An Architect of Science

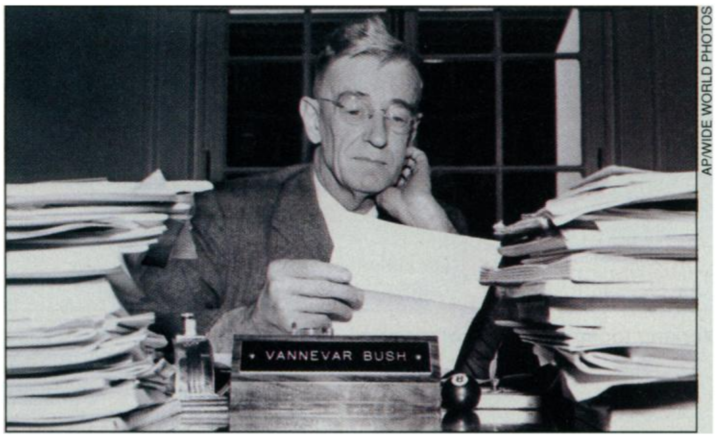
William Aspray

Endless Frontier. Vannevar Bush, Engineer of the American Century. G. PASCAL ZACHARY. Free Press (Simon and Schuster), New York, 1997. viii, 518 pp. + plates. $32.50 or C$43. ISBN 0-684-82821-9.

Welcome indeed is the first biography of the man the author calls "the most politically powerful inventor in America since Benjamin Franklin."

Vannevar Bush did not want his biography written. He believed that most biographies of scientific figures focus on lurid details while neglecting the important issues. Because of his concern about the inexactitude of the social sciences, he remained aloof from the historians who tried to question him during his later years about his career. In part to preclude others from writing about him, he wrote his own memoirs. But *Pieces of the Action* was a poor substitute for a biography, giving little insight into his career and scarcely mentioning such important aspects as his work to control nuclear weapons.

Bush is best known today for marshaling civilian science to support the U.S. military effort in World War II, and for his report to President Roosevelt, "Science: The Endless Frontier," which lays out the pattern of federal funding for university research that has been followed in the half century since the war ended. But Bush's life was much richer and more complex than this contribution, vastly influential though it has been, would imply. Bush chose a teaching career instead of a research position at AT&T so that he would be free to earn royalties on his inventions, the first of which—an analog computing device known as a profile tracer—he had already patented as an undergraduate. In his early years on the faculty at Tufts, he consulted with AMRAD, a company that built radio parts and complete radios for amateurs. After moving to the electrical engineering faculty at MIT in 1919, he helped to create Raytheon out of the remains of the failed AMRAD.



AP/WIDE WORLD PHOTOS

Vannevar Bush. Bush at his desk in Washington, D.C. in 1947 after President Truman appointed him chairman of the Research and Development Board designed to keep the United States ahead in scientific progress.

During the next 20 years at MIT, Bush's career took shape. His earliest contributions were educational. In his doctoral dissertation, Bush had built on the work of Oliver Heaviside to develop a mathematically tractable way to study alternating current circuits and devices. He introduced this method into the MIT curriculum, as a result of which it became a standard approach in electrical engineering. During the 1920s, he served as the director of graduate studies, building up the size and strength of the graduate programs in electrical engineering and training several academically strong students, including Stanford's Frederick Terman, arguably the grandfather of Silicon Valley.

Bush also contributed to research. As an aid to the design of electrical networks for the rapidly expanding power grid in the United States, he devised a series of analog computing devices in the 1920s and 1930s, making himself the leading authority on analog computing in the country. Most of these machines were designed for engineering applications; however, in the late 1930s, he became interested in devices for automating the storage and retrieval of information. In 1937, he built a device, known as a "rapid selector," for Kodak and National Cash Register that helped to choose rapidly a desired item from a large collection of business records on microfilm. This technology was picked up by the U.S. Navy to help automate its code-breaking operations, and subsequent adaptations were used effectively during World War II.

Bush also made his mark as an administrator. Soon after his arrival in 1930 as president of MIT, Karl Compton chose Bush as vice president and dean of the school of engineering. In these positions, Bush helped to build MIT into the powerhouse it is today.

In 1939, Bush left MIT to become the president of the Carnegie Institution of Washington, a leading funder of scientific research in the United States. He wanted to be in Washington, where he believed he could be more influential in preparing the country for war. The appointment had the additional benefit of securing Bush's financial future. The generous salary continued to be paid during and after the war while he worked as a dollar-a-year man in government.

Bush had already begun to exert his influence on a national level before leaving MIT: He revived the Division of Engineering and Industrial Research of the National Research Council in 1937, and served on the National Advisory Committee for Aeronautics from 1939 to 1941. When he arrived in Washington, Bush used his many positions of influence to try to convince the military of the value of scientific research to their mission, and to urge the industrial sector to collaborate with the armed services.

Bush was catapulted into a senior national position when he led a small number of scientific leaders in assembling a coordinating committee, reporting to President Roosevelt, that would contract with university and industrial laboratories to conduct research on behalf of the armed services. Without fuss, Roosevelt approved the formation of the National Defense Research Committee (NDRC) in June 1940, with Bush as chairman. The key to the success of this organization was the research contract; scientists were mobilized for the war effort in their own laboratories. This arrangement limited bureaucracy and improved the quality of scientists working for the NDRC.

About a year later, Roosevelt formed the Office of Scientific Research and Development (OSRD) in order to ensure sufficient funding for scientific research applied to the war effort. NDRC was folded into OSRD, the mandate was widened to include medical research and development, and Bush was appointed director. OSRD was a tremendous success: Development of both the proximity fuse, which helped defend Britain against V1 rockets, and microwave radar, which overcame the threat of German U-boats, as well as the initial research on the atomic bomb, were among its many accomplishments. On Bush's recommendation, Roosevelt turned over the bomb production

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from OSRD to the army, but Bush remained involved as chairman of the oversight committee. The sometimes forgotten accomplishment of Bush and the OSRD is the complete reversal of the attitude of the military both to the importance of science to the military mission and to the value of having the research performed by civilians.

As the end of the war neared, Bush worried about how to translate the successes of OSRD into a peacetime operation that would provide government funding for basic research as the seed corn for both military technological development and national industrial productivity. "Science: The Endless Frontier" was the result. It called on America to change its dependence for national well-being from the rapidly closing geographic frontier to the endless frontier of scientific and technological research. Bush advocated a National Research Foundation to replace the OSRD, and many people believe that today's National Science Foundation is the result. As Zachary carefully shows, however, Bush's unwillingness to compromise and his betrayal of Senator Kilgore, his congressional nemesis on national science foundation legislation, resulted in a delay of 5 years in approval of such legislation. During this half-decade, the military had time to establish its own scientific research organizations—most notably, the Office of Naval Research—for funding university and industrial research. Such military control of the purse strings was exactly what Bush wished to avoid. The National Science Foundation (NSF) that was established in 1950 lacked several features that Bush had fought for: There was no medical division and no military division, the foundation had no role in establishing national science policy, and the director was appointed by the president rather than by the scientific community. Moreover, the initial leadership for the NSF came from the Office of Naval Research. Bush scorned the first director, Alan Waterman, because of his weakness and limited ambition for NSF, and would not allow any of his Carnegie Institution researchers to accept NSF grants.

With the death of President Roosevelt in April 1945 and the retirement of Henry Stimson, Roosevelt's secretary of war, in September of that year, Bush lost his close contacts with the White House. He found, much to his displeasure, that his power to influence such issues as postwar nuclear policy and a national science foundation faded rapidly. He remained at the OSRD until it closed in 1947 and at the Carnegie Institution until his retirement in 1955, but he was increasingly at odds with the government administration, and often at odds with the scientific community, on issues of science policy. The general consensus was that his elitist, technocratic, politically conservative, and contrarian views were acceptable, useful, and, perhaps even necessary in time of war, but that they were out of place and not to be tolerated in the postwar era. He remained active in semi-retirement, both as an inventor and as a policy activist, but he made little contribution of consequence in this period. Bush died in 1974, at the age of 84.

To Zachary, Bush's years in Washington were the most interesting, and he devotes the most attention to and is most effective in describing this period. One might reasonably label this book a political biography. Zachary's treatment of Bush's contributions to the mathematics of electrical engineering, analog computing, computing devices for information retrieval, and the development of the electrical engineering program at MIT adds little to the existing literature by Susann Hensel, Larry Owens, James Nyce and Paul Kahn, and Karl Wildes and Nilo Lindgren, respectively. In sharp contrast, the coverage of Bush as administrator of OSRD and as a policy advocate in the postwar period is both novel and interesting.

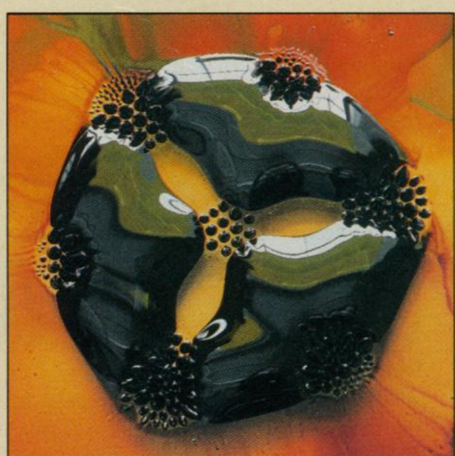
Zachary is a journalist by profession, and, following the common practice for mass-market books on science, he "dumbs down" the scientific treatment in his exposition in the hopes of broadening his audience. With this approach, there is little opportunity to discuss in any meaningful way Bush's technical contributions, such as the design of his calculating machines. One might dismiss this criticism, arguing that these are topics peripheral to Zachary's main interest. However, this approach also diminishes the author's capacity to analyze those topics most central to him. In more than a hundred pages covering the war years, there is no overall discussion of which scientific problems were chosen for study by OSRD and which scientists were selected for them; I do not see how Zachary could have done justice to this subject without a deeper level of analysis of the science and the technology. In the postwar era, Bush was roundly criticized for his reservations about the feasibility of long-distance rocketry. Zachary does not evaluate the scientific basis for Bush's opinions, and thus he is forced to tell this story simply as one of conflicting expert opinions. In these and other ways, his analysis loses richness and authority by not engaging the science and the technology.

Zachary has done a commendable job examining the wealth of archival sources, interviewing more than 50 individuals, and taking advice from notable scholars in the preparation of his manuscript. As substantial as the scholarship is, it does not interfere with the readability of the book. While this effort is a valuable contribution to the literature, there is still a need for a complete scientific biography of Bush. Would Bush have liked this book? I think not, because it second-guesses him too much.

ALSO NOTEWORTHY

On the Surface of Things. Images of the Extraordinary in Science. F. FRANKEL and G. M. WHITESIDES. Chronicle Books, San Francisco, 1997. 160 pp., illus. Paper, $22.95. ISBN 0-8118-1394-0.

In this wondrous book, the artist Felice Frankel and the chemist George Whitesides meld photography and science to create poetry, of both the visual and literary sort. A series of spectacular photographs—many from the laboratory and many of very tiny objects—are paired with descriptions that capture both the science and the beauty of the images. The example below is a ferrofluid, "a gryphon in the world of materials: part liquid, part magnet," that is coaxed into displaying both of its personalities by seven magnets placed underneath in a circle. Over the magnets, the form of the ferrofluid follows the magnetic field; elsewhere its shape is controlled by surface tension, "in a compromise between the siren call of gravity and its own cautious cohesion." In an elegant solution to scientists' perennial problem of revealing the scale of their subject, the authors have included the outline of the head of a pin in subtle blue with each image.



FELICE FRANKEL

—Katrina L. Kelner