting of his knowledge and was freed to prepare his self-acknowledged "uninteresting" thesis on diffraction gratings. However, this work was to provide the basis for one of his World War II inventions.

Lawrence's lab was principally about particle accelerators, primarily a series of cyclotrons of increasingly higher energy that he had invented. Secondarily, it was about nuclear physics, a field that they entered by discovering isotopes of known elements before they began producing previously unknown elements. Finally, as a way of obtaining financial support for the activities of the lab, accelerators and nuclear physics were applied to medicine, which Lawrence's brother, John, exploited to become known as the father of nuclear medicine.

Luie realized that he was spectacularly unqualified to contribute to any of the Rad Lab's activities and so he made himself useful as an extra pair of hands while pursuing a daunting self-improvement program. Each evening he would take home a couple of bound journal volumes from the physics library, and so by the beginning of his second year at the Rad Lab he had read every published nuclear physics paper. In the process Luie discovered that important articles could be identified by the black edges of their pages, caused by the oil from readers' frequent fingerings.

Luie had an eidetic recall of everything that he read, as I once discovered when I casually mentioned Katherine Blodgett's paper on molecular monolayers. Luie then recounted its content and referred me to a graph summarizing her results, including the page on which the graph appeared and where on that page I could find it.

That Luie's nuclear physics self-education program had succeeded was demonstrated when Hans Bethe published his three-part "bible," summarizing all that was known about nuclear physics and predicting much of what was unknown. Luie studied this monumental work with great care but with even greater skepticism, or as Bethe later wrote, "mainly to prove me wrong" (Trower, 1987, p. 25). Specifically, Bethe predicted that helium-3 would be radioactive and hydrogen-3 would be stable. Using the cyclotron as mass spectrometer, Luie found just the opposite to be the case.

Bethe noted that nuclei could cannibalize their innermost atomic electrons but was discouraged about the prospects that the effect would ever be seen. Luie experimentally demonstrated nuclear K-capture. Bethe despaired that the magnetic moment of the neutron, a fundamental constant, would prove to be beyond measuring. Luie measured it, and Felix Bloch calculated its value.

It was nuclear physics that allowed me to get to know Luie. In the spring of 1957 I was a senior at Cal taking a nuclear physics course from a member of Luie's Bubble Chamber Group. Learning that a final exam was imminent, Luie asked if I would like to drop by his house for a review session. Intimidated but flattered, I accepted. Upon my arrival Luie asked me what I would like to drink to which I replied, "scotch," and then he asked if I played gin rummy, to which I responded, "a little," and thus our lifetime of these games began. During the review that followed, I discovered that Luie had contributed to each topic that was covered and he provided a story about how it came about. I held my scotch and my gin rummy proved to be up to his — a fact he stubbornly refused to admit — but I left realizing precisely how high Luie had set the physics bar.

Luie began contributing to the principal activity of Ernest Lawrence's lab by developing methods to extract the cyclotron beams for experiments, and then became deeply involved in constructing the 60-inch machine. Every Monday evening Ernest held an all-hands meeting of his Journal Club. One evening on his way to the meeting, Luie realized that particles passing through an accelerating gap could be made to return to the gap, even as the diameter of the particle orbit increased by ramping up a containing magnetic field. Luie explained his idea to the Club and when he finished, Robert Oppenheimer went to the board and derived the phase relations for what came to be known as the "electron microtron." Unfortunately, Luie's invention was stillborn, as sufficiently powerful radio-frequency sources to animate his accelerator did not yet exist.

In fall of 1941, with war in Europe imminent, Lawrence dispatched his two chief lieutenants, Luie and Ed McMillan, to the Massachusetts Institute of Technology to help found their own radiation laboratory. The focus at MIT was to develop war-fighting technologies that exploited the British-invented high-power microwave generator, the magnetron. Luie's Special Projects Group was charged with developing anything that Luie invented. The SPG first produced the EAGLE radar bombing system that flew in a few missions against Japan and although it was a great system, it ran out of war.

One of Luie's inventions—Ground Control Approach, a system that allowed planes to land in zero visibility—was proven stateside and adopted by both the army and navy. In 1942, Luie deployed GCA in England where it became the Royal Air Force aircraft-landing system and allowed British interceptors to operate under conditions of diminished visibility and thus mitigate German bombing raids.

Another of his projects was the Microwave Early Warning system, a long-range radar using Alvarez linear arrays. Four of these handmade systems were deployed in Europe, where they essentially controlled from England all the allied air activity over the continent.

Luie's last system allowed allied patrol planes to attack surfaced U-boats at night while the Germans were recharging their batteries. Before Luie's VIXEN system, German subs would pick up the radar signal from an approaching bomber, and if the signal intensity increased, the sub would submerge. With VIXEN, after the probing radar acquired the sub, its power was continuously reduced, using the inverse-square law, thereby deceiving the U-boat skipper into believing that the aircraft was flying away from the sub.

When Luie returned from England, he left MIT and briefly stopped in Chicago where his most constructive activity seems to have been playing a variety of parlor games in Enrico Fermi's living room. Then it was on to Los Alamos to work on the Manhattan Project.

On the high plain of New Mexico, Luie was initially tasked with finding a way to simultaneously, and thus symmetrically, explode the tiles that surrounded the plutonium pit required to initiate the nuclear explosion. This was difficult because the current transit times in identical-length wires varied due to individual microscopic defects. Luie blew this problem away, literally, by discharging a large capacitor, whose current surge traveled down each wire at the same speed and in the process vaporized the wires.

Luie's second Los Alamos task was to measure the energy of the nuclear bombs. For this he borrowed airborne pressure sensors developed by Pief Panofsky, then a Caltech graduate student. Luie personally deployed these gauges while flying in the observation plane at the Trinity test and on the Hiroshima raid.

Before the war, Luie had developed detailed designs for a series of experiments to address most of the then important open questions in nuclear physics. He intended to pursue this program once he returned to Berkeley, the Rad Lab, and university life. That was not to be. The war changed everything forever for physicists. The nature, scale, and recognition of the value of our science prompted a revised Golden Rule: "Why use lead when gold will do?" The essentially solitary prewar way of doing physics gave way to that pioneered at Lawrence's lab: collaborative, industrialized-scale activity, which the grateful nation underwrote.

When Luie returned to Berkeley in 1946, Lawrence proposed both him and Ed McMillan for membership in the National Academy of Sciences on the condition that they write his recommendation letters since they knew best what they had accomplished. When Lawrence received the letters, he edited them to make them sound like him, and submitted them. Luie and Ed were elected in 1947 and Luie subsequently used this technique for all future reference letters.

Back at the Rad Lab after the war, Luie designed and constructed a proton linear accelerator using war surplus radar power supplies. Then Lawrence co-opted him to construct the behemoth Materials Testing Accelerator in what was to become the Lawrence Livermore National Laboratory. After several years of struggle, the need for the MTA was obviated by the discovery of plentiful natural uranium by prospectors motivated by Gold Rush-like economics.

The collapse of the MTA project left Luie exhausted and dispirited. With the passage of time his prewar list of seminal experiments fell to others to carry out, several of whom have been honored with Nobel Prizes. Luie returned to the Rad Lab and with the exception of his discovery of the then fastest positron-emitting isotope, nitrogen-12, never again did any nuclear physics. At loose ends, his primary activity at the lab drifted to playing card games, mainly hearts, with the technicians.

The confluence of two events set him on a new path. The first was his assuming responsibility for two graduate students, Lynn Stevenson and Frank Crawford, when their adviser, Herb York, was called to tend other vines. Luie quickly recognized that he knew nothing about particle physics. Thus Lynn and Frank were given the task of instructing him, complete with daily homework exercises, reading assignments, and oral quizzes. As Lynn later said to me, “Our tutoring didn’t even last the month as Luis got up to speed very quickly.”

The second was the announcement that a University of Michigan postdoc, Don Glaser, had observed that passing electrically charged particles produced boiling along their paths in some liquids. Luie immediately realized that for the Glaser discovery to be useful for physics research the liquid would have to be hydrogen so that the target nuclei would always be protons; that the detector volume needed to be as large as possible to produce the greatest number of interactions; and that the data collection and analysis would have to be highly automated to get statistically significant samples of events. This was the beginning of the hydrogen bubble chamber.

During the bubble chamber years, Luie reinstated the Monday night Journal Club, only now it was held at his home with beer and other drinks being provided. Attendance was not compulsory and these meetings were open to all who wished to attend. Alvarez group members and others would present work in progress. Luie would listen attentively to experimenter's presentations, but when a theorist would opine he would usually repair to his study and write in his journal.

Some half dozen years later Luie's group, now several hundred strong, operated a 72-inch liquid hydrogen bubble chamber and photographed, measured, and analyzed huge numbers of particle tracks using a highly automated optical-electronic-computer system. Luie's army of physicists, engineers, technicians, scanners, and programmers produced a sufficient number of previously unknown particles that the systematics of their interrelationships (the Eight-Fold Way) and their initiating constituents (quarks) could be deduced. This resulted in the 1968 Nobel Prize in Physics for Luie. He used part of his prize money to take the senior members of his group and their wives to Stockholm for the presentation.

Luie's sense of professional decorum and ethics nearly cost him his Nobel Prize. He strongly believed that those who did the heavy lifting on the results presented in a paper should enjoy the recognition. Because of his reputation, he believed that if he were on a paper, it would automatically be assumed, incorrectly, that he was the prime mover. Thus, in spite of his providing the means to make the data available for analysis, and his active participation in its analysis, he was often reluctant to be a coauthor except where he was the major direct contributor. When his former student Rich Muller included Luie as an author on the cyclotron carbon-dating discovery paper, Luie made his displeasure known, because, he said, "Everyone will assume that it was my idea not yours!" Thus when the extended series of resonance papers that would serve as the basis for his prize began to be published, Luie had to be encouraged by his junior colleagues into being included in the author lists.

During the bubble chamber era, Luie's respect for talent regardless of formal credentials became even more apparent. Don Gow, after whom Luie's youngest son is named, was a technician with a long association with the Rad Lab and Luie. Even though Don only had a high school education he became the de facto second in command of the Alvarez group, I never heard any of the assembled myriad of talented Ph.D.s question Don's status. Pete Schwemin, a Rad Lab machinist whose formal education also ended with his high school graduation, became Luie's partner in Schwem Instruments formed to commercialize Luie's inventions in stabilized optics. Luie often referred to Pete as a "poet of the machine shop." Bill Humphrey, a Ph.D. in the Alvarez group, was spirited away by Luie to form Humphrey Instruments, which developed Luie's inventions in virtual optics and saw fruition in a device to automatically determine a person's eyeglass prescription.

After Stockholm, Luie's interest drifted away from particle physics. In 1982 I hosted a particle physics conference and asked Luie to give the summary talk. He demurred, saying, "I haven't thought about that subject for more than a half hour in the past three years, and when I have I have not found it interesting." Clearly he was on to other things.

"Other things" included the mythical magnet monopoles attached to a wide variety of materials which he pursued, but did not find. He discovered that there were no undiscovered chambers in the Cephren pyramid. His search for antiparticles in cosmic rays ended with a splash when his balloon-borne superconducting magnetic spectrometer fell into the Pacific Ocean.

Luie was always interested in the larger outside world. Before the war he and other Rad Lab members would volunteer as extras in San Francisco Opera productions. When the Hewlett-Packard Corporation went public, Luie became one of its three outside directors. Luie participated in Lawrence's technically superior but politically unsuccessful effort to develop commercial color television. His enjoyment of golf led him to invent a stroboscopic swing analyzer, which he presented to President Eisenhower.

As an active member of JASON he with other physicists provided technical advice to the U.S. government on a variety of matters, mostly military. He valued the nonscientist contacts that his Bohemian Club membership and his participation in their summer encampments afforded. A lifelong Republican, Luie remarked during the Berkeley campus's so-called free speech movement, "I find their goals are without merit, but their tactics are brilliant."

Luie was egalitarian—accessible to everyone equally—and the only hierarchy he recognized was one based on talent. When visiting the cafeteria for lunch, you would find Luie at a table with students and postdocs listening to the things that interested them: political conspiracy theories, struggles with balky equipment, problems with data analysis. Most of the rest of the lab's senior staff would sit together, often reminiscing about the past.

Anyone could walk into Luie's office unannounced with a complaint about the lab's management with which he usually concurred but invariably despaired that anything would change. Or you could walk in with a physics question and Luie with great patience and his usual unusual way of looking at things, would address it. When he finished, he would ask whether you now understood, and if you answered in the affirmative, he would pose a quick question to verify your understanding. Woe be to those who falsely claimed understanding, as for him ignorance was acceptable and remediable, while faking it was inexcusable.

Luie's frequent lunches with students and postdocs paid off when, as president of the American Physical Society, he was attending a meeting in St. Louis and found himself in his hotel room with little to entertain him. So he began to think about the Kennedy assassination: how many shots were fired, how many shooters, was there a conspiracy. Luie realized that the Zapruder film could be used to answer these questions, two of which were the number of shots and the direction from which they came. Highlights that the sun produced on the car fenders were fuzzed out by the involuntary muscle reaction when Zapruder heard a shot. Thus Luie determined that three shots were fired. Kennedy's head recoiled in the opposite direction to that of a bullet from Oswald's location. Luie's experiments firing shots into Duck-taped watermelons showed that a jet of particles was expelled in the bullet's flight direction, which overcame the impulse of the entering bullet and so propelled the melon in a direction opposite to that of the bullet. Thus Luie showed that a single shooter from Oswald's perch was sufficient to account for the evidence, work that did not quell the conspiracy theorists, but at least offered solid evidence to lay their theories to rest.

Luie had no commitment to intellectual consistency. What he believed yesterday often had no connection with his enthusiasms of today, a trait that freed his creativity but was disconcerting to those who worked with him. On several occasions I was wakened by a phone call with Luie announcing, without salutation, a “great idea” and demanding that I tell him immediately what was wrong with it. He had these revelations most often during his free-ranging evening meditations and so his calls usually rang in my Virginia home well after midnight; a fact that, if he even considered it, was of absolutely no importance to him. In following up on the “great idea” the next day I usually found that Luie had moved on to something new.

Bob Watt, a longtime Rad Lab collaborator, asserted that “Luie might have 100 ideas each day, 50 were probably useless, another 25 were too difficult to do, and among the remaining 25 would be one or two worth a Nobel Prize. It was left to us to drag our feet on all but the best of these ideas” (Trower, 1987, p. 108). Similar sentiments were commonly expressed by many who collaborated with him throughout his career.

Luie’s way of vetting an idea was to present it to a few trusted friends and demand that they immediately tell him what was wrong with it. These friends took the assignment seriously as they didn’t wish to embarrass themselves or to be party to embarrassing Luie. If no fault was identified, Luie would then present the idea to one or another of his antagonists and ask them to verify it. Only those ideas that passed this gauntlet were widely promulgated. Luie, to the best of my knowledge, never published a wrong result.

Luie could be devastating when publicly demolishing a wrong result. Sometimes he was personally gracious, as with his critique of Buford Price's magnetic monopole claim, and at other times not, as with Dewey McLean's volcanism explanation for the K-T extinction. In any case, Luie's outspoken and steely honesty impressed us all. When Dick Feynman identified the probable cause of the space shuttle *Challenger* disaster, he hesitated to perform his now famous O-ring and ice-water demonstration until he thought about what Luie would have done. As he wrote later, "I think of Luis Alvarez, a physicist I admire for his gutsiness…If Alvarez was on this commission, he would do it, and that's good enough for me" (Feynman, 1988, p. 146).

This intellectual honesty only failed Luie once, and that was when he found himself unexpectedly in charge of a commission that evaluated the military situation in Vietnam. When delivering his report to the White House, he was asked if he would like to meet "the boss." When President Kennedy then asked what he thought of the situation, Luie equivocated.

Luie was not free of eccentricities. For example, he owned two pairs of shoes, one brown and the other black, and when one of them got a hole in the sole he threw that pair away, wore the other, and bought another identical pair to the discarded one. When purchasing sport coats it was never individually but a half dozen at a clip, to save time. When collecting his daily mail, he would stand by the waste basket into which he tossed, unopened, every piece that didn't contain a first-class stamp, thus saving, he once reported, "over three days of my life." Rather late in life he discovered Chinese food, and the first meal he ordered pleased him so that every subsequent Chinese meal consisted of exactly the same three dishes.

One day Luie's wife, Jan, got a call from his patent attorney, with whom he had just had lunch, saying that Luie urgently needed a new car, as his present one was both unreliable and unsafe. Jan then called Luie, who was home, and instructed him to buy a new car. Being innocent of automotive fashion, he asked his 14-year-old daughter Helen what kind of a car he should get. She replied, "A Porsche," and soon they were off to the local dealership. When Jan returned home that evening, she found a candy-apple-red Porsche Carrera GT convertible parked in the garage where his offending rattletrap had previously resided.

The crowning achievement of his long career came when his geologist son, Walter, showed Luie a piece of sedimentary limestone from Gubbio, Italy. The rock was bifurcated by a thin layer of what appeared to have once been mud, while the limestone on either side contained fossils of small ocean-dwelling creatures. There were many fossils on one side of the mud and few on the other. Thus began what was to eventually become the extraterrestrial boloid explanation of the extinction of the dinosaurs.

As the K-T extinction hypothesis gained acceptance and the objections of the gradualist geologists were subdued, Luie and I began to work together on two books (Alvarez, 1987; Trower, 1987), a task that was great fun. As a result of our collaboration I subsequently came to Berkeley for a year to work out our scheme to detect explosives using the signal from the decay of Luie's old friend nitrogen-12. We called it the Nitrogen Camera.

When I arrived in California in the late summer of 1987, Luie reported that he was having balance problems, which he excitedly attributed to mini-strokes, a medical condition that his father had predicted but had heretofore not been observed. Luie was convinced that he was demonstrating experimental evidence for these strokes. However, after consulting a physician, his symptoms were found to result from a slowly growing brain tumor, an acoustic neuroma, which was successfully removed. His recuperation did not progress as expected and further tests revealed that he was also suffering from advanced esophageal cancer. The surgeries left him physically impaired and emotionally despondent. He presented his surgeon with a graph, the quality of life on the vertical axis and time on the horizontal, demonstrating that what remained for him to endure was not worth it.

During this final year, Luie was faithfully visited by John Lawrence and Tom Budinger, physician-scientist friends both. Luie and I almost daily played gin rummy, chatted about a wide range of personal and physics matters, and on occasion he would burst forth with a raunchy limerick from his undergraduate years.

One day toward the end Luie said, "I want you to give our Nitrogen Camera a decent burial," by which he meant I was not to abandon it, but I had to rigorously prove by experiment that our scheme could not work. In this I failed. Experiments in Stockholm with their racetrack microtron proved that we could not only definitively detect explosives of every variety, with few false positives, but that we could also determine their size, shape, and location. This work led to construction with Moscow colleagues of a fieldable electron microtron needed to produce the probing electron beam.

Luie died a year to the day after my arrival in Berkeley. On that morning I appeared at his house to find that he was gone, and so we said our silent fare-thee-wells. A few days later a small, heavy cardboard box in hand, I boarded a single-engine Cessna, instructed the pilot to fly out across the Golden Gate Bridge on to the Farallon Islands and there to head, as Luie had done many times piloting his own plane, to Monterey. I then scattered his ashes.

At the conclusion of a memoir, such as this, it customary for the *locuteur* to say how much his subject is missed. However, I carry so much of Luie around with me, which

I freely consult, that I hardly think of him as gone at all. I suspect that many others who had contact with him hold similar feelings.

CODA

Luie used to say that the only products of Ernest's Rad Lab were articles in green books (i.e., the Physical Review) and students. His contribution to "books," recounted herein, is now complete. However, his students, graduate and postdocs, soldier on. One, Rich Muller, a MacArthur and Waterman awardee, would like to instruct presidents on physics but settles for informing nonscience students in his highly regarded UC-Berkeley course. Another, George Smoot, measured the heterogeneity in the primordial cosmic microwave background radiation, an accomplishment for which he shared the 2006 Nobel Prize in Physics. A third, Saul Perlmutter, Rich Muller's Ph.D. student, has recently discovered that the Universe's expansion is accelerating due to the presence of the dominant so-called dark energy. And so Luie survives.

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