Alvin M. Weinberg

1915–2006

BIOGRAPHICAL *Memoirs*

A Biographical Memoir by
James B. Roberto
and Margaret B. Nestor

NATIONAL ACADEMY OF SCIENCES

ALVIN MARTIN **WEINBERG**

April 20, 1915–October 18, 2006

Elected to the NAS, 1961

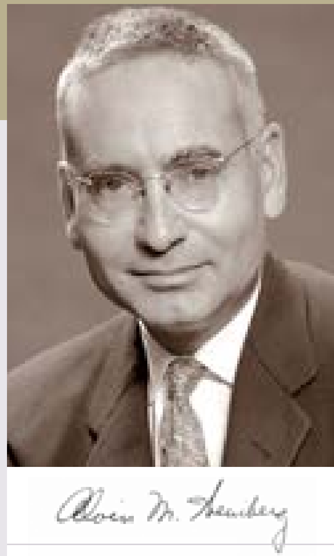

Photo courtesy Oak Ridge National Laboratory.

By James B. Roberto and Margaret B. Nestor

Alvin Martin Weinberg, who possessed a wide-ranging curiosity and an abiding concern for the welfare of humanity, applied these traits to addressing the complex issues that arise at the intersection of science and society. As a pioneer first in the development of nuclear energy and later in a quest to understand the entire energy system, Alvin was a strong proponent of what he called the "technological fix": bringing science and technology to bear on societal problems. Yet he also recognized that many such questions can be asked of science but cannot be answered by science alone. He combined his consideration of these "trans-scientific" questions and his extensive experience as a science administrator to assess the value of scientific inquiry and to establish a set of criteria for scientific choice, especially as it related to "big science"— another of Alvin's coinages that has passed into common use. He spoke and wrote persuasively about these and other issues that engaged his attention, creating a substantial body of work that continues to inform science and energy policymaking.

Alvin began his scientific career at the University of Chicago, where he received a doctorate in mathematical biophysics in 1939. He was drawn into the Manhattan Project in 1941, when one of his professors, Carl Eckart, asked him to help analyze some experiments at the Chicago Metallurgical Laboratory regarding the diffusion of neutrons in beryllium. When Eckart left Chicago in 1942, he was succeeded by Eugene Wigner, under whose direction Alvin worked on reactor design. The two men became lifelong friends, collaborating on the first comprehensive text on nuclear reactor theory, *The Physical Theory of Neutron Chain Reactors*, and Alvin would later edit Wigner's collected works on nuclear energy.

By the end of 1942, Wigner's group had completed the design of a water-cooled and graphite-moderated 500-megawatt reactor that could produce 500 grams of plutonium per day. This design—project reports document Alvin's contributions in resonance escape probability and thermal utilization—was the basis for the massive production reactors constructed at Hanford, Washington. A method for determining fast-neutron collision rates, which helped evaluate the contribution of fast fission to neutron multiplication in reactor design, came to be known as "Weinberg's method" and was used to assess collision probabilities for a uniform fuel lump in spherical, slab, and cylindrical geometries.

Alvin was also assigned responsibility for the nuclear design of the world's first continuously operated reactor, the air-cooled and graphite-moderated X-10 pile. Later called the Oak Ridge Graphite Reactor, the X-10 pile was constructed in 1943 at Clinton Laboratories—the Metallurgical Laboratory's outpost in Tennessee—to provide a pilot-scale demonstration of plutonium production and separation. Alvin paid several visits to the X-10 site in 1943 and 1944, both before and after the pile went critical, and was particularly interested in experiments conducted there by Arthur Snell to test Alvin's predictions of the performance of chain reactors moderated and cooled with ordinary water. These experiments prompted Alvin to write, in September 1944, a note to Richard L. Doan, the research director at Clinton Laboratories, mentioning pressurized water as a possible coolant and moderator for a nuclear power reactor. A subsequent analysis with Forrest Murray, completed in 1946, provided the foundation for the pressurized water reactors adopted first by the U.S. Navy for submarine propulsion and later by the nuclear power industry.

By mid-1944, with the production reactors at Hanford under construction, the focus of the Chicago Metallurgical Laboratory shifted to new activities. The laboratory now addressed three main issues: new pile designs, including breeder reactors; the future of the new field of "nucleonics," which combined nuclear physics, engineering, chemistry, materials science, and other disciplines; and the fate of the facilities established to support the Manhattan Project. Wigner, who had taken a liking to Clinton Laboratories, sketched out ideas for expanding its pilot-scale facilities into a full-fledged nuclear research laboratory, and he persuaded Alvin and several other members of his Chicago theoretical group to join him in launching this enterprise.

Alvin moved to Tennessee in May 1945, shortly before the University of Chicago turned over responsibility for the laboratory's operation to the Monsanto Chemical Co. Wigner became research director during the summer of 1946 but returned to his academic post at Princeton University in autumn 1947.

Alvin would later characterize Wigner's year as director as one of intense activity and expansion, with the newly designated Clinton National Laboratory building new programs in metallurgy and biology, leading a broad effort in reactor development, and establishing a reactor technology training school. Among the students at the school was Navy captain Hyman Rickover, with whom Alvin would form a congenial and productive relationship. Another important event was the 1946 incorporation of the Oak Ridge Institute for Nuclear Studies (ORINS), a consortium of southern universities formed with the goal of connecting faculty and students throughout the region to the scientific resources that had come to Tennessee as part of the Manhattan Project.

Administratively, however, this was a period of extreme uncertainty that culminated in what came to be known as "Black Christmas." In June 1947, the General Advisory Committee of the new U.S. Atomic Energy Commission (AEC) had advised against the construction of a high-flux reactor at Clinton. Monsanto stated that it did not want to hold the contract unless a new reactor was built, so the AEC decided to allow Monsanto's contract to expire. A September announcement that the University of Chicago would resume its management of Clinton proved premature, as contract negotiations stalled and the university was unable to recruit a replacement for Wigner. In December 1947, the AEC's first director of research, James Fisk, came to Clinton to communicate two major decisions: The Commission would contract with the Carbon and Carbide Chemicals Corporation (later Union Carbide) to operate Clinton, and AEC work on reactor technology—including the development of a high-flux reactor—would be consolidated at Argonne National Laboratory, successor to the Chicago Metallurgical Laboratory.

The consternation aroused by this announcement is recorded not only in Alvin's memoir but also in the official history of the AEC.[1] Many of the scientists at Clinton were uncomfortable with the idea of an industrial contractor, and others were unhappy with the decision to transfer the high-flux reactor to Argonne. The AEC responded that it planned for Clinton to maintain basic research programs in biology, physics, chemistry, and health physics; continue use of the graphite reactor as a research tool for isotope research, production, and distribution; and expand programs in chemical engineering and chemical process development.

Alvin, who by this time had succeeded Lothar Nordheim as director of the laboratory's Physics Division, took a much more sanguine view of the situation. He liked the newly created town of Oak Ridge, had a favorable opinion of Union Carbide, and did not believe that the AEC's decision to concentrate all reactor development work at Argonne could be carried out. Years later, his friend and colleague Ellison Taylor would recall Alvin's calming influence "when the rest of us would have walked out on Jim Fisk."[2]

Although Alvin's instincts proved correct, this episode left him with an enduring anxiety about the mission and purpose of the laboratory, renamed Oak Ridge National Laboratory (ORNL) early in 1948. This concern is apparent in his August 1948 proposal to the AEC to construct a moderate-flux reactor at ORNL for general research and isotope production; Alvin stated that such a reactor "would provide needed focus and integration for the laboratory." On joining the new Union Carbide management team as ORNL's associate director for research and development in December 1948, Alvin announced his plan to establish a seminar series to increase the laboratory's cohesion. "If we persevere and if we have fortitude," he said, "Oak Ridge National Laboratory will fulfill its promise as a successful laboratory, a national institution, and a happy place in which to work."

Alvin himself would persevere at ORNL for the next quarter-century, serving as research director until 1955 and as laboratory director from 1955 until 1973.

While ORNL flourished throughout his tenure, Alvin remained, in his own words, "preoccupied with the laboratory's survival and therefore with defining the purpose of the laboratory." These preoccupations would eventually lead him into three closely related endeavors, in each of which he distinguished himself: scientific administration, public policy, and nuclear advocacy.

As a scientific administrator at ORNL, Alvin presided over an enterprise that grew from about 1,500 employees at war's end to more than 5,000 in 1967. Freeman Dyson, a regular visitor to Oak Ridge in the 1970s, attributed much of this growth to Alvin's leadership, writing: "When he took charge of the laboratory after World War II, it was little more than a bomb factory. He converted it into a many-sided scientific center, doing world-class research in biology and medicine as well as in physics and engineering."[3] Similarly, Floyd Culler, who joined ORNL in 1947 and served as its deputy director from 1970 until 1977, with a stint as acting director in 1973–1974, described Alvin as "the architect of ORNL's disciplinary and programmatic structure, the creator of its style."[4]

The question of survival and purpose was evidently on Alvin's mind in 1951 when he said, in his annual "state of the laboratory" address,

> *It is our duty to try to establish for ORNL some notion of what our business is and to retain sufficient flexibility of operation that we can change our course as our current objectives become obsolete or our current modes of operation become untenable."*

In his 1955 talk on "Future Aims of Large-Scale Research," at the Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy, he pointed out that the problems that the national laboratories were established to solve were not unlimited in scope and he urged consideration of what "these edifices of Big Science" would do when they had accomplished their missions in nuclear power. Among his prescient suggestions were geologic engineering (which he described as "large-scale tampering with the earth's environment to cope with our spectacular population growth"), climate change, pollution, and energy.

The passage of the Atomic Energy Act of 1954, which was designed to encourage the commercialization of nuclear power, no doubt contributed to Alvin's sense that ORNL (and the other national labs) needed to broaden their missions to reflect emerging national needs and priorities. But this would be a challenge to accomplish. While ORNL's portfolio in 1955 included projects ranging from basic research in physics, chemistry, and biology to reactor technology, metallurgy, particle accelerators, isotope production, isotope properties, and health protection, almost two-thirds of its $32.7 million budget came from the AEC's Reactor Development Division, which increasingly favored concepts other than those being studied at ORNL.

The AEC acknowledged in 1960 "that the strong capabilities of the laboratories are not the exclusive resources of the atomic energy field; they are held in trust for the nation as a whole."[5] Viewing this as an opportunity to broaden ORNL's portfolio, Alvin organized a series of advanced technology seminars "to identify long-range, valid missions which in scope and importance are suitable for prosecution by ORNL."[6]

Consequently, ORNL secured new assignments in desalination, large-scale biology, civil defense, and environmental research, becoming one of the first national laboratories to build a substantial portfolio of non-AEC assignments.[7] None of them led to the sort of long-range program that Alvin envisioned, but the skills and flexibility acquired through this diversification would prove to be valuable assets during the early 1970s, when nuclear power fell into disfavor and environmental issues came to the fore, dramatically changing the research milieu.

Under his leadership, a dozen reactors were designed, constructed, and operated at Oak Ridge.

During Alvin's tenure as director, however, ORNL remained primarily a nuclear research and development laboratory. Under his leadership, a dozen reactors were designed, constructed, and operated at Oak Ridge. One was the Homogeneous Reactor Experiment, which built on a concept for a breeder reactor described by Alvin, Eugene Wigner, and Gale Young in 1945. This exploration of liquid fuel reactors, first with aqueous solutions and later with molten salts, would occupy ORNL researchers until the early 1970s, when the AEC finally canceled the program. Today the liquid fuel reactor concept is enjoying a global renaissance, with research and development efforts launched by the governments of China, India, and the Czech Republic and by several start-up companies in the United States. The Weinberg Foundation, a nonprofit organization established in 2011, is named in honor of Alvin, who is described on the group's website as "the nuclear scientist who pioneered peaceful nuclear technology and designed the breakthrough Molten Salt Reactor."[8]

The last of the ORNL reactors to be constructed was the High Flux Isotope Reactor, which began operation in 1965. Its primary purpose, as its name implies, was the production of isotopes, but at Alvin's insistence it was equipped with four horizontal beam ports to support neutron-scattering research. Almost half a century later, this reactor continues to provide the nation with forefront capabilities for both missions. It produces most of the world's californium-252 and delivers neutrons to a dozen instruments for research in physics, materials science and engineering, chemistry, and biosciences.

In the latter part of his tenure as director of ORNL, Alvin's long-term interests in science policy and administration led him to begin "moonlighting" as a science policy analyst. His contacts in government and the science community had led to an appointment to the President's Science Advisory Committee (PSAC) and to the chairmanship of PSAC's Panel on Science Information. The report of this panel, published in January 1963, stimulated the creation of a number of specialized information analysis centers, including two that continue to operate at ORNL: the Carbon Dioxide Information Analysis Center and the Radiation Safety Information Computational Center.

Serving on PSAC and other high-level committees led Alvin to explore what he called "the relation between modern society and modern science," including the question of how to allocate resources among competing fields of science. The criteria for scientific choice that he developed to help answer this question, published in the journal Minerva and collected in his 1967 book, *Reflections on Big Science*, stimulated a vigorous debate. Alvin later noted that these criteria had earned him "the wrath of those high energy physicists and behavioral scientists who believe I undervalue their fields,"[9] but they continue to be cited, analyzed, and applied to decision-making.[10]

Throughout his career Alvin was a tireless promoter of the expansion of nuclear energy as a means of averting what he called "Malthusian disaster." He recognized that "we nuclear people have made a Faustian bargain," with nuclear energy placing exceptional demands on society, and he was an ardent proponent of action to meet those demands. He would recall that Fermi had raised concerns about the acceptability of nuclear power during the early days in Chicago, and his own concerns about nuclear safety increasingly brought him into conflict with the AEC and with Congressman Chet Holifield, the chairman of the powerful Joint Committee on Atomic Energy.

Late in 1972, Alvin was informed that he would be replaced as head of the laboratory he had led for a quarter-century. His departure was formally announced in December 1973, when he accepted an appointment as director of the Office of Energy Research and Development in the Nixon Administration's Federal Energy Office, which shortly thereafter became the Federal Energy Administration. During his year in Washington, Alvin proposed the creation of a Solar Energy Research Institute; the proposal was accepted, and the resulting institute, launched in 1977, is now the National Renewable Energy Laboratory based in Golden, Colorado.

Earlier in 1973, while he was officially on leave from ORNL, Alvin had devoted a portion of his time to developing a prospectus for an "energy think tank." He attributed the idea for this Institute for Energy Analysis (IEA) to William O. Baker, vice president for research at Bell Laboratories and a fellow PSAC member, and he enlisted the help of an old friend and colleague, H. G. MacPherson, in preparing the prospectus. With support from the AEC and subsequently from the Energy Research and Development Administration (which replaced the AEC), the new institute was established as a division of Oak Ridge Associated Universities (ORAU, the successor to the Oak Ridge Institute for Nuclear Studies) in 1974. MacPherson, a graduate of the original Clinton Training School, served as IEA's director for its first year.

At IEA, Alvin assembled a diverse team of experts to examine a wide range of energy issues. Many were former colleagues from ORNL, but Alvin also succeeded in attracting a number of economists, engineers, physicists, and political and social scientists from other institutions. Issues tackled by this multidisciplinary team included the greenhouse effect, alternative energy sources, the safety of nuclear reactors, and strategic defense and arms control.

For several years, IEA was the nation's leading center for studies of the effects of carbon dioxide. One notable product was a computer model, first released in 1984, for assessing the influence of economic, technological, demographic, and geological factors on the longterm production, consumption, and trade of energy on a global scale; the model included a module for computing carbon dioxide emissions as a function of fossil fuel use. Alvin would later compare the risks of carbon dioxide from coal combustion to those of nuclear proliferation, recognizing that both are global problems with uncertain impacts that could pose profound challenges to the future of humanity.

Alvin stepped down as IEA director in 1985, remaining at ORAU as a distinguished fellow. In that capacity he continued to explore the future of nuclear energy and to consider the issues surrounding nuclear weapons, with an emphasis on the dangers of nuclear proliferation and the need for arms control. He also campaigned for recognition of Eugene Wigner as the first nuclear engineer and proposed a longevity criterion for nuclear reactors. And he launched a successful effort to bring a bronze friendship bell to Oak Ridge from Japan, part of a campaign for what he called "the sanctification of Hiroshima."

Alvin received an extraordinary number of honors throughout his career, from the U.S. Jaycees' "Ten Outstanding Young Men of 1950" to a collection of more than two dozen honorary academic degrees. He was elected both to the National Academy of Sciences (1961) and the National Academy of Engineering (1975) and was a member of the American Academy of Arts and Sciences, a member of the American Philosophical Society, and a foreign member of the Royal Netherlands Academy of Sciences. Alvin received the Atoms for Peace Award in 1960 and the Department of Energy's Enrico Fermi Award in 1980, the latter for

> *his pioneering contributions to reactor theory, design, and systems; for untiring work to make nuclear energy serve the public good, both safely and economically; for inspiring leadership of the Oak Ridge National Laboratory; and for wise counsel to the executive and legislative branches of the government.*

A founding member of the American Nuclear Society, he was the first recipient, in 1995, of that group's Alvin M. Weinberg award "in recognition of outstanding international technical and policy leadership in nuclear science and technology, and for consistently and effectively illuminating the human dimensions of the nuclear enterprise."

Despite these honors, Alvin was somewhat bemused by the high regard in which he was held, particularly in his adopted hometown of Oak Ridge. He was a frequent and welcome visitor at ORNL, which established a lecture series in his honor when he turned 80. On his way to one of these lectures, he was heard to remark, "I have to go out to the laboratory and be an icon."

At these lectures, iconic status notwithstanding, Alvin continued a practice that had begun when he was ORNL's director—sitting in the front row and asking tough questions. The prospect of these questions was unnerving to many speakers, but they always arose from Alvin's genuine interest in the topic.

When Alvin died in 2006, at the age of 91, he left a remarkable legacy. As Eugene Wigner said in 1966, one of Alvin's characteristics was "his willingness, even eagerness, to accommodate the needs of the day. He changed from physicist to biophysicist, from biophysicist to reactor theorist and reactor engineer, from reactor engineer to appraiser and supporter of a broad spectrum of scientific endeavors. From this, he changed to a philosopher of scientific endeavor."[11] In each of these fields, Alvin made valuable and enduring contributions.

NOTES

1. Hewlett, R. G., and F. Duncan. 1972. Atomic Shield: 1947–1952. Volume II of *A History of the United States Atomic Energy Commission.* pp. 124-126. Washington, DC: U.S. Atomic Energy Commission.
2. Taylor, E. 1974. Words for Alvin Weinberg. *ORNL Review* 7(2):18.
3. Dyson, F. 1996. *Selected papers of Freeman Dyson: With Commentary*. Providence, RI: American Mathematical Society, 44.
4. Culler, F. L. 1974. State of the laboratory—1973: Time of Transition. *ORNL Review* 7(1):2.
5. U.S. Congress. Joint Committee on Atomic Energy. 1960. *The future role of the Atomic Energy Commission laboratories, Volume 1.* Washington, DC: U.S. Government Printing Office, 33.
6. Johnson, L., and D. Schaffer. 1994. *Oak Ridge National Laboratory: The first fifty years.* pp. 106. Knoxville, TN: University of Tennessee Press.
7. Teich, A. H., and W. H. Lambright. 1977. The redirection of a large national laboratory. *Minerva* 14(4):447–474.
8. *http://www.the-weinberg-foundation.org/people/*, accessed on January 18, 2014.
9. Weinberg, A. M. 1970. The axiology of science: The urgent question of scientific priorities has helped to promote a growing concern with value in science. *American Scientist* 58(6):616.
10. See, e.g., Hellström, T., and Jacob, M. 2012. Revisiting "Weinberg's choice": Classic tensions in the concept of scientific merit. *Minerva* 50(3):381.
11. Wigner, E. P. Introducing the 1966 Alfred Korzybski Memorial Lecturer. Online at *http://www.generalsemantics.org/wp-content/uploads/2011/04/gsb-34-weinberg.pdf,* accessed on January 18, 2014.

SELECTED BIBLIOGRAPHY

1942 With G. J. Young, R. F. Christy, G. N. Plass, E. P. Wigner, and R. Williamson. *On a plant with water cooling.* Report CE-197. Chicago Metallurgical Laboratory.

1943 With M. G. J. Boissevain, M. C. Leverett, L. A. Ohlinger, E. P. Wigner, and G. J. Young. *Preliminary process design of liquid-cooled power plant producing 5 × 10^5 kW.* Report CE-407. Chicago Metallurgical Laboratory.

1945 With E. P. Wigner and G. J. Young. *Preliminary calculations on a breeder with circulating uranium.* Memorandum MUC-EPW-134. Chicago Metallurgical Laboratory.

1946 With F. Murray. *High-pressure water as a heat-transfer medium in nuclear power plants.* Report MonP-93. Clinton Laboratories.

1948 *Research pile at Oak Ridge National Laboratory.* Central Files Number 48-8-212. Oak Ridge National Laboratory.

1949 A history of Oak Ridge National Laboratory. *Science* 109:245–248.

1955 Future aims of large-scale research. *Chem. Eng. News* 33:2188–2191.

1958 With E. P. Wigner. *The physical theory of nuclear chain reactors.* Chicago: University of Chicago Press.

1961 Impact of large-scale science. *Science* 134:161–164.

1962 The federal laboratories and science education. *Science* 136:27–30.

1963 Criteria for Scientific Choice. *Minerva* 1:159–171.

Science, government, and information: The responsibilities of the technical community and the government in the transfer of information. A report of the President's Science Advisory Committee. Washington, DC: U.S. Government Printing Office.

1964 Criteria for scientific choice II: The two cultures. *Minerva* 3:3–14.

1967 *Reflections on big science.* Cambridge, MA: MIT Press.

1970 The axiology of science: The urgent question of scientific priorities has helped to promote a growing concern with value in science. *American Scientist* 58:612–617.

1971 Social institutions and nuclear energy. *Science* 177:27–34.

1974 Global effects of man's production of energy. *Science* 186:205–205.

1977 *Can the sun replace uranium?* Report ORAU/IEA(M)-77-21. Oak Ridge Associated Universities.

With G. H. Marland. *Some long-range speculations about coal.* Report ORAU/IEA(O)-77-22. Oak Ridge Associated Universities.

1979 Can we fix nuclear energy? *Annals of Nuclear Energy* 6:473–482.

Salvaging the atomic age. *Wilson Quarterly (Summer)*: 88–112.

1984 With J. N. Barkenbus. Stabilizing Star Wars. *Foreign Policy* 54 (Spring):164–170.

1985 *Continuing the nuclear dialogue: Selected essays.* La Grange Park, IL: American Nuclear Society.

The sanctification of Hiroshima. *Bull. Atomic Sci.* 41 (December):34.

With I. Spiewak, J. N. Barkenbus, R. S. Livingston, and D. L. Phung. *The second nuclear era: A new start for nuclear power.* New York, NY: Praeger.

1992 With A. M. Perry. Nuclear energy. Vol. 5 of *The collected works of Eugene P. Wigner, Part A: The scientific papers*. Edited by Arthur Wightman. Berlin, Germany: Springer-Verlag.

Nuclear reactions: Science and trans-science. New York, NY: AIP Press.

1994 From technological fixer to think-tanker. *Annu. Rev. Energy Environ.* 19:15–36.

The first nuclear era: The life and times of a technological fixer. New York, NY: AIP Press.

1997 The bell and the bomb. *Cosmos J.* Online at *www.cosmosclub.org/web/journals/1997/wein.html*, accessed on January 17, 2014.

1999 Scientific millenarianism. *Proc. Am. Philos. Soc.* 143:531–539.

2003 New life for nuclear power. *Issues Sci. Technol.* 19 (Summer):60–61. Online at *www.issues.org/19.4/weinberg.html*, accessed on January 17, 2014.

2004 On "immortal" nuclear power plants. *Technol. Soc.* 26:447–453.

2007 With D. Spreng and G. Marland. CO_2 capture and storage: Another Faustian bargain? *Energy Policy* 35:850–854.