NATIONAL ACADEMY OF SCIENCES

VANNEVAR BUSH

1890—1974

A Biographical Memoir by

JEROME B. WIESNER

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Vannevar Bush

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March 11, 1890–June 28, 1974

BY JEROME B. WIESNER

NO AMERICAN has had greater influence in the growth of science and technology than Vannevar Bush, and the twentieth century may yet not produce his equal. He was an ingenious engineer and an imaginative educator, but above all he was a statesman of integrity and creative ability. He organized and led history's greatest research program during World War II and, with a profound understanding of implications for the future, charted the course of national policy during the years that followed.

The grandson of two sea captains, "Van" Bush manifested his Cape Cod heritage in a salty, independent, forthright personality. He was a man of strong opinions, which he expressed and applied with vigor, yet he stood in awe of the mysteries of nature, had a warm tolerance for human frailty, and was open-minded to change and to new solutions to problems. He was pragmatic, yet had the imagination and sensitivity of a poet, and was steadily optimistic. These essential qualities speak clearly in the foreword which he wrote in January 1970 for his book of reminiscences, *Pieces of the Action*:

> In my time, it has been my good fortune to have a piece of the action here and there in varied circumstances. It has been a pleasant experience for me to review some of the more rugged of these, and some of the more serene.
>
> Do birds sing for the joy of singing? I believe they do. The complexity of their songs is far greater than is needed for recognition or for marking

of reserved areas. I have become acquainted with a catbird who obviously derives pleasure as he tries out little phrases on his own. Moreover, I believe that evolution produced birdsongs, and the joy that goes with them, because of the survival value they bestow.

He who struggles with joy in his heart struggles the more keenly because of that joy. Gloom dulls, and blunts the attack. We are not the first to face problems, and as we face them we can hold our heads high. In such spirit was this book written.*

Van Bush gave the most comprehensive view of himself in *Pieces of the Action.* Characteristically, he despised pomposity and rather than write a formal autobiography he organized his recollections in a way that would illuminate certain historical episodes and amplify some of his views of life. Written in a direct, down-to-earth manner, the book tells a great deal about the rugged, indomitable spirit of its author.

Bush's father, the Reverend Richard Perry Bush, was also a nonconformist in style and conviction. He started his career as cook on a mackerel smack at Provincetown, Massachusetts at the age of fourteen and worked his way through Tufts College by delivering coal to students' rooms. Although of a Methodist family, he became a minister in the Universalist Church and was a pastor in Everett, Massachusetts when his son was born on March 11, 1890. Story has it that the boy was named for the Reverend John Van Nevar, a colleague of the Reverend Mr. Bush. Between Vannevar Bush and his father there was a strong bond of affection, cemented by a good-humored appreciation in each one for the personality and idiosyncracies of the other. Both were members of the Masonic order, both were good outdoorsmen, and both were wide-ranging in their interests.

As a boy, Vannevar Bush loved to tinker. When his father became a pastor in Chelsea, where Vannevar attended high school, he had a versatile shop at home. After high school he moved on to Tufts College, where he received B.S. and M.S.

* Vannevar Bush, *Pieces of the Action* (New York: William Morrow, 1970), p. ix.

degrees in 1913. Also, while still in college, he secured a patent—the first of many—for a surveying machine, which he built with two bicycle wheels and a device using a pendulum, for integrating and recording horizontal and vertical measurements.

After graduating from Tufts, Bush worked for a time in the test department of the General Electric Company at Schenectady, New York, and then as an inspector for the U.S. Navy. He returned to Tufts in 1914 as an instructor in mathematics. He had higher goals, however, and one of them was to marry Phoebe Davis, a Chelsea girl. Having saved enough money for one more year of study, he proposed to earn a doctorate at the Massachusetts Institute of Technology in that one year so that he could qualify for a better job and afford to get married. There was academic skepticism that he could accomplish this, and he was warned that he would wreck his health; but in 1916, at the end of a year, he had earned a Doctor of Engineering, a degree at that time given jointly by MIT and Harvard University. His health was never better, a troublesome case of rheumatism having disappeared for good. That fall he and Miss Davis were married, and he became an assistant professor of electrical engineering at Tufts. His first technical paper, "Oscillating-Current Circuits by the Method of Generalized Angular Velocities," based on his doctoral thesis, was presented before the American Institute of Electrical Engineers in 1917.

At about that time, Bush became a consultant to American Research and Development Corporation (AMRAD), a small company with quarters on the Tufts campus which, with the backing of J. P. Morgan, was pioneering in the development of radio devices. When the United States entered World War I, Bush went to New London, Connecticut to engage in antisubmarine research for AMRAD. He developed a magnetic device for the detection of submarines, but because of faulty administrative coordination it was never used effectively—a circumstance that he would remember when he took charge of U.S. research during World War II. "That experience," he wrote later, "forced into my mind pretty solidly the complete lack of proper liaison between the military and the civilian in the development of weapons in time of war, and what that lack meant."* He did not serve in the Navy during World War I, but he was a lieutenant commander in the Naval Researve from 1924 to 1932.

In 1919, Bush joined the MIT faculty as associate professor of power transmission. He was placed in charge of the introductory course in electrical engineering and in 1922, with his colleague William H. Timbie, published a textbook, *Principles of Electrical Engineering*. Meanwhile, he had been made director of graduate study and of the Research Division of the Department of Electrical Engineering.

Bush not only continued to serve as a consultant to AMRAD, but was also largely responsible for its progress, despite numerous vicissitudes, toward success. He enlisted Laurence K. Marshall, who had been his roommate at Tufts, to provide business leadership. A new company, eventually named Metals and Controls Corporation, was formed to manufacture a thermostat invented by John A. Spencer, a staff member. Thermionic tubes for the booming radio industry were developed by another company, which took the name of Raytheon Manufacturing Company in 1925 and became a corporate giant. One of the tubes, the S tube, a gaseous rectifier, enabled the owner of a radio set to plug it into the household circuit rather than use what was known as a B battery. The tube was the subject of papers presented before the Institute of Radio Engineers and the American Institute of Electrical Engineers by the inventor, C. G. Smith, and Bush.

At MIT, Bush's interests turned toward computers. A former student, David O. Woodbury, recalls that in 1922 he was working on a master's thesis, assigned by Bush, dealing with three-

* *Pieces of the Action*, p. 74.

phase transients in alternating current motors. The research required onerous slide-rule computation, and Woodbury devised a small machine to do the work. One day Bush saw Woodbury using the machine and asked what it was. When Woodbury explained, the professor said, "Dave, give up all that slip-stick work and write us a thesis on your invention." Woodbury did, and sold the machine to General Electric Company.

The increasing complexity of power transmission networks stimulated further development in methods of analysis. Another of Bush's graduate students, Herbert R. Stewart, based a thesis on the Product Integraph, stating: "It was Dr. Bush's suggestion early in 1925 that a mechanical device should be developed to perform the continuous integration, which was the beginning of a continually expanding program of general solution of transients in networks by electromechanical means" (*A New Recording Product Integraph and Multiplier,* S.M. thesis, 1926).

The Product Integraph was the first in a series of analog computers which, though not direct ancestors of today's digital computers, led in the opening of the modern field of computation. In addition to Stewart, those closely associated with Bush in this development included Frank D. Gage, Harold L. Hazen, King E. Gould, and Samuel H. Caldwell. An advanced machine, called the Differential Analyzer, was completed in 1931 and was so successful that it was the model for the construction of similar machines elsewhere. It could solve sixth-order differential equations or three simultaneous second-order differential equations. Another complex device developed at that time by Harold Hazen and Hugh H. Spencer with Bush's leadership was the Network Analyzer, used in the simulation of power systems.

Preparation of the Differential Analyzer for solving a problem was a cumbersome process. Planning for a more versatile machine, which could be controlled by punched tape, was begun in 1935. Known as the Rockefeller Differential Analyzer because it was funded in part by the Rockefeller Foundation, it had 2,000 electronic tubes, 200 miles of wire, 150 motors, and weighed 100 tons. It was demonstrated for the first time in 1941 and throughout World War II was operated on a three-shift basis in the computation of Navy range tables and studies of fire-control systems, radar antennas, and other critical subjects.

Bush was by no means satisfied with the Differential Analyzer. As early as 1937 he wrote memoranda on the possibility of achieving greater speed with an electronic calculator—the Rapid Arithmetical Machine, as he called it. Preliminary studies of its feasibility and, in fact, of tubes and circuits that might be used were conducted, but investigators were diverted by war research demands, and it was not until the early 1950s that MIT began operating Whirlwind I, a high-speed, high-capacity, highly reliable digital computer.

Although Bush maintained a lively interest in such machines, his career had taken a new direction. He had strong views on education. For example, in "Critical Analysis of the Examination System of American Engineering Schools," he wrote:

> The student is hounded. In four years the student has to take some forty or fifty independently taught subjects in which he is examined formally a total of perhaps a hundred times, and informally several hundred times. . . . All but exceptional students become automatons. . . . Our examinations are poor. . . . Student memories are being taxed with data which any reasonable practicing engineer would keep in notes or a handbook.*

Dr. Karl T. Compton had become president of MIT in 1930, and as part of his program to strengthen the Institute, he reorganized it as three schools and appointed Bush vice president of the Institute and dean of the School of Engineering. In the latter position, Bush became virtually the operating executive. His national reputation was growing, and in 1934 he was

* Vannevar Bush, *Journal of Engineering Education,* 23, no. 5 (January 1933): 322–36.

elected to the National Academy of Sciences. The following year he served on the Committee on the Relation of the Patent System to the Stimulation of New Industries, organized by the Science Advisory Board of the National Research Council.

In 1938 Bush was invited to become president of the Carnegie Institution of Washington. President Compton was so loath to lose him that he suggested an arrangement by which he, Compton, would become chairman of the corporation and Bush would become president of MIT. Bush accepted the Carnegie invitation, however, and shortly afterward was also appointed chairman of the National Advisory Committee for Aeronautics (NACA). As he later put it, he soon "learned quite a bit of the mysterious ways in which one operates in the Washington maze." *

After World War II broke out in Europe in 1939, Bush and others became increasingly concerned by the lack of technological preparedness in the United States. He; James B. Conant, president of Harvard University, and Frank B. Jewett, president of the National Academy of Sciences and president of Bell Telephone Laboratories, were members of the Committee on Scientific Aids to Learning, formed by the National Research Council in 1937, and thus had occasion to meet together and discuss the subject. President Compton of MIT and Richard C. Tolman, dean of the Graduate School at the California Institute of Technology, also joined in these discussions. Irvin Stewart, who was secretary of the Committee on Scientific Aids to Learning, was likewise involved.

Out of the discussions came a plan for the establishment of the National Defense Research Committee (NDRC), which Bush described in four short paragraphs and submitted to President Roosevelt. At the end of ten minutes he had an "OK–FDR," and an order creating NDRC was issued on June 27, 1940, providing

* *Pieces of the Action*, p. 34.

nearly a year and a half of lead time before the United States entered the war. Bush commented thirty years later:

> There were those who protested that the action of setting up NDRC was an end run, a grab by which a small company of scientists and engineers, acting outside established channels, got hold of the authority and money for the program of developing new weapons. That, in fact, is exactly what it was. Moreover, it was the only way in which a broad program could be launched rapidly and on an adequate scale. To operate through established channels would have involved delays—and the hazard that independence might have been lost, that independence which was the central feature of the organization's success.*

Bush was appointed chairman, and other members of the committee, in addition to Compton, Conant, Jewett, and Tolman, were Conway P. Coe, Commissioner of Patents; Rear Adm. Harold G. Bowen, representing the Navy; and Brig. Gen. George V. Strong, representing the Army. Stewart became the executive secretary.

The organization was elaborated in 1942, when the Office of Scientific Research and Development (OSRD) was established, with Bush as its director. OSRD had three principal subdivisions at that time: the NDRC, with Conant as chairman; the Committee on Medical Research (CMR), with A. Newton Richards as chairman; and the Advisory Council, with Bush as chairman. The latter, which included the chairmen of NACA, NDRC, and CMR, as well as Army and Navy representatives, served as a coordinating group. In addition, Bush was chairman of the Joint New Weapons Committee of the Joint Chiefs of Staff and, when the Manhattan District was created, chairman of its Military Policy Committee, which functioned as its board of directors.

Although a certain organizational complexity was inevitable in so large a program, OSRD and NDRC operations were simplified

* *Pieces of the Action,* pp. 31–32.

by the fact that Van Bush was unquestionably the boss. He had the full confidence of the President and Congress. He was decisive and could be tough. "I remember one time when a section walked into my office and resigned as a body," he wrote. "I still do not know quite what the row was about. So I just told them, 'One does not resign in time of war. You chaps get the hell out of here and get back to work, and I'll look into it.' " * His wisdom and integrity were respected.

The organization was a remarkable invention, but the most significant innovation was the plan by which, instead of building large government laboratories, contracts were made with universities and industrial laboratories for research appropriate to their capabilities. OSRD responded to requests from military agencies for work on specific problems, but it maintained its independence and in many cases pursued research objectives about which military leaders were skeptical. Military tradition was that a war had to be fought with weapons that existed at its beginning. Bush believed that World War II could be won only through advances in technology, and he proved to be correct. In some instances, the armed forces were enthusiastically cooperative. In others, resistance to innovation had to be overcome. Bush, himself, went to Europe to make sure that the proximity fuse was introduced to the battlefield and used effectively.

The major exception to the policy of avoiding the building of government laboratories was in the development of the atomic bomb. After preliminary studies by NDRC and OSRD, it became clear that a colossal program would be needed, and Bush recommended to Secretary Stimson that the Army take over the responsibility. The result was the formation of Manhattan Engineering District by the Corps of Engineers. Bush,

* *Pieces of the Action*, p. 41.

with Conant as his deputy, maintained an active scrutiny of the enterprise.

Bush successfully confronted Sir Winston Churchill (and earned his wrath) in London in an argument over the terms of exchanging atomic information. He had the duty, after the death of President Roosevelt, of giving President Truman his first detailed account of the bomb. He was among those whose recommendations prevailed when the President decided—in spite of some objections—that the Smyth Report on atomic energy should be released. He urged the appointment of the Interim Committee to advise the President on use of the bomb and on postwar atomic energy, and he was then appointed a member of the committee. He was a participant in the "Atlee Conference" and prepared the final draft of an agreement with the British proposing control of atomic energy by the United Nations. He was a defender of Dr. J. Robert Oppenheimer. After the Atomic Energy Commission's (AEC) decision that Oppenheimer's clearance be cancelled, he stated: "It does not affect my complete confidence in Dr. Oppenheimer's loyalty and deep devotion to the security of the United States. . . . Our internal security system has run wild." *

Bush did not have a central role in the formation of the AEC, but his voice was heard on this and other issues, such as military unification. He was influential in developing a policy of maintaining a high level of research for the military services and was instrumental in organizing the Office of Naval Research. But his greatest contribution was to launch an unprecedented national program in science and technology.

Long before the war was over, Bush began to devote thought to how the momentum of research could be sustained, with new peacetime goals. In a letter, President Roosevelt asked him to make recommendations on government policies for combating

* *Newsweek,* July 12, 1954, pp. 24–25.

disease, supporting research, developing scientific talent, and diffusing scientific information. Bush, on the basis of studies made by four committees which he organized, responded with a report titled "Science—The Endless Frontier," which provided a blueprint for far-reaching federal policies. "One of our hopes is that after the war there will be full employment," Bush said in the report. "To create more jobs we must make new and better and cheaper products. We want plenty of new, vigorous enterprises. But new products and processes are not born full-grown. They are founded on new principles and new conceptions which in turn result from basic scientific research. Basic scientific research is scientific capital." *

Use of the term "basic research" was not a casual choice. Bush explained later: "There were some on Capitol Hill who felt that the real need of the postwar effort would be the support of inventors and gadgeteers, and to whom science meant just that. When talking matters over with some of these, it was well to avoid the word fundamental and use basic instead."† To provide an organization for the support of basic research, Bush proposed the creation of a National Research Foundation, which would administer fellowships and scholarships and would "place its research contracts or grants not only with those institutions which have a demonstrated research capacity but also with other institutions whose latent talent or creative atmosphere affords promise of research success." ‡

Since 1942 Senator Harley Kilgore had been seeking passage of a bill providing for the support of science and technology, and in the spring of 1945 the bill was modified to provide for the establishment of a national science foundation. Its provisions, tending to favor applied research, were unacceptable to

* J. Merton England, "Dr. Bush Writes A Report: 'Science—The Endless Frontier,'" *Science*, 191 (January 9, 1976):2.

† *Pieces of the Action*, p. 65.

‡ "Science the Endless Frontier," p. 32.

Dr. Bush, whose own recommendations were embodied in a bill introduced by Senator Warren Magnuson. For two years there was debate on the bills. Finally a compromise bill was passed in 1947, with National Science Foundation (NSF) as the name for the new organization. It was vetoed by President Truman on grounds that the director would be appointed by the foundation's board rather than by the President and that he "would be deprived of effective means of discharging his constitutional responsibility." *

The bill was passed a second time, and Bush later related, "I managed to convince Truman he should not veto it again. But I did so on the basis that he was being given protection, a buffer against those coming to seek favors." †

An expectation had been that Bush would be chairman of NSF, but he asked President Truman not to name him to the board, saying, "I have been running about everything scientific during the war, and somewhat since, and I think people are getting tired of seeing this guy Bush run things around here. I think this outfit would be better if it had some new leadership. If you put me on the board, they will elect me chairman, and I do not think the body of scientists are going to like this continuation of one man in the top post."

President Truman remarked, "Van, you should be a politician. You have some of the instincts."

"Mr. President, what the hell do you think I've been doing around this town for five or six years?" was the response.‡

Bush continued to be "around town," and he saw NSF assume the kind of character he had envisioned for it. He served on its Advisory Committee on Government–University Relationships for two years. He was chairman of the Joint Research

* Detlev W. Bronk, "The National Science Foundation: Origins, Hopes and Aspirations," *Science,* 188 (May 2, 1975): 409–14.

† *Pieces of the Action,* p. 65.

‡ Ibid., p. 302.

and Development Board of the War and Navy departments in 1946–1947 and then chairman of the Research and Development Board of the National Military Establishment in 1947–1948. But he withdrew from active leadership in government affairs, and in 1955 retired as President of the Carnegie Institution. Of his service there, Caryl P. Haskins, his successor, observed that "His great gifts of intellect, of personality, and of administrative ability brought to the Institution one of the most formative and dynamic periods inspired by any president in its history, not even excepting the first, Daniel Coit Gilman." * One important accomplishment was an agreement between Carnegie and the California Institute of Technology for the joint operation of the Mt. Wilson and Palomar observatories.

During his retirement, Bush made his home on a hill in Belmont, Massachusetts, with a panoramic view of Cambridge and Boston. He was elected chairman of the MIT Corporation (of which he had been a member since 1932) in 1957 and was honorary chairman from 1959 to 1971. James R. Killian, Jr., former president, who succeeded him in these positions, commented that "Four M.I.T. presidents benefitted from his advice. They were, in fact, the students of his latter days. In this and other ways he showed unwavering devotion to the Institute and never lost his enthusiasm for its mission and potential."† MIT named its Center for Materials and Engineering the Vannevar Bush Building in his honor.

Bush had become a member of the board of Merck & Co., Inc. in 1949, and when George Merck, chairman of the board, died, he was elected to that position in 1957 and actively participated in the company's affairs. He had a deep interest in the advancement of medicine. In the formation of the Com-

* Biographical Memoirs, *Year Book of the American Philosophical Society* (Philadelphia: American Philosophical Society, 1974), pp. 120–27.

† Memorial service for Dr. Vannevar Bush, MIT, October 4, 1974.

mittee on Medical Research under OSRD, he repelled reactionary influences. During World War II, the death rate from disease in the Army was reduced to 0.6 per thousand, compared to 14.1 during World War I, and this was due in part to the effectiveness of the committee's program, notably in making penicillin available early and in large quantities and in consolidating pharmaceutical industry talents. Bush's interest in medicine continued through the years, and he later invented an automatic microtome, a silicone rubber valve for the heart, and a gold valve for use in hydrocephalus.

Although Bush has been called a scientist, and justifiably so because of his broad and profound understanding of science, he preferred to regard himself as an engineer. He was always fascinated by practical applications of science and was never happier than when he could work with his own hands in their achievement. He had shops at his home in Belmont and his summer cottage at South Dennis on Cape Cod, where he not merely tinkered but also attacked difficult problems with high skill. He had fun devising a bird feeder that was inhospitable to greedy pigeons and blue jays, and he worked doggedly for years to solve the problems of gas and free piston engines. He obtained three patents for the latter, in addition to a score of other patents for devices ranging from thermostats to a machine for rifling guns.

At one time Bush had a turkey farm in New Hampshire, but throughout his life he was devoted to salt water and boats. He loved cruising and was too independent-minded for conventional racing. For his ketch he designed unorthodox but efficient sails, ignoring the disapproval of nautical conformists. He was enthusiastic about the potential of hydrofoil boats and participated in designing, building, and testing them.

The most persistent line of Bush's inventive endeavors involved technology for processing information. The Differential Analyzer was the most important product of such activity, but his interests led in other directions. At MIT in the thirties he designed a decoding machine for the Navy. In 1936 he initiated the development of a machine which he called the Rapid Selector, employing 35-mm film, on which microphotographed texts could be made quickly available by the use of photoelectric cells in scanning a coded index. His application for a patent was rejected, but development of the machine was carried forward until World War II interrupted, when the two men working on it were suddenly shipped off to Washington for decoding work in the Navy.

Bush did not lose interest in speeding up the cumbersome process of searching through masses of data. In 1945 he wrote an article for the *Atlantic Monthly* describing "memex," a system by which a researcher sitting at a desk could have almost instant access to microphotographed books, periodicals, and other materials and could use a mechanized "trail" to assist in searching for relevant information.

Twenty years later Bush took part in the inauguration of a program to develop such technology for library use, Project INTREX, which was undertaken by an MIT group. In an essay titled "Memex Revisited,"* he pointed out that the development of the digital computer, the transistor, video tape, and other such devices had heightened the feasibility of such mechanization but that costs would delay its achievement. And although Project INTREX demonstrated that technical problems could be solved, economic ones, as Bush feared, remained a barrier.

The stroboscopic light developed by Bush's former colleague in electrical engineering, Harold E. Edgerton, was used in the Rapid Selector. It was applied with greater success in Photon, a machine for setting type photographically, which was developed by Graphic Arts Research Foundation, Inc., a Cambridge-

* Vannevar Bush, *Science Is Not Enough* (New York: William Morrow, 1967), p. 75.

based enterprise of which Bush was one of the founders. The computer-controlled "cold type" method is now widely used in the printing industry. Bush also held patents for a justifying typewriter and, with Professor Caldwell, for an apparatus for generating continuously variable mechanical operations.

Having had personal experience with patents as well as in administration, Bush maintained a continuing interest in the patent system and was active in seeking its improvement. As director of OSRD, he believed inventions developed with government funds should not be exploited for private profit, and he developed strong patent policies. He had resigned from the Raytheon board when he went to Washington, and although the company became one of the leading industrial contractors in the field of radar, he scrupulously avoided favoring it. At the end of the war, his friend, Laurence K. Marshall, president of Raytheon, claimed the right to patent certain inventions. Bush threatened to fight the issue in the courts. In the end, they agreed to the appointment of an impartial committee which would determine what patents Raytheon could claim, but their long friendship ended.*

Bush was a strong believer in free enterprise and the work ethic. "I had grown up with a deep-seated distrust of most social innovators, whom I regarded as a bunch of long-haired idealists or do-gooders," he wrote. He had been "appalled at some of F.D.R.'s political theory and practice," though his views mellowed as he came to revere President Roosevelt, and his loyalty to him was absolute.†

"I am all for a welfare state in which a powerful government seeks to protect its citizens against the cruelties of nature and chance, and incidentally against the rapaciousness of their fellow citizens," he said in an essay, "Poverty and Oppor-

* Otto J. Scott, *The Creative Ordeal* (New York: Atheneum, 1974), p. 173.
† *Pieces of the Action*, p. 35.

tunity." * "But just trying to abolish poverty leaves me cold. . . . From here on we should not equalize real incomes if we wish to preserve our prosperity and our safety. In the great social pyramid, there should be tangible rewards for those who rise. A state in which all material rewards are cancelled out will not long exist in a turbulent world." He wanted to see "dignity and satisfaction for those who contribute to our well-being" and equality of opportunity for all. He thought that:

> To accomplish this, or part of it, may involve a return to the village, not isolated in the hills, but surrounded closely in the city, the local community looking after its own affairs, the informal groups that hang together because of common interests. Our trends have been in the opposite direction, centralization of power, dictation from above. Even so, there has never been a time, or a country, in all history in which barriers that block the indvidual's path to success, material or intellectual, were so broken down as here and now. This is the hallmark of our way of life.†

Although Van Bush had consorted with the powerful and himself had exercised enormous power, although he was a brilliant technologist, although he shared the awesome view of nature disclosed by science, his devotion to individualism and the ideal of a simple life was central to his character.

Bush had been in failing health for more than a year when he suffered a cerebral vascular accident, developed pneumonia, and died at the age of eighty-four on June 28, 1974. Mrs. Bush had died in 1969. Bush was survived by two sons, Dr. Richard Davis Bush, a surgeon, and John Hathaway Bush, president of Millipore Corporation, by six grandchildren, and by a sister, Edith L. Bush of Provincetown, Massachusetts.

* Vannevar Bush, *Science Is Not Enough* (New York: William Morrow, 1967), pp. 123–39.

† *Science Is Not Enough*, p. 138.

HONORS AND DISTINCTIONS

PROFESSIONAL AND HONORARY SOCIETIES

American Physical Society, Fellow, 1923
American Society for Engineering Education, Fellow, 1923; Honorary Fellow, 1961
American Institute of Electrical Engineers, Fellow, 1924; Honorary Fellow, 1950
American Academy of Arts and Sciences, Fellow, 1925
National Academy of Sciences, elected 1934
American Mathematical Society, Fellow, 1936
American Philosophical Society, Fellow, 1937
Franklin Institute, Honorary Member, 1947
Society of Naval Architects and Marine Engineers, Honorary Member, 1951
American Society of Mechanical Engineers, Honorary Member, 1955
American College of Surgeons, Honorary Fellow, 1956
Phi Beta Kappa
Sigma Xi
Tau Beta Pi
Eta Kappa Nu (Eminent Membership, 1950)

SOCIAL ORGANIZATIONS

Alpha Tau Omega
St. Botolph Club, Boston
Century Association, New York

AWARDS

Louis Edward Levy Medal, Franklin Institute, 1928
Lamme Medal, American Institute of Electrical Engineers, 1935
Research Corporation Award, Columbia University, 1939
Ballou Medal, Tufts University, 1941
Edison Medal, AIEE, 1943
Holley Medal, American Society of Mechanical Engineers, 1943
John Scott Award, Philadelphia City Trust, 1943
Gold Medal, National Institute of Social Sciences, 1945
Distinguished Service Medal, Roosevelt Memorial Association, 1945

Marcellus Hartley Public Welfare Award, National Academy of Sciences, 1945
Washington Award, Western Society of Engineers, 1946
Hoover Medal for 1946, AIEE, ASCE, AIMME, ASME, 1947
Distinguished Service Award, Tufts Alumni Council, 1947
Medal for Merit with Bronze Oak Leaf Cluster, President Truman, 1948
Knight Commander, Most Excellent Order of the British Empire, 1948
Medal, Industrial Research Institute, Inc. 1949
John Fritz Medal, AIEE, ASCE, AIMME, ASME, 1951
Award of Merit, American Institute of Consulting Engineers, 1953
John J. Carty Medal and Award for the Advancement of Science, National Academy of Sciences, 1954
William Proctor Prize, Scientific Research Society of America, 1954
Officer, Legion of Honor, France, 1955
New England Award, Engineering Societies of New England, 1957
Charles F. Kettering Award, George Washington University, 1952
1963 National Medal of Science, President Johnson, 1964
Great Living American Award, Chamber of Commerce of the United States, 1964
Citation, Brotherhood of Temple Ohabei Shalom, Brookline, Massachusetts, 1964
Wisdom Award of Honor, The Wisdom Society, 1965
First Annual Founders Medal, National Academy of Engineers, 1966
Distinguished Service to Science Education Citation, National Science Teachers Association, 1968
Atomic Pioneer Award, President Nixon, 1970

BOARDS

Life Member, Massachusetts Institute of Technology Corporation; Chairman, 1957–1959; Honorary Chairman, 1959–1971
Regent, Smithsonian Institution, 1943–1955
Trustee, Tufts College, 1943–1962 (Emeritus)
Trustee, Johns Hopkins University, 1943–1955
Trustee, Carnegie Corporation of New York, 1939–1950
Trustee, Carnegie Institution of Washington, 1958–1974
Trustee, George Putnam Fund of Boston, 1956–1972

Director American Telephone and Telegraph Co., 1947–1962
Director, Merck & Co., Inc., 1949–1962; Chairman of Board, 1957–1962
Director, Metals and Controls Corporation, 1952–1959
Director and Life Member, Graphic Arts Research Foundation, Inc., 1949–1974

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The coupled circuit by the method of generalized angular velocities. Proc. Inst. Radio Eng., 5:363–73.

1919

Gimbal stabilization. J. Franklin Inst., 188:199–215.

1920

Alignment chart for circular and hyperbolic functions of a complex argument in rectangular coordinates. J. Am. Inst. Electr. Eng., 39:658–59.

A simple harmonic analyzer. J. Am. Inst. Electr. Eng., 39:903–5.

1921

With C. G. Smith. A new rectifier. Proc. Inst. Radio Eng., 10:41–51.

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