NATIONAL ACADEMY OF SCIENCES

LEE ALVIN DUBRIDGE

1901—1994

A Biographical Memoir by

JESSE L. GREENSTEIN

Any opinions expressed in this memoir are those of the author(s) and do not necessarily reflect the views of the National Academy of Sciences.

Biographical Memoir

COPYRIGHT 1997
NATIONAL ACADEMIES PRESS
WASHINGTON D.C.

Courtesy of The White House, Washington, D.C.

LEE ALVIN DUBRIDGE

September 21, 1901–January 23, 1994

BY JESSE L. GREENSTEIN

LEE A. DUBRIDGE WAS born in Terre Haute, Indiana, on September 21, 1901; he died of pneumonia at age ninety-two in a retirement home in Duarte, California, on January 23, 1994. To quote the memoir by John D. Roberts and Harold Brown, DuBridge was "one of the most influential American scientists of the 20th century. He was a first-rate physicist, a leader in research of immense importance to the Allied victory in World War II, an exemplary research university president in a time of enormous scientific, societal, and educational change, as well as an influential statesman for science in the postwar era."[1]

Lee directed the MIT radar lab (1940-45), was president of Caltech (1946-69), and advised the government and military throughout his long career. He received the King's Medal for Service in the Cause of Freedom, the U.S. Medal for Merit, and the Vannevar Bush Award of the National Science Foundation. The Caltech trustees established the Lee Alvin DuBridge professorship.[2]

I will not attempt to describe his full career. He was a modest, eminently likable man, small in stature, but with strong presence. His conversation ranged from reminiscences of great world scientific events and personal friends to the finances of KCET, the Los Angeles PBS station, which he helped found and served as president of its board. He loved opera and made and listened to shelves-full of video recordings of nearly all broadcast performances. I will emphasize his life and personality at the expense of his scientific accomplishments, which came early.

YOUTH

For his family Lee wrote both professional and personal autobiographies of great interest. He deposited one copy, which I have used, in the Caltech archives. It reflects a difficult, poor childhood with many moves and no permanent home. His father, who changed jobs frequently, was a YMCA secretary, football coach, and physical education director at YMCA camps in Iowa, California, Montana, and Michigan, as well as in the Army. Later his circumstances worsened, and he taught, ran a filling station, sold insurance, and after the Depression returned to YMCA work in Chicago. Lee's mother was a poet and writer, who during the Depression wrote poems for greeting cards, some of which are still in use. The Caltech archives has a slender book of her work. Perhaps it was from her that he inherited his fondness for music.

Lee earned whatever money a young boy could; at age sixteen he worked in a Union Carbide laboratory for fifty cents an hour. Nevertheless, he had a good high school education in Sault Ste. Marie. He was somewhat interested in chemistry, but found it monotonous as taught. With small savings and a minuscule scholarship he started at Cornell College in Iowa in 1918. He was a good student but showed little early concentrated interest in science. He lived on a scholarship plus the thirty dollars a month he earned as a waiter in a girls' dormitory. There he met his wife-to-be, Doris Koht. Doris followed him through his career and proved a capable president's wife and hostess at Caltech. Doris died in 1973.

At Cornell he attracted the interest of the physicist O. H. Smith, to whom Lee was long grateful. Lee took advanced work in physics and served as laboratory assistant. Cornell was a small school but had devoted teachers. Smith later received the Oersted Medal for teaching from the American Association of Physics Teachers. Lee had a few years of study and normal student activities (debate, Milton, and singing in oratorios and church choirs), and was president of the student YMCA. He graduated in 1922 with a Phi Beta Kappa and went to the University of Wisconsin for graduate study. At the University of Wisconsin he was awarded a Ph.D. in 1926 (and later received one of his twenty-eight honorary degrees). The physics department was small and congenial and strongly emphasized laboratory work, use of vacuum, and measurement of small currents.

Lee had a summer job with the Bell Telephone Lab with future Nobelist Clinton Davisson. Supported by fellowships at Madison, Lee studied the photoelectric effect from platinum surfaces in which light (photons) causes the emission of charge (electrons) from metallic surfaces. Some photon energy must be expended to remove the electrons from the solid, depending on the material and its surface finish. His first assigned text was Arnold Sommerfeld's new text *Atombau und Spektrallinien* in German, taught by Charles E. Mendenhall. Sommerfeld himself visited two years later. Other instructors included Warren Weaver and Max Mason (with whom Lee had many later contacts).

Lee's first important experiment (published in *Physical Review*) proved that positive ions were definitely not emitted during the photoelectric process. Lee spent fifteen years on the photoelectric effect, building all apparatus required to perform experiments of increasing delicacy and precision. His thesis provided values of the photoelectric thresholds. With his Ph.D. and appointment as instructor (at $1,800 per year) he could at last afford marriage to Doris Koht, on September 1, 1925. Their two children were Barbara Lee (born 1931, and who married David MacLeod in 1955) and Richard Alvin (born 1933). Lee received an offer of a National Research Council fellowship for 1926-28 at $2,000 per year to work at Caltech under Robert A. Millikan. That great figure in American physics repeatedly became Lee's sponsor during his career.

The family bought a car, without a trunk ($400) and drove it across country in 1926, camping for six weeks as they explored the scenery, campgrounds, and treacherous roads of the Mid- and Far West. For thirty-five dollars a month they rented a bungalow in Pasadena. Such details of Lee's early career show how much has changed from the way physics was done in pre-war America. Yet in the next ten years things really did not change much. With my middle-class background, I received an NRC fellowship at $2,200 per year in 1937 and drove with my wife from Cambridge, Massachusetts, to Williams Bay, Wisconsin, in my first car (a Ford that cost $400). My house rented for forty dollars a month. Yet in Madison, 60 miles distant, photoelectric astronomy was being created by astronomer Joel Stebbins and physicist Albert Whitford. Science in the United States was only a small community and had a quite penurious support system.

At Caltech Lee continued to work on the photoelectric effect with Millikan, who was first to verify Einstein's relation between the photon energy and the maximum energy of the ejected electrons. Millikan befriended all young faculty, which he viewed as a big, happy family with himself as genial, strict father. They had many talks about the short history of Caltech, the philosophy of leadership in science, and the overriding necessity to attract the best people in every field of teaching and research. Caltech had such distinguished physicists as Richard C. Tolman, Paul S. Epstein, and students like Clark Millikan, Charles Richter, William V. Houston, and the humanist Clinton Judy. In a far better laboratory with an ultraviolet spectrometer, better vacuum, measuring instruments, and electronics, Lee studied the parallelism of the thermionic and photoelectric emission processes.

In 1928 Lee was invited to Washington University in St. Louis as assistant professor. Chairman Arthur Hughes welcomed him and soon proposed collaboration on a book. Much early work is consequently discussed in two books, *Photoelectric Phenomena* with Arthur L. Hughes (1932), which became a bible for experimenters, and *New Theories of the Photoelectric Effect* (1935). On the theoretical front, R. H. Fowler had just found that free electrons in solids obeyed Fermi-Dirac statistics; Lee's experiments in St. Louis provided many tests, measuring the photon frequency and the temperature dependence of the ejected electrons. Finally, nearing the end of his photoelectric work, he developed a Brown-DuBridge amplifier that proved useful for many years. But changes were coming even at the bottom of the Great Depression.

LEADERSHIP

In 1934 an important change occurred in his career. Lee DuBridge was invited to the University of Rochester, which recently had been heavily endowed by George Eastman. At age thirty-three he had not only become a full professor but department head as well. His salary reached $5,500 as his work and influence changed. He brought Fred Seitz and Milton Plesset to Rochester; he helped rescue Victor Weisskopf from Hitler's Europe.

An abrupt shift to the new subject of nuclear physics was stimulated by the success of Ernest O. Lawrence's cyclotron. The change marked the relatively inexpensive beginning of "big science" in which many people collaborated. They had invaluable advice from Lawrence and Cooksey of Berkeley. DuBridge led a group of physicists and a strong group of electrical engineers at Rochester, who borrowed metal for the magnets, got electrical generating equipment and high-power vacuum tube oscillators free, and raised $4,000 from local philanthropists for cash outlay. By 1936 DuBridge and S. W. Barnes had in operation an 18-inch cyclotron that reached 5 million electron volts and eventually nearly 8 million electron volts. It was still working in 1954.

The targets could be whatever was desired; the bombarding particles were protons from hydrogen. Isotopes of charge (Z) and atomic mass (A) were accessible targets if Z were not too large. A student and collaborator, Joseph B. Platt, remembers a table of isotopes on the control room wall. As each new unstable isotope was produced, its entry square (Z,A) was filled in and colored yellow to denote Rochester's priority. Platt claims that the wall turned mostly yellow. Oddities were detected (i.e., alpha particles); positrons were produced and then decayed. Lee (working with Barnes) found neutrons (n) from their newly discovered (p,n) reactions. Nuclear transmutation, at least from elements of moderate charge Z, became an established procedure. Almost any value of (Z,A) was accessible as the cyclotrons increased in energy and number.

Lee became dean of the Faculty of Arts and Sciences, bought a house, and received an honorary degree from his alma mater, Cornell College of Iowa.

By 1940 when it was clear that this country could be involved in the war in Europe the National Defense Research Committee was organized by President Franklin Roosevelt with members Bush, Compton, Conant, Jewett, and others. Lawrence held a commanding position in physics and in advice to the government and had become Lee's good friend. DuBridge was too successful and well known to be allowed to stay at peace in Rochester. Alfred Loomis (wealthy banker and amateur electronics wizard) and Lawrence recognized the reliance that the British were being forced to place on the United States for help with radar. Britain developed ground and airborne radar with the meter-wavelength magnetron tube at the Telecommunications Research Establishment. It helped win the Battle of Britain against German bombers. But Britain lacked the industrial and manpower base required to exploit microwave radar fully. Loomis initiated the U.S. production of magnetrons working at the higher frequencies and power.

The United States was clearly involved in preparing for a highly technological war. In November 1940, under pressure from Lawrence and Loomis, Lee became the founding director of the new Radiation Laboratory (RadLab) centered at the Massachusetts Institute of Technology. It did not disband until January 1946. His first helpers, recruited on a crash basis, included a dozen from the nuclear physics community, Alex Allen, Ken Bainbridge, Ed McMillan, I. I. Rabi, Norman Ramsey, Stan Van Voorhis, and Milton White; some of the staff later won Nobel Prizes. By 1945 the lab employed 4,000 scientists and engineers. Lee's style, one that he retained all his life, was one of showing leadership rather than exerting authority. He listened and understood the problems well, but he could be finally decisive. Their first project was to design and build a radar for air interception, which took three months plus a year to mount on the Northrup Black Widow airplanes.

Also designed and built were radar to detect ships and submarines at sea, for night bombing, and to point guns. Over 100 types of microwave radar were created. For each there were training programs, service instructions, and manuals for field maintenance. Many prospective users were trained at MIT. RadLab personnel fanned out over the world to train users and improve field operations. The annual budget reached $50 million. The lab and its products (the theory of high-frequency circuits and the many uses of microwaves) were described in an unclassified twenty-seven-volume series published at the end of the war. DuBridge lists in his unpublished "Memories" a few RadLab products he viewed as particularly significant:

LORAN, invented by Loomis, was the universal navigation aid and depended on timing long-wave pulses from three or more transmitters. Essentially these established lines of position, replacing the stars by a worldwide timekeeping radio net. It is the grandfather of the global positioning satellite network.

H2S AND H2X were airborne radar at 10 cm and 3 cm wavelengths and presented maps of the surroundings at sea and land. The radar was widely used for bombing in Europe.

EAGLE, invented by Luis Alvarez, provided even higher resolution for bombardment in Japan. The plane's long cylindrical antenna oscillated as it scanned the forward area.

MEW, used for high-power search to detect aircraft at a distance of 100 miles.

SCR 584 was a system of ground-based antennae that fed range and direction data into computers to help bring down German V-1 missiles over England.

Lee visited Europe. RadLab established overseas radar advisory centers for U.S. forces, one at the Telecommunications Research Establishment in England, one at Air Force headquarters, and one in Paris. Scientists in uniform followed troops in the field, installing new equipment in forward centers. Lee even visited Buchenwald, the recently liberated concentration camp. Radar centers were being established in the Pacific theater and the nuclear bombing of Hiroshima and Nagasaki depended on airborne RadLab radar sights. Lee also saw the first bombs at Los Alamos. He had close friends there, some of whom he had released from RadLab as its mission wound down. Los Alamos and RadLab, each with different styles of management, employed essentially every active physicist of the time and were the sources of physicists of the future.

RadLab was dissolved after the war's end, and in an orderly manner its responsibilities were transferred to industry. Spin-offs followed, among them air traffic control, microwave communications, timing circuits for electronics (including television and computers), the maser, the laser, nuclear magnetic resonance, and even the household microwave oven. Lee summarized his work at the RadLab as largely administrative and claims not to have understood the complex electronic circuitry involved. But his enthusiasm and clarity of expression were outstanding, his personal influence was enormous and he left hundreds of newly educated friends to populate the postwar world of electronics.[3]

Lee's family moved near to Cambridge, where they enjoyed New England vacations and helped create a center for the social life of RadLab. There were parties and picnics, insider jokes, and songs. The latter are epitomized by what Art Roberts wrote for a party honoring Rabi's 1944 Nobel Prize. "It ain't the money that makes the nucleus go 'round. It's the philosophical, ethical principle of the thing."

Lee commuted to Washington almost weekly, flew to Europe in 1943, 1944, and 1945, while Doris took care of the children and prepared for RadLab parties.

Among the important personal relations created between men working at the two laboratories was that of close cooperation between Lee and Robert F. Bacher, who had worked at RadLab, and who at Alamogordo had assembled the charge for the Trinity test weapon. Eventually Bacher joined DuBridge at Caltech. His thoughtful advice and cooperation proved invaluable to Lee and to the Caltech faculty.

Los Alamos continued as a nuclear weapons source and remains an active scientific center, especially now in large-scale computing. Both RadLab and Los Alamos were successful and expensive with unlimited budgets under the military necessity. Security was tight and generally successful at both laboratories.

Scientists and engineers learned a great deal from wartime research, and it changed their lives. Radar was a feature story in *Time*. In 1955 Lee's portrait was on the cover of *Time* where he was called "senior statesman of science." Lee had already been honored by election to the American Philosophical Society and the National Academy of Sciences. His career as a laboratory scientist had ended. He and the world changed. Closing down RadLab and finding jobs for its staff of 4,000, in fact, went particularly well because of openings in universities, which were expanding, and industry, which was converting to peacetime work. The important question was what came next for Lee. Because he wanted to become a university professor again, the letdown he felt in his attempted return to nuclear physics at Rochester must have been severe.

THE CALIFORNIA INSTITUTE OF TECHNOLOGY

Within six months an old friend, Max Mason, phoned.

He had known Lee at Wisconsin, was a former foundation head, and was then a Caltech trustee. He also headed the project to complete the 200-inch telescope. Max said Lee had to come to Caltech to be its first president (Millikan had been chair of the Executive Council of the Board of Trustees, but was never the president). The prospect was intrinsically attractive; the Pasadena climate was far better; the trustees and faculty were cordial; and housing was found. From a life of secrecy that limited friendship to wartime colleagues the entire DuBridge family found themselves in the social and public eye. They were important guests at public and private functions. It was a heady change to go from the relative poverty of his childhood to leadership of a rapidly growing institution in an expanding community. While both Lee and Doris were simple mid-westerners by background, they adapted well to this sophisticated world. Lee had an enthusiastic way of talking about Caltech and about science and engineering. He was almost never without the large, quick smile that helped make him an irresistible public figure. Their daughter Barbara attended a private school (Westridge); son Dick went through the then excellent Pasadena school system and was eventually accepted at Harvard.

Doris was closely involved with the Caltech Women's Club, so much so that it eventually established an annual "Doris DuBridge Day," which is still being celebrated. Social contact with prosperous friends from the community came often through the Caltech Associates, a group of non-academic people who contributed from $10,000 to $25,000 annually. Associates became members of the Athenaeum (the luxurious faculty club) and were able to attend many lectures by distinguished visitors and faculty. The 1,300 Associates are now an important source of Caltech's unrestricted income.

Lee and Doris traveled extensively, partly for Caltech, but often because Lee was a member of a board or committee. Fortunately, in 1949 they found an excellent old (1915) house with large grounds. Caltech purchased and modernized it to become its president's home. The DuBridge children were married in its garden. New and old faculty, families of graduating students, and Associates were entertained at large garden parties.

During the rapid growth of federal support of the sciences a struggle went on to establish the nature of the management of federal agencies, their independence from political pressures, and the size of their budgets. In these struggles Lee was an active participant, especially those involving the National Science Foundation. Caltech received excellent support from the Office of Naval Research, the Air Force Office of Scientific Research, the National Science Foundation, the National Aeronautics and Space Administration, and the National Institutes of Health. Lee also proved skillful at fund raising from private sources, the aerospace industry and foundations. During his presidency[1] the Caltech endowment grew from $17 million to $140 million; thirty new buildings were constructed; the 200-inch Hale telescope was put into service; and the Jet Propulsion Laboratory, originally a military production center, was made into a focal point for unmanned space exploration.

He was in many ways an ideal college president for the twenty-three years he held that office.[4] He was soft-spoken, responsive, and persuasive. He somehow knew how to say "no" and still retain the friendship of a faculty member. He visited faculty offices to ask what was new in a member's field. As senior professor of astronomy I enjoyed Lee's questions as to what had been found recently at Palomar. His broad physical insight gave him quick understanding and he savored what remained puzzling. A further extraordinary ability was to repeat a story, with background and speculation about its future, to a meeting of the Board of Trustees or to the Associates. Sometimes the solution was only money, which he provided at once in small amounts and in large amounts after some effort. Lee spoke very well in public and was under constant pressure to explain Caltech science and education to organizations and the public. In the Caltech archives there is a list of nearly 400 typed manuscripts of the speeches he gave in twenty years. The 347th listed is a "Farewell to Caltech," given on December 20, 1968, before he left for Washington. The faculty grew from 260 to 550 members (if we include postdoctoral fellows); the student body grew slowly from 1,200 to 1,550 in twenty-three years. Women students were admitted.

Among the most actively supportive faculty I must mention Earnest Watson (his early dean of the faculty) and Robert F. Bacher, whom Lee met in 1929 and who served after 1949 as chair of the Caltech Division of Physics, Mathematics, and Astronomy, provost, and vice-president. The history of Caltech's growth under Lee included low-energy nuclear physics, astrophysics,[5] aeronautical science, and all branches of engineering. It also included the 200-inch telescope, which came into general use in 1952, cosmology, and the enormous growth in molecular biology (Nobelist George Beadle) and chemistry (Nobelist Linus Pauling).

Lee was personally most interested in the low-energy physics studied with Van de Graaffs in the Kellogg Laboratory under the leadership of W. A. Fowler and C. C. Lauritsen. They studied both the reactions that produced the energy of stars and the reactions between light elements in the early universe (involving H, He, Li, Be, and B). A billion-volt electron synchrotron was built under Bob Bacher and was successful. But its small size indicated that Caltech could never join the race for the megamachines built, for example, at Berkeley. The local faculty, like most others, participate by bringing experiments and students to the internationally operated giant accelerators.

Lee's influence in the inner circles of the interlocking foundation boards' the "old boys clubs" dates back to 1940, when Lawrence and Loomis first suggested Lee as director of the MIT RadLab. Lee had faculty friends in aeronautics (through Clark Millikan and Theodor von Kármán), biology (Nobelist George Beadle), nuclear physics (Nobelist William A. Fowler), neurobiology (Nobelist Roger Sperry), and chemistry (Nobelist Linus Pauling). He was personally accessible and had strong links everywhere. The system may have invited misuse, but soon after World War II it was working at its best. Another DuBridge link to the inner circle of power was his 1948 election to the Bohemian Club in San Francisco. He attended essentially every summer encampment. He participated and enjoyed the sight of the leaders of California strenuously relaxing. There were symphonies, band concerts, plays, musical comedies, campfires, and lectures. It was also a time of family feeling at Caltech.

One important aspect of his leadership was his personal courage in relations[6] with Washington. The era of Senator McCarthy arrived in the early 1950s, and the chemist Linus Pauling, a fighting liberal, became McCarthy's target. Pauling was accused of membership in the Communist Party because he publicly opposed the continuation of nuclear weapons testing. A few leading Caltech trustees joined the McCarthy witch hunt, demanding that Lee fire Pauling in spite of Pauling's academic tenure and standing as a chemist. Pauling assured Lee in writing that he had never been a member of the Communist Party. Robert Bacher, chair of the Committee on Academic Freedom and Tenure, and Lee disagreed with Pauling's wish to stop nuclear testing, but they stood their ground against the trustees, and Lee offered to resign rather than exert pressure on Pauling. Instead, the trustees resigned. Pauling stayed on at Caltech until he won his second Nobel Prize, the Nobel Peace Prize, and then resigned in 1963.

When Lee retired Harold Brown, secretary of the Air Force, was selected to succeed him as president. Ruben F. Mettler, later chair of the Board of Trustees, says, "He was honored with the title of president emeritus and served as a lifetime trustee . . . Lee A. DuBridge was a towering figure in Caltech's history and in the world of science and engineering. He was also a kind and compassionate man, with a strong love of family and friends . . . His devotion to Caltech was complete. He often said he thought Caltech was the most wonderful place in the world."[4] On a lighter side, literary historian and faculty member Kent Clark wrote several amusing celebratory musicals; the chorus of his "Lee and Sympathy" has the refrain, "Give me a view from DuBridge; give me a ray along the way that lies before us."

Lee was involved in the formulation of national science policy and the creation of the National Science Foundation. In 1951 President Truman had appointed him a member of his Science Advisory Committee. President Eisenhower made him chairman (until 1958). On retirement from Caltech in 1969 he became science advisor to President Nixon. Lee met with the National Science Board and the Science Advisory Committee and became a member of the President's entourage at embassy parties and the summer White House. This was the time of the Apollo program and lunar landing. Lee led a small group of U.S. scientists on a successful mission to England, France, Belgium, the Netherlands, Romania, and Yugoslavia. But, after conflicts with the administration, and well before Watergate, Lee resigned after eighteen months. Back in Pasadena he spoke little of that period, even to old friends. But he did find the Nixon administration lacking in interest in science and technology because of their "only slight political importance."

Lee continued to serve on many boards (e.g., the Rockefeller Foundation) and the General Motors Science Advisory Committee. He and Doris returned to California and in 1970 bought a home in the retirement community of Leisure World in Laguna Hills, where they could participate in Caltech life. There, Doris was found to have spinal cancer; she died in November 1973 after forty-eight years of happy marriage to Lee. In 1974 Lee married the extraordinarily lively Arrola Bush Cole, widow of a college classmate who had been president of Cornell College for seventeen years.

LATER YEARS

Lee and Arrola lived a quiet life less than half a mile from Caltech's Athenaeum. They were well taken care of by a maid who prepared some meals and a driver who took Lee to the Athenaeum or Arrola to a meeting. Arrola had been on the board of and now became active in the ARCS, an organization that raised money for college scholarships. Many of these were awarded to Caltech students at lunches and elegant dinners, where the recipient squirmed before a formally dressed audience of Los Angeles donors. Because Arrola was so interested in students, two foundations have endowed student scholarships in her honor, a step that gave her the utmost delight.

In 1970 the trustees, led by industrial designer Henry Dreyfuss, raised a million dollars to create the Lee A. DuBridge professorship. Lee's interests remained centered on the discoveries and novelties at Caltech; he kept in touch with his old friends and met and talked with new colleagues. The conversation often took place around a large round table at the Athenaeum, where Lee's chair was kept available. That round table is still active. The conversations concerned both national science politics and local academic problems. Lee's personal contacts with Washington were open and he often had news to bring.

Naturally a conservative and a patriot, Lee was quite open to new ideas. He was especially interested in changes in the budgets of the National Science Foundation and the National Aeronautics and Space Administration. He always wanted to know the results of the latest Jet Propulsion Lab experiment and the progress being made on the DNA code. He would, all too rarely, reminisce about what had happened at the RadLab, on problems of Anglo-American relations, and the background of the Cold War, but he never was the hero of his own stories.

Lee was enormously pleased to receive the Vannevar Bush Award of the National Science Foundation in 1982; the fact that he was old and his work had not been forgotten made it a double pleasure. Lee's career as a scientist had ended long before, but his strengths as an advisor and leader marked him as an outstanding human being and stayed with him until the end.

As they approached ninety Lee and Arrola gave up their home and moved to a retirement community, the Royal Oaks Manor (where we lived). Their apartment was carefully designed to house the mementos of a crowded and successful life: awards, opera tapes, autographed photos of presidents, family photos, the symbols of a full, happy life. Lee had to pick his way through the construction that surrounded them and climb the stairs when the elevator was under repair. But in the public dining room, Lee and Arrola spoke to everyone, told stories of their youth, and of Arrola's years as director of the floating World College and as a counselor living inside the Framingham (Mass.) Correctional Facility for Women. In the short time for such exchanges it became even clearer why Lee A. DuBridge was so respected and revered. He died peacefully of pneumonia in our nursing home in 1994; to be near her children, Arrola moved to the Boston area, where she died later the same year.

IN PREPARING THIS MEMOIR I relied heavily on material in the archives of the California Institute of Technology, to whose staff I am deeply grateful. Central was the forty-two-page autobiographical essay titled "Memories" (labeled "Professional") that terminated in 1969 and the sixty-five-page "Memories (labeled "Personal"). They were dictated in 1979 from memory, apparently without reference to his papers in the archives. Four copies of "Memories" were made for his family and one for the archives.

DuBridge's written record in the fully catalogued archives is very large and well indexed; I have consulted only a few sections. There exist further written autobiographical records from 1954, 1969, and 1978, including data from the National Academy of Sciences, to whose staff I am obligated. He kept a very systematic record, but apparently did not plan to write an autobiography. There is a list of sixty-nine national, professional, and civic activities, part of which are in "Selected Honors and Distinctions" below. The material deserves further study, which I could not do because of my age. I am personally indebted to Caltech professors emeriti John D. Roberts (chemistry) and Robert P. Sharp (geology) for critical readings.

NOTES

1. J. D. Roberts and H. Brown. Lee Alvin DuBridge. *Trans. Am. Philos. Soc.* 140(1996):231-38.

2. I had the honor of retiring from Caltech as the first DuBridge Professor Emeritus. The current appointment is held by the distinguished planetary scientist Peter Goldreich.

3. I should mention one of his personal associates at RadLab, Charles Newton, a former newspaper and radio writer, who headed special publications and photography there. Newton came to Caltech with Lee, supervised Caltech publications, lectured in the humanities, helped raise money, and created the Industrial Associates. He died only a few months after Lee.

4. The Caltech alumni magazine *Engineering and Science* [57(1994):14-

21] contains personal recollections by Joseph B. Platt, William A. Fowler, Harry B. Gray, Ruben F. Mettler, and Thomas E. Everhart.

5. One example is DuBridge's organizational effort on behalf of astronomy. The Owens Valley Radio Observatory (OVRO) epitomizes his style. I had strongly pressed for our own radio observatory. Members of the Mount Wilson and Palomar staff had helped make exciting identifications of a few strange radio sources. We needed both the equipment and a leader. DuBridge knew E. G. (Taffy) Bowen and R. Hanbury Brown, who had brought the first magnetron from Britain to the embryonic RadLab. Taffy was postwar head of the Australian Commonwealth Scientific and Industrial Research Organization (CSIRO), which had an experienced scientific staff, but wanted to build a 210-foot parabolic, steerable radio antenna. But, it would cost $10 million, which they did not have. DuBridge and Bacher discussed our needs with Taffy, who loaned John Bolton, an Englishman and a CSIRO radio astronomer, to us for six years. However, the finite term of the loan was never discussed with me. John came to our department in 1955, and designed and built the OVRO interferometer, which had two 85-foot antennae moveable on long tracks. He built the receivers and delay lines and personally trained the first generation of American radio astronomers, many of whom have since become world leaders. John never warned me. He returned to Australia in 1960 to supervise the construction of the 210-foot parabolic dish. But how was that financed? Half the money was provided by U.S. foundations after Lee assured Alfred Loomis that it was a worthwhile project.

6. There were several less pleasant and less well known interludes. Lee seldom described participation in postwar classified projects, but the Korean War brought us an important one, Project Vista, which Lee headed and which involved much of the senior faculty. Dean Earnest Watson had pressed for Caltech's participation in this study for the military as a public service. The name contains no secret acronyms since the locale was the grounds of an old luxury hotel, Vista del Arroya. Managed by William A. Fowler and Charles C. Lauritsen, some of Vista was concerned with the Korean conflict. My group was devoted to combat intelligence. But there was a highly classified part that studied the use of battlefield tactical nuclear weapons. The Strategic Air Command (SAC) at that time monopolized then scarce nuclear material, which it planned to use for stra-

tegic bombing of large targets. Vista brought together many hundreds of experts from much of the U.S. physical science community. It lasted only from November 1951 to March 1952, cost $600,000, and took 7,800 man days. It ended with three debriefings; I participated in two. J. Robert Oppenheimer and Edward Teller were strong-minded visiting participants and Vista may have been one seed in their later mortal conflict. Perhaps the idea of limited nuclear warfare was premature in 1952. It was certainly resisted by SAC. By July 1952 selective leaks, none of Caltech's doing, brought bitter editorial criticism in *Aviation Week,* alleging that the scientists involved were wrong as well as probably disloyal. A full criticism came from military expert Hanson Baldwin in the *New York Times* of June 5, 1952. Baldwin's article is thoughtful, but echoes the strong sentiment of SAC that it should continue to control both the nuclear explosives and the planes on close-support missions. DuBridge's personal folder about Vista in the Caltech archives is nearly empty. All copies were removed and most were destroyed. The report was not generally distributed to the services. Lee's archive folder contains the final financial report, thank-you letters from a few generals, and a final thank-you letter from Frank Pace, Jr., secretary of defense. What were the actual consequences of Vista? One fact was that battlefield tactical nuclear weapons were manufactured and distributed sometime afterward. Yet among the first agreements between the United States and the Soviet Union, reached after détente, was removal and destruction of the numerous tactical nuclear weapons under local command that had spread over most of the European theater.

SELECTED HONORS AND DISTINCTIONS

1934-46	Professor of physics and chairman, Washington University
1938-42	Dean, Faculty of Arts and Sciences, University of Rochester
1940-45	Director of the Radiation Laboratory, MIT
1942	Member, American Philosophical Society
1943	Member, National Academy of Sciences
1945-49	Scientific Advisory Board, U.S. Air Force
1945-51	Naval Research Advisory Committee, U.S. Navy
1946	King's Medal for Service in the Cause of Freedom

1946-69	President, California Institute of Technology
1946-48	Research Advisory Panel, U.S. Army
1946-68	Board of Trustees, Southwest Museum
1947	President, American Physical Society
1947	Research Corporation Award
1948	United States Medal for Merit
1948-61	Board of Trustees, RAND Corporation
1950-54	Member, National Science Board
1950-51	President, Western College Association
1951-56	Science Advisory Committee, Office of Defense Mobilization (chair, 1952-56)
1951-57	Board of Trustees, Carnegie Endowment for International Peace
1953-61	Board of Trustees, Air Pollution Foundation (chair, 1956)
1956-60	Board of Trustees, Institute for Defense Analyses
1956-67	Board of Trustees, Rockefeller Foundation
1958-64	Member, National Science Board (vice-chair, 1962-64)
1959-63	Board of Governors, Los Angeles Town Hall
1960-68	Board of Trustees, Edison Foundation
1962-68	Chair, Board of Directors, Community Television of Los Angeles (KCET)
1962-68	Board of Trustees, Huntington Library and Art Gallery
1964-68	Board of Directors, National Educational Television
1966-67	President's Task Force on Education
1967	Governor's Award, National Academy of Television Arts and Sciences
1968	Sesquicentennial Award, University of Michigan
1968	President's Air Quality Advisory Board
1969-70	Science Advisor to President Richard M. Nixon
1969	Lehman Award, New York Academy of Sciences
1970	Robert Andrews Millikan Award, California Institute of Technology
1971-75	Science Advisory Committee, General Motors
1973	Golden Plate Award, American Academy of Achievement
1977	Advisory Council, Jet Propulsion Laboratory
1982	Vannevar Bush Award, National Science Foundation

HONORARY DEGREES

1940	Sc.D., Cornell College, Iowa
1946	Sc.D., Polytechnic Institute, Brooklyn
	Sc.D., Wesleyan University, Connecticut
1947	Sc.D., University of British Columbia
1948	Sc.D., Washington University, St. Louis
	LL.D., University of California, Los Angeles
1952	Sc.D., Occidental College, Los Angeles
1953	LL.D., University of Rochester
1955	Sc.D., University of Maryland
1957	Sc.D., Columbia University
	Sc.D., Indiana University
	LL.D., University of Southern California
	Sc.D., University of Wisconsin
1958	L.H.D., University of Redlands
	LL.D., Northwestern University
	L.H.D., University of Judaism, Los Angeles
1961	D.C.L., Union College, Schenectady
1962	Sc.D., Pennsylvania Military College
	Sc.D., DePauw University
1963	LL.D., Loyola University, Los Angeles
1965	Sc.D., Pomona College
	D.Sc., Rockefeller University
	Sc.D., Carnegie Institute of Technology
1967	LL.D., University of Notre Dame
1968	LL.D., Illinois Institute of Technology
1969	Sc.D., Tufts University
	Sc.D., Syracuse University
1970	Sc.D., Rensselaer Polytechnic Institute

SELECTED BIBLIOGRAPHY

1925

Positive rays produced by ultraviolet light. *Phys. Rev.* 25:201-207.

1927

The photoelectric properties of thoroughly outgassed platinum. *Phys. Rev.* 29:451-65.

1928

Thermionic emission from clean platinum. *Phys. Rev.* 32:951-66.

1931

Amplification of small direct currents. *Phys. Rev.* 37:392-400.

1932

Further experimental test of Fowler's theory of photoelectric emission. *Phys. Rev.* 39:108-18.

With A. L. Hughes. *Photoelectric Phenomena.* New York: McGraw-Hill.

1933

Theory of the energy distribution of photoelectrons. *Phys. Rev.* 43:727-41.

1935

New Theories of the Photoelectric Effect. Paris: Hermann et Cie.

1938

With S. W. Barnes, J. H. Buck, and C. V. Strain. Proton-induced radioactivities. *Phys. Rev.* 53:447-53.

1939

Some aspects of the electron theory of solids. *Am. Phys. Teach.* 7:357-66.

1940

With J. Marshall. Radioactive isotopes of Sr, Y and Zr. *Phys. Rev.* 58:7-11.

1946

Science and national policy. *Am. Sci.* 34:226-38.

History and activities of the Radiation Laboratory of the Massachusetts Institute of Technology. *Rev. Sci. Instrum.* 17:1-5.

1949

The effects of World War II on the science of physics. *Am. J. Phys.* 17:273-81.

1953

Academic freedom. *Eng. Sci.* 17:2-4.

1954

The inquiring mind. *Eng. Sci.* 18:11-14.

Goals of research. *J. Eng. Educ.* 45:344-39.

Science serving the nation. *Science* 120:1081-85.

1956

The air pollution problem. *Eng. Sci.* 19:18-21.

Science—Endless adventure. *Eng. Sci.* 20:17-22.

1959

With P. S. Epstein. Robert Andrews Millikan. In *Biographical Memoirs*, vol. 33, pp. 241-82. New York: Columbia University Press for the National Academy of Sciences.

1960

Introduction to Space. New York: Columbia University Press.

1962

The place of space. *Proc. Am. Philos. Soc.* 106:461-66.

1963

Policy and the scientists. *Foreign Affairs* 41:571-88.

1969

Science, a humane enterprise. *Conf. Board Rec.* 6:11-14.