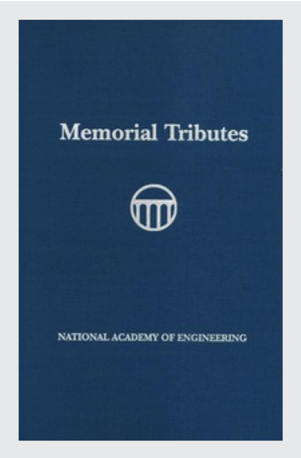

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FOREWORD

THIS IS THE TWENTY-FOURTH VOLUME in the *Memorial Tributes* series compiled by the National Academy of Engineering as a personal remembrance of the lives and outstanding achievements of its members and international members. These volumes are intended to stand as an enduring record of the many contributions of engineers and engineering to the benefit of humankind. In most cases, the authors of the tributes are contemporaries or colleagues who have personal knowledge of the interests and engineering accomplishments of the deceased.

Through its members and international members, the Academy carries out the responsibilities for which it was established in 1964 as an organization of outstanding engineers. Members are elected by their peers on the basis of significant contributions to engineering theory, practice, and literature or for exceptional accomplishments in the pioneering of new and developing fields of technology. The National Academies of Sciences, Engineering, and Medicine share a responsibility to advise the federal government on matters of science, technology, and medicine. The expertise and credibility that the National Academy of Engineering brings to that task stem directly from the abilities, interests, and achievements of our members and international members—our colleagues and friends—whose special gifts and accomplishments we remember in these pages.

Carol K. Hall
Home Secretary

Memorial Tributes

NATIONAL ACADEMY OF ENGINEERING

MIHRAN S. AGBABIAN

1923–2019

Elected in 1982

"Contributions in the application of advanced methods of applied mechanics to structural design, and contributions in the field of structural response to blast and shock and the reduction of seismic hazards to existing structures."

BY ARMEN DER KIUREGHIAN AND PAUL AGBABIAN

MIHRAN SIRAGAN AGBABIAN, known to his early professional colleagues as Mike, passed away on February 12, 2019, at the age of 97.

He was born in Larnaca, Cyprus, on December 9, 1923, to Siragan and Parouhi Agbabian, who had fled Eastern Turkey during the Armenian persecutions of the early 20th century. He had an older brother who died of tuberculosis in his early 20s, and a younger sister and brother, Lucina and Hrant. His father was a Protestant Armenian minister who, 9 years after Mihran's birth, moved the family to Aleppo, Syria, where he had been invited to be the pastor of the Emmanuel Armenian Evangelical Church. A significant Armenian community had settled in Syria following the demise of the Ottoman Empire, and the Syrians were a friendly host during the British Mandate. Mihran's Armenian Evangelical family upbringing significantly influenced his life of service to his profession and his Armenian heritage.

Mihran showed an early interest in science, mathematics, and physics while attending high school in Aleppo. Upon graduation he attended the American University of Beirut, where he graduated with a BA in physics in 1944. These were the war years, and he decided that physics might be a difficult professional course, so, while serving part-time as a radio operator for the British, he followed his BA with a BS in engineering in 1947. He applied to UK and US graduate schools and was granted a full scholarship with room and board at Brighton College. On the eve of his departure for Britain, he received an acceptance to the California Institute of Technology, which was his preference. He returned his paid fare to the British Embassy and arranged his travel to Pasadena.

One challenge with attending Caltech was that he did not receive a scholarship and his acceptance was contingent on his ability to provide for tuition and accommodation. He debarked in New York City with $50 and the suit he was wearing, but an Armenian family friend loaned him money for the cross-country train journey to Pasadena. A cousin and her husband offered him lodging on Hill Street adjacent to the campus, which he paid for via a teaching assistant job at Caltech.

After he earned his MS in civil engineering in 1948, he wanted to get his doctorate in structural mechanics and traveled to Berkeley, thinking he might continue his education at the University of California, Berkeley. To his dismay, he learned that the school was not offering a doctoral program in structural mechanics. However, a young assistant professor, Egor Popov, took him under his wing and introduced him to the chair of the Civil Engineering Department to make the case for starting a doctoral program. Mihran returned to Caltech and a few months later received a letter informing him that he would be the first student in the newly formed doctoral program in structural mechanics at UC Berkeley.

While at Berkeley, Mihran courted and later married Elizabeth Apkarian, also the daughter of an Armenian Protestant minister who was the pastor of a church in Oakland. Elizabeth became Mihran's lifelong partner, supporting his professional career as well as his work for the Armenian community.

Upon receiving his PhD in 1951, Mihran started his professional career at Bechtel in San Francisco. In 1955 he and Elizabeth moved to Los Angeles, where he worked for a short time at the firm of John Minassian & Associates before continuing his engineering work at the Ralph M. Parsons

Company (1955–62), where he rose to the position of chief engineer.

Mihran had the entrepreneurial bug and decided to join with Stanford professor of mechanical engineering Lydik S. Jacobsen, a pioneer in structural dynamics, to form an engineering consulting firm in 1962, which they named Agbabian Jacobsen Associates. When Jacobsen retired in 1969, the firm was renamed Agbabian Associates (AA). Its stated mission was to provide in-depth consulting of the highest technical level to government and industry for the design, analysis, and testing of civil and military structures and mechanical systems.

Throughout the 1960s many of the firm's contracts revolved around Cold War defense work, including structural hardening of facilities to withstand nuclear attacks. Their customers included the Nuclear Regulatory Commission (US NRC) Atomic Energy Commission, US Air Force, and National Science Foundation. His work for the NSF renewed Mihran's interest in research and academia, interests that endured the rest of his life.

Defense work was important, but after Jacobsen's retirement AA chose to expand into other areas that could benefit from the practice of structural and civil engineering and experimental mechanics. Mihran acquired assets from a small firm called DigiTek to augment AA's capabilities with an automotive crash testing facility in Mira Loma and computer software packages developed by University Software Systems, including the MAC/RAN software for time series, shock, and spectrum analysis of digitized vibration data. He also ventured into adjacent projects, such as aeroelectric power, which required sophisticated structural engineering for the design of extremely tall towers—up to 5000 feet from the desert floor—that could sustain high wind forces.

After the 6.5 magnitude 1971 San Fernando earthquake, AA's expertise in vibrations and structures became important in the updating of building codes and new design methods for tall structures, nuclear reactors, and hospitals to withstand high-magnitude tremors.

AA's research projects in 1975–79 included analysis of geotechnical and strong motion earthquake data from US accelerograph stations, with historical data from earthquakes such as the 1940 El Centro earthquake in Imperial Valley, CA. Statistical analyses of earthquake ground motion parameters were carried out for the US NRC's Division of Reactor Safety Research.

Mihran became more involved with the Earthquake Engineering Research Institute during the 1970s and 1980s, and was president in 1983–84. He also served as the coordinating editor of the *EERI Monograph Series*, with contributions by some of the most important names in earthquake engineering, including George Housner, Nathan Newmark, Anil K. Chopra, and Donald Hudson.

AA was a strong proponent of computer simulations of structures under load from ground motions using the finite-element method, originally developed by Ray Clough. Mihran wanted AA to have a stronger research focus in this area and began a visiting professor program with the University of Southern California and UC Berkeley, bringing in consulting professors such as Sami Masri, Thomas Hughes, and the author (ADK) to work on research projects with the AA technical staff. At the time a young assistant professor at USC, the author later became his partner and cofounder of the American University of Armenia (AUA).

In 1982 Masri suggested that Mihran apply for the newly vacant Fred Champion Chair of Civil Engineering Department at USC. The university wanted to bring in practical industry experience to better equip students for their careers and to assist with fundraising that would help make USC's engineering school a world-class institution. Mihran chaired the department from 1984 to 1992 and retired as professor emeritus in 1998. During his tenure, he planned and raised funds for new laboratories in instructional and research programs. In particular, the structures, dynamics, concrete, geotechnical, hydromechanics, and strong ground motion labs of the department were revitalized. His fundraising efforts produced a continuous stream of research funds that allowed for the purchase of state-of-the-art experimental equipment.

As department chair, he had a prominent role in the initial proposal for a California-based national center for earthquake engineering. His stature at the national level contributed to the ability of the School of Engineering to receive funding from private organizations and public agencies.

Other achievements included the creation of undergraduate degree programs in civil engineering–environmental engineering and in environmental engineering. At the time of his retirement, the number of students in these programs represented one third of the undergraduate civil engineering enrollment.

On December 7, 1988, the Soviet Republic of Armenia was struck by a devasting earthquake. More than 25,000 people died, more than 100,000 were injured, and half a million became homeless. The US National Academy of Sciences and US Geological Survey dispatched a reconnaissance team of 22 seismologists and earthquake engineers to Armenia. Mihran and the author were members of that team. Upon investigation of the effects of the earthquake and the poor quality of structural design and construction, they resolved to take action to improve the quality of education and training in earthquake engineering in the country.

In March 1989 they prepared a proposal to establish an American-style university that would promote evidence-based inquiry and critical thinking and serve as a bridge between western academia and Armenian educational and research institutions. After receiving a promise of funding from the Armenian General Benevolent Union, they approached the University of California for assistance in establishing the new university. In June 1990, the University of California President's Office sent 11 academics to Armenia including Mihran and ADK. Upon their return, the UC team recommended offering support and leadership to the nascent American University of Armenia. Mihran was appointed the founding president of the university in March 1991. In July 1991 a proposal for affiliation between the University of California and the AUA was approved by the UC Board of Regents and an agreement was signed by Agbabian and UC president David Gardner in September 1991, a momentous event that charted the course of AUA. The American University of Armenia started its instructional programs on September 21, 1991.

Mihran was president of AUA until 1997. During the 6 years of his presidency, he planned and implemented all the essential elements of a modern university—academic programs with faculty and deans, offices for admissions, registrar, accounting, information and communication technologies, alumni and career development offices, and even the student council and faculty senate. Due to the breakup of the Soviet Union and blockade of Armenia by its neighbors, the living conditions were extremely difficult and there were severe shortages of food and essential utilities. Realizing how difficult it was for students to commute and find food, Mihran arranged for food vouchers for them and allowed those who were commuting from distant areas to stay on campus overnight. He organized the first graduation ceremonies in 1993 with complete regalia and a faculty procession typical of American universities. He also developed good relations with the government officials and representatives of other local universities, no small feat considering the cultural and language differences.

With the heavy workload of running AA, chairing the USC Civil Engineering Department, and the effort required to start AUA, Mihran sold his company to the earthquake instrumentation firm Kinemetrics in 1989.

In 1982 he was inducted into the National Academy of Engineering, and in 1990 he was elected as a foreign member of the National Academy of Sciences of Armenia. In 1995 he received the Ellis Island Medal of Honor for distinguished immigrants, and in 2001 the Movses Khorenatsi Medal from the president of the Republic of Armenia for exceptional achievement in educational development. The Armenian Church recognized him with the Sahag-Mesrob Medal from His Holiness Catholicos Karekin I, the St. Mesrob Medal from His Holiness Catholicos Aram I, and the St. Vartan Medal from His Holiness Catholicos John Bedros XVIII. Other honors include the UC Berkeley Distinguished Engineering

Alumnus Citation (1987), California Institute of Technology Award of Distinguished Alumnus (2000), and honorary doctoral degrees from Yerevan State University (1994), the State Engineering University of Armenia (2003), and Haigazian University in Lebanon (1980).

Mihran retired from AUA in 1997 and from USC in 1998, but remained active in contributing to both institutions in a volunteer capacity. In particular, he was instrumental in helping to build the USC Institute of Armenian Studies and its endowment fund, and he served for many years as a member of the AUA board of trustees. In 2002 he published *AUA: A New Beginning for a New Generation*, a history of the founding and early years of the AUA. In June 2019 the AUA posthumously bestowed upon Mihran its most prestigious award, the Presidential Commendation, for his role in founding the university and for leading it during the critical initial years.

Mike is survived by his wife of 65 years, Elizabeth Apkarian; sons Paul (Kate Nyberg), Bryan (Valina Ghoukassian), and Michael; and four grandchildren.

JOHN F. AHEARNE

1934–2019

Elected in 1996

"For leadership in energy policy and the safety and regulation of nuclear power."

BY PETER D. BLAIR AND MICAH D. LOWENTHAL
SUBMITTED BY THE NAE HOME SECRETARY

JOHN FRANCIS AHEARNE, a leading figure in US and international energy policy and in nuclear power, died peacefully in his sleep March 12, 2019, at the age of 84.

John was born June 14, 1934, and raised in New Britain, Connecticut, where he met his future wife, Barbara, during their senior year of high school. He received a BS in engineering physics in 1957 and an MS in physics from Cornell University in 1958. He began serving in the US Air Force in 1959 and, during his service, completed MA and PhD degrees in physics at Princeton University in 1963 and 1966, respectively.

John was an associate professor of physics at the US Air Force Academy from 1964 to 1969, simultaneously serving as adjunct professor of physics at the University of Colorado Extension and lecturer in physics at Colorado College. Following his resignation from the Air Force as a major after 11 years of service, he served on the civilian staff of the Air Defense Division of the Office of the Assistant Secretary of Defense for Systems Analysis. From 1970 to 1972, he was director of the Tactical Air Directorate, followed by positions as deputy and principal deputy assistant secretary of defense for program analysis and evaluation (1972–77) in the White House Energy Office and deputy assistant secretary of energy for resource applications (1977–78).

John was appointed by President Jimmy Carter to the US Nuclear Regulatory Commission in 1978. He chaired the commission from December 1979 to March 1981, in the wake of the accident at the Three Mile Island nuclear power plant, a critical time for establishing public trust and confidence in the agency as it dealt with complex scientific and engineering issues for public safety. He completed his distinguished career of federal service as a management consultant to the General Accounting Office (now the Government Accountability Office) on long-range planning for GAO's work on nuclear regulation, energy, research, and defense issues.

Upon retirement from federal service, John was involved in a variety of advisory and corporate boards, including the GAO Executive Council on Information Management and Technology, Department of Energy Nuclear Energy Research Advisory Committee, US-Russian Independent Scientific Commission on Disposition of Excess Weapons Plutonium, Wisconsin Energy Corporation, Wisconsin Electric Power Company, and Wisconsin Gas Corporation. He also served as chair of the University of California's President's Advisory Council for the Los Alamos, Livermore, and Berkeley National Laboratories.

In the 1980s he was appointed vice president and senior fellow of Resources for the Future, a Washington think tank, where he remained an adjunct scholar for many years. In 1989 he was recruited to become executive director of Sigma Xi, The Scientific Research Society, into which he had been inducted in 1964. He subsequently served as director of the Society's Sigma Xi Center (1997–99) and of its ethics program (until 2001). The latter position led him to write the popular ethics booklet, *The Responsible Researcher: Paths and Pitfalls* (Sigma Xi, 1999), a companion volume to the society's widely circulated guidebook, *Honor in Science*. John's booklet addresses ethical issues relevant to researchers engaged in all sectors—academia, industry, government, and nongovernmental entities. Sigma Xi recognized John's many contributions to the society by naming him executive director emeritus and featuring him in *American Scientist*'s "100 Reasons to Become a

Scientist or Engineer."[1] During his years at Sigma Xi he was also a lecturer in public policy at Duke University (1995–2006) and adjunct professor (1996–2002).

John's extensive expertise in nuclear energy, security, and risk assessment made him a highly sought-after participant in scores of efforts across the globe addressing reactor safety, international nuclear fuel supply and weapons proliferation, energy issues, comparative risk analysis, and resource allocation. He was a fellow of the American Physical Society, Society for Risk Analysis (president, 2000–01), American Association for the Advancement of Science, and American Academy of Arts and Sciences, and a member of the National Academy of Engineering, Sigma Xi, and the American Nuclear Society.

In addition to his wide-ranging professional associations, John fashioned a whole additional professional life by being an exceptionally productive and involved expert in the advisory functions of the National Academies of Sciences, Engineering, and Medicine (the National Academies). Between 1985 and 2019 he served on some 50 boards and committees, chairing many important ones, and also ensuring the quality of the National Academies' work with a diligent and extensive role in the institution's formal report review process. He was particularly effective in managing and refereeing work on controversial and divisive topics, such as ballistic missile defense, environmental risk management and communication, international security and arms control, nuclear waste and reactor safety, and engineering ethics. One colleague captured the sentiments of many when he said "He was made to be a chairman. Everyone thought he understood their perspective."

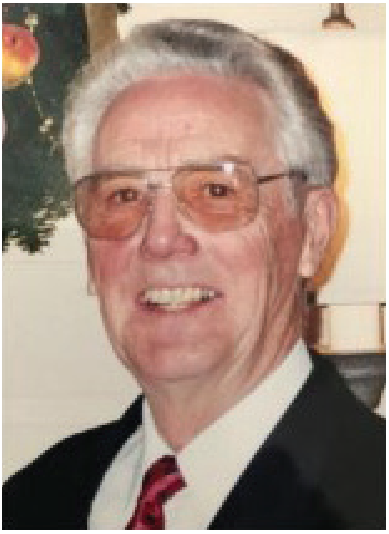
If service to the nation was a central theme and motivator in his career, promotion of international cooperation to address problems of global importance was a major interest evident in decades of engagement with international experts through direct connections and international organizations such as the International Institute of Applied Systems Analysis in Austria, and pursuit of US-Russian cooperation through the

[1] *American Scientist* 100(4):300–05 (2012).

two countries' academies. Working with Nikolai Laverov, vice president of the Russian Academy of Sciences, and several other Russian colleagues, John addressed key challenges that arose from the linked legacies of the US-Soviet Cold War rivalry—nuclear arsenals trained against each other, radioactive waste, environmental contamination—and how best to manage the potential consequences of nuclear energy by improving regulation, design, and practices for safety and proliferation prevention.

John lived a life that emphasized honesty, perseverance, and objectivity. He worked tirelessly in his faith community as well, serving as lector, Eucharistic minister, and on parish boards, steering committees, and the board of directors of the former Woodstock Theological Center at Georgetown University.

John's family was always a priority for him. He was a loving husband, father, and grandfather and proud of his children and grandchildren. He is survived by his wife Barbara; children Tom Ahearne, Paul Ahearne, Mary Ann Ahearne-Ray, Robert Ahearne, and Patricia Ahearne-Kroll; and eleven grandchildren.



STIG A. ANNESTRAND

1933–2018

Elected in 1989

"For outstanding contributions to the development of economical and reliable high-voltage AC and DC transmission technology."

BY VERNON L. CHARTIER

STIG ALVAR ANNESTRAND was a pioneer in the development of both high-voltage alternating and direct current transmission systems. He died March 27, 2018, at age 84.

He was born September 18, 1933, and raised in Darla-Husky, Sweden, where the family farm is still in operation. He graduated in 1958 from the Royal Institute of Technology, Stockholm, with an MS degree in electrical engineering.

He began his technical career at General Swedish Electric Company (ASEA) where from 1962 until 1967 he was manager of research. At that time ASEA was developing hardware and systems for the eventual deployment of high-voltage direct current (HVDC) lines; it operated an HVDC Laboratory at Ludvika and conducted tests on a 300-mile HVDC test line at Chalmers University of Technology in Gothenburg.

In 1967 Stig came with his young family to the Bonneville Power Administration (BPA) in Portland, Oregon, having been recruited for his expertise in high-voltage electrical systems. His first position was in the High-Voltage Unit of the Division of System Engineering, where, thanks to his knowledge and leadership ability, he was made head within months of his arrival. His important contributions in direct-current transmission and surge protection are demonstrated by the technical papers he wrote or cowrote.

In 1974 he was appointed to the newly formed Electrical Investigation Section in the Division of Laboratories. At the time, this division was primarily a testing laboratory and engaged in research only under the direction of engineers from other BPA engineering organizations. Stig's mandate was to greatly improve the quality of the work of the laboratories, which meant the engineers who worked in them for the first time had to write reports on the results of their testing programs. Stig's persistence enabled him to overcome significant resistance not only from these engineers but also from those in other BPA divisions. For the first time BPA's laboratories began producing quality reports and technical papers for publication in journals of the IEEE and other technical publications.

In the early 1970s the Washington Public Power Supply System (WPPSS) had plans to build five nuclear power plants on the east side of the Cascades to meet the projected load growths for the northwest United States. To transmit that power to the large load centers of Seattle and Portland, BPA concluded that there would need to be a higher transmission voltage than 500 kV, the highest operating voltage on the BPA system at that time. Stig and others were heavily involved in the design of a new Ultra-High Voltage Laboratory in Vancouver, Washington, as well as the design of a 1200 kV test line that was built near Lyons, Oregon.

My experience in managing the research at the Apple Grove 750 kV Project (a joint project of Westinghouse Electric and American Electric Power) in West Virginia led Stig to ask me to come work at BPA's laboratories in Vancouver. I agreed and moved my young family from western Pennsylvania to Portland in 1975. Stig was my first supervisor at BPA, and he was the best boss I had during my entire engineering career. As he advanced up the management ladder at BPA, he was not only an outstanding supervisor but he retained his technical curiosity, which he eagerly shared with everyone who worked for him.

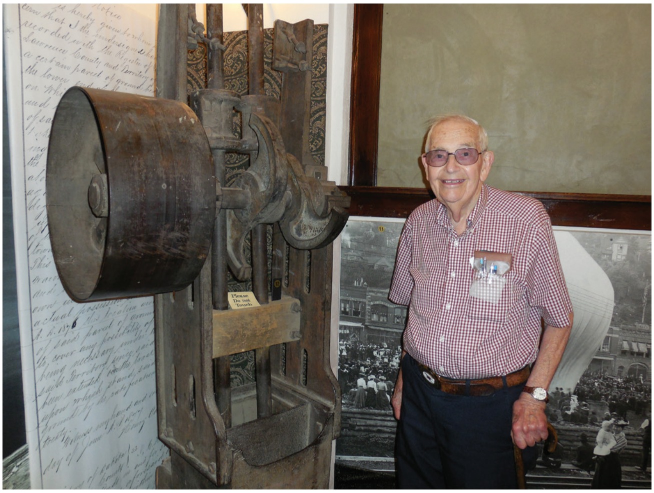
Stig was promoted to assistant director of the laboratories in March 1977 and to director in November, overseeing first-class high-voltage and mechanical laboratories, a chemistry laboratory, and an instrumentation and calibration laboratory. Three years later, in 1981, he was named BPA's manager of research and development, a position he held until his retirement in October 1987.

After he retired, Stig continued to distinguish himself, as an ambassador of technology. Before leaving on a technological mission to Saudi Arabia (1989–93), he was a consulting senior staff engineer with Battelle Pacific Northwest Laboratories.

In addition to his NAE election in 1989, he was elected an IEEE fellow in 1978 and served as an IEEE Congressional Fellow in 1986, assigned to the US House of Representatives Committee on Science, Space, and Technology. He was also fellow and board chair of the Portland-based Institute of Science, Engineering and Public Policy.

Stig was an avid outdoorsman with interests ranging from a weekly tennis match to summitting Mt. Hood. He was a loving husband and father who imparted wisdom and honor to his sons. While raising his boys, he was a scoutmaster, seeing both boys to the level of Eagle Scout. Most importantly, he was a man of integrity whose warm presence brought kindness to all.

Stig was predeceased by his wife of 62 years, Britta Vivi-Ann, on July 17, 2015. He is survived by sons Peter (Linda) and Thomas (Lori), and eight grandchildren.



FRANK F. APLAN

1923–2020

Elected in 1989

"For contributions to education and research in the mineral industry through the integration of theory and practice covering metallic ores, industrial minerals, and coal."

BY DOUGLAS W. FUERSTENAU AND RAJA V. RAMANI

FRANK FULTON APLAN, one of the most influential leaders of the mineral processing industry and academia for 60 years, and Distinguished Professor Emeritus at Pennsylvania State University, passed away peacefully in Berwick, Pennsylvania, on November 3, 2020, at the age of 97.

His association with the mineral engineering profession had many dimensions—engineer, scientist, manager of research, and teacher, to name a few—and his performance in each of these roles was exceptional. Most of all, Frank was an outstanding human being: brilliant, dedicated, gritty, hardworking, and demanding. He expected excellence from himself and from everyone else. His friends learned many lessons about how to accept and deal with adversity from Frank's four difficult but successful campaigns against cancer.

Frank was a warm and friendly person who provided wise counsel and a helping hand. He often said that "no man is an island. There are a half-dozen or more people that probably helped you along in your career…. my philosophy is that often you cannot pay back but you can pay forward…. that is why I've gone out of my way to recommend all kinds of people for awards and honors and so forth and I try to give generously to charity and education."

He was born August 11, 1923, in Boulder, Colorado, to Frank F. and Helen Fischer Aplan, and raised in Fort Pierre, South Dakota, during the decade-long depression, drought, and plague of grasshoppers of the 1930s. His illustrious career in science, engineering, and technology of mineral processing, spanning five universities and five major mineral industry companies, began with an early interest in the chemistry of paints, sparked at the age of 10 by a house painter. To develop his interest in chemistry, his mother bought him a Gilbert "Chemistry Lab." Ever the entrepreneur, Frank charged neighborhood children $0.05 to watch his experiments. All went well until he began extracting hydrogen from water, leading to a small fire….

He entered the South Dakota School of Mines and Technology (SDSM&T) in 1941 in chemical engineering, but interrupted his education to enlist in the army in November 1942. He was extremely proud of his wartime service, serving as an infantryman in a rifle company of the 69th Infantry Division carrying a mortar across Europe, for which he received the Combat Infantryman's Badge and Bronze Star Medal. Discharged as a technical sergeant in 1946, he returned to SDSM&T and completed his BS degree in metallurgical engineering in 1948; 2 years later he got an MS in mineral processing engineering from Montana School of Mines (later known as Montana Tech).

In 1948–51 Frank worked at Homestake, Day Mines, and Climax Molybdenum, and from 1951 until 1953 as an assistant professor at the University of Washington (Seattle). From there he enrolled in the Massachusetts Institute of Technology as a graduate student in mineral engineering (metallurgy), receiving his ScD in 1957 for a classic piece of work on the thermodynamics of the adsorption of hexyl mercaptan on gold. While at MIT, he met Clare Marie Donaghue of Dorchester, Massachusetts; they married July 30, 1955.

Upon graduation, Frank joined the research staff of Kennecott Copper in Salt Lake City as a senior scientist but soon accepted an offer from Union Carbide as research engineer in the research laboratories of Electrometallurgical

Company in Niagara Falls as he felt "they had an excellent laboratory…there were close to two hundred people there.… It was the best postgraduate school in the field." By 1968 Frank had risen to group manager and was closely involved in the development of processing a wide range of ores for Carbide's domestic and international production of a multitude of metals and nonmetals; his experience led him to justly claim "you name the commodity, and I have probably worked with it one time or other." He traveled to many of these operations, particularly in their development and early operational stages, gaining the skill for which he later became an acknowledged leader—integrating theory with practice in the processing of coal, ores, and industrial minerals.

Frank joined Penn State in 1968 as professor and head of the then Department of Mineral Preparation and moved quickly to enlarge the research program on the science and technology of mineral processing, particularly in the area of coal flotation, motivated by the importance of coal mining to the state of Pennsylvania. In addition, he initiated new programs in particle technology, applied surface chemistry, chemical processing, and mathematical modeling of processes. By the time he retired in 1992, he had also served as the chair of mineral processing and metallurgy programs and a guiding member of the newly formed Environmental Systems Engineering Program in the Department of Mineral Engineering.

The growth of the Penn State Mineral Processing Program to preeminence was primarily attributable to Frank's breadth and depth of academic and industrial experiences and his outstanding leadership in attracting and fostering young faculty to become leaders themselves. This was perhaps stated best by Kwadwo Osseo-Asare, Distinguished Professor of Material Sciences and Engineering: "I'm on the Penn State faculty today because of Prof. Frank Aplan, a giant in our field. He brought me to Penn State…. I mourn the departure of a kind, humble, and transparent mentor.… I write with tears in my eyes, of sorrow and also of gratefulness."

Frank supervised about 50 MS and PhD candidates and developed and taught several new undergraduate and graduate courses to hundreds of students from several other programs. He was a demanding but master teacher, and undergraduate students loved his classes and insightful stories of plant experiences that he sprinkled throughout his lectures. In directing graduate students, his principal aim was to develop in them self-reliance and independence, qualities he knew from his own experience to be key to success and in which he excelled. Even after he retired he remained active at PSU for more than a decade, teaching classes, directing students, and attending technical meetings.

Penn State recognized Frank's outstanding performance with the Matthew J. and Anne C. Wilson Excellence in Teaching Award in 1977 and named him to the first class of Distinguished Professors in 1990. At the national level, his outstanding teaching was recognized in 1992 with the AIME Mineral Industry Education Award.

At the time of his retirement, the Frank F. and Clare M. Aplan Centennial Scholarship in Mineral Engineering was established and endowed at Penn State to celebrate Frank's contributions and encourage future generations to follow his lead. At SDSM&T, Frank and his wife had established the Frank F. and Clare M. Aplan Native American Fund in Metallurgy to support a scholarship for native Americans to attend the school.

Frank was a world authority on flotation processes, especially known for his fundamental studies of the wetting of solids and their control through the adsorption of surfactant films and for his work on the effect of atomic defects on the properties and behavior of solid-liquid interfaces. His contributions to the areas of gravity concentration, suspension rheology, industrial mineral processing, and environmental pollution control are particularly noteworthy. He also emphasized environmental remediations by building on the past strengths of the existing academic program and an increased environmental emphasis in all courses. This was a logical extension of the program because the separation of metals and glass from municipal solid waste, the removal of acids and metals from water, and the trapping of fine particles from industrial off-gases all require techniques that extractive metallurgical engineers were using long before environmentalism became popular.

In addition to his academic engagement he was a major contributor to the affairs of professional societies and to technical symposia and congresses. He belonged to the American Institute of Mining, Metallurgical, and Petroleum Engineers (AIME); Society for Mining, Metallurgy, and Exploration (SME); Metallurgical Society (now the Minerals, Metals and Materials Society; TMS); Engineering Foundation; American Chemical Society; American Institute of Chemical Engineers; and Archeological Institute of America. His services to each of them, in both the trenches and leadership, were extensive. He was a member of the board of directors of SME and the Engineering Foundation; chair of the SME Mineral Processing Division and TMS Hydrometallurgy Committee; member of the editorial board, coeditor, and section editor for major books including *Mineral Processing Handbook* (SME), *Froth Flotation* (SME), and the proceedings of the 1974 Solution Mining Symposium[1]; and a program evaluation visitor for the Accreditation Board for Engineering and Technology (ABET) for mineral processing (SME) and metallurgy (TMS) programs. In addition, he authored, presented, and published over 150 research papers in prestigious journals and national and international symposia that would continue to illuminate mineral processing aspirants with his findings and knowledge.

Frank was very active in the Engineering Foundation. He chaired a conference on fine and ultrafine particles in 1967 and served on a number of conference committees beginning in about 1975. He was a member of the foundation's board of directors from 1977 onward, and his dedicated and distinguished service as board chair (1987–89) was recognized by the foundation's creation, in 1989, of the annual Frank F.

[1] Aplan FF, McKinney WA, Pernichele AD. 1974. *Solution Mining Symposium.* New York: American Institute of Mining, Metallurgical, and Petroleum Engineers.

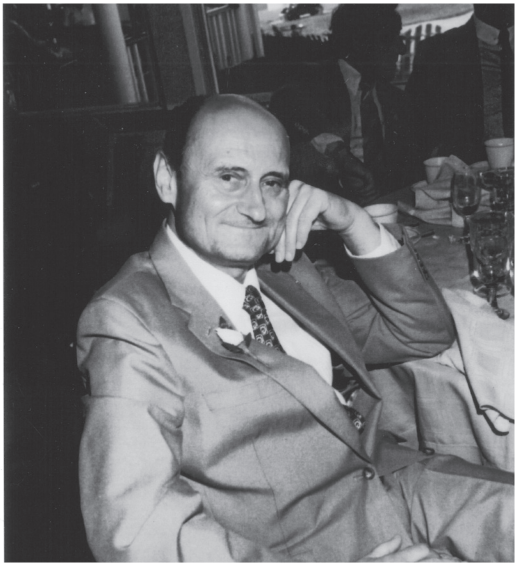
Aplan Award as a tribute to his "lifelong productive career in coal and mineral processing research and education," to be awarded to eminent contributors to the mineral processing field. Frank was the first recipient.

Mineral processing researchers around the world celebrated his role in their lives and in the field of mineral processing by contributing papers to a special volume of the *International Journal of Mineral Processing* (vol 17(3–4), 1998) in honor of his 75th birthday. And in 2003 Frank's oral history, *Mineral Education Generalist, Professor of Metallurgy and Mineral Processing, 1951–1998*, was published by the Oral History Center of the Bancroft Library at the University of California, Berkeley, as part of the Western Mining in the 20th Century series.

Frank's contributions to the science, engineering, and education of mineral processing were widely acknowledged by his peers with a number of honors: honoris causa, Engineer of Mines, Montana School of Mines and Technology (1968); distinguished member of SME and Robert H. Richards Award of AIME (both in 1978); Arthur F. Taggart Award of SME and Centennial 100 Alumni of the South Dakota School of Mines and Technology (both in 1985); election to the NAE (1989); honorary member of AIME and Antoine M. Gaudin Award of SME (both in 1992); SDSM&T Distinguished Alumnus Award and Guy E. March Medal (both in 1996); AIME/ASME Percy Nichols Award (1997); South Dakota Hall of Fame (1998); Chancellor's Medallion, Montana Tech (2015); and election to the National Mining Hall of Fame (2016).

For all Frank's name and fame in the profession, he was a very modest, devoted family man. Outside of work, he was a devout Catholic, a soldier, a gardener, an avid photographer, a jazz aficionado, and a philanthropist. Other interests included reading, theater, crawling around most of the old mills and ghost mining camps of the West, mining history of the western United States, the US military, and the railroad. His keen sense of humor and repertoire of stories and anecdotes always contributed to an enjoyable time in his company. He will be missed.

Frank was preceded in death by his wife of 55 years, Clare, and daughter Margaret Anne (in childhood). He is survived by daughters Susan Bower and Lucy, son Peter, five grandchildren, and four great-grandchildren.



EGON BALAS

1922–2019

Elected in 2006

"For contributions to integer programming and its applications to the scheduling and planning of industrial facilities."

BY GÉRARD CORNUÉJOLS

EGON BALAS' life reads like an adventure tale. Born June 7, 1922, in Cluj, Romania, into a Jewish Hungarian family, he wanted to study physics but was blocked by anti-Semitic laws. Determined to fight Nazism, he joined the underground Hungarian Communist Party, distributing leaflets and helping to organize a strike. He was arrested by fascist Hungarian authorities in 1944, tortured, and thought he would be killed. Sentenced to 14 years of hard labor, he escaped during transport to Germany and made his way home, where he learned that all of his immediate family had been killed along with most of the 18,000 Jews who had lived in Cluj before the war. In 1948 he married Edith Lovi, herself a Holocaust survivor who had returned home to Romania after being released from Auschwitz at the end of the war. They were married for 70 years.

After the war and still in the Communist Party, Balas taught himself economics and changed his birth name from Blatt, a common Jewish surname, to Balas in order to serve in the Romanian government as economics director in the Ministry of Foreign Affairs. During a power struggle in 1952 he was arrested by party leaders, put in solitary confinement for more than 2 years, and subjected to interrogations and torture. Upon his release he was expelled from the Communist party.

In 1959 Balas started a career in mathematics at age 37. He had joined the Forestry Institute in Bucharest, which planned and scheduled timber harvesting in Romania. To develop appropriate logistics tools, he became an autodidact, learning mathematics and operations research from books he could get his hands on. Peter Hammer, who was to become a prominent operations researcher himself, was also working at the Forestry Institute at the time. Together they developed tools for transportation planning based on network flow theory and linear programming. They published a dozen papers together (Hammer was using the name Ivanescu at the time), mostly in Romanian.

In 1962 Egon confronted an interesting variation on the wood harvesting problem: In one area of the forest, a network of roads had to be built in order to access various plots. Decisions about which plots to harvest and where to build roads were intricately connected and required logic: If road segment A were built, then road segment B would also have to be built to reach A. Egon formulated the problem as a linear program in 0,1 variables, recognizing the versatility of this model for a wide range of applications.

There was no computer code to solve 0,1 programs at the time, so he designed his own algorithm, simple enough that instances with about 30 binary variables could be solved by hand. The algorithm performed an implicit enumeration of the solution set, relied on a series of logical tests that explored the implications of fixing certain variables to 0 or 1, and the only operations needed were additions and comparisons. Balas' algorithm can be viewed as a precursor of constraint propagation in constraint programming.

The work was presented to the research community in the West at the International Symposium in Mathematical Programming in London in 1964. The Romanian government would not allow Egon to travel to England to present his paper, so his talk was read by a colleague at the conference. This was one of the many constraints that led to Balas' disillusionment with communist Romania.

The same year a short version of his paper was published in *Comptes Rendus de l'Académie des Sciences*, Paris. The full-length paper was published in 1965.[1] It was extremely influential in the development of integer programming, establishing implicit enumeration and branch-and-bound as a simple and powerful solution method. In fact, it was identified in the early 1980s as the most cited paper in *Operations Research* (citation classic in *Current Contents 1982*).

By the early 1960s, the oppressive conditions and lack of freedom in Romania had become intolerable and Egon applied to emigrate. His application was denied several times, with increasing hardship on the family. Finally, he and his wife and two daughters were granted permission to emigrate in 1966. By then Balas had achieved some visibility in the West thanks to his work on the additive algorithm. He first went to Rome, where he spent 6 months as a research fellow at the International Computation Center, headed by Claude Berge. During this period he also managed to earn two doctorates, one in economics from the University of Brussels and the other in mathematics from the University of Paris.

The next year, in 1967, Egon was offered a professorship at Carnegie Mellon University. Bill Cooper, one of the founders of the Graduate School of Industrial Administration, was key in this brilliant recruitment decision. He was very familiar with Balas' recent research accomplishments as he had been associate editor of *Operations Research* in charge of handling his paper on the additive algorithm. Egon was forever grateful to Carnegie Mellon for the stability that this position provided to his family.

His most significant contribution is undoubtedly his extensive work on disjunctive programming, starting with intersection cuts.[2] These ideas were novel and the operations research community was slow to accept them.

Cutting planes had been introduced by Dantzig, Fulkerson, and Johnson (1954) and Gomory (1958). But by the late 1960s

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[1] Balas E. 1965. An additive algorithm for solving linear programs with zero-one variables. *Operations Research* 13:517–46.

[2] Balas E. 1971. Intersection cuts: A new type of cutting planes for integer programming. *Operations Research* 19:19–39.

and throughout the 1970s and 1980s, the general sentiment regarding the practicality of general cutting planes had become rather negative, in great part due to the success of branch-and-bound algorithms such as the additive algorithm.

Balas understood that enumeration was inherently exponential in complexity and that it could tackle only small or medium-size instances. He felt that the real potential was in convexifying the feasible set, potentially reducing an integer program to a simpler linear program. He also found that theory was lacking.

Using tools of convex analysis, he showed how to derive rich families of cutting planes from any feasible basis of a linear relaxation and any convex set *S* whose interior contains the basic solution but no feasible integer point. These cuts are Balas' intersection cuts. When the convex set is the region between two parallel hyperplanes, one recovers Gomory's mixed integer cut as a special case. Egon observed that intersection cuts derived from polyhedral sets *S* can be understood using an alternate point of view: If the polyhedron *S* is defined by linear inequalities, then the requirement that no feasible point is in the interior of *S* can be described through a disjunction of the reverse inequalities. The feasible region can then be regarded as a union of polyhedra.

This new viewpoint gave rise to important generalizations. It motivated Balas to introduce disjunctive programming, defined as optimization over a union of polyhedra. He proved two fundamental results on disjunctive programs that have far-reaching consequences for the solution of linear 0,1 programs.

First, there is a compact representation of the convex hull of the union of polyhedra in a higher-dimensional space. Projecting back onto the original space gives a full description of the convex hull, so one can compute a deepest disjunctive cut by solving a linear program. The number of variables and constraints in the higher-dimensional representation only grows linearly in the number of polyhedra, which makes this a practical tool when the number of disjunctions is not too large.

Second, for a large class of disjunctive programs, called *facial*, the convexification process can be performed sequentially.

For example, 0,1 programs are facial disjunctive programs: If there are *n* 0,1 variables, the convex hull of the solution set can be obtained in *n* steps, imposing the 0,1 conditions one at a time. This distinguishes 0,1 programs from more general integer linear programs. These theorems were proved in a technical report in 1974.[3] Unfortunately, the significance of the results was not recognized by the referees at the time and the paper was rejected for publication. Twenty-four years later the importance of Balas' pioneering work had finally become clear, and the technical report was eventually published as an invited paper in 1998.

In the spring of 1988 László Lovász gave a beautiful talk at the Mathematisches Forschungsinstitut Oberwolfach about his work with Lex Schrijver on cones of matrices. Sebastian Ceria, who was just starting his PhD at Carnegie Mellon, and I decided to investigate what would happen if one performed the Lovász-Schrijver operation sequentially, one variable at a time, with the idea of making it more practical for implementation. We were very excited to realize that, as in the full Lovász-Schrijver procedure, our simplified lift-and-project procedure still generated the convex hull in *n* steps for a problem with *n* 0,1 variables. When we showed this result to Egon, his reaction was immediate: "There is nothing new under the sun. This is the sequential convexification theorem!" He was right, of course; there was a nice connection between our streamlined version of the Lovász-Schrijver procedure and disjunctive programming.

This connection was very fruitful, providing a perfect framework for cut generation. Sebastian, Egon, and I had much fun collaborating on this project.[4] We developed the mixed-integer program optimizer, which incorporated lift-and-project cuts

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[3] Balas E. 1974. Disjunctive programming: Properties of the convex hull of feasible points. Management Sciences Research Report No. 348, Carnegie Mellon University, July 1974. Published in 1998 as an invited paper in *Discrete Applied Mathematics* 89:3–44.

[4] Balas E, Ceria S, Cornuéjols G. 1993. A lift-and-project cutting plane algorithm for mixed 0-1 programs. *Mathematical Programming* 58:295–324.

in a branch-and-cut framework. The success of lift-and-project cuts motivated us to try other general-purpose cuts, such as the Gomory mixed-integer cuts. These cuts had a bad reputation, with repeated claims in the literature that they perform poorly in practice. So we were very surprised to discover that they worked very well.[5] The sentiment about general cutting planes changed overnight in the integer programming community. By the late 1990s, all commercial solvers for mixed-integer linear programs were using a battery of general-purpose cuts, resulting in significant improvement in the size of instances that could be solved optimally.

Egon Balas' research contributions span a broad range of topics. On the subject of disjunctive cuts, additional aspects include monoidal cut strengthening,[6] the efficient generation of the cuts,[7] and other directions such as generalized intersection cuts. At age 96, Balas wrote his first (and only) textbook, *Disjunctive Programming* (Springer, 2018), presenting the advances in this area over nearly 5 decades.

Egon also made noteworthy research contributions to the knapsack and set-covering problems and in the area of scheduling: machine scheduling via disjunctive graphs, the shifting bottleneck procedure for job shop scheduling (with Joe Adams and Dan Zawack), choosing the overall size of the US strategic petroleum reserve, the prize-collecting traveling salesman problem, and an application for scheduling rolling mills in the steel industry (with Red Martin), among others.

His contributions were recognized through numerous prizes and honors. He received the US Senior Scientist Award of the Alexander von Humboldt Foundation (1980), John von Neumann Theory Prize of INFORMS (1995), EURO Gold Medal of the European Association of Operational Research

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[5] Balas E, Ceria S, Cornuéjols G, Natraj N. 1996. Gomory cuts revisited. *Operations Research Letters* 19:1–9.

[6] Balas E, Jeroslow RG. 1980. Strengthening cuts for mixed integer programs. *European Journal of Operations Research* 4:224–34.

[7] Balas E, Perregaard M. 2003. A precise correspondence between lift-and-project cuts, simple disjunctive cuts, and mixed integer Gomory cuts for 0-1 programming. *Mathematical Programming B* 94:221–45.

Societies (2001), and Harold Larnder Prize of the Canadian Operations Research Society. In addition he was elected an INFORMS fellow (2002) and external member of the Hungarian Academy of Sciences (2004), inducted into the IFORS Hall of Fame (2006), and elected a member of the NAE (2006), a corresponding member of the Academy of Sciences of Bologna, Italy (2011), and a SIAM fellow (2016). He received honorary doctorates from Miguel Hernández University of Elche, Spain (2002), University of Waterloo, Canada (2005), and University of Liège, Belgium (2008).

Urged by his wife, Edith, Balas wrote a well-received memoir, *Will to Freedom: A Perilous Journey Through Fascism and Communism*, published in 2000 by Syracuse University Press and available in six languages.

Egon died March 18, 2019. He is survived by Edith, professor emerita of art history in the College of Humanities and Social Sciences at Carnegie Mellon University; daughters Anna Balas and Vera Balas Koutsoyannis; three grandchildren; and four great-grandchildren.

Egon Balas was a good friend and colleague (as well as a great tennis partner—he was still a formidable player in December 2018, a few months before his death).

GRIGORY I. BARENBLATT

1927–2018

Elected in 1992

"For major contributions to understanding flow of fluids through fractured porous media that have aided production of gas and oil worldwide."

BY EMMANUEL DETOURNAY, CHRISTINE EHLIG-ECONOMIDES, AND YANNIS C. YORTSOS

GRIGORY ISAAKOVICH BARENBLATT died in Moscow on June 22, 2018, at the age of 90.

He was born in Moscow on July 10, 1927, to parents who were accomplished in medicine. His mother, Nadezhda Veniaminovna Kagan, was a virologist who developed a vaccine against viral encephalitis (unfortunately, she contracted and died from the disease); his father, Isaak Grigorievich Barenblatt, was an endocrinologist.

Grigory graduated in 1950 from Lomonosov Moscow State University (MGU), Faculty of Mechanics and Mathematics, and in 1953 successfully defended his PhD thesis, under the guidance of Andrei N. Kolmogorov—one of the most influential mathematicians of the last century—and his DSc thesis in 1957. He became a professor at MGU and then head of the Plasticity Department of the Institute of Mechanics (1961–75).

Over the decades Barenblatt held a number of positions at the USSR Academy of Sciences. He worked at the academy's Institute of Petroleum (1953–61). He took part in the creation and was deputy director of the Institute of Problems in Mechanics (1965). He later served as head of the Theoretical Department at the Institute of Oceanology (1975–92).

The authors drew on the obituary for G.I. Barenblatt published in the *European Mathematical Society Newsletter* 2018-9(109):33–38.

Many of us knew him for his beautiful work on self-similarity, particularly in flows in fractured and porous media, and on intermediate asymptotics, a domain he founded following his PhD work. His partnership with another mathematician of note, Yakov Zeldovich, led to the discovery of the relationship between similarity and asymptotics, and its applications to fluid flow in porous media, among other areas. (Interestingly, Barenblatt was also the son-in-law of Pelageia Yakovlevna Polubarinova-Kochina, another giant of applied mathematics, who contributed significantly to understanding of flow in porous media.)

Barenblatt contributed pioneering work in flow in fractured media, including the classic text on naturally fractured reservoir characterization (introduced in Western literature by Warren and Root, 1963). That work became the standard for conceptual models used both for pressure transient analysis and for numerical simulation models. He also provided key insights in the modeling of cracks in brittle media, hydraulic fracture, flow of groundwater, nonequilibrium two-phase flow in porous media (capillary imbibition, water-oil displacement, and solid phase precipitation), and the mathematical modeling of gas-condensate flow in fractured porous media. In parallel, he developed a large body of work on turbulent flows, nonlinear waves, intermediate asymptotics, the stability of self-similar solutions and traveling waves, and the theory of combustion.

With the fall of the Soviet Union, Barenblatt traveled overseas, as did many of his contemporaries and colleagues, including another notable mathematician with interests in subsurface fluid flow, the late Vladimir Entov, whom one of us (YCY) hosted in 1991. Together with Entov and V.M. Ryzhik, Barenblatt coauthored the monograph *The Motion of Fluids and Gases in Natural Rocks* (in English) (Kluwer, 1990).

But to us, his most original and insightful book was *Scaling, Self-Similarity, and Intermediate Asymptotics* (foreword by Y.B. Zeldovich) (in English; Plenum Press, 1979; Cambridge University Press, 1996). It opened up a new (and beautiful) way to view the development of similarity solutions in a number of nonlinear partial differential equations.

He became the G.I. Taylor Professor of Fluid Mechanics at the University of Cambridge in 1992 (and subsequently held the title emeritus). Over several years he did stints as a visiting professor at the University of Rome Tor Vergata (1992), Universidad Autónoma de Madrid (1993, 1996), and University of Minnesota (1994).

In 1996 he joined the University of California, Berkeley, as a visiting professor, later becoming professor in residence; he held a concurrent position at the Lawrence Berkeley National Laboratory (LBL). It is at UC Berkeley that one of us (YCY) met him at an LBL seminar on February 10, 1999, on flow and displacement in fractured rock, organized in honor of the 80th birthday of another giant in the field, the late Paul Witherspoon. Grigory's enthusiasm on the subject and his immense curiosity about other people's approaches were contagious. His communications often inquired about different approaches and methods in a variety of problems in porous media.

In addition to his election as a foreign member of the NAE, Barenblatt was an international member of the US National Academy of Sciences, American Academy of Arts and Sciences, and Royal Society of London, as well as scientific societies in other countries. Among his many awards are the Lagrange Prize of the Accademia Nazionale dei Lincei (1995), G.I. Taylor Medal of the US Society of Engineering Science (1999), J.C. Maxwell Medal and Prize of the International Congress for Industrial and Applied Mathematics (1999), and Timoshenko Medal of the American Society of Mechanical Engineers (2005).

He returned to Moscow in his last years and is survived by daughters Nadezhda Kochina and Vera Kochina.

BRUNO A. BOLEY

1924–2017

Elected in 1975

"Contributions in research and teaching in applied mechanics, particularly on thermal stress analysis and on dynamical problems."

BY FRANK DiMAGGIO
SUBMITTED BY THE NAE HOME SECRETARY

BRUNO ADRIAN BOLEY, who died at age 92 on February 11, 2017, was a distinguished figure in engineering mechanics, as both a scientist and an administrator.

He was born May 13, 1924, in Gorizia, Italy, with the original family name Bolaffio. After a hurried exit from Italy to escape anti-Semitic laws and a circuitous trip through Europe, his family arrived in the United States in 1939. A change in family name and a quick high school experience followed.

He earned a BS in civil engineering from the City College of New York in 1943 and in 1945–46, as a student of the eminent Nicholas Hoff, an MS and ScD in aeronautical engineering from the Polytechnic Institute of Brooklyn, where he remained as assistant professor until 1948.

After practicing engineering at Goodyear Aircraft for 2 years, he returned to academia as assistant professor of aeronautical engineering at the Ohio State University until 1952, associate and then full professor of civil engineering at Columbia University until 1968, J.P. Ripley Professor and chair of the Department of Theoretical and Applied Mechanics at Cornell University until 1972, and Walter P. Murphy Professor and dean of the Technological Institute of Northwestern University until 1986, when he returned to stay at Columbia.

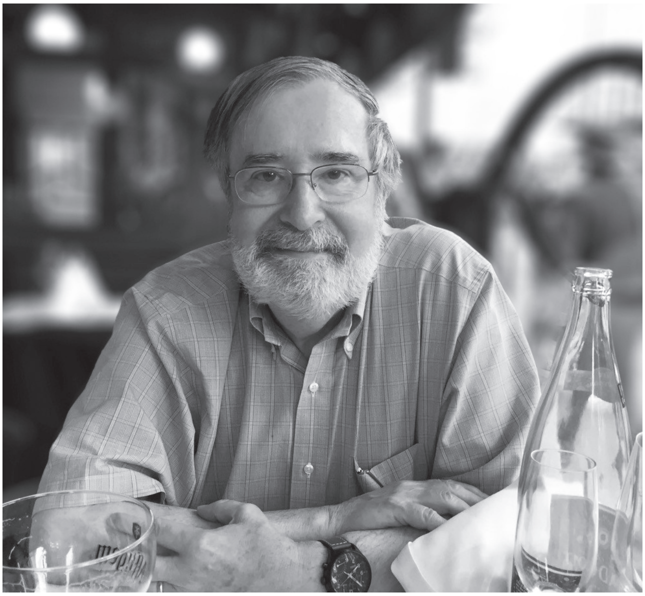
He made significant contributions in a wide spectrum of applied mechanics, reported in over 100 technical papers, but his most important work, for which he received international recognition, was in the analysis of thermal stresses, much of which was exhibited in the classic treatise *Theory of Thermal Stresses*, which he coauthored with Jerome H. Weiner (Wiley, 1960; reprinted by Dover in 2011).

Concurrently with his scientific work, he was involved with many governing bodies and technical societies in mechanics. He was founder of the Association of Chairmen of Departments of Mechanics, editor in chief of the journal *Mechanics Research Communications*, and served as president of the American Academy of Mechanics and the Society of Engineering Science. He was on the board of governors of the American Society of Mechanical Engineers (ASME) and Argonne National Laboratory, and was chair of the US Committee on Theoretical and Applied Mechanics.

In recognition of his contributions he was elected to the National Academy of Engineering in 1975, and in 1991 received both the Worcester Reed Warner Medal from ASME and the Theodore von Kármán Medal from the American Society of Civil Engineers.

Professor Boley's interest in intellectual areas outside his principal discipline was eclectic. He had a particularly deep knowledge of European (especially Italian) literature and history, and was an accomplished public speaker.

He was predeceased by his wife Sara (née Kaufman) and daughter Jacqueline, and is survived by his son Daniel and a granddaughter.



EDMUND M. CLARKE

1945–2020

Elected in 2005

"For contributions to the formal verification of hardware and software correctness."

BY RANDAL E. BRYANT

EDMUND MELSON CLARKE JR., formerly the FORE Systems University Professor of Computer Science at Carnegie Mellon University and cowinner of the 2007 ACM Turing Award, died December 22, 2020, of covid-19, after a long illness. He was 75.

Ed was born July 27, 1945, and grew up in Smithfield, Virginia, before attending the University of Virginia and studying mathematics; he got his bachelor's degree in 1967. Following receipt the next year of a master's degree in mathematics from Duke University, he switched to computer science and earned a PhD from Cornell University in 1976. From there he went on to faculty positions at Duke and Harvard until he was hired in 1982 in the Computer Science Department at Carnegie Mellon University (CMU), where he remained until his retirement in 2015.

Early in his career, Ed took on the challenge of finding ways to ensure that hardware and software systems operate as they should, especially systems that must handle multiple activities with uncertain timing. While at Harvard, he and his graduate student Allen Emerson devised an approach they called "model checking" and published their first paper on the topic in 1981. Their idea was to describe the possible actions of a system in *temporal logic*, a formal notation for describing events occurring in time without explicitly using time values. For example, temporal logic can encode the statement "If a car approaches a traffic light, the light will eventually turn green." A model checker then exhaustively considers all possible ways the system can operate and either determines that all of them satisfy the specification, or it provides a specific case where the system may misbehave. This "counterexample" can then be used by the designer in debugging the system design.

Model checking was a novel idea when introduced. At the time, to formally verify computer systems, methods researchers were simply using extensions of methods that humans used to prove mathematical statements, in terms of lemmas, theorems, and their proofs. Model checking did not require any human reasoning or intervention. It took advantage of the power of computers to systematically consider the many cases that could arise during system operation.

The original model checkers were limited to very simple systems and protocols, since the number of possible states of a system can grow exponentially with the number of memory elements—a single 64-bit computer word can have over 10^{19} different values. This limitation was overcome in 1987 when Ed's graduate student Ken McMillan recognized that the analysis required for model checking could be performed symbolically, without explicitly enumerating state values. Just as Pythagoras didn't have to prove that $a^2 + b^2 = c^2$ by drawing and measuring a bunch of right triangles, a symbolic model checker can encode the possible states of a system in symbolic form and manipulate these representations algorithmically. In this case, Ken made use of the ordered binary decision diagram (BDD) representation and algorithms that I had published the year before.

Symbolic model checking became a breakthrough technology for the computer industry. Major companies, such as IBM, Intel, and Fujitsu, developed their own model checkers and applied them to their system designs. They were especially effective at verifying the then new protocols used by multiprocessor systems to maintain a consistent memory state, despite having values stored across multiple cache memories.

In 2002 a group at Microsoft Research devised a model checker for abstracted forms of software, enabling them to automatically verify the operating system code used to operate external devices. This tool was made available to the large number of third-party software developers writing device drivers for the Windows operating system. Use of this tool vastly decreased occurrences of the "blue screen of death" when the computer reached a deadlock condition.

Ed, his graduate students, and his postdoctoral researchers remained at the forefront of model checking research. Starting in 2009, Ed led the NSF-sponsored Computational Models and Analysis for Complex Systems Center, which applied model checking and related methods for software verification to problems in the areas of pancreatic cancer modeling, atrial-fibrillation detection, distributed automotive control, and aerospace control software. His PhD students and former postdocs have gone on to successful academic and industry careers throughout the world.

Over his career, Ed was recognized with many awards and honors, both for his intellectual contribution of model checking (and the vast research community it engendered) and for the practical impacts of his ideas on real-world hardware and software. He received the 2004 IEEE Harry H. Goode Memorial Award "For significant and pioneering contributions to formal verification of hardware and software systems, and for the profound impact these contributions have had on the electronics industry." The next year he was elected to the NAE. In 2007 the ACM Turing Award—sometimes referred to as the "Nobel Prize of Computer Science"—was presented jointly to him, Allen Emerson, and Joseph Sifakis of France, who had independently devised an approach very similar to model checking around the same time as Clarke and Emerson. They were cited "for their role in developing model checking into a highly effective verification technology that is widely adopted in the hardware and software industries." Ed also received the International Conference on Automated Deduction (CADE) Herbrand Award for Distinguished Contributions to Automated Reasoning (2008), and in 2014 the

Bower Award and Prize for Achievement in Science from the Franklin Institute. He was elected to the American Academy of Arts and Sciences and was a fellow of the ACM and IEEE.

Ed is survived by his wife, Martha, whom he met in high school. They were married for over 50 years. Their three sons have had successful careers themselves: James, director of Quantum Hardware at Intel Corporation in Portland, Oregon; Jonathan, a professor in the business school at Georgia Tech; and Jeffrey, an oncologist at Duke University Hospital. There are currently six grandchildren. Ed was an active member of the Mt. Lebanon United Methodist Church.

ARCHIE R. CLEMINS

1943–2020

Elected in 2006

"For the creation and initial fielding of the US Navy's transformational use of information, which has enabled net-centric operations."

BY JAMES O. ELLIS JR.
WITH CONTRIBUTIONS FROM
HIS COLLEAGUES, FAMILY, AND FRIENDS

Retired US Navy Admiral ARCHIE RAY CLEMINS, oldest child of Archie Cornell Clemins and Earline Pepple Clemins, died at home in Boise, Idaho, on March 14, 2020, at the age of 76, in the presence of his loving family.

Born November 18, 1943, in Mount Vernon, Illinois, Archie graduated from Urbana High School and received both his bachelor of science and master of science degrees in electrical engineering from the University of Illinois at Urbana-Champaign.

Commissioned into the US Navy through the Naval Reserve Officer Training Program, he completed the Naval Nuclear Power Program and served on both ballistic missile and attack submarines before tours as the executive officer on the USS *Parche* (SSN 644) and commanding officer of the USS *Pogy* (SSN 647).

As he rose through the Flag (Admiral) ranks in the Navy, follow-on commands included Commander–Submarine Group Seven (Yokosuka, Japan), Commander–Pacific Fleet Training Command (San Diego), Deputy Commander–US Atlantic Fleet (Norfolk, Virginia), and Commander–US Seventh Fleet (Yokosuka). Upon promotion to the rank of 4-Star Admiral, he assumed command of the US Pacific Fleet (Pearl Harbor).

Archie Clemins was a quiet combatant during a time of wars both hot and cold and when the difference between the two was often just a matter of semantics. His critical early leadership roles encompassed some of the most demanding of Cold War operational scenarios, and he became known throughout the submarine force as a man of extraordinary competence, integrity, moral courage, and calm in the most stressing circumstances.

Despite all his professional success, Archie always believed that his most important job was to produce the leaders of tomorrow. Known for his ability to turn around failing or flailing organizations, his impact as a charismatic leader at the tactical and operational level was far reaching and shaped a generation of submariners, many of whom rose to operational leadership or command positions themselves. To this day, the lore of those junior officers and sailors that he taught, mentored, and led is filled with comments such as "All I needed to know, I learned from Archie Clemins." They have produced a litany of his questions and principles that, while they have the sound of aphorisms, are reflective of the standards Archie set for himself, the trust he placed in subordinates, and the exceptional and unique way in which he led and served others. They include: "You're either getting better or worse; there's no such thing as staying the same"; "I don't want someone who tells me what he can't do. I want someone who tells me what he can do"; and, in times of constrained budgets, "There is always enough money if you really need something. You just have to find it." My personal favorite, which Archie would quietly and patiently say after any less-than-positive outcome, is: "What did you learn?"

Archie touched the lives of so many in the Navy, and, in many cases, inspired them to their own careers of service. In the words of Jack Burdick, Chief of the Boat (COB; senior enlisted leader) in Archie's first submarine command and his lifelong friend: "In my first conversation as COB Archie told me the Navy has sent us the best and the brightest and it was our responsibility to challenge them every day, to not only do their best but always do the right thing. He didn't tell us what the right thing was, he showed us. He set high standards for himself and inspired us to do the same.… Archie Clemins never took credit for accomplishments and success. It was always the crew that was given the credit."

For Archie, the coin of the realm was *trust*. He was an outstanding teacher and mentor who also knew, perhaps instinctively and often before you knew yourself, when to allow you to make your own choices and spread your wings. Though I suspect he was often quietly watching from the sidelines, his joy and greatest reward lay in seeing you succeed and then ensuring that you and your team received the lion's share of the credit.

Known as a visionary and tech-savvy leader, Admiral Clemins is widely credited with bringing Naval operations into the digital age in the 1980s and 1990s. The late Senator Daniel Inouye called him "the father of Naval high technology" as a tribute to Archie's role in implementing the Navy's Information Technology for the 21st Century program (IT-21). Most of the shipboard innovations in computers for command, control, communications, and intelligence (C4I) that entered the fleet so significantly and impactfully in those years can be traced to his inspired vision for how the fleet could and should operate differently.

He retired from the Navy in December 1999 after 34 years of active duty service. Admiral Clemins and the commands he led received many military honors, including two Presidential Unit Citations, three Distinguished Service Medals, seven Legions of Merit, the Meritorious Service Medal, and awards from the governments of Japan and Korea. Again, always known for accepting responsibility but sharing credit, he was quoted in his CINCPACFLT biography as noting, when asked, that he was "most proud of the two Presidential Unit Citations, two Navy Unit Commendations, and the Meritorious Unit Commendations, because they recognize the participation and accomplishment of all crew members."

After retirement from the Navy, Archie and his wife Marilyn settled in Boise, Idaho, where he founded Caribou Technologies Inc., an international consulting firm. His specialty was alliance building, with a focus on using innovative commercial technologies to solve intrinsic problems in the government.

He also served on the board of directors of two publicly held corporations and several startup companies. His leadership and technical skills were in constant demand and he generously gave of his time to advise and inform Navy and private sector technological initiatives and to thoughtfully help the many of us who still sought his wise counsel.

Accolades continued to flow to Archie during his time in the private sector. Civilian recognitions include the David Sarnoff Award from the Armed Forces Communications and Electronics Association and the Naval Order of the United States–Distinguished Sea Service Award. His alma mater, the University of Illinois, honored him with a Distinguished Service Award, Alumni Achievement Award (1998), Distinguished Alumni Award from the Department of Electrical and Computer Engineering (1999), and honorary doctor of engineering degree (2005).

Archie was elected to the National Academy of Engineering in 2006 and served on both the Section 12 and NAE Peer Committees and, after 3 years as vice chair, chaired Section 12 (2012–13). As section chair, he led successful efforts to broaden the diversity and increase the number of qualified candidates for election to the NAE. In addition, he was appointed to several study committees of the National Academies of Sciences, Engineering, and Medicine: Mainstreaming Unmanned Undersea Vehicles into Future US Naval Operations (2015–16), C4ISR for Future Naval Strike Groups (2004–06), and FORCEnet Implementation Strategy (2003–06).

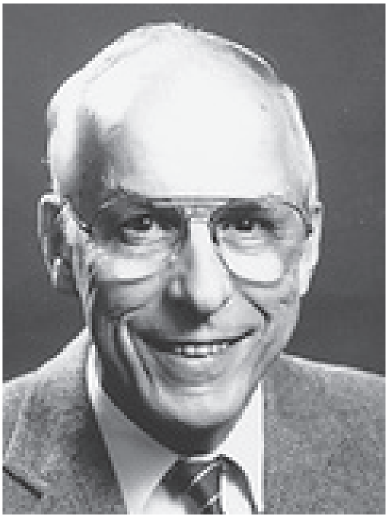
Marilyn Clemins recalls Archie's last change of command ceremony upon his departure from the Pacific Fleet and his retirement from the Navy. The guest speaker was Secretary of the Navy Richard Danzig. After recounting Archie's remarkable career, his myriad contributions to the service, and his unequalled professional reputation, the secretary noted that "some people lead with the sun shining brightly on them while others lead by reflecting that sunshine onto others." Archie Clemins clearly fell in that latter category and it is a perfect description of his character and his life, not just as a naval officer, colleague, and friend, but as a human being.

The memories of him and all that we shared will be with us always.

Archie is survived by his wife of 52 years, Marilyn (née Paddick); their children, Becky (Dan) Lewis of San Diego and Travis (Urszula) Clemins of Boulder; and four grandchildren, all of whom he loved deeply.

"Your legacy is not measured by your accomplishments. It is measured by the accomplishments of the children you raise and the people you train."

– Archie Clemins



DALE L. CRITCHLOW

1932–2016

Elected in 1991

"For technical leadership and key contributions to the development of metal-oxide semiconductor (MOS) devices and dynamic random access memory (DRAM) technology."

BY JOHN M. COHN

DALE L. CRITCHLOW was one of the world's leading experts in the science and business of semiconductor memory. The innovations that he and his team drove have made possible everything from cell phones to supercomputers.

Dale died May 6, 2016, of cancer in Shelburne, Vermont, at age 84. He was born January 6, 1932, in Harrisville, Pennsylvania, the son of Lee and Susie Critchlow. He was a graduate of Grove City College (1953) and received his master's (1954) and doctoral (1956) degrees in electrical engineering from Carnegie Institute of Technology (now Carnegie Mellon University). He then spent 2 years as an assistant professor at Carnegie Tech before joining IBM Research in Yorktown Heights, New York, in 1958. In 1977 he moved to IBM East Fishkill, NY, and in 1981 to Essex Junction, VT, where he finished his 35-year IBM career.

At IBM Dale became one of the world's leading experts in metal oxide–semiconductor field-effect transistors (MOSFETs) and their application to dynamic random access memory (DRAM). In 1973 he and his colleagues Robert Dennard (NAE) and Stanley Schuster published the seminal paper that outlined the physics and mathematics of semiconductor scaling:

"Design and Characteristics of n-Channel Insulated-gate Field-Effect Transistors."[1]

Dale's longtime collaborator and one-time employee Bob Dennard relates that Dale set the combined technical and business goal of his group to build the world's first computer memory that cost less than one milli-cent ($0.00001) per bit. That single-minded focus simultaneously drove innovations in semiconductor process scaling (now known as "Dennard scaling"), process technology innovation, and circuit innovations necessary to make the world's first truly affordable DRAM. The availability of affordable and reliable DRAM has been a key component in the development of all computers from cell phones to supercomputers and has been a direct driver of the $3 trillion growth of the semiconductor industry over the last 4 decades.

In recognition of this body of work, Dale was named a fellow of the Institute of Electrical and Electronics Engineers in 1985 "for contributions to the research and development of LSI [large-scale integration] and VLSI [very large-scale integration] MOSFET technologies." In 1986 he was named an IBM fellow, the company's highest technical honor. In 1989 he became a founding member of the IBM Academy of Technology, the company's technical leadership body.

In 1991 he was deeply honored to be inducted into the National Academy of Engineering—and so inspired by his NAE membership that in 1995 he helped create the Vermont Academy of Science and Engineering (VASE). VASE supports understanding and appreciation of science and technology in Vermont, and under Dale's guidance established grant programs that support hands-on science in Vermont schools.

In 1993 Dale retired from corporate life and returned to teaching, a wonderful way to share his decades of experience with the next generation, whether they were young employees or students. He was an outstanding and demanding teacher, and for 13 years a much-admired adjunct professor at the University of Vermont.

[1] *IBM Journal of Research and Development* 17(5):430.

He was a man of many interests and active in both mind and body. He was an avid cyclist and enjoyed pedaling Vermont's green mountains into his 80s. He was also a gifted woodworker and helped establish a state-of-the-art woodworking facility at the Wake Robin retirement community where he and his wife Alice lived. The beautiful and elegant desks and tables he made can be found everywhere around Wake Robin.

Dale leaves behind his beloved wife of 60 years, Alice Ellenberger Critchlow, and large and loving family: their daughter Sally Terris and her husband, Bruce; daughter Kathryn Luther and her husband, Mark; son John Critchlow and his wife, Jennifer; five grandchildren, and eight great-grandchildren. Dale was able to hold his first great-grandchild just the week before he died.

Dale was a strong and inspiring technical leader. His attention to scientific rigor, his deep understanding of human nature, and his dry, folksy humor made him an inspiring technical and personal mentor to many people at IBM, across the industry, at the University of Vermont, and in the communities where he and his family lived. All of us are very grateful to have known Dale Critchlow.

RICHARD E. DEVOR

1944–2011

Elected in 2000

"For contributions to the field of manufacturing research and its applications."

BY JOHN W. SUTHERLAND AND SHIV G. KAPOOR
SUBMITTED BY THE NAE HOME SECRETARY

RICHARD EARL DEVOR, a manufacturing thought leader, innovative researcher, motivational teacher, inspirational mentor to hundreds of students and colleagues, and distinguished scholar and faculty member in the Department of Mechanical Science and Engineering at the University of Illinois at Urbana-Champaign (UIUC), passed away July 26, 2011, at his home in Lake Mills, Wisconsin. He was 67.

Dick was born in Milwaukee on April 18, 1944, to Robert and Betty (née Hale) DeVor. The family relocated to Lake Mills in the 1950s when Dick's father established the DeVor Tool and Die company. Dick graduated in 1962 from Lake Mills High School, where he was a multisport athlete and outstanding student, and attended the University of Wisconsin–Madison, where he received his BS, MS, and PhD degrees in mechanical engineering in 1967, 1968, and 1971. As a graduate student, he was mentored by Shien-Ming ("Sam") Wu.

After his father died in 1971 Dick became president of DeVor Tool & Die, a position he held until his passing. Over the years he grew the company to support the livelihoods of 20 employees and serve as an economic pillar of the Lake Mills community.

Also in 1971 he accepted a position as an assistant professor in the Department of Mechanical and Industrial Engineering

(M&IE) at UIUC and spent the remainder of his academic career there. He undertook many research investigations sponsored by government agencies and industry, and authored hundreds of papers.

Initially, his research focused on applying statistical methods to manufacturing (e.g., experimental design and time series). Over time he made substantial contributions to quality engineering, mechanistic modeling of machining systems, and micromanufacturing. He was named the Grayce Wicall Gauthier Professor in 1995 and the College of Engineering Distinguished Professor of Manufacturing in 2000 (emeritus in 2001).

In the classroom Dick was an inspirational and award-winning teacher. He taught courses on statistical design of experiments and industrial quality control and, on occasion, other classes related to manufacturing. Students thoroughly enjoyed his engaging and dynamic lectures—a mix of theory, trivia, jokes, practical insights, and professional wisdom. He often met with students outside the classroom to help them with difficult topics and to provide one-on-one counsel. As a graduate advisor, he mentored more than 150 MS, PhD, and postdoctoral students.

He held students to a high standard and expected them to meet it. Setting daunting goals, he inspired his students to rise to the challenges put before them. Students knew that failure was not an option. He was steadfast in his quest for excellence; the writing of a paper could go through uncountable drafts before it passed muster. Dick's personal drive for high quality was passed on to nearly all his students. While he was a tough task master, he cared deeply about his students and was a fierce advocate for them. He continued to advise his students on nearly every aspect of their lives even after graduation.

His mentoring was not limited to his students. Industrial practitioners and faculty were often the recipients of his guidance and effective communication of his work ethic. He was not shy about sharing "uncomfortable truths" with colleagues, who ultimately benefited from his frank observations.

Dick was also a principal player in the quality renaissance in US manufacturing that occurred in the 1980s. Aided by associates such as Tsong-how Chang and Don Ermer and supported by many of his graduate students, he developed and began teaching a series of industry short courses on statistical methods for quality and productivity improvement. Hundreds of these workshops were delivered to OEMs and their suppliers across the country, giving thousands of manufacturing professionals the opportunity to learn about statistical process control and design of experiments from a gifted teacher.

In addition to lectures and discussions, the industry courses incorporated computer games and software tools that enabled participants to make control charts or construct designed experiments and then use them to study and improve a computer-simulated manufacturing process. When quality pioneer W. Edwards Deming saw the students feverishly working during one of the game sessions, he complimented Dick on the ingenuity of the games and expressed his thrill to see the students' enthusiasm. The instructional materials used for these short courses led to the development of a popular textbook, *Statistical Quality Design and Control: Contemporary Concepts and Methods* (Prentice Hall, 1992).

It was in the late 1970s that Dick began the research for which he is best known, mechanistic modeling of machining systems. He worked with one of the authors (SGK) as well as numerous students to create computer simulation models for various machining operations. These models were based on "first principles" and could predict the performance of such processes as end milling, face milling, and cylinder boring. This early work to "cut with the computer" did much to advance the cost-effectiveness of designing products and processes by avoiding the widely used "cut and try" approach. It also laid the groundwork for such current ideas as the digital twin and digital manufacturing.

In the mechanistic modeling paradigm, the geometry and structural properties of the part to be machined are input to the computer; other inputs include the tooling geometry, material characteristics, machine tool character, and process geometry. The computer-based mechanistic model enables a product or process designer to simulate the cutting of the part, and the designer can modify a variety of parameters to identify how to best process the part. For example, different process geometries and operating conditions can be explored to find settings that are suitable in terms of forces, surface finish, power limitations, and part/machine tool deflection/vibration. Using computer simulations, a manufacturer could also identify the most effective way to fixture a part and guide the development of online process monitoring schemes for fault diagnosis.

In the early 1990s these mechanistic models were made available via the internet, to create virtual machining testbeds. Through Dick's leadership, internet-based hardware testbeds were also established to remotely monitor and control machining systems. These seminal contributions paved the way for the Industrial Internet of Things, data analytics, and smart manufacturing.

From the early 1980s on, many companies worked with Professor DeVor on mechanistic machining model applications. These collaborations resulted in better processing strategies for new engine block concepts, gear broaching, and better machine tool structures. Insights were also provided to corporate partners on threading operations and drill geometry.

Dick's research helped to lay the foundation for the field of mechanistic modeling and simulation of machining processes, and machine tool design and automation. His pioneering contributions also advanced understanding of cutting fluid filtration and helped to establish the nascent field of micromanufacturing in the early 2000s.

Over and above his teaching, research, scholarship, and mentoring, Dick actively served his university and the professional community. At UIUC, in addition to his professorial duties, he was associate head for graduate programs of the M&IE Department (1987–91) and director of the Institute for Competitive Manufacturing (1989–96 and 1999–2000).

He served the Society of Manufacturing Engineers (SME) as a member of the scientific committee of its North American Manufacturing Research Institution (NAMRI; 1982–98) and as president of NAMRI/SME in 1992. He helped organize the

1988 North American Manufacturing Research Conference, held at UIUC. He was also active on behalf of the NSF/DARPA Machine Tool–Agile Manufacturing Research Institute (MT-AMRI), International Conference on Micro-Manufacturing (ICOMM), and International Institution for Micro-Manufacturing (I2M2).

Dick was amazing to watch in these service activities. Through his dogged persistence and sheer force of personality he not only accomplished a great deal himself but also was extremely effective at motivating others to "get the job done."

At UIUC Dick was recognized more than 10 times for his teaching excellence by the *Daily Illini* (the campus newspaper). Department alumni bestowed on him the Two-Year Effective Teacher Award four times, and the Five-Year Effective Teacher Award three times. He was further honored with the College of Engineering Everitt Award for Teaching Excellence (1985), UIUC Campus Award for Excellence in Undergraduate Teaching (1987), and College of Engineering Halliburton Engineering Education Leadership Award (1989). He was recognized at the national level with the 1993 SME Education Award.

For his contributions to the manufacturing research literature, he was honored three times (1983, 1997, and 2008) with the ASME Blackall Machine Tool and Gage Award. He also received the ASME William T. Ennor Manufacturing Technology Award (2003) and NAMRI/SME S.M. Wu Research Implementation Award (2010). He was elevated to the rank of SME fellow in 1993 and ASME fellow in 1996. He was elected to the NAE in 2000 and in 2007 named an honorary member of ASME.

Richard DeVor contributed his leadership and enormous force of personality to every pursuit in which he was involved. His legacy and long-term impact can be characterized via several different measures based on those pursuits.

Through his research related to mechanistic modeling of machining systems, the science and practice of manufacturing have been significantly advanced, and the competitiveness of numerous industrial partners has been substantially improved. He authored over 300 papers that appeared in journals and conference proceedings, and research scholars will build on these works for decades to come. Thousands of students at the university and in companies across the country benefited from his knowledge, wisdom, and clarity of communication. His teaching and scholarship related to statistical quality design and control contributed to the US manufacturing renaissance in the 1980s.

But if you were to ask Dick what he felt his legacy was, the answer would likely be his students. Through his guidance and motivation, they learned that they could achieve far more than they thought possible.

Those who knew Richard DeVor in the classroom, as a research advisor, or as a colleague or business associate dramatically benefited from his vision, wisdom, practical insights, commitment to excellence, and an incredible capacity for working hard. His dynamic personality, passion for manufacturing, enjoyment of a stimulating conversation, and genuine personal interest will be the things we remember most about him. He will continue to be a source of inspiration for all.

His wife of 43 years, Jearnice (née Luedtke), died May 18, 2011.

GEORGE E. DIETER

1928–2020

Elected in 1993

"For contributions to engineering education in the areas of materials design and processing."

BY HOWARD KUHN AND JIM WILLIAMS

GEORGE ELLWOOD DIETER JR. was born in Philadelphia on December 5, 1928, and raised in Germantown. He enrolled at Drexel Institute of Technology (now Drexel University) in 1945 and received his BS in metallurgical engineering in 1950 (at this co-op school with a focus on serving the technical and operational needs of regional industries, 5 years is typically required for the BS degree). George's academic accomplishments were highly regarded, so he was recommended for graduate study elsewhere as Drexel did not have a graduate program at that time.

He continued his studies in metallurgical engineering at the Carnegie Institute of Technology (CIT), from which he received his ScD in 1953. His thesis advisor was Robert F. Mehl who, as director of the Physical Metallurgy Laboratory at the Naval Research Laboratory (1928–31), had become highly regarded in defense circles for his development of gamma radiography as a method for evaluating large naval castings. As director of the Metals Research Laboratory (1932–35) and head of the Department of Metallurgy (1935–60) at CIT, Mehl played a strong role in establishing a science base for the study of metallurgy, introducing a fundamental approach to courses in phase transformations and mechanical behavior and promoting the use of advanced mathematical analysis in his students' research.

Mehl was also a regular consultant for various companies, which later had an influence on George. He stressed the importance of applying basic science to understand metallurgical phenomena, but always with a focus on problems of industrial importance.

Against this backdrop and influence, George's doctoral research focused on the statistical aspects of fatigue failure of steels, the importance of which was highlighted by numerous failures in defense and industrial equipment during the previous decades. His research, funded by the National Advisory Committee for Aeronautics (NACA), led to two NACA reports: *Investigation of the Statistical Nature of Fatigue of Metals* (NACA TN 3019, September 1953) and *Statistical Study of Overstressing in Steel* (NACA TN 3211, April 1954).

Upon completing his ScD degree, George fulfilled the military obligation resulting from his ROTC participation at Drexel at the US Army Laboratory at Aberdeen Proving Grounds (1953–55). After his military service as an officer, he worked as a research engineer and research supervisor at E.I. DuPont Engineering Research Laboratory, in Wilmington, Delaware.

His more influential activity during this period was writing the textbook *Mechanical Metallurgy* (McGraw-Hill, 1961). While mechanical metallurgy courses had been presented at many universities, there was not a unified or comprehensive curriculum for the subject. *Mechanical Metallurgy* filled that gap. One of us (JW) used this text in graduate school and found it to be very helpful and a tremendous consolidation of the literature in this area.

With perfect timing, Doc Grosvenor, longtime head of Drexel's Metallurgy Department, retired in 1962 and Dieter was the obvious choice to fill the vacancy. As department head (1963–68) Professor Dieter assembled research-oriented faculty members and grew the research portfolio at an impressive pace. This new emphasis on research coincided with Drexel's transition from a teaching institution to a research university, directed by the newly appointed president, William Hagerty, formerly dean of engineering at the University of Texas.

Through George's drive and foresight, the Metallurgy Department was soon 20 years ahead of the other Drexel engineering departments in developing a productive research program. The department also broadened its focus beyond metals by adding faculty in ceramics and polymers to become a Materials Engineering Department.

Dieter was very active in recruiting top high school talent in the region to bolster the department's reputation and upgrade its students' admission credentials. Despite his stern approach to teaching and research, he had a heart of gold and took a personal approach to making incoming students as well as his new faculty feel more comfortable and welcome in their new surroundings. For example, George invited me (HK) and my wife to stay with his family while we looked for housing before our relocation to Philadelphia and he helped find a property that we rented for our move.

Diran Apelian wrote that "George Dieter was my teacher, mentor, and guardian angel of sorts. I was an immigrant to America having had two years of high school before entering Drexel in the metallurgical engineering department that Dieter headed. His support, inspiration, and encouragement were pivotal to my success as an undergraduate. He took me under his wing and encouraged me…and made me do things I did not think I could do.… He was an amazing individual—highly disciplined, visionary, with a superb strategic mind…. He was a leader who ensured that others were given opportunities to lead and who cared deeply about his colleagues, students, and staff. His disciplined stern façade was just that; he had a heart of gold and touched many of us."

A humorous anecdote further testifies to the general recognition and appreciation of his nature. During holiday parties at Drexel the students would present parodies of the faculty. One of these depicted George being held up at the airport metal detector before boarding a flight—this actually had happened and the students got wind of it; recreating the incident, the students asked, "Was this caused by his will of iron, his heart of gold, or what?"

Professor Dieter also instituted a graduate course in design for materials engineers. This experience led him to refine the course content of his book *Engineering Design: A Materials and Processing Approach*, which was even more widely used than *Mechanical Metallurgy*. His monumental effort revolutionized materials education by collecting results from a multitude of sources into a cohesive curriculum on design, filling a need in materials departments worldwide for the methods that convert engineering science and discoveries into useful products and successful enterprises.

As a reflection of Dieter's grasp of the breadth of mechanical metallurgy, he hired one of us (HK)—a mechanical engineer with interests in materials—to expand the mathematical and design component of the evolving curriculum. He had learned of my interests in plasticity mechanics and metallurgy through his consulting work with TRW and DuPont, companies where I had interviewed for employment. When I joined the Drexel faculty in 1966, Dieter already had a project on high-temperature torsion testing sponsored by the Naval Research Laboratory, which provided a start for my research program. He also made connections for me with industrial and federal agencies, whose funding led to breakthrough theories of ductile fracture and plasticity of porous materials.

These results were a springboard to development and commercialization of the powder forging process under the powder metallurgy program. At the time the powder metallurgy industry was increasing in importance as a source of critical components for defense and aircraft, but the subject lacked a broad science base. One response to fill this need was a Defense Department program called Themis that addressed the spectrum of powder metallurgy processes from powder making to high-density forming to economics. Dieter, together with Richard Heckel (recruited to Drexel from DuPont), wrote a successful proposal that launched Drexel to an eventual leadership position in the powder metallurgy industry, a role that continues. Alan Lawley, an expert in scanning and transmission electron microscopy (SEM/TEM) and dislocation, was principal investigator of the Themis program, and faculty from other engineering departments were enlisted to cover the wide range of topics in powder metallurgy.

George Dieter's success in growing the Materials Engineering Department at Drexel led to his promotion to dean of engineering in 1969. His attempt to reorganize the School of Engineering into a matrix of departmental capabilities and individual research interests, aimed at promoting interdisciplinary collaboration to create appeal to a broader range of research opportunities, was ahead of its time and was unsuccessful due to divergent faculty interests.

In 1973 he returned to CIT, now Carnegie Mellon University (CMU), to serve as director of the Processing Research Institute. In meetings with potential industry sponsors Dieter displayed his clear vision for linking fundamental research to industrial needs. His no-nonsense approach was apparent in his preference to quickly and efficiently get to the heart of a meeting agenda and his impatience with industrial protocol.

One of us (JW) joined the faculty of the CMU Materials Department in 1975, coming from over 15 years in the aerospace industry. George was wonderfully supportive of new faculty members as we worked to establish our research groups and settle in to new, unfamiliar roles. George willingly and unobtrusively provided tremendous help. I remain grateful to him.

Dieter longed to return to the excitement and challenge of an educational leadership role, and in 1977 he gladly accepted appointment as dean of the Clark School of Engineering at the University of Maryland. He held this position until his retirement in 1994, and then continued to play an active role in the school nearly until his death.

He was active in the broader community as well. He chaired the Engineering Deans Council and served as president of the American Society for Engineering Education (ASEE). He was appointed to a number of committees of the National Academies of Sciences, Engineering, and Medicine, including the Committee on Assessing Corrosion Education (2007–08), the Army Research Laboratory Technical Assessment Board (2001–04) and its Panel on Armor and Armaments (2001–02; chair, 2002–04), the Committee on Materials Science and Engineering: Forging Stronger Links to Users (1997–99), Workshop Committee on Structural Materials Research Advancements (chair, 1997–98), Committee on Assessment of Research Needs for Wind Turbine Rotor Materials Technology (chair, 1989–91), and National Materials and Manufacturing Board (1979–81).

His contributions were recognized by the SME Education Awad (1987), election to the NAE (1993), the TMS Educator Award (1994), and ASEE's highest award, the Lamme Medal (1996).

He spent more time at UMD than anywhere else, and his influence was—and still is—felt in every corner of the university. He made competition a priority and encouraged students to participate in national engineering competitions. He launched the Maryland Technology Enterprise Institute, invited distinguished alumni to keep the Clark School's classes and programming at the leading edge, established a Capstone Design Fund, and supported a professorship named in his honor. As a tribute to their daughter Barbara June Dieter (1958–88), he and his wife, Nancy, established a merit-based scholarship for a mechanical engineering student in the Women in Engineering Program.

On December 5, 2018, the occasion of George's 90th birthday, a ceremony was held at UMD to honor him with the dedication of the George E. Dieter Jr. Materials Instructional Laboratory.

George died December 12, 2020, at age 92. Nancy (née Russell), his wife of 67 years, predeceased him on January 16, 2020. They are survived by their daughter Carol Joan Dieter.

DIARMUID DOWNS

1922–2014

Elected in 1987

"For significant contributions to the understanding of combustion processes in internal combustion engines and to advances in engine design."

SUBMITTED BY THE NAE HOME SECRETARY

DIARMUID DOWNS, known as a "gentleman engineer," died February 12, 2014, at the age of 91. His research improved the internal combustion engine, reducing knock in car engines and producing cleaner, more efficient engine technology.

Diarmuid Downs was born April 23, 1922, in London. His father ran a small engineering business, manufacturing equipment for the oil industry. He was educated at Gunnersbury Catholic Grammar School and the Polytechnic, London. He then studied at Northampton Engineering College, London, where he graduated with first class honors in 1942.

He won a postgraduate grant for further research and study, which he took up that November at Ricardo and Company Engineers Ltd. in Oxford (following its wartime evacuation from the Sussex coast). He spent his entire career there. In 1947 he was made head of the Petrol Engine Department, in 1957 he became a member of the board and in 1967 managing director, and in 1976 he was appointed joint chair and managing director, a post he retained until his retirement in 1987. He was

A detailed biographical memoir of Sir Diarmuid Downs was published by the Royal Society in March 2019. It includes more photos as well as personal anecdotes and is available at https://royalsocietypublishing.org/doi/10.1098/rsbm.2018.0036.

also involved in the purchase of G. Cussons Ltd. in 1964 and became its chair.

For his initial 15 years, Sir Diarmuid pursued a fundamental study of abnormal combustion phenomena in the petrol engine, resulting in a clearer understanding of the problems of knock and preignition. He published numerous papers on internal combustion engines in the British and international engineering journals and conference proceedings. Over the years he became well known and highly respected not only among Ricardo's clients but in the automotive industry in general, as attested by his regular technical addresses to large numbers of attendees at the SAE Detroit Congress.

He was active in the broader community, as a member of the Advanced Council for Applied R&D (1976–80), UK Science and Engineering Research Council (1981–85), Design Council (1981–89), and Advanced Board of the Parliamentary Office of Science and Technology (1988–93). He also served on the boards of the Society of Automotive Engineers (1983–86) and the British Council (1987–93). In addition, he was a member of the Council at City University (1980–82), a visiting fellow at Lincoln College, Oxford (1987–88), and Pro Chancellor of Surrey University (1992–94).

Early in his career Sir Diarmuid won three prizes from the Institution of Mechanical Engineers (IMechE) for his research: the George Stephenson Research Prize and the Crompton Lanchester Medal, both in 1951, and the Dugald Clerk Prize the following year. In 1985 he received the James Alfred Ewing Medal of the Institution of Civil Engineers, and in 1986 the FISITA Medal of the International Federation of Automotive Engineering Societies.

Sir Diarmuid became an IMechE fellow in 1961 and president in 1978. He was a fellow of both the Royal Academy of Engineering (1979) and the Royal Society (1985), and in 1987 was elected a foreign member of the US National Academy of Engineering. He was made a Commander of the Order of the British Empire (CBE) in 1979 and received his knighthood in 1985. Since 1984 he was a liveryman in the Worshipful Company of Engineers.

In Sir Diarmuid's foreword to John Reynolds' book *Engines and Enterprise: The Life and Work of Sir Harry Ricardo* (Sutton Publishing Ltd., 2000) he wrote: "I had the great privilege of working for Sir Harry Ricardo for the last thirty years of his life, first as a young engineer and eventually as his chosen successor as head of the company. His staff…in continuing and building on [his] achievements benefited from the comments and guidance of Sir Harry himself, right up to his death in his ninetieth year. Sir Harry was a fine engineer and a delightful man. The story of his life…has lessons and fascination for us all."

An epitaph that family, friends, and colleagues would agree is just as fitting for Sir Diarmuid himself.

Sir Diarmuid was survived by his wife Carmel (née Chillman; she died November 2, 2016); their children Ann, Lucy, Clare, and Martin; and five grandchildren.

MILDRED S. DRESSELHAUS

1930–2017

Elected in 1974

"Contributions to the experimental studies of metals and semimetals, and to education."

BY JING KONG AND TOMÁS PALACIOS
SUBMITTED BY THE NAE HOME SECRETARY

MILDRED SPIEWAK DRESSELHAUS, a pioneer and one of the most influential leaders in the field of nanoscience and technology, died February 20, 2017, at the age of 86.

Millie was born November 11, 1930, in Brooklyn, New York, to Ethel (née Teichtheil) and Meyer Spiewak, two Polish Jewish immigrants. Her youth was marked by very limited financial resources, requiring her and her older brother Irving to start working at a young age to help support the family. One of her early jobs was tutoring a special education child, and the experience was key to Millie's discovery of her passion for working with students and helping them understand complex concepts. And because she knew the sufferings of the poor and disadvantaged, she sought throughout her life to help as many as she could through her work.

Millie was also an exceptional violin player; her love of music and the violin lasted throughout her life—she played her violin almost every day. As a young girl she received a scholarship to a music school, where she befriended children whose academic school environments far exceeded the educational opportunities at her neighborhood school. The divide (and her brother's encouragement) motivated her, at age 13, to apply for a spot at the competitive Hunter College High School for Girls.

Millie's brilliant mind was vividly captured early on by a ditty in the Hunter High School yearbook: "Mildred Spiewak: Any equation she can solve, every problem she can resolve. Mildred equals brains plus fun. In math and science she's second to none."

She went on to receive her AB in liberal arts from Hunter College of the City University of New York (1951), where she took a class with Rosalyn Yalow, the future Nobel Prize winner, who became a lifelong mentor and encouraged her to become a physicist. With a Fulbright Fellowship, she then studied for a year at the University of Cambridge (Newnham College). She returned stateside and in 1953 earned her MA in physics from Radcliffe College at Harvard University. Five years later she got her PhD, also in physics, from the University of Chicago on the microwave properties of a superconductor in a magnetic field. She met Enrico Fermi, who had a great influence on her although unfortunately he passed away in 1954. Millie always remembered the early morning walks with Fermi on their way to the university.

While in Chicago she met her husband Gene Dresselhaus, a theoretical physicist well known for his work on spin-orbit interaction effects in solids. In 1960 they both became staff members at MIT Lincoln Laboratory.

In 1967 Millie was appointed the Abby Rockefeller Mauze Visiting Professor in the Department of Electrical Engineering at the Massachusetts Institute of Technology. The next year she became a tenured faculty member in the department and in 1983 a joint professor in physics. In 1985 she was the first woman appointed Institute Professor, MIT's highest honor for distinguished accomplishments in scholarship, education, service, and leadership. Throughout her 50 years at MIT, she was a remarkable inspiration and influence on campus.

In terms of her technical accomplishments, Millie was one of the pioneers and most prominent experts in the study of carbon science. From 1975 to 1990, she published extensive work on graphite intercalation compounds, which became highly influential in graphite research. Overall she authored or coauthored nine books and some 1700 papers during her career.

Her insights about the link between zero dimensional fullerenes and macroscopic carbon fibers spurred the first observation of carbon nanotubes in 1991 and their study for years to follow. Her theoretical work demonstrated that the semiconducting or metallic behavior of a single-walled nanotube (SWNT) is determined by its geometric structure. This theoretical prediction came before SWNTs could be synthesized and greatly stimulated and inspired the experimental work in carbon nanotube research. These experimental efforts quickly broadened to cover synthesis, characterization, separation, and their use for fundamental physics studies and transistor applications.

In 1998 Millie accelerated carbon nanotube research again with her discovery of individul SWNT Raman spectroscopy. This technique revolutionized understanding of how individual molecules can be probed macroscopically and enabled breakthroughs in fields as diverse as catalyst research, DNA hybridization, and single molecule sensors. Her findings paved the way for others' work that was recognized by at least two Nobel Prizes—for fullerenes in 1996 and graphene in 2010—and earned her the nickname "the Queen of Carbon Science."

Millie's great scientific contributions were not limited to carbon. In 2012 she received the prestigious Kavli Prize in Nanoscience (the first solo recipient) for "her pioneering contributions to the study of phonons, electron-phonon interactions, and thermal transport in nanostructures."

Her contributions to the use of nanostructures in thermoelectrics have defined the modern directions of this field. The dimensionless thermoelectric figure of merit (ZT) in the best thermoelectric materials had remained near 1 for over 50 years. In 1993 she proposed that it might be possible to increase the ZT of certain materials by preparing them in quantum-well superlattice structures or in one-dimensional form, such as in nanowires. Her seminal papers on this topic, cited more than 4000 times, enabled experimental breakthroughs in the ZT value of nanostructured thermoelectrics. In many ways Millie's research helped usher in the age of nanotechnology.

Throughout, Millie was a prominent advocate for women pursuing careers in science and engineering. In 1971 she and a colleague began the Women's Forum at MIT, a seminar series exploring the roles of women in science and engineering. And in 1973 she received a Carnegie Foundation grant supporting her efforts to encourage women to enter traditionally male-dominated fields like physics and engineering.

For a number of years she also led an MIT seminar in engineering for first-year undergraduate students; originally designed to build the confidence of female students, it drew a large audience of both men and women. In all her travels around the world to give speeches and seminars at labs and universities, she always made an effort to meet female students and encourage them toward their careers. She was a much-loved mentor and an inspiring role model worldwide.

Equally remarkable was Millie's service to the scientific community, at MIT, nationally, and globally. As associate department head of the MIT Department of Electrical Engineering (1972–74) she was instrumental in starting the computer science part of the department. As head of the MIT Center for Materials Science and Engineering (1977–83) she helped multiple junior faculty members.

At the national level, she was appointed director of the Office of Science at the US Department of Energy (2000–08), and cochaired a highly influential 2003 DOE study, *Basic Research Needs for the Hydrogen Economy*. In addition, she was active in the professional societies; she chaired the governing board of the American Institute of Physics and served as president of the American Physical Society and the American Association for the Advancement of Science.

She also served on countless advisory boards and committees and was exceptionally active in the work of the National Academies. In addition to her service over decades (1984–2014) on numerous internal NAE and NAS committees (e.g., on membership, nominations) as well as the Academies' Governing Board and both the NAE and NAS councils, she was appointed to the committees on an Assessment of and Outlook for Condensed-Matter and Materials Physics (cochair;

2006–07); Global Dialogues on Emerging Science and Technology (2004–06); Facilitating Interdisciplinary Research (2003–04); Human Rights (1997–2000); Capitalizing on US Leadership in Fields of Science (1996–99); and Women in Science, Engineering, and Medicine (chair; 1990–93), among others.

Her many civic, social, and scientific contributions were recognized with numerous awards and honors. Among them were the Presidential Medal of Freedom (2014), the highest honor bestowed by the US government on American civilians; the National Medal of Science (1990), given to the nation's top scientists; the IEEE Medal of Honor (2015)—for which she was the first female recipient—for "leadership and contributions across many fields of science and engineering"; the Enrico Fermi Award (2012) from the US Department of Energy for her "leadership in condensed matter physics, in energy and science policy, in service to the scientific community, and in mentoring women in the sciences"; and the Vannevar Bush Award (2009). She was elected to the National Academy of Engineering (1974) and National Academy of Sciences (1985) and inducted to the National Inventors Hall of Fame (2014). In addition, she was awarded nearly 30 honorary doctorates from institutions worldwide.

When asked why she spent so much time on civic and social efforts for science, Millie cited the time she played violin for Eleanor Roosevelt as a child in her after-school music class. The first lady was a true inspiration for young Millie and ignited in her a deep call to service. Millie said she owed her country, and potential great women everywhere, a debt of gratitude, because they helped form her into the woman she became.

Millie was a beloved giant who left a tremendous legacy. Her eminent contributions and persistent endeavors to the benefit of the scientific community, her deep care for her students and colleagues, and her dedicated service to her country and beyond will leave an enduring impact on generations to come. She is greatly missed.

Millie was survived by her husband, Gene (he died September 29, 2021); their children Marianne (Geoffrey), Carl, Paul (Maria), and Eliot (Françoise); and five grandchildren.

TONY F.W. EMBLETON

1929–2020

Elected in 1987

"For outstanding contributions and international leadership in engineering acoustics."

BY SHEILA EMBLETON
SUBMITTED BY THE NAE HOME SECRETARY

TONY FREDERICK WALLACE EMBLETON, a leader in noise control engineering and acoustical measurement techniques, as well as in standards development and several professional organizations, died November 13, 2020, at the age of 91 after a 7-year battle with bladder and prostate cancers.

Tony was born October 1, 1929, to Frederick William Howard Embleton and Lucy Violet Muriel (née Wallace) Embleton in Hornchurch, Essex, England, now part of the London borough of Havering. He graduated from Brentwood College School in 1947. Several generations of his family had been involved in international merchant trade, and he was the first in his family to attend university. In 1947 he enrolled at Imperial College, part of the University of London, with a Royal Scholarship, receiving an honors BSc in physics in 1950.

In 1949 he joined the newly formed acoustics group in the Physics Department at Imperial College, under R.W.B. (Ray) Stephens, and earned a PhD in physics for his experimental

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This tribute is based on a number of sources, including extensively on the encomium written by Edgar Shaw on the occasion of Tony's receipt of the Acoustical Society of America's Silver Medal in Noise in 1986, a 1994 interview in the American Institute of Physics oral history archive (aip.org/history-programs/niels-bohr-library/oral-histories/5199), and recollections of his colleagues Gilles Daigle and Mike Stinson.

work on finite amplitude waves in 1952. He later received a DSc from the University of London.

A 1-year postdoctoral fellowship at the National Research Council of Canada in Ottawa turned into a permanent position in the Acoustics Section in the Division of Physics. He became a principal research officer in 1974, head of the Acoustics Section in 1985, and retired in 1990 as head of acoustics and mechanical standards. He then moved to Nobleton, Ontario, just northwest of Toronto, to be near family, but remained active for a number of years thereafter in several professional organizations.

In the early 1950s the intense noise generated by large suction rolls in the production of paper was a serious industrial concern in Canada. Tony worked with George Thiessen, then head of the Acoustics Section at the Canadian NRC, to demonstrate a considerable noise reduction by substituting the simple rows of holes in the cylinders (through which the air flowed, generating a quick burst of noise) with more complex patterns, in effect smoothing out the bursts of noise. The success of this project showed the value of fundamental research in support of noise control, and the solution of industrial problems more generally, and was key to launching the reputation of the NRC lab in noise control, both in Canada and internationally. Similar successful projects followed through the 1960s.

Interestingly, the measures that reduced noise in machinery often resulted in improvements in their mechanical efficiency as well. One excellent example of this is Tony's first patent, filed in 1969 with Thiessen ("stator blading for noise reduction in turbo-machinery"), which increased efficiency in jet engines while quietening them, an advance eagerly adopted around the world. Tony's other patent, "mufflers for percussive pneumatic machines," filed in 1980 with Stanley Baldwin and Vernon Hampton, not only quietened pneumatic drills but led to higher drilling speeds, less icing in the muffler, and less vibration (often a source of physical damage to miners' hands).

Other very practical projects during this time involved measurement of train noise in relation to the use of adjacent land, including the efficacy of planting trees as potential noise barriers, and office noise and its dependence on the acoustical reflectivity of walls, ceilings, and floors.

In the 1970s Tony's interest in sound propagation outdoors was rekindled due to growing public and governmental concerns about urban noise, in particular from traffic. This led to a series of theoretical and experimental studies of sound propagation outdoors, some in partnership with Joe Piercy, addressing the effect of the ground on near-horizontal sound propagation, measurement of ground impedance, acoustic characteristics of actual ground surfaces (e.g., asphalt, gravel, grass, snow, sloping terrain), phase and amplitude fluctuations due to turbulence, refraction due to wind and temperature, and the special characteristics of moving noise sources. There were many practical applications to airport and vehicle noise and the utility of highway noise barriers (some of which had more success psychologically than in physical reality).

Tony was author or coauthor of more than 50 scientific papers, many technical reports, invited articles, and book chapters. The latter, particularly "Sound in Large Rooms" and "Mufflers" (both in Leo Beranek's 1971 *Noise and Vibration Control*; McGraw-Hill) were the standard reference works in the field for several decades.

He was a visiting lecturer at the University of Ottawa, Carleton University, and the Massachusetts Institute of Technology, and a seminar leader at the NASA-ASEE Summer School (Old Dominion University), the US Environmental Protection Agency Noise Technology Symposium in Dallas, and the Government of Alberta Seminar on Transportation Noise. He gave keynote or invited plenary lectures at several of the most prestigious international conferences in his field.

Tony was equally dedicated to the profession more generally, with numerous editorial and professional administrative commitments in Canada, the United States, and internationally, with contributions not only to acoustics but also to other fields upon which his work touched. He was a key participant in discussions to form a national acoustics organization in Canada, and was elected the first secretary of the Canadian Committee on Acoustics (later the Canadian

Acoustical Association), later serving on its board of directors. He was the founding editor in chief of *Acoustics and Noise Control in Canada/L'acoustique et la lutte antibruit au Canada* (1972–75; later *Canadian Acoustics/Acoustique canadienne*). For the Acoustical Society of America (ASA), he was a member of and chaired the Technical Committee on Noise, served on a number of both technical and administrative committees, including the executive council and the technical council, as vice president, acting president, president (1980–81), and later standards director, even after retirement. He was associate editor of the *Journal of the Acoustical Society of America*. He served in many capacities with the Institute of Noise Control Engineering (INCE) and for the International Institute of Noise Control Engineering, and was on the editorial board of the *Noise Control Engineering Journal*. He chaired the NRC Associate Committee on Machinery Noise and Acoustics and Noise Control Committee of the Canadian Standards Association, and was a member of the Noise Subcommittee of the Canadian Pulp and Paper Association.

He was also engaged in his community, elected to the Rockcliffe Park Public School Board for the last few years before it amalgamated with the Ottawa School Board (at which point he successfully resisted all entreaties to run for the larger board).

Tony was a skilled meeting organizer. He was the technical program chair for the 1986 International Congress on Acoustics in Toronto, technical chair for the ASA meeting in 1968 (Ottawa) and the first three joint meetings in Honolulu with the Acoustical Society of Japan in 1978, 1988, and 1996, and general chair of the 1981 meeting (Ottawa). The final meeting that he attended was in Honolulu in 2016, again joint with the Acoustical Society of Japan, where he knew he would find many old and new professional friends.

He enjoyed meeting so many people from varied walks of life, often through noise-related consultancy, and had connections in many places, such as the Canadian Passport Office (open-plan offices and noisy passport printing machines were not a good combination); throughout Europe, in association with NATO scientific committee work involving outdoor sound propagation; and the Ottawa Police, whom he assisted with countless noise complaints over the years.

He was proud of his contributions as the scientist on the first of the NRC's many Industrial Research Assistance Program projects, which took him to a noisy underground mine in Thompson, Manitoba; his service as a noise consultant on the world's first next-to-the-runway airport hotel built by a major hotel chain (Hilton Dorval Airport, now Sheraton Montreal Airport, with its strategically angled windows); his suggestion of a novel way to scare birds away at Vancouver Airport; and the evidence he provided for the Royal Canadian Mounted Police as to whether a gun-silencer actually did quieten the gun (only one over the years did not, resulting in an accused who was very surprised but grateful for his acquittal).

He enjoyed encouraging younger scientists and engineers, particularly, of course, in acoustics, and was an advocate and mentor for women in science and engineering. For several decades there was a steady flow of postdoctoral fellows and occasionally sabbatical visitors in his NRC lab in Ottawa, many from India and Japan, and later from Europe and the United States. These led to long-term friendships and invitations to lecture abroad.

His work attracted considerable recognition. In 1964 he received the ASA's Biennial Award (later renamed the R. Bruce Lindsay Award) and was elected a fellow. He was a corecipient (with Joe Piercy) of the Arch T. Colwell Merit Award of the Society of Automotive Engineers in 1974. In 1976 he delivered the Rochester Institute of Technology's second annual Distinguished John Wiley Jones Lecture, titled "Noise Control from the Ancient Past to the Near Future." He received the ASA's Silver Medal for Noise in 1985, and in 2002 its Gold Medal for "fundamental contributions to understanding outdoor sound propagation and noise control and for leadership in the Society." He was elected a fellow of the Royal Society of Canada in 1978 and served as its treasurer (1982–85); he remained an active member and was looking forward to the society's annual meeting in Toronto (unfortunately virtual in

2020) but sadly he passed away 2 weeks before the meeting. He was elected a foreign member of the US National Academy of Engineering in 1987.

Tony married Eileen Blackall in 1953. She had a PhD in chemistry from University College London; they had met in their Russian Reading Knowledge class. She passed away in 2016. They are survived by daughter Dr. Sheila Embleton, son-in-law Dr. Wolfgang Ahrens, and a granddaughter, as well as relatives in England, Australia, and Switzerland.

FAZIL ERDOĞAN

1925–2015

Elected in 1997

"For contributions to fracture mechanics."

SUBMITTED BY THE NAE HOME SECRETARY

FAZIL ERDOĞAN, a former dean of the engineering college at Lehigh University who earned a reputation as one of the world's foremost experts in fracture mechanics, died October 2, 2015, at his home. He was 90.

He was born February 5, 1925, in Kars, Turkey, to Hamit and Hanım Erdoğan. He received his BS (1948) and MS (1949) degrees in mechanical engineering from the Technical University of Istanbul and in 1952 came to the United States to pursue his PhD at Lehigh. He earned his doctorate in 1955 and joined the faculty in 1957. Over the next decades he went on to chair the Department of Mechanical Engineering and Mechanics and, in the late 1990s, became interim dean of the P.C. Rossin College of Engineering and Applied Science. He retired in 2001 as G. Whitney Snyder Professor Emeritus.

In addition to fracture mechanics, Erdoğan conducted research into applied mathematics and the mechanics of engineering materials. His studies of the propagation of cracks in materials were of critical importance to airplanes, bridges, buildings, and other engineering systems. Over a 30-year

Adapted from a tribute published by Lehigh University, October 7, 2015 (https://www2.lehigh.edu/news/memoriam-fazil-erdogan-expert-fracture-mechanics).

period, his work was supported by continuous grants from NASA and the National Science Foundation.

He received many of the highest honors in his field. In 1983–84, he spent 10 months at the Fraunhofer Institute for Solid Mechanics in Freiburg, Germany, as a recipient of the Alexander von Humboldt Foundation Senior Scientist Award, one of the top research fellowships given by the German government. He received the Humboldt Award a second time in 1999. In 1993 he was named A.C. Eringen Medalist of the Society of Engineering Science. In 1997 he was elected to the National Academy of Engineering, one of the highest distinctions accorded to engineers in the United States.

In 1998 Lehigh hosted the International Symposium on Mechanics and Applied Mathematics in Erdoğan's honor. The 3-day event drew many of the world's foremost experts in the two fields, including many of the more than 40 PhD recipients whom Erdoğan supervised throughout his career. In remarks at the symposium, Ferdinand Beer, a former chair of the Mechanical Engineering Department, credited Erdoğan, with colleagues George Sih and Paul Paris, for bringing to Lehigh a "truly international reputation" in fracture mechanics.

In 2001 Erdoğan spent 3 months in Japan through the eminent scientist invitation program of the Japanese government. The following year, he stayed another 2 months in Japan through the invitation fellowship program of the Japan Society for the Promotion of Science.

In 2008 the *Journal of Applied Mechanics* published a special issue, based on a symposium in Erdoğan's honor in Hawaii in 2006, recognizing his contributions to fracture mechanics and applied mathematics. Titled "Honoring Professor Erdoğan's Seminal Contributions to Mixed Boundary-Value Problems of Inhomogeneous and Functionally Graded Materials," the issue featured 13 articles, many of them by former students and research collaborators. The guest editorial praised Erdoğan for influencing several generations of engineers working on mixed boundary-value problems in inhomogeneous media: "The analytical approaches that [Erdoğan] had developed with his students in the 1960s and 1970s for the formulation and reduction of fracture mechanics problems…have motivated researchers working in this area throughout the world.... He continues to be a source of inspiration to the mechanics community in leading the way in the area of mixed boundary-value problems in inhomogeneous and functionally graded media and also in providing selfless guidance to others."[1]

Herman Nied, professor of mechanical engineering and mechanics at Lehigh and one of Erdoğan's PhD students, echoed those comments. "Fazıl Erdoğan has made very significant contributions both to the mathematical and the experimental side of fracture mechanics, particularly to the fracture of pressure vessels and piping and to the behavior of material interfaces."

Erdoğan was the author of more than 200 scholarly articles and a fellow of the American Society of Mechanical Engineers. He also served as a visiting professor at universities in Germany and at the Technical University of Denmark, and as a visiting research scientist for DuPont Co.

One side of Professor Erdoğan that might be less well known was his love of teaching and the excellent mentoring he provided to his graduate students. "As a student who took several courses from him I can attest that he was an excellent teacher," said Feridun Delale, professor of Mechanical Engineering at the City College of New York and a former PhD student and postdoc of Erdoğan. "He usually came to class…and derived complex formulas from scratch without ever consulting notes, to the amazement of students. We later learned that he would spend a significant amount of time before class preparing for his lecture, and he did it out of respect for his students. When it came to mentoring doctoral and master's students, he had an open door policy and one could walk into his office any time to discuss research results or seek advice."

Fazıl also loved traveling, reading, walking, skiing, and most of all in his later years spending time with his grandchildren.

He was survived by his wife, Barbara (née Blake; she died in 2017); daughter, Ann Tracy; son, Turan Erdoğan; and eight grandchildren.

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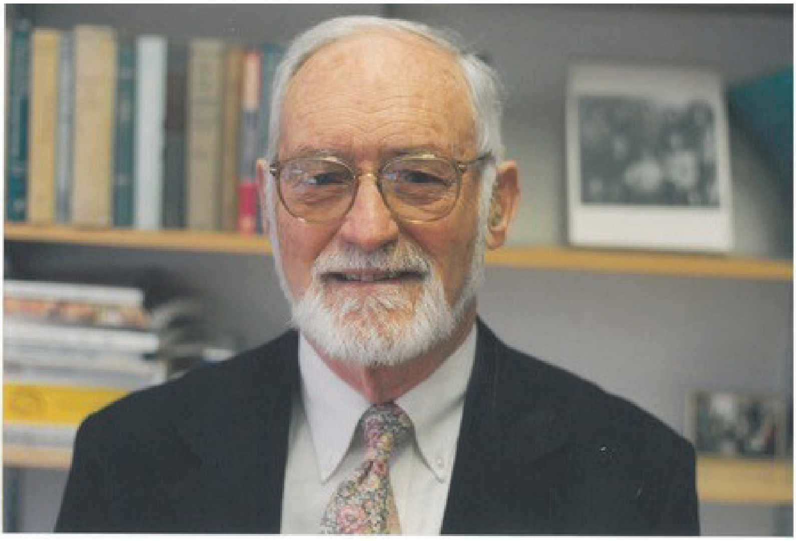
[1] Pindera M-J, Paulino GH. 2008. Guest editorial. *Journal of Applied Mechanics* 75(5):050301.



JAMES A. FAY

1923–2015

Elected in 1998

"For contributions to fluid and plasma dynamics, combustion, environmental technology, and recent creation of the first hypermedia fluid mechanics text."

BY RONALD PROBSTEIN

JAMES ALAN FAY, professor of mechanical engineering at the Massachusetts Institute of Technology and former Massport director, passed away June 2, 2015, of complications from lymphoma. He was 91.

Jay was born November 1, 1923, the fourth of five children, in Southhold, New York, on Long Island's east end. He grew up in Brooklyn, NY, but spent his summers in Southold, on the Long Island Sound. This motivated his lifelong interest in sailing; in fact, as a teenager he sewed a set of sails from Egyptian cotton cloth that he bought in Manhattan's Garment District.

He received a BS in naval architecture from the Webb Institute in 1944, having trained in an accelerated program while serving as a Navy ensign. In 1946 he married Agatha (Gay) Kelly of the Bronx and they moved to Boston, where he earned a master's degree in marine engineering from MIT in 1947. In 1951 he got his PhD in engineering mechanics from Cornell, having studied the unsteady propagation of gaseous detonation waves. He joined the Cornell faculty and taught there until 1955 when he was hired into the Department of Mechanical Engineering at MIT.

His early career work on combustion and detonation, hypersonic heat transfer, magnetohydrodynamics, and plasmadynamics led to his election to the NAE. Other research, geared to the common good, focused on environmental issues, such as air and water pollution problems (e.g., the dispersion of air pollutants in the atmosphere), acid rain, safety hazards of liquefied gases, renewable energy, and the spread of oil and other hazardous liquids on the ocean. He opted to take emeritus professor status in 1989 but continued to teach an introductory course in mechanical engineering. His books include *Molecular Thermodynamics* (Addison-Wesley, 1965) and *Introduction to Fluid Mechanics* (MIT Press, 1994).

The hallmark of Jay's success as an innovator, contributor, and leader was to listen carefully and crystallize the essence of a discussion. Having reached that point, he was committed to seeing the process through to the appropriate conclusion. His great ability to synthesize solutions in difficult circumstances was amply demonstrated in his service to the Commonwealth of Massachusetts as chair (1972–77) of the Massachusetts Port Authority (Massport), which controls Logan Airport and the Boston seaport, and serves other Boston area transportation facilities.

Under Jay's leadership, Massport was miraculously transformed from an aloof and environmentally insensitive institution to a public-serving entity. Alan Altshuler, then secretary of transportion for Massachusetts, noted that "Jay's combination of wisdom, deep knowledge, total integrity, and courage in the face of (unfair public) attacks through even the most stressful controversies was absolutely remarkable."

In addition to his NAE membership, Jay was a fellow of the American Academy of Arts and Sciences, American Physical Society, American Institute of Aeronautics and Astronautics, and American Association for the Advancement of Science, and a member of four other technical societies. He served on 12 boards, committees, and panels of the National Research Council (NRC), including as chair of the Jamaica Bay Environmental Study Group, which in 1971 produced a definitive report on the ecological impacts of extending the John F. Kennedy Airport runways into Jamaica Bay.[1] The report stated

[1] *Jamaica Bay and Kennedy Airport: A Multidisciplinary Environmental Study*. Washington: National Academy Press.

bluntly that "an airport is a great environmental hazard to the surrounding area" (p. 18) and said, rather presciently (p. 2),

> Because the environment is a public resource, decisions to control or prevent its degradation must be public decisions, openly arrived at after informed discussion. Individuals, local communities, and public and private agencies at the local, regional, and national level must all declare their interests and assess the consequences of various possible actions. In large measure, the current high intensity of controversy over environmental issues is a consequence of past and present failures of public officials to incorporate adequate and continuing participation of all affected parties, especially local communities, in the decision-making process. This will assume even more importance in the future as it becomes more difficult to find and more costly to use new technological means of simultaneously satisfying different human needs competing for the same limited environmental resources.

He also served two terms on the NRC's Environmental Studies Board and was appointed to the Committee on Risk Perception and Communication and the Panel on Integration of Socio-Economic Criteria into the Site Selection Process for a High-Level Radioactive Waste Repository.

He was a founder (1969) and lifetime director of the Union of Concerned Scientists and a trustee of the Conservation Law Foundation. In 1980 he was an Overseas Fellow of Churchill College at Cambridge University, and in 1990 he was a Fulbright Lecturer in India.

In retirement Jay and his wife spent summers at their second home in Georgetown, Maine, where he docked his Tartan 27, which he sailed from the Bay of Fundy to Florida.

Gay predeceased him in 2012. They are survived by their six children and their spouses: David Fay and Roben Campbell (Harvard, MA and Georgetown, ME), Mark Fay (Sandisfield, MA), Colin Fay and Stephanie Holmes (Brunswick, ME), Jamie and Maureen Fay (Ipswich, MA), Peter Fay and Sue DeRivera (Jamestown, RI), and Michele Fay and Tim Price (Ripton, VT); 18 grandchildren; and four great-grandchildren.

The number of people who will miss Jay extends to the many professionals at MIT and a host of other institutions and causes that benefited from his extraordinary personal talents. We are all of one mind in declaring that he was a delightful companion and inspirational individual to the end.

CHRISTODOULOS A. FLOUDAS

1959–2016

Elected in 2011

"For contributions to theory, methods, and applications of global optimization in process systems engineering, computational chemistry, and molecular biology."

BY IGNACIO GROSSMANN

CHRISTODOULOS ACHILLEUS FLOUDAS died August 14, 2016, of a heart attack while vacationing in Greece. He was a highly respected world leader who set very high standards, goals, and challenges in research. The mathematical optimization and process systems engineering communities were deeply shocked at his loss since he was only 56 years old and at the pinnacle of his brilliant professional career.

He was born August 31, 1959, in Ioannina, Greece. After earning his diploma in chemical engineering at the Aristotle University of Thessaloniki in 1982, he came to the United States to continue his education.

I was extremely fortunate to have had Chris Floudas as a PhD student at Carnegie Mellon, where he earned his degree in 1986. He was a truly outstanding student who showed great passion for and devotion to his research. The main paper of his PhD work on automatic synthesis of heat exchanger networks was based on a novel nonlinear programming model and established him as an important contributor in the area.[1] The work enabled network designs to be obtained by optimizing superstructures that contained all the alternative topologies

[1] Floudas CA, Ciric AR, Grossmann IE. 1986. Automatic synthesis of optimum heat exchanger network configurations. *AIChE Journal* 32:276.

(series, parallel, and combinations thereof) for the minimum number of stream matches and minimum energy cost. Chris also extended this work to synthesize flexible heat exchanger networks with uncertain flows and inlet temperatures.

Chris had an exceptional career, first at Princeton (1986–2015), where he became the Stephen C. Macaleer ’63 Professor in Engineering and Applied Science, and then at Texas A&M (2015–16), where he was director of the Energy Institute and the Erle Nye ’59 Chair Professor for Engineering Excellence.

One of his major contributions was the development of global optimization algorithms. Initially, the most notable was the αBB algorithm, which can be used to rigorously find global optima in nonlinear and mixed-integer nonlinear programs.[2] This research, with his students Claire Adjiman, Ioannis Androulakis, and Costas Maranas, is recognized as pioneering in the field of global optimization because of the wide class of functions and constraints it can handle (e.g., bilinear, trilinear, concave, linear fractional, and general twice-differentiable).

The key idea in the αBB algorithm was the construction of a converging sequence of upper and lower bounds on the global minimum through the convex relaxation of the original problem. This relaxation is obtained by replacing all nonconvex terms of special structure—bilinear, trilinear, fractional, fractional trilinear, univariate concave—with customized tight convex lower bounding functions and by selecting some suitable value of α to generate valid convex underestimators for nonconvex terms of generic structure. A crucial step was in the use of interval arithmetic on the Hessian matrix or the characteristic polynomial of the function being investigated. These theoretical ideas were implemented using a number of rules for branching variable selection and variable bound updates. The algorithm was successfully tested on a set of challenging test problems, mostly from chemical engineering.

[2] Androulakis IP, Maranas CD, Floudas CA. 1995. αBB: A global optimization method for general constrained nonconvex problems. *Journal of Global Optimization* 7(4):337–63.

His more recent accomplishments in global optimization, with his PhD student Ruth Misener, resulted in the development of the global optimization codes GloMIQO[3] and ANTIGONE.[4] The former is for solving mixed-integer quadratic programming problems and has, for instance, been applied successfully to the classic pooling problems that arise in the petroleum industry. ANTIGONE can handle general algebraic nonconvex mixed-integer nonlinear programming models.

The key ideas were the development of the facets of low-dimensional ($n \leq 3$) edge-concave aggregations dominating the termwise relaxation of the mixed-integer quadratically constrained quadratic program (MIQCQP) at every node of a branch-and-bound tree.[5] Concave multivariable terms and sparsely distributed bilinear terms that do not participate in connected edge-concave aggregations were handled through piecewise-linear relaxations. The major algorithmic components of GloMIQO involved reformulating user input, detecting special structure including convexity and edge-concavity, generating tight convex relaxations, partitioning the search space, bounding the variables, and finding good feasible solutions. GloMIQO was extensively tested on 400 test problems of varying size and structure, including general nonconvex terms. The structure of ANTIGONE was based on the previous MIQCQP and mixed-integer signomial optimization computational frameworks. ANTIGONE was tested on 2500 test problems from standard libraries and performed competitively with codes such as BARON, Couenne, and SCIP.

Chris Floudas also made outstanding contributions in the area of batch scheduling, where his work with Marianthi

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[3] Misener R, Floudas CA. 2013. GloMIQO: Global mixed-integer quadratic optimizer. *Journal of Global Optimization* 57(1):3–50.

[4] Misener R, Floudas CA. 2014. ANTIGONE: Algorithms for coNTinuous / Integer Global Optimization of Nonlinear Equations. *Journal of Global Optimization* 59(2–3):503–26.

[5] Misener R, Floudas CA. 2012. Global optimization of mixed-integer quadratically-constrained quadratic programs (MIQCQP) through piecewise-linear and edge-concave relaxations. *Mathematical Programming* 136:155–82.

Ierapetritou introduced a novel mathematical formulation for scheduling problems for batch processes with general network structure.[6] That work introduced a novel mixed-integer linear programming model based on a continuous time representation, whereas earlier work was based on the less rigorous discrete time representation.

Chris also did very fine work in areas of synthesis of reactor networks and separation systems. His work has had industrial impact as it has been applied by companies such as Shell, Aspen Technology, BASF, and Atofina Chemicals.

In computational biology Chris introduced a first-principles structure prediction method, ASTRO-FOLD, for helical and beta-sheet topology; invented new methods for NMR structure refinement based on atomistic modeling; and pioneered de novo design strategies for peptides and proteins. His first-principles approach to the latter led to the design of an inhibitor with 45-fold improvement over compstatin, the best-known complement inhibitor; Phase I clinical trials were successfully completed by Potentia Pharmaceuticals for age-related macular degeneration.

More recently, he developed very-large-scale supply chain models for hybrid feedstock for energy for converting coal, biomass, and natural gas to gasoline, diesel, and kerosene. This work, based on multiscale modeling and incorporating materials considerations for the various energy technologies,[7] received a great deal of attention as it addresses the US supply chain. It was also to a large extent the basis for his appointment as director of the Energy Institute at Texas A&M.

Chris gave many keynote talks at major international meetings, was prolific in writing papers (over 350 publications), and was the author of two graduate textbooks, *Nonlinear Mixed-Integer Optimization* (Oxford University Press, 1995) and

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[6] Ierapetritou MG, Floudas CA. 1998. Effective continuous-time formulation for short-term scheduling. 1. Multipurpose batch processes. *Industrial & Engineering Chemistry Research* 37:4341–59.

[7] Floudas CA, Niziolek AM, Onel O, Matthews LR. 2016. Multi-scale systems engineering for energy and the environment: Challenges and opportunities. *AIChE Journal* 62:602–23.

Deterministic Global Optimization (Kluwer Academic Publishers, 2000). He also coedited the *Encyclopedia of Optimization* (with Panos Pardalos; Springer, 2008) and ten monographs/books. His publications have been cited tens of thousands of times.[8]

For his teaching, research, and writing, Chris received numerous awards and honors: the NSF Presidential Young Investigator Award (1988); Engineering Council Teaching Award, Princeton University (1995); Bodossaki Foundation Award in Applied Sciences (1997); Best Paper Award in Computers and Chemical Engineering (1998); AspenTech Excellence in Teaching Award (1999); AIChE Professional Progress Award for Outstanding Progress in Chemical Engineering (2001) and Computing in Chemical Engineering Award (2006); Graduate Mentoring Award, Princeton University (2007); and National Award and Operational Research Gold Medal from the Hellenic Operational Research Society (2013).

He was also elected to the NAE (2011); selected for China's One Thousand Global Experts (2012–15); and elected a SIAM fellow (2013), AIChE fellow (2013), member of the Academy of Medicine, Engineering, and Science of Texas (2015), corresponding member of the Academy of Athens (2015), and fellow of the National Academy of Inventors (2015). He was designated a TAMU Institute for Advanced Study fellow and eminent scholar (2013–14), received an honorary doctorate from Finland's Åbo Akademi University (2014), and was recognized as a Thomson Reuters Highly Cited Researcher (2014 and 2015).

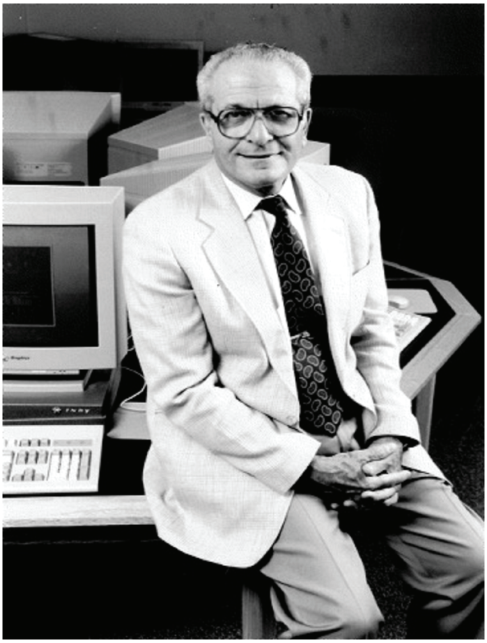
Chris's legacies include the outstanding PhD students and postdocs he advised and mentored who have taken academic positions; they include Claire Adjiman, Peter DiMaggio, Chrysanthos Gounaris, Faruque Hasan, Marianthi Ierapetritou, Nina Lin, Costas Maranas, and Ruth Misener. His students have also been very well received by industry.

Chris Floudas' death is a huge loss to the mathematical optimization and process systems engineering communities.

[8] His publications have been highly cited (42,000 Google Scholar citations and an h-index over 100 as of September 2021).

He was not only a major intellectual leader but also a very good friend. His absence will be felt for many years. The only consolation is to know that his legacy will continue through his students and that his work will inspire new generations of researchers in optimization and process systems.

We offer our deepest sympathy to his wife Fotini and daughter Ismini. Chris will be sorely missed. May he rest in peace.



ABDEL-AZIZ A. FOUAD

1928–2017

Elected in 1996

"For contributions to the analysis of the dynamics, stability, and control of electric power."

BY VIJAY VITTAL

ABDEL-AZIZ AHMED FOUAD, a celebrated academic scholar and industry consultant in electrical engineering, and Emeritus Anson Marston Distinguished Professor at Iowa State University, passed away at the age of 89 on October 21, 2017. In addition to his significant contributions as a lifelong educator, his research changed our understanding of the dynamic behavior of the large power grid, enabling better analysis and control that avoided large-scale blackouts.

Aziz was born in Cairo, Egypt, on May 10, 1928. He obtained his BS degree from Cairo University in 1950, his MS degree from the University of Iowa in 1953, and his PhD degree from Iowa State University in 1956, all in electrical engineering.

He started his career as an instructor in the Electrical Engineering Department at Iowa State (1954–56), returned to Cairo as a lecturer at Ain-Shams University (1956–60), and in 1960 joined the Iowa State faculty as an assistant professor of electrical engineering. By 1966 he was a full professor, and in 1990 he was named the Anson Marston Distinguished Professor. He also served as interim chair of the Department of Electrical and Computer Engineering (1995–96).

In addition, he was a visiting professor at the University of the Philippines (1969–71) and at the University of Rio de Janeiro in the summer of 1972.

His industrial experience included engineering assignments with the Cairo Gas and Electricity Administration, Brazilian Traction, Light and Power Co., Ltd., Jersey Production Research Company, and Atomics International. He also worked as a project manager with the Electric Power Research Institute's Electrical Systems Division.

Dr. Fouad pioneered the development of stability analysis of the electric power transmission grid; his contributions increased the reliability of the electricity supply. Electricity generators across North America spin in synchrony, producing voltages and currents that fluctuate 60 times a second; for example, generators in Iowa are synchronized with generators in Florida and Ontario. A massive blackout can occur if this synchrony is suddenly lost, so it is necessary to operate the power grid sufficiently far from this condition even if some transmission lines suffer faults that remove them from service. The methods Aziz developed are used in control center software across the nation to keep the transmission grid operating.

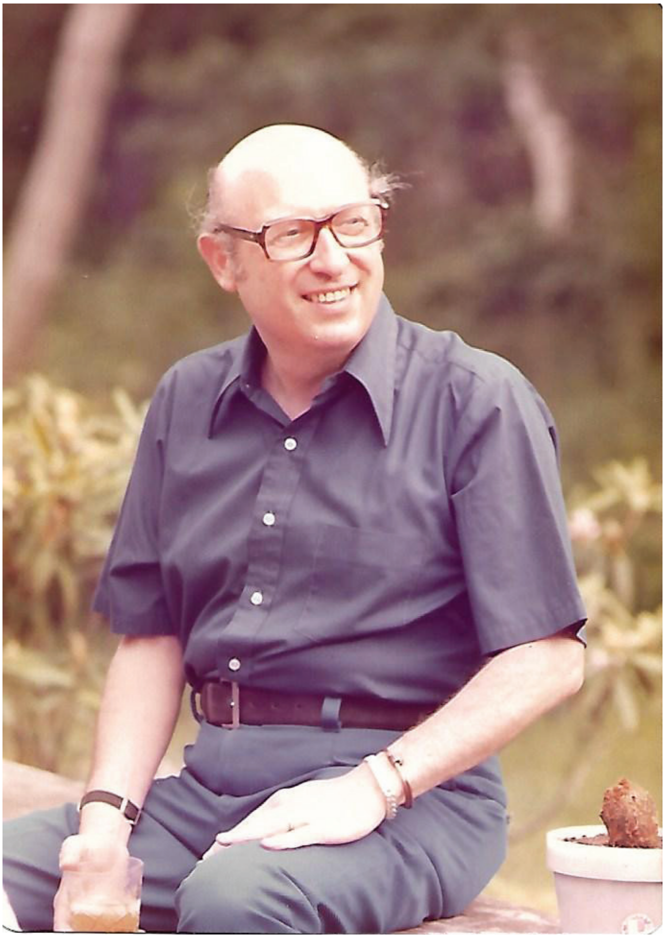
He coauthored two books that are classic and foundational references describing the dynamics of large-scale electric power transmission grids: *Power System Control and Stability* (John Wiley & Sons, 1977) and *Power System Transient Stability Analysis Using the Transient Energy Function Method* (Pearson, 1991). Every graduate student seriously studying power system dynamics refers to these books.

Aziz received many honors during his lifetime. In addition to his NAE membership, he was a fellow of the Institute of Electrical and Electronics Engineers and winner of its Herman Halperin Electronic Transmission and Distribution Award (1994). At Iowa State he earned the College of Engineering David R. Boylan Eminent Faculty Award for Research, the Wilton Park International Service Award, the Marston Medal, and the Faculty Citation Award from the ISU alumni association.

Having lived in a variety of countries (Egypt, Brazil, the Philippines) and traveled extensively, Aziz had a great interest in economic development around the world. He founded (and chaired, 1972–78) an interdisciplinary graduate program at Iowa State University on Technology and Social Change in Foreign Cultures, a program that was revolutionary and very popular. And because of his interest and involvement in the issue of technology and social change, he was appointed to serve on the Commission on International Relations of the National Research Council (1975–78).

Aziz was a very social person, and his delightful humor and easy charm made him the life of a party, whether it was a gathering of close friends in his home or a professional event on the other side of the world. He was an avid tennis player and a bridge enthusiast. He was a long-time member of the Rotary Club of Fort Collins and a contributing member of the Northern Colorado Senior Tennis League.

While at the University of Iowa, Aziz met his wife of 56 years, Maria Elisabeth (née Leal) Fouad. She predeceased him in 2009. They are survived by their two children, Nadya Fouad (Robert Leitheiser) and Sam H. Fouad (Jill Norman), five grandchildren, and two great-grandchildren.



ROBERT A. FROSCH

1928–2020

Elected in 1971

"Contributions toward the improved application of engineering resources to large-scale engineering developments with special emphasis on underwater acoustics."

BY LAWRENCE D. BURNS

ROBERT ALAN FROSCH, one of the nation's foremost R&D leaders, died December 30, 2020, in South Hadley, Massachusetts, at the age of 92.

Bob was born in New York City to Herman and Rose (née Bernfeld) Frosch on May 22, 1928, and grew up in the Bronx, where he attended public schools. Blessed with deep intellect and curiosity, he attended Columbia College, where he earned a bachelor of arts degree in 1947, and Columbia University, where he earned his doctorate degree in theoretical physics in 1952 when he was just 23 years old.

After graduation Bob embarked on an extraordinary research and development career in government, industry, and academia. His formidable contributions spanned oceans, skies, outer space, and land, and enhanced this country's defense systems, exploration capabilities, automobile transportation, and environmental quality. Few people have accomplished so much in so many areas. And even fewer have been so successful while also being a model of kindness, integrity, and service.

Bob's first job was at Hudson Laboratories of Columbia University in Dobbs Ferry, NY, an organization under contract to the Office of Naval Research. He worked on problems in underwater sound, sonar, oceanography, marine geology, and marine geophysics. In addition to his research, he was associate director and then director of the laboratories and managed 300 employees and two ocean-going research vessels. He was also technical director of Project Artemis, a large experimental active sonar system development program.

In 1963 Bob moved to Washington, DC, to become director for nuclear test detection in the Defense Department's Advanced Research Projects Agency (ARPA), where he led the design and building of the computer-controlled Large Aperture Seismic Array (LASA). He was appointed deputy director of ARPA in 1965 and in 1966 assistant secretary of the Navy (research and development), responsible for all Navy research, development, engineering, and test and evaluation programs, averaging $2.5 billion annually. These programs included the Aegis antiair system, new submarine and antisubmarine systems, and early "smart" weapons and systems.

He took on global responsibilities in 1973 when he became the first assistant executive director of the United Nations Environment Program (UNEP), with the rank of assistant secretary general. Two years later he became associate director for applied oceanography and director of research at the Woods Hole Oceanographic Institution.

Bob transitioned from oceans to outer space when he became NASA's fifth administrator in 1977. During his tenure the first space shuttle was built and ground-tested, and spacecraft projects were created to investigate Venus with radar imaging and the universe with x-rays and gamma rays.

In 1982 he transitioned again—this time from government to industry—when he became vice president of research at General Motors. With the growing proliferation of electronics and computers in automobiles in the early 1980s, vehicle design was becoming more complicated. Bob brought the concept of systems engineering (used at NASA) into the design of cars and trucks. This led to the creation of the GM Systems Engineering Center, and all future GM vehicles were designed and engineered using concepts stemming from Bob's initiative and experience.

Also at GM, Bob created the field of *industrial ecology*, the systematic study of material and energy flows through industrial systems. The articles he wrote with his GM colleague Nicholas E. Gallopoulos in the late 1980s and early 1990s, including one in *Scientific American* titled “Strategies for Manufacturing,” drew attention to the importance of managing industrial processes and waste in an environmentally acceptable manner. He became internationally recognized for his contributions to the development of environmentally friendly technologies.

After retiring from GM in 1992, Bob joined the John F. Kennedy School of Government at Harvard University as a senior research fellow. For the next 28 years he remained active at Harvard in scientific and technical policy activities related to energy, innovation, space security, industrial ecology, and globalization. He also engaged as a guest investigator and mentor at Woods Hole Oceanographic Institution.

In addition to his research and leadership accomplishments, Bob was exemplary in his professional service. He gave generously of his time and talents, serving on governing or advisory bodies for a dizzying array of professional organizations, educational and research institutions, government entities, and philanthropic and health organizations. In 1981 he became the first president of the American Association of Engineering Societies (AAES). He was a member of Phi Beta Kappa, member and president of Sigma Xi, fellow of the American Academy of Arts and Sciences, foreign member of the Royal Academy of Engineering, and a fellow of at least seven other technical societies.

He also served on numerous NAE and National Academies committees and studies and chaired quite a few, including the committee that produced the 1989 NAE consensus study *Technology and Environment*.

As the first NAE member to cochair the Academies’ Report Review Committee (RRC), Bob signed off on close to 200 report reviews monitored by the RRC, and during his 23 years on the RRC he served as review monitor or coordinator for nearly 150 reports. During his term as cochair, the RRC instituted refinements in policies and procedures such as a streamlined approach for responding to reviews that made the review process more effective and efficient. In addition, RRC meeting discussions were opened to the participation of the NAS, NAE, and IOM presidents, staff from the NRC Executive Office and six division executive offices, and select project staff. Bob approached the job with his characteristic diligence and humor and had a way of making even the most mundane tasks interesting.

For his innumerable contributions, Bob was awarded the Navy Distinguished Public Service Award, NASA Distinguished Service Medal, IEEE Founder's Medal, Defense Meritorious Civilian Service Medal, Neptune Award of the American Oceanic Organization, and IRI Medal of the Industrial Research Institute for his leadership at GM. In 2003 he received the NAE's prestigious Arthur M. Bueche Award, which honors an engineer who has shown dedication in science and technology as well as active involvement in determining US science and technology policy, promoting technological development, and contributing to the enhancement of the relationship between industries, government, and universities.

Bob was married to Jessica Rachael Denerstein of Brooklyn, NY, for 59 years, until she passed in 2016. They are survived by daughters Elizabeth Frosch-Dratfield (Paul Dratfield) and Dr. Margery Frosch (Dr. Meryle Weinstein) and two grandchildren.

Robert Alan Frosch had a beautiful mind and was an outstanding leader and person. We are all blessed by his life.

RALPH S. GENS

1924–2019

Elected in 1983

"Contributions to the advancement of electric power transmission technology through creative engineering accomplishments and management leadership of research and development."

BY CARSON W. TAYLOR

RALPH SAMUEL GENS, who led the Bonneville Power Administration's development of the Pacific Northwest 500 kV transmission grid with California interties and the introduction of high-voltage direct current in the United States with the Pacific Northwest–Pacific Southwest DC intertie, died at age 94 on January 3, 2019, in Kailua-Kona, Hawaii. His many contributions to the advancement of electric transmission technology—sound, progressive engineering and innovations and refinements—had a profound effect on the industry on a national and international scale.

Born in Berlin, Germany, on November 25, 1924, Ralph came to live in Portland, Oregon, in 1939 at age 14, via Kindertransport. He told of standing on the street with his father, a decorated World War I veteran, watching Hitler pass. In Portland Ralph lived with his aunt and uncle, Edna and Richard Genserowski (a 1902 Olympic gymnast), both leaders in Portland's German community. His Washington High School class awarded him a scholarship to Oregon State University, but he could not use it at the time as the campus was too near the Pacific Coast—German nationals were not

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Much of the information for this tribute was provided by Ralph Gens' daughter, Marilyn Gens Johnson.

allowed within many miles of the ocean. Drafted while a student at the University of Washington, Ralph became a US citizen while in basic training and served in the Pacific as a scout in the US Army Infantry (1943–46), ending his service in Japan after its surrender.

In 1949 he earned a BS in electrical engineering from Oregon State College (now Oregon State University, OSU), where Eugene Starr (NAE 1977) became his mentor and steered him toward the Bonneville Power Administration in Portland during his senior year. Ralph began his BPA career as an engineering aide in the System Engineering Branch, then became chief of the branch in 1966.

Ralph's work included insulation coordination, high-voltage practices, planning and economic analyses, and R&D. He was particularly interested in high-voltage phenomena, in terms of insulation coordination and the application of new concepts to reduce insulation requirements to make higher-transmission voltage more attractive. He had considerable influence on high-voltage technology, and his early work refining control of high-voltage insulation became widely used throughout the world.

Later he guided the development of BPA's 500 kV transmission network, at the time the largest in the world, and provided the motivation and expertise that led to acceptance of high-voltage direct current (HVDC) transmission in the United States. Eventually he guided the world's first three-phase 1100 kV transmission line for test and demonstration purposes. Other innovations that came about under his direction included improved switching surge controls, insulation levels, series capacitors, large braking resistors, high-speed circuit breakers, staged system tests, advanced system computer programs, computer-aided design, and greatly reduced electrical losses on transmission lines.

It was as a direct result of Ralph's suggestions that BPA established the first HVDC test facility in the United States, at the Big Eddy Substation above The Dalles, Oregon. He recruited talented expertise from within BPA and around the world, bringing in engineers from Sweden, India, Germany, and the United Kingdom (the three that became US citizens were later elected to the NAE[1]). Ralph's own expertise enabled him to evaluate technical proposals for the facilities required for the Pacific Northwest–Pacific Southwest DC Intertie from the Columbia River to Los Angeles, and then solidify the negotiations between government agencies, electric utilities, and manufacturers to create a most successful pioneer long-distance project.

In 1974 he became manager of planning and research, and in 1977 was appointed BPA assistant administrator, engineering and construction (chief engineer), a position he held until his retirement in 1980, after which his consulting activities took him to the jungles of Papua New Guinea and South America. For 10 years Ralph was a technical and management consultant for the Papua New Guinea Electricity Commission, mentoring young nationals to assume senior civil service positions while advising on the construction of the transmission system connecting the new Yonki Dam to Port Moresby.

At BPA he was a dynamic, innovative, and demanding chief engineer. RWI became a favorite expression of his engineers—Ralph Wants It. As an example, he wanted to promote Bill Tinney (NAE 1998) to GS-15, but his higher-up manager would not approve the promotion—Ralph did it while the manager was on vacation. His management ability and unconventional style inspired high performance while bringing together engineering personnel with diverse talents. Always supportive of engineering excellence, one of his initiatives was the establishment of a technical career advancement path for engineers, parallel to management paths, that was helpful to many (including this writer).

Ralph credited the BPA librarian, Erik Bromberg, with fostering his curiosity in what was happening around the world in the specific engineering areas he was already focusing on early in his career. This librarian had the new idea of ordering technical periodicals that could communicate the newest technical activities—especially research, which led to Ralph's reading

[1] Stig Annestrand, Narain Hingorani, and John Vithayathil

about HVDC applications around the world long before there were any in the United States. Vision and enthusiasm throughout his career were fueled by the international experience.

Ralph Gens held a patent and authored more than 20 technical publications, several of which were considered benchmarks in his field. In addition to his work at BPA, his research interests involved him as coordinator of Project EHV/UHV. He was also invited or elected to serve in several leadership positions: as US vice president and US national advisor for CIGRÉ (International Council on Large Electric Systems; 1979–80), chair of the IEEE Surge Protection Devices Committee and later the CIGRÉ Study Committee on System Analyses and Techniques, and chair of the Department of Energy's Energy Research Advisory Board (1984–85).

Beginning in 1972 Ralph was selected as a member of the Joint US-USSR Coordinating Committee on Scientific and Technical Cooperation in the Field of Energy; he headed delegations to the USSR in both 1976 and 1978, and in 1978 the delegation at the US meetings. He was the National Science Foundation project advisor for an electrical energy project in Yugoslavia, and served in an official US delegation to the People's Republic of China assisting that country in developing hydroelectric resources and transmission facilities.

His many honors included recognition as a fellow of the Institute of Electrical and Electronics Engineers (1969), Meritorious and Distinguished Service Awards from the Department of the Interior (1973 and 1978), election to the NAE (1983), the IEEE Habirshaw Award and Centennial Award (both in 1984), election to the OSU Engineering Hall of Fame (1999), the IEEE Medal for Engineering Excellence (2003), and the CIGRÉ Philip Sporn Award (2018).

Quoting from one of his award recommendations: "Mr. Gens is a truly outstanding public servant. He has given his time and talents in full measure and is respected within and outside BPA for his industry, resourcefulness, dedication, and loyalty to the government. The tremendous amount of drive which he exhibited throughout his working life has not been motivated by any desire for personal recognition, for Mr. Gens is one of those modest and unassuming successful men. As a public servant, he is one of the best."

In 1951 he met Ida Mattson on a bus going to work, before he realized that they worked in the same office at BPA. They married the following year and Ida provided encouragement as well as professional and domestic support throughout his career.

Ralph's proudest legacy was the family he and Ida created. The impacts of his experience as a teen refugee and the loss of most of his extended family in the Holocaust instilled a deep desire to foster meaningful relationships and honor his extended family. He traveled the world with Ida, their children Marilyn and David, and grandchildren, introducing them to their cousins and leaving them with a close and loving global family. He instilled values of loyalty to family, work, education, and humanity.

In retirement he, Ida, and their son David built a home at Mt. Hood, OR, and "The Cabin" became a place for summer reunions with far-flung family, reconnecting and enjoying hikes in the forest and fields. Into his 90s, Ralph enjoyed chainsaw work, walking the property line, and directing his grandchildren on how to build a proper bonfire. He would claim that his most significant retirement project was encouraging and supporting all five of his grandchildren to their university degrees.

At Ida's request they retired to Kona in 1987. There, even at age 94, Ralph swam regularly in Kahalu'u Bay. He followed world affairs, played bridge, tended the yard, and engineered his solar array. This solar energy project required him to get his professional engineering license from the state of Hawaii. When asked to provide contact information for the licensed professional engineers that supervised his work, a routine question, he had to respond that there were none still living.

For many, including his family, Ralph Gens was larger than life. The respected patriarch of an extended family that spanned continents, he was intellectual, elegant, generous, loyal, and accomplished. He is remembered fondly by his family, friends, and colleagues around the world.

IRVIN GLASSMAN

1923–2019

Elected in 1996

"For contributions as researcher, author, editor, and educator in combustion and propulsion."

BY CRAIG T. BOWMAN, FREDERICK L. DRYER,
WILLIAM A. SIRIGNANO, AND RICHARD A. YETTER

IRVIN GLASSMAN passed away December 14, 2019, at the age of 96. We miss now an extraordinary colleague and friend, well known for highly energetic, productive, and impactful engagement in research, teaching, mentoring of younger colleagues, editorial leadership, and organizational development. Through these activities, he was a very prominent leader both in defining the modern field of combustion science and engineering and in mentoring undergraduate and graduate students.

Born September 19, 1923, in Baltimore, Maryland, Irv Glassman was educated in the public schools and graduated from Baltimore City College in 1940. His life was a testament to the transformative power of education. A scholarship to Johns Hopkins University (JHU) enabled him to leave his mother's grocery store, obtain undergraduate and graduate degrees in engineering, and eventually become a professor at Princeton University. He earned a bachelor of chemical engineering degree at JHU in 1943 and immediately joined the US Army, working on the Manhattan project at Columbia University while serving for the rest of World War II. He returned to JHU and received a doctorate in chemical engineering in 1950.

The authors appreciate input from Robert Socolow, former director of Princeton's Center for Environmental Studies (1979–97).

He then joined the newly created Daniel and Florence Guggenheim Jet Propulsion Center in the Aeronautical Engineering Department at Princeton as a research associate, assigned to work on designing supersonic nozzles. He advanced to the research staff in 1954, leading the experimental ramjet research effort. He was appointed assistant professor of aeronautical engineering in 1955, and promoted to associate professor in 1959 and professor in 1964 in the newly formed Department of Aerospace and Mechanical Sciences (now the Department of Mechanical and Aerospace Engineering).

Irv's early research led to his recognition of the importance of fuel properties to rocket performance and instability. It also stimulated his overarching career interests in chemical effects on fire safety, propulsion, energy conversion, and environmental emissions.

His research was done mostly at the Guggenheim Laboratories on Princeton's Forrestal Campus until 1973, when the research moved to the main campus to involve more undergraduates and to advance the newly established Center for Energy and Environmental Studies, which Irv directed until 1979. He was also appointed the American Cyanamid Professor of Environmental Sciences (1972–75), the Robert H. Goddard Professor of Mechanical and Aerospace Engineering (1988–99), and MAE department chair (1989–90).

Irv was instrumental in founding the Center for Environmental Studies in Princeton's School of Engineering and Applied Science (1971), was its director (1973–78), and remained involved as mentor and behind-the-scenes supporter. (In 1974 the center's name was changed to the Center for Energy and Environmental Studies in recognition of the centrality of energy issues to an environmental center in an engineering school.) As director, Irv ensured the center's future and its autonomy as he appointed its first senior research staff and helped secure its early funding. Under his leadership the center launched programs in nuclear power, renewable energy, energy efficiency, sustainable development, and land use. The center became broadly recognized for innovative thinking, interdisciplinarity, international collaborations, and the mentoring of graduate students and intrepid early-career scholars reorienting their careers.

Over his half-century career at Princeton and as professor emeritus since 1999, Irv contributed broadly and extensively to applications-inspired fundamental combustion science and technology. His earliest work addressed propellants for air and space propulsion applications, including impacts on combustion instabilities. The effort gave emphasis to gas-phase behavior; chemical kinetic properties of hydrogen/oxygen, methane, and storable spacecraft propellants; and metals combustion. He postulated the "Glassman criterion" for characterizing when and how metal oxide condensation affects a metal's burn rate.

He subsequently turned to fuels-related work in ground and air transportation, including carbon monoxide oxidation and hydrocarbon pyrolysis/oxidation, especially of alkylated and aromatic fuel components. Through these fuel studies, he contributed substantially to fire safety, elucidating the phenomena controlling flame spread over solids and over fuel spills and through stratified fuel vapor/air mixtures and pool fires. His work on sooting in premixed and diffusion flames, especially for aromatics, significantly enhanced characterization of fuel properties related to radiative transfer in gas turbine combustors and emissions of nitrogen oxides, carbon monoxide, and soot from combustion systems.

Irv thought deeply about the chemical and physical issues related to a problem, demonstrating extraordinary knowledge and fundamental insight and, importantly, considering the implications of the applied findings. Though many of his major contributions were experimentally inspired, a hallmark of his work was developing insights that advanced theoretical understanding, especially chemical-kinetic and thermodynamic-related aspects, while also acknowledging the influences of molecular transport processes and fluid mechanics.

Leading contributors in academia and industry have emerged from his stellar mentoring of undergraduate and graduate students, postdocs, professional research staff, and visiting scholars. His former students now form a significant leadership group in combustion science and engineering; 21 of his 35 PhD students became faculty members at major universities; three of them are now members of the National Academy of Engineering; and another was elected to the Canadian Academy of Engineering.

His strong emphasis on connecting applications to fundamental work led to his advisory roles with the National Research Council (for example, as a member of the committee that advised EPA administrator William Ruckelshaus on the schedule for the 1970 Clean Air Act) and NATO, and consultancies for prominent corporations such as United Technologies and Chrysler. He authored about 250 scholarly articles and two books. His textbook *Combustion*, first published in 1977 (Academic Press), is now in its fifth edition. Like his lectures, it emphasizes the understanding of simple physical concepts, instilling an ethos for lifelong learning and imagination.

Irv also enjoyed editing, beginning with his involvement as associate technical editor of the *Journal of the American Rocket Society* (1951–64), predecessor of the *AIAA Journal*. He founded the journal *Combustion Science and Technology* in 1971 to convey the more applied aspects of combustion science to the broader community. These legacy publications will continue to mentor new leadership in the field of combustion for many decades to come.

Professor Glassman was recognized by the Combustion Institute as an inaugural fellow "for pioneering studies on the chemical kinetics of combustion systems with a particular emphasis on aromatics and soot," and in 1982 he received the institute's Egerton Gold Medal "for distinguished, continuing, and encouraging contributions to the field of combustion." In other recognition of his extraordinary contributions to education and research, he received the 1984 Ralph Coats Roe Award from the American Society for Engineering Education; was elected to the NAE in 1996; and was a fellow and 2018 Daniel Guggenheim Medalist of the American Institute of Aeronautics and Astronautics (one of the greatest honors for a lifetime of contributions to aeronautics). In 2011 the Eastern

States Section of the Combustion Institute established the Irvin Glassman Young Investigator Lecture and Award to recognize rising contributors in the field. In 2009 Irv was awarded an honorary doctor of science degree by Princeton University. The announcement stated:

> His half-century of research and teaching defined a field that propelled us to the moon and started us on the path to more efficient use of energy. He insisted, for himself and his students, on a deep understanding of the science behind the chaos of a flame, sending forth scores of new leaders who now populate the field. His gift for looking ahead led him 35 years ago to see beyond the raw power of fuels and train his energy on challenges to the environment, sparking a field of critical importance today that may determine our quality of life tomorrow.

Irv is survived by his wife of 68 years, Beverly (née Wolfe); their three children, Shari Powell (Warren), Diane Gienger (Edwin), and Barbara Glassman (Arthur Rubin); and six grandchildren.

In addition to his personal family, Irv was instrumental in creating a large and devoted "Princeton family" in the combustion community, to which many graduates of the Princeton Mechanical and Aerospace Engineering Program, as well as their colleagues in academia and industry, belong. He was very proud of his legacy as a teacher.

Through his interest in others, kindness, and positive outlook, Irv became not only a teacher but a lifelong mentor to many of his academic "children." In 1972 he instituted the tradition of a biennial Princeton reunion at the International Combustion Symposia, which continues to this day.

The strong influence of the Princeton family in the combustion community and his numerous and wide-ranging scholarly contributions define the professional legacy of Professor Irvin Glassman.

ROBERT W. GORE

1937–2020

Elected in 1995

"For the invention and commercialization of high-technology products, including Gore-Tex."

BY BABATUNDE A. OGUNNAIKE AND ERIC W. KALER

ROBERT WALTON GORE, president and chair of the board of W.L. Gore and Associates, died September 17, 2020, at the age of 83 at his summer home in Earleville, Maryland.

He was born in Salt Lake City on April 15, 1937, the oldest of five children of Wilbert L. (Bill) and Genevieve W. (Vieve) Gore. His family soon moved to Delaware, where his father worked for the DuPont company and became interested in uses of polytetrafluoroethylene (PTFE) in industrial products; he left DuPont to form W.L. Gore and Associates in 1958.

Bob graduated from Newark High School in 1955 and went on to earn a bachelor of science degree (1959) at the University of Delaware (UD) and then a master's (1961) and PhD (1963) at the University of Minnesota, all in chemical engineering. He had become a member of the board of directors of W.L. Gore and Associates in 1961, and in 1963 returned to Delaware to rejoin the company.

Bob's technical successes came early and often. While a UD sophomore, he worked with his father to find a way to wrap wires and create insulated cables and harnesses using PTFE; Bob played a key role in solving the technical issues. This became the first product of W.L. Gore and Associates and helped launch the company. Bob became the technical director in 1967.

By 1969 the company sold several products in the wire and cable sector, had been a key supplier to the growing computer industry, and was a vendor for the Apollo space program. But there was strong motivation to reduce the cost of PTFE in their applications. This led to the idea of "expanded" PTFE, made by stretching PTFE tape. The challenge was that, under all conditions explored, the tape would stretch a bit but ultimately retract or break.

One evening, after trying for hours to coax a stretch, Bob gave a heated PTFE rod a sharp yank—and the rod stretched almost 1000 percent. That was the moment of creation of expanded PTFE, which provided the basis for Gore-Tex, the billion-dollar product that catapulted the company to an unprecedented level of success. Gore-Tex is now a household name, and the company has expanded to Gore Industrial Products and Gore Medical Products.

Bob became president and CEO of the company in 1976 and served until 2000. He stepped down as chair in 2016. He was not only a great inventor but also a fierce, yet kind, leader.

Terri Kelly, who succeeded Bob as president, observed that, "In addition to Bob's numerous contributions to technology and innovation, he was known for his incredible business intuition, critical thinking skills, and willingness to challenge the status quo. He made significant contributions to the creation of new business tools and concepts, which were quite ingenious and simple in principle but created powerful organizational discipline. Throughout Bob's career he was a mentor to so many, challenging you to explore things at a deeper level and always asking the most insightful questions."

A superb practical engineer, "Bob was a master at finding the fastest way to test something," according to Bret Snyder, chair of W.L. Gore and Associates and Bob's nephew. Recognizing his uncle as a gifted leader, he continued, "One time Bob challenged a business unit leader on the mission of the business. After some questions and challenges from Bob, the next week the business unit leader came back with a single sentence that precisely and elegantly defined the mission, to Bob's satisfaction. Bob didn't allow intellectual laziness and confusion."

Son Scott Gore remembers his father's routine: "After the evening news, he would gather a large yellow pad of paper and pencil, his slide rule, and drafting tools such as a scale ruler, protractor, and compass. Sitting in front of the TV, he would design process machinery. My bedtime was 9:30 p.m., and often he was still working when I went to my room. Dad always tried to instill a sense of urgency. At some point he would inevitably want to know 'What are you going to do this week, this month, this year?'"

Betty Snyder, Bob's sister and a member of the board of W.L. Gore and Associates, recalls that her brother "was dedicated to discovering and acting on truth—scientific truth, customer truth, the true nature of a person, and the true nature of a group. This was his defining characteristic. He believed that proven facts are something you could hold on to. Good decisions could not be based solely on opinions." She added that "Bob believed in trying hard. He himself tried to do his best in every effort—nothing was done in a mediocre way. When I recently asked him his advice to Associates, this was his response: 'try hard.' He believed that the accumulation of years of trying hard, no matter what the task at hand, result in significant personal development. And this was the case with him."

Bob was committed to education and was a member of the board of directors of the UD Research Foundation and the UD board of trustees. He and his family were extraordinary philanthropists, giving generously to many organizations, including both UD and the University of Minnesota.

Bob and his family began their impactful support of UD facilities in the mid-1990s. After a conversation with then-president David Roselle about the need for more general-purpose classroom space on the campus, Bob agreed to contribute $15 million for such a building to fill the last empty space on the north Green. When the project cost climbed to $18.5 million, he was unwavering in his full support, and adamant that it should match the classic Georgian style of its neighboring buildings on the Green. The result was Gore Hall, the first new building on the Green in more than 35 years and home to 25 high-tech classrooms and other facilities.

The holder of nine US patents, Bob received many honors in recognition of his creativity and leadership, including the Society of Plastics Engineers John W. Hyatt Award for benefits to society through the use of plastics and the Perkin Medal for innovation in applied chemistry resulting in commercial development from the Society of Chemical Industry (American Section). He also was an active member of the American Chemical Society and the 2019 Carothers Award recipient (Delaware Section). He was elected to the NAE in 1995 and inducted into the US National Inventors Hall of Fame in 2006.

Bob leaves behind a large family, including his wife, Jane, sons Scott, Tom, and Brian and daughter Sharon; stepchildren Debi, Jayne, Jack, Tom, Chris, and Steve; sisters Susan, Ginger, and Betty, and brother Dave; 28 grandchildren; and 13 great-grandchildren.

WILLIAM R. GOULD

1919–2006

Elected in 1973

"Contributions and leadership in fossil fuel and nuclear power developments, siting, environmental impact, and water desalinization."

BY WAYNE R. GOULD
SUBMITTED BY THE NAE HOME SECRETARY

WILLIAM RICHARD GOULD was born on Halloween in 1919 in Provo, Utah. He was born at home, in an adobe house, to Pauline Eva (née Feser) and William John Gilbert Gould. His father was a steam locomotive engineer for the Utah Railway.

As a child, Bill stuttered badly. To avoid being the target of youthful pranks and ostracism he became a loner, independent and determined to succeed. Sensing his loneliness, his father began taking him to work on the railroad. Bill often rode on his father's lap in the big steam locomotive and before long fell in love with this world of fuel and steel, fire and steam, motion and power.

When he came of age, he enrolled at the University of Utah as an engineering student. On one of his first days a counselor, noticing his speech impediment, told him that he could never be successful as an engineer and suggested he should drop out of school and go back to the family farm. Bill resolutely told the counselor that there wasn't a family farm to go back to, so he "guessed" he would stay and give it a try. He completed his bachelor's degree in mechanical engineering in 1942 and went on to become a registered professional engineer in California and Utah.

While at the university he met his future wife, Erlyn Arvilla Johnson. A childhood illness had left her with the fragile body of a "China Doll." But this China Doll had the heart of a lion and a fierce independent determination, bred of poverty, to live life to its fullest and not ask for any favors. They were an equal pair—two tough kids from poor backgrounds and with personal challenges but an indomitable spirit. They were married March 20, 1942, in the Salt Lake City Temple of the Church of Jesus Christ of Latter-day Saints. Together they would face adventure, excitement, and hardship. They lived successfully and they lived well. Their marriage clearly demonstrated that the whole far exceeded the sum of the parts.

As an ensign in the US Naval Reserve, Bill was sent to the Massachusetts Institute of Technology and Dartmouth University for graduate courses in engineering. After this advanced training, he was stationed at the Long Beach Naval Shipyards, where he served throughout World War II as a trials officer in charge of testing the propulsion machinery of ships before their departure for war zones.

His wartime experience qualified him for postwar employment with the Southern California Edison Company (Edison) in Los Angeles and then nearby Rosemead. In 1948 it was a hydroelectric utility that was just beginning to transition to thermal generation; it needed someone who knew something about fuel and steel, fire and steam, motion and power.

Bill worked for Edison for 44 years. Its prosperity was his prosperity and that of his family. The company grew into a world-class utility renowned for energy innovation and the application of cutting-edge technologies. As the company grew, Bill assumed positions of increasing responsibility and authority, becoming president in 1978 and chair and chief executive officer in 1980. When he retired in 1984 he was designated chair of the board emeritus and consultant to the management, remaining involved in the company until 1992.

Bill and Edison were inextricably connected, and many suggested that he was the heart and soul of the enterprise. In recognition of his exceptional career, in 1992 Southern California Edison created the William R. Gould Award for Engineering and Operational Excellence, presented annually to two outstanding employees.

Bill may be best remembered for his pioneering work in the development, sponsorship, and acceptance of alternative and renewable energy. In the early 1980s he informed employees that Edison's policy was "to devote our corporate resources to the accelerated development of a wide variety of future electrical power sources which are renewable rather than finite." He called on employees to develop alternative sources such as windmills, solar panels, and fuel cells, and opened the door to the acceptance of third-party independent power producers. Among large-scale projects, he helped lead the construction of the Pacific Intertie, a major electricity transmission line linking Southern California to the Pacific Northwest, and the San Onofre Nuclear Generating Station, a 2200-megawatt power station in San Diego County.

For its forward-looking advances, in 1982 the company was awarded the Tyler Prize for Environmental Achievement, cited as "the first major utility in the United States to establish as policy a shift to alternate and renewable energy sources [and with] strong corporate leadership." At the time of Bill's passing, nearly a fifth of Edison's electricity was provided through renewable sources—more than any other major utility, according to the company.

Bill's efforts would change the utility industry forever. As he said in a 1981 *Forbes* interview, "If a species doesn't go through a mutation to meet its new environment, it doesn't survive. A corporation is in the same situation."

In addition to his work at Edison, Bill was active in a variety of other capacities. He chaired the Atomic Industrial Forum, Electric Power Research Institute, National Energy Foundation, and Institute for the Advancement of Engineering, and served on the boards of the Aerospace Corporation, Beckman Instruments, Inc., and Science Applications International Corporation, among others. For the National Academies of Sciences, Engineering, and Medicine, he served on the Energy Engineering Board (1978–81 and 1985–89), chaired its Panel on the Future of Central Station Electric Power (1986–87), cochaired an ad hoc Committee on Energy Conservation Research (1985–86), and was appointed to the high-profile Supercollider Site Evaluation Committee (1987–88).

His legacy also includes the William R. and Erlyn J. Gould Distinguished Lecture on Technology and the Quality of Life, at the University of Utah. Endowed by the couple in 1991, the annual lecture by a noted scientist or engineer focuses on technical and environmental issues.

His excellence as both an engineer and a captain of industry was well recognized. In addition to his election to the NAE in 1973, he received the George Westinghouse Gold Medal (1979), IEEE Centennial Medal (1984), Oliver Townsend Medal of the Atomic Industrial Forum (1983), California Industrialist of the Year (1985), and American Society of Mechanical Engineers Award of Recognition (1993).

To define Bill's life in terms of his professional successes or by the positions he held in his industry, faith, or community would be to do a great injustice to his memory. His most rewarding accomplishments were at home with his wife and family. He and Erlyn raised four children: Erlyn Sharon, William Richard Jr., Gilbert John, and Wayne Raymond. As parents they were fully invested in the individual and collective success of the family, constantly encouraging their children to overcome challenges and to achieve. The couple were devout and served in many positions of responsibility in the Church of Jesus Christ of Latter-day Saints.

After witnessing the graduations and marriages of their four children and celebrating their 50th wedding anniversary, Erlyn's China Doll body broke and, despite her leonine heart, she died in 1992. After her death, Bill renewed an acquaintanceship with Mildred (Millie) Nielsen Johnson, an elementary school classmate who in the third grade had reached out a supporting hand while Bill stuttered through a class recitation. Like Bill, Millie had lost her spouse; after a short courtship they married and lived happily together until Bill's death March 11, 2006, at the age of 86. Bill and Erlyn are survived by their four children, 25 grandchildren, and 40 great-grandchildren.

At a retirement luncheon from Edison's board of directors to honor Bill and his professional achievements, he was asked to share some observations about what he had learned over an illustrious career. First he thanked everyone for the honor they had bestowed upon him. “Haven’t we all had fun!” he said. Then looking at Erlyn, he added, “Paraphrasing Emily Dickinson, all I know about love, is that love is all there is.”

Bill Gould was an incredible man, known and appreciated for his professional ability, integrity, and most of all his humanity.

THOMAS L. HAMPTON

1931–2017

Elected in 1997

"For contributions to design of large aircraft engines."

BY JAN C. SCHILLING

THOMAS LEE HAMPTON loved the aviation industry and spent his career advancing the state of the art of aircraft engine design and structural integrity. He passed away October 4, 2017, at the age of 86, in Jupiter, Florida.

Tom was born January 24, 1931, in Covington, Kentucky. He received a bachelor of science degree in aeronautical engineering from the University of Notre Dame in 1952 and a master of science in aerospace engineering from the University of Cincinnati in 1968.

He started his career in 1952 at McDonnell Aircraft and then in 1955 joined General Electric Aircraft Engines in Evendale, Ohio. During his 26 years at GE, he progressed from working as a structural designer to managing a number of units: Advanced Structures, Advanced Fans and Compressors, GE F101 Hot Section, and, finally, Energy Efficient Engine.

In 1981 he moved to Pratt & Whitney Government Properties Division of United Technologies Corporation as director of propulsion technology and chief engineer. In 1989 he became director of engine design and chief engineer responsible for military aircraft and rocket mechanical design and technology. Upon retiring from P&W in 1993, he became an independent consultant in engine design until 2002.

Tom's professional experiences spanned concept to production to fielded engines. At GE he developed structural analysis methods for determining the axial stiffness of strutted frames and for variable vane actuation systems. These methods were used during the early days of modern jet engine design, until the development of modern computational methods. Under Tom's leadership of the Advanced Fan and Compressors unit, a Kevlar fan blade containment case was developed for the CF6-80 engine, which reduced containment structural weight and all major structural components, including aircraft mounting, that are limited by a blade release event.

At P&W Tom made a number of significant contributions. He conceived unique structural designs in support of the F100-PW-229 increased thrust engine for installation on F-16 and F-15 aircraft. He supported the redesign of the F100-PW-220 compressor variable stator vane actuation system to reduce hysteresis and wear, enabling the engine to achieve both operability and durability requirements. He directed the turbomachinery structural design configuration of the F119-PW-100 advanced tactical fighter engine for F-22 aircraft, resulting in fewer turbomachinery stages, bearing compartments, and frames, leading to reduced weight and cost.

Tom was an excellent mentor for young engineers. He always approached designs or problems with designs using engineering first principles. He maintained a positive attitude even in exceptionally challenging situations. In the early years of component design, general design rules were not as established as they are today. If there was a failure, Tom would look at it as a learning experience and make it a priority not to repeat the mistake by documenting the learning in the company's design practices. This was done at both GE and P&W for frame structures, engine mounting, stator case construction, and variable stator actuation systems.

In addition to his NAE membership, he was an associate fellow of the American Institute of Aeronautics and Astronautics (AIAA) and a member of SAE. He served on the Air Force Ordinance and Propulsion Committee (1997), Air Force Research in Aero Propulsion Technology Advisory

Board (1984–92; chair, 1989), and University of Florida Engineering Advisory Council. In retirement, he was a consultant to the USAF Independent Review Team for the F119 engine and USAF Materials Lab, and chair of the F119 Fan Blade Independent Review Team and the Integrated High-Performance Turbine Engine Technology Industry Panel. Tom had several publications through AIAA/SAE/ASME related to the design and durability of engines.

Well recognized for his knowledge and approach to solving problems, Tom was sought after as a chief engineer and consultant, positions that require one to maintain engineering integrity and product safety at the highest level and to work with diverse internal and external experts. His topnotch technical mind, credibility, and demeanor were ideally suited to these roles.

In retirement Tom enjoyed travel, boating, and gardening.

His wife Edith (née Archambeult) predeceased him in 2006. They were married for 53 years and are survived by their two children, Kathy Lynn Neuman (of Cincinnati) and Kevin Lee Hampton (of Covington, KY), seven grandchildren, and nine great-grandchildren.

ZVI HASHIN

1929–2017

Elected in 1998

"For contributions to the theory and technology of advanced composite materials."

BY J.N. REDDY

ZVI HASHIN passed away October 29, 2017, in his hometown of Haifa at the age of 88. He was one of the world's leading experts on micromechanics of composite materials and a pioneer in the exploration and application of materials across many fields of engineering—from marine vehicles to space and aerospace structures like the Boeing 787 Dreamliner. His collaboration with physicist and classmate Shmuel Shtrikman on calculating the tightest bounds on the elastic moduli for two-phase composites, known in the literature as the "Hashin-Shtrikman bounds," was hailed as one of the 100 most important mechanics projects of the 20th century.

Zvi was born June 24, 1929, in the Free City of Danzig (today Gdańsk, Poland). In 1936 he emigrated with his family to British Mandatory Palestine and settled in Haifa. After his military service, he wanted to study mathematics and physics, but his father persuaded him to take up engineering, telling him that it was a good way to make a living. He earned a BS degree in civil engineering in 1953 and MS degree in mechanics (under Markus Reiner) in 1955 from the Technion, and completed his studies as a *docteur ès sciences* from the Sorbonne in 1957. His dissertation was on development techniques for strengthening bridges.

His career began with positions as a lecturer (1957–58) and senior lecturer (1958–59) at the Technion, after which he was hired as a research fellow at Harvard University (1959–60) and then as an associate professor (1960–65) and professor (1965–71) at the University of Pennsylvania. He returned to Haifa to take a position as a professor at the Technion (1971–73) before joining the faculty at Tel Aviv University, where he was a professor and founding chair of the Department of Solid Mechanics (1973–77; he again chaired the department in 1979–81). He held the Nathan Cummings Chair in Mechanics of Solids until his retirement in 1981.

He was also a visiting professor at the University of Pennsylvania, Harvard University, University of California at Berkeley, University of Cambridge, and École Polytechnique (outside Paris). And he worked as a consultant for companies all over the world, including General Electric and Scott Paper, and held research contracts with NASA as well as the US Army, Air Force, and Navy.

By definition, composite materials are made up of two or more constituents; for example, fiber-reinforced composites are made of fibers and a matrix material, which can be a polymer or metal. They vary greatly in their physical characteristics (e.g., modulus, thermal conductivity, permeability, electrical and magnetic properties) at both the macro- and microscopic scales. To create a composite that has the desired properties, the constituents have to be combined in such a way that their differing properties will complement each other. A good understanding of how each constituent responds to stress and strain loads is essential for the prediction of damage and failure modes in a composite material.

Zvi Hashin was recognized for five decades as the world's preeminent authority in the micromechanics of composite materials. He pioneered contributions in two broad areas related to such materials: (1) estimation of properties and (2) damage and failure.

His most celebrated publication (when he was at the University of Pennsylvania), coauthored with Shtrikman, describes the application of variational principles in the linear theory of elasticity to the derivation of upper and lower bounds for the effective elastic moduli of quasi-isotropic and quasi-homogeneous multiphase materials of arbitrary phase geometry.[1] The work has been cited nearly 5800 times. In his own words,

> At that time the literature on the subject was already considerable, but only a small number of rigorous results were available. These consisted of solutions for properties of composites described as matrix containing dilute concentration of spherical particles, effective bulk modulus for a special geometry—composite spheres assemblage—for all volume concentrations of spherical particles, and bounds for effective properties based on the classical variational principles. Many workers in the field did not recognize the fact that phase volume fractions are totally insufficient information for determination of effective properties, although W.F. Brown Jr. of the University of Minnesota had shown in 1954 that effective electric properties of a two-phase medium depend on the entire statistics of the phase geometry.
>
> Since, however, the statistics of phase geometry are never known in detail, a logical approach is to bound effective properties in terms of available geometrical information. This we did in terms of the simplest such information: phase volume fractions. The bounding procedure was based on new variational principles in elasticity, in terms of the stress polarization, which we had established.[2]

Hashin's first monograph on the subject of composite materials was published as a NASA report, *Theory of Fiber Reinforced Materials* (NASA CR-1974; 1972), when there were no authoritative books available on the subject. He presented a unified and rational treatment of the theory of fiber-reinforced composite materials along with detailed derivations of the effective elastic moduli, considering viscoelastic and thermoelastic properties. In a 1991 article he outlined a rigorous solution of

[1] Hashin Z, Shtrikman S. 1963. A variational approach to the theory of the elastic behavior of multiphase materials. *Journal of the Mechanics and Physics of Solids* 11(2):127–40.

[2] From *This Week's Citation Classic*, CC/NUMBER 6 (A1980JC93400001), University of Pennsylvania, February 11, 1980.

the spherical inclusion problem with remote uniform strain or stress and imperfect elastic spring-type interface conditions.[3] In the case of a thin elastic interphase, the interface spring constants were expressed in terms of interphase elastic properties and thickness.

In the field of damage and failure of composite materials, his first major contribution was in a 1980 paper in which he properly accounted, for the first time, for physically observed failure modes and presented three-dimensional failure criteria of unidirectional fiber composites in the form of quadratic stress polynomials, expressed in terms of the transversely isotropic invariants of the homogenized unidirectional composite.[4] Four distinct failure modes—tensile and compressive fiber and matrix modes—were modeled separately, resulting in a piecewise smooth failure surface.

In 1985 he made another significant contribution to damage mechanics when he applied variational methods to cross-ply laminates with an array of transverse cracks for estimating rigorous lower bounds of the elastic properties.[5] This work was extended to orthogonally cracked cross-ply laminates in a paper 2 years later and subsequently to angle-ply laminates, as reported in a 2010 paper.[6] In this paper, stiffness reduction of the laminates with intralaminar cracks in the middle layers was studied and lower bounds to stiffness coefficients were derived using the principle of minimum complementary energy.

Zvi Hashin's lasting contributions to micromechanics and damage and failure in fiber-reinforced composites earned him several significant awards. He was elected a foreign member of the NAE in 1998. In 2007 he was awarded the Israel Prize for

[3] Hashin Z. 1991. The spherical inclusion with imperfect interface. *Journal of Applied Mechanics* 58(2):444–49.

[4] Hashin Z. 1980. Failure criteria for unidirectional fiber composites. *Journal of Applied Mechanics* 47(2):329–34.

[5] Hashin Z. 1985. Analysis of cracked laminates: A variational approach. *Mechanics of Materials* 4:121–36.

[6] Vinogradov V, Hashin Z. 2010. Variational analysis of cracked angle-ply laminates. *Composites Science and Technology* 70:638–46.

his research in engineering. In 2012 he received the Benjamin Franklin Medal from the Franklin Institute "For ground-breaking contributions to the accurate analysis of composite materials, which have enabled practical engineering designs of lightweight composite structures, commonly used today in aerospace, marine, automotive and civil infrastructure."

Composite materials are now an indispensable part of multifunctional materials for modern technologies. Many researchers and engineers have contributed to the field of micromechanics, but Zvi Hashin stands out for his extensive fundamental and impactful contributions. His damage and failure theories and bounds on material properties for fiber composites raised the level of scientific rigor and physical understanding in the field. His contributions will continue to help researchers and engineers reach new levels of understanding of interfaces and interphases and associated failures in multiphase composites in the 21st century and beyond.

Hashin is survived by his wife Tamar, three children, and five grandchildren.

ROBERT C. HAWKINS

1927–2018

Elected in 1985

"For sustained outstanding contributions to engine design and inspired leadership in the development of advanced gas turbine technology."

BY JAN C. SCHILLING

ROBERT CLEO HAWKINS was elected to the National Academy of Engineering in 1985 for his groundbreaking work and leadership in defining modern military and commercial aircraft engines at General Electric.

Bob was born March 20, 1927, in Bedford, Virginia. He studied mechanical engineering at Virginia Polytechnic Institute and received his bachelor of science magna cum laude in 1950. Upon graduation he went to work for the Allison Engine Company, attaining supervisor responsibilities for aircraft engine turbine thermodynamics and engine performance.

In 1957 he joined the General Electric Aircraft Engine Division, supporting the company's early military aircraft engines. He was an exceptional engineer and spent his first 5 years at GE as supervisor of preliminary design.

In the early 1960s Bob was part of the leadership team that defined the "core" concept (compressor, combustor, and turbine) designed for a specific airflow, which was used as a foundation for a variety of additions that generated as many as 30 different products. He was the engineering design manager for the core, called GE1, from 1962 to 1967. This core concept engine was critical to the success of the TF39, the industry's first high-bypass (7:1) engine for Lockheed's C-5 military transport aircraft, and the CF6, a commercial engine initially supporting the McDonnell Douglas DC-10.

The GE9, another use of the core family, was configured for the advanced manned strategic aircraft Mach 2 application. This configuration was followed by the F101 for Rockwell's B1, for which Bob was the engineering manager. This state-of-the-art afterburning turbofan included a tip-shrouded fan, a highly loaded compressor, and a single-stage high turbine, and made use of powdered metal technology and advanced electronic control systems. The F101 core engine was the basis for both military and commercial engines for numerous aircraft. The CFM56 is best known as the commercial utilization on the Boeing 737 and Airbus A320 series aircraft, and the F110 for military use on the F15 and F16 aircraft; a scaled version became the F404 used for the F18 aircraft. These engines were all developed in the 1970s when Bob was manager of GE's Evendale Engineering Operations. And under his commercial engineering leadership in the late 1970s, the CFM56 engine was developed and the CF6-80 series of high-efficiency engines initiated.

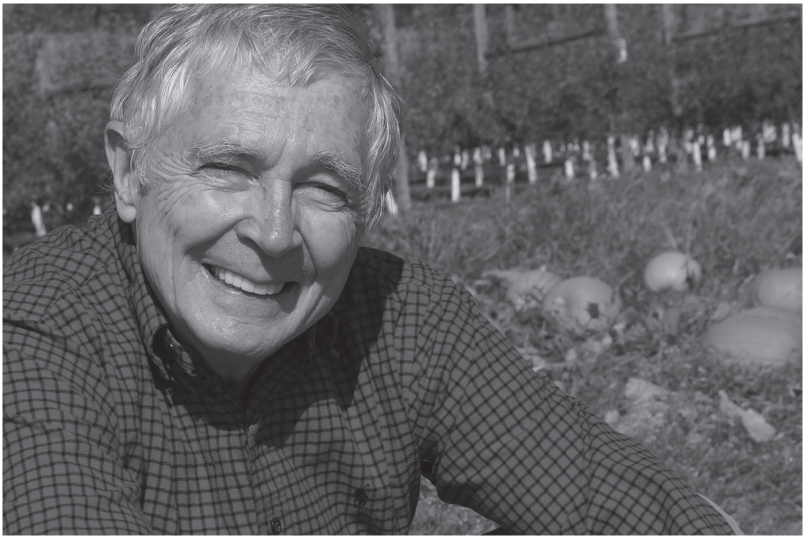
Bob supported the design and production of advanced products throughout his GE career. Drawing on his expertise and leadership, in the early 1980s he became general manager of advanced technology operations.

Under his leadership, two advanced engine designs that were well ahead of their time were initiated. While these engine designs did not make it into production, elements of each appeared in GE products introduced after Bob's retirement. One of these engines was the military demonstrator XF120 (GE37) for an advanced tactical fighter aircraft. Late in the 1980s it became the YF120 but was never installed because of lack of congressional funding. The other was the unducted fan (UDF) (GE36) designed and tested as part of a joint GE-NASA program. Later a production version was designed for a new Boeing 7J7 aircraft and as a replacement engine on the McDonnell Douglas MD-93/95. The engine had a 30–35 percent fuel burn advantage over conventional low-bypass engines powering existing narrow-body fleets, but, with low fuel costs at the time, the UDF was never put into production. Nonetheless, associated advances in engine thermodynamics and materials appear in GE products today; for example, graphite epoxy fan blades are now used on all GE and CFM commercial engines.

Bob was a man of the highest personal and professional competence and principles. He was highly respected throughout General Electric, the aeronautical industry, and government agencies. He was active in the American Institute of Aeronautics and Astronautics (AIAA), including as chair, and he cochaired the AIAA/ASME/SAE Joint Propulsion Conference in 1984. He was presented the GE Cordiner Award (named for a former CEO) for his outstanding contributions to engineering for the design and development of the GE1 engine. He also received the GE Aircraft Engine Division award for technical contributions to the F110 engine, and in 1991 was inducted into the GE Aviation Propulsion Hall of Fame for his work advancing propulsion across several GE programs.

Bob was a great listener and always made recommendations based on sound engineering principles. He drove his engineering teams hard but always sought to support them with the best tools. He led developments in materials technology and technical computerization. GE engine products since his retirement have been built on the solid foundation that he influenced so greatly.

He was 91 years old when he passed away on December 28, 2018. His wife of more than 70 years, Dorothy (née Russell), died October 21, 2019.

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L. LOUIS HEGEDUS

1941–2017

Elected in 1989

"For contributions to the design and performance of catalysts and catalytic reactors."

BY F. PETER BOER, JAMES A. TRAINHAM III, AND MARTIN B. SHERWIN

L. LOUIS HEGEDUS, a leader in the field of reaction engineering, one of the inventors of the automobile catalytic converter, and a distinguished research executive, died May 24, 2017, at the age of 76.

Louis was born April 13, 1941, in Szolnok, a small town outside Budapest. His father, Lajos Hegedus, was a chemical engineer and his mother, Anna, a teacher. He graduated with a degree in chemical engineering from the prestigious Budapest University of Technology and Economics, where he met his future wife, Eva Brehm, at a dance. Louis escaped from communist Hungary in 1965 to Germany, where he shoveled coal and took other odd jobs while learning German at an American military base. From there he secured a job in a materials testing laboratory of Daimler-Benz—all the while working to get Eva out of Hungary. She eventually succeeded in escaping to Austria, and the two were later married in Mannheim, Germany, in 1968. They left Germany when Louis was accepted to a doctoral program at the University of California, Berkeley, based on the recommendation of fellow Hungarian Gabor Somorjai.

At Berkeley, Louis pursued an interest in reaction engineering and catalysis and wrote his thesis under the supervision of Eugene Petersen. His work exploited the fact that the performance of catalyst pellets is determined by a complicated interaction of internal and external transport effects with the intrinsic kinetic rate at the active surface. Petersen and Hegedus also published pioneering papers that advanced the field of catalyst poisoning, an area that would prove to be of central importance to catalyst development. Louis received his PhD in chemical engineering in 1972.

His timing and choice of field were fortuitous, as air pollution was becoming a national issue in the United States. The Environmental Protection Agency was phasing out leaded gasoline and mandating that most gasoline-powered vehicles be equipped with a catalytic converter starting with the 1975 model year. But the technical challenges were enormous, in terms of (i) the required reactor performance in both oxidative and reductive modes over a very wide range of temperatures and space velocities and (ii) integration of a working reactor system in a car. This complex project was likely one of the largest commercial R&D programs of the century.

Given the technical challenges and political imperative, it is no wonder that General Motors offered Louis a job in 1972. In time he advanced from bench scientist to group leader in charge of catalytic research.

Lead, which was ubiquitous in gasoline until it was outlawed, is a potent poison of catalytic surfaces. His work identifying and understanding this phenomenon positioned Louis to write the first monograph on catalyst poisoning.[1] During this period of intense technical challenge and professional accomplishment, Louis's and Eva's first daughter was born while the family lived in Grosse Pointe, Michigan.

In 1980 Louis was recruited by W.R. Grace and Company to be director of inorganic research at its Washington Research Center in Columbia, Maryland, where the second Hegedus daughter was born.

This transition initiated the second stage of his career in industry. Grace's inorganic research portfolio consisted mostly

[1] Hegedus LL, McCabe RW. 1984. *Catalyst Poisoning*. New York: Marcel Dekker Inc.

of catalysts (in particular, petroleum catalysts), construction materials, and battery separators. The company had no position in emission control. Louis led an effort to control NO_x emissions by selective catalytic reduction. He identified and then licensed the appropriate technology in Japan and helped transfer it to a new plant built in Bergisch Gladbach, Germany (east of Köln). He also successfully scaled up technology for absorbing both SO_x and NO_x air pollutants, and it was implemented in a 5-megawatt pilot plant operated by Ohio Edison; in both of these endeavors, he worked closely with two of the authors (FPB and MBS).

Louis's catalysis group introduced metallocene catalysts to Grace, helping to make the company the top supplier of polyolefin catalysts to industry. His construction products group also developed several generations of superplasticizers that led to high-strength concretes, and chemical technologies for asbestos abatement. In batteries, Grace early recognized that a fusible battery separator was key to the safety of lithium batteries, and Louis' group held and defended a key patent on that important concept. In time, Louis was promoted to vice president in the Corporate Technology Group.

The third major phase of Louis' professional career began in 1996 when he was recruited to head US chemical research for Elf Atochem, a unit of the largest French petroleum company, Elf-Aquitaine. His responsibilities included directing a 300-person research laboratory in King of Prussia, Pennsylvania, and coordinating its programs with the company's other research groups around the world. Their leading products were in thiochemicals, fluorochemicals, fluoropolymers, and hydrogen peroxide. The laboratory also pursued advanced technologies in electronic chemicals and fuel cells. Elf later merged with Total, another French petroleum giant, and the chemical operations were soon spun off as Arkema. Despite the structural changes, Louis adapted well to the French engineering and business culture and ran these laboratories successfully until his retirement in 2006 as senior vice president.

Louis was elected to the NAE in 1989 and participated in a number of National Academies studies on topics including the

Potential for Light-Duty Vehicle Technologies, New Directions in Catalyst Science and Technology, Critical Technologies: The Role of Chemistry and Chemical Engineering in Maintaining and Strengthening American Technology, and Benchmarking the Research Competitiveness of the US in Chemical Engineering. In addition, he was appointed to the Board on Chemical Sciences and Technology, Chemical Sciences Roundtable, and Commission on Physical Sciences, Mathematics, and Applications. He also served as vice chair, section liaison, and chair of the Section 3 (Chemical Engineering) Executive Committee.

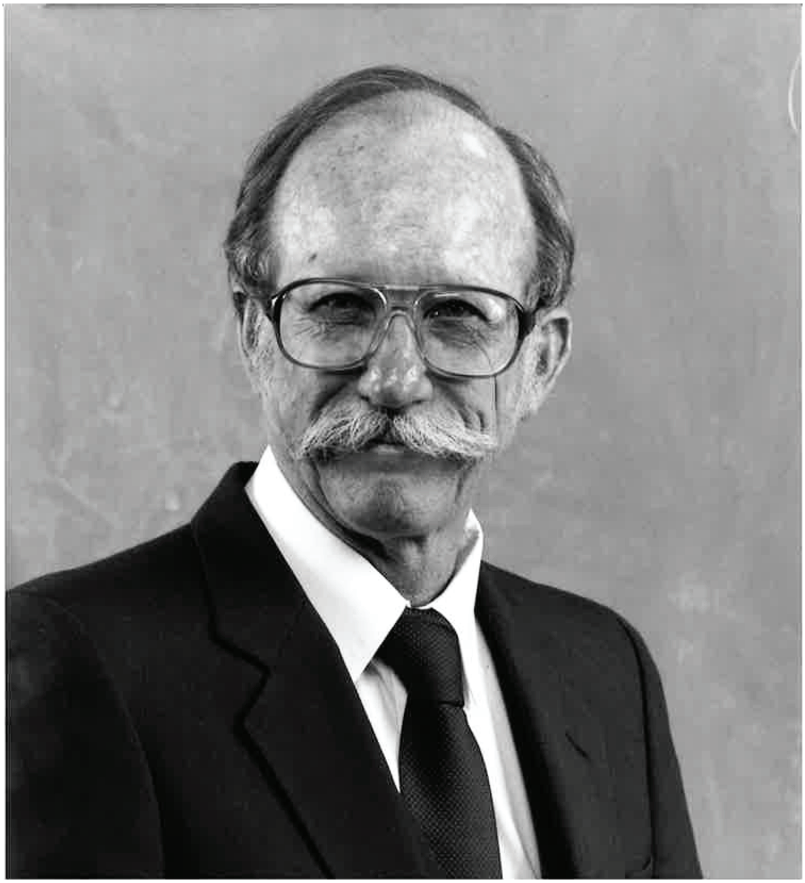
His last major publication was an important policy monograph, *Viewing America's Energy Future in Three Dimensions*, coedited with Dorota S. Temple (RTI Press, 2011).

Among his professional honors was the 1988 R.H. Wilhelm Award in Chemical Reaction Engineering. In 2008 he was named one of the top 100 Chemical Engineers of the Modern Era by AIChE.

On his own time, Louis was a serious and careful pilot, holding an instrument rating and flying with his family and friends around the country in his elegant Socata Trinidad. Aviation was perhaps his favorite subject of conversation. He was also fond of both fast cars and fine German cars. He had a Corvette when he was at GM, a large imported Mercedes sedan when he was at Grace, and he also drove a Porsche Boxster. His last car was a Porsche Panamera.

After Eva passed away in 2012, Louis moved to Pasadena, California, to be closer to his daughters and their families. He met new friends and neighbors, visited local gardens, traveled, flew his plane, and enjoyed spending time with family and old friends. He remained a loving father, grandfather, and friend throughout his struggle with cancer.

Louis is survived by his daughters Caroline Hegedus Borncamp, an attorney with Link Law specializing in estate planning, and Monica Hegedus, MD, a pediatrician at Cedars Sinai Medical Center, and a granddaughter.



J. DAVID HELLUMS

1929–2016

Elected in 1998

"For the application of biofluid mechanics and cellular engineering methods to biological research and education."

BY LARRY V. McINTIRE

JESSE DAVID HELLUMS, the A.J. Hartsook Professor Emeritus in Bioengineering and in Chemical and Biomolecular Engineering at Rice University, died June 26, 2016, at age 86.

He was born to Fannye May (née Beauchamp) and John Verrell Hellums on August 19, 1929, in Stamford, Texas, and raised in nearby Rotan. He attended the University of Texas in Austin and received a BS in chemical engineering in 1950. After spending 6 years as a process engineer for Mobil Oil and in the US Air Force, he resumed his studies in chemical engineering at the University of Texas (MS, 1958) and then the University of Michigan (PhD, 1961), where he worked with Stuart Churchill.

David joined the faculty of chemical engineering at Rice University in 1960 as an assistant professor and remained there for his entire career. He became an associate professor (1965), professor (1968), department chair (1970–76), director of the Biomedical Engineering Laboratory (1968–80), and dean of the George R. Brown School of Engineering (1980–88), and in 1988 he was named the A.J. Hartsook Professor of Chemical Engineering and later also of bioengineering. He held concurrent appointments, until his retirement in 1998, as adjunct professor of medicine at Baylor College of Medicine (from 1968) and at the University of Texas Medical School in Houston (from 1973).

David Hellums was a pioneer in the application of quantitative chemical engineering analysis to important problems in cardiovascular medicine and one of the true founders of what is now called cellular engineering. His early studies on the mechanisms of individual red cell hemolysis in artificial heart valves provided basic design guidelines for combinations of fluid stress magnitude and exposure times that need to be avoided in blood-contacting devices in patients because they lead to red cell damage.[1]

Human blood platelets play a crucial role in arterial thrombosis, the cause of heart attacks and stroke, the largest cause of death in the Western world. David and his colleagues at the Texas Medical Center demonstrated that shear stresses associated with blood flow in many medical devices and stenotic arteries play a vital role in platelet activation and receptor expression.[2] These studies identified the significant role of von Willebrand factor in arterial thrombosis and the formation of platelet emboli under flow, leading to important new ways of thinking about therapeutic approaches.

David and his students also made seminal contributions to quantitative knowledge of oxygen transport in microcirculation,[3] using a single-cell-level approach that combined computational modeling with complex well-controlled in vitro experiments. These studies enhanced understanding of resistances to mass transfer at the micron scale in capillary beds, leading to important applications in several pathologic states, including sickle cell anemia, and in the evaluation

[1] Leverett LB, Lynch EC, Alfrey CP, Hellums JD. 1972. Red blood cell damage by shear stress. *Biophysical Journal* 12:257–65.

[2] Moake JL, Turner NA, Stathopolos NA, Nolasco LH, Hellums JD. 1986. Involvement of large plasma von Willebrand factor (VWF) multimers and unusually large forms derived from endothelial cells in shear stress induced platelet aggregation. *Journal of Clinical Investigation* 78:1456–61.

[3] Hellums JD. 1977. Resistance to oxygen transport in capillaries relative to that in surrounding tissue. *Microvascular Research* 13:131–36.

of proposed blood substitutes such as chemically modified hemoglobin and artificial red cells.

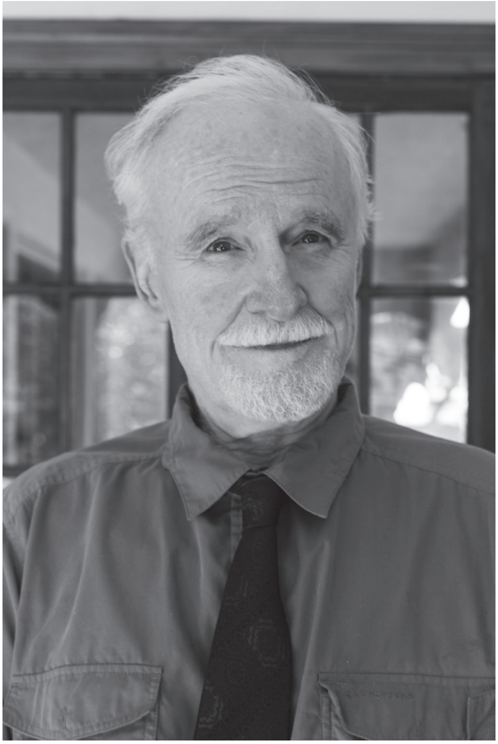
David was one of the first engineers to be honored with the National Institutes of Health MERIT Award (1986–97), a 10-year award given to investigators for exceptional research contributions and productivity. He also served on the Cardiology Advisory Committee of the National Heart, Lung, and Blood Institute (1987–91). The Biomedical Engineering Society awarded him the Whitaker Foundation Distinguished Lectureship in 1993. He was elected to the National Academy of Engineering in 1998 and was a fellow of the American Institute of Chemical Engineers and a founding fellow of the American Institute for Medical and Biological Engineering.

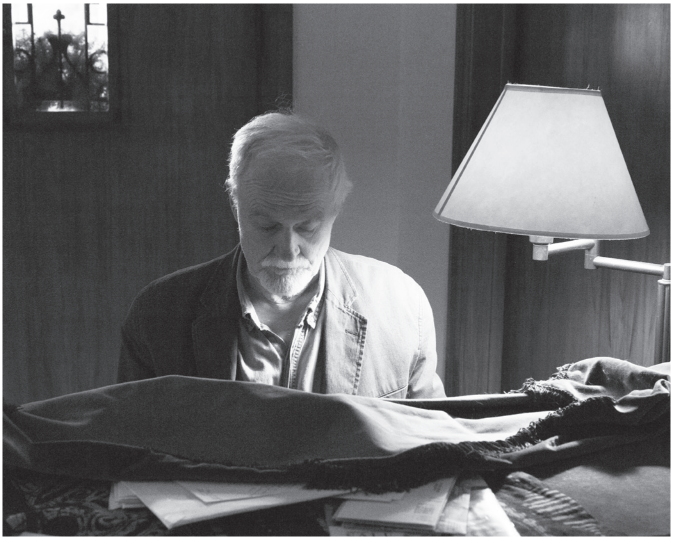
David loved life and lived it to the full. When he was in Austin at UT he met the love of his life and soulmate, Marilyn Biel; they married in 1957. They both loved sailing, particularly along the Texas Gulf Coast, and delighted in leisurely multiday excursions along the beautiful bays and channels with family, friends, and wonderful food. Magnificent sunsets provided an exceptional backdrop to the conviviality on board.

In addition to attending several America's Cup Races, including those in New Zealand, Spain, and San Francisco, they loved international travel and learning about different cultures, and developed a special fondness for Japan. They spent sabbatical years at Cambridge University (1966–67), Imperial College London (1974–75), Tokyo Institute of Technology (1989), and University of Tsukuba (1995). In 1997 David was named eminent scientist at the Institute of Physical and Chemical Research (RIKEN) in Wako, Japan.

David was a dedicated tennis player into his 80s. His style of play could be disarming, as he would appear to be tired, and then hit a hard left-handed topspin forehand zipping past his opponent for a clean win.

David is survived by Marilyn, sons Mark William (Joyce) and Jay David (Julia), and five grandchildren. He was preceded in death by son Robert James, who died of a congenital heart defect. This family tragedy was an underlying motivation for David's lifelong interest in cardiovascular research.





ROBERT W. HELLWARTH

1930–2021

Elected in 1977

"Contributions to the understanding of quantum electronics and the invention of new laser devices."

BY PAUL DANIEL DAPKUS

ROBERT WILLIS HELLWARTH, distinguished engineer and physicist and a pioneer in quantum electronics, nonlinear optics, and photonics, died in Santa Monica, California, on January 20, 2021, at the age of 90. He was a University Professor Emeritus at the University of Southern California, where he had also been the George Pfleger Professor of Electrical Engineering and professor of physics and astronomy until his retirement in 2018.

Born December 10, 1930, in Ann Arbor, Michigan, Bob was the son of Arlen Roosevelt Hellwarth, an electrical engineer who worked for the Detroit Edison Company,[1] and Sarah Townsend Hellwarth, a college-educated homemaking mother. The oldest of four boys, he attended neighborhood public schools including Cooley High School. He developed a strong interest in science and engineering by tinkering with the electrical gadgets and tools in the family basement.

An adept student, Bob was offered a scholarship to Princeton without actually applying, based on his college board exams. After initially declining the offer, he reconsidered

[1] It is worth noting that in 1958 Arlen Hellwarth retuned to his alma mater, the University of Michigan, where he became professor of electrical engineering and then associate dean and secretary of the College of Engineering. All four of his sons studied engineering.

and graduated in 1952 as valedictorian of his class with a dual BS degree in electrical engineering and physics. He attended St. John's College in Oxford University as a Rhodes scholar, joined the Clarendon Laboratory, and earned a doctorate in physics in 1955; his dissertation title was "An Investigation of Hyperfine Structure Using the Atomic Beam Magnetic Resonance Method." His fondness for Oxford brought him back many times over the years.

In his third year at Princeton, he got a summer job at a Danish shipyard. At the end of the summer, during the 11-day transit back to the United States aboard a Dutch ship, he met Abigail Gurfein, who was returning to New York City after touring Europe with a student group. They spent time together aboard the ship and, after Bob completed his doctorate, married in 1957. The couple had three children, Ben, Margaret, and Tom, during their 20-year marriage.

The aerospace industry was booming in those times and Bob accepted a position with Hughes Aircraft Company in Culver City, later transferring to the newly completed Hughes Research Labs in Malibu. During his career at Hughes, he rose through positions of increased responsibility, ultimately managing the Theoretical Studies Department in 1968. In 1971 he moved to the University of Southern California as a professor of electrical engineering and of physics.

While at Hughes, Bob also held appointments of various types at Caltech, where he formed a lasting friendship and collaboration with Richard Feynman that strongly influenced his career and life. Feynman was Hellwarth's best man at his marriage to Theresia de Vroom in 1985. Both men were "spirits" who relished a free flow of ideas and shared the outlook that exploring the laws governing the physical world was fun.

Shortly after the demonstration of an operating maser, Hellwarth collaborated with Feynman and Frank Vernon on work that was to become his most highly cited paper,[2] an

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[2] Feynman RP, Vernon FL Jr, Hellwarth RW. 1957. Geometrical representation of the Schrödinger equation for solving maser problems. *Journal of Applied Physics* 28(1):49–52.

intuitive analysis of a two-level atomic system that is pedagogically simple and easily extendable to describe many of the properties of masers and lasers. Feynman and Hellwarth also collaborated on a paper analyzing electron transport in polar crystals in which the concept of a polaron was introduced.[3]

Bob Hellwarth's scientific contributions are many and varied. He approached science with joy and curiosity—he would typically describe his latest interest as "great fun." His curiosity about the physical world propelled him into new fields, and his intellect allowed him to consider scientific problems in unique ways.

He was at Hughes when the first laser was created there by Theodore Maiman, leading to one of his most substantive contributions. Bob knew Maiman well and was one of the first people to witness an operating visible laser. Early ruby lasers exhibited spontaneous fluctuations in their output intensity. Most people took the view that these fluctuations were a "problem" that required a solution. Bob, on the other hand, viewed them as a "feature" that offered potential for unique properties. He and colleagues studied their properties, and Bob devised an approach to increase and control the amplitude of the fluctuations. Q-switching, as he called it, was a technique for storing the energy in the laser in the atomic system until it was controllably released in short, intense pulses of light—increasing the peak power emitted by the laser a millionfold. These short intense pulses of light now form the basis for many current and emerging industrial and scientific applications of lasers, including cutting, sculpting, and material welding; medical processes; study of nonlinear optical phenomena; and, if Bob's dreams were to be realized, enabling laser fusion for clean energy creation. Many different Q-switched laser systems are now available and have spread the impact of Bob's invention to applications unimaginable at that time.

High-power lasers also enabled Bob's study of nonlinear optical phenomena, the "sandbox" in which he chose to play

[3] Feynman RP, Hellwarth RW, Iddings CK, Platzman PM. 1962. Mobility of slow electrons in a polar crystal. *Physical Review* 127(4):1004–17.

for much of his career at USC. In his research he focused on understanding and developing materials for nonlinear optical processes and devices. The rich physics of these processes provided ample feedstock for his inquisitive mind and led to the exploration of new phenomena, often with important applications.

For example, his exploration of four-wave optical mixing led to his development of optical phase conjugation that generates a time-reversed image of an optical beam—the underlying principle used in astronomy to correct astronomical images distorted by fluctuations in the atmosphere. This technique has found broad application in areas such as optical tracking and pointing, spatial and temporal image processing, optical filtering, and optical computing. He also invented the Raman-induced Kerr effect and Raman-induced phase-conjugation processes for which he was subsequently feted. His last scientific paper was published shortly before his 88th birthday.[4]

Bob Hellwarth's research creativity and accomplishments garnered him wide recognition in the scientific community. He was a member of both the National Academy of Engineering and National Academy of Sciences, and a fellow of the American Physical Society, Institute of Electrical and Electronics Engineers (IEEE), American Association for the Advancement of Science, Optical Society of America (OSA), and American Academy of Arts and Sciences. He received the OSA's Charles Hard Townes Award in 1983 "For his invention of the Q-switched laser, codiscovery of the Raman laser and explanation of stimulated scattering phenomena, and the theory of optical phase conjugation." He was also the recipient of the IEEE Quantum Electronics Award in 1985 "For fundamental contributions to lasers, Raman scattering, and nonlinear optical processes." In 1976 USC recognized him with its highest honor, the Associates Award for Creativity in Research (electrical engineering-electrophysics).

[4] Huang L, Hellwarth RW. 2018. Azimuthally polarized hollow beams in free space: Exact vector solutions to Maxwell's equations. *Physical Review A* 98(2):023843–46.

Bob loved the challenge of spirited technical discussion and did much to elevate the level of campus discourse by stimulating it as much as he could. He was known to issue cash challenges to anyone who could address some knotty scientific question that was occupying his mind. These challenges were typically posted on bulletin boards around campus. It was not clear if he expected a student or one of his colleagues to answer the challenge as much as he looked forward to the stimulation of a discussion. He was interested to see how people thought about science. Faculty candidates and seminar speakers were often caught off-guard by one of Bob's questions, offered politely, but penetrating to the core of their work. He would have read their work beforehand (typically requesting a copy of a sole-author paper), and was curious to understand their thought processes.

Long before it became a national discussion, Bob was a strong advocate for faculty diversity. For years he played an important role in maintaining and improving the strength of the department's program as a member of the faculty recruitment committee. He was a consistent and uncharacteristically loud voice encouraging gender and racial equity in department hiring practices. His successful advocacy strengthened both the department and the university.

Despite his many accomplishments, Bob was a modest man characterized by a good nature and engaging personality. In an obituary posted on the Rhodes Trust website, Bob was lovingly described by his eldest son, Ben, as "an archetypical absent-minded professor, mustachioed for most of his life, and with requisite sartorial quirks. But unlike the chalk-dusted bumblers often sent from central casting, this professor was 6-foot-2 and athletic—a fun-loving mashup of Indiana Jones and 'Doc' Emmett Brown, with an optimistic, self-effacing mien, and an easygoing kindness that Mr. Rogers would have admired."[5]

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[5] https://www.rhodeshouse.ox.ac.uk/media/45669/robert-w-hellwarth.pdf

Bob was typically dressed in shirt sans tie, sport coat, casual pants specially tailored with extra deep pockets that lent them a measure of bagginess, and New Balance running shoes. He strode the campus displaying a detachment that likely belied the intellectual activity occupying his mind.

He was a gentle person with a myriad of talents: not only a world-class scientist and engineer but also a talented musician with perfect pitch who could perform classical pieces by ear on a grand piano, popular music on an accordion, and country favorites on his trusty harmonica. He was a swimmer in high school, played football at Princeton, became a lifelong skier, and frequently rode his bike and roller skated with his kids at the beach. He was a spirited Renaissance man who will be greatly missed by his family and colleagues.

Bob Hellwarth is survived by his wife of 36 years, Theresia de Vroom, and their son, William, of Los Angeles; the three children from his first marriage, Ben, of Santa Monica; Margaret, of San Diego; and Tom, of Bend, Oregon; and four grandchildren.

STEPHEN A. HOLDITCH

1946–2019

Elected in 1995

"For contributions in hydraulic fracturing and developing low-permeability gas reservoirs, and for technology transfer in both of these fields."

BY IRAJ ERSHAGHI

STEPHEN ALLEN HOLDITCH, a towering figure in petroleum engineering and the oil and gas industry, died August 9, 2019, at the age of 72. He devoted more than four decades of service to the nation.

He was born near Corsicana, Texas, on October 20, 1946, to Damon and Margie (née Stephens) Holditch. His father's career in oil and gas meant that Steve moved several times. He lived in San Antonio for the first 3 years of high school and then graduated from Richardson High School in 1965. He attended Texas A&M University (TAMU), where he became a member of the Corps of Cadets and earned his bachelor of science degree (1969), master of science degree (1970), and PhD (1976), all in petroleum engineering. When he got his PhD he left his job at Shell Oil, where he designed large hydraulic fracture treatments to stimulate production from deep, low-permeability, geopressured gas reservoirs in South Texas, to accept appointment as an assistant professor at his alma mater.

In 1977, while still on the TAMU faculty, he formed S.A. Holditch & Associates, with a focus on analysis of low-permeability gas reservoirs and the design of hydraulic fracture treatments. He became a recognized expert in the areas of tight gas reservoirs, coalbed methane, shale gas reservoirs, and the design of hydraulic fracture treatments, and his consulting company became known globally for its ability to solve the most difficult petroleum engineering problems. It was acquired by Schlumberger in 1997 and Steve was designated a Schlumberger fellow for his many valuable technical contributions and his work to advance understanding of low-permeability sandstones, tight shales, and coalbed methane.

At TAMU he was promoted to head of the Harold Vance Department of Petroleum Engineering (2004–12) and director of the Energy Institute (2011–13). After his term as department chair, he was named a Texas A&M Engineering Experiment Station (TEES) Distinguished Research Professor. He retired in 2013.

During his tenure he supervised more than 100 MS and PhD students, taught 97 courses, and served on more than 175 graduate committees. He was a popular and very effective teacher, and the endowment of the Petroleum Engineering Department grew thanks to significant support from former students. In 2012 an endowed chair was created to honor him by many of his former students, and within months of his passing two other former students established the Stephen Holditch ’69 Endowed Scholarship in his honor.

Steve was invited to serve on many private and government organizations, and throughout his life undertook concurrent assignments and tasks outside of his employment. He was president of the Academy of Medicine, Engineering, & Science of Texas (TAMEST), a member of the NAE Finance Committee, member of the National Petroleum Council, and board member and chair for the Research Partnership to Secure Energy for America.

In recognition of his leadership abilities and integrity, he was appointed president of the Society of Petroleum Engineers (SPE) in 2002. He served on a number of SPE committees and on the SPE Foundation board of trustees, and was also president of the AIME board of trustees.

Steve was a global expert on hydraulic fracturing whose work resulted in a better understanding of fracture conductivity, the role of proppants, and methods to determine properties of induced fractures. His enormous contributions to the field of hydraulic fracturing and unconventional resources are reported in his 279 publications, which include journal articles as well as several books that are widely used as reference materials.[1] To cite just two of his impactful peer-reviewed articles, his resource triangle concept published in 2010 became a standard in the work, publications, and presentations of others.[2] And he enhanced understanding of emerging US gas shales with a 2012 paper reporting a technical and economic study of completion techniques.[3] His contributions to a better understanding of coal-seam reservoirs opened the way for expanded development of this resource worldwide.[4]

His work was recognized with numerous honors. He was inducted into the NAE in 1995, at the age of 49. He received some of SPE's highest technical awards: the Lester C. Uren Award (1994), John Franklin Carll Award (1999), and Anthony F. Lucas Gold Medal (2005). In 2006 he was named an SPE honorary member and in 2014 SPE honored him for his lifetime achievements with the Legends of Hydraulic Fracturing Award. He was named a Texas A&M Distinguished Alumnus in 2014, and in 2016 inducted into the Corps of Cadets Hall of Honor, a distinction of which he was very proud. In 2020 SPE established the Stephen A. Holditch Visionary Leadership Award to recognize individuals that, like Steve, have devoted significant time, effort, thought, and action and demonstrated

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[1] Notable examples are *Unconventional Oil and Gas Resources Handbook: Evaluation and Development*, with YZ Ma (Elsevier/Gulf Professional Publishing, 2015); and *Tight Gas Reservoirs*, with J Spivey and JY Wang (SPE, 2020).

[2] Martin SO, Holditch SA, Ayers WB, McVay DA. 2010. PRISE validates resource triangle concept. *SPE Economics & Management* 2(01):51–60.

[3] Agrawal A, Wei Y, Holditch SA. 2012. A technical and economic study of completion techniques in five emerging US gas shales: A Woodford shale example. *SPE Drilling & Completion* 27(01):39–49.

[4] Holditch SA, Ely JW, Carter RH, Semmelbeck ME. 1988. *Coal-seam Stimulation Manual.* Topical report, January 1987–December 1988. Washington: US Department of Energy. Also Holditch SA. 1993. Completion methods in coal-seam reservoirs. *Journal of Petroleum Technology* 45(03):270–76.

exceptional visionary leadership resulting in a lasting and momentous impact for SPE and/or the oil and gas industry.

Throughout his long and productive life, Steve Holditch was known as "a straight shooter" and recognized not only for his technical knowledge but also his wide-ranging intelligence, integrity, vision, and engaging leadership qualities. Colleagues, friends, and students enjoyed being around him as he mixed technical knowledge with homespun wit and was a source of encouragement, support, wise counsel, and knowledge. Stories abound of his warmth, commanding presence, expectations of excellence, and creative vision. For my part, I was truly impressed by his wisdom and sincere dedication to serving the nation when I traveled with him to Washington, DC, to talk to congressional leaders about the importance of academic research support for the future of US energy independence.

Steve was a season ticket holder for a variety of Texas A&M sports throughout the years, but Fightin' Texas Aggie Football and Kyle Field were closest to his heart. He retained a lifelong devotion to his alma mater and loved giving back to the university he credited for much of his success. He encouraged all his students to "Always remember the Aggie Code of Honor."

Steve is survived by his wife of 48 years, Ann (née Friddle), of College Station; daughters Katie Holditch (Loyd Rowe III), of The Woodlands, and Abbie Walsh (Kenn), of College Station; and five grandchildren, who were the lights of his life.

D. BRAINERD HOLMES

1921–2013

Elected in 1977

"Contributions to large electronic systems and leadership in manned space flight and industrial management."

SUBMITTED BY THE NAE HOME SECRETARY

DYER BRAINERD HOLMES, NASA's first director of manned spaceflight, former president of Raytheon, and retired chair of Beech Aircraft, died January 11, 2013, at age 91.

He was born May 24, 1921, in Brooklyn, New York. He prepared for college by attending Carteret Academy and Newark Academy in New Jersey and graduated from Cornell University in 1943 with a BS degree in electronic engineering. In 1943–44, as an ensign in the US Naval Reserve, he completed graduate studies in radar at both Massachusetts Institute of Technology and Bowdoin College. He was later awarded an honorary doctor of science degree from the University of New Mexico (1963) and an honorary doctor of engineering degree from Worcester Polytechnic Institute (1978).

Upon completion of his military service he worked at Bell Telephone Laboratories and Western Electric Company (1945–53), during which time he developed advanced repeaters, amplifiers, and measuring equipment. He then went to work at RCA (1953–61), where he rose to become general manager of the Major Defense Systems Division, responsible for a federally sponsored project to design and implement the Air Force's Ballistic Missile Early Warning System (BMEWS), with radar installations in Alaska, Greenland, and the United Kingdom. This system protected the United States and allies for over 4 decades, one of the longest running and most successful Cold War projects. At RCA he also oversaw the development of the Talos antiaircraft missile system and the launch control and checkout equipment for the Atlas missile system.

Based on his accomplishments in the private sector, he attracted the attention of NASA and became director of its Office of Manned Space Flight (OMSF) in October 1961. He led the national effort to go to the moon and directed NASA's other efforts in manned spaceflight; among other things he explored options for a new heavy-lift launch vehicle to meet the president's goal.

A brilliant engineer, Mr. Holmes was instrumental in tackling the practicalities of President John F. Kennedy's challenge of putting a man on the moon by 1970. He was so influential in the Apollo era that he was featured on the cover of *Time* magazine (August 10, 1962) as the agency's "Space Planner." He was quoted in the cover story, "When a great nation is faced with a technological challenge, it has to accept or go backward. Space is the future of man, and the US must keep ahead in space." Mr. Holmes adhered to this edict and continued to revolutionize the aerospace industry throughout his career.

In December 1961 he raised the issue of orbital rendezvous in his outline of an expanded version of the Mercury capsule, formally named "Project Gemini." The project focused on mastering orbital rendezvous and docking, long-duration flight, controlled land recoveries, and astronaut training.

In October 1962 he was appointed NASA deputy associate administrator, while continuing to direct OMSF; all NASA field installations dealing with manned space flight issues reported directly to him. In April 1963 he urged Congress to increase spending on the Gemini program because of its ambitious technical goals, including new transmission equipment to handle higher data rates, a more reliable rendezvous radar, and a heavily modified environmental control system. He also called on NASA to streamline its management structure, improve internal communications, and determine the method it would use to reach the moon.

When Neil Armstrong and Buzz Aldrin landed on the moon in 1969, Holmes told the *New York Times* "we should remember such endeavors as these and know that when given a challenge Americans today can be as hard, as aggressive, and as brave as the men who founded this land."

In September 1963 he left NASA to become a director at Raytheon, managing its military engineering, research, and development. In 1975 he was named president, and when Raytheon acquired Beech Aircraft in 1982 he also became chair of that company. His engagement with aircraft extended far beyond the traditional role of CEO; as a commercial-rated pilot, he logged over 4500 hours in a variety of aircraft, including jets, and as a test pilot of experimental aircraft. When he retired from Raytheon in 1986, the company's annual sales during his tenure had grown to $7.3 billion.

Beyond his professional career, he served on boards for many companies and philanthropies, including the MITRE Corporation, Smithsonian National Museum of Natural History, Bank of Boston (16 years), Wyman-Gordon Company (Worcester, MA; 20 years), and Kaman Corporation (Bloomfield, CT; 20 years).

Holmes received a 1963 NASA Medal for "his outstanding leadership of the manned space flight program during the formative period of Project Apollo and for his imaginative and energetic leadership in forging a manned space flight organization dedicated to advancing the United States toward its goal of preeminence in space," as well as the Arnold Air Society's Paul T. Johns Award for outstanding contributions to aeronautics and astronautics.

He was a member of the National Academy of Engineering and a fellow of the American Institute of Aeronautics and Astronautics and Institute of Electrical and Electronics Engineers. He was also a member of the engineering honor societies Eta Kappa Nu and Tau Beta Pi.

A lifelong Episcopalian, Mr. Holmes was a parishioner of St. Paul's Church on Nantucket.

His marriage to Dorothy Bonnet Holmes ended in divorce and his second wife, Roberta Donohue (Bobbie) Holmes, died in 1999. In 2002 he married Mary Margaret England Wilkes; they lived in Wellesley, Massachusetts. She survives him, as do daughters Katherine Holmes Kobos (Michael) and Dorothy "Pixie" Holmes Kather; stepson Scott Pierce Ledbetter Jr. (Margaret O'Connor); stepdaughters Baylor Ledbetter Stovall (Howard) and Margaret Ledbetter Weaver (Jock); six grandchildren; and seven great-grandchildren.

EDWARD E. HOOD JR.

1930–2019

Elected in 1980

"Contributions to the advancement of aircraft engines in efficiency, reliability, and environmental compatibility and the application of the engines to the commercial airline industry."

BY JAN C. SCHILLING

EDWARD EXUM HOOD JR. died February 3, 2019, at age 88. He was born September 15, 1930, in Zebulon, North Carolina, to Edward Exum and Nellie (née Triplett) Hood. He grew up in Boonville, where he met Kay Transou, his next-door neighbor; she became his high school sweetheart and then his devoted wife of 68 years. He was class valedictorian at Boonville High School and received his undergraduate and master's degrees in nuclear engineering from North Carolina State University in 1952 and 1953. He then served 3 years in the US Air Force.

Ed began his 36-year career with General Electric as a design engineer in the Flight Propulsion Division in Evendale, Ohio, in 1957. Within 2 years he had begun an extensive optimization study of subsonic turbofan engines, which resulted in quantitative definition of the high-power extraction cycle, a concept that led to a major improvement in subsonic engine performance; he formulated the program of development of components, materials, and manufacturing processes.

His work with nuclear propulsion and new design concepts for gas turbine engines led to his being named head of GE's Supersonic Transport Project in 1962, when he made the preliminary design of the Mach 2.7 supersonic transport engine (GE4). He planned and implemented the program of development, detailed design, and testing.

In 1968 he was designated company vice president and general manager of the Commercial Engine Division, leading GE's reentry into the commercial aircraft engine market with the development, certification, and production of the CF6-6 high-bypass turbofan engine for the DC-10 aircraft, the first commercial engine designed to meet specific noise and emission standards. A marine version of the engine powers frigates and destroyers of the US and other navies.

In 1972 he was promoted to vice president and executive of GE's International Group in Connecticut, and in 1979 he became vice chair and executive officer, a position he held until his retirement in 1993.

Ed was both dedicated to and instrumental in determining the future of GE's jet engine technology and gas turbine activities, and his knowledge and reputation led to his being named chair of the Aerospace Industries Association board of governors. He also served as vice chair of the National Electrical Manufacturers Association and was an associate fellow of the American Institute of Aeronautics and Astronautics. He remained active after his retirement from General Electric, serving as a director on the boards of Lockheed Martin Corp., Gerber Scientific Inc., Lincoln Electric Company, Martin Marietta Corporation, and Flight Safety International.

In 1988 President Ronald Reagan selected Ed to serve as vice chair (1990–91) of the President's National Security Telecommunications Advisory Committee.

Ed's lifelong belief in and appreciation for the importance of higher education were reflected in his philanthropy and volunteerism. In addition to serving on the NCSU Alumni Association board of directors and the university's board of trustees (1995–2003), he served on the boards of trustees at Rensselaer Polytechnic Institute (1980–95; 10 years as chair) and Lees-McRae College. He and Kay established endowed scholarships at all three schools, helping hundreds of students pursue higher education and achieve personal and professional success. At RPI the couple also established the Edward E. Hood Jr. Endowed Chair of Engineering in 1989 to encourage excellence in education by "recognizing and rewarding an outstanding faculty member."

Thanks to his selfless work in higher education Ed received two of NC State's highest honors: the Watauga Medal (2004) and the Menscer Cup (2005). NCSU also conferred on him the 1980 Distinguished Alumnus Award in recognition of his innovative achievements that placed him at the top of one of the nation's largest corporations. At RPI he was designated chair emeritus in 1995, and at Lees-McRae he was awarded an honorary doctorate of humanities in 2011.

Ed had a lifelong passion for aviation, having gotten his pilot's license at the age of 15. He loved to take the captain's seat when traveling on business in GE's corporate jets, and after retirement owned and piloted several private jets.

Ed will be remembered for his kind and generous spirit, his remarkable intellect, and his philanthropic endeavors.

Kay died January 9, 2020; they are survived by daughters Lisa Bezzeg (Robert) and Molly O'Brian Watkins (David), and six grandchildren.

EDWARD E. HORTON

1927–2015

Elected in 2002

"For innovative contributions to the development of systems and structures for oil drilling and production in very deep water."

BY J. RANDOLPH PAULLING

EDWARD EVERETT HORTON, one of the most creative and innovative engineers in the offshore oil and gas industry, died at the age of 87 on August 13, 2015, in Houston, Texas.

He was born November 13, 1927, in San Gabriel, California, to Winter David and Edith Kendall Horton. He received a BS degree in civil engineering from Yale University (1949) and a master's degree in petroleum engineering from the University of Southern California (1957). While at Yale he entered the Navy on the Holloway Plan[1] and was a decorated veteran of the Korean War, serving on the USS *Helena* and, as a qualified submariner, the USS *Sea Leopard*.

After his naval career, Ed moved into the new and growing field of ocean engineering, where his fertile imagination and expertise, combined with his Navy experience, afforded him the opportunity to fully develop his creative talents.

Some years earlier, a group of earth scientists had conceived the idea of drilling into the boundary between the Earth's crust and mantle to obtain a sample of the mantle material. Since the crust is substantially thinner under the deep ocean than under land, it would be expedient to conduct this drilling

[1] A post–World War II program to replace officers (mostly reserve) who left or would shortly leave the Navy.

in deep water from a floating platform. Ed was selected by the National Research Council as a principal engineer on this drilling effort, called the Mohole Project.[2]

In 1961 initial drilling was carried out from existing vessels, and construction was begun on a large semisubmersible platform to support the Mohole drilling. Unfortunately, before the project could achieve its goal, it was cancelled because of rapid cost escalation. It nevertheless generated much fundamental knowledge and engineering experience that finds use today in the design of floating platforms used for oil drilling and production in deep water.

As a result of his involvement and contributions, Ed became well acquainted with not only the technology but also many of the people and companies involved in engineering in the deep ocean. A small group of them, under the leadership of Ed's good friend Willard Bascom, formed a company, Ocean Science and Engineering, appointing Ed as a vice president and board member. OSE developed platforms, tools, and engineering concepts for offshore use in both deep and shallow water.

Within the framework of OSE, Ed formed his own subsidiary company, Deep Oil Technology (DOT), specializing in deepwater oil drilling and production. As head of DOT, Ed became one of the most recognized innovators in the offshore oil business, leading to his numerous patents on platforms, well controls, mooring systems, and other concepts.

Among his inventions are the surface platforms that support the drilling and production equipment and the wellhead that controls access to the well. DOT put substantial initial effort into the tension leg platform (TLP), a floating platform whose buoyancy exceeds its weight and is held in position by taut vertical anchor tendons. The tendons maintain vertical equilibrium under the excess of buoyancy over weight and, at the same time, suppress wave-induced vertical motion,

[2] Derived from the term for the boundary between Earth's crust and mantle, the Mohorovičić Discontinuity or Moho. The National Academy of Sciences observed the project's 50th anniversary in 2011 (https://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=04152011).

thus providing a stable base to support drilling and other operations.

Early in his development of the TLP, after much small-scale model testing and computer simulation, Ed convinced a consortium of 19 oil and offshore companies to fund a joint venture to build a large physical model, at about one-third scale, of a TLP. This model, to be tested at sea off the Southern California coast, was named the DOT X-1. It would be large enough to ensure that scale effects on hydrodynamic forces would be minimized yet small enough that the expected wave conditions in the area of testing would represent severe storm seas at full scale. It was equipped with instruments to record waves, platform motions, anchor tensions, and internal structural forces. The DOT X-1 was built and moored at sea as planned, where it provided about 3 years of experience data.

The TLP was only the beginning of a series of concepts for platforms to support drilling in the deep ocean. It was previously known that a simple vertical spar with small cross-sectional dimension (diameter) compared to its length (height) will have low wave-induced forces and motions if the dimensions are properly chosen in relation to the proportions of the waves. Ed conceived several variations on the simple spar, some consisting of multiple spar-like members of different diameter joined either coaxially or in an array of parallel members. He also invented a way to support marine risers in the spar, leading to spars in several configurations that have become some of the most successful new concepts for drilling and production platforms in deep water. Even today, TLPs and spars are the only platforms in deep water capable of supporting permanent vertical risers for drilling and production, allowing the well heads to be located at the surface rather than the sea floor for more economic operation. About half of the deepwater floating platforms that have been built in the past 2 decades are either TLPs or spars.

Later in life his interests included ocean monitoring and offshore wind, wave, and other sources of renewable energy from the ocean. And he was constantly studying new materials and construction methods for applications to old and new concepts.

In addition to his 2002 election to the NAE, Ed received numerous honors and awards for his contributions. The National Academy of Sciences awarded him the Gibbs Brothers Medal in 2001 for "visionary and innovative concept development and design of offshore platforms, mooring systems and related technology that have significantly influenced development of deepwater operations." Other major honors were the 1997 Offshore Technology Conference Distinguished Achievement Award for Individuals; 2004 Projects, Facilities, and Construction Award from the Society of Petroleum Engineers; and 2010 "Hall of Fame" award from ASCE for his 1970 paper on the tension leg platform.[3] He was also named an Offshore Pioneer by the Oilfield Energy Center (2008) and chosen as a Rhodes Petroleum Industry Leader by ASME (2005).

Ed served on numerous advisory boards and committees. He was a member of the American Bureau of Shipping Offshore Technical Committee, Marine Technology Society, American Concrete Institute, Yale Alumni Association, and Advancement Committee of the Civil and Environmental Engineering Department of Rice University.

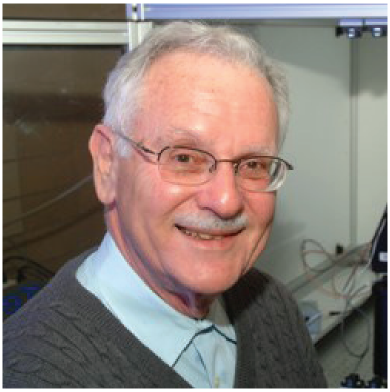
Ed was as original and creative in his private life as in his business. He had a wonderful sense of humor, loved music and movies, and delighted in creating and reciting poems, especially for children. He was close to his three daughters—Winter Horton Hoffman, June Horton Van Nort, and Janet Horton—and six grandchildren, and was a guest in classrooms over the years. He was a devoted family man and a mentor and inspiration to many others.

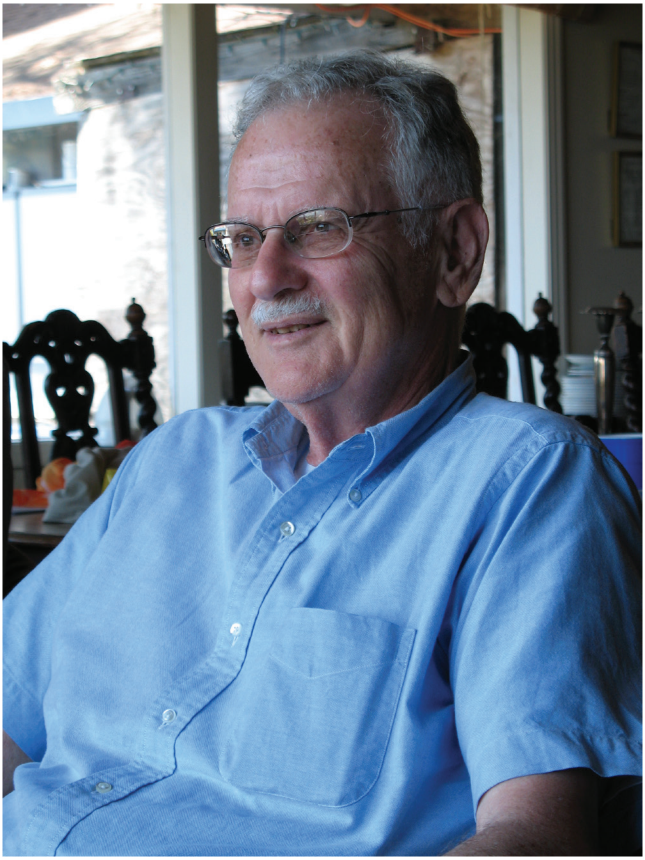
Although Ed's principal business activity was in Houston, he maintained the home in California that had been his residence for many years. He and his beloved wife Anne Watts Horton were members of St. Martin's Episcopal Church, two

[3] Paulling JR, Horton EE. 1970. Analysis of the tension leg stable platform. Paper presented at the Offshore Technology Conference, April 21–23, Houston.

dance groups, and the Utopia Yacht Club of Lake George, New York, and also enjoyed traveling the world.

He was preceded in death by his first wife, Janet Durst Horton.





LEON M. KEER

1934–2021

Elected in 1997

"For the application of elasticity to design problems involving contact and fracture."

BY WEI CHEN, Q. JANE WANG, AND ZDENĚK P. BAŽANT

LEON MORRIS KEER, Walter P. Murphy Professor Emeritus of Civil and Environmental Engineering and Mechanical Engineering at Northwestern University and a leader and prolific researcher on contact and fracture mechanics and tribology, died January 12, 2021, at the age of 86.

Born September 13, 1934, in Los Angeles to William and Sophie Keer, Jewish Ukrainian immigrants, he grew up and attended school in the Beverly/Fairfax area. As a young man he developed a sense of curiosity and wonder about the world that would serve him well for the rest of his life. He had an analytical mind and enjoyed debate as well as tennis and graduated from Fairfax High as the class valedictorian. He enrolled at the California Institute of Technology and received his BS degree in 1956 and his MS degree in 1958, both in mechanical engineering.

In 1956 he married the love of his life, Barbara Davis, and they started a family the next year. Their love for each other

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The authors drew in part from the nomination for Leon Keer's Mayo D. Hersey Award and from a tribute written by his wife Barbara, "Professor Leon Keer – A Life Well Lived," which includes delightful photos (https://splashmags.com/index.php/2021/01/24/professor-leon-keer-a-life-well-lived/#gsc.tab=0).

and their growing family kept him grounded as he advanced professionally.

Leon initially worked as a member of the technical staff at Hughes Aircraft Company (1956–59) but, feeling the pull of academia, left to pursue his doctorate at the University of Minnesota. He studied with Lawrence E. Goodman and received his PhD in aeronautics and engineering mechanics in 1962.

As a graduate student, he read *Theoretical Elasticity* by Alfred E. Green and Wolfgang Zerna. He did not fully understand it, but thought he might if he studied with Professor Green. His curiosity led him to a very productive period (1962–63) as a NATO Postdoctoral Fellow at the University of Newcastle upon Tyne, in England, where he worked closely with Green on elasticity.

Back stateside, Leon spent a year as a preceptor at Columbia University and then joined the Northwestern University faculty in 1964 as an assistant professor in civil engineering. He remained there for more than 55 years. He was promoted to associate professor in 1966, professor in 1970, and named Walter P. Murphy Professor of Civil Engineering in 1994. He served as associate dean for research and graduate studies (1985–92), during which time the school's graduate ranking improved to 13th in the nation. He also chaired the Department of Civil Engineering (1992–97) and was director of the university's Center for Surface Engineering and Tribology (CSET) beginning in 1998. He served twice as chair of the Northwestern University Chapter of Sigma Xi (1976–77, 1987–88).

He published nearly 400 scholarly articles on elasticity, fracture mechanics, contact mechanics, and tribology, but his proudest academic legacy was his 55 doctoral students and 22 master's students.

Leon was known for his collaborative support of research both at the university and internationally, thanks to his broad network of former students and colleagues around the world. At Northwestern, he maintained long-term collaborations with Herbert S. Cheng on tribology, Morris E. Fine on solder material development, Yip-Wah Chung and Kornel Ehmann on multilayer coating design, and one of the authors (QJW) on computational contact mechanics. Under his leadership of CSET, and with the help of several Northwestern colleagues, the center received an Integrative Graduate Education and Research Traineeship (IGERT) Award from the National Science Foundation in 2001.

Leon was particularly well known for several areas of research: with Lawrence E. Goodman on the elastic contact problem of a sphere indenting a cavity with a slightly larger radius, which extended the Hertz contact theory to allow the contact length to be a significant fraction of the size of the contacting spheres[1]; with Michael Bryant on the Cattaneo-Mindlin seminal solution for contacting elastic spheres subjected to a tangential load that is too small to cause gross sliding, applied to ellipsoidal bodies and other engineering applications[2]; on the Mindlin field for a concentrated force at an interior point of a half-space, or the Rongved field for a force at a point within one of two joined half-spaces, setting up integral equations for three-dimensional crack problems; with Nasser Ahmadi and Toshio Mura on a technique to calculate the subsurface elastic strain in a half space[3]; with Igor Polonsky on solving rough-surface contact problems with the conjugate gradient method[4]; and on the singular stress field near the tips of conical notches.[5]

[1] Goodman LE, Keer LM. 1965. The contact stress problem for an elastic sphere indenting an elastic cavity. *International Journal of Solids and Structures* 1(4):407–15.

[2] Bryant MD, Keer LM. 1982. Rough contact between elastically and geometrically identical curved bodies. *Journal of Applied Mechanics* 49(2):345–52.

[3] Ahmadi N, Keer LM, Mura T. 1983. Non-Hertzian contact stress analysis for an elastic half space—normal and sliding contact. *International Journal of Solids and Structures* 19(4):357–73.

[4] Polonsky IA, Keer LM. 1999. A numerical method for solving rough contact problems based on the multi-level multi-summation and conjugate gradient techniques. *Wear* 231(2):206–19.

[5] Bažant ZP, Keer LM. 1974. Singularities of elastic stresses and of harmonic functions at conical notches or inclusions. *International Journal of Solids and Structures* 10(9):957–64.

The hallmark of Leon's research was his successful development of useful, exact, analytical solutions to a number of difficult and technically crucial problems, such as crack propagation in rolling contact fatigue, edge effects in the flanging problem of wheel-rail contact and demonstration of their influence on life prediction and design, the influence of service loading on shell growth in rails, life prediction of gears and bearings, and the treatment of hydraulic fracture growth for reservoir simulation.

His work also impacted biomechanics and geophysics. His analysis provided the basis for interpreting an indentation test, still in use, that enhanced understanding of testing procedures for articular cartilage and was critical in the development of controlled testing procedures. He developed analytical methods to determine whether isolated pressurized cracks intersect joints, by using elasticity to model the process of hydraulic fracturing. In the area of quantitative nondestructive evaluation, he theoretically predicted resonance effects on a crack near a free surface.

In addition to his publications, collaborations, and analytical techniques, Leon served the research community as an associate editor for mechanics journals, including *Elasticity* (1977–79 and 1987–89) and *Journal of Applied Mechanics* (1987–88; technical editor, 1988–92). He was chair of the Transactions Board of Editors of the American Society of Mechanical Engineers (ASME; 1993–97), and president of the American Academy of Mechanics (AAM; 1988–89).

For his extensive contributions Leon received many honors and recognitions. He was a fellow of the John Simon Guggenheim Memorial Foundation (1972), AAM (1983), ASME (1984), Japan Society for the Promotion of Science (1986), American Society of Civil Engineers (ASCE; 1988), and Acoustical Society of America (2002). He received ASME's Daniel C. Drucker Medal (2004) and Mayo D. Hersey Award (2008) and ASCE's Raymond D. Mindlin Medal (2011). His collaborative coating work with Chung and Ehmann won the 2002 Innovative Research Award from ASME's Tribology Division, and he shared the 2014 Captain Alfred E. Hunt Award from the Society of Tribologists and Lubrication Engineers for his collaborative contact modeling work.[6]

Leon was highly respected by his colleagues, collaborators, students, and friends. A beloved and esteemed member of Northwestern's McCormick School of Engineering, he remained an active researcher and collaborator even at age 86.

He is fondly remembered and deeply missed for his contributions to the growing stature of the mechanical engineering department and his consistently positive attitude. Colleagues commented: "In addition to being a giant in elasticity and contact mechanics, Leon was a wonderful human being, who with his wife Barbara provided a warm and welcoming environment for the mechanics group." "When I was a new faculty member struggling to find my way, Leon took me on as a collaborator and taught me a ton. He was unrelentingly positive, something I'll never forget. Such a gentleman. He will be missed." "Our mechanics group stood out because of great scholars like Leon. And more importantly, he was such a great colleague and mentor." "He…was incredibly supportive of young faculty. He was always at peace with himself, which made him beloved by so many."

While research was Leon's academic passion, what he valued most was his family. He cherished his devoted wife Barbara, to whom he was married for 64 years. Those who knew Leon well will remember him fondly with Barbara by his side. He also took great pride in his four children, Trish (Dave), Jackie (Steve), Harold (Amy), and Michael (Cindy). He was blessed with seven grandchildren and six great-grandchildren.

Leon enjoyed art, fine dining, and cool jazz. His wry sense of humor surprised many. He delighted in Monty Python, Tom Lehrer, and the Bonzo Dog Doo-Dah Band. He and Barbara traveled around the world, attending conferences and extending their trips with visits to see friends, colleagues, and former

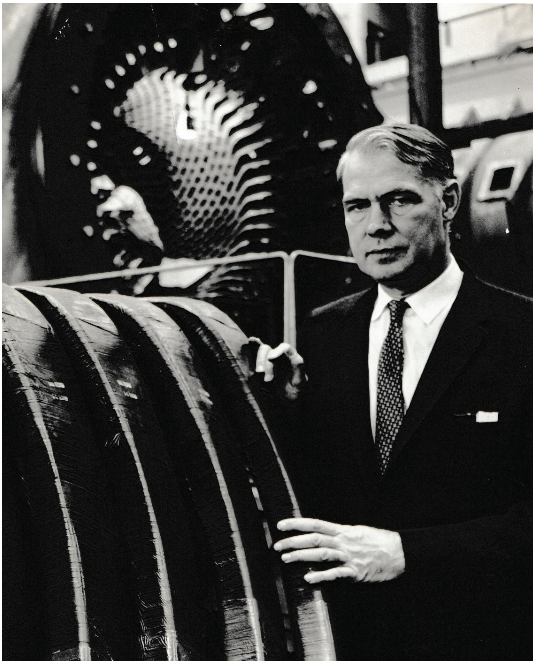
[6] Wang Z, Jin X, Keer LM, Wang QJ. 2012. A numerical approach for analyzing three-dimensional steady-state rolling contact including creep using a fast semi-analytical method. *Tribology Transactions* 55(4):446–57.

students. In 2011 they had the unusual opportunity to meet another Leon Keer, a prominent Dutch artist.

Leon's wish for his 85th birthday was to gather the family together for a weekend, which they did in January 2020. Nobody knew that covid-19 would prevent future gatherings. Leon was very happy with his memories of that special birthday and grateful for the time spent together. He said of his life, "I feel very lucky," and shared some wisdom acquired over the years:

> To some extent, learning has to come spontaneously…. The world is an amazing thing and you have to have an appreciation for how it works. So you have to have curiosity. I've always been curious—sometimes too curious.

His was certainly a life well lived. Northwestern's engineering community will long remember Professor Leon Keer's charismatic smile that shone with his wisdom, kindness, and relish for life.



LEE A. KILGORE

1905–2000

Elected in 1976

"Contributions in electromechanical engineering, particularly in the development and design of large rotating electric machinery."

BY JAMES KIRTLEY

LEE ALTON KILGORE, a pioneering figure in the electric power apparatus industry, passed away on October 23, 2000, at age 95.

He was born August 10, 1905, to Isaac Alton and Julia (née Kelly) Kilgore in Leavitt, Nebraska, a town that no longer exists in Dodge County. It had been built around a sugar beet refinery, and when that closed during Lee's childhood the family moved to Fremont. Isaac Kilgore, who had very little education, was a sign painter who considered himself an artist and also wrote poetry.

Lee attended school in Fremont and later said that it was an excellent high school with a superintendent who insisted on hiring good teachers. Lee described himself as "a good student, near the top if not at the top" of his class.[1] His brother, George Ross Kilgore, was a radio amateur, and Lee said he "dabbled in it" but was never good enough at Morse code to earn a general license. George went on to have a distinguished

[1] This and other quotations are from an oral history conducted December 8, 1993, by William Aspray, IEEE History Center, Piscataway, NJ, http://ethw.org/Oral-History:Lee_Kilgore. The IEEE History Center has a collection of more than 800 oral histories in electrical and computer technology; they can be accessed via http://ethw.org/Oral-History:List_of_all_Oral_Histories.

career in electrical engineering himself and was awarded the Third Millennium Medal in 2000 by the IEEE Electron Devices Society.

In high school Lee worked at a tree nursery and saved enough money to attend the University of Nebraska, which he said he selected because "tuition was free" and his parents were unable to contribute to the expenses of his college education. During summers and breaks in the school year he worked as a lineman for Northwestern Bell and Lincoln Telephone Company. He majored in electrical engineering, with a focus on power, and graduated as one of the top students in his class in 1927.

During the summer after his junior year he enrolled in a program at Westinghouse called the Junior Student Course. He was assigned to build a small demonstration of a circuit breaker invented by Joseph Slepian, called the deion breaker. The basic principle of this circuit breaker was involved in magnetic blast breakers, which used a magnetic field to move a developing arc. Lee's interactions with Slepian proved to be valuable in his career.

Degree in hand, Lee went to work at Westinghouse in East Pittsburgh, Pennsylvania, and attended classes at the University of Pittsburgh at night, earning a master's degree in 1929. Working with Carl Soderberg, he contributed to the theory of transient behavior of turbogenerators. This involved a lot of experimentation and, in his words, "we…nearly wrecked one of the machines." As a result, he learned something about bracing of armature windings and wrote a classic paper, "Calculation of Synchronous Machine Constants—Reactance and Time Constants Affecting Transient Characteristics."[2]

Lee was engaged in the design of large generators and wrote a design manual for turbogenerators, based in part on the work of Benjamin G. Lamme but with much original material as well. He was responsible for the design, in 1934, of a 165 MW, four-pole generator that became the most highly rated generator in service for about 18 years.

[2] Published in *Transactions of the American Institute of Electrical Engineers* 50(4):1201–13, December 1931.

Later, as manager of engineering, he oversaw the Westinghouse development of inner-cooled generators, in direct competition with Allis Chalmers and General Electric. All three companies were working on the same sorts of cooling techniques at the same time, although Kilgore said that GE was behind. He credited the invention of direct, inner-cooled generators to "a fellow named Baudry,"[3] but, he said, "I got to present the thing to the Management Committee."

Mr. Kilgore was diverted for 2 years to working, as the junior partner of Joseph Slepian, on the design of mercury arc rectifiers. In 1936 he designed an ignitron rectifier, the first of its kind.

In 1938 he was put in charge of large motor design. In his oral history, he said wryly, "but I hadn't, say, designed a motor. Furthermore, they already had two excellent chaps: one on synchronous motors, Mr. Lory, who later became engineering manager of that whole group; and P.C. Smith, who had worked as an induction motor designer for 30 years before they had made him any kind of a supervisor." Kilgore said he "applied myself mostly to developing better methods of calculation."

As manager of motor design, among other responsibilities, during and after the Second World War,[4] he developed motor and drive systems for large wind tunnels at Wright Field (now Wright-Patterson Air Force Base) and Moffett Field (now NASA Ames). These were quite large, variable-speed motors in applications for which stability is an issue. The job at Wright Field required a variable-speed 40,000 horsepower motor, and Westinghouse provided what was to become

[3] René André Baudry was an engineer, section manager, and engineering department manager at Westinghouse for at least 40 years (1925–65).

[4] He was also recognized, with an official certificate from the US War Department (Army Service Forces – Corps of Engineers: Manhattan District), for having "participated in work essential to the production of the Atomic Bomb, thereby contributing to the successful conclusion of World War II. This certificate is awarded in appreciation of effective service." It was dated August 6, 1945, and signed by Secretary Henry L. Stimson. The nature of his contributions is not known.

known as a Kramer drive, with slip energy recovery through a motor/generator set. In Kilgore's words, "You get an inherent instability in these things." He figured out how to stabilize the system by picking an appropriate slip speed.

The system at Moffett Field was even bigger, involving six large motors, each driving a fan. To maintain uniform flow, all six motors had to be turning at the same speed, so a system of wound rotor motors with both primary and secondary circuits connected together was to be used. But it presented a bunch of different modes of oscillation, some unstable. Lee eventually figured out how to shape the torque/speed curve of the motors, using a tuned circuit, to force them to run together stably.

During the development of drives for wind tunnels, Lee found himself again competing with General Electric, and again coming out ahead. While he was running the motor design section, he also designed large motor/flywheel/rectifier systems for major physics experiments at the University of California, Berkeley, where he worked with Ernest Lawrence, and at Brookhaven National Laboratory. In his oral history, he described how Westinghouse had devised a relatively simple design for the flywheel/generator set using an ignitron rectifier. Lawrence had expressed some concerns about the Westinghouse design partly because of observations made by GE staff and partly because GE had made a proposal that was much more expensive. But Westinghouse got the job because Kilgore was able to cite experience that justified the parts of their proposal that had raised concerns, including peripheral speeds of the flywheel and possible misfiring of the ignitron devices.

In 1954 Kilgore became manager of engineering for the East Pittsburgh Division of Westinghouse. His responsibilities included motors, generators, and even switchgear. He noted that, while the generator engineers did a lot of calculations but very little experimentation, the switchgear groups in East Pittsburgh took a "cut and try" approach: the "circuit-breaker switchgear people never did any figuring—they didn't even have a slide rule." So he took to improving the analytical and experimental skills of the engineers, particularly in the switchgear area, by teaching them "how to figure temperatures in their apparatus, and how to figure short circuits, forces, and stuff." He also "prodded the generator people to make a nice laboratory." Thus one of his major contributions was to help his staff develop both analytical and experimental capabilities.

In 1956 Kilgore received an honorary doctorate from his alma mater, the University of Nebraska. In 1959 he was honored by IEEE with the Lamme Medal, named for the same Benjamin G. Lamme who had led development of rotating electric machinery at Westinghouse early in the 20th century but who had passed away shortly before Lee started working at the company. His Lamme Medal citation was "for meritorious achievements in the design of electrical machinery; more specifically, for analyses of synchronous machine reactances, for inventions of special armature windings, and for inventions and designs related to large adjustable-speed alternating-current motors."

When he was a couple of years from retirement, the job he had held was eliminated in a reorganization, so he became a "consulting engineer." Beyond teaching about technical topics like engineering design, heat transfer, and field mapping, he also developed educational resources for his divisions. Together with two colleagues, he developed a course called "Human Relations for Engineers" that addressed a long-felt need at the East Pittsburgh works. This he taught personally to his engineering managers, with the idea that they would propagate it to their employees. He reported, "All together, we got at least 80 percent of the engineers in East Pittsburgh to go to a night course on their own time."

Lee was active in the affairs of the American Institute of Electrical Engineers (AIEE) and its successor, the Institute of Electrical and Electronics Engineers. In addition to presenting his work at their meetings, he chaired the Electric Machinery Committee and the Power Systems Committee and participated in standards development. He was elected a fellow of AIEE in 1945.

Dr. Kilgore was, in his words, "well acquainted with" Charles Concordia (1908–2003) of General Electric, another

NAE member (elected in 1978). Another good friend and competitor was Sterling Beckwith (1905–92) of Allis Chalmers; he had worked at Westinghouse earlier in his career. Among his contemporaries at Westinghouse were John Calvert, who eventually left to teach at the University of Pittsburgh, where he became head of the Electrical Engineering Department, and Eugene Whitney (1913–98; elected to the NAE in 1986). During the period when GE, Westinghouse, and Allis Chalmers were developing inner-cooled generators, Kilgore said, Professor Calvert was speaking with both Kilgore and Beckwith, but sharing nothing said by one with the other. Lee shared a delight in the rivalry with GE's Edwin Harder (1905–2004), a contemporary who was also awarded the Lamme Medal and elected to the NAE in 1976.

Lee was married to Ellen Connor Kilgore and they had four children, whom he regaled at the dinner table with tales of growing up in Nebraska. He belonged to a canoe club on the Allegheny River, where he and the family spent many happy hours, and he spent evenings in his easy chair making slide rule calculations to test out his engineering ideas. In retirement he used his artistic ability to make clay sculptures of scenes from his boyhood, animals, and busts of his grandchildren. He and Ellen enjoyed traveling to visit friends and family.

Ellen passed away in 1988. They are survived by their children Nancy Rice (Edward), Gordon, Susan Aoki (Thomas), and Robert, and eight grandchildren.

Lee Kilgore made important contributions to the design of electric power apparatus, including enhanced use of analytical techniques for design, and to the design of rotating machinery and switchgear, including field mapping techniques for understanding breakdown. He taught engineering analysis and design to numerous engineers at Westinghouse, where he also developed and taught about management of people. His influence on engineering design practice and on the modern power system continues.


BIOMATERIALS

SUNG WAN KIM

1940–2020

Elected in 2003

"For the design of blood-compatible polymers with human application, including drug delivery systems."

BY JINDŘICH KOPEČEK

SUNG WAN KIM, Distinguished Professor of Pharmaceutics and Pharmaceutical Chemistry and Distinguished Professor of Biomedical Engineering at the University of Utah, passed away at the age of 79 on February 24, 2020, in Salt Lake City.

He was born August 21, 1940, in Busan, Korea, to Jong Kyu Kim and Shin Hee Lee. After difficult times during the Korean War, he enrolled at Seoul National University, where he received his BS in chemistry in 1963 and MS in physical chemistry in 1965. While he was a master's student, he had a chance encounter with Prof. Henry Eyring, who was visiting from the University of Utah chemistry department. Eyring suggested that Sung Wan move to the United States, and in 1966 he did, joining Eyring's laboratory. After receiving his PhD in physical chemistry (1969) he stayed, continuing as a postdoctoral fellow with Prof. Willem Kolff, the father of artificial organs.

After doing postdoctoral research on biomaterials at the University of Utah's Institute for Biomedical Engineering and Department of Materials Science, Sung Wan was hired in 1971 as an assistant research professor in the College of Pharmacy. This is where he started his own research in biomaterials and drug delivery systems, focusing on early events in blood-biomaterial interactions.

His studies of the mechanism of surface-induced thrombosis guided the design of heparin-containing biomaterials, prostaglandin-releasing biomaterials, and block copolymer–based biomaterials. Other important achievements were self-regulating drug delivery systems, including insulin delivery using competitive binding of glycosylated insulin and glucose to concanavalin A. In addition, his group developed smart hydrogels and stimuli-sensitive polymers for drug delivery. In particular, the design of ReGel, a thermosensitive (when the sol-gel transition occurs after administration), biodegradable, drug-releasing injectable hydrogel, has shown great potential for the development of novel anticancer therapies.

Beginning in 1996, Sung Wan's efforts centered on polymeric and biomolecular approaches to gene delivery. Instead of frequently used viral systems, he developed nonimmunogenic polymer-based gene carriers. The development of bioreducible polymers as gene carriers was especially significant, resulting in delivery systems with improved biological activities and biocompatibility. The advanced design was validated by the successful development of therapeutics for the treatment of cardiovascular diseases, diabetes, and cancer.

Sung Wan's pioneering research in biomaterials and drug delivery was truly inspiring. The interdisciplinary research results from his laboratory not only were translated to clinics but also created influential scientific foundations that facilitated further inventions worldwide.

He published over 500 papers in high-impact journals and received numerous patents. Most important, he trained over 150 scientists from all over the world, creating an environment where young people could develop their talents to the fullest.

Sung Wan's efforts enhanced the standing of the College of Pharmacy and the University of Utah around the world. In 1983 he started a biennial symposium on drug delivery, in 1986 he founded the university's Center for Controlled Chemical Delivery (which he led as codirecor until his retirement in 2007), and over the years he initiated numerous international scientific collaborations. One noteworthy partnership was "The Triangle," a collaboration of the University of Utah

(Kim) in the United States, University of Twente (Jan Feijen) in the Netherlands, and Tokyo Women's Medical College (Teruo Okano) and University of Tokyo (Kazunori Kataoka) in Japan. These activities created an opportunity for students to meet and talk with leaders in the field and, through an associated exchange program, to work in different laboratories and experience diverse cultures.

Sung Wan was also a successful entrepreneur, as founder of Expression Genetics and Macromed, and cofounder of TheraTech.

For his outstanding contributions Sung Wan received numerous honors: the Biomaterials Society's Clemson Award for Basic Research (1988), Utah Governor's Medal for Science and Technology (1988), Controlled Release Society Founders Award (1995), Dale Wurster Award from the American Association of Pharmaceutical Scientists (1998), Volwiler Research Achievement Award from the American Association of Colleges of Pharmacy (2002), University of Utah Distinguished Research Award (1987) and Rosenblatt Prize for Excellence (2003), Korea's Ho-Am Prize (2003), Research Achievement Award from the Pharmaceutical Sciences World Congress (2004), and Terumo Global Science Prize (2014), among others. He was a member of the National Academies of Medicine (1999) and Engineering (2003), and fellow of the National Academy of Inventors (2012). In addition, he received an honorary doctorate from the University of Twente (2006) and was designated a Distinguished Professor at Hanyang University in Korea.

He was active in service to the scientific community, including 12 years on NIH study sections. He was also a generous philanthropist who supported academic institutions, scientific conferences, and young researchers.

Sung Wan Kim was an outstanding researcher, innovator, and teacher but also a wise, modest man who enjoyed life, travel, skiing, and playing golf. He cherished personal contacts with friends and was a devoted family man. He is survived by his wife, Hee Kyung, son Alex (Catherine), daughter Kara (Brian), and four grandchildren.

Sung Wan Kim's devotion to research and discovery, his innovative spirit, and his wisdom and kindness influenced both the careers and the character of his students, coworkers, and friends. He was a great teacher, a great scientist, and a great man.

JOHN F. KNOTT

1938–2017

Elected in 2003

"For advancing our understanding of the mechanisms and microstructure of fracture and fracture mechanics with application to the failure of engineering alloys and structures."

BY ROBERT O. RITCHIE AND JAMES R. RICE

JOHN FREDERICK KNOTT, a leading light in understanding of the mechanics and mechanisms of fracture, with particular application to gas turbine engines and nuclear power, died October 5, 2017, at the age of 78. At the time of his death, he was the Feeney Professor Emeritus of Metallurgy and Materials at the University of Birmingham.

He was born December 9, 1938, to Fred and Margaret (née Chesney) Knott in Bristol, where he spent his teens excelling in math and sciences at the Queen Elizabeth's Hospital school before going to Sheffield University to study metallurgy. He won the school's Mappin and Nesthill Medals and graduated in 1959 with a BMet degree with first-class honors. He then went to Cambridge University to study under Alan H. Cottrell on the notched-bar mechanics of the deformation and fracture of steel. He graduated with a PhD degree in 1963.

After Cambridge, John joined the Central Electricity Research Laboratories (CERL) in Leatherhead to work with a newly formed but well-known group of researchers in the Metallurgical Engineering section under the leadership of

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Additional details and photographs are available in the biographical memoir prepared by the Royal Society, https://royalsocietypublishing.org/doi/pdf/10.1098/rsbm.2018.0005.

Edwin (Ted) Smith. Smith's group was focused on failure mechanisms relevant to the power generation industry, allowing John to continue his work on notched-bar mechanics pertinent to brittle cleavage fracture in steels.

In 1967 he left CERL to begin his academic career as a lecturer in the Metallurgy Department at Cambridge University and as Goldsmith's Fellow at Churchill College (he was vice master of the college in 1988–90). His reputation in the field of fracture began to thrive with his work on the mechanistic aspects of ductile, brittle, and fatigue fracture. He continued this work on the micromechanisms of fracture throughout the 1970s and '80s, aided by a cadre of excellent graduate students and several distinguished overseas fellows at Churchill, including Charles McMahon from the University of Pennsylvania and somewhat later Louis Coffin from General Electric. One of us (JRR, then at Brown) met and began collaborating with John via that same Churchill College route.

In 1990 John left Cambridge to become professor and head of the Metallurgy and Materials Department at Birmingham University, where he became dean of engineering (1995–98) and was named Feeney Professor of Metallurgy in 1996.

While at Cambridge John became known as one of first people to develop the metallurgical-mechanistic aspects of the rapidly emerging field of fracture mechanics in metallic materials. In writing the first internationally recognized book on fracture mechanics, *Fundamentals of Fracture Mechanics* (Butterworth & Co. Publishers, 1973), he brought this mechanics-dominated topic into the world of the materials scientist. He was one of the first researchers to embed local fracture criteria, related to metallurgical models of fracture, in continuum fracture mechanics solutions of crack-tip fields; one example was the so-called RKR model for cleavage fracture, developed by John and the authors of this tribute.

By combining materials science and mechanics understanding, John and his students developed micromechanical models for several modes of fracture and were some of the first researchers to formulate such models on a probabilistic basis. He also worked on the topic of fatigue and somewhat later creep, where he was again able to develop mechanistic understanding of such failures.

His principal contributions to the field of materials engineering can be essentially summed up as bringing materials science into continuum fracture mechanics, providing a metallurgical-mechanistic counterpart to the applied mechanics breakthroughs of George Irwin, John Hutchinson, and others in the early development of fracture mechanics, and establishing the micromechanistic or local approach to modeling fracture.

By integrating a microscopic understanding of mechanisms with a continuum mechanics description of crack-driving forces, John was a pioneer in defining how materials scientists study fracture today, and he was a major proponent of the application of this discipline to help solve problems in the nuclear energy and aircraft gas turbine engine industries.

Even as he remained active at Birmingham, he spent considerable time serving on prestigious and national committees where his extensive knowledge and experience were frequently sought. From 1991 to the end of his life, when he was paralyzed (after a fall in 2015), he was a member of the Marshall committee to assess the safety of pressurized light water nuclear reactors in the UK, a founder (and chair, 2010–17) of the Technical Advisory Group on Structural Integrity (to provide advice to the civil nuclear power industry), and a member of the Graphite Technical Advisory Committee (on the use of graphite in advanced gas-cooled Magnox reactors), the Ministry of Defence Research Programmes Group (to advise on new nuclear propulsion plants for submarines), Nuclear Safety Advisory Committee, and Defence Nuclear Safety Committee.

In addition, he was a member of the research board of the Welding Institute; member and subsequently chair (2000–11) of the Rolls-Royce Materials, Manufacturing, and Structures Advisory Board; and an honorary fellow and president (1993–97) of the International Congress on Fracture (ICF). He also served for a decade as editor of the journal *Materials Science and Technology*.

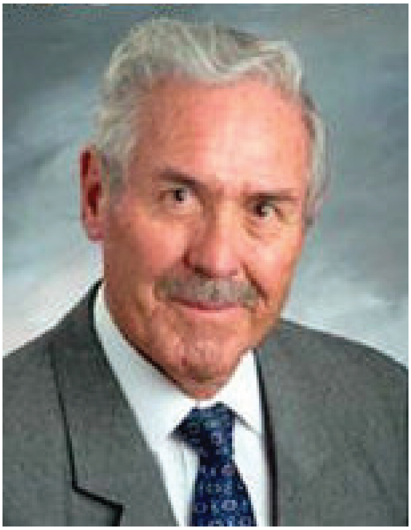
For his significant contributions, John Knott made the New Year's Honor List in 2004 with the award of an Officer of the

Order of the British Empire (OBE) for services to nuclear safety in the United Kingdom. He was also made a fellow of the Royal Academy of Engineering (FREng; 1988) and Royal Society (FRS; 1990), a foreign member of the National Academy of Sciences of Ukraine (1993), and a foreign fellow of the Indian National Academy of Engineering (2006). He was elected a foreign associate of the US National Academy of Engineering in 2003 and a fellow of the UK Institute of Materials and of the Institution of Mechanical Engineers. He received the L.B. Pfeil Prize for Physical Metallurgy (1973; jointly with Richard Dolby), Rosenhain Medal (1978), Griffith Medal (1999), TWI Brooker Medal (2007), Institute of Materials Platinum Medal (2009), and ICF's Sir Alan Cottrell Gold Medal (2013).

John, or Knotty as he became affectionately known, was described as a "treasured, irreplaceable, and once irrepressible friend" to us all. He was the "life and soul" of so many conferences, banquets, and after-hours discussions, yet he was always *on cue* early the next morning to fully engage in whatever presentations or technical discussions he was scheduled to participate in. He was an avid writer of poems and limericks, which he would gleefully deliver to honor some colleague at a formal event or just to delight whoever would listen. He loved solving crossword puzzles and was enthusiastic about "trad jazz."

He was married twice, first to Chris (née Roberts) in 1963 (they divorced in 1986) and then to Sue (née Jones) in 1990. She survives him along with sons William (Tania) and Andrew (Alison) from his first marriage, stepsons Paul (Yuki) and James from his second marriage, and four grandchildren.

Above all John was an articulate, passionate, yet modest man, who always put his students, postdocs, and close colleagues first. He is sorely missed.



LEONARD J. KOCH

1920–2015

Elected in 1981

"Contributions to fast reactor development, applying nuclear power to electricity generation and articulating the facts about nuclear power."

BY JOHN A. SHANAHAN
SUBMITTED BY THE NAE HOME SECRETARY

LEONARD JOHN KOCH, an internationally recognized pioneer in the development of breeder reactor nuclear power technology, died May 15, 2015, at the age of 95 as a result of complications from a fall.

His father, Philip, was a machinist and his mother, Christine, a homemaker. Len was born March 30, 1920, at home on the south side of Chicago, two months premature; his mother and aunt kept him alive. In fact, the primary emphasis of his early childhood was on survival since the family was dirt poor, especially during the 1930s.

He became particularly aware of financial circumstances during his senior year at Morgan Park High School. His fellow students planned to go to college, and he pretended to be going also. He received a "half scholarship" to attend an "accounting college," then heard about the co-op program at Armour Institute of Technology, now Illinois Institute of Technology; the 5-year program in mechanical engineering involved 8-week semesters of school and work for 5 years. He worked at Liquid Carbonic Corp., manufacturer of bottle-filling machines.

Upon graduation in 1943, he worked for three companies in the development and manufacture of internal combustion engines, his love at the time. The first company was Chrysler

Corporation, where he worked during World War II on development of engines for state-of-the-art bombers for service in the Pacific. Then at Tucker Corporation he worked on rear-mounted engines for high-performance automobiles. It was there that he learned about Argonne National Laboratory and atomic energy.

Len applied to ANL and was interviewed by the director, Walter Zinn.[1] He was incredibly lucky to be in the right place at the right time: He was hired in 1948 for the Experimental Breeder Reactor-I project, thanks to his experience in solving practical engineering problems for important government and private industry projects, and Zinn became his mentor and hero. EBR-I was the first reactor to produce electricity that lit the entire facility.

Len next became project manager of EBR-II, responsible for its development, design, and construction. It was the first US attempt to develop a small prototype of the long-range concept of future nuclear plants, which had been conceived by Enrico Fermi and his colleagues and scientifically demonstrated by the EBR-I experiment. When the EBR-II facility commenced operation, the project organization was dissolved.

Len became director of ANL's Reactor Engineering Division in 1963, responsible for engineering development and "the next step" in the advancement of nuclear power. Unfortunately—for Len and for nuclear power in the United States—the Atomic Energy Commission revised its nuclear development organizational structure in 1972. This was a time when the nation was faced with the monumental task of reconciling energy needs, environmental concerns, and economic goals. Len concluded that the government was not likely to design or build any more experimental power reactors and left Argonne in 1972.

From the federal sector he went to work as vice president at Illinois Power Co. (IP), which was starting plans for a standard commercial light water reactor (LWR) nuclear power plant—the company's first involvement in nuclear power plants. But

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[1] See his tribute on pp. 397–403 in this volume.

the project received a significant blow from the Three Mile Island accident in early 1979, at about the peak construction period of the IP Clinton Power Station. Len persisted, and continued to stump for "real nuclear power" breeder reactors, but when it became obvious that he would not be able to finish the plant before his retirement, he retired in 1983. From then until his passing in 2015, Len was active with many other pioneering scientists and engineers in promoting public education about nuclear power.

Notwithstanding the disappointments, his contributions were recognized with his election to the NAE in 1981. In 2004 he was awarded the Global Energy International Prize from Russia "for his pioneering contribution to the development of fast-breeder nuclear reactors for power generation and fundamental studies into the thermophysical properties of matter at extremely high temperatures." It was the technical recognition highlight of his life. In 2007 he received the Walter H. Zinn Medal from the Operations and Power Division of the American Nuclear Society, an award that had special significance for him because of his long and special association with Zinn. In 2012 the American Nuclear Society awarded Len the W. Bennett Lewis Award for lifetime contributions to nuclear science and sustainable energy.

The standard LWR commercial plant used in all countries has become the workhorse for generating electricity using nucear power. While these plants have been very successful and well managed, they have a once-through fuel design that uses only about 1 percent of the potential nuclear energy in the original ore. The uranium-fueled breeder reactor technology that Len helped pioneer with spent-fuel recycling can use nearly all the potential energy stored in the ore.

If the LWR spent fuel and depleted uranium from the enrichment process stored in the United States were used in breeder reactors, it would have a value of several trillion dollars and be able to power all the electrical energy needs of the United States for several thousand years. University of Pittsburgh physics professor Bernard Cohen published an estimate in 1983 that breeder reactors like the one Len helped develop could use the available uranium ore from mining on the land and dissolved uranium in the oceans to provide all the energy the world will need for electricity and other energy applications for as long as humans will live on Earth.[2] Nuclear-powered fast reactors have an added advantage of being able to use thorium, which is more abundant than uranium, making the technology potentially even more sustainable.

In the twilight of his life Len participated in the effort to educate the public with facts about energy options. He gave talks in towns where he lived and engaged in internet discussions with nuclear advocates. He also published "Fast Reactor Future – The Vision of an Atomic Energy Pioneer"[3] (online at thesciencecouncil.com) and "Nuclear power – The next 50 years and beyond" (in *Nuclear News* in 2002). He worked with John Shanahan, founder of the website allaboutenergy.net, where he and Ted Rockwell provided advice and articles for public education.

And on a beautiful day in April 2013, Len stepped lively up to a video camera situated among flowering cactus and other desert plants in Tucson, Arizona, the Tucson Mountains in the background. With a friendly smile and firm voice, he described how nuclear power had been his life's work, avocation, and obsession. He said he hoped that America would embrace nuclear energy and not let false alarmists and politicians force the country to think it can rely on wind and solar.

Len's wife, Rosemarie (née Schafer), predeceased him in 2007. They are survived by son William Koch and two grandchildren.

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[2] Cohen BL. 1983. *Before It's Too Late: A Scientists's Case for Nuclear Energy.* New York: Plenum Press.

[3] Based on his presentation at the international symposium "Science and Society," March 13, 2005, in St. Petersburg, Russia.

JUAN C. LASHERAS

1951–2021

Elected in 2012

"For studies of atomization, turbulent mixing, and heat transfer and for the development of medical devices."

BY ALBERT P. PISANO, GENO PAWLAK,
AND ANTONIO L. SÁNCHEZ

JUAN CARLOS LASHERAS, Distinguished Professor of Mechanical and Aerospace Engineering and Bioengineering at the University of California, San Diego, passed away February 1, 2021, after a brief battle with cancer. He was 69 years old.

Juan was a brilliant scholar, a visionary leader, a supportive mentor, and a dedicated educator, with a larger-than-life presence in the Department of Mechanical and Aerospace Engineering (MAE) and in the Jacobs School of Engineering. More than that, he was a beloved friend and dear colleague.

He was instrumental in founding the UCSD Aerospace Engineering Program and in forming the MAE Department. In 1999, when the Department of Applied Mechanics and Engineering Sciences (AMES) split into MAE and the Department of Structural Engineering, Juan served as the first chair of the new MAE department. He was also the founding director of the UCSD Center for Medical Devices, and served as interim dean of engineering in 2012. Beginning in 2007, he held the Stanford S. and Beverly P. Penner Endowed Chair in Engineering or Applied Sciences.

Adapted from the UC San Diego Jacobs School of Engineering press release (https://jacobsschool.ucsd.edu/news/release/3218). The authors appreciate thoughtful assistance and input from David Miller, Elizabeth Simmons, George Tynan, and Forman Williams.

Juan was born August 16, 1951, in Valencia, Spain, and spent most of his formative years near Murcia, where his father, a mathematician by training, was stationed as a colonel at the Air Force Academy. At age 18, Juan began his studies in aeronautical engineering at the Universidad Politécnica de Madrid. Sadly, his academic plans were disrupted at the end of his first year by his father's passing. To provide for his family, Juan moved back to Murcia and, for the next several years, worked as a teacher and director of a preparatory school for Air Force cadet candidates. Unable to attend college lectures in Madrid, 300 miles away, he prepared for course exams using class notes shared with him by his classmates. Despite these challenges, he graduated at the top of his class in 1975.

Upon graduation with his bachelor's degree in aerospace engineering in 1977, Lasheras secured a Guggenheim fellowship to continue his studies at Princeton University under the guidance of Irvin Glassman,[1] a renowned combustion scientist. He earned master's (1979) and doctoral degrees (1981) in mechanical and aerospace engineering.

It was at Princeton that Lasheras began to develop his skills as a creative experimentalist. He designed a combustion facility from scratch that, for the first time, allowed investigation of the mechanisms for explosive (disruptive) burning of multicomponent and emulsified fuel droplets. His pioneering work attracted the attention of the Research Department at the Shell Corporation, which hired him as a research scientist in 1981 to direct the combustion group at the Royal Dutch Shell Laboratory in Amsterdam.

In 1983 Lasheras returned to the United States as an assistant professor in the Department of Mechanical Engineering at the University of Southern California. There, he used his experimental skills to investigate a number of fluid dynamics problems related to aerospace propulsion applications. For example, his experiments helped clarify the structure and stability of turbulent mixing layers and jets, as well as the regimes of liquid atomization relevant to the design of rocket engines.

[1] See his tribute on pp. 129–33 in this volume.

While in Los Angeles, Juan met Alexis Hix. They were married in the Picos de Europa in Cantabria, Spain, in 1985.

Already a renowned experimentalist, Lasheras joined UC San Diego as a professor in the AMES Department in 1991. While he maintained an active research program addressing flow problems for engineering applications, he also developed an interest in biomedical applications following the deaths of two of his sisters at an early age. With initial guidance from Shu Chien, UCSD Distinguished Professor of Bioengineering and Medicine, Lasheras quickly built a brilliant career working at the interfaces between mechanics, biology, and medicine. His work laid the foundation for significant advances in biomechanics.

He addressed a wide variety of problems and applications at the macroscopic level, including endovascular techniques to induce and control mild hypothermia, unsteady blood flows, and the risk of rupture of aortic and intracranial arterial aneurysms. More recently, his work encompassed cerebrospinal flow in the central nervous system and its role in intrathecal drug delivery procedures. His contributions are equally important at the cellular level, including development of a novel three-dimensional cell-traction-force microscopy method and resolution of some of the biochemical pathways for the generation of traction forces exerted by cells during migration.

A true engineer, Juan was driven by a fundamental interest in both the underlying physical mechanisms and the ultimate applications. He held nearly 50 patents, including one for an endovascular blood-cooling catheter that served as a heat exchanger, the first device approved by the FDA to rapidly cool the body temperature after cardiac arrest to protect the brain.

He was drawn to complex problems that required an interdisciplinary approach. His research style combined an outstanding ability to identify relevant problems in need of further understanding and quantification with a deep knowledge of the key physical and biological elements involved. With mastery of the central physical phenomena and the capacity to describe them in a clear and concise manner, he had a gift for designing insightful experiments that revealed underlying phenomena with minimum associated complexity.

An exceptional communicator, he could convey very complex ideas in simple terms. In a laboratory meeting he could explain the different roles of viscous and pressure forces in blood flow to a doctor, and then turn around and explain the physiology of a red cell to an engineer.

His success was also due to his remarkable ability to form and motivate research teams that included individuals from different disciplines who were able to contribute a wide range of research tools. His exceptional interpersonal and communication skills enabled and promoted the collaborative work of people with completely different backgrounds, facilitating harmonious interactions of biologists and medical doctors with electrical, mechanical, and aerospace engineers.

These skills also contributed to his effectiveness and popularity as a teacher. Students consistently gave him the highest evaluations, he received the MAE department's Teacher of the Year Award on multiple occasions, and he was recognized by the Tau Beta Pi Engineering Honor Society. He was often sought by campus colleagues to serve on academic senate faculty committees.

Fortunately for colleagues and students, Juan was extremely generous with his time. He somehow seemed to have endless hours available for either serious discussion or friendly conversation, and he handled both with ease. He never turned down a request when his help or advice was needed.

His generosity extended to active service to the scientific community. He was an associate editor of the *Journal of Fluid Mechanics* and a participant in activities of the American Physical Society (APS) and National Institutes of Health (NIH). Besides serving as secretary/treasurer and later chair of the APS Division of Fluid Mechanics, he was a member of the APS Executive Council and chaired the organizing committee for two annual meetings. He was also heavily involved in NIH studies and a permanent member of the Study Section on Modeling and Analysis of Biological Systems. In addition, for many years he chaired the board of advisors at Universidad

Carlos III in Spain, where, with his friend Shu Chien, he helped organize a bioengineering program that has become the leading program in the country. He contributed deep thought and time to all these activities, always trying to make sure that what was done would be best for the scientific community.

His numerous contributions were recognized with various honors. He was a member of the National Academy of Engineering, National Academy of Inventors, and Spanish Royal Academy of Engineering. In 1990 he was elected an APS fellow and shared the François Frenkiel Award for Fluid Dynamics.[2] He held honorary doctoral degrees from the Universidad Politécnica de Madrid and Universidad Carlos III de Madrid.

Beyond all his professional accomplishments and accolades, Juan was a caring and generous person who had a profound impact on many students, staff, and faculty at UC San Diego. This legacy is evident in their countless anecdotes about his career advice, his role in bringing them to UC San Diego, and the help he graciously offered to them or their relatives in the face of personal challenges.

Outside of work, Juan was an excellent golfer and a talented chef. In his cooking, he applied the same creativity he used in the laboratory, always ready to try new recipes. He and Alexis loved to entertain friends, students, and colleagues and hosted many memorable gatherings in their La Jolla home.

Juan Lasheras leaves an extraordinary academic legacy, not only in his scientific contributions but also in the innumerable graduate and undergraduate students, postdocs, and colleagues who have benefited from his teaching and mentorship.

He is survived by Alexis; his siblings, Maruja, Arsenio, and Teresa; and seven nephews and nieces.

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[2] Lázaro BJ, Lasheras JC. 1989. Particle dispersion in a turbulent, plane, free shear layer. *Physics of Fluids A* 1(6):1035–44.

EDWIN N. LIGHTFOOT JR.

1925–2017

Elected in 1979

"Contributions to mass transfer and separation processes, and research on quantitative design procedures in biochemical and biomedical engineering."

BY ABRAHAM M. LENHOFF, BERNARD O. PALSSON, AND STUART L. COOPER

EDWIN NIBLOCK LIGHTFOOT JR., Hilldale Professor Emeritus of Chemical Engineering at the University of Wisconsin–Madison, passed away October 2, 2017, at the age of 92.

He was born in Milwaukee September 25, 1925, to Edwin and Harriet Grimm Lightfoot, and grew up in nearby Wauwatosa. As a boy he loved chemistry and thought about becoming a chemist—until his father took him to Cutler Hammer to see where the chemists worked (the electroplating shop) and then where the engineers worked (desks and drawing boards). From that day forth, E.N. Lightfoot Jr. became an advocate for engineering education.

He received his BS degree in 1947 and his PhD degree in 1950, both in chemical engineering, from Cornell University. In 1949 he married Lila Smith of Newburgh, New York, which began a partnership that lasted 67 years.

Ed's first job out of grad school was with the Charles Pfizer Co. in Brooklyn, NY, where he received a patent for the manufacture of vitamin B_{12}. In 1953 he joined the University of Wisconsin–Madison Department of Chemical Engineering at the invitation of the chair, Olaf A. Hougen, who encouraged him to develop a biochemical research and education program in the department. Ed was promoted to associate professor in

1957 and full professor in 1961. During his career he supervised 49 doctoral students, many of whom are professors at leading universities and researchers in industrial biochemical and biomedical laboratories. He retired formally in 1996 but remained physically and intellectually active long beyond that time.

After World War II, as the field of chemical engineering matured and challenges became more complex, Lightfoot and colleagues R. Byron Bird and Warren Stewart recognized a growing need to provide students with unifying principles in a variety of transport phenomena. In the 1950s the trio developed an undergraduate course in the area, and in 1960 they published the groundbreaking textbook *Transport Phenomena* (John Wiley & Sons), which became widely known simply as "BSL" (the authors' initials). The book beautifully unified the interrelated subjects of mass, heat, and momentum transfer and fundamentally changed how chemical engineering (and other engineering disciplines) were taught worldwide. The original text was in print 41 years and saw 5 translations; the second edition remains in print.

Separate from his renown as an author of BSL, Ed established a reputation as a brilliant researcher who, during his career of more than 50 years at Wisconsin, advanced the frontiers of an extraordinarily diverse range of highly interdisciplinary research topics. At the core was a pioneering research program in biochemical engineering, true to Hougen's original guidance, that included collaborations with colleagues in disciplines ranging from medicine to environmental engineering.

Ed studied the dynamics of biological systems on length scales ranging from the physiological, where transport phenomena are pivotal, to the intracellular, where the complexities of metabolic networks dominate. His analyses of biomedical problems and contributions to the design of artificial organs, for example, contributed to his leadership in the emergence of biomedical engineering.

His interest in biochemical engineering also extended to bioprocessing, where his research on separation processes, especially membrane processes and liquid chromatography, gained prominence. That the modern biotechnology industry was born near the midpoint of his career made his insightful opinions highly visible as this major industry sector took shape.

Ed's research contributions beyond the biological sphere were also significant, including fundamental questions related to transport mechanisms. But his analytical approach was especially suited to dealing with the complexities of poorly defined systems, including many biological ones. Often starting from limiting order-of-magnitude calculations, he could pick apart largely impenetrable datasets to extract key organizing principles. These discoveries were fast-tracked into his teaching in such a way that different versions of his class on transport phenomena in living systems could cover substantially different topics. Preparing a lecture would include finding the data in the biomedical literature long before the days of online searching.

His painstaking efforts led to Ed's authorship of *Transport Phenomena and Living Systems: Biomedical Aspects of Momentum and Mass Transfer* (Wiley, 1973), in addition to more than 225 papers and comprehensive book chapters. He continued to break new ground in his contributions to understanding biochemical and biomedical systems as he remained active in his research into his 90s, seeking insights especially into complex systems and issues. For instance, he studied parallels between biological processes and chemical industry systems and sought to develop an organizational framework for design, including by drawing parallels with evolution. He also published articles reporting observations of his own response to different medical therapies.

Ed earned a reputation for clearly conveying complex topics and instilling a love of learning—and of chemical engineering—in his students. He strongly felt that the purpose of education was to train the mind to be innovative, not to memorize facts—a philosophy he learned from his father, who held 55 utility patents plus a design patent and was known for disparaging "handbook engineers."

Ed was always a teacher, whether in the halls of academe, enjoying the outdoors with his students, or at the dinner table. His students knew him as energetic, kind, and particularly accessible as a mentor. He was also generous with his time at conferences and would go out of his way to compliment a young researcher whom he did not previously know on his/her presentation. He was proudly independent and iconoclastic, and thrived on debate; perhaps his most lasting impact on many students, not only those in his research group, was through his challenging and thoughtful questions often well beyond the typical technical issues that engineering students discuss.

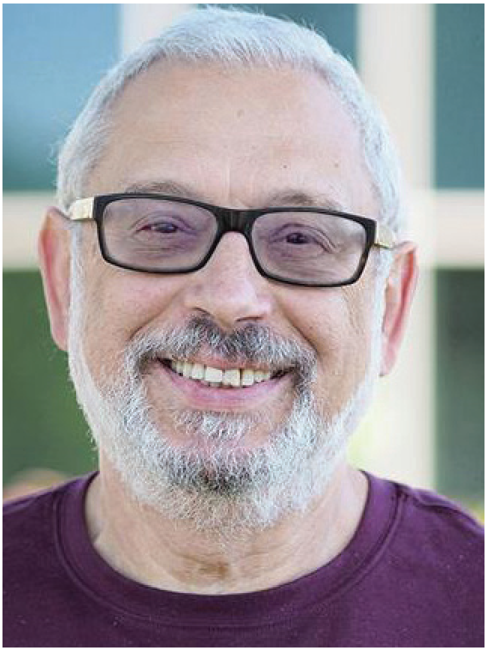
Among his many honors, he was elected to the National Academy of Engineering in 1979 and the National Academy of Sciences in 1995. He received AIChE's William H. Walker Award in 1975 and Warren K. Lewis Award in 1991 for contributions to chemical engineering literature and education, respectively. In 1992 he was recognized as a founding fellow of the American Institute of Medical and Biological Engineers, as well as a fellow of the American Academy of Arts and Sciences. In 2004 he was selected for the National Medal of Science "For his innovative research and leadership in transport phenomena focusing on biochemical and biomedical engineering with application to blood oxygenation, bioseparation techniques, and diabetic responses." He received honorary doctorates from the University of Trondheim and the Danish Technical University.

Ed's service to the profession was also noteworthy. He was on departmental and college advisory committees at the University of Utah, University of Houston, Purdue University, Montana State University, and Duke University. He also served on the National Research Council's Committee on Separation Science and Technology (1983–87) and the NAE's Membership Policy Committee (1993–96).

Ed enjoyed reading (in multiple languages), his dogs, the woods and especially his Sauk county farm, counting cranes, travel, cross-country skiing, sailing, canoeing, and bicycling. He traveled the world and lived in Norway (1962), on a Fulbright Fellowship, and New Zealand (1972), on an Erskine Fellowship; he also spent time in Denmark and Taiwan. He had a deep concern for those in need and was always a cheerful, warm, and generous man.

Ed's beloved wife, Lila, passed away in 2016. He believed that her influence was the key to not only his personal happiness but also his professional success. Together, they generously opened their home to many students and colleagues who became part of the extended Lightfoot family.

They are survived by their children Dory (Enrique Rueda), Edwin (Sue Dempsey), Nancy (Nick McGill), Robert (Karin Hunsicker), and David (Barry Burciul), and a granddaughter.



EUGENE LITVINOV

1950–2020

Elected in 2020

"For development of optimization mathematics for new electricity markets and innovative applications for electric grid control, visualization, and planning."

BY GORDON VAN WELIE, ELLEN FOLEY,
AND VAMSI CHADALAVADA

EUGENE LITVINOV, chief technologist for ISO New England Inc., died September 25, 2020, at age 70. He lived life to the fullest, and his legacy will continue through the impacts of his pioneering work in the electricity industry and his relationships with colleagues, peers, and friends.

Born July 1, 1950, in Kiev, Ukraine, Eugene received his master's in electrical engineering from the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" in 1973 and his PhD in computer-based power system control from Ural State Technical University in 1987. He worked for two decades at Kiev's Power Systems & Network Research Design Institute as a senior researcher and engineer.

In 1991 he emigrated with his family as a refugee from the Soviet Union. In the United States he joined the New England Power Pool, predecessor of ISO New England, as a senior engineer. He later became a US citizen and volunteered to help other refugees establish fruitful lives in western Massachusetts through the Jewish Family Services organization.

In a career spanning 28 years, Eugene led ISO's technical effort in support of the regional policy goal of restructuring

Adapted from IEEE PES eNews Update, November 2020 (https://site.ieee.org/pes-enews/2020/11/30/in-memoriam-eugene-litvinov-1950-2020/).

the electric system. He was a visionary both for the company and the industry at large, transforming theoretical auction concepts and high-level regulatory tariffs into successful online market platforms for wholesale electricity. His unique blend of skills in power system control, optimization, and software design, as well as his technical leadership, enabled the New England region to implement "best-in-class" market design and power system control algorithms, thereby improving the efficiency and reliability of the region's power system serving 14.5 million people.

Eugene collaborated extensively with both industry and academic partners around the world to seek optimal solutions to real-world power system problems. His optimization mathematics and designs were recognized and adopted by other independent system operators, vendors that support wholesale power systems and markets, and the Federal Energy Regulatory Commission (FERC), advancing the level of efficient market structures across the industry. His contributions were fundamental in ensuring a progressive and stable wholesale market that attracted more than $16 billion of investment in new generating resources to New England and $20 billion in transmission and distributed resources.

Following are just some of his remarkable accomplishments:

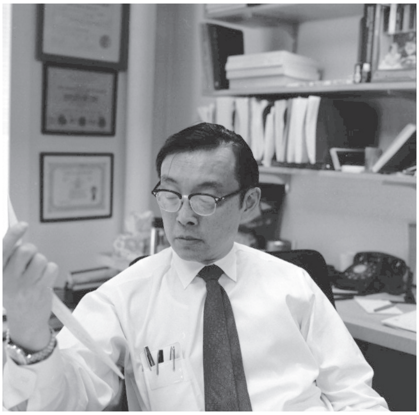
- The industry's first nodal energy market that included losses and congestion
- The first cooptimized reserve markets in the real-time market, with operating reserve demand curves
- Best practice enhancements to enable fast-start resources to set energy prices, as recognized by FERC
- State-of-the-art design of nested, locational, convex, capacity market demand curves that recognize the marginal reliability contribution of resources in adjacent capacity zones
- A pioneering optimization approach in unit commitment and economic dispatch
- New algorithms and applications designed for phasor measurement unit (PMU) technology, including the

development of oscillation source location using a dissipating energy flow method and on-line voltage stability analysis
- Use of cloud computing for power system control and planning applications in the ISO environment
- A new regional market settlement system, one of the most successful settlement architectures in the industry, with the first implementation of semiweekly and 5-minute settlements
- Creation of a mathematical framework to optimize power flow between two regional systems, New England and New York, in relation to wholesale market prices, known as coordinated transaction scheduling; wholesale market monitors recognized this implementation as the most efficient in the industry
- Coleader of a novel market design to address energy scheduling and storage problems in an energy-constrained system and marketplace.

Eugene was also the author or coauthor of many academic papers and research articles for industry journals, winning several best paper awards from the IEEE Power and Energy Society (PES). In addition to his NAE membership, he was an IEEE fellow; a member of the IEEE PES Fellowship Committee, CIGRÉ (International Council on Large Electric Systems), and the PSERC (Power System Engineering Research Center) Industrial Advisory Board; chair and member of ARPA projects; and an editor of *IEEE Transactions on Power Systems*.

Eugene was a leader in every facet of his life, a visionary who pushed the envelope in the electricity industry, and who rallied his colleagues and staff to be the best they could be, both professionally and personally. He made friends all over the world, and his influence and imprint on the industry will endure as his legacy is carried on by all who knew, admired, and loved him.

Eugene was a loving husband, father, and grandfather, and will be dearly missed by his wife, Yelena; daughters Anna and Alexandra; and three grandchildren.



JAMES W. MAR

1920–2017

Elected in 1981

"Leadership in research and education in aerospace structures and composite materials, and for service to his country."

BY DANIEL E. HASTINGS

JAMES WAH MAR, a prominent aeronautics and astronautics professor and researcher at the Massachusetts Institute of Technology (MIT), passed away peacefully on March 4, 2017, a week shy of his 97th birthday. He was recognized for his innovative work in structures, aeroelasticity, and materials. Those of us who knew him remember him as a scholar, an educator, a friend, and above all a kind and gentle person who always offered sage advice.

He was born to Fook Wah Mar and Mabel Chin Mar in Oakland, California, on March 10, 1920. The family moved to Seattle, Washington, where he graduated from Garfield High School. He initially enrolled in the University of Washington in 1938. In an interview for a history of the Air Force Chief Scientists,[1] he said, "My father wanted me to be a doctor but I couldn't stand the sight of blood." What he was good at was mathematics; "I could do the multiplication tables and things like that," he joked. "In 1938, without telling anybody, I applied for admission to MIT."

He enrolled at MIT as a sophomore and received his SB in 1941 in civil engineering. He then worked as an aeronautical

[1] Published in *Lightning Rod: A History of the Air Force Chief Scientist's Office* by Dwayne A. Day (University Press of the Pacific, 2005).

engineer with Curtiss-Wright in Buffalo, New York, from 1941 to 1944 before enlisting in the US Navy (1944–46). He returned to MIT for his SM (1947) and PhD (1949), both in civil engineering, and then joined the faculty of the MIT Aeronautics Department, where he served for the next 41 years, retiring in 1990.

Mar's research focused on advanced filamentary composite materials and large structures in space. He made major contributions to understanding of the fracture mechanics of various kinds of composites. His work in crack propagation at bimaterial interfaces was particularly notable.

His MIT career included his designation in 1980 as the Jerome C. Hunsaker Professor of Aerospace Education and a term as head (1981–83) of the Department of Aeronautics and Astronautics and its Division of Structures, Materials, and Aeroelasticity. He founded and directed both the Technology Laboratory for Advanced Composites and, with Rene Miller, the Space Systems Laboratory. He was instrumental in creating the unified engineering subjects, which became the well-known foundation of the department's undergraduate education. And he chaired numerous faculty committees, including the Committee on Admissions and Financial Aid, Committee on Engineering Education, the Athletic Board, and the Independent Activities Period.

In 1970–72 he took leave from MIT to accept appointment as the US Air Force Chief Scientist, the first person of color to serve in this position. As chief scientist, he helped the Air Force understand the structural problems on the B-1, F-111, and C-5.

Throughout his career he took on numerous advisory assignments, including NASA's Space Systems and Technology Advisory Committee, the FAA's Technical Oversight Group for Aging Aircraft (chair), and government panels examining development of Air Force and Navy jet engines and the operation of the Air Force Logistics Command and Military Airlift Command.

He served on quite a few National Research Council boards and committees, including as vice chair of the panel that provided a technical evaluation of the Space Shuttle's solid rocket booster redesign following the 1986 *Challenger* disaster (1986–89), chair of the committees on the Status and Viability of Composite Materials for Aircraft Structures (1985–87) and on Technology to Enhance Logistics Performance on Fielded Weapon and Support Systems (1991–93), and member of the Aeronautics and Space Engineering Board (1978–83) and Air Force Studies Board (1987–93).

Mar's substantial contributions were recognized with various honors. Besides his election to the National Academy of Engineering, he received the US Air Force Decoration for Exceptional Civilian Service twice, for his work as chief scientist and on the Air Force Scientific Advisory Board. In 1983 he gave the invited 24th SDM lecture of the AIAA, ASME, ASCE, and AHS, and in 1987 he received the AIAA Structures, Structural Dynamics, and Materials (SDM) Award for "extraordinary contributions in research,…outstanding leadership in research and development in the Air Force, NASA, and the aerospace industry;…[and] notable accomplishments in engineering education." In 1992 he was elected an AIAA honorary fellow, the institute's highest honor.

Those who knew him remember him as a kind person who gave prescient advice. MIT aeronautics and astronautics professor Paul A. Lagace, who began his MIT aeronautical education as one of Mar's students, said, "Jim Mar was an outstanding person in many ways, making significant contributions to aerospace engineering, to the institute, and to the aeronautics and astronautics department. But most importantly, he sincerely cared about, and helped, each student with whom he worked. I wouldn't be where I am today without all he did for, and with, me." Indeed, as a testament to his effectiveness in the classroom, it may be worth noting that four of his students went on to land on the moon.

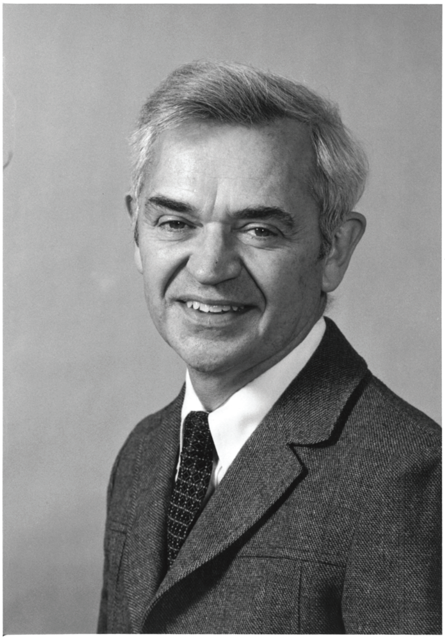
Institute Professor and former secretary of the Air Force Sheila Widnall was one of Mar's advisees as an MIT undergraduate in the late 1950s. "Jim was a giant in the field. His expertise and his passion really shaped the AeroAstro department," she said. She recalled a semiserious hurdle that he suggested for department faculty candidates, which became known as the Jimmy Mar Test: "Jim would say that if an airplane flew over and the candidate didn't look up, that candidate didn't belong in our department." This test has served the department well over the years.

Several former Air Force chief scientists and former chairs of the Air Force Scientific Advisory Board (SAB) remember his influence. Michael Yarymovch said, "Jimmy was my predecessor once removed. I learned a lot from him about the role of chief scientist and continued the tradition. We will all miss him as the great intellect he was." Natalie Crawford, former chair of the Air Force SAB, remembered that, "During the early years of my involvement with the SAB he was a member …[and] very active. Always soft spoken. And always willing to teach a very new person. He was a gentleman and a scholar and a treasured mentor." An accomplished tennis and squash player, Jim assured his MIT colleague and new SAB member Larry Young that it was perfectly acceptable to carry a tennis racquet onto the Air Force jet for SAB meetings. As a former Air Force chief scientist, the author of this tribute is pleased to acknowledge that I also benefited directly from Professor Mar's excellent advice during my term.

Jim is survived by his wife of 75 years, Edith Lew Mar; their children Chris (Susan Rice), Cori, and Tim (Eliza Ward); four grandchildren; and a great-granddaughter. He was preceded in death by daughter Karen Lew Mar Walker and daughter-in-law Maureen Kivlin Mar.

James Mar will be sorely missed by all who interacted with him. He had many accomplishments but it was his kindness that people will always remember.

His service to the country, to the profession of aeronautics and astronautics, and to MIT was exemplary. We shall carry on his example.




EXIT

FRANK E. MARBLE

1918–2014

Elected in 1974

"Contributions in aero-thermo-chemistry, and applications to problems of gas turbines."

BY ANN R. KARAGOZIAN

FRANK EARL MARBLE, among the nation's preeminent aerospace propulsion scientists during the second half of the 20th century, passed away August 11, 2014, at the age of 96. His pioneering technical contributions changed the direction of several important fields that are foundational to both aircraft and rocket systems. He also made outstanding contributions to aerospace engineering through his gifted teaching and insightful training of legions of graduate students at the California Institute of Technology and through his example of courage and loyalty during the McCarthy era and long afterward.

Frank was born July 21, 1918, in Cleveland, Ohio, and from a young age developed a passion for two things that remained with him throughout his life: airplanes and music. Ohio in the 1920s and 1930s was becoming a rather significant player in the development of America's burgeoning aviation industry. Young Frank took the streetcar regularly to the Cleveland Hopkins Airport, where he would wander into the hangars, look at the airplanes up close, and talk with the pilots and mechanics. This set him on a lifelong journey of discovery with aircraft.

This tribute is adapted from *Proceedings of the US National Academy of Sciences* 112(18):5550–51 (available at https://doi.org/10.1073/pnas.1501896112).

His love of music also began at an early age, when he took up the trombone. He showed a great deal of talent, and twice won the state championship in trombone solo.

Frank's fascination with airplanes eventually won out over his musical focus, at least professionally. With financial assistance from his aunt and sister, he entered the Case School of Applied Science (now Case Western Reserve University) and majored in mechanical engineering. While there his eyes were opened to the exciting world of aeronautics, the newly established field underlying the mechanics of flight.

As he developed his technical gifts and interests, he dreamed of pursuing graduate studies at Caltech with the eminent fluid mechanician Theodore von Kármán, but the outbreak of World War II altered his plans temporarily. After completing his master's degree in applied mechanics at Case (1942), he worked at the newly established aeropropulsion laboratory in Cleveland, created by the National Advisory Council on Aeronautics (NACA); this was the predecessor of NASA's Glenn Research Center at Lewis Field.

As "employee number 67" of the NACA Engine Research Lab, Frank was responsible for tackling a number of technological problems related to aircraft engines used in the war effort. He was able to solve engine cooling problems on the B-26 bomber (the Martin Marauder) and B-29 bomber (Superfortress). While the propulsion systems for these bombers were of the air-cooled reciprocating/radial type, Frank's work at NACA also introduced him to gas turbine engine technologies, which showed promise for future air transportation systems. He credited the experience with changing the direction of his focus and career from aerodynamics to jet propulsion.

After the war, Frank received a National Research Council predoctoral fellowship to study at Caltech, and he and his young wife, Ora Lee (née Collins), headed to California in their "house trailer." What started as a short stay for his doctorate turned into a lifelong association with Caltech and Pasadena, where Frank and Ora Lee raised their children, Steve and Patricia.

Frank thoroughly enjoyed and excelled in his graduate classes in advanced mathematics, physics, and aeronautics. And although his formal doctoral coadvisors in Caltech's Guggenheim Aeronautical Laboratory were von Kármán and the rising young fluid mechanician Hans Liepmann, his thesis topic was one that he had brought with him from his work at NACA, involving the fundamental fluid physics of rotating blades.[1]

His pioneering doctoral work, among the first to use rigorous mathematical methods to analyze blade aerodynamics in turbomachinery, led to his hiring at Caltech immediately after his graduation in 1948. He started as an instructor in aeronautics, and then became an assistant professor of jet propulsion and mechanical engineering. It was during this time that he encountered yet another unexpected career diversion: his appointment by Prof. Tsien Hsue-shen as part-time chief of combustion research at Caltech's new off-campus facility, the Jet Propulsion Laboratory. The position was concurrent with his faculty appointment at Caltech.

Like his unexpected involvement in gas turbine engines at NACA, Frank's work at JPL opened up several new research directions for him based on important aerospace propulsion problems of that era. His work on exploring ramjet engines led to a seminal analytical approach for predicting premixed flame stability in shear layers, developed with one of his earliest doctoral students, Tom Adamson.[2] Known as the Marble-Adamson problem, its use of activation energy asymptotics became a model for scores of researchers exploring both premixed and nonpremixed flame stabilization.

Frank's work at JPL and Caltech also involved experiments and analysis of the often catastrophic "screech" phenomenon

[1] Marble FE. 1948. Some problems concerning the rotational motion of a perfect fluid. PhD dissertation, California Institute of Technology. Available at thesis.library.caltech.edu/4518/.

[2] Marble FE, Adamson TC Jr. 1954. Ignition and combustion in a laminar mixing zone. *Journal of Jet Propulsion* 24(2):85–94.

in ramjets and afterburners[3]; this led him and his collaborators to develop one of the first phenomenological explanations of acoustically coupled combustion instabilities and bluff-body flame-holding mechanisms.[4]

After he became a full professor in 1957, Frank stepped down from his JPL post. But he continued throughout his career to work as a consultant for numerous government and industrial organizations, pursuing problems relevant to both air-breathing and rocket propulsion systems. These experiences, in addition to his funded research from the US government, led to the exploration of numerous propulsion problems for which Frank discovered new underlying physical phenomena. He made seminal contributions in the analysis of dusty gases,[5] relevant to particulate flows in solid rocket motor nozzles; acoustic attenuation by liquid droplets,[6] relevant to noise problems in air-breathing engines; a coherent flame model for the analysis of turbulent combustion,[7] which became the foundation of contemporary flamelet modeling; flame-vortex interactions,[8] relevant to turbulent premixed and nonpremixed combustion instabilities; and shock-induced mixing[9] and combustion phenomena, relevant to supersonic combustion ramjets.

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[3] Rogers DE, Marble FE. 1956. A mechanism for high-frequency oscillations in ramjet and afterburner combustors. *Journal of Jet Propulsion* 26:456–62.

[4] Zukoski EE, Marble FE. 1956. Experiments concerning the mechanism of flame blow off from bluff bodies. *Proceedings of the Gas Dynamics Symposium on Aerothermochemistry* (Northwestern University), pp. 205–10.

[5] Marble FE. 1970. Dynamics of dusty gases. *Annual Review of Fluid Mechanics* 2:397–446.

[6] Marble FE, Candel SC. 1975. Acoustic attenuation in fans and ducts by vaporization of liquid droplets. *AIAA Journal* 13(5):634–39.

[7] Marble FE, Broadwell JE. 1977. *The Coherent Flame Model for Turbulent Chemical Reactions.* Project Squid Technical Report TRW-9-PU, Purdue University.

[8] Karagozian AR, Marble FE. 1986. Study of a diffusion flame in a stretched vortex. *Combustion Science and Technology* 45(1-2):65–84.

[9] Marble FE. 1994. Gasdynamic enhancement of nonpremixed combustion. *Symposium (International) on Combustion* 25:1–12.

For his extraordinary range of deep, fundamental technical work Frank was elected to both the National Academy of Engineering (1974) and, rare for an engineer at the time, National Academy of Sciences (1989). In 1999 he received the Daniel Guggenheim Medal, one of the highest honors bestowed on an American aeronautical engineer; he was recognized "For major fundamental theoretical and experimental contributions to the fields of internal aerodynamics, combustion and propulsion especially with respect to gas turbines and rockets, and educating generations of leaders in industry and academia."

Over his decades of seminal research, Frank also focused on an aspect of the academic enterprise too often minimized at top-tier research institutions: teaching. He maintained the ability to deliver rigorous, well-organized lectures throughout his career, teaching courses in fundamental fluid mechanics, combustion, and air-breathing and rocket propulsion. His 8:00 AM lectures were legendary; in addition to his shared insights in research, they are perhaps what most of his graduate students remember best about Frank, myself included. As an expression of gratitude, generations of his graduate students endowed both the Frank and Ora Lee Marble Professorial Chair and the Marble Graduate Fellowship at Caltech in 2012 and 2013, respectively.

Beyond the Caltech campus, he contributed to activities of the National Research Council, serving on the Aeronautics and Space Engineering Board (1991–97) and its Panel on Small Spacecraft Technology (1993–94), Panel on Propulsion (chair, 1990–92), and Committee on Strategic Assessment of Earth-to-Orbit Propulsion Options (1991–92), as well as the Committee on Hypersonic Technology for Military Applications (1987–88) and internal committees of the NAE and NAS.

Finally, there is yet another aspect of Frank Marble's legacy that must be acknowledged: his devotion and loyalty, during the persecutions of the McCarthy era, to his friend and colleague at Caltech, Prof. Tsien Hsue-shen (Qian Xuesen). This pioneering researcher and scholar in fluid mechanics and propulsion had come from China in 1935 to study at MIT, worked on the Manhattan Project during World War II, and been recruited to Caltech by von Kármán. In 1950 he was accused of being a communist, had his security clearance revoked, and was put under surveillance by the Immigration and Naturalization Service for 5 years, during which time his Caltech research activities were severely curtailed.

Throughout this ordeal, Frank remained devoted to Prof. Tsien and his family, taking him to his legal proceedings, arranging for housing for the Tsiens when they were evicted, and even providing room for them to live in the Marble home. Eventually, the Tsiens returned to China, where Tsien became the father of the Chinese rocketry program, including development of what has become today's Long March rocket vehicle. Frank's courage and loyalty to his friend and colleague during this difficult time are among his greatest legacies. The two reunited in Beijing when Tsien retired in 1991.

He recounted this and others of his remarkable life experiences in a series of interviews conducted in 1994–95 through Caltech's Oral Histories Archive.[10] They reveal many insights about this remarkable man, his contributions, and his experiences and are well worth reading.

Frank's beloved wife of 71 years, Ora Lee, died just 2 months before he did. They are survived by their son Steve and his family; Patricia died in 1996.

Frank was a brilliant scientist, gifted teacher, and devoted colleague and friend. His loss is deeply felt. There won't be another like him.

[10] Available at oralhistories.library.caltech.edu/138/.

BENJAMIN F. MONTOYA

1935–2015

Elected in 2001

"For environmental and organizational leadership in both the US Navy and public power sector while maintaining total dedication to societal values."

SUBMITTED BY THE NAE HOME SECRETARY

BENJAMIN FRANKLIN MONTOYA, 80, died December 19, 2015, in Fairfield, California, at age 80. He was buried with military honors at Coachella Valley Cemetery.

Ben was born May 24, 1935, in Indio, CA, to immigrant farm workers Benjamin C. and Margarita Ramirez Montoya. A gifted student, accomplished athlete, and Associated Student Body president at Coachella Valley High School, he went on to attend California State Polytechnic Institute in San Luis Obispo for a year before being appointed midshipman at the United States Naval Academy. He graduated in 1958 with a general BS degree, was commissioned as an ensign in the Civil Engineer Corps, and married his high school sweetheart, Virginia Cox.

Admiral Montoya's 32-year naval career began that year with a tour as assistant shops engineer at Naval Air Station Miramar in California. Following this tour he attended Rensselaer Polytechnic Institute, where in 1960 he received

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This tribute is based on text submitted by the Naval Facilities Engineering Command Staff, a National Academy of Construction tribute (https://www.naocon.org/members/montoyaben/) prepared by Jack Buffington (NAE), input from Michael R. Johnson (NAE), and a brief biography posted by the US Naval Academy (https://www.usna.com/document.doc?id=280).

a bachelor of science degree in civil engineering, as was customary in the Navy for more specialized education. Follow-on tours took him back to California, with assignments in Long Beach and Port Hueneme.

Naval Mobile Construction Battalion Three (NMCB 3) in Guam was his next stop, where he got his first taste of life with the Seabees, serving as intelligence, training, and eventually operations officer. While serving with NMCB 3, he deployed twice to Vietnam—Da Nang in 1965, where he led an advance party to supervise the construction of the first base camp built by Seabees, and Chu Lai in 1966, where he participated in the construction of a base camp, supply point, hospital, and Marine Corps helicopter base. For his Vietnam service, Lieutenant Montoya earned the Bronze Star with Combat "V" and the Navy Commendation Medal. He was promoted to lieutenant commander (LCDR).

In 1967 he enrolled at Georgia Tech, where he earned a master of science degree in sanitary engineering and environmental studies in 1968, knowledge that he applied in assignments as public works officer at Naval Station San Juan in Puerto Rico and as command ecology officer of the Western Division of Naval Facilities Engineering Command (NAVFAC) in San Bruno.

In 1973 he was promoted to commander and the following year relocated to Washington, DC, where he became director of the Environmental Quality Division and Environmental Protection Officer at NAVFAC headquarters. In this role, with responsibility for environmental compliance, he led the Navy to understand the problem and take the difficult but necessary steps toward compliance. He earned a law degree from Georgetown University to familiarize himself with the legal as well as physical aspects of compliance, and in 1981 was admitted to the District of Columbia Bar. The Army, Air Force, and other branches of the service, as well as many federal agencies, followed suit leaning on Ben's leadership and effectiveness.

During tours in Hawaii and California he rose through the ranks and in 1986 Commodore Montoya returned to Washington as director of the Shore Activities Division in the

Office of the Deputy Chief of Naval Operations. The next year he was promoted to rear admiral (upper half) and reached the pinnacle of his career when he succeeded Rear Admiral John Paul Jones Jr. as commander of NAVFAC and chief of civil engineers.

An important feature of RADM Montoya's tenure as NAVFAC commander was the development of a culture of innovation through a partnership with the Construction Industry Institute (CII). NAVFAC commissioned CII studies to evaluate new initiatives, such as constructability. The practice of sending promising young NAVFAC officers to work on relevant graduate degrees and use NAVFAC projects to gather data for their theses and dissertations was encouraged. The results were presented to key groups for possible implementation. (One such presentation was in the rehearsal stage in the Pentagon a few doors from the location of the plane strike on 9/11.)

In 1989, after more than 3 decades of dedicated service, Rear Admiral Montoya retired from active duty. He pursued a civilian career in the utility industry, first at Pacific Gas and Electric in San Francisco, where he became a senior vice president and general manager of the gas supply business unit. In 1993 he became president and CEO of the Public Service Company of New Mexico (the state's major utility) and chair of the board in 1999.

For the National Academy of Engineering, he served on the Committee on the Diversity of the Engineering Workforce (2001–02), and in 2006 he was appointed to the NASA Advisory Council as a member of the Space Operations Committee. He also served on many civic boards, including the National Parks Foundation, California State Board of Education, Albuquerque Community Foundation, United Way of Greater Albuquerque, and New Mexico State University Business Advisory Council.

In all his endeavors Ben was a leader who compelled every participant in the task, committee, or board to perform well beyond expectations. Whether he was chair or team member, he took charge and accepted only the finest performance from everyone. His work ethic was contagious.

Civilian honors included selection as US Hispanic Engineer of the Year (1989), presidential appointment to the US Naval Academy Board of Visitors (1995–96) and Base Realignment and Closure Commission (1995), 1997 Executive of the Year—National Hispanic Employee Association, and 1998 induction into the Hispanic Engineer National Achievement Awards Conference Hall of Fame. He was elected to the NAE in 2001, and in 2006 to the National Academy of Construction (NAC) for his work on the Navy's major shore facilities environmental restoration program.

Ben was described as "a man of action," with "great personal integrity and a high sense of honor." He also had a strong but quiet faith.

He was diagnosed with cancer in 2013 but for 2 years he was able to continue enjoying a full life in retirement. He was survived by his wife of 57 years, Ginney (she died in 2020); their sons Ben, Chris, Pat, Mike, and Dave and daughters Terri and Natasha; 17 grandchildren; and 3 great-grandchildren.

More than all of his many career accomplishments, Ben Montoya deeply touched the lives of many and will be greatly missed.

SIA NEMAT-NASSER

1936–2021

Elected in 2001

"For pioneering micromechanical modeling and novel experimental evaluations of the responses and failure of modes of heterogeneous solids and structures."

BY ALBERT P. PISANO

SIAVOUCHE NEMAT-NASSER, renowned theoretical and experimental materials scientist, passed away January 4, 2021, from complications of acute myeloid leukemia. He was 84 years old.

He was a Distinguished Professor of Mechanics and Materials in the Department of Mechanical and Aerospace Engineering at the University of California–San Diego Jacobs School of Engineering. He officially retired in 2019 but remained active as a researcher through his Center of Excellence for Advanced Materials.

Sia was born April 14, 1936, in Tehran, Iran, and immigrated to the United States in 1958 to complete his undergraduate degree in civil engineering at Sacramento State College (now University). He earned his MS (1961) and PhD (1964) degrees in structural mechanics from the University of California, Berkeley.

He joined the UC San Diego faculty twice, first from 1966 to 1970. From there he went on to a brilliant 15-year career at Northwestern University, with a one-year visiting professorship at the the Technical University of Denmark (1972–73), before returning in 1985 to UCSD, where he set out to create a materials science program.

At UCSD he helped recruit young, talented scholars and then served as founding director of the university's Materials Science and Engineering Program, a globally recognized, integrated campuswide graduate degree program. He also initiated a program on the mechanical behavior of materials. The two programs became magnets for researchers from around the world, and earned both broad community recognition and support from the National Science Foundation for UCSD's Institute for Mechanics and Materials, for which he served as codirector and then director from 1992 to 2000.

Sia studied how materials fail and why. Renowned as both a strong theoretician and innovative experimentalist, he examined a broad range of materials: ceramics, ceramic composites, high-strength alloys and superalloys, rocks and geomaterials, and advanced metallic and polymeric composites with electromagnetic, self-healing, and self-sensing functionality; ionic polymer-metal composites as soft actuators/sensors; and shape-memory alloys. His work enabled the design of more resistant, useful, and safer materials for a variety of applications, from civil infrastructure to space stations (to withstand meteorite impacts), biotechnology, and defense. He and his research teams also developed or codeveloped many of the novel research instruments used in their laboratories.

Over the course of his prolific academic career, Nemat-Nasser published more than 500 scientific articles, which have over 33,000 citations according to Google Scholar. In addition, he was founding editor in chief of the journal *Mechanics of Materials*, a position he held for 37 years until his retirement. He also authored, coauthored, or edited over 20 books and proceedings, including two book series, *Mechanics Today* (Pergamon) and *Mechanics of Elastic and Inelastic Solids* (Springer). Notable scholarly texts include *Micromechanics: Overall Properties of Heterogeneous Materials* (with Muneo Hori; Elsevier, 1999), and *Plasticity: A Treatise on Finite Deformation of Heterogeneous Inelastic Materials* (Cambridge University Press, 2004).

Teaching and mentoring were crucial to Nemat-Nasser. He taught undergraduate courses in mechanics and mathematics throughout his career, and advised more than 70 PhD students and 30 postdoctoral researchers. In a 2008 UCSD TV video segment he expressed his passion for teaching and training future generations of researchers.[1] He relished working with graduate students who would develop into intellectual partners from whom he could learn and who have often gone on to become leaders in the field of mechanics. In 2015 he received the UCSD Academic Senate Distinguished Teaching Award for his highly effective teaching of undergraduate students, using an approach that integrated inventive and alternative teaching methods.

Among his numerous honors, Sia was elected to the NAE (2001) and he received the highest awards in mechanics: from the American Society of Mechanical Engineers (ASME), the Timoshenko Medal (2008) and ASME Medal (2013); and from the American Society of Civil Engineers (ASCE) the Theodore von Kármán Medal in Engineering Mechanics (2008). The Society of Engineering Science (SES) selected him for the William Prager Medal (2002), which is presented for outstanding research contributions in theoretical or experimental solid mechanics or both. And the Society for Experimental Mechanics (SEM) honored him with the Lazan Award (2007), presented for outstanding original technical contributions to experimental mechanics; the Murray Lecture (2009); and the Frocht Award (2012), presented for outstanding achievement as an educator in the field of experimental mechanics. Academic awards bearing his name were created by both ASME, focused on underrepresented minorities and women in engineering, and SEM.

In addition to his illustrious UCSD contributions, Nemat-Nasser was an active member of ASME, ASCE, SEM, SES, the American Academy of Mechanics, American Society for Metals (ASM) International, the Minerals, Metals and Materials Society (TMS), and the World Innovation Foundation, among others. He also served on the Panel on Air and Ground

[1] The video is available at https://www.youtube.com/watch?v=okl1pdnT_50; the roughly 13-minute conversation with Dr. Nemat-Nasser, including demonstrations of his work, begins at about minute 23.

Vehicle Technology (2003–06) for the National Academies' Army Research Laboratory Technical Assessment Board and cochaired the NAE's Mechanical Engineering Search Committee (2007–10).

Sia was proud of his Persian heritage and eager to share its richness. He was fond of the Persian poets Ferdowsi and Omar Khayyam, who was also a great mathematician and astronomer. He not only personally translated poetry from Farsi to English but also wrote his own poetry in Farsi, illustrated it, and translated it into English.

In 2016 he and his wife Éva established the Roghieh Chehre-Azad Distinguished Professorship in the UCSD Division of Arts and Humanities to foster new projects and future works exploring the music, art, literature, and history of Persian culture. In establishing the gift, Sia explained that it honored his mother, Chehre-Azad, a well-known actor in Iran who pursued her passion of acting at great personal risk when it was taboo in that country for women to perform on stage.

Sia was a person of great energy, discipline, and dedication. He swam for an hour every day until 2018. For many years he went to La Jolla Cove at night and swam alone in the ocean, to Éva's dismay.

Sia is survived by Éva; their children Michaela, Elizabeth, Katherine, David, Syrus, and Shiba; and four grandchildren.

JUN-ICHI NISHIZAWA

1926–2018

Elected in 2010

"For contributions to the static induction devices, dislocation-free semiconductor processing, and optical device technologies."

BY TATSUO ITOH

JUN-ICHI NISHIZAWA, professor emeritus of Tohoku University, excelled as a scientist, engineer, university president, and advisor to local governments. He was born September 12, 1926, in Sendai, Japan, and passed away October 21, 2018, at age 92 in the presence of family in his birth city.

He was born into an academic family. His father, Kyosuke Nishizawa, was a professor of inorganic chemistry at Tohoku University, which is where Jun-ichi earned his bachelor's degree in 1948 and 12 years later his PhD degree, both in engineering. In 1953 he was hired at the university's Research Institute of Electrical Communication and went on to serve as institute director (in both 1983–86 and 1989–90). His younger brother, Taiji Nishizawa, also taught at the university, as a professor of material science.

During his indefatigable career Jun-ichi was also president of Tohoku University (1990–96), first president of the Iwate Prefectural University (1998–2005), first president of the Tokyo Metropolitan University (2005–09), and senior advisor and specially appointed professor at Sophia University in Tokyo (2009–13). In addition, he advised local governments in Miyagi prefecture and Sendai city; both the governor and mayor appreciated his various contributions.

Jun-ichi Nishizawa was not only a dedicated professor and mentor but also a prolific inventor, credited for many sophisticated semiconductor devices for high-frequency and/or high-power devices, often produced in collaboration with colleagues such as Yasushi Watanabe. Starting in 1950 with his invention of the static induction transistor and PIN diode, he went on to introduce the avalanche photodiode (1952), solid-state maser (1957), tunnel-injection transit-time (TUNNETT) diode (1958), and static induction thyristor (1973).

To realize these concepts and devices, he also developed novel technologies, such as ion implantation, perfect crystal growth, epitaxial growth with temperature difference method under controlled vapor pressure, and atomic layer deposition, and other process techniques that significantly advanced the semiconductor industry. For example, he demonstrated that the ideal static induction transistor had an oscillation frequency of 780 GHz (1979), and calculated that the ideal static induction tunneling transistor had a cut-off frequency well into the THz range; for these technical achievements a feature article dubbed him "THz Shogun."[1]

In the optoelectronics field, Nishizawa invented the semiconductor optical maser, laser diodes, high-intensity light-emitting diode (LED), and optical glass fiber (patent filed in 1964). He successfully established three essential components of optical communication—laser diode as transmitter, PIN (photo)diode as receiver, and optical fiber as transmission line—to create a fully integrated optical communication system.

He proposed direct-current power transmission technology using his high-power devices. At an OPEC general meeting in 1986 he gave a presentation on a system that could send hydroelectric power to factories and the environs of

[1] Siegel PH. 2015. Terahertz pioneer: Jun-ichi Nishizawa "THz Shogun." *IEEE Transactions on Terahertz Science and Technology* 5(2):162–69 (https://ieeexplore.ieee.org/document/7047877). The article presents a very engaging portrait of Nishizawa.

major cities via DC power transmission as a global warming countermeasure.[2]

The Semiconductor Research Institute was created 1961, thanks to his tremendous efforts, and he became director in 1968. It was affiliated with but independent of Tohoku University. In 2008 it was donated to Tohoku University and named the Jun-ichi Nishizawa Memorial Research Center.

For more than 40 years, every year in the summer off-season at skiing resort Mt. Zao, he held a 3-day research seminar for young scientists and engineers to discuss emerging semiconductor technologies. After dinner, spontaneous discussions arose among participants and often continued late into the night. Many young engineers were impacted by and influenced each other during these seminars.

His seminal contributions were internationally recognized. He was a life fellow of the Institute of Electrical and Electronics Engineers (IEEE) and a fellow of the Physical Society of Japan, Russian Academy of Sciences, and Polish Academy of Sciences. In 2010 he was elected a foreign member of the NAE.

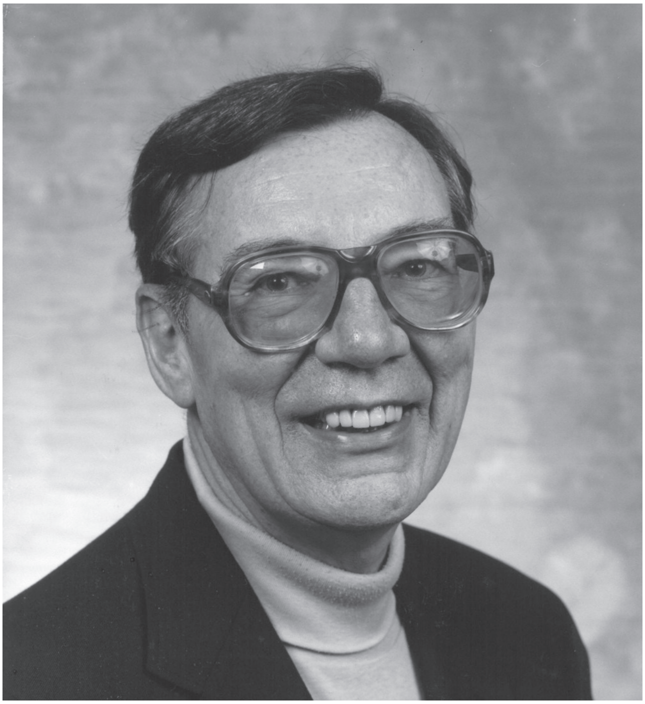
Among the many awards bestowed on him were the IEEE's Jack A. Morton Award (now the Andrew S. Grove Award) (1983) for "invention and development of the class of static induction transistors (SIT) and for advances in optoelectronic devices," and Edison Medal (2000) for "contributions to materials science and technology, and the invention of the static induction transistor." In 2002 the IEEE created the Jun-ichi Nishizawa Medal in his honor; it is presented for "outstanding contributions to material and device science and technology, including practical application."

In Japan he was designated a Person of Cultural Merit (1983), the country's highest civilian honor, and received the Order of Cultural Merit from His Majesty the Emperor (1989). He was also awarded the Japan Academy Prize (1974), the government's Purple Ribbon Medal (1975), the Honda Prize

[2] This and other achievements are described in an interview recorded at Sophia University, published in the May 2011 *Japan Quality Review* (https://jqrmag.com/e/pdf/01_Interview.pdf).

(1986), and the First Class Order of the Sacred Treasure (2002), among many others.

Jun-ichi Nishizawa leaves behind his wife, three children, and many colleagues and former students who are distinguished professors or excellent scientists, engineers, and human beings because they knew him and were influenced by him.



ROBERT PLUNKETT

1919–2019

Elected in 1974

"Contributions to experimental and analytical mechanics to solve noise, vibration, and fatigue problems."

BY ROGER R. SCHMIDT AND WILLIAM GARRARD

ROBERT PLUNKETT was an internationally recognized authority in vibrations and experimental measurements of mechanical behavior of materials. He passed away March 19, 2019, shortly after celebrating his 100th birthday in Austin, Texas, with family, friends, former students, and colleagues.

Born in New York City on March 15, 1919, Robert was the son of Becky (née Edelsohn) and Charles Plunkett. He entered the Massachusetts Institute of Technology when he was in his mid-teens and received a bachelor's degree in civil engineering in 1939. He remained at MIT after graduation as a research assistant and instructor until, in 1942, he enlisted in the US Army during World War II. A combat engineer, he landed at Normandy on D-Day+1.

He separated from the Army in 1946 as a major and returned to MIT, where he taught and earned his doctor of science degree in mechanical engineering in 1948. He was then hired as an assistant professor in mechanical engineering at Rice University, until in 1951 he went to work at General Electric Co. as a consulting engineer in vibration and acoustics. In 1960 he accepted a professorial appointment in engineering mechanics at the University of Minnesota and remained there until his retirement in 1988.

During his nearly three decades at the University of Minnesota he was active in teaching and advising at both the graduate and undergraduate levels. He led 16 students through PhD studies (including the first PhD the department awarded to a woman), and was a mentor, role model, and friend to many junior faculty members. He was also a Fulbright scholar in France, Israel, and Italy.

Professor Plunkett was a strong advocate for undergraduate education and "real-world, hands-on" educational experiences for students. He was instrumental in maintaining the quality and relevance of the undergraduate teaching laboratories, and introduced an undergraduate course in composite materials and structures when these were just beginning to be used extensively in the aerospace industry. Over the years, this course has been extremely popular and a version is still taught.

Plunkett became famous for his application of mechanical mobility to the solution of acoustic vibration problems involving large electrical machinery on thick platforms. This pioneering accomplishment led to measurement techniques for acoustic mobility, models for the (acoustic) vibration response of damped systems, methods for modeling bending and torsional waves in inhomogeneous bars, characterization of transient response of dissipative structures, and determination of optimum structural damping. He developed methods for reducing (acoustic) vibrations in foundations and enclosures where rotating or reciprocating machinery is involved. He contributed to noise control for appliances, pneumatic tools, piston rings, and aerospace structures, in addition to fatigue, vibration damping, and stress analysis. He published over 60 research papers on these topics.

During and after his career at the University of Minnesota, Robert was a consultant for over 40 organizations, including GE, Westinghouse, Medtronic, Electric Power Research Institute, Honeywell, Hughes Tool, Hamilton Standard, Ford Motor Co., and the US Department of Defense, including the Navy, Army, and Air Force.

His honors included election to the National Academy of Engineering, designation as an ASME honorary member, and an honorary doctorate from the University of Nantes in France. He was a fellow of the American Society of Mechanical Engineers, American Association for the Advancement of Science, and Acoustical Society of America, and a member of the Society of Experimental Stress Analysis, American Society for Engineering Education, American Institute of Aeronautics and Astronautics, and Institute of Noise Control Engineering. For ASME he served on the board of governors (1981–82), Roe Medal Committee (chair, 1989–90), and Committee on Investment (chair, 1991–92; vice chair 1990–91). For the National Research Council he served on the US National Committee on Theoretical and Applied Mechanics (1984–88) and the Committee on Marine Structures (1985–88) of the Transportation Research Board.

Robert married Helen Catharine (Katie) Bair on May 11, 1946. They traveled widely, visiting over 100 countries, and were extraordinary hosts when at home. Sunday night dinners prepared by Katie at their home on Lake Owasso in Roseville were legendary for the food and conviviality. Robert's laugh, once heard, could never be forgotten. He loved teaching and being an engineer, and was never at a loss for words or for an opinion.

Perhaps fostered by his year in the Merchant Marines at age 14 (although accepted to MIT his mother thought he was too young for college) he was happiest being on the water (and snow)—summers sailing and winters cross-country skiing. Many years he and Katie escaped part of the Minnesota winter by sailing in the Caribbean. A highlight was several months sailing from island to island with best friends Paul and Charlotte Paslay.

Robert was determined to hit 100 (he said it was a nice round number) and then was ready to go. His last words to his family before he peacefully closed his eyes: "It's been a wonderful life and I love you."

He is survived by three children—Chris (wife Toni), Brian (wife Criss), and Peggy (partner Bill)—as well as five grandchildren and numerous great-grandchildren. Katie, the love of his life, died at age 97 in 2016 after 70 years of marriage.

HOWARD RAIFFA

1924–2016

Elected in 2005

"For contributions to decision analysis, negotiation analysis, and engineering decision making."

BY RALPH L. KEENEY

HOWARD RAIFFA, a pioneer in all aspects of the decision sciences, was an emeritus professor at both the Harvard Business School and the Harvard Kennedy School of Government. He passed away peacefully in his sleep at home in Tucson, Arizona, on July 8, 2016, at the age of 92.

He made substantial contributions to the decision sciences and the fields of systems analysis and operations research. His remarkable books have influenced countless individuals and organizations. He guided the introduction of the decision sciences into numerous fields, from business to medicine, public health, environmental sciences, and law.

With a brilliant mind and enormous personal charisma, his main professional interest was to help individuals, organizations, countries, and groups of countries make better decisions by using insights from better analyses. He was concerned with both theory and practice, because if theories are not used, they can have no influence.

Howard was born January 24, 1924, in New York City and grew up in the Bronx. He briefly attended the City College

Many interesting details of Howard's life are discussed in his *Memoir: Analytical Roots of a Decision Scientist* (CreateSpace Independent Publishing Platform, 2011).

of New York and then joined the Army just before his 19th birthday. He was trained in the use of radar and served in air traffic control in the Pacific. After the war, he returned to the United States and in 1945 married Estelle Schwartz, his high school sweetheart. Soon after, they went to the University of Michigan, where Howard received his BS (1946) and PhD (1951) in mathematics and MS in statistics (1947) and Estelle got a teaching degree. Their son Mark was born in 1952 and their daughter Judith in 1955.

Howard's first faculty position, in 1952, was at Columbia University, where he and Duncan Luce wrote *Games and Decisions: Introduction and Critical Survey* (John Wiley & Sons, 1957), which organized and communicated the concepts, results, and relevance of game theory to a wide audience, including social scientists and political analysts. This book is the classic source for the basic concepts and results of game theory, as well as the original foundation for decisions under uncertainty. Although deep in substance, it is accessible for many readers, a common feature of Howard's publications.

In 1957 Howard accepted an appointment in the Harvard Business School, and went on to hold academic appointments in the Departments of Economics and Statistics, Kennedy School of Government, and Graduate School of Business. In addition, consistent with his often expressed interest in applying the decision sciences, he developed and taught courses on decision making in the schools of law, medicine, and public health, and for Harvard College undergraduates. He had approximately 90 doctoral students and helped thousands of students through his dedicated teaching and guidance. He retired as professor emeritus in 1994.

When he arrived in 1957 he began working with Robert Schlaifer and John Pratt in statistical decision theory. The resulting books, *Applied Statistical Decision Theory* (Harvard University, 1961) and *Introduction to Statistical Decision Theory* (McGraw-Hill, 1965), provided the foundations for Bayesian analysis of standard statistical problems, combining prior knowledge about problems with specific data gathered to lend operational insight for decisions. *Applied Statistical Decision*

Theory was republished in 2000 (Wiley) as a classic in mathematics and statistics.

The three also coauthored the article "The Foundations of Decision Under Certainty: An Elementary Exposition,"[1] which jointly axiomatized utility and subjective probability to provide a practical basis for a prescriptive theory to guide decision making. Howard's next book, *Decision Analysis* (Longman Higher Education Division, 1968), illustrated the operational use of these ideas and introduced many advanced topics such as risk sharing, group decisions, and multiple objectives.

In the mid-1960s Howard's interest expanded from classes of problems focused on management and economics to problems relevant to the public domain, concerning government policy, science policy, public health, and clinical medicine. Such problems usually involve multiple objectives and their resolution requires the consideration of value trade-offs among the objectives.

Howard spent the summer of 1965 at the RAND Corporation developing a foundation for thinking about the analysis of problems with multiple objectives. He was my advisor when I completed my dissertation on the theory and application of multiple-attribute utility in 1969, and we coauthored *Decisions with Multiple Objectives* (John Wiley & Sons, 1976). The book provides the theory and procedures to expand the use of decision analysis to resolve complex decisions involving multiple objectives, and was selected for the ORSA Lanchester Prize for the best operations research publication in 1976.

A few years later Howard's book *The Art and Science of Negotiation* (Harvard University Press, 1982) established the discipline of negotiation analysis. Until then, much of the knowledge about negotiations was basically art and folklore, with little structure or science. Howard developed the concepts and procedures that created negotiation analysis as a field with substance meriting serious study. This book brilliantly communicates and illustrates the simple message that analysis of negotiations can provide very useful insights for negotiators. It

[1] *Journal of the American Statistical Association* 59(306):353–75, 1964.

also stresses the value of cooperative negotiations by explaining how all sides can better achieve their objectives through various cooperative strategies. It was awarded the 1985 Leo Melamed Prize of the University of Chicago Business School for the most significant published work by a faculty member in a school of business in the preceding 2 years. The book *Negotiation Analysis* (Belknap Press, 2002) integrates much of Howard's earlier work and includes developments in negotiation analysis since 1982.

In 1995 Howard, John Hammond, and I decided to write a book to synthesize the fundamental ideas and procedures of decision analysis and communicate them in a manner that anyone facing important decisions could understand and use. Our goal was to broaden the use of the key tenets of good decision making. The result, *Smart Choices* (Harvard Business School Press, 1999), was awarded the annual publication prize of the Decision Analysis Society in 2001.

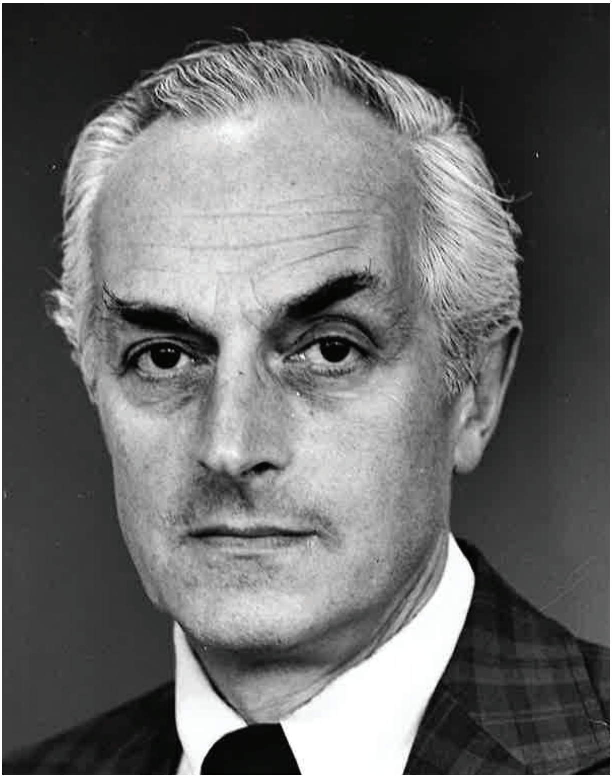
Beyond his teaching and prolific writing, Howard took a leading role in the formation of two significant institutions. In 1968–72 he participated in the negotiations that created the International Institute for Applied Systems Analysis (IIASA, located near Vienna), the first nongovernmental international research institute. The motivation for its establishment was to enable scientists from East and West to work together on problems of common concern, and it was sponsored by the national academies of science of 12 countries, including the United States and the former Soviet Union. IIASA came into existence on October 4, 1972, and Howard served as its first director (1972–75). The institute has flourished and today is sponsored by national scientific organizations of 24 countries. Howard's leadership and legacy at IIASA are still very evident.

Howard was also instrumental in creating Harvard's Kennedy School of Government. His original suggestion was "a school with its own faculty, primarily stressing a professional master's program, with say 50% to 75% of its instruction by the case method, and with its own mini-campus." He became part of a committee of four who designed the Kennedy School and are recognized as its founders. Howard firmly believed that it was important to educate leaders and future leaders about the significant contributions of thoughtful analysis to make better decisions.

Howard's intellectual and academic achievements were widely recognized. He was elected a member of the American Academy of Arts and Sciences (1972) and received the Distinguished Contribution Award of the Society of Risk Analysis (1984), Frank P. Ramsey Medal of the Decision Analysis Society (1985), Gold Medal of the International Society for Multiple Criteria Decision Making (1998), Carnegie Mellon University Dickson Prize in Science (2000), and INFORMS Saul Gass Expository Writing Award (2002). He was elected to the NAE in 2005. He also received honorary doctoral degrees from Carnegie Mellon University, the University of Michigan, Northwestern University, Ben-Gurion University of the Negev, and Harvard University.

Yet for all his accomplishments and honors, Howard had personal humility and was generous with his time and attentive to the ideas and concerns of others. He was clear thinking, unwaveringly considerate, ethical, fair, loyal, often humorous, ever positive, inspiring, and a wonderful colleague and friend.

Howard and Estelle celebrated their 70th wedding anniversary in 2015. She passed away in January 2017. They are survived by Mark (Ruth), Judith, and four grandchildren.



EUGENE D. REED

1919–2008

Elected in 1971

"Technical contributions and leadership in the exploration and development of microwave electronics."

BY C. PAUL ROBINSON

EUGENE D. REED was a pioneering leader in microelectronics and integrated circuits at AT&T's Bell Laboratories and subsequently at AT&T's Sandia National Laboratory in New Mexico, where he led one of the major organizations, Component Development and Engineering, with a staff of nearly 1200 professionals. Dr. Reed died October 29, 2008, in Pebble Beach, California, at the age of 89.

Born October 12, 1919, and raised in Vienna, Austria, he developed a fondness for both classical music and science, a duality embraced by many bright young men of his geography and time. When the Nazis occupied Austria, Eugene and his family, along with his fiancée Joan, fled for their lives and found refuge with relatives in London. There he endured the terror of the Blitz while moving ahead with his education, earning a bachelor of science at the University of London in 1941. He and Joan married in 1942 and, with his family, left to join cousins who had earlier emigrated to Brooklyn, New York, where he enlisted in the US Army and served through the end of World War II. Under the GI Bill he attended Columbia University and earned a master's degree (1947) and a doctorate (1953), both in electrical engineering.

Eugene then joined AT&T, the company that had pioneered radar systems that were of irreplaceable value in winning World War II and the leading company in electronics after the war. He served with distinction for the next 30 years at Bell Laboratories and several of its major subsidiaries in New Jersey and Pennsylvania. He helped guide the leading edge of electronics development and engineering, resulting in the fundamental transition from vacuum tubes to integrated circuits.

Along with his technical accomplishments he was steadily selected to take on increasing managerial responsibility. This led to his transfer in October 1975 to Sandia National Laboratories, which was then operated by AT&T for the US Atomic Energy Commission. He served for nearly 9 years as vice president of the organization, responsible for developing the components and systems for arming, fusing, and firing US nuclear weapons. These major responsibilities in highly classified work placed him among a small cadre of scientists and engineers whose contributions ensured US leadership in designing and producing "our nation's nuclear deterrent," which undergirded the security of the United States and the free world during the Cold War and beyond.

When Gene retired in August 1984, to spend his remaining years in California, he had presided over one of the most dramatic periods of change in the history of electronics. At Sandia, the nonnuclear components of US nuclear weapons had grown from systems with a typical total of 30 to 50 vacuum tubes (in the mid-1950s) to nearly a quarter of a million transistors, incorporated in each integrated circuit. Gene played a major role in guiding this revolution, harnessing intelligent systems into not only the arming and fusing functions but guidance and other control functions as well.

The revolution in the use of integrated circuits in microelectronics in the wider world was simply breathtaking throughout Gene's tenure and allowed many major advances in the safety, security, and reliability of nuclear weapons and other important national security systems. Just before his retirement, he predicted that there would likely be no end to the expansion of the utility of electronics systems in the highest security programs, a statement that certainly proved prophetic.

Eugene was a skilled and accomplished technical leader, but he also became known for mentoring many scientists and engineers who would themselves come to occupy highly responsible positions. Among those he helped develop into outstanding leaders at the laboratories were Leon Smith, Bob Gregory, Jack Worth, Bill Spencer, Orval Jones, Harry Saxton, and John Crawford.

Gene is particularly remembered for helping to migrate the technology, skills, and manufacturing techniques that were originally developed at Bell Labs to the crucial defense systems work at Sandia—demonstrating the wisdom of those who, under Harry Truman, had recommended the creation of Sandia as a major standalone lab, like its sister labs at Los Alamos and Livermore, which together comprised the US nuclear weapons research and development mission. Gene's practice of drawing in other key leaders from the Bell system to come to Sandia and, conversely, his assignments of key "Sandians" to serve a rotation at Bell Laboratories—two practices to transfer knowledge of advanced design and production technologies—became a key factor in the rapid growth of US weapons technology. They also helped ensure that these US classified programs remained at the leading edge.

Over time, Gene's wise and judicious assessment was that the technologies that had revolutionized US classified defense systems could also provide similar superior performance in a variety of other applications. His organization gave birth to concepts relevant to diverse fields, such as the first implanted biomedical devices, used as alternatives to injections for delivery of insulin, chemotherapy, and other medications and substances, such as those used for pain management.

Above and beyond Gene's considerable technical and managerial skills and responsibilities, at Bell Labs he had chaired a committee that investigated the continuing education needs of the professional and technical staff, to avoid obsolescence and keep them at the very top of their game. Within one year of their launch in 1968, the in-house education programs grew to enroll about 3000 professionals—making them "the largest graduate school in the world"—significantly larger than MIT in the number of technical "students." Noting a similar need at Sandia, upon Gene's arrival there the president, Morgan Sparks, asked him to chair all of Sandia's educational programs, *in addition to* his other significant responsibilities. Gene substantially expanded the national lab's in-house educational activities, offered both during and after working hours. For many years "the Sandia model" was used for educational programs at other US national laboratories and major technical companies around the country.

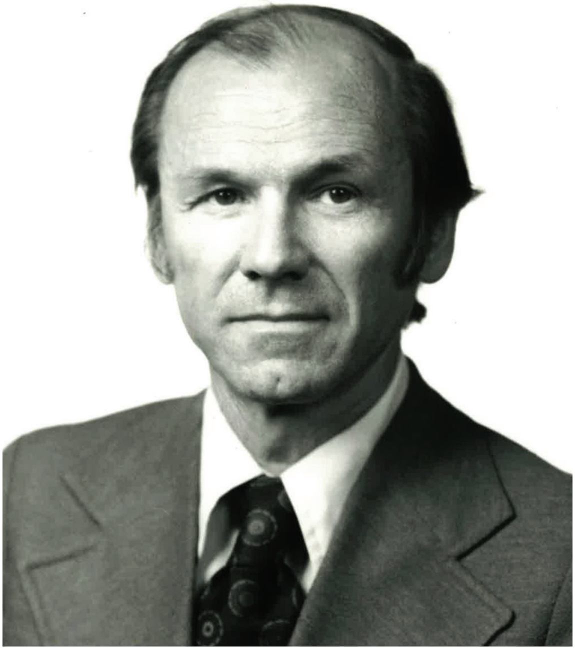
In reflecting on the factors that affected his success at both Bell and Sandia, Gene commented that the proximity and cooperation of the exploratory work by component developers and the ingenuity of systems and subsystems design engineers drove progress on both fronts and led to the creation of new technologies and the identification of novel uses of those advances. He recognized that you could never clearly determine whether major innovations happen because pioneering exploratory systems require new components or because research into exploratory components gives birth to new systems. His greatest contributions were perhaps in integrating both of these approaches to build the extraordinary teams and enable the magnificent advances that together produced very high performance electronic systems—now taken for granted as a hallmark of Sandia's work—and in driving the development of advanced control systems for all US defense systems.

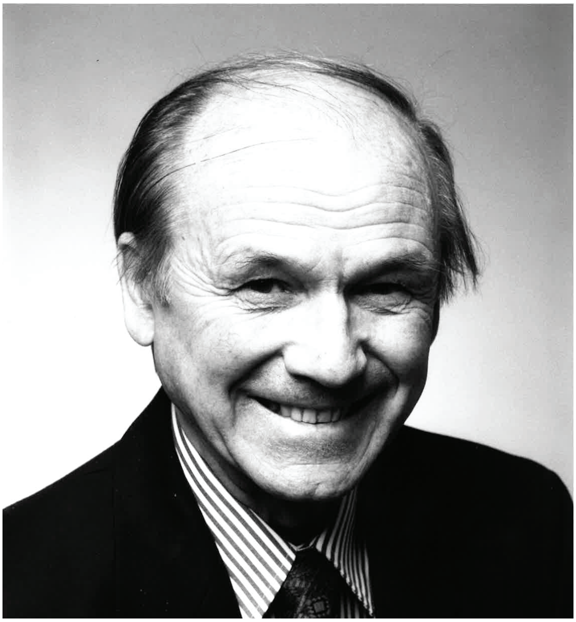
One of the greatest challenges Gene faced during his career at Sandia was the perpetual need for modern facilities for developing and manufacturing the generations of ever smaller electronics. Just before his retirement, he managed to set in motion what eventually became one of Sandia's most famous facilities, the Center for Radiation-Hardened Microelectronics. Although this work began in reclaimed World War II buildings, it quickly converted much of Sandia's campus into "clean rooms" that produced advanced electronics for a wide variety of systems for the stockpile as well as for all major satellites for use in space systems. Soon after completion in the late 1960s the Rad-Hard Microelectronics facility's products quickly diversified to the point that half of its microelectronics systems output served Sandia's core weapons responsibilities, while the other half went to satellite and other space programs, with a surprisingly large portion of its systems also dedicated to other Defense Department programs. This became a pattern for wider applications of Sandia's major advanced electronic systems being applied for the benefit of many US defense and space programs as well as US commercial and industrial systems.

These major national transformations significantly helped to render in fact the words of President Harry S Truman in his letter to AT&T asking the company to manage the Sandia Laboratories: "I believe you have an opportunity to render an exceptional service in the national interest," a phrase that became the enduring purpose for the laboratories.

Throughout his career, Eugene D. Reed made many such exceptional contributions to US technology and to the security of our nation and the world. His life mirrored those very words of exceptional service to our nation.

Gene was survived by Joan, his beloved wife of 66 years, their daughter Eve Nichol, and a granddaughter.





ANATOL ROSHKO

1923–2017

Elected in 1978

"Contributions to our knowledge of separated flows, turbulent wakes, and mixing layers."

BY MORTEZA GHARIB AND ROBERT PERKINS

ANATOL ROSHKO, the Theodore von Kármán Professor Emeritus at the California Institute of Technology, died January 23, 2017, at the age of 93 at his home in Altadena. He is recognized for his research on fluid and gas dynamics, in particular his identification, through high-speed photography, of discrete structures in turbulence.

Roshko was born July 15, 1923, in Bellevue, Alberta, Canada. He received a BSc degree in engineering physics from the University of Alberta in 1945 and, after a brief tour in the Royal Canadian Artillery, came to the Guggenheim Aeronautical Laboratories at Caltech (GALCIT, now known as the Graduate Aerospace Laboratories at Caltech). He earned his MS (1947) and PhD (1952) degrees in aeronautics and spent the rest of his professional career at Caltech, starting as a research fellow (1952–54) and senior research fellow (1954–55). He went on to be appointed assistant professor (1955–58), associate professor (1958–62), and professor (1962–85). He was named von Kármán Professor in 1985, served as acting director of GALCIT (1985–87), and retired in 1994.

An accomplished theorist, modeler, and experimentalist, Roshko made seminal contributions to problems of bluff-body aerodynamics, separated flow, shock-wave boundary-layer interactions, shock-tube technology, and the structure of turbulent shear flows. With his advisor, pioneering aerodynamics researcher Hans Liepmann, he coauthored the classic textbook *Elements of Gasdynamics*, published in 1957 by Wiley and translated into Russian, Spanish, and Japanese, a worldwide resource used by generations of graduate students.

At the time of his passing, Roshko had been teaching a course at Caltech with his former student and long-time collaborator and friend, Garry Brown of Princeton University. Their first paper together, "On density effects and large structure in turbulent mixing layers," was published in 1974 in the *Journal of Fluid Mechanics* and became the most widely cited paper in the journal's history. It announced the finding of large coherent structures in turbulence. Before this work, turbulence was considered a featureless subject, totally random and unrecognizable. Roshko and Brown showed that not to be the case. Indeed, through high-speed photography, they showed that turbulence has internal organization in the form of large coherent vortical structures, a discovery that proved crucial to a more accurate understanding of aerodynamics.

Roshko was also a consultant to government laboratories and companies including McDonnell-Douglas, Rockwell International, and General Motors. He helped organize the Wind Engineering Research Council and served on its executive board (1970–83).

In addition to his election to the National Academy of Engineering (1978), Roshko was a member of the National Academy of Sciences (2002), a fellow of the American Academy of Arts and Sciences, American Institute of Aeronautics and Astronautics (AIAA), American Physical Society (APS), and Canadian Aeronautics and Space Institute, and an honorary member of the Indian Academy of Sciences. His many honors include the APS Otto Laporte Award (1987), a Distinguished Alumni Award from the University of Alberta (1998), AIAA's Fluid Dynamics Award (1998) and Reed Aeronautics Award (2009), and the Timoshenko Medal (1999) of the American Society of Mechanical Engineers.

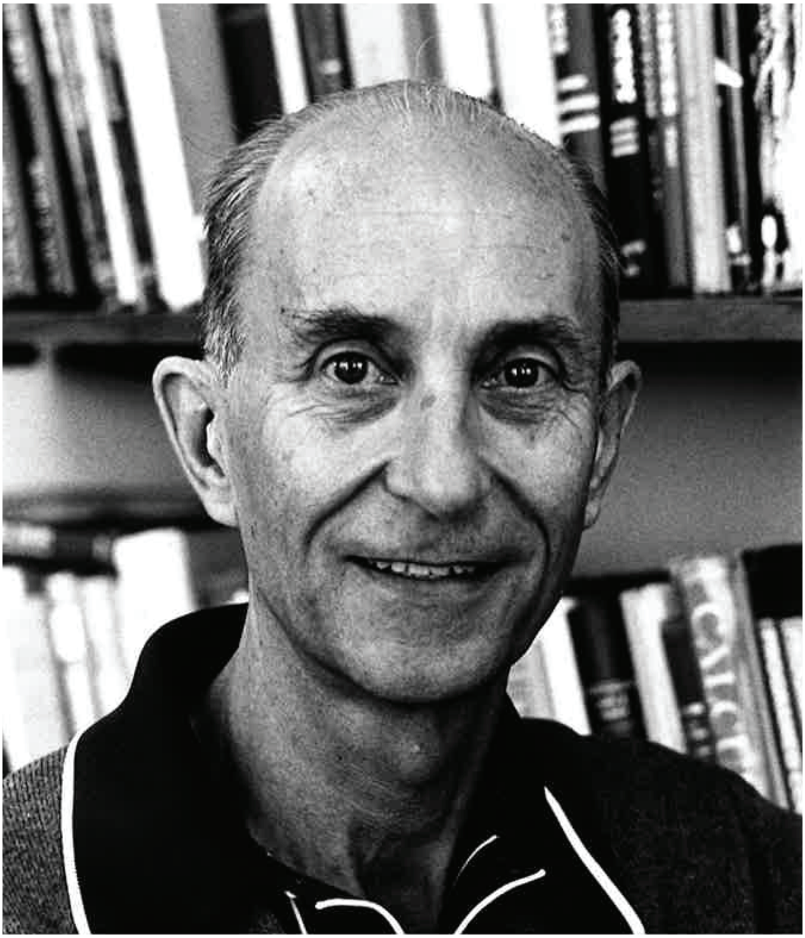
Notwithstanding his high-profile success and recognition, Roshko was always approachable and good-natured. He had a talent for gently encouraging students to solve problems creatively. His graduate students remember him as a generous teacher who challenged them to be innovative and resourceful.

International students, colleagues, and visiting researchers found hospitality and conviviality at the home of Anatol Roshko and his wife, Aydeth, an accomplished artist, who passed away about a decade ago. She was a second mother to Caltech grad students and their friends who visited the couple's home. Colleagues and students have fond memories of parties around the fireplace at Roshko's house and hikes with him in the San Gabriel Mountains above Altadena.

In letters from students, scientists, and colleagues from industry, written for Anatol on the occasion of a symposium to honor him on his 75th birthday, it's clear that he made an impact on each with his warmth, willingness to listen, high standards and sense of fairness, tough questions, and readiness to admit when he didn't know the answers. Several letter writers appreciated that he knew how to ask limited questions so that answers could be found and new understanding achieved. One correspondent mentioned that on several occasions Roshko pointed out that "there are many simple experiments which have been carried out for as long as 100 years and we still haven't gotten them right, for example, the vortex shedding problem." In another remembrance, Gary Ratekin and the aerodynamics staff at Rocketdyne mentioned that, thanks to Roshko's guidance in understanding the flow in the space shuttle main engine, they created a new duct design for future flights.

Alan Davenport wrote, "It might be said that, for a person of Anatol's trim physique, the wake he leaves behind is much wider than bluff-body theories would predict. His figurative, intellectual wake has washed up on students, researchers, wind engineers, aerodynamicists, and beyond. His quiet-spoken but reverberant statements on fluid mechanics have provided inspiring insights to many."

Anatol is survived by his sons Peter and Richard, daughter Tamara, 12 grandchildren, and 13 great-grandchildren.



VICTOR H. RUMSEY

1919–2015

Elected in 1980

"Research in practical applications of electromagnetic theory, especially in design of radio antennas insensitive to frequency and polarization."

BY PETER ASBECK

VICTOR HENRY RUMSEY, an internationally recognized expert in the design of antennas, died March 11, 2015, in Forestville, California, after an extended period of declining health. He was 95.

He was born November 22, 1919, in the West Country village of Devizes in Wiltshire, England. His academic ability was recognized by a perceptive teacher, and he was steered to the University of Cambridge, where he earned his BA degree in mathematics (with distinction; 1941) and later his PhD degree in physics (1973). During World War II (1941–45) he worked on radar at the Telecommunications Research Establishment in the United Kingdom and at the US Naval Research Laboratory in Washington, DC. He then spent 3 years at the Canadian Atomic Research Laboratory (in Chalk River, Ontario), where he met George Sinclair, who in 1948 persuaded him to go to the Ohio State University to direct the Antenna Laboratory.

The Antenna Laboratory had been in existence since 1942, established during the war to develop antennas for aircraft and to calculate radar cross-sections. Rumsey became supervisor of the laboratory in 1948 and had a major influence on its subsequent development. He was a brilliant theoretician and inspiring teacher and attracted a large number of excellent graduate students, mostly veterans of World War II. Five of these students (Thomas E. Tice, Curt A. Levis, Edward M. Kennaugh, Carlton H. Walter, and Leon Peters Jr.) eventually became lab directors, as did Robert A. Fouty, who was hired by Rumsey as research manager.

In 1954 Rumsey moved to the University of Illinois at Urbana-Champaign to head the Antenna Laboratory there, where he led the successful development of frequency independent antennas. In 1957 he was persuaded by John Whinnery to join him at the University of California, Berkeley, where he stayed until 1965, when he was approached by Henry Booker to join the recently formed Department of Applied Electrophysics at the new University of California, San Diego (founded in 1960). Rumsey stayed at UCSD until his retirement 20 years later.

In addition to his technical contributions, he helped to set the strategic directions for the growing department and served as chair (when it was known as the Department of Applied Physics and Information Science, en route to its present name, Department of Electrical and Computer Engineering). He advised and mentored a host of students, several of whom later became professors; one (Bill Coles) followed in his footsteps as department chair at UCSD.

Over a productive career lasting more than 45 years, Rumsey had a major impact on the theory and practice of electromagnetics and antenna design. One of the highlights among his many technical contributions was the pioneering concept of frequency independent antennas. Prior to his work, experience showed that all antennas were selective to frequency, with radiation patterns that invariably changed as frequency was raised—major beams sharpened and minor beams became more numerous. The discovery of frequency independent antennas overturned these empirical laws and produced a radical improvement in the technology of radiating systems.

His 1996 book *Frequency Independent Antennas* (Academic Press) both explained and popularized the new designs. Based on the insight that antennas defined by angles rather than lengths would be naturally less frequency dependent, he demonstrated that frequency independent antenna design should obey a scaling principle (shape should be invariant to a change in scale) as well as a truncation principle (antenna current should be attenuated more rapidly than the inverse of the distance from the terminals). In related work, he pioneered the design of receiving antennas capable of recording simultaneously all states of polarization.

His designs and concepts have been applied in the Parkes 64-meter dish radio telescope in Australia and the Arecibo 305-meter dish in Puerto Rico. A more recent application of his concepts is in the wideband feeds for the Allen Telescope Array at the Hat Creek Radio Observatory in California.

Another highlight of Rumsey's work was development of the reaction concept in electromagnetic theory. This concept brings to bear reciprocity analysis for problems in radiation scattering and diffraction and has been regarded as one of the few really novel concepts introduced in the late 20th century. Rumsey defined the "reaction" as a measure of the effect of one set of electric and magnetic currents on another set defined in the same electromagnetic environment, and used it to simplify the formulation of boundary value problems. To illustrate its value, he used the reaction formulation to obtain results for scattering coefficients, transmission coefficients, and aperture impedances in a variety of geometries. The concept has since been used for computer-based calculations in multiple electromagnetics problems.

In his later years, Rumsey turned his attention to propagation of waves through turbulent media. Using space-time analysis of radio waves in random media, he made a series of contributions that quantified the scintillation characteristics of the transmitted waves. He was one of the first to bring attention to the importance of refractive effects and to show how they modulate the diffractive scattering previously analyzed. These advances have been applied to optical and radio communications through the atmosphere, ionosphere, and interplanetary medium, and have contributed to understanding of solar wind.

Victor Rumsey was widely recognized as a superb theoretician, an exceptional instructor, and an inspiring advisor and mentor. He received the IEEE Morris N. Liebmann Memorial

Award (1962) for "basic contributions to the development of frequent independent antennas"; an honorary PhD degree from Tohoku University, Sendai, Japan (1962); a Guggenheim Fellowship in the field of applied mathematics (1964); the George Sinclair Award at Ohio State University (1982), "In recognition of his oustanding leadership in research and graduate education which enabled the Antenna Laboratory (now the ElectroScience Laboratory) to expand into an institution whose excellence in electromagnetic research and its application is internationally recognized"; and the IEEE John Kraus Antenna Award (2004) for "his creative and innovative development of frequency independent antennas." He was also named an Outstanding Educator of America (1971).

He was predeceased by his wife, Doris, in 1999 and is survived by their children, John, Peter, and Anne; four grandchildren; five great-grandchildren; and countless very grateful students. His students, their students, and their students in turn carry on his legacy of fundamental research and patient, thoughtful advising, in universities, observatories, and laboratories all over the world.

T.W. FRASER RUSSELL

1934–2019

Elected in 1990

"For introduction of reaction engineering principles and continuous processing to the manufacture of thin-film electronic materials and for contributions to two-phase flow."

BY A.M. LENHOFF AND NORMAN J. WAGNER

THOMAS WILLIAM FRASER RUSSELL, the Allan P. Colburn Professor Emeritus of Chemical and Biomolecular Engineering at the University of Delaware, died November 29, 2019, at the age of 85.

Fraser was born in Moose Jaw, Saskatchewan, on August 5, 1934, to T.D. and Evelyn Russell. The family moved to Oxbow, Saskatchewan, where his maternal grandparents lived, and later to Lethbridge, Alberta, where Fraser completed high school. The young man intended to pursue a career in pharmacy, but an uncle felt that he lacked the interpersonal skills to deal with the general public. After a summer job in retail sales, Fraser agreed with this assessment and instead pursued a BS in chemical engineering (1956) at the University of Alberta. Ironically, in his later years he was beloved by a very wide circle of friends.

His summers at the British American Oil Company's refinery in Edmonton introduced him to industrial process operations and design, which became a signature strength throughout his career. During subsequent employment at the Research Council of Alberta he was one of a pioneering group who recovered a load of tar sands from the wilds by canoe. His study of the pipeline flow of this material suspended in crude oil–water mixtures earned him his master's degree from the University of Alberta in 1958—and established a long-term interest in two-phase flows that led him to work on a broad range of multiphase mass transfer problems, from mass contactors to sewage and wastewater treatment.

He then spent 3 years as a successful design engineer with Union Carbide Canada, where his work included the design and startup of a multipurpose, continuous chemical processing unit at the company's Montreal East facility, the first of its kind in Canada.

In 1961 he enrolled at the University of Delaware and did his doctoral dissertation research, with David E. Lamb, on two-phase flow. Fraser's successful, large-scale industrial experience, design expertise, and leadership qualities earned him the respect not only of his fellow students but also of the department chair, Robert L. Pigford, who appointed him to a faculty position in 1965. Fraser spent the rest of his career at Delaware and distinguished himself professionally as an inspiring teacher, a versatile researcher motivated by chemical engineering practice, and an academic administrator. The immense respect for his abilities was evident in his appointment to a series of leadership positions: associate dean (1974–77) and acting dean (1978–79) of the College of Engineering, director (1979–95) and chief engineer (1996–2009) of the Institute of Energy Conversion, chair of the Chemical Engineering Department (1986–91), and vice provost for research (2000–05).

He was most gratified by his engagement and influence in the careers of the thousands of undergraduate and graduate students he taught. He was a consummate educator whose pedagogical expertise was equally valued by students and colleagues. He coauthored three chemical engineering texts, each bringing his unique insights and experience to enrich undergraduate education.[1] His educational philosophy is perhaps best captured in one of his favorite quotations, which appears

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[1] *Introduction to Chemical Engineering Analysis* (John Wiley & Sons, 1972); *Structure of the Chemical Process Industries* (McGraw-Hill, 1979) with James Wei and M.W. Swartzlander; and *Mass and Heat Transfer: Analysis of Mass Contactors and Heat Exchangers* (Cambridge University Press, 2008) with Anne Skaja Robinson and Norman J. Wagner.

in the frontispiece of each of his textbooks (and was prominently displayed on course syllabi and exams):

> "Get the habit of analysis—analysis will in time enable synthesis to become your habit of mind." – Frank Lloyd Wright

He was particularly passionate about the dozens of doctoral students he mentored in a program, unique and progressive in the discipline, that began as the DuPont Teaching Fellows and that he later endowed as the Fraser and Shirley Russell Teaching Fellows. The program provided a unique pedagogical experience and support for doctoral students considering careers in academia by enabling them to coteach classes under the guidance of a faculty mentor, providing the student with a realistic teaching experience and the opportunity to develop a teaching portfolio.

The impact of the teaching fellows program has been significant, with many successful academics who have come through the ranks, including in a complementary program endowed by Fraser at his alma mater, the University of Alberta, and in many similar programs adapted by former teaching fellows at their institutions.

Fraser also made important contributions to a broad range of important engineering research fields, including fundamental studies of multiphase fluid motions and semiconductor reaction and reactor engineering, with over 90 publications and 7 patents. He successfully applied these basic studies to the design and operation of commercial-scale equipment for both the photovoltaic and chemical process industries. In addition, he consulted with a number of companies, including 30 years with DuPont Engineering.

For the US National Research Council, he served on the Committee on Programmatic Review of the DOE Office of Power Technologies (1998–2000) and Committee on Chemical Demilitarization (2013–17), among others.

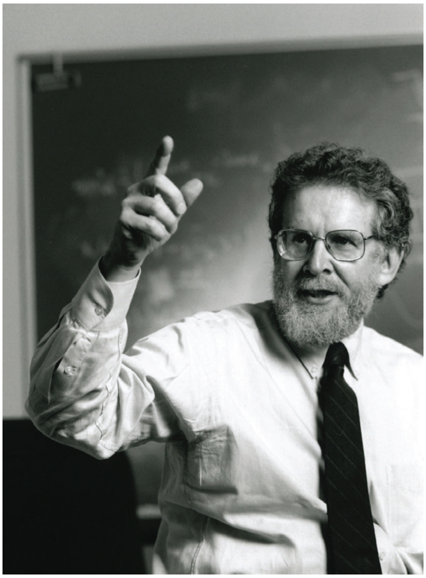
As a professional engineer, he was pleased to receive DuPont's Engineering Excellence Award (2005), which he proudly displayed on his desk as he was the only awardee not a DuPont employee. He was also one of very few academics to receive the AIChE Award in Chemical Engineering Practice (1987), among other national awards. For his teaching, he was honored to receive the AIChE Warren K. Lewis Award (2010) and ASEE's Award for Lifetime Achievement in Chemical Engineering Pedagogical Scholarship (2009).

Fraser's legendary contributions to excellence in education, research, and academic life more broadly at the University of Delaware spanned almost half a century. His extensive academic service was noteworthy for his candor, honest evaluations of merit, and immense dedication to his staff and the community more broadly. His engaging personality and sincere personal interest engendered lifelong friendship and loyalty, and his wisdom and experience garnered requests for consultation and guidance from university presidents, provosts, and administrators from all disciplines, including after his retirement in 2009. A rare honorary doctoral degree in 2010 from the university formally recognized his lifetime effort to enrich the academy that treasured him dearly.

Renowned for his refined taste in the beverage of his Scottish heritage, an evening with Fraser could refresh one's soul while heartfelt discussions revealed critical paths for solving vexing problems. Even more legendary were his lunchtime walks in the nearby forest preserve, where it was typical for him to lead groups of students, staff, faculty, or university administrators, including the president, on sojourns into the Delaware wilds.

Fraser was predeceased by his wife of 42 years, Shirley (née Aldrich). He is survived by sons Bruce (Laurie), Brian, and Carey (Melanie), and four grandchildren, as well as many colleagues, students, and friends whose lives and careers he enriched.

As noted by UD's provost, Robin Morgan: "Joining the faculty in 1964, he handily combined all the best attributes of a scholar and scientist, earning accolades for both his teaching and service, while distinguishing himself and the university in the realm of research in chemical engineering. Fraser's talent for leadership resulted in important administrative posts on campus where his expertise and insights catalyzed meaningful change at UD. Throughout his long career, countless faculty, students, and staff members have been enriched by his keen intellect, his heartfelt and steadfast dedication to the University of Delaware, and his unforgettable impish sense of humor."



MURRAY B. SACHS

1940–2018

Elected in 2002

"For contributions to the understanding of the neural encoding and signal processing of complex sounds, and for leadership in bioengineering education."

BY JENNIFER H. ELISSEEFF

MURRAY B. SACHS, a guiding figure in the field of biomedical engineering and former professor at Johns Hopkins University, died March 3, 2018, at the age of 77.

He was born in St. Louis, Missouri, on September 3, 1940, and grew up in University City, the son of a lawyer who left legal practice to start a woodworking factory. Murray received his undergraduate (1962) and graduate degrees (1964, 1966) in electrical engineering from the Massachusetts Institute of Technology. During his graduate work, he turned his attention to studying the brain, working with the noted auditory neuroscientists Nelson Kiang, William Peake, and Tom Weiss. His postdoctoral research extended to visual neuroscience at the University of Cambridge. He returned stateside in 1969 to serve in the Navy and joined the Naval Underwater Sound Laboratory, working on submarine communication.

In 1970 Dr. Sachs became an assistant professor of biomedical engineering at Johns Hopkins University, where he spent his scientific career, rising to the rank of professor. His scientific research broke new ground about the way the brain receives and processes information about sound. With colleagues, he developed methods for estimating the responses of large populations of auditory neurons to sounds and applied the methods to show how information about human speech is represented in the brain. This revolutionary research allowed scientists to understand the global picture of sound representation—as opposed to methods that focused on single neurons studied one by one—and provided a basis for designing and improving hearing aids.

As director of the Department of Biomedical Engineering (1991–2007) he more than doubled the size of the faculty and spearheaded the funding and design of a new building to accommodate the growth. He advanced the boundaries of biomedical engineering into new scientific areas to leverage tremendous developments in basic biological science, in areas such as genetics, cellular communication and organization, and medical imaging. The department's reputation as one of the best in the world derives in large part from Dr. Sachs' leadership during this period of growth.

The importance of his scientific work is matched by his organizational and leadership accomplishments. He initiated and led the Johns Hopkins Center for Hearing and Balance, which brought together researchers from biological, medical, and engineering departments to collaborate on these sensory systems. The center flourished under his leadership and remains a major internationally recognized research group.

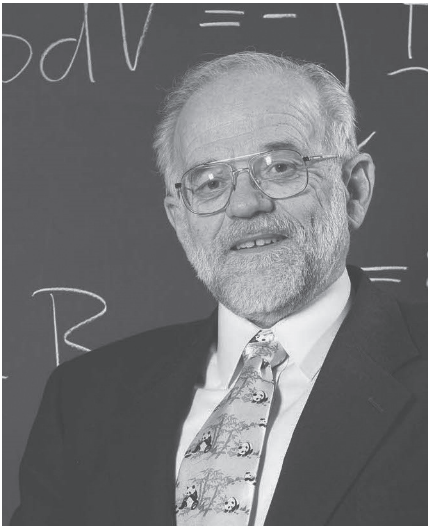
Murray was committed to his students and to mentoring. This focus gave rise to leading researchers and academics across the country, some of whom went on to chair major BME departments. In the laboratory, he was warm and supportive while conveying the rigor and excitement of high-quality scientific inquiry. He encouraged his students to think independently and to advance their work in unanticipated directions, helping them to expand the boundaries of their thinking—which explains why many of his students now work in scientific disciplines remote from their thesis work.

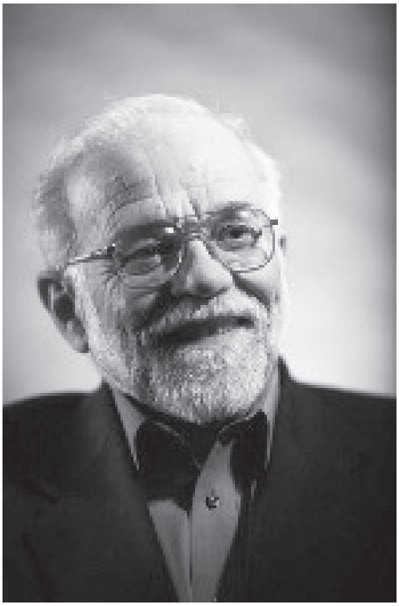
Dr. Sachs' research accomplishments were recognized by prestigious honors, including the 1999 Award of Merit of the Association for Research in Otolaryngology, the 1998 von Békésy Medal of the Acoustical Society of America for "contributions to understanding the neural representation of complex acoustic stimuli," and election to both the Institute of Medicine (now the National Academy of Medicine; 1990) and National Academy of Engineering (2002). He served the National Academies as a member of the Committee on Hearing, Bioacoustics, and Biomechanics (1985–88) and membership section and nominating committees.

During college, Murray met his future wife, Merle Diener, in St. Louis and traveled to see her during school breaks. They married in 1968 and moved to Baltimore in 1970. His beloved Merle preceded him in death by 3 weeks.

Murray was an avid sailor who loved captaining his boat *The Gratitude* in the Chesapeake Bay and sailing with his friends in Casco Bay, Maine. He was a runner who completed the Maryland and New York marathons. He also was a lifelong baseball fan—he came to adore the Orioles and avidly followed the Colts and Ravens.

Murray loved being a grandfather and spending time with his grandchildren. He is survived by his sons Benjamin and his wife Lisa, Jonathan and his wife Kate, and six grandchildren.





LANNY D. SCHMIDT

1938–2020

Elected in 1994

"For the application of principles of surface science to the design of new catalytic cycles and the molecular understanding of catalytic reaction engineering."

BY RAYMOND J. GORTE, RAUL A. CARETTA,
PAUL J. DAUENHAUER, AND ROBERT W. McCABE

LANNY D. SCHMIDT, Regents Professor emeritus of chemical engineering and materials science (2002–14) at the University of Minnesota and lifelong student of chemical reacting systems, died March 27, 2020, at the age of 81.

He was born May 6, 1938, in Waukegan, Illinois, and, when the time came, enrolled at Wheaton College, where he received his bachelor of science degree in chemistry in 1960. He then proceeded to the University of Chicago, where he studied under the direction of Robert Gomer, one of the pioneers in ultra-high-vacuum (UHV) studies of adsorption on metal surfaces. Lanny's thesis work involved studies of alkali metal adsorption on tungsten, utilizing field ion emission spectroscopy. After completing his doctorate in physical chemistry in 1964, followed by an additional year of postdoctoral work with Gomer, he accepted a faculty position at the University of Minnesota (lured by fellow Chicago grad H. Ted Davis), taking on the challenge of teaching chemical engineering and starting a research program focused on fundamental surface chemistry. Lanny remained on the Minnesota faculty for 49 years, and was designated emeritus in 2014.

The university's Chemical Engineering Department provided a unique environment in the 1960s that transitioned from traditional unit operations to chemical engineering theory and mathematical modeling. The department chair, Neal Amundson, assembled a faculty that included not only chemical engineers but mathematicians, biologists, and chemists. Lanny settled in quickly, initially continuing UHV studies of adsorption on single-crystal metals and then expanding to technologically important catalytic applications, including ammonia oxidation and automotive emissions control.

Studies of fundamental understanding of surface chemical mechanisms and kinetics ultimately formed the foundation of modern catalysis, evolving from global reaction kinetics to microkinetic models. Lanny capitalized on his surface chemistry experience, linking fundamental steps of reactant adsorption, surface reaction, and product desorption to develop detailed catalytic reaction models. His group published numerous studies of simple gas-phase reactions on metal surfaces, in many cases directly confirming Langmuir-Hinshelwood kinetics, but also revealing the rate-limiting steps as influenced by the choice of catalytic material and reaction conditions. This fundamental focus transitioned catalysis from a predominantly trial-and-error exploratory process to the molecular basis required to guide catalyst discovery and design.

Throughout his career, Lanny exhibited two overarching research characteristics that drove him to new, emerging problems. He continually pushed to evolve his research toward engineering technology, and he had an insatiable hunger for high-quality data as the driver of scientific discovery. He never lost his love of being in the laboratory and doing hands-on experiments. He was not beyond sneaking into the lab when his students were not around and doing experiments—sometimes pushing conditions to the extreme to satisfy his curiosity and desire for data.

While he started as a physical chemist and surface scientist, he transitioned in the 1970s to problems of particles and reacting flows, including early transmission electron microscopy studies of supported nanoparticle catalysts and novel flow-reactor designs. In particular, he developed new experimental techniques to understand catalytic reactions on surfaces at both vacuum conditions, where experimental insight was obtained, and high-pressure conditions simulating real-world applications. He also invented techniques to understand fundamental reactions on different facets and defects of particles, as exist in supported heterogeneous catalysts. He went even further to predict the faceting of nanoparticles based on their surface energy, expanding the bridge between fundamental surface characteristics and industrial catalyst synthesis.

Lanny moved further into the field of reaction engineering in the early 1980s in collaboration with his colleague Rutherford ("Gus") Aris as they focused on problems of complex catalytic systems including catalytic combustion. In a field dominated by modeling, Lanny introduced sophisticated experiments and intuitive insights into the chemistry to understand the interactions of coupled surface and gas-phase reactions. These experiments led to new understanding of the stability of catalytic reactors and the emergence of complex oscillatory surface chemistry and multiple steady states.

While those studies retained fundamental aspects, Lanny never lost sight of the potential applications. Initially, his forays into practical catalysis involved primarily reactions on unsupported metals, evolving from single crystals to wires and foils, and ultimately to simulations of noble metal mesh catalysts of the types used in the Ostwald process for nitric oxide production and the Andrussow process for HCN synthesis.

In 1989 Lanny solidified his break from surface science studies on unsupported metals to metals deposited on ceramic foam monoliths. He initially asked whether the platinum-rhodium (Pt-Rh) gauze that is used commercially in the Ostwald and Andrussow processes could be replaced with Pt on a cordierite monolith. This began his foray into short-contact-time reactors. Focusing critically on the methane-oxygen side of the Andrussow reaction composition space, he and his students successfully demonstrated high selectivity for methane oxidation to synthesis gas, a development that became the cornerstone on which Lanny built a successful multidecade short-contact-time research program.

The catalytic foam reactors opened the door to a wide range of millisecond-contact-time reactions. By operating oxidative reactions on catalytic foams, Lanny invented reforming technology that could shrink conventional industrial reactor technology by orders of magnitude for basic chemical production. His breakthrough of methane autothermal reforming demonstrated small-scale capability for natural gas reforming. Following thereafter was a fast ethane dehydrogenation technology to mass produce ethylene in fast-responding microreactors. By developing novel experimental chemical sampling techniques, he was able to deconstruct both the fundamental surface catalysis and reaction sequence leading to fast selective chemistry, thereby pushing his students to advance both science and technology in parallel.

Lanny's focus on novel reactor design ultimately led him to address catalytic technology for sustainability. In 2004 he invented a microreactor that could convert ethanol into hydrogen gas for the hydrogen economy. This breakthrough led to a decade of new technologies to utilize agricultural and lignocellulosic feedstocks to produce renewable fuels and chemicals and develop rural economies. His interest in chemical research expanded into the challenges of implementing a bioeconomy, and he advocated for research that integrated agriculture, chemical technology, energy, and the environment.

His passion for developing a new bioeconomy diffused into his teaching, where he integrated sustainability in his courses in reaction engineering and process design. Building on his leading undergraduate reaction engineering textbook, *The Engineering of Chemical Reactions* (Oxford University Press, 1997; the 2nd edition is still in print), he excelled at exciting engineering students to develop the sustainable chemical technology necessary to solve the problems of the next century. His lecture style was engaging, with a combination of deep knowledge of chemical reaction engineering and his inclination to include compelling and often entertaining anecdotes.

Lanny published over 350 papers with his students and collaborators, but his success as an educator and leader in chemical engineering also included his ability to develop researchers. He supervised students through more than 90 doctoral theses and 15 master's theses; these students have gone on to successful careers in both industry and academia, including four former students inducted into the NAE. Even more, Lanny's style of curious and adventurous pursuit of research transferred to his students, creating an extended family of professional engineers—proudly referring to themselves as Schmidtsters—with a similar drive to measure, create, and invent bold new experiments and audacious chemical technologies.

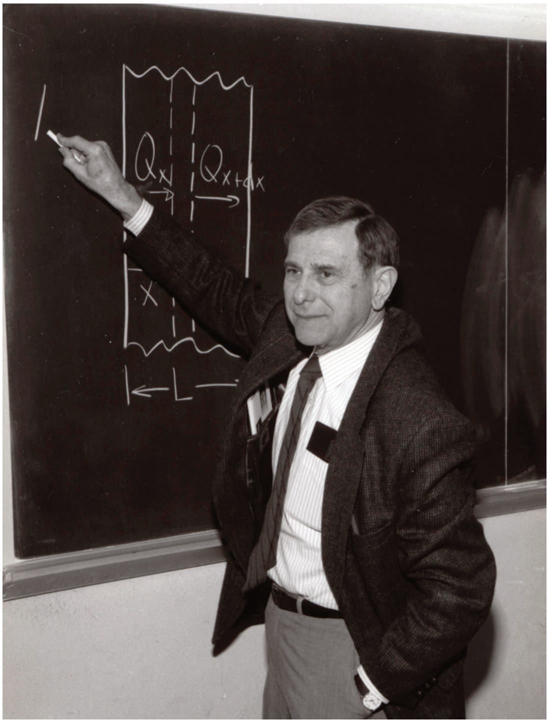
As important as research and data were to Lanny, he also cared deeply about the well-being of his students—both in and beyond the lab. While he might have broken a student's apparatus going for an extreme data point, he was right there to fix it, with dexterity and trouble-shooting skills that few could match.

Lanny's contributions were recognized with various honors. In 1987 he received the Giuseppe Parravano Memorial Award for Excellence in Catalysis Research and Development from the Michigan Chapter of the North American Catalysis Society; it is presented to a researcher in North America "for outstanding achievement in the conduct of clever, productive, and influential research on problems of central interest and importance in catalysis and related fields." In 1994 he was elected to the NAE and selected for the Humboldt Prize. In 2013 his innovative approaches to research were recognized with the Neal R. Amundson Award, presented to "a pioneer in the field of chemical reaction engineering who has exerted a major influence on the theory or practice of the field through originality, creativity, and novelty of concept or application." And in 2014 he was named by *Scientific American* as one of the 50 most outstanding American scientists.

He and his wife, Charlotte (called Sherry), often invited students to their home where, among other things, they were introduced to the Schmidt menagerie of animals ranging from hamsters to a lineage of large dogs. To this day, Schmidtsters identify with the resident canine that marked their tenure in Lanny's group, be it Anka, Gitta, Tasha, or Duke.

Though diminutive in stature, Lanny Schmidt was big of heart, and made unparalleled contributions—both fundamental and practical—connecting the fields of surface science, catalysis, and chemical reaction engineering.

He is survived by his wife of 58 years, Sherry (née Hargrave), daughters Diana Joy (Christopher Lee) Kitzman and Amanda Jean (Peter Hans) Docter, four grandchildren, and a legion of Schmidtsters.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EPHRAIM M. SPARROW

1928–2019

Elected in 1986

"For outstanding, prodigious contributions to heat transfer through analysis and experimentation, and for superlative teaching."

BY ROGER R. SCHMIDT, JOHN R. HOWELL, AND DAVID Y. PUI

EPHRAIM MAURICE SPARROW was an internationally recognized authority in heat transfer, considered by many the father of modern heat transfer. His work was characterized by impeccable quality and presented in over 850 peer-reviewed and widely cited technical papers that helped to set the standard of quality for an entire field. He passed away at age 91 on August 1, 2019.

Born in Bridgeport, Connecticut, on May 27, 1928, Eph was the son of Charles and Frieda (née Gottlieb) Sparrow. He received his BSc from MIT in 1948 at the age of 19, stayed to complete his MS in 1949, and then earned an MA and PhD at Harvard in 1950 and 1952, all in mechanical engineering. His PhD thesis was titled "Free Convection with Variable Properties and Variable Wall Temperature" under the supervision of Howard Emmons.

He began his professional career at Raytheon, working on a number of heat transfer problems including radar, the first microwave oven, and electronics cooling. Later he joined the National Advisory Committee for Aeronautics (NACA) at the Lewis Flight Propulsion Laboratory in Cleveland, where he worked on fluid mechanics and heat transfer. His many publications from his work at NACA (now NASA) included two papers in the first issue of the ASME *Journal of Heat Transfer*.

At NACA he began to appreciate and master the importance and skills of computation. He used to tell the story of how early numerical computations of boundary layer flows were done by rows of human "computers," with each row representing a forward step in the marching integration process!

In 1959 he started his career at the Thermodynamics and Heat Transfer Laboratory in the Department of Mechanical Engineering at the University of Minnesota in Minneapolis. He was promoted to professor and served as the Fluid Mechanics Program chair (1968–80). He did a concurrent tour of duty at the National Science Foundation (1986–88, commuting back to the university on weekends to continue his work as professor of mechanical engineering), first as program manager for heat transfer (where he was notorious for calling tardy reviewers late at night to urge them to submit their reviews) and then as director of the Chemical, Bioengineering, Environmental, and Transport Systems Division in the Engineering Directorate.

His time at NSF, where he stressed the need to focus on practical problems and important fundamental issues, had a profound impact on his thinking. When he returned to the University of Minnesota, he followed his own advice, focusing on real-world engineering problems and leaving behind, to some extent, the world of academic problems. Companies flocked to him for advice, and he would help them all, asking little or nothing in return for his effort. He enjoyed applying his deep and broad knowledge to solve the toughest problems companies presented to him.

Over the years he worked actively in every facet of heat transfer and always at or near the frontiers of knowledge. His research included foundational studies in radiation heat transfer, turbulent flows in ducts, natural convection, film condensation, boundary layer flows with separation, laminar-turbulent transitions, force convective heat transfer with flow over objects, solid-liquid phase change problems, flow and heat transfer in porous media, inverse solutions, thermal optimization, biological heat transfer and fluid flow, development of new modeling techniques, cooling of electronic equipment, and many more. One of his favorite experimental tools was the naphthalene sublimation technique, which allows very detailed measurements of local mass transfer coefficients. For many years, visitors to the mechanical engineering building got a strong whiff of that mothball smell!

He was unusual in his effectiveness in both experimentation and analysis/computation. He was among the first to recognize the enormous potential of the digital computer as a tool for solving highly complex problems in heat transfer and fluid flow. While he steadily produced analytical and computationally based research, he was perhaps best known as an innovative and painstaking experimentalist.

He was keenly focused on accurate and carefully controlled experiments. For example, when he wanted to perform some experiments for laminar flow at very high Reynolds numbers, he ran the experiments in the middle of night when traffic vibrations from the road outside his lab were minimized. Similarly, his wind tunnel work required so much electricity that he had to experiment on Sunday evenings when the load on the municipal electrical grid was sufficiently low to allow his power usage. For his convection experiments, he needed a room where the temperature was stable over days; he found one, with very thick walls and no windows, in the basement of the Aerospace Engineering and Mechanics Department and "borrowed" it.

As a classroom teacher, Professor Sparrow had no peer. He had an extraordinary ability to inspire, mesmerize, and convey complex materials in eloquently simple ways, simultaneously fostering in students an intellectual curiosity and a diligence that served them for life. His interactions with students also conveyed his devoted care and concern for them and their future. He supervised some 300 master's and 100 doctoral degree students; many of the latter went on to become professors at well-known universities around the world.

Beyond the classroom and lab, he contributed significantly to the effective transmission of technical information. In 1979 he cofounded, with W.J. Minkowycz, the journal *Numerical Heat Transfer* as a forum for dissemination of ideas and research in the field of numerical heat transfer and computational fluid dynamics; he chaired the editorial board. He was also a member of the editorial boards of the *International Journal of Heat and Mass Transfer* and of *International Communications in Heat and Mass Transfer*. He was editor of the ASME *Journal of Heat Transfer* for 8 years, during which it became one of the most prestigious publication vehicles in the field, with quality standards second to none. In recognition of his efforts he received the Distinguished Service Award from ASME's Heat Transfer Division. He was also coeditor of a series of books on computational methods in mechanical and thermal sciences.

Professor Sparrow's contributions were recognized by numerous honors and awards. In addition to his NAE election in 1986, he was a fellow of the American Society of Mechanical Engineers (1976) and received its Max Jakob Memorial Award (1976), Charles Russ Richards Memorial Award (1985), and Worcester Reed Warner Medal (1986). The American Society for Engineering Education selected him for the 1978 Ralph Coats Roe Award, and in 1993 Sigma Xi presented him with the Monie A. Ferst Award. He also received two teaching awards from the Institute of Technology of the University of Minnesota.

His contributions extended to international activities. In 1966 he headed a faculty team that established the first graduate programs in engineering in Brazil, resulting in his being awarded an honorary doctorate by the Pontifical Catholic University of Rio de Janeiro.

The deep affection for him among his colleagues, former students, and friends was captured in a tribute published in the February 2020 online issue of *International Journal of Heat and Mass Transfer*, a portion of which is captured here:

> The numbers of researchers he has touched and whose research he has influenced are nearly uncountable…. Some of us met him early in his career, after he left the NACA Lewis Research Center in Cleveland and joined the faculty at the University of Minnesota in 1959. For others, the encounter was later, in the 1960s–1980s when he was at the height of his scientific productivity, publishing papers at an unbelievable rate. Yet others among us met him in the 1990s–2000s when his scholarly

> interest had shifted to tackling challenging real-world problems. But regardless of our/your Eph story, it undoubtedly was marked by interactions with a kind, caring, charismatic mentor for sure, but first and foremost, a friend. Many of us have shared long, late-night hours with him working on projects or discussing deep issues of life. His most treasured word, possibly his guiding signpost, was “kindness.” He lived and breathed a deep affection and kindness to all—and we were all beneficiaries.

Eph was a self-proclaimed workaholic and spent many late nights and weekends on campus, often working with students on their experiments or helping them with their thesis. He continued to work right up to the end, completing several papers and theses in the last year of his life. At the time of his death, he was both the oldest and the longest-serving faculty member in the Mechanical Engineering Department.

He was survived by his beloved wife of 67 years, Ruth (née Saltman) and their daughter Rachel and her husband Satish. With both Ruth and Rachel, Eph’s teaching and research were a family affair—they helped proofread his journal papers before publication, and Ruth typed almost all of his 850 journal publications on their trusty IBM Selectric typewriter.

The greatest legacy anyone can leave behind is to positively impact the lives of others. Eph had a profound influence on so many of us, and our lives have been enriched tremendously by knowing him. We will greatly miss our mentor and friend.

ROGER W. STAEHLE

1934–2017

Elected in 1978

"Contributions to the quality and strength of the national and international efforts to mitigate corrosion."

BY RONALD M. LATANISION AND PETER L. ANDRESEN

ROGER WASHBURNE STAEHLE, founding director of the Fontana Corrosion Center at the Ohio State University and former dean of the Institute of Technology at the University of Minnesota, passed away January 16, 2017, after taking a fall while walking along the lake that he treasured and that his North Oaks home overlooked. He was a few weeks short of his 83rd birthday.

Roger was born February 4, 1934, to Carrie and Haswell Staehle in Detroit, and grew up in Columbus, Ohio, where he earned three degrees from the Ohio State University, all in metallurgical engineering: his BS and MS in 1957, and PhD in 1959. He was a doctoral student of the legendary Mars Fontana.

When he completed his first two degrees Roger became an officer and nuclear engineer (1957–61) with the US Navy and Atomic Energy Commission Naval Nuclear Reactor Development Program (with Vice Admiral H.G. Rickover). He then returned to Ohio State, as a research associate, and was promoted through the years to full professor by the time he left in 1979 to head the University of Minnesota's Institute of Technology, where he was subsequently a professor of chemical engineering and materials science (1983–88). He was also president and chair of Automated Transportation Systems Inc. in Minneapolis (1984–86).

In addition to his teaching and research, much of it associated with the environmentally induced cracking of engineering materials and components, he was a master at failure analysis and forensic investigations. In 1988 he became an adjunct professor and served as a consultant to industry and government, a role in which his vast experience as a corrosion engineer was much in demand.

He edited 29 volumes on topics ranging from stress corrosion cracking (SCC) and hydrogen embrittlement to localized corrosion and intergranular crack growth in nuclear materials. Many of these volumes were conference proceedings, which were remarkable for Roger's energy in attracting key contributors from around the world. Some were very broad in focus, others very specific; all were huge efforts and major contributions to the world's progress. The volumes served to review the state of the art of the topic of interest and to set the research agenda for decades to come.

Roger was a mentor and encourager to thousands of researchers throughout the world and regularly organized conferences, workshops, and other forums for the exchange of data and ideas. For his expertise he was appointed to several committees of the National Research Council, including the Committee on the Waste Isolation Pilot Plant (1978–83), Panel on Review and Evaluation of Alternative Chemical Disposal Technologies (1995–96), and Panel on Survivability and Lethality Analysis (1998–99).

All engineering systems—from power plants to airframes to prosthetic devices—are constructed with materials and then put into service, often in environments that are hostile. Roger considered it important that engineers who design, build, operate, inspect, and maintain engineering systems understand the limits of chemical stability of all the materials of construction of such systems. No one contributed more to this understanding than Roger, including through his more than 220 papers.

Admirably, as research methods and the information they convey evolved, he was not reluctant to adjust to change. For example, in his paper *Critical Analysis of Tight Cracks*, published in *Corrosion Reviews*, Roger pointed to a "paradigm shift" in considering mechanisms of stress corrosion cracking based on the use of sophisticated, modern analytical equipment. New experimental observations led him to consider *tight cracks* or *molecular cracks* that are just 1–5 nm wide, and he concluded that "There is evidence suggesting that the advance of SCC is a brittle process and is not associated with breaking of passive films. Studies of mature SCC after cracking at the crack tip show that the oxides formed do not come from the crack tip but rather from in-situ oxidation." We shared the view that the unprecedented convergence of computational modeling and simulation software and experimental facilities that allow atom-order observation provides a new era of understanding of the many forms of environmentally induced cracking.

Roger was recognized for his remarkable work with an extensive list of honors. From the National Association of Corrosion Engineers (NACE) he received the Willis Rodney Whitney Award, presented for outstanding contributions to corrosion research (1980); T.J. Hull Award, presented for outstanding contributions in the field of publications (1992); and recognition as a NACE fellow for outstanding contributions and organizational skills in the field of corrosion research and dissemination of valuable scientific and engineering data (1993). His effectiveness in the classroom was recognized with an Award for Innovative Teaching (1975) from the Ohio American Society for Engineering Education. In addition to NACE and his NAE membership, he was a fellow of the Electrochemical Society and American Society of Metals, among others.

He was determined that the nuclear infrastructure industry in China become fully informed about the opportunities as well as the safety and reliability challenges of nuclear electric generation, and he was made an honorary professor of the Nuclear Power Institute of China and of the Suzhou Nuclear Power Research Institute.

Roger's sense of humanity was legendary. Among his many gifts was the vision to see the essence of any issue, technical and nontechnical alike, and he always saw a path forward, a solution. He often described this as political metallurgy. He could have been a very effective politician. He was the model for the adage that reasonable people can disagree without being disagreeable.

An outstanding photographer, his photographic tours of China and other parts of the world (all as part of technical interactions with his hosts) are thoughtful and moving. He became interested in other cultures, especially Buddhism, and in Asian art.

Roger Staehle worked on technical problems that interested and concerned him. His vast contributions made the world a better place. His influence was global, as was his presence; scientists and engineers all over this planet recognized him and his impact on corrosion science and engineering. NAE member and faculty colleague Robert A. Rapp wrote at the time of Roger's passing in 2017 that "It is my opinion, perhaps widely shared, that Roger became the best metallurgist in the world in this specialty [nuclear materials], and as good as any metallurgist anywhere overall."

Roger was the epitome of a technological statesman. We all have much to learn from his professional convictions and personal interaction with people all over the world.

He is survived by five of his children—Elizabeth Van Arsdale Krier, Eric Washburne Staehle, Sara Staehle Henry, Catherine Erin Staehle, and William Staehle—and six grandchildren. He was predeceased by his son George Washburne Staehle.

Roger's children and grandchildren inherited many of his gifts and interests and are profoundly grateful for the gift of each other.

DERALD A. STUART

1925–2010

Elected in 1983

"Major engineering contributions and technical direction leading to the successful development and operation of the Fleet Ballistic Missile System."

BY L. DAVID MONTAGUE

DERALD ARCHIE STUART had a long and distinguished career as vice president and general manager of Lockheed's Missile Systems Division in Sunnyvale, California, and vice president of the parent Lockheed Corporation. He led the successful development, production, and fleet support of the US Navy's Fleet Ballistic Missile Programs from 1970 until his retirement in 1987. Those programs in which he played a major role are widely acknowledged as among the most successful in Department of Defense history. He died May 26, 2010, at the age of 84.

He was born November 9, 1925, in Bingham Canyon, Utah, and served in the US Navy during World War II before attending the University of Utah, where he earned his BS, MS, and PhD in physics in 1947, 1948, and 1950. While in graduate school he met and married his lifelong beloved Isabel and they had two children. After graduation he was hired as an associate professor at Cornell University, where he taught engineering materials, mechanics, and mathematics. He conducted research in materials, dynamic behavior of structures, electric and plastic wave propagation, and theory of the glassy state.

While at Cornell Stuart consulted for several government agencies, coauthored *Engineering Mechanics* with Dwight Gunder (John Wiley & Sons, 1959), and coauthored numerous articles and reports for various technical journals and the proceedings of the Joint Army-Navy-Air Force Solid Propellant Committee.

I first encountered Dr. Stuart in 1953 when I was an engineering student at Cornell; he was teaching a materials course on metallurgy. He would occasionally be away from campus and the rumor was that he was consulting on some "secret bomb project" for the government. After graduating and going to work for Lockheed in 1956, I found that the "secret project"—on which Dr. Stuart was consulting for the US Navy—was exploring the feasibility of developing much larger, more energetic, and longer-burning solid-rocket motors than any existing at the time.

That work helped to establish the basis for what was to become the US Navy Polaris submarine-launched ballistic missile program. It also led in 1958 to his joining Lockheed's recently formed Missile Systems Division that had been chosen 2 years earlier to develop the Polaris.

At Lockheed, Stuart made major engineering and management contributions to the successful development and operation of six generations of the US Navy's Fleet Ballistic Missile (FBM) programs, initially as manager of the missile systems propulsion staff, with responsibility for overseeing development of the solid-propellant rocket propulsion for the Polaris program. In 1966 he was named chief engineer of the Missile Systems Division. Four years later he was selected as VP and general manager of the division, with responsibility for all of Lockheed's work on the longer-range Trident I and II FBM programs and more than 10,000 engineers, scientists, subcontractors, and manufacturing employees. He held that position for nearly 17 years until he retired in 1987.

Stuart served on the Army Scientific Advisory Board and National Contract Management Association Board of Advisors, and was a fellow of the American Institute of Aeronautics and Astronautics. His honors included election to the NAE in 1983, the AIAA Wyld Propulsion Award (1979) for "outstanding achievement in the development or application of rocket propulsion systems"; the John J. Montgomery Award (1964) from the National Society of Aerospace Professionals; the US Navy Meritorious Public Service Award; and the Navy Certificate of Commendation, Navy Strategic Systems Program Director's Steering Task Group (1968–77).

To me, as one who worked with Dr. Stuart for almost 30 years, it was clear that he was above all a man of uncompromising integrity and honesty. He embraced and practiced the ideals of partnership between customer and contractor, leader and subordinate, based on earned trust and open communication. In that regard he always sought win-win solutions at every level of relationships and was known for his "over-the-horizon radar" and taking the long view, earning the respect of his customers, suppliers, employees, and associates.

After his retirement, the Stuarts moved to Arizona where he pursued his hobbies of woodworking and painting, and continued to study philosophy, astronomy, and mathematics. He was survived by Isabel (she died October 25, 2018); their children, twins Ronald Sturtevant-Stuart and Ryda Stuart; and two grandchildren.


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GEORGE W. SWENSON JR.

1922–2017

Elected in 1978

"Contributions to the theory and design of radio telescopes and to radio engineering."

BY CHESTER S. GARDNER
SUBMITTED BY THE NAE HOME SECRETARY

GEORGE W. SWENSON JR., a talented electrical engineer, radio astronomer, and academic administrator, died February 22, 2017, at the age of 94.

He was born in Minneapolis to George W. and Vernie Swenson on September 22, 1922. His family moved to Houghton, Michigan, 6 years later, when his father was hired by the Michigan College of Mining & Technology (now called Michigan Technological University) to establish a department of electrical engineering, which he led for 32 years.

Houghton is in upper Michigan at the base of the Keweenaw Peninsula, which juts north into Lake Superior. George's boyhood escapades in the surrounding forests and mountains, especially during the long and prodigiously snowy winters, nurtured his lifelong interests in wildlife and wilderness adventure. Predictably, he became a Boy Scout, eventually achieving the Eagle Scout designation. He also became a ham radio operator in high school, earning a class A license at the age of 16.

In his senior year he took an exam for a college scholarship in a national competition sponsored by the Radio Corporation of America (RCA). He was invited to New York City as a semifinalist for a month's further evaluation by the contest judges and was eventually selected as the winner of a full scholarship for 4 years of undergraduate study in radio engineering. The die was cast and, although World War II later intervened to complicate his education, in 1940 he enrolled as a freshman in electrical engineering at Michigan Technological University. He eventually completed his BS degree in 1944, by correspondence, while serving on active duty in the US Army and earning a commission as a second lieutenant in the Signal Corps. He earned his SM degree from the Massachusetts Institute of Technology in 1948 and PhD from the University of Wisconsin–Madison in 1951, both in electrical engineering.

George joined the faculty at the University of Illinois at Urbana-Champaign in 1956, after brief stints on the faculties of Washington University in St. Louis, the University of Alaska at Fairbanks, and Michigan State University in East Lansing. He was recruited jointly by the UIUC Electrical Engineering and Astronomy Departments to establish a radio astronomy program and to design and build a radio telescope for observational research by faculty and students. After traveling around the world studying radio astronomy installations in New Zealand, Australia, England, Europe, and the Soviet Union, he conceived, designed, and oversaw the construction of the 400-foot cylindrical radio telescope at the university's Vermillion River Observatory (VRO) near Danville.

The VRO telescope was used to discover and map thousands of new cosmic radio sources and to produce the first cosmic source catalogue at 600 MHz. George and his colleagues went on to develop a steerable 120-foot dish at the VRO that was used to make observations of complex molecules in the interstellar gas of the Milky Way.

Perhaps the capstone of George's radio astronomy career was his 4-year tenure in the late 1960s at the National Radio Astronomy Observatory (NRAO) as chair of the Design Committee for the Very Large Array. This seminal work laid the foundation for the design of very long baseline radio interferometers worldwide and eventually led to the construction of the Very Large Array in central New Mexico west of Socorro.

Based on these observations and experience, George later coauthored, with A. Richard Thompson of the NRAO and James

M. Moran of the Harvard-Smithsonian Center for Astrophysics, a comprehensive book on the design and operation of astronomical radio telescopes, *Interferometry and Synthesis in Radio Astronomy* (John Wiley & Sons, 1986). Its third edition was printed in 2017.

In the fall of 1957, upon hearing the news that the Soviet Union had launched Sputnik I (October 4), George immediately organized Illinois faculty colleagues and students to build a crude radio interferometer beside the campus optical observatory. They made some of the very first detailed observations of radio signals emitted from Sputnik I, observed the significant ionospheric propagation effects on those signals, and produced the first accurate orbital parameters of the satellite. Those observations were published just a few weeks later in the British journal *Nature*.[1]

Excited by the radio science that emerged from these initial observations, George was later able to convince NASA and the Department of Defense to fund the construction at UIUC of two small radio beacons, the Nora-Alice 1 and 2 satellites, which were hurled into orbit bolted to the final stages of rockets being used to launch some of the very first military satellites.[2] The Nora-Alice observations were used to study radio propagation effects and to probe the structure and electron content of the Earth's ionosphere.

The consummate storyteller, George loved to reminisce about the design challenges encountered with the Nora-Alice satellites and the resourceful and economical solutions to them. For example, he and his colleagues solved the problem of deploying the Nora-Alice antennas in space by using a carpenter's tape measure (purchased at a local hardware

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[1] King IR, McVittie GC, Swenson GW Jr, Wyatt SP Jr. 1957. Further radio observations of the first satellite. *Nature* 180:943.

[2] In a 1994 "Reminiscence," George explained that "The payload needed a name, of course. We decided on 'Nora-Alice' after the heroine of [cartoonist] Walt Kelly's ode to the IGY [International Geophysical Year, 1957–58], as recited by Pogo: 'O, roar a roar for Nora / Nora Alice in the night / For she has seen Aurora / Borealis burning bright.'" In I*EEE Antennas and Propagation Magazine* 36(2):32–35.

store) for the antenna, and an explosive pin-puller, supplied by an Air Force contractor, to allow the tape measure to unfurl on-orbit.

George had an uncanny ability to combine his personal interest in wildlife and the wilderness with his professional work. During his early years at the University of Alaska, he parlayed his radio engineering skills into numerous adventures in the high Arctic to repair or adjust faulty radio equipment, including a winter trip in a military DC-3 to an ice island research station floating just 30 miles south of the North Pole. He and his climbing companions also made several first ascents of remote mountains in the Alaskan wilderness, including Institute Peak in the Alaska Range, named after the Geophysical Institute at the University of Alaska where they worked.

An avid pilot, at UIUC George worked with William W. Cochran at the Illinois State Natural History Survey. Bill, a pioneer in the art of radio tracking of wildlife, often secured George's help in tracking birds from the air; George provided piloting services not only in the Midwest but also in the high Canadian wilderness. And while working for the Corps of Engineers he led the development of novel instruments for automatic tracking of radio-tagged wildlife. In later years he served as a technical advisor on wildlife research to the Barrow Colorado Island field station (part of the Smithsonian Tropical Research Institute) in the Panama Canal Zone.

While he is best known for his radio astronomy work, George also had a keen interest in acoustics, which resulted in a textbook early in his career (*Principles of Modern Acoustics*, Van Nostrand, 1953) and, after he retired from UIUC in 1988, occupied much of his technical work on noise mitigation for the US Army Corps of Engineers. He was a board-certified member of the Institute of Noise Control Engineering.

Beyond his extensive technical expertise, George was a talented administrator. In addition to directing observatories and large engineering studies, at UIUC he served as acting head of the Astronomy Department (1970–72) and head of the Department of Electrical and Computer Engineering (1979–85).

He also participated in the work of the National Research Council. His committee service included the US National Committee for the International Union of Radio Science (1980–82); the Office of Scientific and Engineering Personnel's Panel on Engineering, Mathematics and Computer Sciences (1983–87); Panel on Airport Passenger Screening (chair; 1995–96); Committee on Commercial Aviation Security (1995–2000); and NASA Technology Roadmap: Robotics, Communications, and Navigation Panel (2011–12).

George's professional interests were, as amply illustrated, wide ranging and he made important original contributions in all the areas in which he worked. His peers recognized the significance of those contributions by electing him to the National Academy of Engineering in 1978. He was also a life fellow of the Institute of Electrical and Electronics Engineers (IEEE) and American Association for the Advancement of Science, and a Guggenheim fellow.

George loved wilderness adventure, but he was definitely not a loner and sought companionship for his adventures with family members and professional colleagues. For their honeymoon, George took his new wife Janice on a bush pilot's tour of Alaska, with him serving as the bush pilot! He was an avid bird watcher, conservationist, and canoeist who paddled much of the shoreline of Isle Royale in Lake Superior and circumnavigated the Keweenaw Peninsula. He and Janice donated 80 acres of Keweenaw woods to the Michigan Nature Association; the land is now the Gratiot Lake Overlook Nature Sanctuary.

He loved to tell stories about his professional exploits and wilderness adventures and, an excellent writer, in later years he published versions of many of those stories in *The Bridge* of Eta Kappa Nu, IEEE's international electrical and computer engineering honor society.

George was greatly admired by friends and colleagues for his absolute integrity, his generosity to his family and the institutions he cared most about, his personal charm, and the enormous talents that propelled him to a stellar career and a full and consequential life.

He is survived by his beloved wife of 46 years, Joy Janice Swenson; four children from his first marriage: George W. Swenson III (Mary Knight), Laura Swenson, Julie L. Carney (John), and Donna J. Jones (Mark); five grandchildren; and four great-grandchildren.

PETER B. TEETS

1942–2020

Elected in 1999

"For contributions to the nation's space and launch vehicle programs and for management of aerospace programs."

BY NORMAN R. AUGUSTINE

PETER BURRITT TEETS died November 29, 2020, in Colorado Springs, Colorado, at the age of 78. He devoted his 37-year industrial career to Martin Marietta and Lockheed Martin, and served 4 years as undersecretary of the United States Air Force.

Pete, a westerner at heart, was born February 12, 1942, in Denver and spent his life in Colorado except for a tour at the Lockheed Martin headquarters in Bethesda, Maryland, and his government service in the Pentagon. He graduated from East Denver High School and attended the University of Colorado Boulder, where he received a bachelor of science in applied mathematics (1963). He subsequently received a master of science degree, also in applied mathematics, from the University of Colorado Denver (1965). Later, recognizing his remarkable talent and leadership potential, Martin Marietta sponsored his attendance at the Massachusetts Institute of Technology, where in 1978 he received a master of science degree in management.

Pete's ability to learn and contribute to new fields took him from mathematics to engineering to government policy. His initial role at Martin Marietta in Denver was that of a flight control analyst during the early intercontinental ballistic missile program, where he was responsible for the solution of a number of vexing technological problems in guidance, control, and navigation. Based on these contributions he was promoted to manager of the inertial guidance system effort on the Titan III ballistic missile program. His next step up the management ladder was to serve as program manager for the Transtage, an upper stage used in the US space program. Soon thereafter he became director of all space systems activities at Martin Marietta Denver, and then vice president of business development for the Denver Aerospace Division. As anticipated by all, when the position of president of Martin Marietta Denver Aerospace opened, Pete was selected for it.

The time eventually came for Pete to leave his beloved home state when in 1993 he was called to the corporation's headquarters in Bethesda to serve as president of the Martin Marietta Space Group. When Lockheed and Martin Marietta merged, representing the combination of all or parts of 17 different firms as the industry consolidated following the sudden end of the Cold War, Pete became president and chief operating officer of the Information and Services Sector (1995–97) and then president and chief operating officer of the entire Lockheed Martin Corporation (1997–99).

Throughout his career, Pete's accomplishments marked him not only as an immensely capable technologist but also as a strong manager and leader. He was identified at every stage as an individual with enormous potential for greater responsibilities, which he undertook with high ethical standards and as a leader of teams that included diverse talents. Working in the space program strongly left its imprint on Pete, given its demand for focus on mission success, attention to detail, and functioning as part of a team…not to mention confronting the unforgiving nature of space activities.

Pete's ever-expanding responsibilities and record of success found him highly qualified to serve as undersecretary of the Air Force, a position to which he was confirmed by the Senate just as the new millennium began (2001–05). In that capacity he also served as director of the National Reconnaissance Office, where he focused on improving procurement practices and utilizing commercial space capabilities to serve national defense needs.

He was recognized with numerous awards and citations, including the Gen. James V. Hartinger Award for contributions to military space (2003); W. Stuart Symington Award (2004); Robert Goddard Memorial Trophy (2008); James E. Hill Lifetime Space Achievement Award (2009); Wernher von Braun Space Flight Trophy from the National Space Club of Huntsville, Alabama; Bob Hope Distinguished Citizen Award, presented by the Los Angeles chapter of the National Defense Industrial Association (NDIA) to those "who have made significant contributions to the space industry" (2004); and membership in the Space Foundation's Colorado Space Heroes Hall of Fame (2016).

He was elected a member of the National Academy of Engineering in 1999 and a fellow of the American Institute of Aeronautics and Astronautics and American Astronautical Society, and received an honorary doctor of science degree from the University of Colorado. In 1996 the NDIA's Space Division established the Honorable Peter B. Teets Award, recognizing public or private sector leadership or achievement that results in significant contributions to the development, introduction, operational contribution, or support of space systems.

Pete served on several boards including those of the Aerospace Corporation, Draper Laboratories, Challenger Center of Colorado, First Presbyterian Church of Colorado Springs, and as an honorary member of the board of directors of the Space Foundation.

Among Pete's favorite pastimes were tennis, golf, skiing, and hiking in the Colorado Rockies. He was known to all for his outgoing personality and cheerful greeting of everyone who crossed his path. He is survived by his wife Vivian (née Brearley); their children Karen Avery (Rich), Jennifer (Mike Welch), Kevin (Cathy Moorhead), Matthew (Rhonda), and Christopher (Ashton); and seven grandchildren. He was predeceased by son David.

DANIEL M. TELLEP

1931–2020

Elected in 1979

"Pioneering theoretical, experimental, and design contributions in the development of reentry systems for US Fleet Ballistic Missiles."

BY SHERMAN N. MULLIN
SUBMITTED BY THE NAE HOME SECRETARY

DANIEL MICHAEL TELLEP, retired first chair and chief executive officer of Lockheed Martin Corporation, died at his home in Saratoga, California, on Thanksgiving morning, November 26, 2020, a scant week after his 89th birthday.

He was born November 20, 1931, in the small coal mining town of Forest City, Pennsylvania, the son of John, a coal processor and later carpenter, and Mary, who worked for a thread company. Around 1940 the family moved to San Diego. Years later Dan remembered the wonderful experience of enjoying the California sunshine. He became a devoted Californian.

He graduated summa cum laude from the University of California, Berkeley, with a bachelor's degree (1954) and stayed to get his master's degree, both in mechanical engineering, the next year. He particularly appreciated gaining extensive mathematical knowledge and perceiving its engineering utility. Years later, after a successful career, he happily endowed an engineering professorship at his alma mater.

He started his engineering career in 1955 as one of the first 200 employees of the newly formed Missile Systems Division

Readers are also referred to the family's delightful, illustrated tribute, available at https://www.lockheedmartin.com/content/dam/lockheed-martin/eo/photo/news/features/tellep/daniel-m-tellep-family-tribute.pdf.

of Lockheed Aircraft Corporation in Van Nuys. He rapidly became known to Willis Hawkins, the director of engineering, who became a mentor and supporter. The division soon evolved into Lockheed Missiles and Space Company, with a large new plant in Sunnyvale and a research and development laboratory in Palo Alto. Over the next 3 decades the company became Lockheed's largest, most profitable operating division, and the engineering and management career of hard-working, self-confident Dan Tellep flourished.

In 1955 the US Navy had selected Lockheed to design and produce a submarine-launched, solid-rocket-propelled, long-range fleet ballistic missile, later designated the Polaris missile. Dan's first major project assignment was on the Polaris missile system, where he focused on the pioneering design of the hypersonic reentry body. In November 1960, despite many development problems, Polaris missiles became operational on the first newly designed nuclear-powered fleet ballistic missile submarine. This project initiated Dan's productive, satisfying relationship with the US Navy, which continued for many years on the Poseidon longer-range missile program (operational in 1971) and the much more capable Trident missile (initially operational in 1979).

Dan excelled in a series of demanding technical and management assignments, and advanced to become president of Lockheed Missiles and Space Company (1984), a director of Lockheed Corporation (1987), and chair and chief executive officer of Lockheed Corporation (1989), headquartered in Calabasas. He was the first engineer to hold that position, leading four operating groups: missile and space systems, aeronautical systems, technology services, and electronics systems. One of his tasks was to restructure his aeronautics group, which had underutilized large plants in Burbank and Palmdale, California, and in Marietta, Georgia. The historic original Burbank plant was closed and the Skunk Works became Lockheed Advanced Development Company, consolidated in Palmdale.

Dan loved being involved with the military aircraft divisions, including the Lockheed Skunk Works. He was immediately included in oversight of the Lockheed-Boeing-General Dynamics F-22 advanced tactical fighter aircraft team, which was competing with the Northrop-McDonnell Douglas F-23 team for the Air Force production contract. He was very pleased in April 1991 when the Lockheed-led F-22 team won the US Air Force fighter competition, contracted to put the stealthy supersonic jet with its new design digital avionics system in volume production.

Lockheed had become one of the major aerospace companies in the world, with 82,000 employees and annual sales of $10 billion. In 1993 Dan led its acquisition of the Fort Worth military aircraft division of General Dynamics, producers of the F-16 fighter aircraft for the US Air Force and many allied countries. This acquisition, combined with the F-22 fighter win, resulted in a major expansion of the aeronautical systems group.

He continued expanding Lockheed's capabilities and resources to compete in the post–Cold War era. When major acquisitions proved unaffordable he turned to potential mergers, and identified Martin Marietta as a very promising candidate. He contacted the company's CEO Norm Augustine in 1994 to privately explore the possibility of "a merger of equals," resulting in secret merger negotiations. The new Lockheed Martin Corporation was announced in early 1995, with Dan as its first chair and CEO and projected annual sales of $23 billion; his *New York Times* obituary characterized him as the "engineer who turned Lockheed into a behemoth." Norm Augustine succeeded him as CEO in 1996, with Dan remaining as chair through 1998.

He was an honorary fellow of the American Institute of Aeronautics and Astronautics, which in 1964, when Dan was just 32, had selected him for its Lawrence B. Sperry Award for his contributions to reentry technology and the application of thermodynamics in aerospace systems development. In 1986 he received the AIAA Missile Systems Award "For over 25 years of major technical and leadership roles in the research and development of advanced missile/payload systems and for his contributions to the success of each generation of Fleet Ballistic Missile programs."

Dan Tellep, proud to be a creative, disciplined aerospace engineer, became one of the most accomplished aerospace leaders of the 20th century, concluding his career with the establishment of a successful post–Cold War aerospace corporation that has expanded and endured. Sales exceeded $65 billion in 2020.

In retirement Dan continued to be an avid tennis player, runner, and sailplane pilot, with lifetime logbooks totaling over 600 hours of soaring and more than 4500 miles of cross-country flights. He also enthusiastically pursued a new passion: painting in watercolors, often near his second house in the beach town of Carmel.

He is survived by daughters Teresa Tellep, Mary Tellep, Susan Tellep (Cindy), and Patricia Axelrod (Mark); his first wife, Margaret Lewis; two stepdaughters from his second marriage, Chris Chatwell (May) and Anne Bossange (Kent); and seven grandchildren and five great-grandchildren. He was predeceased in 2005 by his second wife, Patricia Taylor Baumgardner.

JOSEPH F. TRAUB

1932–2015

Elected in 1985

"For initiating optimal iteration theory, for creating significant new algorithms that solve diverse problems, and for educational leadership in computing."

SUBMITTED BY THE NAE HOME SECRETARY

JOSEPH FREDERICK TRAUB, a pioneering computer scientist and founder of the Computer Science Department at Columbia University, died August 24, 2015, in Santa Fe, New Mexico. He was 83. Most recently the Edwin Howard Armstrong Professor of Computer Science, he was an early pioneer in computer science years before the discipline existed, and he did a lot to shape the field.

He was born June 24, 1932, in Karlsruhe, Germany, the only child of Leo Traub, a banker, and the former Mimi Nussbaum. After the Nazis seized the bank in 1938 the family fled, arriving in New York in 1939. Joe attended Bronx High School of Science, where he was captain of the chess team, and City College of New York, where he earned degrees in math and physics (1954) before entering Columbia University intent on a PhD in theoretical physics. That plan changed when he discovered computers, not at Columbia—which had no computers—but at the IBM Watson lab then located in Casa Hispanica, just off campus at 612 W. 116th Street. He was hired there as a fellow, with the perk of unlimited computer time.

Adapted and reprinted with permission from the Columbia University Computer Science Department.

In 1959 he earned his PhD under the Committee of Applied Mathematics at Columbia. After his first choice to work on a chess problem was rejected, he proposed instead a quantum problem that involved 6 months of programing to calculate the ground energy state of a helium atom, correct to four decimal places.

After graduating, Traub went to work at Bell Labs, then in its "golden 60s" when researchers were given wide latitude to choose projects and conduct pure research. It was there that a colleague one day walked into his office with a problem: Could Traub find the zero of a function that involved an integral? Mulling over the problem led to two observations: one, it was expensive to compute the function; and two, there were lots of ways of solving it. His thinking about how to select the best possible algorithm led to his 1964 monograph *Iterative Methods for the Solution of Equations* (Prentice-Hall). It was the start of his career, with many publications to come.

Traub was most known for his work on optimal algorithms and computational complexity applied to continuous scientific problems. In collaboration with Henryk Woźniakowski, he created the field of information-based complexity, where the goal is to understand the cost of solving problems when information is partial, contaminated, or priced. Applications for information-based complexity are diverse and include differential and integral equations, continuous optimization, path integrals, high-dimensional integration and approximation, and low-discrepancy sequences.

Understanding the role of information about a problem was a unifying theme of Traub's contributions to a number of diverse areas of computing. Often collaborating with others, he created significant new algorithms, including the Jenkins-Traub algorithm for polynomial zeros, the Kung-Traub algorithm for comparing the expansion of an algebraic function, and the Shaw-Traub algorithm to increase computational speed. He authored or edited 10 monographs and some 120 papers in computer science, mathematics, physics, computational finance, and quantum computing.

Apart from his scientific research, he had a major role in building and leading organizations that promoted computer science. In 1971, at the age of 38, he was appointed chair of the Computer Science Department at Carnegie Mellon University, overseeing its expansion from fewer than 10 professors to 50 and making it one of the strongest computer science departments in the country. Based on his achievements there, Columbia University in 1979 invited him to found its Computer Science Department. He accepted the offer and chose to locate computer science in the engineering school, which at the time had a single computer, only three tenured faculty members teaching computer science—and a huge demand for computer classes.

After securing a $600,000 gift from IBM (which later provided another $4 million), he was able to add faculty and attract top students. Within a year the department was awarding bachelor's and master's degrees as well as PhDs. As chair of the department (until 1989), he oversaw the 1982 construction of the Computer Science Building, working closely with architects to come up with a final design that would later win awards.

Traub liked building things from scratch. In 1985 he was the founding editor in chief of the *Journal of Complexity* (a position he held at the time of his death). He was invited to serve as the founding chair (1986–92) of the Computer Science and Technology Board (now the Computer Science and Telecommunications Board) of the National Research Council, and was reappointed chair from 2005 to 2009.

His awards and honors are many and include election to the National Academy of Engineering in 1985, the 1991 Emanuel R. Piore Medal from IEEE "For pioneering research in algorithm complexity, iteration theory and parallelism, and for leadership in computing education," and the 1992 Distinguished Service Award from the Computer Research Association. He was a fellow of the Association for Computing Machinery, American Association for the Advancement of Science, Society for Industrial and Applied Mathematics, and New York Academy of Sciences. He was selected by the Accademia Nazionale dei Lincei in Rome to present the 1993 Lezioni Lincee, a cycle of six lectures. And in 1999 he received the New York Mayor's Award for Excellence in Science and Technology, presented by Mayor Rudy Giuliani.

In 2012, his 80th birthday was commemorated by a symposium at Columbia University to celebrate his pioneering research and other contributions to computer science.

Traub always described himself as lucky: Lucky in his early life that his parents were able to flee Nazi Germany in 1939 and settle in New York City; that he had a knack for math and problem solving just when those skills were needed; that a fellow student's prescient suggestion led him to visit IBM's Watson Laboratories where he first encountered computers. And lucky to be among the first to enter a new, unexplored field when he had the ambition to make new discoveries and a hunger to do something significant. In an interview recalling his life, he said "I'm almost moved to tears but who could have expected such a wonderful life and such a wonderful career."

His luck extended to his personal life. He was married to Pamela McCorduck, a noted author who also taught science writing at Columbia.

He enjoyed skiing, tennis, hiking, travel, and good food, and regularly spent his summers in Santa Fe, where he was an external professor at the Santa Fe Institute and played a variety of roles over the years, often organizing workshops to bring together those working in science and math.

He is survived by Pamela; daughters Claudia Traub-Cooper and Hillary Spector, from his first marriage, to Susanne Traub; and four grandchildren.

DANIEL I.C. WANG

1936–2020

Elected in 1986

"For basic contributions to the field of biotechnology resulting in improved control of bioprocesses and recovery of biomaterials."

BY STEPHEN W. DREW

DANIEL I-CHYAU WANG, Institute Professor at the Massachusetts Institute of Technology and an early pioneer in the field of biotechnology, died August 29, 2020, at the age of 84. He was recognized around the world as one of the founders of biochemical engineering, a field that arose from interdisciplinary studies in chemical engineering, food science, environmental engineering, biology, microbiology, genetics, and other related disciplines.

Danny, as he was generally called, was born in Nanking, China, on March 12, 1936. He came with his family to the United States in 1946 when his father was appointed supply commissioner in the Chinese Consulate by the Nationalist government. He earned a bachelor of science degree in 1959, followed by a master's in 1961, both from MIT in chemical engineering. In 1963 he earned his PhD, also in chemical engineering, from the University of Pennsylvania with Arthur E. Humphrey, who became a lifelong friend; his thesis was "The kinetics of death of bacterial spores at elevated temperatures."

He joined the MIT faculty in 1965, hired as an assistant professor of biochemical engineering in the Department of Nutrition and Food Science, which housed the BCE program. Within a few years he had initiated the fermentation technology summer program; it has run continuously since then and is now under the guidance of Kristala Prather.

In 1985 Danny was the driving force behind the launch of MIT's Biotechnology Process Engineering Center, a multidisciplinary research center with faculty from the Departments of Biology, Chemistry, and Chemical Engineering. Its establishment coincided with the emergence of biotechnology as an industry and a research field.

He also worked to forge international ties between MIT and universities in other countries, particularly in Asia. He established a joint program in molecular engineering of biological and chemical systems with the National University of Singapore; it became part of the Singapore-MIT Alliance for Research and Technology (SMART).

He coauthored five books, published more than 250 papers, was editor in chief of *Biotechnology and Bioengineering* (1984–90),[1] and was awarded 15 patents. In 1995 he was named an Institute Professor, MIT's highest faculty honor.

"Danny's work and impact in the field of biochemical engineering were profound, and led to a major shift in the growth of chemical engineering at the interface with biology," said Paula T. Hammond, the David H. Koch Professor and head of the MIT Department of Chemical Engineering. "He extended chemical engineering concepts to bioreactors and the first efforts in bioprocesses, enzyme technology, and mammalian cell culture."

At the national level, Danny led efforts in biotechnology as an elected member of the council of the National Academy of Engineering (1995–98) and service on the NAE Membership Committee (1989–95, including a term as chair) and Bioengineering Peer Committee (1987–89); and through his appointments to serve on the National Research Council's Committee on Opportunities in Biotechnology for Future Army

[1] In December 2020 the journal published a detailed appreciation of Danny Wang's career and contributions: Afeyan NB, Cooney CL. Professor Daniel I.C. Wang: A Legacy of Education, Innovation, Publication, and Leadership. *Biotechnology and Bioengineering* 117(2):3615–27 (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7839494/).

Applications (1999–2001), Committee on Biobased Industrial Products: National Research and Commercialization Priorities (1994–99), Committee on Bioprocess Engineering (1991–93), Board on Chemical Sciences and Technology (1990–93), Committee on Biotechnology (1988–95), and Committee on a National Strategy for Biotechnology in Agriculture (1984–87).

In addition, he was a cofounder of the Society for Biological Engineering of the American Institute of Chemical Engineers (AIChE), and a member of the American Academy of Arts and Sciences and the National Biotechnology Policy Board at the National Institutes of Health.

For his contributions he was honored with the AIChE William H. Walker Award (1994) and the Amgen Biochemical Engineering Award (1995). In 2014 MIT's Frontiers of Biotechnology Lectureship was renamed the Daniel I.C. Wang Lecture; it honors achievements at the frontiers of biotechnology, and the distinguished scientists and engineers responsible for them. In 2019 AIChE established the annual D.I.C. Wang Award for Excellence in Biochemical Engineering, which "recognizes individuals for their contributions to the field and to the practice of biochemical engineering through their position in industry or academia as exemplified by Professor Wang in his 50 years of contributions."

Danny loved to travel, cook, and eat. He traveled all over the world and, whether in Paris, Zürich, or Singapore, would find the finest Chinese restaurant in the city. He was also extremely competitive and derived significant pleasure from beating his students at tennis and poker. He relished spending time with his granddaughters.

Daniel I.C. Wang is survived by his wife of 54 years, Victoria (née Dawn); their son Keith (Katherine); and two granddaughters.

ROBERT L. WIEGEL

1922–2016

Elected in 1975

"Leadership in applying scientific findings in oceanography to the solution of civil engineering problems in the ocean."

BY CARL L. MONISMITH, JORG IMBERGER,
AND STEPHEN G. MONISMITH

ROBERT LOUIS WIEGEL, professor of civil engineering emeritus at the University of California, Berkeley, died July 9, 2016, in Berkeley. He was 93.

One of five children, Bob was born October 17, 1922, in San Francisco to Louis Henry and Antoinette L. (née Decker) Wiegel; they moved to Oakland the next year. Bob graduated from Oakland High School and attended the University of California, Berkeley, where he received his BS in mechanical engineering in 1943. While at Berkeley, he was in the ROTC program (Army Ordnance Corps) and after graduating was sent to Europe as a second lieutenant, assigned to a US Army Ordnance Tank Repair Unit. While in England he met his future wife, Anne Pearce. He was discharged from the Army as a first lieutenant in 1946, returned to Berkeley, married Anne in 1948, and received his MS degree in mechanical engineering in 1949.

Motivation instilled by his parents, his undergraduate study, and 3 years of US Army service all whetted Bob's interest in becoming an academic, pursuing his natural curiosity and a desire to design and build things. While in his MS program he was appointed an assistant research engineer and later an associate research engineer, and worked with Joe W. Johnson, Richard G. Folsom, John D. Isaacs, Willard N. Bascom, and others under the general supervision of Morrough P.

O'Brien on what was then called the "Waves Project." Bob was appointed lecturer in mechanical engineering in 1957 and associate professor in civil engineering in 1960. In 1963 he was advanced to the rank of professor in civil engineering, a position he held until he retired in 1987. As professor emeritus, he came to campus daily (when in town), continuing his assistance to faculty and students when requested in the hydraulics and construction areas through 2014.

Bob's extensive service to Berkeley and the UC system included roles as assistant dean of the College of Engineering (1963–72) and acting dean of the college (1972–73); secretary of the Academic Senate (1988–89); and, at the systemwide level, director of the State Technical Services Program (1965–68). Association with other universities included visiting professorships at the National University of Mexico (1965), Polish Academy of Sciences (1976), and University of Cairo (1978); and many invited lectures to both US and international universities as well as professional societies and government agencies.

Bob was a pioneer in the field of coastal engineering and was instrumental in building this specialty area in the United States and around the world. He established national and international preeminence for the University of California through his research and publications and through his seminal book *Oceanographical Engineering* (Prentice-Hall, 1964). He also edited (and authored a chapter on tsunamis) *Earthquake Engineering* (Prentice-Hall, 1970), the first major effort in this field. He made major contributions to the solution of many civil engineering problems in the ocean, applying oceanographic knowledge: wave-structure interaction, wave analysis, wave forces on structures, beach erosion control, tsunamis, and ocean current measurement and analysis. He was active in developing techniques and equipment for hydraulic model studies of coastal works; an example was the laboratory model (and field study) of the hydraulic problems at the Diablo Canyon nuclear power generating station in California.

Bob's service to the profession and governmental agencies was exemplary. A distinguished member of the American

Society of Civil Engineers (ASCE), he served as a member and chair of a number of committees in the Waterways, Harbors, and Coastal Engineering Division, including the executive committee (chair, 1974–75) and Coastal Engineering Research Council (chair, 1978–92). He was also a consultant to government and industry (since 1964); founder and first president (1972–75) and honorary member (1988) of the International Engineering Committee on Oceanic Research; member, Coastal Engineering Research Board, Chief of Engineers, US Army (1974–85); commissioner, California Advisory Commission on Marine and Coastal Resources (1968–74); member, Monterey Bay Shoreline Study: Scientific and Technical Advisory Committee, State of California Resources Agency, Department of Boating and Waterways (1985–86); vice president and director (1988–95), American Shore and Beach Preservation Association; and member, Review Committee, Barrow Beach Nourishment Project, North Slope Borough, Alaska, Science Advisory Committee.

For the National Research Council, he served on the committees on Engineering Implications of Changes in Relative Mean Sea Level (1984–86), on Coastal Erosion Zone Management (1988–90), and on Beach Nourishment and Protection (1992–95).

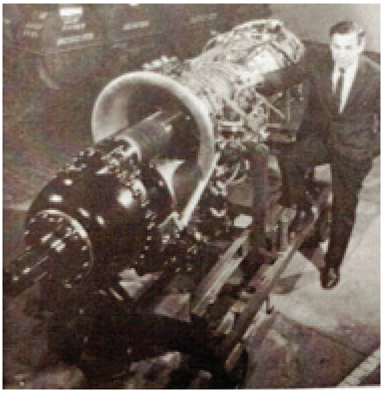
Bob received many awards and honors for both his research and service, including ASCE's Walter L. Huber Civil Engineering Research Prize (1962), John G. Moffatt-Nichol Harbor and Coastal Engineering Award (1978), and International Coastal Engineering Award (1985); election to the NAE (1975); designation as Senior Queen's Fellow in Marine Science, Australia (1977); Outstanding Civilian Service Medal, US Army Corps of Engineers (1985); and the UC Berkeley Citation (1987). He was named a Distinguished Diplomate, Coastal Engineering, of the ASCE Academy of Coastal, Ocean, Port, and Navigation Engineers, and in 2011 ASCE published *Civil Engineering Classics: Selected Coastal Engineering Papers of Robert L. Wiegel* in his honor. The Robert L. Wiegel Conference Room at the US Army Coastal Engineering Research Center in Vicksburg, Mississippi, is named in his honor. He also was a fellow of the

American Association for the Advancement of Science and an honorary member of the Japan Society of Civil Engineers.

Bob was a superb role model for colleagues, students, and staff through his teaching, research, service, and concern for students and staff. One of the contributors to this memorial (JI) provides some comments illustrating Bob's care for students and staff:

> I first came to UCB as a PhD student in September 1968.… As I stepped into the area of the 3rd floor offices of Professors Hugo Fischer, Bob Wiegel, Joe Johnson, Jim Harder, and Hans Einstein, I felt…an air of excitement…in the spirit of engineering. The transition from my life in Australia to life in Berkeley in the late 60s was huge for me, and I would not have survived without the personal support of Joe Johnson and Bob Wiegel. My supervisors, Hugo Fischer, Gill Corcos, and Hans Levy, provided great intellectual technical support and Joe and Bob ensured that all of us students could somehow reconcile what was going on outside our offices with the demands of our thesis work and with the life we had all come from…. [T]he mentoring at both levels helped me not only to finish my PhD in record time, but also to form a whole new world view, a view that I have lived my life by…. [T]hank you Bob, Joe, Hugo, Gill, and Hans! I returned to O'Brien Hall in 1976 as an assistant professor. Bob Wiegel ensured that I was made to feel welcome and worked with the chairman of the Department of Civil and Environmental Engineering to resolve my transition to a tenured associate professorship.
>
> Professionally, M.P. O'Brien has been given the credit for laying the foundations of "coastal and ocean engineering," but Bob Wiegel must surely be given the credit for building the house on these foundations. I shared many chats with Bob during my days as an academic at UCB, as his working hours were similar to mine. Bob was a kind, honest, and incredibly hard working person, who saw engineering as a way to contribute to America and the world community. Bob, you were successful, your contributions will stand the test of time!

Bob is survived by Anne, his wife of 67 years, son John, daughters Carol and Diana, and one grandchild.



EDWARD WOLL

1914–2010

Elected in 1977

"Contributions to the pioneering development and evolution of aircraft gas turbines."

BY FREDRIC F. EHRICH

EDWARD WOLL, a pioneer in the development of jet engines in the United States, died December 17, 2010. He was 96, with a mind that retained its keen edge. The day before his death he was "talking shop" with a colleague at his retirement home in Westwood, Massachusetts.

Eddie was born May 29, 1914, in Boston to parents who had immigrated from Minsk and Lvov; he had three brothers and a sister. He graduated from Boston Latin School in 1931 and got his BS degree in mechanical engineering from the Massachusetts Institute of Technology in 1935.

He started his eventful and productive career as an Army Air Force officer during World War II in the Power Plant Laboratory at Wright Patterson Air Force Base. He left Wright Patterson as an Army captain at the war's end and continued his gas turbine work at Rensselaer Polytechnic Institute, where he received his master's degree in aeronautical engineering in 1946.

Degree in hand, he joined General Electric Company's nascent Aircraft Gas Turbine Department as a development engineer. First quartered at Boston's North Station, the department moved to Lynn, where Eddie managed product planning, engineering, and engine development projects. After becoming manager of the Small Aircraft Engine Department

(1961–66), he rose to the positions of vice president and general manager of the Military Engine Division and the Engine Group's Advanced Engineering Division. He retired as vice president of GE Aircraft Engines in 1979.

He distinguished himself early on with the design and development of the first successful US afterburning jet engine with variable area nozzle (J47-GE-17). He went on to lead the conception, design, and development of a series of turboshaft/turboprop engines:

- the T58, about which Kenneth M. Rosen (NAE 1997), former VP of research and engineering at Sikorsky Aircraft Co., UTC, noted that "Ed led the development of the T58 turboshaft engine and greatly contributed to its subsequent successful experimental installation in the nose of a Sikorsky S-58 helicopter. This event was a real technological turning point for both GE and Sikorsky. The aircraft first flew in 1957, and proved to be a great technical success…as did the free turbine concept pioneered by Ed."
- the J85 turbojet engine family—which made possible the first modern "lightweight fighter" (the Northrop F-5 "Freedom Fighter") and T38 trainer—and its derivatives;
- the CJ610 (commercial aircraft derivative);
- the CF700 (aft fan version), which powered thousands of aircraft, from military fighters and trainers to business jets (such as the CJ610-powered Learjet and the CF700-powered Dassault Falcon), in over 30 countries; and
- the TF34 engine, which powered (i) the aircraft carrier–based S-3A (it entered Navy service in 1974); (ii) the A-10 Thunderbolt, known as the "Tank-buster"; and (iii), in its derivative commercial version (the CF34), the Bombardier Challenger commuter airliner, among others.

Ed was also a leader in conceiving, designing, developing, and applying two successive generations of advanced turboshaft/turboprop engines—embodied in the T64 and T700—that revolutionized helicopter propulsion in the 1950s and 1960s.

Each engine embodied a wave of new technology that enabled lighter weight, lower fuel consumption, fewer emissions, and less operating cost for users. Today they power more than 15 types of aircraft in both military applications (such as the T64/Sikorsky CH-53 heavy-lift helicopter and the T700/Sikorsky H-60 "Hawk" series of helicopters) used by the US Army, Air Force, Navy, and Marine Corps and commercial applications (such as the CT7/Sikorsky H-70 helicopter and CT7/Saab 340 turboprop commercial transport) used around the world.

Never one to rest on his laurels, he helped conceive and direct development of

- the low-bypass fighter engines (so-called cool-skin engines) that powerered a new lightweight fighter generation, the advanced development YJ101 engine, which powered the experimental fighter YF-17 and reached mass production as the F404 engine powering the F-18 series of fighter aircraft—this series is considered the leading powerplant in its class and is the benchmark for an entire generation of military combat aircraft propulsion systems for simplicity, design-to-cost, and ease of maintenance to balance the advanced technology features vital to its success;
- the F101X engine, which matured into the renowned F110 fighter engine that powers the world-class F-15 and F-14 aircraft; and
- the CF6 and CFM56 subsonic transport engines and the F101 supersonic bomber engine.

He was also a key player in the joint development program with France's Société Nationale d'Étude et de Construction de Moteurs d'Aviation (SNECMA), a renowned model of international cooperation that developed the CFM56 turbofan engine that powers, among other aircraft, the Boeing 737 and the Airbus A320/A340 and is the most successful and numerous commercial transport engine ever produced.

Under Ed's indefatigable and visionary leadership, GE was responsible for successful demonstration of the NASA-sponsored

Energy Efficient Engine (E^3). The advanced-technology powerplant had a 13.5 percent lower specific fuel consumption rate than the base CF6-50 engine. Substantially lower emission targets were also achieved. The engine was later used as the technology base for the GE90 engine that powered the Boeing 777 modern large commercial aircraft.

A leader for the entire spectrum of GE aircraft engines, Eddie was recognized as the driving force behind the GE engine business's Zero Defects program, for being on a first-name basis with employees as he walked the shop floor, and for cultivating and mentoring young engineers. In appreciation of these attributes, the division's auditorium at Lynn was named in his honor on his retirement and he was elected to the GE Propulsion Hall of Fame.

For his considerable contributions he received many honors, including the American Institute of Aeronautics and Astronautics' Air Breathing Propulsion Award (1977), "for 30 years of sustained significant contributions to the aircraft industry through innovative conception, design, and development of gas turbine engines, including the total engine spectrum from small turboshaft to large bypass turbofans; through active participation in many technical societies and advisory boards; and through innovative leadership in design-to-cost principles"; and, from the Vertical Flight Society, the Dr. Alexander Klemin Award (1975), "For his years of leadership in design and development of jet engines, and his prime influence in overall design of the US Army T700 turbo-shaft engine to power advanced helicopter of the 80s."

In addition to his NAE membership, he was a distinguished member of the Jet Pioneers Association of America and a fellow of the AIAA. Over the years, he served on many national, industry, and professional committees dealing with standards, regulation, sponsorship, and specification of gas turbine aircraft engine technology. And for his alma mater he was secretary of his class and established an endowed education fund for MIT undergraduates.

Eddie Woll was a major force in the gas turbine industry and a leading contributor to aircraft engine science and technology—and a rare species in an industry with a lot of macho, tough guys. He was gentle-mannered, gentlemanly, considerate, and very careful and thoughtful in his dealings with people.

He resided most of his adult life in Wenham, MA, where in about 1947 he bought a house that was built in the mid-1600s (when they moved in it had no plumbing). He and his wife, Barbara (who predeceased him), restored that precious antique of a home over many years.

Eddie is survived by his daughter, Barbara Jones (Falmouth, MA), and son, Edward Woll Jr. (Cambridge, MA), six grandchildren, and five great-grandchildren.

M. GORDON WOLMAN

1924–2010

Elected in 2002

"For outstanding contributions in fluvial processes, water resources management and policy, and environmental education."

BY RUTH S. DEFRIES AND THOMAS DUNNE
SUBMITTED BY THE NAE HOME SECRETARY

MARKLEY GORDON WOLMAN died February 24, 2010, at age 85. He was one of the founders of the modern quantitative approach to fluvial geomorphology, and he devoted his career to developing and teaching methods for applying earth science to questions of environmental management and public policy, creating a legacy of published work, influential reports to government, and students inculcated with his profound commitment to applying science as public service. His work guided public policy related to water management and environmental problems throughout the world as he pioneered interdisciplinary, systems-based approaches to solving complex societal problems ranging from land-use controls for limiting water pollution to river management for controlling disease vectors.

Known as "Reds" for his carrot-colored hair, Wolman was born August 16, 1924, in Baltimore, Maryland, to Abel and Anna (née Gordon) Wolman. He attended Haverford College in 1942 but was drafted into the Navy after one semester. After World War II he completed his undergraduate studies at

Adapted with permission from *Biographical Memoirs of the National Academy of Sciences* (available at www.nasonline.org/memoirs), which includes a list of M.G. Wolman's most significant publications.

Johns Hopkins University with a BA in geology (1949) and all-American honors in lacrosse. He received his master's (1951) and PhD (1953) from Harvard University, also in geology. From 1951 to 1958 he worked as a hydrologist for the US Geological Survey (USGS), where he focused on quantitative analysis of river channels and floodplains.

He returned to Johns Hopkins University in 1958 as chair of the Isaiah Bowman Department of Geography. The department merged with the Sanitary and Water Resources Engineering Department in 1968 to become the Department of Geography and Environmental Engineering (DOGEE), which he chaired from 1970 to 1990. He then became director of the Center for Environmental Health Engineering at the Johns Hopkins Bloomberg School of Public Health while maintaining his DOGEE faculty position.

Wolman's intellect and career sprang from his lifelong companionship and conversations with his father, Abel Wolman, who was elected to the National Academy of Sciences in 1963 and the NAE in 1965. Abel Wolman championed the links between public health and engineering at a time when they were not obvious to many.

An only child, Reds grew up in a home of robust discussion and dedication to public service. Later, father and son were constant companions and were often together in seminars and meetings on the Hopkins campus. When Abel Wolman died in 1989, his son penned his biographical memoir for the National Academy of Sciences. About his inspiration from "Pop," he wrote, "My friendship with my father, that I can recall, began when I was about four.… The talk did not stop until he died on February 22, 1989. My father and I worked together, traveled together, and reviewed each other's manuscripts."[1]

Both Abel and M.G. Wolman's research and public service related to water, Abel with water for public supplies and M.G. with water in natural rivers. Both were also dedicated to Johns

[1] *Biographical Memoirs of the National Academy of Sciences*, vol. 83 (2003), pp. 344–61. Washington: National Academies Press. Also see the NAE memorial tribute for Abel Wolman published in vol. 5 (1992), pp. 284–89.

Hopkins University, spending nearly their entire careers there. The president of the university, Ronald J. Daniels, and the dean of engineering, Nicholas P. Jones, sent the following message to the Hopkins community when Reds died: "For the first time since 1937, the Johns Hopkins University is without a Professor Wolman on its faculty. Reds and his father were giants. We are a far better university for the years they spent here, and far better people for having known and learned from them."

In the late 1950s and early 1960s Reds authored or coauthored papers on river channel morphology that significantly broadened the earlier paradigm of the graded river, and opened up a more flexible approach to explain the variety of river forms and behavior by applying hydraulic theory, laboratory experiments, and field measurement. His papers from this period established many of the concepts and vocabulary that still dominate fluvial studies. Topics included channel adjustments to temporal and spatial changes in flow (1955), the formation of floodplains (1957), the morphological significance of floods of various sizes (1960), meanders and other river channel patterns (1957, 1960), and knick points in river profiles (1960). Most of this work was summarized in the coauthored textbook *Fluvial Processes in Geomorphology* (with Luna B. Leopold and John P. Miller; W.H. Freeman, 1964); it was the bible of the discipline for 20 years, and reprinted in 1995, still with many stimulating ideas, not all of which have been fully explored.

Reds worked with students and colleagues to increase knowledge of river channel behavior with his provocative, novel ideas. For example, a 1978 paper extended his study of the magnitude and frequency of morphogenetically significant weather events from river channels to the hillslopes of watersheds, in 1987 he demonstrated how flood discharge sequences control temporal fluctuations of channel geometry, and in 1990 he extended systematic study of channel geometry to forested mountain ranges and also expanded his earlier work on channel-forming discharges.

In the 1960s he turned his attention to an emerging public policy issue: sedimentation in stream channels of urban areas, and once again he wrote definitive papers that crystallized understanding and still provide the basis for regulation and channel restoration. His paper on the effects of construction on fluvial sediment (1967) was among the first to link urban land use and water quality. His research quantified increased runoff and sediment load from construction associated with urbanization and illustrated how such impacts should be expected to spread through a landscape over time, consonant with predictable trajectories of urban development.

In 1971 he wrote an important paper demonstrating how the flood-prone areas of valley floors could be rapidly delineated through the use of simple field mapping without slow, expensive hydraulic data collection and computation, practices that continue to slow the delineation of flood-prone lands and allow development to spread into dangerous areas faster than regulation and sound advice can be implemented.

Another influential paper in 1971 was his review of water quality, the first to illustrate temporal trends in the quality of the nation's rivers and the extremely nonlinear response of water quality to cleanup efforts. This work became the impetus for the USGS National Water-Quality Assessment Program (NAWQA), aimed at tracking trends in the nation's water quality. Later he summarized downstream impacts of dams on channel bed sediment and morphology (1985), leading to policy discussions about the environmental consequences of large dams.

He was well recognized for his outstanding research contributions. In addition to the NAE, he was elected to the National Academy of Sciences, American Academy of Arts and Sciences, and American Philosophical Society. He was an elected fellow of all the major societies in earth and environmental science, and received the Cullum Geography Medal (1989) of the American Geographical Society, Ian Campbell Medal (1997) from the American Geosciences Institute, Penrose Medal (1999) from the Geological Society of America, and the American Geophysical Union's Robert E. Horton Medal (2000).

Reds Wolman set an extraordinary standard for public service, as a member and officer of numerous committees, boards, and commissions—national, international, regional, and local—that provided advice to government and addressed emerging or enduring environmental problems.

He was very active in the work of the National Academies, serving on the Committee on the St. Lawrence Seaway: Options to Eliminate Introduction of Nonindigenous Species into the Great Lakes, Phases I and II (2004–08); Committee to Assess the US Army Corps of Engineers Methods of Analysis and Peer Review for Water Resources Project Planning (2001–04); Committee on the Interaction Between Population Growth and Land Use Change in China, India, and the United States (chair, 1996–2001); Board on Sustainable Development (1995–99); Water Science and Technology Board (1989–92); and Committee on Conservation Needs and Opportunities (chair, 1984–86), among many others.

He also devoted considerable service to his home state of Maryland. His work in the 1960s to link runoff from construction projects with sedimentation of Maryland's streams led to the first state regulations in the nation to address the problem. In the 1990s he chaired the Oyster Roundtable to develop a plan to restore the Chesapeake Bay's shellfish, which were suffering from disease and overharvesting. Beginning in 2003 he chaired Maryland's Advisory Committee on the Management and Protection of the State's Water Resources, which led to a state law requiring a water management plan before building.

He also used his expertise in fluvial geomorphology to address global issues through service on international committees. He addressed issues ranging from the impacts of soil erosion on crop productivity to links between population, land use, and environment. His colleagues in these endeavors frequently elected him to leadership positions in societies, where he gently prodded them to reflect on the future conditions and possibilities of their disciplines.

He was both internationalist in perspective and nationalist in the most constructive sense of the word. He was committed to social justice and equity in his choice of environmental science problems to work on, and he exemplified the model of a truly ethical scientist-statesman. Observing him inspired his colleagues in the environmental sciences to do better for humanity.

He published influential papers, reports, and book chapters on important resource problems facing the United States and the world. These reports still deserve attention mainly because the problems are so important: energy, human response to flood hazard in developed and developing nations, water supply and human health, pollution of waterways, the management of large rivers, the transmission of water-borne diseases in tropical rivers, land degradation and soil productivity, water resources, and toxic waste disposal policies. His work also guided the application of systems analysis and interdisciplinary approaches to derive solutions for environmental problems.

Wolman thrived beyond the halls of academe and scholarly publication. Every Thursday afternoon during spring semester he donned his green rubber boots and piled into a van with his students for field trips to streams, farms, and suburban developments around Baltimore. Here he was in his element, in the messy world of real-life environmental problems.

Visiting urban streams, he explained to his students the principles of fluvial geomorphology, urbanization, ecological succession, and transport of pollutants to weave an interdisciplinary vision of the stream's behavior and evolution. In the rolling hills north of Baltimore, he explained the geology, soils, history of farming, and potential for soil erosion and sedimentation with impending suburban expansion. The message to students was to understand the environment in all its complexity, and to avoid focusing exclusively on any single disciplinary perspective.

He extended his interdisciplinary vision to the design of educational programs at DOGEE during his reign as chair. The department reflected his breadth of vision, with scholarship ranging from microbiology to Marxist theory and operations research. The graduate program exposed students to the humbling realization that a single discipline alone cannot solve environmental problems. He encouraged students to gain firm grounding in quantitative methods, systems analysis, and a core area of expertise, while maintaining knowledge of the breadth of disciplines required to solve real-world problems.

He presided over one of the first and most ambitious experiments in interdisciplinary research and education, firmly rooted in his notion that "the rationality for interdisciplinary studies is based on the common observation that problems in the real world are not separable into disciplines."[2] He acknowledged the difficulties of establishing an interdisciplinary faculty and graduate program in a discipline-based academy (a continuing problem with no resolution in sight), but concluded that

> a number of recurring environmental themes, such as the inseparability of natural and social processes, the existence of spillover effects or externalities, the problem of the commons, the existence of incommensurate and nonmonetary values, and the importance of large-scale natural processes undergoing dynamic and evolutionary change, appear to warrant continuing emphasis.

Wolman's legacy resides largely in the principles for interdisciplinary research that he strove to transmit to his many students: rigor, appreciation for multiple perspectives, service to humanity, and problem solving in a real-world context.

Reds and his wife, Elaine (née Mielka), raised four children: Elsa Wolman Katana (Tom), Abel Gordon Wolman (Deborah Locke), Abby Lucille W. McElroy (Peter "Mac"), and Fredericka J. Wolman. At the time of his death he had two grandsons. Elaine died March 25, 2019.

[2] Wolman MG. 1977. Interdisciplinary education: A continuing experiment. *Science* 198(419):800–04.

LEONARDO ZEEVAERT WIECHERS

1914–2010

Elected in 1978

"Analysis, design, and construction of tall, heavy structures on difficult foundations in severe seismic environments."

BY WILLIAM H. HANSMIRE

LEONARDO ENRIQUE ZEEVAERT WIECHERS, professor emeritus of the Universidad Nacional Autónoma de México (UNAM; National University of Mexico), passed away in Mexico City on February 16, 2010, at age 95.

He was born in Veracruz, Mexico, on November 27, 1914. A strong student in math and physics, he became interested in engineering during his high school studies in San Idelfonso. He obtained a civil engineering degree from UNAM in 1937 and, after a stint with the National Highway Commission, resumed his studies. In 1940 he got a master's degree in Structures and Soil Mechanics from the Massachusetts Institute of Technology, where he also assisted in the hydraulics laboratory. Back in Mexico, he was recommended by one of his MIT professors to work on a local project with Karl Terzaghi, who invited him to collaborate at the University of Illinois at Urbana-Champaign, where he earned his PhD in civil engineering in 1949.

In his professional practice as a consulting engineer, he carried out soil mechanics surveys and performed analysis and design of structures and foundations for nearly 700 projects during his career of more than 50 years. He developed several foundation systems for highly compressible soils such as those encountered in Mexico City, including the concept of intergranular viscosity to explain and calculate the phenomenon of secondary consolidation.

In the technical area of soil mechanics and foundation engineering, he developed a number of calculation procedures and tools, introduced the basic theory of compensated foundations combined with friction piles, and proposed a new method to estimate negative skin friction on point-bearing piles. He extensively studied the seismic behavior of the soil-foundation-structure complex. He designed the free torsion pendulum to be able to estimate in the laboratory the dynamic modulus of rigidity of the soil and thus determine the speed of shear and surface seismic waves. This work earned him Mexico's National University Award in Technological Innovation in 1989.

One of the most important projects in which he was a leading participant was the Latinoamericana Tower, a 44-story building in Mexico City for which he conducted soil mechanics studies and designed the foundation. He was also the consulting engineer and director for the design of the steel structure, where the concept of controlled flexibility was applied for the first time (1947–48). At the time of its construction (completed in 1956), it was the tallest building in Latin America.

Dr. Zeevaert developed a new procedure for the construction of buildings, eliminating columns in the facade to provide more architectural flexibility at the ground floor level. These ideas were introduced in the design of the headquarters of Compañía de Seguros Monterrey (1960) and Celanese Mexicana SA (1968), both built in Mexico City.

He did the analysis and design of foundations for electric power turbine generators at several industrial plants and provided advice for the foundation design of an atomic energy plant in San Jose, California.

He was also active in the field of coastal engineering, studying wave action on the coastline and hydraulics of marginal lagoons. He designed harbors and marinas for small boats at various sites in Mexico.

In some of his most important research Dr. Zeevaert sought to develop improved analysis methods for different foundation systems and to forecast the seismic behavior of building foundations and superstructure. The innovative methods that he developed to assess interactions between soil and structure are still used worldwide.

For the first time in Mexico City he recorded earthquakes (May 11 and 19, 1962), making it possible, using the seismic records of those magnitude 7 earthquakes, to define the response spectra of the subsoil in the downtown area. These data were subsequently used in the preparation of the building code for seismic design in the city's Federal District.

He also developed a method to determine subsoil resonance periods, for use in the design of tall buildings subjected to seismic forces, and sought in his research to solve problems in coastal engineering and in dewatering systems.

In addition to his substantial technical work, he was the first professor of soil mechanics and foundation engineering at UNAM's School of Engineering. After teaching at the undergraduate level (1941–71) he joined the graduate faculty, where he introduced a course on Seismic Design of Foundations. He continued teaching until 2000, including as emeritus professor after 1985.

He wrote more than 200 papers on diverse topics of soil mechanics, foundation engineering (now referred to as geotechnical engineering), and earthquake engineering. He authored the books *Foundation Engineering for Difficult Subsoil Conditions* (Van Nostrand Reinhold, 1974), *Interacción Suelo-Estructura de Cimentaciones Superficiales y Profundas Sujetas a Cargas Estáticas y Sísmicas* (Limusa, 1980), and *Seismo-Geodynamics of the Ground Surface* (Editoria e Impresora Internacional SA de CV, 1988).

In recognition of his expertise, Dr. Zeevaert was appointed an official delegate to a number of international conferences and presented his work in various technical forums. He was also invited to deliver lectures and courses on soil mechanics and earthquake engineering at universities in the United States, Europe, Central and South America, the West Indies, Taiwan, and the People's Republic of China.

He was nationally and internationally recognized for his considerable contributions. The American Institute of Steel Construction honored him with a prize for the resilience of the

Latinoamericana Tower during the magnitude 7.9 earthquake of 1957 in Mexico City. This prize was the first awarded to the tallest building outside the United States subjected to a strong earthquake and built on difficult subsoil. In 1964, for the time capsule to be buried during the World's Fair in New York, he was invited to supply information on advances in civil engineering. In 1965 he received the gold Allied Professions Medal from the American Institute of Architects. He was an honorary member of the Royal Academies for Science and the Arts of Belgium and a foreign associate of the US National Academy of Engineering. In 1987 the American Society of Civil Engineers (ASCE) selected him to deliver the Terzaghi Lecture at the convention in Anaheim, CA.

He was a member of the Asociación de Ingenieros y Arquitectos de México, Colegio de Ingenieros Civiles de México, American Concrete Institute, ASCE, Geological Society of America, Seismological Society of America, Earthquake Engineering Research Institute, and Sociedad Mexicana de Mecánica de Suelos (now Sociedad Mexicana de Ingeniería Geotécnica), for which he was a founding member and president from its establishment in 1954 until 1968. He also served as vice president for North America of the International Society for Soil Mechanics and Foundation Engineering (1961–65).

He enjoyed athletic engagement and, after youthful participation in soccer, boxing, and swimming, became proficient in golf in his later years.

His wife Celia Alcántara Sordo-Noriega died in 1995. They are survived by their two daughters and three sons: María Celia Zeevaert Alcántara (husband Alberto Peniche Echánove), Leonardo Ángel Zeevaert Alcántara, Alejandro Zeevaert Alcántara, Leonardo Zeevaert Alcántara (wife María del Rosario Zardáin), and N. Zeevaert Alcántara.

A man of great integrity and discipline, he was dedicated to his native country and revered by colleagues and students.

WALTER H. ZINN

1906–2000

Elected in 1974

"Contributions to nuclear physics and reactor development."

BY ALVIN M. WEINBERG AND ROBERT ZINN

WALTER HENRY ZINN was Enrico Fermi's close associate during the Manhattan Project and after World War II became the leading US figure in the earliest development of nuclear energy. So pervasive was his stamp on the field that a proper memorial to Walter Zinn must be nothing short of an account of the origins of nuclear energy and of his influence on its development. He died at age 93 on February 14, 2000, in Clearwater, Florida.

Walter was born December 10, 1906, in Kitchener, Ontario, Canada, the second son of Maria Anna (née Stoskopf) and John Zinn. He was the only one of his immediate family to attend college. His father worked for much of his life in a tire factory, and his brother Albert, 10 years his senior, was also a factory worker. As a boy, Walter too worked in one or more factories. He managed, though, to skip a few grades during elementary school, and when the time came entered Queen's University. He graduated in 1927 with a BA degree in mathematics and got his MA degree in 1930. In 1933 he married Jennie (Jean) A. Smith, whom he had met when they were students at Queen's. The next year he got his PhD in physics at Columbia University, and in 1938 he became a naturalized US citizen.

Adapted with permission from *Biographical Memoirs of the National Academy of Sciences*, available online at www.nasonline.org/memoirs.

Walter held teaching positions at Queen's (1927–28) and Columbia (1931–32), and was on the faculty at City College of New York (1932–41). By the time fission was discovered in 1938 he was collaborating, in a laboratory at Columbia, with Leo Szilard and Enrico Fermi to elucidate the nature of fission.

Walter had a tremendous admiration for Fermi, and was awed by his genius both as an experimental physicist and as a theorist. He appreciated that at one moment Fermi could invent a novel way to make a difficult measurement and in the next argue a subtle point in theory with the very best theorists (e.g., Eugene Wigner). Walter later enjoyed telling about having served twice as a real estate agent for Fermi by finding places for his family to live near New York City and then Chicago, traveling for work together, and what it was like to have Fermi as a friend and colleague.

He also had high regard for Leo Szilard, his collaborator on one of the first experiments on fission. While he acknowledged that Szilard was of little real help with the design or operation of the experimental apparatus, Walter characterized him as an "idea man" with few peers who motivated others to conduct the "right" experiments.

In those exciting days nuclear physicists were asking how many neutrons were emitted by a uranium nucleus undergoing fission induced by a neutron. If the answer were greater than one, a nuclear chain reaction was possible; if less than one, a divergent chain reaction was impossible. Zinn and Szilard found that about two neutrons were emitted by a fissioning uranium nucleus, confirming the results of Fermi, Herbert L. Anderson, and H.B. Hanstein. Thus was born experimental verification of the Manhattan Project's purpose: to make an atomic bomb.

After this important result was achieved, Fermi lost no time in demonstrating the chain reaction. Zinn joined Fermi's experimental team and soon became his "executive officer" as he organized the heavy experimental work necessary to carry out Fermi's plan to build a divergent chain reaction.

The aim was to demonstrate that a lattice of uranium and graphite would chain-react if it were large enough, a difficult feat given the small amount of uranium and graphite then available. Zinn participated in the first of these experiments, which was done at Columbia. This first attempt was unsuccessful, but Fermi was confident that purer uranium and graphite and improved experimental geometry would yield a positive result.

By late 1941 the plutonium branch of the uranium project was consolidated under Arthur Compton at the University of Chicago Metallurgical Laboratory, and Zinn accompanied Fermi to the Met Lab. Each experiment involved a pile of graphite and uranium about 11 feet high and 8 feet wide. Changing from one configuration to another required a team of strong university athletes bossed by Zinn, who was in daily contact with Fermi.

The first experiment that showed a divergent chain reaction was performed in May 1942. Wigner said he was so sure the pile would chain-react that he doubted he would attend the historic event (he did attend).

For the first criticality experiment, at about 3:20 p.m. on December 2, 1942, Fermi was in overall charge and Zinn saw to it that his directions were carried out. At the instant of criticality Walter was responsible for the so-called "zip" rod, a simple bar of cadmium held by a spring and tied outside the pile by a 100-pound counterweight. Holding an axe, he was ready to cut the rope holding the zip rod if the chain reaction got out of hand. Fortunately the "landing in the new world" (Compton's words in a phone call to James Conant) was uneventful and Zinn did not have to cut the rope that kept the zip rod from entering the pile.

His accounts of events at the beginning of the Manhattan Project and this first chain reaction corresponded with those published by historians, but captured much more of the excitement of the moment. He also recalled the great concern among the scientists about the possibility that the Germans were ahead of the United States in the race to produce the first bomb.

By 1946 the Atomic Energy Act had been passed by Congress and the Manhattan Project was transformed into the US Atomic Energy Commission (AEC). Most of the senior members of the project returned to their universities; their replacements included Zinn as director at Argonne: he had emerged as a natural leader—he was intelligent, very close to Fermi, and tough.

In 1948 the AEC designated Argonne as the national laboratory responsible for all work on reactors and Walter became the nominal scientific boss of several reactor projects. These included the High Flux, a water-moderated, highly enriched reactor being designed in Oak Ridge under Wigner's supervision; the NaK-cooled fast breeder prototype (EBR-1), being developed directly under Zinn's supervision at Argonne; and the newly established Submarine Thermal Reactor (STR) for naval propulsion, essentially a pressurized version of the High Flux reactor.

The EBR-1 project, Walter's baby from the start, smoothly merged with the rest of Argonne and became the first reactor to generate electricity. The High Flux, renamed the materials testing reactor (MTR), had already received extensive preliminary design at Oak Ridge, so the project was divided between the Oak Ridge group, which was responsible for the interior of the MTR, and the Argonne group, which was responsible for the external facilities required to manage the 30,000 kW generated in the MTR. Zinn chaired a five-member steering committee that oversaw the project. MTR was the first successful demonstration of a very-high-power-density, water-moderated, and water-cooled reactor.

STR was a different story. Although the AEC had assigned a naval reactor role to Argonne, Zinn's relations with Captain Hyman G. Rickover were never friendly, with the result that Argonne's role in developing STR became secondary to that of the Westinghouse Bettis Laboratory.

Relieved of prime responsibility for STR, Zinn experimented with boiling-water reactors (BWRs), which now account for about 20 percent of the world's fleet of approximately 440 nuclear power plants.

Although EBR-1, MTR, and the BWR were the main efforts at Argonne, the laboratory designed or built several other reactors: the first medium-power (300 kW) heavy-water reactor; the huge D_2O tritium producers built and operated at Savannah River, South Carolina, by the DuPont Company; and power reactors cooled by various coolants.

Walter's important role as leader of the postwar development of reactors was symbolized at the First Geneva Conference on Peaceful Uses of Atomic Energy in August 1955. This UN-sponsored gathering involved over a thousand nuclear energy experts from both sides of the Iron Curtain. The opening session was like a 13th century jousting tournament, with the Soviet Union and United States each putting forward its champion. D.I. Blokhintsev described the Obninsk 5000 kW graphite-moderated, water-cooled pilot plant; Zinn then gave the first public account of successful experiments with the boiling-water reactor. The Russian pilot plant was the forerunner of that country's plutonium-producing reactors; Argonne's BWR experiments led to the 90 large commercial BWRs now operating.

The McCarthy era occurred during Walter's tenure as director of Argonne National Laboratory, and he had a few stories to tell about the hysteria that enveloped that period, including imagined security breaches at Argonne. One particularly frustrating episode for him involved a small bottle of slightly enriched uranium that some media people and politicians were convinced had been taken by Russian spies. Walter was in some hot water until the missing bottle was discovered in Argonne's landfill. Experiences like that caused Walter to hold most politicians in low esteem, because they seemed less interested in the truth than in advancing their careers.

He left Argonne in 1956 after serving 10 years as its first director. The general campus-like layout of the laboratory reflects his sensitive practicality. He was a model of what a director of the then-emerging national laboratories should be: respectful of the aspirations of both contractor and sponsor, and confident enough to prevail when necessary.

Because at Argonne he was in no position to design and build large power reactors, he left to establish the General Nuclear Engineering Company (GNEC) with headquarters in Dunedin, Florida. The company flourished and was much involved in large-scale pressurized-water reactors. Eventually GNEC was acquired by Combustion Engineering Company, and Walter became head of its fast-growing Nuclear Division. He retired from Combustion in the early 1970s but remained on its board of directors until the early 1980s.

Walter Zinn greatly influenced the earliest postwar decision as to which of the myriad power reactor concepts to pursue. He suggested two basically different paths: variants of the naval STR, which led to the commercial PWRs and BWRs; and the fast breeder, which led to the EBR-1 and its successor, EBR-2, and breeders in Russia, Japan, the United Kingdom, France, and India. It was his persistent advocacy of the NaK-cooled EBR-1 that thrust the US reactor program on this dual path, which has been followed by most nuclear-developing countries.

His espousal of the fast breeder was based on the earliest estimates of how much uranium could be extracted. In those early days uranium was thought to be scarce, so the breeder would have to be developed if nuclear energy were to be a long-term source of energy. Thus a primary goal of the earliest reactor development plan was the fast breeder. In hindsight, the relative abundance of uranium made the quick development of the fast breeder unnecessary, although Zinn's EBR-2, a 20,000-kW sodium-cooled reactor, was a major technical success.

Walter was proud of his work on the development of nuclear energy for the production of electricity. He worked on many of the designs that later became standard for the nuclear power industry. He prioritized reactor safety, and recalled experiments at the Idaho test site where a reactor was purposely destroyed to better understand various safety issues. He held that properly designed and operated reactors were very safe and firmly believed in a bright future for nuclear energy.

Many of the most important decisions of the early American nuclear effort are attributable to Zinn. Among those were the establishment of the Reactor Test Station in Arco, Idaho, where the prototypes of the first naval reactor as well as

MTR, EBR-1, and EBR-2 were built and operated; and the founding of the American Nuclear Society (ANS), for which he was the first president. Today ANS has about 10,000 members and is the main technical society in the field of nuclear science and engineering.

As something of a gray eminence of nuclear development, Walter received the highest honors: the Ford Family's Atoms for Peace Award (1960), the Enrico Fermi Award (1969), and election to membership in both the National Academy of Sciences (1956) and National Academy of Engineering (1974). He also served on the President's Science Advisory Committee during the 1960s. In 1957 Queen's University awarded him an honorary DSc degree.

Jean died in 1964. In 1966 Walter married Mary Teresa Pratt; she died in 2008. His stepsons Warren and Robert Johnson died in 2020 and 1991, respectively. He is survived by his sons John Eric and Robert James Zinn and nine grandchildren.

APPENDIX

Members	Elected	Born	Died
Mihran S. Agbabian	1982	12/9/1923	2/12/2019
John F. Ahearne	1996	6/14/1934	3/12/2019
Stig A. Annestrand	1989	9/18/1933	3/27/2018
Frank F. Aplan	1989	8/11/1923	11/3/2020
Egon Balas	2006	6/7/1922	3/18/2019
Grigory I. Barenblatt	1992	7/10/1927	6/22/2018
Bruno A. Boley	1975	5/13/1924	2/11/2017
Edmund M. Clarke	2005	7/27/1945	12/22/2020
Archie R. Clemins	2006	11/18/1943	3/14/2020
Dale L. Critchlow	1991	1/6/1932	5/6/2016
Richard E. DeVor	2000	4/18/1944	7/26/2011
George E. Dieter	1993	12/5/1928	12/12/2020
Diarmuid Downs	1987	4/23/1922	2/12/2014
Mildred S. Dresselhaus	1974	11/11/1930	2/20/2017
Tony F.W. Embleton	1987	10/1/1929	11/13/2020
Fazıl Erdoğan	1997	2/5/1925	10/2/2015
James A. Fay	1998	11/1/1923	6/2/2015
Christodoulos A. Floudas	2011	8/31/1959	8/14/2016
Abdel-Aziz A. Fouad	1996	5/10/1928	10/21/2017
Robert A. Frosch	1971	5/22/1928	12/30/2020
Ralph S. Gens	1983	11/25/1924	1/3/2019
Irvin Glassman	1996	9/19/1923	12/14/2019
Robert W. Gore	1995	4/15/1937	9/17/2020
William R. Gould	1973	10/31/1919	3/11/2006
Thomas L. Hampton	1997	1/24/1931	10/4/2017
Zvi Hashin	1998	6/24/1929	10/29/2017
Robert C. Hawkins	1985	3/20/1927	12/28/2018
L. Louis Hegedus	1989	4/13/1941	5/24/2017
J. David Hellums	1998	8/19/1929	6/26/2016
Robert W. Hellwarth	1977	12/10/1930	1/20/2021
Stephen A. Holditch	1995	10/20/1946	8/9/2019
D. Brainerd Holmes	1977	5/24/1921	1/11/2013
Edward E. Hood Jr.	1980	9/15/1930	2/3/2019
Edward E. Horton	2002	11/13/1927	8/13/2015
Leon M. Keer	1997	9/13/1934	1/12/2021

continued next page

Members	Elected	Born	Died
Lee A. Kilgore	1976	8/10/1905	10/23/2000
Sung Wan Kim	2003	8/21/1940	2/24/2020
John F. Knott	2003	12/9/1938	10/5/2017
Leonard J. Koch	1981	3/30/1920	5/15/2015
Juan C. Lasheras	2012	8/16/1951	2/1/2021
Edwin N. Lightfoot Jr.	1979	9/25/1925	10/2/2017
Eugene Litvinov	2020	7/1/1950	9/25/2020
James W. Mar	1981	3/10/1920	3/4/2017
Frank E. Marble	1974	7/21/1918	8/11/2014
Benjamin F. Montoya	2001	5/24/1935	12/19/2015
Sia Nemat-Nasser	2001	4/14/1936	1/4/2021
Jun-ichi Nishizawa	2010	9/12/1926	10/21/2018
Robert Plunkett	1974	3/15/1919	3/19/2019
Howard Raiffa	2005	1/24/1924	7/8/2016
Eugene D. Reed	1971	10/12/1919	10/29/2008
Anatol Roshko	1978	7/15/1923	1/23/2017
Victor H. Rumsey	1980	11/22/1919	3/11/2015
T.W. Fraser Russell	1990	8/5/1934	11/29/2019
Murray B. Sachs	2002	9/3/1940	3/3/2018
Lanny D. Schmidt	1994	5/6/1938	3/27/2020
Ephraim M. Sparrow	1986	5/27/1928	8/1/2019
Roger W. Staehle	1978	2/4/1934	1/16/2017
Derald A. Stuart	1983	11/9/1925	5/26/2010
George W. Swenson Jr.	1978	9/22/1922	2/22/2017
Peter B. Teets	1999	2/12/1942	11/29/2020
Daniel M. Tellep	1979	11/20/1931	11/26/2020
Joseph F. Traub	1985	6/24/1932	8/24/2015
Daniel I.C. Wang	1986	3/12/1936	8/29/2020
Robert L. Wiegel	1975	10/17/1922	7/9/2016
Edward Woll	1977	5/29/1914	12/17/2010
M. Gordon Wolman	2002	8/16/1924	2/24/2010
Leonardo Zeevaert Wiechers	1978	11/27/1914	2/16/2010
Walter H. Zinn	1974	12/10/1906	2/14/2000