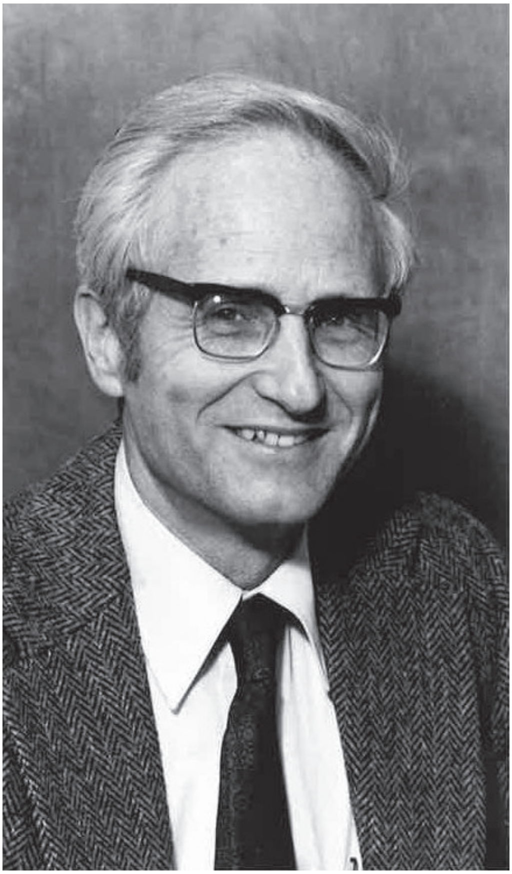

JACK L. KERREBROCK

1928–2019

Elected in 1978

"Contributions in the development of propulsion and energy conversion systems design and research, education, and national service."

BY EDWARD M. GREITZER AND ALAN H. EPSTEIN

JACK LEO KERREBROCK, a world figure in aerospace propulsion, died at his home in Lincoln, Massachusetts, on July 19, 2019. He was 91.

His career was marked by insightful and pathbreaking research, technical innovation, eminence in education, and leadership and counsel for government and industry. His research included airbreathing propulsion, space propulsion, and turbomachinery; his inventions and innovations included the gas core nuclear rocket, the technology for transient turbomachinery testing, and many devices and techniques for diagnostics and improvements in jet engines; his educational contributions included a seminal book on gas turbine engines as well as decades of excellence and positive impact in teaching and mentoring students; and his advice to industry and government was widely recognized and highly sought.

Jack started his career as a theorist, where his combination of physical insight and mathematical abilities fueled contributions to propulsion and to magnetohydrodynamics (MHD), but he soon broadened his focus to a major emphasis on experimental research. This switch came about, he explained, because a theorist could only blame himself for a lack of progress while an experimentalist could always blame it on the equipment. In Jack's case, excuses were rarely needed because he combined extraordinary skills in both experimentation and theory. The term role model, in its best sense, could be used to describe him—someone to look up to not only for guidance but also for how an exemplary individual behaves and what we can learn from him or her.

Jack was born in Los Angeles on February 6, 1928, to Oscar and Florence (Hoy) Kerrebrock. He grew up in Oregon and obtained a BS (1950) at Oregon State University and then an MS (1951) at Yale University, both in mechanical engineering. His passion for aerospace took him to NACA Lewis Research Center (1951–53) in Cleveland, the forerunner of the NASA Glenn Research Center. During this period he met and married Bernice (Vickie) Veverka, who was then a comput*or*—i.e., a *person* who calculates or computes—at Lewis. In 1953 the Kerrebrocks left for Caltech, where Jack completed his PhD, also in mechanical engineering, in 1956. His thesis topic was the interaction of turbulence with shockwaves, and he worked with Frank Marble (NAE 1974, NAS 1989); they formed a close relationship that lasted throughout their careers.

Doctorate in hand, Jack went to Oak Ridge National Laboratory as a research engineer, but he returned to Caltech 2 years later as a senior research fellow. In 1960 he joined MIT as an assistant professor. When he applied for the position, he was courted by three departments: Aeronautics and Astronautics, which he joined, Mechanical Engineering, and Nuclear Engineering. Reportedly, the dean called the three department heads together and told them, “I don’t care which of you get him, but I’m not letting you bid against each other. I’m writing the offer.”

Jack spent his very fruitful career at MIT, aside from two stints away from the campus. Promoted to associate professor in 1962 and to full professor in 1965 (a rapid rise indeed), he founded the Space Propulsion Laboratory in 1962 and directed it until 1976, when it merged with the Gas Turbine Laboratory, of which he had become director in 1968. He was named the R.C. MacLaurin Professor in 1975, and in 1978 he accepted the role of head of the Department of Aeronautics and Astronautics. He also served MIT as associate and then acting dean of engineering. From 1983 to 1985 he was on leave from MIT as the NASA associate administrator for aeronautics and space technology, and he spent a year at Caltech as Sherman Fairchild Distinguished Scholar (1990–91).

He supervised 85 PhD and MS theses at MIT, sharing his love of, and enthusiasm for, propulsion and energy conversion with several generations of students. He was a mentor to faculty as well, including the authors.

Contributions to Space Power and Propulsion

Jack's work on nuclear space propulsion started when he went to Oak Ridge in 1956. There he conceived of the gas core nuclear rocket engine. Major challenges to the concept were fluid instabilities and vortex containment. His physical insight and mathematical prowess in these areas were later applied to many aeropropulsion and power fields.

In the early 1960s there was great enthusiasm for MHD generators for aerospace applications. At MIT he conceived of the nonequilibrium MHD generator and demonstrated it in a large-scale experiment. He later extended this concept to nonequilibrium MHD lasers, also demonstrated at MIT. He returned to space propulsion in the early 1990s, studying flow instabilities in particle bed nuclear reactors for space propulsion.

Contributions to Gas Turbine Technology

Jack's important contributions to gas turbine technology include basic conceptual features of compressor phenomena. One of these, referred to today as the Kerrebrock-Mikolajczyk effect, concerns the behavior of wakes in compressors, specifically the transport of a wake across a turbomachinery blade passage. It is the type of analysis that (i) can be explained, as he did, by simple geometric construction and that (ii) causes one to say "Of course—why didn't *I* think of that?" It resolved a widespread mystery that lurked in compressor data, and there were sessions devoted to it at technical meetings for some years, for turbines as well as compressors.

His paper explaining the effect[1] received the American Society of Mechanical Engineers (ASME) Gas Turbine Award (1970) for best gas turbine paper of the year. Another, very different, metric for the paper was that the MIT AeroAstro Department's doctoral exam used to have a section in which the students read a paper and then explained the ideas and conclusions to the examining faculty. We took considerable care in our choice of papers in terms of readability, ideas, intellectual nuggets (a Kerrebrock term), and importance, and Jack's paper was a charter member of this select group.

Jack's invention of the blowdown compressor pioneered the use of transient testing techniques to obtain data on transonic compressor behavior in a rapid and low-cost manner, without the large (several thousand horsepower) motors and other infrastructure used in industry and government laboratories. It made possible the investigation of aeroengine turbomachinery, at realistic conditions, in a university setting. The facility, and the results obtained from it, was the forerunner of a blowdown turbine later developed at MIT by one of the authors (AHE), and then, in a larger incarnation, a transient turbine facility commissioned at the Air Force Research Laboratory.

An important part of Jack's research included experiments on turbomachinery aeromechanics, particularly flutter, another topic not previously accessible at a university. To do the unsteady aerodynamic and aeromechanic experiments, he had to develop his own high-frequency response measurement techniques based on semiconductor pressure transducer technology, but he saw that as part of the challenge—and the fun. For some years, therefore, in contrast to the photographs in our department brochures of faculty looking directly into the camera, the photo of Jack was of the back of his head as he stared into a microscope while crafting the miniature probes he had designed.

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[1] Kerrebrock JL, Mikolajczyk AA. 1970. Intra-stator transport of rotor wakes and its effect on compressor performance. *ASME Journal of Engineering for Gas Turbines and Power* 92(4):359–68.

Jack was the first to recognize and describe the coupling of different fluid dynamic disturbances that occurs because of the swirling flows inherent in turbomachinery and that creates (heretofore undescribed) three-dimensional motions. His paper on the topic,[2] when one of us read it in the mid-1970s, seemed a whole new way of thinking about inlet distortion in turbomachines, a departure from the two-dimensional analyses that were then the standard. As with wake transport, there was a clear and bright light of a new idea being presented, the essence of which Jack could sum up in one or two sentences (although the resulting algebra giving the detailed scientific explanation was not for the faint of heart—another type of Kerrebrock trademark tour de force that can be traced back to his PhD thesis). The ideas in his paper helped greatly in defining new research on this topic.

In later years Jack was the originator of vaporization cooling, a scheme to allow turbine blades to operate at a nearly uniform temperature, and of the aspirated compressor. In connection with the former, his work on heat transfer in internal passages, recognized by the ASME International Gas Turbine Institute as the best heat transfer paper of the year,[3] provided a first-of-a-kind clarification of the mechanism responsible for the heat transfer coefficients observed in rotating blade rows. The latter concept—involving the use of strategically designed suction (i.e., aspiration) to control the behavior of the viscous flow in compressor blading, thereby permitting higher aerodynamic loading and thus fewer stages than conventional compressors—was experimentally confirmed at MIT and then at NASA.

Contributions to Engineering Education

Beyond his eminence in research, Jack shone as an engineering educator. His gas turbine engine textbook, *Aircraft Engines and*

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[2] Kerrebrock JL. 1977. Small disturbances in turbomachine annuli with swirl. *AIAA Journal* 15:794–803.

[3] Bons JP, Kerrebrock JL. 1999. Complementary velocity and heat transfer measurements in a rotating cooling passage with smooth walls. *ASME Journal of Turbomachinery* 121(4):651–62.

Gas Turbines (MIT Press, 1st ed., 1977; 2nd ed., 1992), is used around the world as the reference book of choice, setting the standard for rigorous exposition of gas turbine phenomena and their impact on design. It reaches beyond fluid mechanics to include other important aspects of the technology, such as structural design, aeromechanics, noise, and rotor dynamics. One of its strengths is treating propulsion as a system rather than a set of individual disciplines.

In person at MIT, his classes drew rave reviews from undergraduate and graduate students. The latter invariably finished their research excited about their work and enormously pleased to have had the opportunity to work with him.

In addition to Jack's gas turbine teaching, in the mid-1970s he and two MIT colleagues, Gene Covert (NAE 1980) and Jim Mar (NAE 1981), invented unified engineering, a new approach to undergraduate aerospace education that integrated and brought together four main aerospace disciplines. The subject carried twice the credit of a typical course and was thus roughly half the academic load of a typical student; it was given to the whole second-year class as a cadre. "Unified," as it is simply called, has been the foundation of the aeronautics and astronautics undergraduate curriculum for over 4 decades.

Jack's commitment to undergraduate education was also evident in the fact that he was asked to teach the undergraduate propulsion subject in the spring 2001 term before he "retired" (in name, but not in fact). In this last class at MIT, he received the Undergraduate Teaching Award given by the students.

His educational leadership extended beyond the classroom. As head of the Gas Turbine Laboratory, head of the Department of Aeronautics and Astronautics, and dean of engineering, Jack did much to maintain gas turbine engineering at the forefront of the department's engineering curriculum.

He was also the faculty leader of the department's Daedalus Project, a human-powered aircraft that, on April 23, 1988, flew 72.4 miles (115.11 kilometers) in 3 hours, 54 minutes, from Heraklion on the island of Crete to the island of Santorini. Daedalus still holds the world record for human-powered flight. The culmination of a decade of work by MIT students and alumni, the flight was the capstone of a wonderful experience for faculty, staff, and students, and it made a major contribution to the understanding of the science and engineering of human-powered flight.

Leadership in the Broader Aerospace Community

As the associate administrator for NASA Aeronautics and Space Technology, as well as in his many roles as an advisor to the government, Jack had an invigorating influence on national aerospace policy and played a key role in maintaining support for NASA aeronautics R&D.

He was a valued and sought-after advisor and consultant for both industry and government on broad policy and challenging technical barrier engineering issues. An illustrative selection of his service includes the National Commission on Space (a presidential committee), and many committees as part of the US Air Force Scientific Advisory Board, for which he chaired the ad hoc Committee on the Aeropropulsion System Test Facility, Science and Technology Advisory Group AF Systems Command, and Division Advisory Group of the Aeronautical Systems Division. For NASA, he served on the Space Station Advisory Committee and Advisory Board for Aircraft Fuel Conservation Technology. He was also a member of the Defense Science Board Task Force on National Aero-Space Plane Program.

For the National Academies and National Research Council, Jack was active in volunteer service as a board, committee, and panel member and chair. For example, he chaired the Committee on Hypersonic Technology for Military Applications (1987–88), Committee on the Space Station (1991–94), and Aerospace Industry Panel (1998–2000) of the Committee on Impact of Academic Research on Industrial Performance (on which he served as a member, 1997–2000). He was also vice chair of the Engineering Research Board (1984–86) and a member of the Committee on Aircraft and Engine Development Testing (1984–86), Committee on Requirements for Advanced Space Technology (1989–92), Committee on

Strategic Assessment of Earth-to-Orbit Propulsion Options (1991–92), Aeronautics and Space Engineering Board (1992–94; chair, 1994–95), and Committee on Engineering Challenges to the Long-Term Operation of the International Space Station (1998–2000), among others.

Characteristically, Jack viewed his role as not merely to critique programs and policies but to directly address and solve the problems (technical and organizational), cutting to the root difficulty of complex systems and pointing out elegant, often simple, solutions. He was noted for his insight and wisdom about complex problems, his high level of integrity, and as someone who would have a substantial positive effect on a wide variety of programs.

His contributions were recognized by a number of awards and honors, in addition to his election to the NAE. These include membership in the American Academy of Arts and Sciences and designation as an honorary fellow of the American Institute of Aeronautics and Astronautics (AIAA), AIAA Dryden Research Lecturer (1980), Sherman Fairchild Distinguished Scholar (Caltech), Distinguished Alumnus (Caltech), and honorary professor at Beijing University of Aeronautics and Astronautics (he was pleased that he was Number 007). After the 1970 ASME Gas Turbine Award, he received the Air Force Exceptional Civilian Service Medal (1981), NASA Exceptional Service Medal (1983), and 1992 AIAA Leland Atwood Award (for educational contributions).

Mentoring and Impact on Others

Jack hired both of the authors at MIT. One was a former student of his who used the opportunity to move into new areas, just as Jack had done. The other came from industry with no knowledge about how a university worked, let alone what he was supposed to be doing. From the beginning, Jack encouraged both of us, provided guidance about choice of research topics, and made sure that opportunities were given. The takeaway is that, no matter what the initial conditions, Jack was a thoughtful, encouraging, and immensely effective mentor.

This description of Jack is heard over and over from the numerous faculty and students that he helped, mentored, and encouraged over the years. The details may be different, but the overall result and the outpouring of gratitude for his help are invariant. One of his legacies is that many of his students have become leaders in government, industry, and academia. By the authors' count, at least 10 members of the NAE consider Jack a mentor and major influence on their careers.

In this context, one of Jack's great strengths was his focus on people. He had the gift of focusing on the individual. The person he was with at the time, no matter how junior, felt that Jack was really there for him or her, and he was. Also, from what appeared to be a casual chat, Jack could determine that a prospective graduate student from a not very highly ranked institution, or one with a less than stellar record, had the potential to excel at MIT. He then advocated for, and mentored, the student who might not otherwise have been admitted or prospered. In the hothouse of the MIT meritocracy, Jack was unusual in accepting people as they were, not as he (or others) might have wished them to be. A student with the ability to perform at only a B or C level was given as much attention, encouragement, and appreciation as an A+ superstar.

Inventing

Jack was a prolific inventor whose creations spanned the gamut from the everyday to the profound. In addition to those described above, examples include the Kerrebrock tractor, which he invented with his father and brother while in high school. It had a very narrow track, and a cursory search reveals several websites describing the tractor, one of which contains the quote: "That has to be the coolest tractor I have ever seen."

He also came up with numerous improvements to sailboats, combining two of his passions, sailing and inventing. His boats always had unusual, custom enhancements, many of them not obvious to the casual observer (and later removed as experience trumped enthusiasm).

Activities Outside Technology

This tribute would not be complete without at least a brief mention of Jack's enthusiasm for the outdoors. He was perhaps never happier than when climbing a mountain, hiking a wilderness trail, or leading a group of youngsters through ice and snow to teach them independence and survival skills. His outdoor contributions earned him fellowship in the Explorers Club. He ran his first Boston Marathon in his early 50s on a whim and with no special training, and followed that with several more, including the Marine Corps Marathon in Washington, DC. He was still hiking in the White Mountains in his late 70s.

Jack's first wife, Vickie, passed away in 2003 after 50 years of marriage, and Jack married Rosemary "Crickett" (Keough) Redmond in 2007. Jack and Crickett traveled widely, to South Africa, Scotland, Tuscany, Paris, and a special trip to Cape Canaveral for one of the last space shuttle launches, where he was able to introduce Crickett to one of her heroes, Neil Armstrong.

In addition to Crickett, Jack leaves behind two children, Nancy Kerrebrock (Clint Cummins) of Palo Alto, and Peter (Anne) Kerrebrock of Hingham, MA, and five grandchildren. He was preceded in death by his son Christopher. He also is remembered fondly by the Redmond children, Paul J. Jr. (Joe Palombo), Kelly (Philip Davis), Maura, and Meaghan Winokur (James), and their two children.

Jack would occasionally tell the story of his work in a machine shop in high school, turning steel stanchions for Navy destroyers. He cranked up the lathe speed until the tool glowed red, to make his parts as fast as possible. An older machinist came over, put his arm around Jack's shoulders, and said, "Look around, nobody else goes this fast, what's your rush?" Jack never did slow down—as an engineer, a teacher, a human being.

The authors feel privileged to have had Jack Kerrebrock as a colleague, a role model, a mentor, and a friend. He changed our lives.