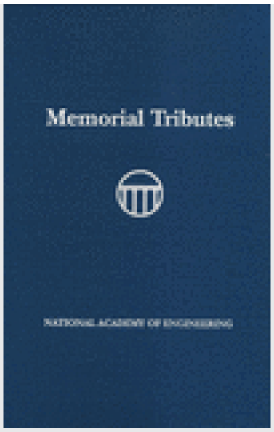

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FOREWORD

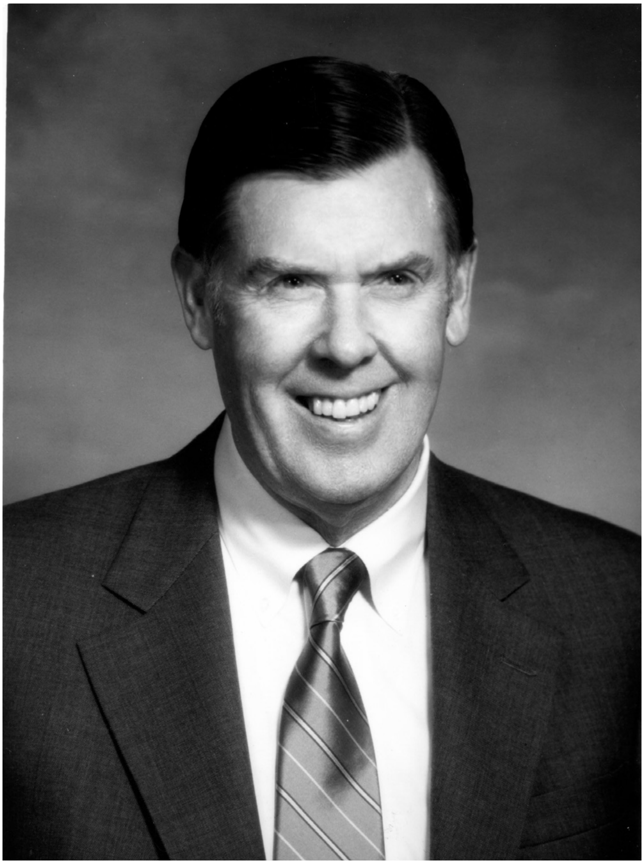
THIS IS THE TWENTIETH VOLUME in the *Memorial Tributes* series compiled by the National Academy of Engineering as a personal remembrance of the lives and outstanding achievements of its members and foreign members. These volumes are intended to stand as an enduring record of the many contributions of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

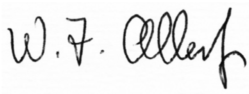
Through its members and foreign members, the Academy carries out the responsibilities for which it was established in 1964. Under the charter of the National Academy of Sciences, the National Academy of Engineering was formed as a parallel organization of outstanding engineers. Members are elected by their peers on the basis of significant contributions to engineering theory and practice and to the literature of engineering or on the basis of demonstrated 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 and technology. 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 foreign members, our colleagues and friends, whose special gifts we remember in these pages.

Julia M. Phillips
Home Secretary

Memorial Tributes

NATIONAL ACADEMY OF ENGINEERING





WILLIAM F. ALLEN JR.

1919–2014

Elected in 1986

"For creative design and analysis of advanced electric generating stations and outstanding leadership of a large and innovative engineering-construction company."

BY KENNETH F. REINSCHMIDT

WILLIAM F. ALLEN JR., of Braintree, Massachusetts, passed away September 21, 2014. He was born on June 22, 1919, in North Kingstown, Rhode Island. Bill graduated with a BS degree in civil engineering from Brown University where he later worked as a mechanical engineering instructor. He served in the US Navy as a Lieutenant (jg) from 1944 to 1946. In August 1945 he was on board one of the vessels in the US invasion fleet headed toward a landing in the Japanese home islands when the atomic bombs fell on Hiroshima and Nagasaki to end the war. He often recollected later that atomic weapons had saved his life. He served in Japan for 10 months, describing in his own words, "I was at sea on LST 751 when the Japanese capitulated. Since we were supposed to storm the beaches we were initially not equipped to occupy Japan; we were ordered to find equipment and material to supply our forces and to feed the Japanese people who were starving when we arrived."

He was a staunch supporter of civilian nuclear power and was instrumental in seeing the need to adapt military technology such as nuclear submarines to the civilian energy sector. He firmly believed that civilian nuclear power would be a clean, safe, economical, and unlimited source of energy for years to come.

After the war's conclusion Bill stayed with the US occupation forces to house and feed the Japanese civilian population and to rebuild and replace infrastructure destroyed by US bombing. Although a relatively junior Navy officer, Bill had a high level of responsibilities and learned much in a short time about large project management, project engineering, construction of large engineering projects, supply chain management, and collaboration among different organizations, disciplines, and backgrounds (for example, the US Navy and US Army). This project experience would serve him well on his return to civilian life in engineering and construction. After demobilization in 1946, Bill returned to the US and enrolled in Harvard University under the GI Bill of Rights. He received an MS degree in mechanical engineering from Harvard in 1947, where he then became a teaching fellow.

In 1948 Bill joined the Stone & Webster Engineering Corporation in downtown Boston. At that time the company was relatively small by today's standards and served largely industrial and utility clients but had completed projects across the width of the US as well as in selected foreign countries. It was founded in 1889 by Charles Stone and Edwin Webster, members of the Massachusetts Institute of Technology's first graduating class in electrical engineering. They emphasized engineering professionalism, integrity, and service during their stewardship of the company. Bill Allen exemplified the founders' traditions, professionalism, and management ethics.

He rose rapidly in the company's organizational ranks, from mechanical engineer to engineering manager, to vice president and director of engineering (1968), to senior vice president (1971), to president (1972) and chief executive officer (1973), and retired in 1995 after serving as CEO for more than 20 years. On his watch, Stone & Webster expanded to more than 17,000 employees and opened new offices in New York City, Houston, Cherry Hill, New Jersey, Denver, Chicago, Pleasanton, California, Atlanta, Toronto, London, and other locations in order to have close access to clients as well as local engineering resources.

Bill participated in many engineering and construction projects throughout the world and was noted for his commitment to technical excellence and innovation. He wrote 16 significant technical publications, generally in the areas of steam electric power plants, two-phase flow (water/steam), improvements in overall steam power plant efficiency, the heat cycle, and properties of steam.

One of his major impacts was in the field of nuclear power where he recognized its potential and very quickly moved Stone & Webster into the nuclear era, starting with the first civilian nuclear power plant in Shippingport, Pennsylvania. Space is too short to list the projects, nuclear and otherwise, that Bill and Stone & Webster worked on serving the nuclear, electric utility, and process chemical industries worldwide. Unfortunately, events such as the accident at Three Mile Island Nuclear Power Station, the accident at Chernobyl in Ukraine, and inconsistent policies of government agencies made it difficult to succeed in the nuclear power sector.

Under Bill's leadership, Stone & Webster was also innovative in other areas. He acquired computers for use on projects as early as the 1970s, when a computer was a huge IBM water-cooled mainframe. Stone & Webster expanded its use of computers for project management and then acquired minicomputers for computer-aided design (CAD) and construction long before its competitors made the investment in this technology. Making use of Stone & Webster's expertise in engineering, construction, procurement, plant operations, and the use of powerful computer systems, he led Stone & Webster in developing and applying a computer-based integrated project management system for use in the engineering and construction industry. Then, in the 1980s, Stone & Webster led the trend from mainframes and minicomputers to personal computers for engineering, design, and drafting applications.

Bill was a licensed professional engineer in 46 states and Canada. He displayed all his licenses on his office wall, an awe-inspiring sight for new employees as well as prospective clients.

Reflecting his many contributions to the field of mechanical engineering, especially multiphase flow and properties of steam, Bill was elected a member of the Newcomen Society, the world's oldest society specializing in the history of engineering and technology, in 1990. As a result of his interest and involvement with engineering education, he received the honorary degree of doctor of technology from the Wentworth Institute of Technology in Boston in 1983 and the honorary degree of doctor of engineering from Northeastern University in 1990.

He was well known for caring about the people who worked with and for him. He was invariably polite, cordial, and gentlemanly. He answered all his incoming telephone calls himself and dialed all outgoing calls rather than deferring to his secretary or an answering machine. If an employee called Bill's number, the CEO himself would answer. Part of his humanity was his phenomenal ability to remember the names and faces of all acquaintances and employees. If he encountered a newly hired employee whose name he didn't know, he would ask other employees for the name until he learned it; after that he never had to ask again.

One former employee recalls the time that Bill sent an interoffice memo (in pre-email days) to all staff with a reprint of an article that he had read, while on an airplane, regarding hotel safety and how to survive a hotel fire. Bill felt that it would be useful for the many Stone & Webster people who traveled to read the article. Later that year, an employee was on vacation when the hotel he was staying at caught on fire. The employee was able to escape from the inferno by using information from the article that Bill had distributed. While 85 people perished in the fire, the employee was fortunate to escape and still contends that, if it were not for Bill's thinking of others and sharing the article, the outcome of his vacation could have been much different.

Bill was down to earth and could communicate with clients and employees at all levels. His father died when Bill was young, and he was devoted to his mother who lived to be 94. He would personally perform maintenance to his mother's house and yard every other Saturday as he had done since childhood.

Bill gave generously of his time to participate on public service boards and charitable organizations, including as vice chairman of the Board of Trustees of Northeastern University, chairman of the Board of Trustees of Thayer Academy, and member of the Board of the Massachusetts Eye & Ear Infirmary and of Massachusetts Blue Cross/Blue Shield, among others. He was a director of the National Board of Junior Achievement and the US Council for Energy Awareness. He was a member of Sigma Xi, Tau Beta Pi, and the National Society of Professional Engineers. He was a founder of St. Clare's Parish in Braintree, MA, later joking that he helped found St. Clare's because his former parish was too far to walk to Mass on cold snowy mornings.

Bill was known as a stalwart leader and dear friend to many who was devoted to his family, community, and church. He will be remembered for his intellect, generosity, modesty, sincerity, charm, and wit. He could be very humorous, with a very dry wit, some of which passed over his listeners' heads, so Stone & Webster employees had to be alert to his remarks to be sure he was being understood and not just being facetious. His technical understanding coupled with his direct, low-key management style inspired great loyalty among his employees, many of whom stayed with Stone & Webster for 20 years and more. Even those who left for other employment would later, when making a decision, ask themselves, "What would Bill Allen do in this situation?"

He was married for 62 years to the late Doris (Pendoley) Allen and is survived by sons William, Thomas, and Paul; daughter Janet; and five grandchildren.

Bill Allen's influence was widespread; he will be greatly missed by his family, friends, coworkers, colleagues, and many others whose lives he impacted. As Ralph Waldo Emerson said, "An institution is the lengthened shadow of one man." This was never truer than in the case of Bill Allen and Stone & Webster.


C. A. Amann

CHARLES A. AMANN

1926–2015

Elected in 1989

"For contributions to the technical advancement of heat engines of all types and leadership in furthering the understanding of such engines."

BY JOSEPH M. COLUCCI

When his son Rick was in kindergarten, he was asked what his dad did. He replied, "He walks and he talks and he thinks a lot."

CHARLES A. AMANN, or Chuck as he preferred to be called, was a leading force in General Motors' and the automotive industry's efforts to improve engine efficiency, reduce emissions, and evaluate numerous alternative power plants. He died on March 10, 2015, at age 88, leaving a legacy not only of outstanding technical contributions but also as a loving husband, father, grandparent, great grandparent, coach, educator, friend, and all-around good guy.

Chuck was born on April 21, 1926, in Thief River Falls, Minnesota (in the upper northwest corner of the state), and grew up in St. Paul, where he played trumpet and piano and was in a dance band. He obtained a BS in aeronautical engineering and an MS in mechanical engineering from the University of Minnesota in 1946 and 1948 respectively.

He joined General Motors Research Laboratories (GMR) in 1949 and got involved in design, analysis, simulation, and experimental research on a broad range of engines and devices. These included automotive and aircraft gas turbine engines, reciprocating internal combustion engines (Otto and diesel cycle), Rankine and Stirling cycle engines, various supercharging techniques, and air-cushion vehicles. The main focus of his research was to understand how the combustion process and thermodynamic and fluid mechanic principles could be utilized to improve engine efficiency and reduce engine emissions.

His skill as a research engineer led to supervisory and managerial positions at GMR. He was assistant head of the Gas Turbines Department, and then head of the Engineering Research and Engine Research Departments from 1973 to 1989. In 1989 he was appointed a research fellow and director of GMR's Engineering Research Council.

Chuck was a prolific writer. While at GMR he authored more than 50 technical papers, mainly for the Society of Automotive Engineers (SAE). He also coauthored two books: *Combustion Modeling in Reciprocating Engines* (with James N. Mattavi; Plenum Press, 1980) and *Passenger Car Diesels* (SAE, 1982). He received 18 patents. In addition, he was an exemplary speaker and gave invited lectures in Europe and Asia as well as North America.

Chuck was recognized for his contributions in many ways. In addition to his election to the NAE in 1989, he was elected as a fellow of the SAE in 1984, served on numerous committees, and received the society's Arch T. Colwell Merit Award for technical papers in 1972 and 1984 as well as the Lloyd L. Withrow Distinguished Speaker Award in 1986 and 1992. He also received the American Society of Mechanical Engineers (ASME) Internal Combustion Engine Division's Internal Combustion Engine Award in 2000. In 1991 he was selected for the University of Minnesota's Outstanding Achievement award.

In addition to the SAE, Chuck was a member of ASME, the Combustion Institute, Tau Beta Pi, and Sigma Xi.

When he "retired" from GM in 1991, he formed a consulting company called KAB Engineering. The name stood for "keeping Amann busy," and is a small exposition of Chuck's wry wit. In retirement he maintained his strong interest in engines, their emissions and fuel economy, automotive propulsion alternatives, alternative fuels, energy resources and their supporting infrastructures, and the threat of global warming. He continued to write, and provided numerous technical papers and lectures for the SAE's Historical Committee. By the time of his last lecture, Chuck was confined to a wheelchair. But his determination was still strong. He was wheeled to the stage by his son Rick and gave another outstanding Amann talk.

Chuck served on technical advisory committees for the Gas Research Institute and Oak Ridge National Laboratory, and on National Research Council study committees. He taught engineering courses at Minnesota, Arizona, and Wayne State Universities, and was a guest lecturer at Michigan State University for over 15 years. He was a firm believer in the importance of education, and he was a strong supporter of the SAE's "A World in Motion" program to teach STEM skills in primary schools.

Chuck believed that there was more to education than classroom learning. He and Marilynn took their four children on motor trips around the country. He believed that an information center a day made it a good trip.

Throughout his career, and with his family, he stressed, "To your own self be true." He was not afraid to take contrarian positions in discussions, whether at work regarding technical issues or at home with his family discussing life.

Chuck and his wife of 64 years, Marilynn, were founding members of the Northminster Presbyterian Church in Troy, Michigan. He sang in their choir for 55 years. He wrote music and coached the Birmingham, Michigan, YMCA swim team for years. He is survived by Marilynn; children Richard, Nancy, Barbara, and Julie; 10 grandchildren; and six great-grandchildren.

It was my honor to have known Chuck for 55 years. He was a respected technical associate and a true friend. He will be missed.

FREDERICK T. ANDREWS

1926–2013

Elected in 1988

"For contributions and leadership in the establishment of world telecommunication standards and in the development of digital transmission and switching systems."

BY STEVE WEINSTEIN
SUBMITTED BY THE NAE HOME SECRETARY

The IEEE Communications Society (ComSoc), together with the larger IEEE community, was saddened by the death on September 15, 2013, of a deeply respected and admired colleague, FREDERICK THOMAS ANDREWS.

Fred was president of ComSoc in 1986–1987, among many other responsible positions he held in both ComSoc and the IEEE. He was elected an IEEE fellow in 1973 for "contributions to digital transmission and to systems, and to transmission objectives and standards" and eventually became an IEEE life fellow. He was a noted communications industry innovator and executive, retiring as vice president for Technology Systems of Bellcore, the telephone companies' R&D organization that came out of the breakup of AT&T. It later became Telcordia and, most recently, a unit of Ericsson. To the many people he worked with in ComSoc and the telecommunications industry he was also a modest and good-natured colleague and friend, a model for the idea that a great manager can at the same time be a gentle and considerate human being.

Fred—better known to his family by his middle name "Tom"—was born October 6, 1926, and graduated in electrical engineering from Pennsylvania State University in 1948. A brilliant student, he was chair of the university's IEEE Student Branch in 1946–1947 and valedictorian of his engineering class, and after graduation was quickly hired by Bell Laboratories, where he worked for the next 35 years on digitization of the telephone network. He made pioneering contributions to digital communications, most significantly to development of the first commercial PCM (pulse-code modulation) system, a huge innovation after many decades of reliance on FDM (frequency division multiplexed) systems for transmission of multiple voice channels either between local telephone offices or over large inter-city distances. The ambitious plan was to use existing twisted pairs, interconnecting telephone offices, that had previously been used for one voice channel alone, for a multi-channel TDM (time division multiplexed) signal. The 24-channel T1 system that resulted was one of the most important telecommunications innovations of the 20th century.

Fred and the other young engineers defining a digital transmission system came up with concepts that were critically important to a successful design, addressing problems such as baseline wander (for the decision threshold between "1s" and "0s") and crosstalk between twisted pairs. As he reported in his April 2011 article "Early T-carrier history" in *IEEE Communications Magazine*, "One day the proverbial light bulb went on and we had the idea that solved this [baseline wander] and several other problems. If '1s' were transmitted by alternative positive and negative pulses and a '0' by no pulse, there would be virtually no wander…. Bob Aaron analyzed the new bipolar proposal [and] was quick to show that the new bipolar line signal's frequency components extended to only half the frequency of the original line signal. The resulting lower crosstalk levels saved the day." Fred contributed to further innovations in this first T-carrier system including the frame synchronization scheme. As Irwin Dorros notes, these contributions "[made] it possible to get 1.544 megabits per second on wire pairs that had inherent distortions and crosstalk, at one mile repeater spacings. It doesn't sound like much now, but it was a great achievement at the time in the 1960s." True to Fred's character, his 2011 article is full of acknowledgments to colleagues while claiming little for himself, but it is certain that he was a creative and essential member of the team that created the T-carrier system and launched the digital era of communications.

Fred's involvement with international transmission standards began in the early 1960s when he became chair of Study Group Twelve of the CCITT (International Telegraph and Telephone Consultative Committee, a unit of the International Telecommunications Union that was later renamed ITU-T). Among other accomplishments, he helped define limits on delay performance of voice circuits incorporating satellite links and replacing older subjective methods for rating telephone sets by objective measurements, in particular using a reproducible machine-generated voice-like signal source. This work "led to my involvement with the Communications Society," as Fred explained in his 1999 oral history interview for the IEEE.[1]

ComSoc much later awarded him the Edwin Howard Armstrong Achievement Award (1980) for his pioneering contributions to digital communications and international cooperation (this is the citation for the award he received in 1985). He received the IEEE Award in International Communications (1985) "for his contributions and leadership in the establishment of international transmission objectives and standards." He also won Telephony's Ray Blain Award for Outside Plant Achievement in 1991 and the IEEE Haraden Pratt Award in 1988 "for sustained contributions and commitment to the Institute, particularly for leadership in strategic planning and electronic product development."

His rise in the managerial ranks at Bell Labs began with his T1 accomplishments. In 1956 he was promoted to lead a group

[1] Andrews FT. 1999. Transcript of Oral History Interview. IEEE Global History Network, available at www.ieeeghn.org/wiki/index.php/Oral-History:Fred_Andrews.

applying digital carrier concepts in the local network. Between 1958 and 1982 further promotions and broader responsibilities followed, including transmission planning, military communications engineering, loop electronics development, and switching system engineering. He became a director in 1962, leading the formulation of specifications and controls for voice quality in end-to-end connections across the Bell System network, and an executive director in 1979, responsible for meeting the systems challenges of an evolving digital telephone network. With the AT&T divestiture he was appointed to head the Bellcore vice presidential area responsible for generic requirements and technical analysis of telephone networking equipment used by the Bell Operating Companies, a position he held until his retirement in 1990. Innovations from his area were incorporated in Operating Company specifications, facilitating optimum purchase decisions.

He simultaneously became a leader in his technical community. His ComSoc involvement began in the early 1960s with a working group on telephone testing standards. In addition to terms as chair of ComSoc's Transmission Systems Technical Committee, VP Technical Affairs, board of governors member, vice president and president, he was chair from 1984 to 1990 of the Steering Committee of the International Switching Symposium. Those of us who were active with him in ComSoc remember him conducting board of governors meetings with a calm assurance that gave everyone a chance to participate but kept the meeting moving along.

At the IEEE level, he was, at different times, a member of the IEEE Awards Board and of the IEEE Fellow Committee, chair of the Alexander Graham Bell Medal Committee, chair of the TAB Electronic Products Committee, chair of the IEEE Strategic Planning Committee, and 1992–1993 Division III director on the IEEE Board. In several of these contexts he helped define the IEEE Electronic Library as a functional system and as a business, a large contribution to what the IEEE is today. He also became the first vice president of the IEEE Foundation. Vijay Bhargava recalls, from the time in the early 1990s when he and Fred were both on the IEEE board of directors, that

Fred was a calming influence in the debates over globalization of the IEEE and supported efforts to open an IEEE Singapore office, as well as acting as a mentor to many of his younger board members.

There are fond memories among his colleagues of working and relaxing with Fred. Ralph Wyndrum recalls:

"I am reminded of being in Mississippi, among the biting chiggers on Rte. 468 outside of Brandon. We were there with Fred Andrews, Eric Sumner, Irv McNair, and possibly Hank Hardaway viewing the installation of one of the first T1 line based subscriber loop multiplex systems in about 1972. Fred, always a very professional photographer with a good sense for interesting scenes, took a photo of an old, natural wood ramshackle frame house on a trailer, going by on the highway pulled by a 1950s pickup truck. Fred took several pictures of it as it rolled by, and seeing that we were wondering why, said it must be the home of someone from further out in this rural area who had heard that Brandon was getting upgraded from eight-party to two-party and single-party service, and would be solid evidence of the contribution AT&T and South Central Bell was making to the future of Mississippi! Fred was a great boss, wise, yet humorous, always with valuable and timely advice and willing to take the time to coach his people."

Alan Chynoweth wrote that "No one could have had a finer colleague. When Bellcore was being formed, my decision to join was much helped by knowing that Fred had already agreed to do so." He recalls a golf game during a Bellcore management retreat which he and Fred joined as a learning experience since neither of them had golfed before. "Painfully slowly we hacked our way around from hole to hole, taking many strokes beyond par each time. So, at the next hole, though the preceding players were still on the green, there was no point in us waiting. Fred took a mighty swing and, miraculously, connected so cleanly that the ball went clear as far as the green and landed in the golf cart of our startled colleague, Tom Powers, just as he was driving away. That evening, at the 'awards' dinner, Fred was presented with a mangled golf club."

Not just a technologist, Fred loved the outdoors, particularly the beautiful lakes and forests of the Adirondack Mountains of upstate New York. He was both a participant and an audience member for music and theatrical events in his community. He had acting and other roles in amateur theater productions by the Stony Hill Players in Union County and Wagon Wheel Players in Monmouth County and supported the Paper Mill Playhouse in Milburn, New Jersey. He and his wife, Nancy, sang in church choirs and performed in musical events of their retirement community. As his friend Fox Stoddard commented, "They joined several other BTL and AT&T retirees who also reside there. Tom volunteered on community committees—financial review and operations—where his friendly personality, knowledge, and leadership skills became known to all. He was elected chairman of the residents council, which coordinates and directs all the many community committees. His leadership was greatly appreciated and helped make Fellowship Village [NJ] a wonderful place to live. A memorial service was held at Fellowship Village on September 21, 2013, attended by Tom's family, friends, and BTL/IEEE colleagues."

Fred remained close to his professional community, writing his authoritative T1 history article among other activities in recent years. His friends and colleagues will not forget his initiative, technical insights, and warm personality that had so much influence in creating the infrastructure and professional environment for the vibrant communications industry of today.

ALBERT L. BABB

1925–2014

Elected in 1972

"Engineering contributions to the development of artificial kidney systems and medical applications of nuclear energy."

BY BRUCE A. FINLAYSON

ALBERT LESLIE BABB, a central figure in developing the home kidney dialysis unit, died October 22, 2014, at age 88. He was born in Vancouver, British Columbia, on November 7, 1925, and earned a bachelor's of applied science (first class honors) in chemical engineering at the University of British Columbia in Vancouver (1948), and MS (1949) and PhD (1951) degrees from the Department of Chemical Engineering at the University of Illinois.

In 1952 he was appointed assistant professor of chemical engineering at the University of Washington in Seattle with the task of developing a Nuclear Engineering Department. His thesis work had involved mass transfer, and he took summer jobs with General Electric in Richland, Washington (working on separating plutonium and uranium from fission products), and Argonne National Laboratories in Illinois to learn about the nuclear industry. By 1955 the first graduate courses in nuclear engineering at the University of Washington were ready, and in 1965 the Department of Nuclear Engineering was formed with Babb as chair (1965–1981). He was also director of the university's Nuclear Research Laboratory from 1961 to 1973. The laboratory was to play an important role in his accomplishments.

In 1963 Belding Scribner, head of the Division of Nephrology at the University of Washington, had developed a technique for continuous hemodialysis to treat acute kidney failure in individual patients, but the process was costly and labor intensive, limiting the number of patients that could be treated. Wells Moulton, chair of the Chemical Engineering Department, referred him to Dr. Babb, whose experience in mass transfer was an excellent background for understanding the nature of dialysis. In collaboration with Dr. Scribner's medical team, Dr. Babb and a team of engineers (at the Nuclear Research Laboratory) designed a device (dubbed the "monster" by patients and nurses) that safely automated dialysis and could serve several patients at one time while cutting the cost in half. Instead of the previously used sodium bicarbonate, the dialysate was sodium acetate and the device could provide dialysate to five bedside stations simultaneously. Later it was learned that using sodium bicarbonate would have created severe contamination problems in the home dialysis unit that were not a concern with sodium acetate. The unit did, however, use large tanks and was very noisy.

Since there were many more patients than could be accommodated at the Artificial Community Kidney Center, a committee selected those who should be treated, eliminating, for example, those under 16 years of age. Dr. Scribner had been treating a 15-year-old girl who would need dialysis in four months and he asked Dr. Babb if he could design a home unit. While there had been a few examples of a home unit using a batch tank as the dialysate supply system, this approach would not have been acceptable to the selection committee as it would have been construed as circumventing the selection process. Dr. Scribner suggested developing a home dialysis unit as an experimental research project with external funding, a project over which the committee would have no jurisdiction. After learning the girl was the daughter of someone he knew, Dr. Babb carefully thought about the problem and accepted the challenge.

As director of the Nuclear Reactor Laboratories, Dr. Babb had a team of engineers that agreed to work on the project. The constraints were severe: build a system that would remove creatinine and urea and other chemicals in a fail-safe environment without the attendance of nurses and doctors. Dr. Babb took a stopwatch to the university hospital to see how the current system operated; it was very labor intensive and not suitable for an unmonitored system. His design team worked with Dr. Scribner's medical team to establish the design criteria. A central logic unit would provide alarms to protect the patient. The thermal hydraulic system had to mix precise proportions of dialysate and tap water and heat to a precise temperature. Some of the necessary equipment, including gauges and sensors, was not available for standard purchase, but manufacturers provided what was needed and the pumps were quiet enough for home use. A fault-tree analysis estimated the consequences of component failure.

While the engineers at the Nuclear Research Laboratory worked on their design and tests, they established a "dean watch": the dean had been instrumental in getting the laboratory going and frequently brought visitors to see it; when he did, the engineers would move the dialysis unit out of sight until the visit was over. The final machine was called Mini-I (to avoid the word monster). It was delivered four months later and the girl and her mother were trained in its use. By November 1964, hemodialysis had been performed in 40 homes without any significant incidents. The optimization work suggested that short, multiple parallel blood paths with a thickness of about 200 micrometers were best, which eventually led to disposable hollow fiber dialyzers. The Kiil dialyzer, the workhorse since 1960, became obsolete.

Designs were then made for Mini-II, and the university advertised the availability of bid documents. Invention disclosures were prepared, but the design was not patented because in 1964 the University of Washington did not have a patent department (it does now!). One important consideration was that patenting the design would have delayed treatment for people who needed it to stay alive. Only four bids were received, and Milton Roy Company of St. Petersburg, Florida, was selected. By the end of 1965, five additional patients were using the commercial device for their kidney dialysis. All the patients did the dialysis during sleeping hours at home. As machine use spread around the country, it was found that some tap water had to be purified (Seattle's water was sufficiently demineralized that this had not been necessary).

In 1977 Dr. Babb published a paper that was recognized in 1996 as the top Landmark Article in 25 years in *Dialysis and Transplantation*. It showed that vitamin B-12 could be used as a surrogate molecule to design dialyzers to remove molecules with high molecular weights in addition to urea and creatinine, the main chemicals of interest. The paper gave clear, concise instructions on the design and optimization of the units.

Les Babb was recognized by membership in the National Academy of Engineering (1972) and Institute of Medicine (1982). He received the Clyde Shields Distinguished Service Award of the Northwest Kidney Foundation (1992) and was named one of the top 100 chemical engineers in the modern era by the American Institute of Chemical Engineers (2008). He was a member of the Washington State Academy of Sciences and a fellow of four technical societies. He held 21 patents and authored or coauthored 170 journal publications. A registered chemical and nuclear engineer, he was a member of 15 professional and scholarly societies, served on countless boards nationwide, and consulted with numerous companies, largely in nuclear engineering and for the Public Health Service and medical device firms. He supervised 106 graduate students in nuclear engineering and chemical engineering, 11 of whom became university faculty members. He retired in 1991 as professor emeritus of chemical engineering and nuclear engineering. His most lasting legacy, though, is the 500,000 patients around the world who undergo dialysis using commercial versions of the Mini-I prototype.

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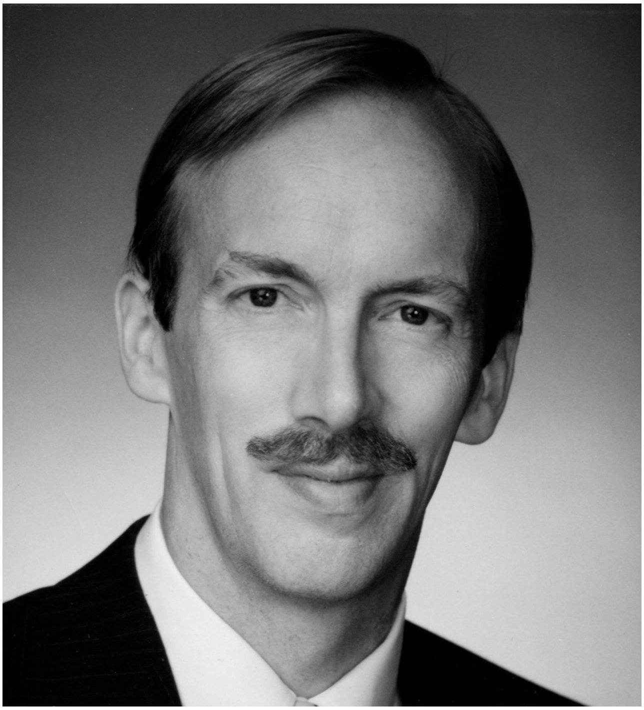
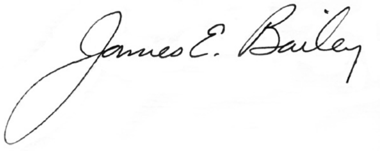



James E. Bailey

JAMES E. BAILEY

1944–2001

Elected 1986

"For research leadership in fundamental kinetic models, and for innovative basic measurements of genetically engineered cells and immobilized enzyme biocatalysts."

BY HARVEY BLANCH

JAMES EDWARD BAILEY was a pioneer in biochemical engineering and a leader in the development of metabolic engineering. His many contributions focused on the application of engineering to biological systems. He died on May 9, 2001, in Zurich aged 57.

The only child of Jim "Mac" and Doris Bailey, Jay grew up in Rockford, Illinois. He was an avid guitar player and played in his own band in high school. He studied chemical engineering at Rice University, and earned his BA in 1966 and PhD in 1969. His doctoral thesis with Fritz Horn was on the dynamics of chemical reactions with periodic operation.

After graduation Jay worked for a short period with Shell Development before joining the Chemical Engineering Department at the University of Houston in 1971. His initial research activities examined the behavior of chemical reacting systems in response to forced and autonomous oscillations. His research interests shifted toward the application of chemical engineering to biological systems. His early publications were on microbial population dynamics, development of tools such as flow microfluorimetry for characterizing dynamics of bacteria and yeast, and the behavior of immobilized enzyme reactors. His coauthored text *Biochemical Engineering Fundamentals*, with David Ollis (McGraw-Hill, 1977), brought engineering rigor to a field that had seen significant changes with the advent of recombinant DNA technology, and represented a landmark in biochemical engineering education and industrial biotechnology applications.

In 1980 Jay moved to Caltech, where he established a program in biochemical engineering that embraced opportunities in the new field of genetic engineering to manipulate cell metabolism and advance industrial biotechnology. He recognized the potential impact of incorporating entire metabolic pathways, rather than single genes, into microorganisms to produce a much broader range of microbial products.

This was the genesis of *metabolic engineering* and Jay played a key role in its development. He studied the regulation of complex biochemical pathways and their carbon flows. Jay expanded the application of metabolic engineering beyond industrial microorganisms to encompass mammalian cells and tissues and medical applications. The second edition of his textbook, published in 1986, highlighted the engineering aspects of recombinant DNA technology. The fundamental approaches he established are central to industrial biotechnology today.

At Caltech, Jay mentored a large group of graduate students, many of whom have had exceptional careers in academia and in industry. But science was not all work and no play: his research group's legendary Friday afternoon "Ho Ho's" at Caltech's Rathskeller combined free-flowing discussions with the best products of fermentation.

In 1992 Jay moved to Switzerland as professor of biotechnology at the Swiss Federal Institute of Technology, Zurich (ETHZ), where he established a large, multidisciplinary group that benefited from state-of-the-art instrumentation and computational capabilities to conduct groundbreaking studies on metabolic engineering and microbial physiology. He was an early proponent of quantitative biology and was quick to adopt experimental tools that permitted new measurements. His research output was exceptional and he continues to be widely cited.

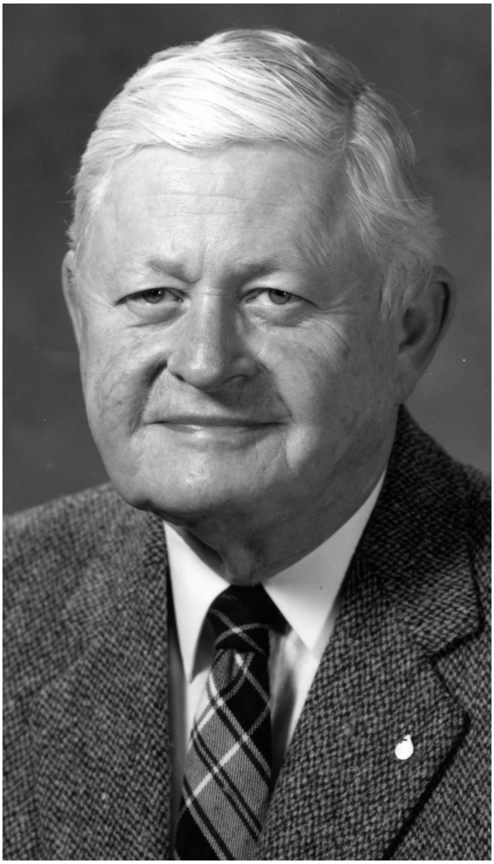
Jay's educational legacy is profound—he, perhaps more than any other, incorporated modern molecular biology into biochemical engineering, demonstrating the strengths of both fields.

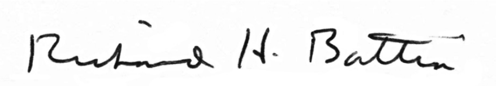
Jay advised over 100 graduate students and postdoctoral fellows over his 30-year career. His impact in fostering their independence, creativity, and passion for research is apparent. He engaged with them on a personal level, following and guiding their careers.

Jay received many honors for his research contributions, including the Alan P. Colburn Award for Excellence in Publications by a Young Member of the Institute and the Food, Pharmaceutical, and Bioengineering Division Award in Chemical Engineering Award of the American Institute of Chemical Engineers. He is remembered today by the Society for Biological Engineering's James E. Bailey Award for Outstanding Contributions to the Field of Biological Engineering, established in 2005. The award description recognizes Jay's professional and educational impact in a fitting tribute:

> James Bailey's educational legacy touched many modern biochemical and biological engineers in the profession today. The award is presented to an individual who embodies the spirit of James Bailey, one that is a pioneer, a mentor, an innovator, an integrator of biology and engineering, a teacher, and whose achievements have provided a major impact to the field of biological engineering.

Jay is survived by sons Michael Sean Bailey and Sgt. James Howard Bailey. Sean decided on a career in the movie business and is now president of Walt Disney Studios Motion Picture Production. He was recently appointed a trustee of Caltech. James, 25, is a helicopter crew chief in the US Army.





RICHARD H. BATTIN

1925–2014

Elected in 1974

"Contributions to the technology for control, navigation, and guidance for Apollo missions."

BY DONALD C. FRASER

Born in Atlantic City, New Jersey, RICHARD HORACE BATTIN (March 3, 1925–February 8, 2014) was educated at the Massachusetts Institute of Technology, where he received a BS in 1945 and a PhD in 1951. He became assistant director of the MIT Instrumentation Laboratory in 1951.

Dick was a brilliant mathematician with an uncanny ability both to solve practical problems in an intuitive way and to explain complex procedures in simple, elegant terms. The latter enabled him to provide a deep understanding of difficult subjects to generations of students who otherwise may have been lost in the mathematics, myself among them.

Battin's early 1960s paper that originated the concept of gravitational assist is perhaps the single most important insight that opened the door to exploration missions to every planet in the solar system. His work has also had a dramatic influence on the US aerospace guidance and control industry. We might very well not have landed a man on the moon if it were not for Dick Battin's pioneering effort.

An early example of Dick's intuition dates back to the 1950s, when he and J. Halcombe (Hal) Laning, a brilliant colleague of Dick's who among other things developed the world's first algebraic compiler, were collaborating on methods to guide missiles. Until then people were determining trajectories and guiding missiles back to them when they deviated. Dick and Hal realized that what was needed was a velocity vector that would take the missile from its current position to the target—the initially desired trajectory was not important. Out of some very complex analysis came a simple equation that became known as "Q guidance," named after the letter they chose to represent the key matrix in the underlying vector differential equation. But Dick's even greater contribution to this was a simple observation that had not been made before: calculating the difference between current velocity and the desired velocity yielded the "velocity to be gained." Aligning the thrust accordingly reduced the velocity to be gained to zero so that the missile went where it was supposed to go. This scheme was used in the Polaris guidance system and has been used ever since in virtually all missile and spacecraft guidance systems.

Charles Stark (Doc) Draper became a legend in the aerospace industry based on his World War II fire control work and his subsequent leadership in inertial guidance. As a result of this reputation, government agencies frequently came to his laboratory (the MIT Instrumentation Laboratory, now the Draper Laboratory) for solutions to "impossible" navigation, guidance, and control problems. They also allowed some brainstorming on what might be future needs. Shortly after the dawn of the space age Doc used this freedom to consider issues involved with sending a spacecraft to Mars to take photographs and bring the film home. Yes, film! Doc turned to Dick, Milton Trageser, and a few of their MIT Instrumentation Lab colleagues for the answer.

It was during this period that Dick developed his now well-known techniques for navigating and guiding a spacecraft outside Earth's gravity. These included the use of a telescope to do star and planetary/lunar limb sightings and the development of recursive algorithms to improve the quality of navigational estimates, including Q guidance refinement and entry guidance. He documented much of this and his later work on Apollo in his book *Astronautical Guidance* (McGraw-Hill, 1964). During this period he also discovered that one could design orbits that used the gravitation of both Earth and other planets to make more efficient trajectories in interplanetary space. The "Grand Tour" of the outer planets later used this technique.

In 1962 President Kennedy declared that the United States would land a man on the moon and return him safely to the Earth by the end of the decade. By this time, Dick had already done the work described above on space guidance and navigation and Draper's lab had developed and operated both inertial systems and early "computers" in the Polaris missile and in ship guidance systems. Based on this, NASA again turned to Doc Draper and asked him to develop the Apollo guidance and control system. His laboratory was awarded the first prime contract on the Apollo program, just 11 weeks after the Kennedy speech. Seven years later, history was made, but without Dick's early work on the Mars probe this may not have been possible.

Dick dedicated the next decade of his career to the development of the algorithms and software for the Apollo missions and those that came later. Under the leadership of Ralph Ragan (former AIAA VP of publications and second editor in chief of the AIAA *Journal of Spacecraft and Rockets*) and David Hoag, chief engineer, the program at the MIT Instrumentation Lab was divided into hardware design and development, run by John Miller (later founder of Intermetrics), and software, which Dick headed. All algorithms for guidance, navigation, and, after 1964, flight control, as well as the code to implement these algorithms, were developed under his leadership. An amusing anecdote from early in the period is that when NASA called MIT asking how big their computer for the mission would be, Dick replied, "Well, we've got to give them a number; just tell them it's a cubic foot." And that is what it became.

Following are a few of his accomplishments during this era.

As noted above, while working out how to get to Mars, Dick realized that he needed a means to improve navigational accuracy by using multiple measurements taken throughout the mission. This of course meant he also had to have a way of combining older measurements, taken elsewhere on the trajectory, with current ones. He devised what is today known as the "Kalman" filter before ever reading about Kalman's work. He did not do this in the abstract; what he did was in the context of a very real application—another example of his practical insight. By linearizing the dynamics relative to the nominal nonlinear trajectory, Dick was able to propagate covariance between measurement times using what is now widely known as the state transition matrix to obtain a remarkably compact algorithm that had to be compatible with a very constraining computer architecture. Compare Dick's 1962 paper on the recursive least squares celestial navigation problem to Kalman's original 1960 paper and you will see what I mean about his ability to make a complex problem seem simple.

The "filter" that Dick developed was dynamic in that the celestial equations of motion had to be processed in order to bring prior events forward to the time of the latest measurements. This piqued Dick's interest in the classical problems worked in earlier centuries by people like Kepler and Lambert. Dick spent several years working on his favorite hobby problem, known as the "Lambert problem," in which one seeks to find the orbit connecting two points in space with a specified time of flight. The problem is highly significant in mission analysis and orbit transfers generally. Dick's efficient "universal" solution of this problem holds for the entire energy range, covering elliptical, parabolic, and hyperbolic transfers, and he eliminated all classical singularities except those where the orbit plane is inherently not unique. He mentioned during the Richard H. Battin Astrodynamics Symposium that his solution of the Lambert problem was among his favorite accomplishments. Throughout the rest of his career he refined the solutions to these challenges with elegant, simple, and effective mathematics, many of which were published in the AIAA's *Journal of Guidance, Control and Dynamics*. He always laughed when I told him I expected his next paper on these subjects to be the impossible closed form solution!

Apollo was the first all digital fly by wire aerospace vehicle guidance, navigation, and control system. Given little or no history to work from, Dick and his team had to come up with methods for both the development and verification of the software—and on a program that was executed before the eyes of the entire world! He set the standard of excellence that was required by this high-profile manned space program and his mastery of making complex matters seem simple continuously came to bear on the problem. Methods developed under his leadership during this period are still in use today to develop and verify mission-critical software in myriad areas.

The Apollo guidance computer was extremely rudimentary by comparison to current models. It had less capacity than many of today's wristwatches, and enormously less than a smartphone. It was developed at Draper's lab under the leadership of Ramon Alonzo and Eldon Hall. The hardware had to withstand the space environment and simply could not fail—there was only one computer in each spacecraft, because of weight and space constraints. Widespread use of common hardware (for example, a single type of logic circuit) and exhaustive hardware testing succeeded—no Apollo guidance computer ever failed before, during, or after the Apollo missions.

These computers had a wire rope memory of 36,864 words and only 2,048 words of erasable memory to perform the entire mission, including all aspects of guidance, navigation, and control. The word length was only 16 bits, but one bit was used for sign and another for parity, leaving only the remaining 14 to do calculations—less than five full decimal numbers. There was no room for a higher-order language so all programming had to be done in machine language. The limited word length in particular was a continuous challenge to the software design, including the navigation filter.

The first attempts to use the filter in the Apollo guidance computer failed because of word length issues. Dick was very concerned about this and asked a young new employee, James Potter, to look at the issue. Jim was a brilliant cross-eyed mathematician who often seemed to be thinking about and looking at anything but the subject at hand (sort of like another MIT legend, Norbert Wiener). Jim disappeared for a few weeks, causing Dick to fret about both the practical problem at hand and his new employee. But Jim returned to Dick's office with the square root formulation of the "Kalman" filter, which resolved the issue—and is in regular use to this day.

This anecdote is testimony to the fact that Dick tended to gather brilliant people around him—they all enjoyed working with him and held him in the highest esteem. Most of us have been in environments where employees complained about the boss; I never heard such criticism of Dick—only the reverse.

Which leads me to some personal recollections about Dick, our time working together, and how he affected my career. He hired me from the Poseidon missile guidance group at the MIT Instrumentation Lab in 1964 and I worked for him until 1980 when I became the vice president of technical operations for the entire Draper Laboratory, at which time our roles reversed. My first assignment under him was to evaluate the feasibility of adding flight control to the Apollo guidance computers. The payoff if this could be done would be to eliminate significant weight from spacecraft by eliminating flight control–specific hardware.

With Dick's encouragement of a green engineer in his 20s (most of the team fit this description), our team thought it could be done. He agreed and NASA decided to proceed. Apollo became the world's first all-digital fly-by-wire control system. After the first lunar landing, some key members of the Apollo team left Draper's lab to form Intermetrics under the leadership of John Miller. This left some key positions open, including the head of flight control design and software for all the subsequent Apollo missions. Dick appointed me to that job (I was not yet 30), an act that greatly influenced my future and led to some very senior positions. But this is just one example of a story that repeated itself many times—many people for whom Dick was a mentor and/or teacher went on to have a significant impact on the aerospace and defense industry.

I began my association with AIAA publications as associate editor of the *Journal of Spacecraft and Rockets*. At the time, Dick was an associate editor of the *AIAA Journal*. It was very helpful to have such an experienced hand nearby to teach me the intricacies of the job. I later became editor in chief and eventually moved on to become the founder of the *Journal of Guidance and Control*. The first editorial team consisted of experienced associate editors with relevant backgrounds from the other AIAA journals plus a few new people like Stephen Osder, who proved to be the "Lou Gehrig" of associate editors. Having Dick as part of the founding team played a large part in the early success of this journal and made the task of getting it going a lot easier. It also occasioned some levity. As my boss he was just down the hall. Because he was also an associate editor for the American Astronomical Society (AAS), he sometimes received a paper that we had already rejected for our journal (rejecting papers almost always made him feel bad since he was a very feeling person). Needless to say, AAS did not publish those papers either.

Then there are the fun anecdotes. Arthur Bryson recalls that not long after Dick and Hal Laning published *Random Processes in Automatic Control* (McGraw-Hill, 1956), the local newspaper in Lexington, Massachusetts (where the Battins lived), reported that he had published a book on *Random Prophesies*. Given his ability to anticipate technical issues, perhaps this was more accurate than it seems.

The most famous of the Battin anecdotes was a software meeting in his office. A housefly was buzzing around annoying people. Dick, our world-famous guidance mentor, was fiddling with a pair of scissors. He suddenly lashed out with the scissors and cut the fly in two in midair—something no one was willing to attribute to luck!

There were other fun times, many involving travel. Perhaps tops among these for me was when he took me to an AAS conference at the Grand Teton Lodge in Wyoming, my first trip there. I think we gave a paper or a short course. But beyond the spectacular setting and the moose on the lodge's veranda one evening, my lasting memory from that trip was Dick introducing me to John Breakwell. (Between Dick and Doc Draper I had the good fortune of meeting most of our industry's early leadership.) But instead of discussing astrodynamics, John took us into the kitchen of the lodge, where a piano was stored, and entertained a growing group of people for at least an hour with his ability to play anything you wished. Another remarkable person and another technical giant!

Dick served on the MIT faculty for over 40 years. He introduced and taught the course on astrodynamics, and incorporated numerous practical examples based on his work on Apollo and other programs so his students were not learning in the abstract. Four of the people who walked on the moon and 38 astronauts have been students at MIT, and most took his course. He managed to simultaneously teach, write several books, and successfully manage a significant component of perhaps the nation's most challenging technical program. His classical textbook *Mathematics and Methods of Astrodynamics* (AIAA, 1999) is the most indispensable book in the field of astrodynamics, both for academic teaching and research and for advanced applications. It is a treasure trove of Battin's unique developments as well as numerous classical developments that he breathed new life into through his remarkable insights; these include his redevelopment of Gauss's hypergeometric functions and infinite fractions, and of Euler's "top-down method" for computing infinite fractions, and finally his use of these "special function" topics for important advances in astrodynamics computation.

When the MIT Department of Aeronautics and Astronautics established in 1981 an award in "recognition of outstanding teaching," Dick was the first recipient. Teaching was perhaps his fondest activity, and among his many lifelong honors, he was most proud of this one. From AIAA he received the Louis W. Hill Space Transportation Award (1972) (now the Goddard Astronautics Award), Mechanics and Control of Flight Award (1978), Pendray Aerospace Literature Award (1986), von Kármán Lectureship in Astronautics (1989), and recognition as an honorary fellow (1990); in 1996 he was selected for the AAS Dirk Brouwer Award; and in 2002 he received the Aerospace Guidance, Navigation, and Control Award.

Dr. Battin had been married for 65 years to the former Margery Milne who died in 2012. He leaves two sons, Tom and Jeff and their wives, Daryl and Linda, a daughter, Pamela and her husband Steve Sacks, five grandchildren (Matthew, Beth, Rachel Sacks, Kelly, and Christopher), and a great grandson, Logan, son of Matthew and his wife, Amber.

TED B. BELYTSCHKO

1943–2014

Elected in 1992

"For development of nonlinear finite element methods and their applications to large-scale simulation."

BY JAN D. ACHENBACH AND WING KAM LIU

TED BOHDAN BELYTSCHKO, a mechanical engineering professor at Northwestern University for more than three decades and a pioneer in the art of computational mechanics, died September 15, 2014, at age 71.

Ted was born Bohdan Belytschko in the town of Proskurov in western Ukraine on January 13, 1943. World War II was raging and in February 1944 his parents, Stephan and Maria Belytschko, were forced to flee westward ahead of the rapidly advancing Soviet Army. They left precipitously with only their 13-month-old son, a little food, and a few photos. They were very fortunate to board the last train from Poland to Berlin before the railroad tracks were bombed. The family continued westward in Germany, reaching the Rhine Valley and eventually settling in the town of Krefeld where they waited out the end of the war. It was there that the first name Bohdan was deemed "too foreign" by the German authorities and Bohdan was rechristened Theodore.

Ted's father was concerned about the future geopolitical uncertainties of living in a divided Germany, and immediately began to apply for permission to emigrate under the Displaced Persons Act. This was a challenging and competitive process, and one of the requirements for receiving permission to enter the United States was a sponsor who could confirm that applicants had a specific destination and would have a place to stay. Stephan and Maria made contact with a Professor Mikhailenko who lived in Chicago and who agreed to fill this role.

After numerous delays and frustrations, the family arrived in Chicago late in 1951. The Belytschkos were always profoundly grateful for the assistance "the Professor" provided as they adjusted to a totally new environment, not knowing English and with few marketable skills or financial resources. The respect and admiration voiced by his parents for "the Professor" over the years undoubtedly influenced Ted's later interest in the world of academia.

This was a difficult time, but Ted's parents found work anywhere they could and gradually achieved stability and a degree of prosperity. With the facility of the very young, Ted learned English quickly and one of his teachers in the local public school suggested that he might benefit from a different learning environment. He made some suggestions about private schools in the city, and Ted was eventually granted a scholarship at the Francis Parker School. This required a very long daily bus journey from the working-class neighborhood where he lived, but the school's academically nurturing culture provided him with a glimpse into the possibilities open to someone with ability and ambition.

By the end of middle school at Parker, Ted had developed a clear interest in mathematics and science, and he transferred to Lane Technical High School, a magnet school before the term existed, in the Chicago public school system. He graduated at the top of his class and entered Illinois Institute of Technology in Chicago on a full scholarship. Two things happened at IIT: he met his future wife Gail and Professor Philip Hodge.

IIT had a mechanics group that was very highly regarded and Ted was drawn to the field not only because of his growing interest in computational mechanics, but also because of the teaching skills and gentlemanly demeanor of Professor Hodge. With Hodge as his advisor Ted entered the graduate program in 1965 and received his PhD in 1968. He and Gail married in 1967 and were blessed with three children, Peter, Nicole, and Justine.

Ted taught at the University of Illinois at Chicago Circle until 1977, when he accepted a position at Northwestern University in Evanston, Illinois. In his remarkable career at Northwestern Ted excelled in his field and became one of the most accomplished computational mechanicians in the world. He made major innovative and fundamental contributions to solid mechanics, and especially to computational mechanics, where his pioneering research gave the field the status it enjoys today.

His contributions were multifaceted and truly visionary, and have inspired many new directions of research. For example, he developed nonlinear explicit finite element methods and multiscale and mesh-free methods, which have enabled the solution of previously intractable problems such as simulations of automotive crashes and dynamic crack growth. Other major accomplishments among his numerous innovations include methods of time integration, solid-fluid interactions, element-free Galerkin methods, the extended finite element method (X-FEM), and multiscale modeling such as bridging domain methods.

Among his important contributions to computational engineering, his three major papers on mesh-free methods have been cited more than 4,200 times and his six major papers on X-FEM have been cited about 4,000 times. He is one of the most highly cited authors in engineering science: 30,417 citations and an h-index of 91 (ISI Web of Science Citation Report, January 2014). His books on the finite element method are extremely popular with students, engineers, and professors.

His work also had an important impact on computational methods in industry. All commercial finite element software for crashworthiness analysis now uses the Belytschko-Tsai element. His method of reduced integration with hourglass control removes locking and significantly increases speed, making numerical simulations of crashworthiness possible. These inventions have been adopted for the commercial finite element software ABAQUS-EXPLICIT and LS-DYNA, and by the public domain code DYNA. His development of the pinball and related sorting bucket algorithms is used in modeling of the deployment of airbags from their fully folded configuration. These simulations have allowed companies to confidently design products using computers, reducing costs and the time required to move new designs quickly into production.

Ted received numerous honors for his research. He was a member of the National Academies of Sciences and Engineering, and a fellow of the American Academy of Arts and Sciences. From the Association for Computational Mechanics he received the Computational Structural Mechanics Award in 1997 (renamed the Belytschko Medal in 2013) and John von Neumann Award in 2001; he was also selected for ASCE's Theodore von Karman Medal in 1999, the ASME Timoshenko Medal in 2001, the Gauss-Newton Medal from the International Association for Computational Mechanics in 2002, and the William Prager Medal from the Society of Engineering Science in 2011.

He provided invaluable leadership to the mechanical engineering community. He chaired the ASME Applied Mechanics Division Executive Committee (1990–1991) and the Mechanical Engineering Department at Northwestern University (1997–2002); authored popular textbooks on computational mechanics; and served as editor in chief of the *International Journal for Numerical Methods in Engineering*, a major journal in computational science and engineering.

Professor Belytschko's legacy will live on in the work of the many students, postdocs, and researchers whose lives he influenced.

He was a true world leader in computational mechanics.

Arthur Edward Bergles

ARTHUR E. BERGLES

1935–2014

Elected in 1992

"For seminal contributions and outstanding service and leadership in the field of heat transfer."

BY R.M. MANGLIK AND R.J. GOLDSTEIN

ARTHUR EDWARD BERGLES passed away March 17, 2014, after an extended battle with a malignant brain tumor. He was 78.

During his exemplary academic and professional career over more than five decades, Art, as he was known to his many friends and colleagues worldwide, made seminal and path-breaking contributions in boiling and two-phase flows, process heat transfer, electronic and microelectronic cooling, and enhancement or augmentation of heat transfer.

Because of his pioneering work, which spanned the spectrum from microscale to the very large-scale, the field of heat transfer enhancement grew rapidly and came to be regarded as a "second-generation heat transfer technology" across the globe. Underscoring the urgency of addressing the energy-water nexus, Art would paraphrase the poet Coleridge's dilemma ("Water, water, everywhere, / And all the boards did shrink; / Water, water, everywhere, / Nor any drop to drink") and tirelessly advocate conservation along with research in and application of advanced enhancement techniques in all heat and mass transfer systems.

Art was born in New York City on August 9, 1935, to Edward and Victoria Bergles, who had immigrated from Austria. A self-taught engineer, Edward and his family moved to Rhinebeck, New York, where he completed building a hydroelectric power plant in 1938, which ran almost continuously for 47 years, producing 25 kW power.

Art attended a one-room schoolhouse and subsequently the Rhinebeck Central School System, where he graduated as valedictorian and earned his Eagle Scout Award. He studied mechanical engineering at the Massachusetts Institute of Technology (MIT), where he received his combined SB and SM degrees in 1958 and his PhD in 1962, with an intervening year as a Fulbright Scholar at the Technical University in Munich. While at MIT, he met his future wife, Priscilla (Penny) Maule, who was working in the Magnet Laboratory; they married in 1960. He earned his PE (mechanical engineering) in the state of Massachusetts in 1965.

Art started his academic career at MIT, first as research staff at the National Magnet Laboratory and in 1963 as the Ford Assistant Professor in Mechanical Engineering, before moving to the Georgia Institute of Technology as professor in 1969. In 1972 he became chair of Mechanical Engineering at Iowa State University (ISU) and was named the Anson-Marston Distinguished Professor of Engineering in 1981. After stepping down as chair in 1983, he continued to direct the Heat Transfer Laboratory at ISU until his move to Rensselaer Polytechnic Institute (RPI) in 1986. At RPI he was appointed Clark and Crossan Professor of Engineering and later served as dean of engineering (1989–1992).

In 1997 ill health forced him to retire, but even in "retirement" Art remained active as the Clark and Crossan Professor of Engineering Emeritus and senior lecturer in mechanical engineering at MIT, with an adjunct appointment as Glenn L. Martin Institute Professor of Engineering at the University of Maryland. He continued to write papers, give seminars, interact with researchers around the world, travel to conferences, and more, and would often remark, "I'm still doing what I was doing before I retired, but now I don't get paid for it."

Art's research in heat transfer was multifacetted and multidisciplinary, covering a variety of engineering systems and all modes of heat transfer processes. Most significantly, in his pioneering and extensive work on enhanced heat transfer, his many fundamental experimental and theoretical investigations were always conducted in the context of practical applications and the need to move research to industry. He was a very early investigator of, and advocate for, improved microelectronics cooling. He worked in boiling, condensation, and laminar and turbulent single-phase flows, and his passion for fundamental and applied research was further anchored by a strong interest in history; he wrote several papers on the history of heat transfer. Besides his many seminal, groundbreaking, original research articles, his writings included numerous well-received review papers that provided guidance for researchers seeking newer directions.

Relative to this latter effort, and highlighting Art's dedication to ensuring a meaningful future of heat transfer education and research, he and Warren Rohsenow very generously endowed and established the Bergles-Rohsenow Young Investigator in Heat Transfer Award in 2003. This ASME society–level annual award has been given to 10 outstanding young professors to date. Moreover, in 1997 Art and Penny endowed the Bergles Professorship in Thermal Sciences in the ISU Department of Mechanical Engineering to attract or retain an outstanding senior faculty member. This shared commitment to scholarship and research, with gifts from friends, faculty, colleagues, and corporations, also led to the endowment of the Dr. Arthur E. Bergles Scholarship in 1996 on the occasion of his retirement from Rensselaer.

Art's passion for education and fostering the careers of young scientists is further reflected in the fact that he was an advisor for 82 thesis students, and volunteered his time to serve on a number of fellowship and award selection committees. His research with students and colleagues resulted in more than 400 papers, 26 books, and some 400 invited lectures around the world.

Art was acknowledged as one of the world's leading experts in the thermal sciences, as evidenced by the international honors and awards that marked his distinguished career. Besides being elected to the NAE, he was inducted in the Polish

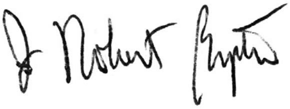
Society of Theoretical and Applied Mechanics (1987), UK Royal Academy of Engineering (2000), Academy of Sciences and Arts of Slovenia (2001), and Italian National Academy of Sciences (2003). He was a fellow of the American Society of Mechanical Engineers (ASME), American Association for the Advancement of Science (AAAS), American Institute of Chemical Engineers (AIChE), American Society for Engineering Education (ASEE), and American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), and associate fellow of American Institute of Aeronautics and Astronautics (AIAA), and was awarded four honorary professorships (University of Ljubljana, Slovenia, 1997; Technical University of Denmark, 1998; Beijing Polytechnic University, 2001; and St. Petersburg State Polytechnic University, Russia, 2008), and received honorary doctorates from the University of Porto, Portugal (1998), Rand Africaans University, South Africa (1999), and Sapienza University of Rome (2009). He was honored with all the major awards in heat transfer: the ASME Heat Transfer Memorial Award (1979), AIChE Donald Q. Kern Award (1990), ASME-AIChE Max Jakob Memorial Award (1995), ICHMT (International Centre for Heat and Mass Transfer) Luikov Medal (1998), Nusselt-Reynolds Prize (2001), ASHRAE's F. Paul Anderson Medal (2000) and Holladay Distinguished Fellow Award (2002), and the International SFT Award by the French Thermal Society (2002), among many others.

Not only did Art pursue education and research, he gave back to the community by being very active in professional organizations. He was named a life member of ASEE and ASHRAE and a 50-year member of ASME. His achievements and recognitions in professional service included terms as ASME president (1990–1991), honorary member, its highest recognition (1996), and member of the board of governors, as well as selection for the ASME Medal (2000) and the ASEE Benjamin Garver Lamme Medal (1987). He served a six-year term as the National Research Council (NRC) liaison for the Mechanical Engineering Section of the NAE, and was a member of the NRC panel to select Ford Doctoral Fellows, the Visiting Committee in Mechanical Engineering at Maryland,

and the Engineering Advisory Committee at the University of Connecticut. He served on the board of directors of the MIT Club of Cape Cod for four years, cochaired the MIT Class of 1957 50th Reunion, and was elected president of the class. He was also president of the Osterville, Massachusetts, Rotary Club in 2010–2011.

In an insightful reflection of the past and contemporary times, Art had constantly held "the future to be bright for heat transfer," and especially for enhancement of heat transfer, as the essential role of the associated advanced research and engineering is unquestionable in the renewed global urgency of addressing energy and energy-water nexus issues.

Art Bergles is survived by Penny, sons Eric and Dwight, and five grandchildren. He and Penny had celebrated their 50th wedding anniversary on June 19, 2010, and while he was also an avid golfer, they had shared interests in swimming, snorkeling, skiing, and gardening.



J. ROBERT BEYSTER

1924–2014

Elected in 1989

"For outstanding scientific and engineering contributions related to nuclear energy and national defense."

BY BOB WERTHEIM

JOHN ROBERT BEYSTER, entrepreneurial business leader and founder of Science Applications International Corporation (SAIC), died of natural causes on December 22, 2014, at his home in La Jolla. He was 90 years old.

Bob Beyster's philosophy was "Those who contribute to the company should own it, and ownership should be commensurate with a person's contributions and performance." He put this philosophy into practice when, in 1969, he founded SAIC with a handful of scientists. From the beginning, SAIC was an employee-owned firm. The business—the largest employee-owned research and engineering firm in the United States—grew to annual revenues of $11 billion before it was split into two separate companies in 2013.

Bob was born in Detroit on July 26, 1924, to John F. and Lillian E. Beyster and grew up in Grosse Ile, Michigan. He attended Slocum Truax High School in Trenton, Michigan, and was salutatorian of his graduating class. As he prepared to graduate from high school, the United States entered World War II, and he enlisted in the Navy. He was sent by the Navy to the University of Michigan, where he was enrolled in the V12 Officer Training Program. He was commissioned as an ensign, and eventually served on a destroyer based in Norfolk, Virginia, before leaving the service six months later.

He received his BSE in engineering and physics (1945), and master's (1947) and doctorate (1950) degrees in physics, from the University of Michigan.

In the early 1950s, Dr. Beyster worked briefly for the Westinghouse Atomic Power Division on the company's nuclear submarine program. He soon followed many of his college associates to New Mexico to work as a research physicist at the Los Alamos National Laboratory, where he met his wife to be, Betty Jean Brock. The couple were married in Austin, Texas, in September 1955. In 1957, Bob joined General Atomic in La Jolla, as chair of the Accelerator Physics Department, where his research on neutron thermalization led him to coauthor the book *Slow Neutron Scattering and Thermalization* (with D.E. Parks, M.S. Nelkin, and N.F. Wikner; Addison Wesley Longman, 1970).

In 1969 Dr. Beyster raised money to start SAIC by investing the proceeds from selling stock he had received from General Atomic, combined with funds raised from the early employees who bought stock in the young enterprise. Initially, the company's focus was on projects for the US government related to nuclear power and weapons effects study programs. As SAIC grew, Dr. Beyster fought to preserve the values that had made the young company successful—employee ownership, entrepreneurship, a flexible and decentralized organizational structure, technical excellence, high standards of ethical conduct, and a firm belief in customer service. He developed one of the first high-tech corporations with broad-based employee ownership and profit sharing, and he demonstrated that broad-based financial inclusion could work and prosper. SAIC attracted and retained highly intelligent and motivated entrepreneurs who helped the company grow and diversify. When he retired as chair in 2004, the company had annual revenues of $6.7 billion and more than 43,000 employees.

With his beloved wife Betty, Bob Beyster was an active participant and philanthropist in the San Diego community. In support of their longstanding interest in education and health care, they made major gifts to the University of California, San Diego (UCSD), including its Sulpizio Cardiovascular

Center and Beyster Institute, University of Michigan College of Engineering, the University of San Diego Hahn School of Nursing and Health Science, the J. Craig Venter Institute, Salvation Army Door of Hope, Father Joe's Villages/St. Vincent de Paul, San Diego Regional Fire Foundation, KPBS, the San Diego Public Library, La Jolla Music Society, Achievement Rewards for College Scientists (ARCS), Rutgers School of Management and Labor Relations, and the Foundation for Enterprise Development (FED).

Dr. Beyster founded the FED in 1986—dedicated to the growth of US-based science and technology companies through research, education, and services that advance innovation, entrepreneurship, and broad-based ownership. In 2004, the FED launched the Beyster Institute at UC San Diego's Rady School of Management to advance the practice of employee ownership with technologists, entrepreneurs, executives, and educators.

Committed to education, Bob wrote or coauthored approximately 60 publications and reports, as well as the books *The SAIC Solution: Built by Employee Owners* and *Names, Numbers, and Network Solutions: The Monetization of the Internet*.

A fellow of the American Nuclear Society, Dr. Beyster chaired its Reactor Physics Division and Shielding Division. He was a member of the National Academy of Engineering, a fellow of the American Physical Society, and served the US Strategic Command Strategic Advisory Group. He also served as chair emeritus of the board of directors of the UC San Diego Foundation.

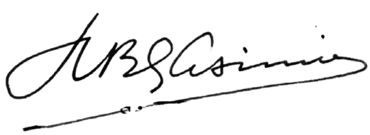
The Defense Advanced Research Project Agency (DARPA) designated Dr. Beyster an Honorary Program Manager for his distinguished contributions to the agency over his career. He also received the Engineering Manager of the Year Award in 2000 from the American Society of Engineering Management, the 2001 Spirit of San Diego Award from the San Diego Regional Chamber of Commerce, the Lifetime Achievement Award from Ernst & Young in 2003, and recognition as a Supporter of Entrepreneurialism from Arthur Young and *Venture* magazine at their Entrepreneur of the Year awards ceremony for his efforts to support and promote entrepreneurship.

In 2006 the San Diego Regional Economic Development Corporation (EDC) recognized Dr. Beyster with the Herb Klein Civic Leadership Award for his outstanding leadership in addressing regional challenges through collaboration with public, private, and civic partners. Dr. Beyster is the recipient of a lifetime achievement award from the University of California, San Diego's CONNECT program for providing 25 years of outstanding service to the community. The Horatio Alger Association for Distinguished Americans selected him to receive the 2008 Horatio Alger Award. This honor is bestowed upon those individuals who have overcome adversity to achieve great successes through the American free enterprise system. In 2014 he was awarded the US Joint Chiefs of Staff Medal for Distinguished Public Service.

Dr. Beyster was an avid sailor and longtime member of the San Diego Yacht Club. His interest in the sport peaked when the United States lost the America's Cup in 1983 to Australia. Convinced that the loss reflected a weakness in the naval architecture technology selected by the New York Yacht Club, he suggested to fellow San Diego Yacht Club members Dennis Conner and Malin Burnham that SAIC's naval architects could provide the winning edge. They agreed, and SAIC became a major participant on the technical team, playing an instrumental role in helping Conner's boat *Stars & Stripes* defeat the Australians in 1987 and bring the Cup back home to the United States—an outcome of which Bob was particularly proud.

Bob Beyster is survived by his wife of 59 years, Betty, of La Jolla; daughter Mary Ann of La Jolla; sons Jim of San Diego and Mark of Las Vegas; two grandchildren; one great-grandchild; and a sister, Virginia.

A public memorial tribute to the life of J. Robert Beyster was celebrated on January 31, 2015, by hundreds whose lives were enriched by his.



HENDRIK B.G. CASIMIR

1909–2000

Elected in 1976

"Leadership in research and development of electron tubes, solid-state devices, and glass and metal products."

BY MARTIN SCHUURMANS
SUBMITTED BY THE NAE HOME SECRETARY

HENDRIK BRUGT GERHARD CASIMIR, a brilliant scientist and leader of industrial research, died on May 4, 2000, at the age of 90 in Heeze, the Netherlands, after a brief illness.

My account of Casimir's work and life builds on my earlier paper in *Physics Today* [1] and an article in the *New York Times* [2]. It is guided and complemented by my interactions as a member of Philips Research with Henk Casimir.

Born in the Hague on July 15, 1909, Casimir was endowed with a strong body, fabulous memory, and great intelligence. He started his study at Leiden University in 1926. As a student of Paul Ehrenfest, he studied theoretical physics. He also spent 18 months of his graduate education in Copenhagen as a student of Ehrenfest's close friend Niels Bohr. Casimir's PhD thesis, which he completed in 1931, dealt with the quantum mechanics of a rigid spinning body and the group theory of the rotations of molecules.

After earning his PhD, Casimir became active in the young field of quantum mechanics. For example, he used Heisenberg's matrix mechanics to establish a relation between natural line width and radiation damping. He also used the time-dependent Schrödinger equation to treat the diffusion of an alpha particle from a Gamow potential well. And he proposed the hypothesis that the nucleus contains an electrical quadrupole, thereby accounting for the hyperfine structure of europium.

Casimir spent 1932–1933 with Wolfgang Pauli in Zürich, an experience that had a lasting and far-reaching influence on him. He loved to recount his relationship with Pauli and would include anecdotes from that period in most of his seminars in later life.

After Ehrenfest's untimely death in 1933, Casimir returned to Leiden, where he continued to be active in both physics and mathematics. With the physicist Evert Gorter, he worked out the thermodynamic theory of superconductive states. With the mathematician Bartel van der Waerden, he proved the complete reducibility of the representations of semisimple Lie groups. In addition, he worked on the thermodynamic interpretation of paramagnetic relaxation phenomena with Frits du Pré. This work formed the basis for the introduction of the notion that the temperature of a magnetic system is different from the lattice temperature.

In 1938, in addition to his regular duties as conservator (Dutch for curator) of the Kamerlingh Onnes Laboratory, he became a part-time, one-day-a-week physics professor at Leiden University. At the time he was actively studying both heat conduction and electrical conduction, and contributed to the attainment of millikelvin temperatures.

In 1942, during World War II, Casimir moved to the Philips Research Laboratories in Eindhoven, the Netherlands, because of the pressure of the German occupation forces on Leiden University as an active research center. He kept his position as professor at Leiden until 1977 and used it to remain active as a scientist and PhD counselor for many coworkers at Philips Research. In 1945 he wrote a well-known paper on Lars Onsager's principle of microscopic reversibility. Once the war ended, Casimir decided to stay at Philips Research as it offered in his view the best opportunities for good physics research in the Netherlands and he didn't want to emigrate as part of the "brain drain" [3]. In 1946 Gilles Holst, founder of Philips Research, retired and Casimir was appointed one of the company's three research directors.

In 1948 he published a seminal paper with Dik Polder on the influence of retardation on the London–van der Waals forces [4]. The authors imagined two parallel metal plates placed close together in a complete vacuum, with the following interpretation in quantum mechanics: Due to the Heisenberg uncertainty principle of quantum mechanics, vacuum is filled by zero-point fluctuation electromagnetic waves. In the constrained space between the two parallel metal plates fewer zero-point fluctuation waves can arise than outside of the parallel plates where there is more "volume"; between the plates only short wavelength waves can exist, whereas outside all waves exist. The net effect is an attraction between the plates with an inverse dependence on the fourth power of the distance between the plates.

What is now known as the Casimir force was convincingly demonstrated experimentally in 1996 by Steve Lamoreaux [5] at Los Alamos National Laboratories. Since Lamoreaux's initial measurement this dependence has been verified with better and better accuracy and applied in other fields of physics such as the wetting of surfaces and the theory of black holes.

Casimir had an infinite desire for simplification and simple understanding. The calculation of the weak force, though, is a high form (6th order) of quantum mechanical perturbation theory and covers many pages of hard mathematical (and physics) work involving the cancellation of several quasi-infinities. Casimir quickly realized, however, that the essence of the effect could be grasped in a model in which electric dipoles in matter interact with the electric field rather than with the vector potential [6]. All quasi-infinities drop out, the interpretation in terms of zero-point fluctuations becomes straightforward, and the calculation becomes a one pager.

In 1957 Casimir was appointed a member of the board of management of Philips, in charge of all research activities of Philips worldwide. He contributed to their expansion, while remaining scientifically active. An interesting example is his work with Chris Bouwkamp on the representation of the field of spatially distributed electrical currents into a series of multipole fields, which became the basis for extensive work on antennas with arbitrary current distributions.

In this period he also laid the foundation for what came to be known as the science–technology spiral. Technology uses science with a time delay of, say, 10 years; science in turn is driven by new developments in technology; and both progress together. For example, radio lamps made it possible for new aspects of atomic and nuclear physics to be researched. The resulting science–technology spiral is largely responsible for the great technological progress of the 20th century. A much more comprehensive description of Casimir's views (and excellent reading) is in his autobiography *Haphazard Reality: Half a Century of Science* (Harper & Row, 1983).

The Philips labs had been isolated from the rest of the world during World War II. Consequently, catching up in science and technology was paramount. With that aim, Casimir strongly cultivated contacts with colleagues from other scientific centers and industry all over the world. In this effort, he drew on his impressive fluency in several languages and his deep conviction that "research is essentially an international activity, and…repetition and duplication are useless!"

At Philips he did not put many restricting boundary conditions on suggestions for programs of work, provided they were potentially of interest to Philips and not merely, as he put it, "advanced classroom experiments." He stimulated people with knowledgeable hints for progress in widely diverging fields, avoiding short-term interference with their affairs. His abundant knowledge of science (and arts!) together with his extraordinary capacity for dissecting the most intricate problems, often by the use of amusing metaphors, made conversation with him on the bottlenecks in scientific progress not only entertaining but also effective. In 1973, he was the obvious choice as the first president of the Royal Netherlands Academy of Arts and Sciences, and he held this almost full-time job until 1978.

He contributed substantially to an atmosphere at the Philips research facility that was fertile and productive. After his retirement in 1972, he continued to foment research by coming into the laboratory in Eindhoven and asking young people, "What is new in physics and what can we learn from it?" As a young theoretical physicist at Philips, I was greatly stimulated by such conversations.

Let me give you one anecdotal example. Together with Polder and Quirin Vrehen, I addressed in 1979 the 25-year-old [7] problem of the onset of superfluorescence (giant collective fast emission from initially excited [inverted] atoms with no classical dipole moments). It was solved [8] in terms of a kick-off of spontaneous emission and dipole formation by the zero-point fluctuations of the electromagnetic field. Casimir of course was very interested in this. And I owe it to his comments (I was grilled!) during one of his visits that I finally published the correct understanding [9] of the transition of superfluorescence to amplified spontaneous emission. Henk was then 7 years retired from Philips!

Casimir was active on the Dutch and European physics and industry scenes. He was involved in the founding of the European Physical Society in 1968 and served as president from 1972 to 1975. He was also one of the founders and the first head of the European Industrial Research Management Association (EIRMA). In 1965 the OECD hosted the European/North American Conference on Research Management, which he chaired. The conference concluded with a recommendation to form a European body devoted to industrial research management. The following year, EIRMA was born as an independent not-for-profit organization with 32 industry members and Casimir as its founding president.

He was awarded many prizes and honors, among them the 1982 Wilhelm Exner Medal and in 1985 the Matteucci Medal. Most recent was the American Physical Society's George E. Pake Prize (1999) for outstanding scientific and industrial research leadership.

Hendrik Casimir loved strenuous walking in mountainous areas, eating good food, and playing the violin. With his extraordinary memory, he recited by heart poems to his children and used poems in his lectures. He loved a good chat with people from almost any discipline, particularly the arts or literature. He visibly and deeply loved his wife Josina Jonker, a fellow student in the early days at Leiden university, and their five children. They formed a fine family and have nine grandchildren. His wife died at the age of 100 in 2011.

With the death of Henk Casimir, we lost one of the most gifted scientists and industrial research leaders of the 20th century.

Acknowledgment

I feel privileged to have known Henk Casimir and I am grateful for what I learned from him about both science and innovation. I am indebted to his son Rommert for comments on the first version of this tribute.

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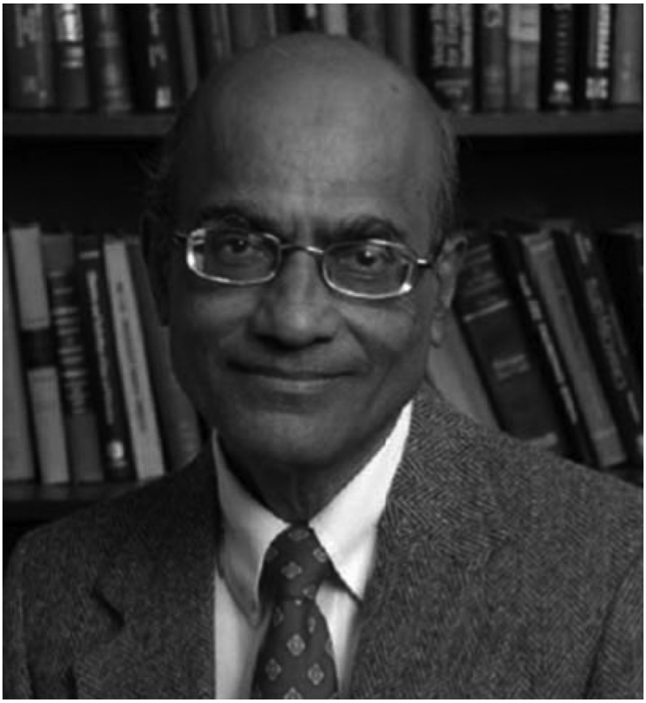


Subrata Chakrabarti

SUBRATA K. CHAKRABARTI

1941–2009

Elected in 2002

"For major contributions to the field of hydrodynamics and fluid structure interaction in the design of harbor, coastal, and offshore structures."

BY ZEKI DEMIRBILEK AND R. CENGIZ ERTEKIN
SUBMITTED BY THE NAE HOME SECRETARY

With great sadness we observe the passing of our renowned friend SUBRATA KUMAR CHAKRABARTI on January 23, 2009. Like his family, friends, and students throughout the world, his colleagues in the engineering profession were shaken by this great loss. Before we recognize his outstanding works, we acknowledge his great love for his wife Prakriti, son Prabal and daughter Sumita, and two grandchildren Sajni and Anandi.

Subrata was born February 3, 1941, and in 1963 received his BS degree from Jadavpur University, India, where he was awarded the Jadavpur Gold Medal, and his MS and PhD degrees in 1965 and 1968, respectively, from the University of Colorado, winning a scholastic citation. He had a long and illustrious career at Chicago Bridge and Iron (CBI) Company in Plainfield, Illinois, from 1968 to 1996, much of it as director of marine research. This was followed by a varied career as a consultant; as a founder and president of Offshore Structure Analysis Inc.; and as a teacher and member of the College of Engineering faculty at the University of Illinois in Chicago.

Adapted from Demirbilek Z, Morrison D, Ertekin R. 2009. Tribute to Subrata Kumar Chakrabarti. *Journal of Waterway, Port, Coastal, and Ocean Engineering* 135(4):125–126.

Subrata loved to teach and to share his shining intellect. He reached out to industry by teaching his famous courses on dynamics of floating structures and model testing and on the theory and practice of risers and mooring systems. And his long list of invited lectures took him from coast to coast in North America and to Brazil, Italy, France, Denmark, India, China, and Australia, among other countries. He lectured at many prestigious schools, such as the Technical University of Denmark/Lyngby, the Indian Institute of Technology (Madras), and the US Naval Academy (Annapolis).

The fruits of Subrata's professional life are as stunning in quantity as in quality. In addition to seven books on offshore engineering, numerical modelling of fluid-structure interactions, hydrodynamics and vibrations, offshore structure modelling, and nonlinear methods in offshore engineering, he authored more than 125 refereed journal publications and over 75 conference proceedings. He was an internationally known expert on wave-structure interactions related to offshore and coastal structures, and made important contributions in hydrodynamics, floating structure dynamics, numerical and experimental fluid mechanics, structural vibrations, and statistical methods for metocean data analyses.

His projects included the development of software for onboard monitoring of drilling rig risers and mooring systems, hydrodynamic software development and verification, and model testing supervision. He was responsible for the promotion of testing facilities; design of wave tanks, wave generators, instrumentation, and numerous model tests; research, analytical studies, and software development in fluid-structure interaction; and testing of hydrodynamic projects. He led the design and analysis of various offshore projects, including the Dubai storage tanks, the CBI submersible, the Garoupa mooring tower (a North Sea production platform), Gulf of Mexico platforms, and the development of a deepwater-compliant drilling platform in the Santa Barbara channel.

He studied viscous flow effects and their coupling with wave-structure interaction, and was involved in the analysis of heave plates for added mass and damping for wave energy structures and in the integrated hydrodynamic and structural analyses of deepwater-compliant offshore systems, including spars, tension leg platforms (TLPs), floating production storage and offloading systems (FPSOs), and semisubmersible concepts. His success in developing a world-class laboratory testing facility at CBI and his skillful consulting efforts led him to assist others in establishing wave tanks, for example, to refurbish basins at Escondido, California, and to launch the world's largest model basin at the University of Rio de Janeiro's Coimbra Institute of Graduate Studies and Research in Engineering (COPPE).

Subrata's son Prabal informed us that his father loved and appreciated his native Bengali culture, especially music and the works of the Bengali poet and Nobel laureate Rabindranath Tagore. Tagore said, "I slept and dreamt that life was joy. I awoke and saw that life was service. I acted and behold, service was joy." This attitude permeated Subrata's life. According to Prabal, "Our Baba always felt that he, and everyone, was obligated to serve. I think he regarded his desire to serve as God's gift to him. Service to his profession was his calling."

Subrata gave an enormous amount of his time and energy to our profession by organizing international conference series such as the Offshore Mechanics and Arctic Engineering (OMAE) Offshore Symposium. He was also active in a variety of roles on numerous editorial boards:

- technical editor, *Applied Ocean Research* (Elsevier; 1998–2009) and ASME's *Journal of Offshore Mechanics and Arctic Engineering* (1986–1996);
- proceedings coeditor, OMAE and ASME (1985–2004) and *Fluid-Structure Interaction*, Vol. I (2001), Vol. II (2003);
- associate editor, *Ocean Engineering* (Elsevier; 2006–2009), *Applied Ocean Research* (Elsevier; 1991–1998), ASME's *Journal of Energy Resources Technology* (1984–1986);
- editorial board member, *Topics in Engineering*, CML Publications (1987); *Applied Ocean Research* (1982–1991), and *Marine Structures Journal* (1988–1991);
- publication committee member, WPCOE, ASCE (1978–1984); and

- international editorial board member, *Advances in Fluid Mechanics Series* (1993–2009).

Although his colleagues tried to reward him, it was always evident that Subrata took his real reward in a deep love for his profession. Still, the awards and honors accorded him demonstrate his exceptional services, which his colleagues continually sought and appreciated. In addition to his election to the National Academy of Engineering, he was recognized as a fellow of the American Society of Civil Engineers, American Society of Mechanical Engineers, and American Association for the Advancement of Science. And he won the following awards:

- J. James R. Croes Medal (ASCE, 1974);
- Freeman Scholar (ASCE, 1979);
- Outstanding New Citizen, Chicago (1981);
- Ralph James Award (ASME, 1984);
- Ocean, Offshore, and Arctic Engineering (OOAE) Division Special Achievement/Service Awards (ASME, 1988, 1990, 1991) and Distinguished Service Award (ASME, 1998); and
- OOAE Division–ASME Life-Time Achievement Award (2005).

Subrata distinguished himself in all areas.

In 2011 ASME's OOAE Division honored Subrata by establishing the prestigious OMAE Subrata Chakrabarti Young Professional Award, given annually at the OMAE conference to a young professional who has presented an outstanding paper. The award recognizes both the originality and technical merit of the manuscript and the delivery of the presentation.

Subrata lectured worldwide and served as an expert and consultant to industry and governments, but his greatest virtue was his humility. He was kind, considerate, and friendly, and his hallmark was a great smile. We are blessed to have had the opportunity to serve with a cordial colleague and a master teacher who inspired us by setting a great example of how we can serve our profession, and by loving and working with people of different origins, religions, and cultures. As George Bernard Shaw said, "Life ranks all men, but death reveals the eminent." It appears that these words were meant to describe our esteemed colleague.

Farewell to our "gentle giant," compassionate leader, articulate diplomat, dedicated professional, loving husband and father, and efficient organizer, as well as an approachable, patient, and persevering human being. In closing, we use the words of Subrata's admired Tagore: "Death is not extinguishing the light; it is only putting out the lamp because the dawn has come." We will all miss Subrata, and take comfort in his light that lives on in his works and in our memories.


Esther Marly Conwell

ESTHER M. CONWELL

1922–2014

Elected in 1980

"Contributions to the semiconductor device industry and pioneering integrated optics and organic conductors."

BY ELSA GARMIRE

ESTHER MARLEY CONWELL (ROTHBERG), a condensed matter theoretician, died November 16, 2014, at the age of 92, ending a distinguished 62-year career investigating fundamental properties of new electrically conductive materials.

Dr. Conwell received wide recognition for her work in semiconductors, highly conducting quasi-one-dimensional organic crystals, conducting polymers, and DNA. She was honored with the National Medal of Science (2009), election to both the National Academy of Sciences (1990) and the National Academy of Engineering, and selection by *Discover* magazine as one of the Top 50 Women of Science (2002). In 1997 she became the only woman ever chosen to receive the Edison Medal of the Institute of Electrical and Electronics Engineers (IEEE), the institute's oldest medal (111 years), awarded for a career of meritorious achievement in electrical science, electrical engineering, or the electrical arts. She was honored "for fundamental contributions to transport theory in semiconductor and organic conductors, and their application to the semiconductor, electronic copying and printing industries."

Conwell's introduction to research was her 1943 master's thesis from the University of Rochester, deriving the scattering of electrons by impurities in germanium from first principles. Working alone on a suggestion from Victor Weisskopf, she produced what became universally known as the Conwell-Weisskopf formula. During her PhD studies at the University of Chicago she calculated, also from first principles, the energy levels of the H-minus ion for astrophysicist Subrahmanyan Chandrasekhar and graduated in 1951.

She interned for a year at Bell Laboratories, where she wrote a review paper for William Shockley that explained the basic properties of semiconductors. As she said in an interview, "That article was really many people's introduction to semiconductors." This paper solidified her reputation as someone with a profound understanding of the complexity of electrons and holes in semiconductors.

In 1952 Conwell joined Sylvania Labs (which became GTE Labs in 1962), continuing theoretical analysis of germanium and silicon. She focused on carrier transport in both p- and n-type materials, lightly or heavily doped, in high and low electric fields and at various temperatures, always comparing her theoretical understanding with experimental results. In 1958 she compiled the known properties of Si and Ge in two influential review papers. Her research analyzed the mobility of hot carriers and conductivity at high fields; she also derived properties of thermoelectric semiconductors such as bismuth selenide (Bi_2Se_3).

When GTE took over, her focus shifted to research supporting telecommunications, adding gallium arsenide (GaAs) to her research portfolio. Her 1967 monograph *High Field Transport in Semiconductors* (Academic Press) was influential in the development of semiconductor electronics. She supported research toward devices: optical frequency shifting by the electrooptic effect in zinc selenide (ZnSe); parametric amplification and nonlinear mixing of ultrasonic waves in cadmium sulfide (CdS). Next she moved into integrated optics, with an elegant solution to optical waveguides formed by diffusion, a field in which I overlapped her technically and personally. All her papers have been heavily cited.

In 1972 she left GTE to join Xerox Webster Research Center in Rochester, New York, where she studied organic conductors and quickly became a leading force in quasi-one-dimensional crystalline conductors. She derived fundamental models for band transport in tetrathiafulvene (TTF) and tetracyanoquinodimethane (TCNQ), and calculated how the phonon frequency, mobility, and magnetic susceptibility depend on temperature and pressure. By 1981 she coedited a special volume devoted to one-dimensional organic conductors, adding metal-complex and polymeric materials into the mix. She then began to investigate polymers with parallel chains, such as polyacetylene, shown to be one-dimensional conductors.

She foresaw the synergism of theoretical and experimental physics with synthetic chemistry and developed a collaboration with the Chemistry Department at the University of Rochester. She calculated the 3D band structures from first principles and elucidated the role of localized excitons in PPV [poly(phenylene vinylene)] and polyanilines, focusing on photoinduced charge transfer.

In 1991 Conwell represented Xerox as associate director of the new NSF Center for Photoinduced Charge Transfer at the University of Rochester, opening up new research opportunities: Investigating electron-hole interactions in conductive polymers led to excitons, polarons, and polaron pairs, as well as interchain coupling in photoluminescence and contact injection into polymer light-emitting diodes.

In 1997 she wrote the seminal review "Excimer Formation and Luminescence in Conducting Polymers" (*Trends in Polymer Science* 5(7):218–222). The next year she retired from Xerox and moved to the university as a research professor. She continued to analyze high field effects, photogeneration of polaron pairs, and evolved into studying ladder polymers, whose unique geometry led her to investigate DNA. In 2000 she suggested that an injected electron or hole can form a polaron on a DNA stack. Further research showed that the polaron results from polarization of the surrounding water. She had journal papers out for review when she died.

Looking back in 2003, Conwell said, "My life is the story of women scientists making a place in the world." The year she received her PhD, only five other women in the United States received similar degrees. Her father, an immigrant to New York City from Eastern Europe, provided motivation: "He impressed on his three daughters that in order to have a future, to be able to get married, we had to have jobs and be able to earn money, and he would prefer that we be professionals."

Born May 23, 1922, she was naturally attracted to mathematics and an excellent student, and in 1938 at age 16 she entered Brooklyn College, where she majored in physics. "I was frequently the only woman in the class.… My idea was to be a high school physics teacher, because that was all that I had ever seen." Her mentor, Professor Bernhard Kurrelmeyer, however, suggested she apply to graduate school—he was married to a physics professor at Columbia and understood what women could do.

While her contributions to physics rival those of her male peers, she faced difficulties that they didn't and often had to work alone. In the summer of 1942 she was hired at Western Electric as "assistant engineer," but "there was no such payroll classification for women as 'assistant engineer,' and I would have to be 'an engineer's assistant.' And it's obvious what that did to my salary.… There was no legislation at that time." It was difficult to find an advisor in graduate school, partly because World War II called away most of them, including her MS advisor. She worked out her PhD thesis alone since she had married and was living in New York. "Having a PhD from the University of Chicago, any guy would figure on getting a nice professorship at a good university," said Conwell. "But in physics in the early 1950s, there was no such thing for women and no such thing for me." She would spend most of her time in industry.

During her Bell Laboratories internship, she felt very conspicuous as a woman and lacked a sense of security or confidence. Fortunately Bill Shockley was impressed with her work and found her the job at Sylvania. One advantage she pointed out: "It was not long after the invention of the transistor and a marvellous time for research." She expressed satisfaction with her treatment at Sylvania, working with younger theoreticians who did the calculations, but she admitted that

"I did not get my share of invited papers, and that was due to being a woman.… I felt many times that I should have gotten an invited paper, but I didn't. But I also didn't know how to work the machinery. As a woman, I was not properly socialized.… We're not given a reason to have the same kind of self-confidence that some of the men do." At Sylvania she began encouraging young women to become scientists and mentored Mildred Dresselhaus as an undergraduate intern.

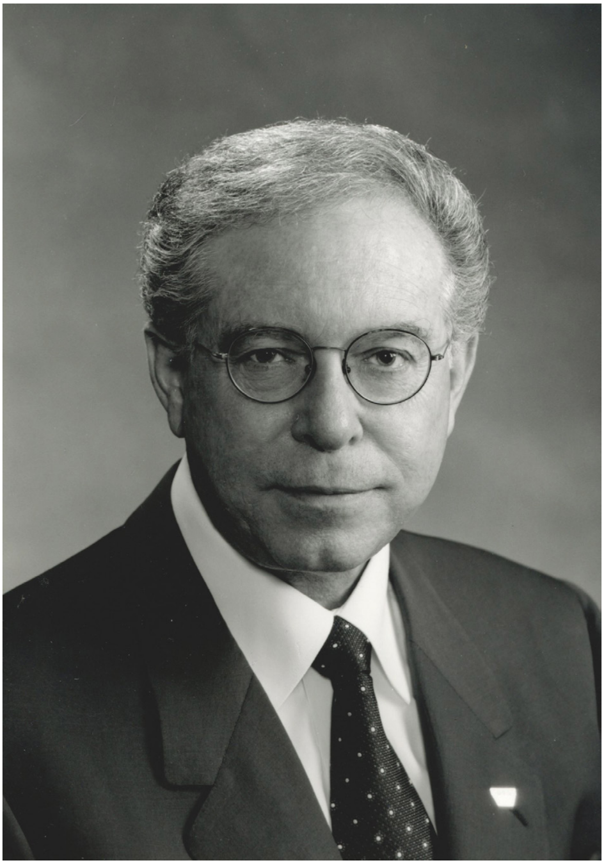
After unexpected termination when GTE downsized, Dresselhaus invited her to MIT to fill a temporary chair, from which she found her position at Xerox, where again she was comfortable. Conwell felt that "women had been treated better in industry than in academia.… I guess talented women seem to be getting more what they deserve in industry. They're promoted.… On the subject of women in academia, I would say I have never gotten a reasonable offer of a job from a university, and I've had a good reputation for some time. I'm a member of both academies, for instance. So that says something, that I spent my life in industry."

Conwell provided an excellent role model for women in physics. She lived a balanced life with her writer husband Abraham Rothberg, whom she met at Brooklyn College and married in 1944, and pursued her passion for ballet, enjoying its beauty, discipline, and order. She mentored young women all her life and was recognized for her dedication with the Dreyfus Foundation's Senior Scientist Mentor Program Award (2005) and the American Chemical Society Award for Encouraging Women into Careers in the Chemical Sciences (2008). As she said, "Although it's not nirvana yet, women have come a long way in my working lifetime, and it gives me hope."

Her son, Lewis Rothberg, is a tenured professor of chemistry and physics at the University of Rochester. He remembers that his father "made substantial sacrifices of his own career and ambitions to help his wife." He adds that his father, a distinguished author intimately involved in the publishing business, left New York in 1972 to move to Rochester so that Esther could accept a job at Xerox. "His advice, encouragement, and support were an integral part of her success." Abraham Rothberg died in 2011.

According to Dresselhaus, "Esther was right there at a very exciting time in semiconductor research. Her work is the basis, the very fundamentals, of what we study today.… Esther is a true role model for what it means to stay vital as a scientist and as a woman. There is no denying that when Esther and I were first beginning, we faced many difficulties and obstacles as women scientists. But that climate is changing, and I'm proud of the role we've played."

As a highly successful and influential woman in physics and chemistry, Conwell inspired countless young women worldwide to pursue and grow in scientific and engineering careers.



EUGENE C. FIGG JR.

1936–2002

Elected in 2001

"For leadership in architectural excellence, structural innovation, and efficient construction of major bridges."

BY JEREMY ISENBERG

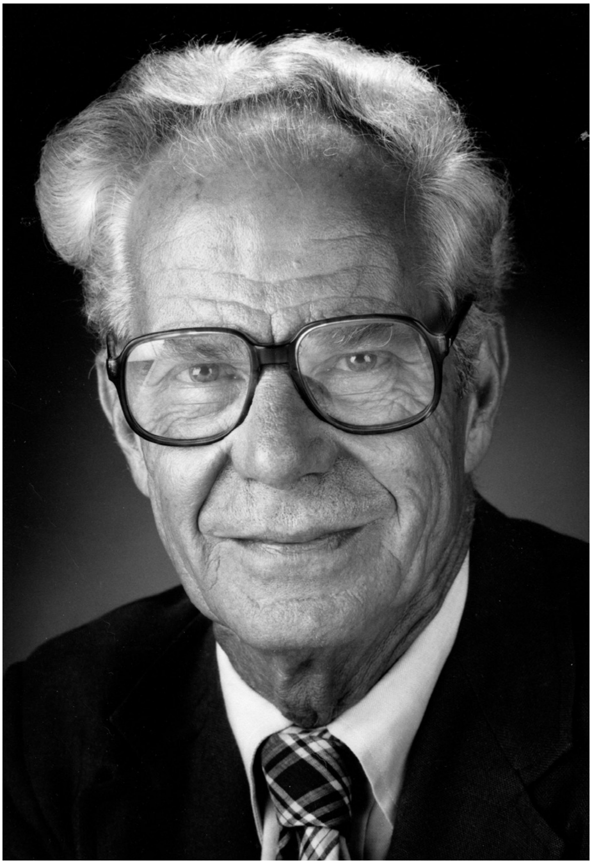
EUGENE CECIL FIGG JR., founder, president, and director of Bridge Art of the Figg Engineering Group, died March 20, 2002. He is widely recognized as the originator and leading practitioner in the United States in the field of concrete segmental bridge construction.

Born in Charleston, South Carolina, August 4, 1936, Gene followed the example of his father, a high-ranking civil engineer at the US Naval Shipyard, into the civil engineering program at the Citadel. There, he said, he absorbed the values of time management, leadership, and personal discipline that helped him to compete in the business world.

Gene Figg's career was built on the premise that bridges should be not only functional and cost efficient, but also works of art. He inspired the practice of involving the local community in a new project so as to open the design process to local preferences. The practice, which he trademarked as FIGG Bridge Design Charette, introduces the technical requirements of the project to those who will be most affected by it and invites ideas that ensure respect for local context. His chosen media were the precast, segmental, and cable-stayed bridge types in which short segments of box girder are cast on shore, then erected and stabilized by inducing longitudinal compression through external stay cables or internal post-tensioning tendons. Beginning with the Seven Mile and Long Key Bridges in the Florida Keys, he moved to longer and more dramatic projects including the I-275 Bob Graham Sunshine Skyway Bridge in Florida, which was completed in 1987 and was the first concrete cable-stayed bridge in the US with a single pylon and single plane of stays; Blue Ridge Parkway Viaduct around Grandfather Mountain in North Carolina, which introduced top-down progressive cantilever construction to protect the environment; and the Natchez Trace Parkway Arches with its graceful 582-foot precast concrete arch.

Recognition included the John A. Roebling Award for Outstanding Lifetime Achievement in Bridge Design (2000); three Presidential Design Awards (1984, 1985, 1995) through the National Endowment for the Arts; and inclusion in an exclusive list compiled in 1999 by *Engineering News Record* as one of 10 bridge designers selected worldwide who made a difference in the past 125 years. In 2002 he was awarded posthumously the Outstanding Projects and Leaders (OPAL) Award of the American Society of Civil Engineers, its highest honor for lifetime achievement in design. He is memorialized by the International Bridge Conference award, the Eugene C. Figg Jr. Medal for Signature Bridges. He founded the American Segmental Bridge Institute in 1988 and served as president from 1996 to 1998. He was a trustee for the National Building Museum and a member of the Citadel Development Board.

He is survived by his wife of 43 years, Ann Ruth Figg, and by four daughters, one of whom, Linda, is president and CEO of the firm Gene founded. Under her direction and guided by her father's example the firm has completed such distinguished projects as the new I-35W Bridge in Minnesota, Penobscot Narrows Bridge and Observatory in Maine, Allegheny River Bridge near Pittsburgh, Fourth Street Bridge in Pueblo, Colorado, and US 191 over the Colorado River, Utah.



VLADIMIR HAENSEL

1914–2002

Elected in 1974

"Contributions to the development of processes for oil refining, including platforming, used to produce high-octane gasoline without lead."

BY STANLEY GEMBICKI
INTRODUCTION BY MARY GOOD

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The following biography of Vladimir Haensel (written by Dr. Stanley Gembicki, then director of research for UOP) is an excellent overview of Dr. Haensel's life and a great accounting of his seminal invention of the platforming process for the production of high-quality gasoline and aromatics. However, it does not capture the quality and uniqueness of the human we all called "Val."

I first met Val in 1979/1980 when he was retired from UOP Inc. but still quite active with the company as a consultant. One of his assignments for the company was to help them find a new vice president and director of research. He was then a professor at the University of Massachusetts at Amherst and a consultant to the petroleum refining industry. I was on the faculty at Louisiana State University in Baton Rouge and Val came to Baton Rouge to consult with the Exxon refinery and to talk to me about the research position at UOP. His enthusiasm for UOP and its mission was contagious. His description of the importance of fundamental chemistry tied directly to engineering practice was a challenging revelation to me. I was intrigued by the UOP culture and by what seemed a unique approach to rapid commercial exploitation of research results.

I did interview at UOP, was hired as VP for research, and spent several challenging and enjoyable years there. I continued to interact with Val during my tenure at UOP and he was my personal advisor on many issues at the UOP laboratory. During that time I came to realize how unique Val was, both in his scholarship and in his interaction with his colleagues. He could speculate on the details of catalytic reactions and then describe the engineering that would be necessary to both test his chemical theories and provide pilot plant testing to prove (or disprove) their utility in process design. His insight was holistic in ways that we rarely see but he was always sharing them with colleagues, especially young researchers. His influence was phenomenal. Personally he knew everyone in the laboratory and relished the opportunity to visit with them and challenge them to discover new insights for themselves.

Val was always upbeat and optimistic, even after the many tragedies in his own life beginning with his early years as a refugee and the tragic deaths of his first wife and one of his daughters. He was devoted to his other daughter, his son-in-law, his grandchildren, and his second wife, Hertha.

I have always felt a rare privilege having known Vladimir Haensel and being able to interact with him over many years. He was a unique human being who provided support and guidance to many people. His technology contributions through the platforming process were phenomenal, probably one of the most important environmental discoveries of all time. That process removed tetraethyl lead from gasoline, providing high-octane fuel (which allowed for high-performance, high-compression engines) and a source of aromatics for the plastics industry (which eliminated the need for coal tar chemistry). Such people are to be admired and remembered and, when possible, emulated.

VLADIMIR ("VAL") HAENSEL WAS born to Nina Von Tugenhold and Paul Haensel (Pavel Petrovich Genzel) on September 1, 1914 (one month after the outbreak of World War I) in Freiburg, Germany. He spent much of his youth in Moscow, where his father was a respected professor of economics from 1903 to 1928. Shocked by the outbreak of the Bolshevik Revolution, his family fled Moscow, but was captured and returned to meet an uncertain fate. Officially rehabilitated, his father resumed his professorship and was made director of the financial section of the Institute of Economic Research in Moscow from 1921 to 1928; there he authored Lenin's first five-year plan. After escaping the USSR in 1928, the Haensel family lived briefly in Germany, France, and Austria. They came to the United States in 1930 when Haensel's father accepted a teaching position at Northwestern University.

Haensel entered Northwestern University in 1931 and received a bachelor of science degree in general engineering in 1935. He received his master's degree in chemical engineering from the Massachusetts Institute of Technology in 1937.

Haensel joined the Universal Oil Products Company in 1937 as a research chemist. From 1939 to 1946, while still working for the company, he was assigned to the Ipatieff High Pressure Laboratory at Northwestern University as an assistant to the famous catalysis researcher Prof. V.N. Ipatieff (NAS, 1939), who was affiliated with both Northwestern University and UOP. (Some years earlier Ipatieff had defected from Russia, where he had been a general in the Imperial Army and a professor of chemistry at St. Petersburg University. Haensel told how Ipatieff's catalysis research grew out of his having been an artillery officer in the Imperial Army, intrigued with the high-pressure, high-temperature combustion chemistry occurring in cannons.) While at the laboratory, Haensel continued his education and earned his PhD in chemistry from Northwestern University in 1941. In the same year he was assigned as the coordinator of the "cracking" research division of UOP. During this time, his work focused on the use of catalysts other than platinum in the general reactions. Among his early successes was the development of a catalytic method of selective demethylation to make triptane, the hydrocarbon with the greatest antiknock properties of any compound. In 1951 he was appointed the director of refining research and in 1960 became the director of process research. In 1969 he became vice president and director of research, and in 1972 he was appointed vice president for science and technology, a position he held until 1979.

In the early 1950s it was established that the deadly photochemical smog frequently experienced in locales such as the Los Angeles basin was produced when nitrogen oxides and unburned or partially burned fuel hydrocarbons in auto exhaust reacted in bright sunlight. Haensel, at United Oil Products from 1956 to 1974, played a key role in establishing research and development programs that eventually culminated in the automotive catalytic converters that were first used on almost all US autos in the 1975 model year, and today are virtually ubiquitous in most of the developed and developing nations on the five nonpolar continents.

After 1979 Haensel was a consultant at UOP and a professor of chemical engineering at the University of Massachusetts, Amherst. He was a member of the National Academy of Sciences and the National Academy of Engineering and was recognized with awards that included the National Medal of Science, the Perkin Medal, the first National Academy of Sciences Award for Chemistry in Service to Society, the Professional Progress Award (American Institute of Chemical Engineers), the Draper Prize, and the Chancellor's Outstanding Teacher Award (University of Massachusetts).

Haensel was a multifaceted person, deeply interested in the world around him and the process by which it advanced. He was a patron of the arts, enjoying plays and music, particularly in the company of friends. His interest even extended to the writing of short stories, usually illustrating a lesson he had derived from his experience and study of the reactions of people to advancing knowledge. Perhaps best known of these is his whimsical *Lucky Alva* short story in which he brought forth his view of important lessons from the life of America's most famous inventor and entrepreneur (1967).

During the later years of his career in industry and his tenure at the University of Massachusetts, he felt an obligation to use his life experience to foster and mold the careers of young scientists. It was a joy for him to see young scientists develop into accomplished researchers who would make a real difference in the world. In his obituary he was quoted from a 1995 interview: "Work to produce something important. Do something new. Do something interesting, something that makes you want to shout out loud when you've got it. Life is too darn amazing—and too short—for anything less."

Of him it can be said: He lived life to the fullest and left his mark as a researcher and as a person. We are all the better for having known him and for having benefited from his work.

Development of the Platforming™ Process

Haensel's most important invention is without doubt the Platforming process. By 1940 the octane number of gasoline could be improved by the Houdry process, using clay catalysts, or by adding octane boosters. One octane booster was iso-octane, prepared by the Pines-Ipatieff process using strong liquid acids as the catalyst to alkylate olefins with branched paraffins. Another octane booster was tetraethyl lead, which was used heavily until the 1970s, when it was phased out of gasoline because of the toxicity of the lead compounds in auto exhaust. It was not generally understood that the clay catalysts used by Eugène Houdry were in reality solid acids and that the chemistry of catalytic isomerization and catalytic cracking of straight hydrocarbons was thus akin to that of the liquid-acid catalyzed alkylation invented by Ipatieff and Pines.

In 1947 Haensel began exploring the possibility of using platinum catalysts for upgrading petroleum. When he started working on what came to be called the Platforming process, there was no economically practical way to upgrade gasoline to high-octane numbers by reforming processes. Thousands of catalysts had been tried, but none was able to generate the necessary results. The existing 65-octane fuel was inefficient and caused knocking in the compression cycle of engines. Consequently, it prevented the development of high-compression engines and their promise of higher efficiency. In looking for a better way Haensel took a different approach and proposed something that at the time was considered both impractical and uneconomical.

He suggested the use of the precious metal platinum in the refining process, supported on alumina as a bifunctional catalyst. The marvelous catalytic properties of platinum had been described by J.W. Doebereiner and Humphry Davy around the year 1800. Doebereiner had even experimented with platinum supported on clay. Haensel thought that the miracle catalyst platinum might also be good for upgrading gasoline.

To most of his contemporaries this sounded crazy. Gasoline costs were between 8¢ and 10¢ per gallon, and platinum had never been considered a viable catalyst because it was too expensive—more expensive than gold—and could only be obtained in significant quantities in Russia and South Africa. However, Haensel understood that a catalyst that had a long life and could be regenerated and reused in situ would, in fact, be more economically efficient in the long run than a "cheap" catalyst with a short life. After his initial tests confirmed the high stability and good activity of platinum on alumina, he tried to minimize the amount of platinum. He knew that only surface atoms are used in heterogeneous catalysis, so he directed his efforts to prepare extremely high dispersed supported platinum. In 1947 he showed that a catalyst with 0.01 percent platinum on alumina was both active and stable. Clearly, the platinum particles of this catalyst must be extremely small. Hydrogen adsorption indicates that more than 50 percent of the platinum atoms are surface atoms.

Even more important was his proposal that platinum on alumina was a dual-functional catalyst, ideally suited to the catalytic reforming chemistry. Platinum is an excellent hydrogenation and dehydrogenation catalyst, but acid-base chemistry is required to go from saturated alkane chains to aromatic rings. That was evident from the work of Houdry, Ipatieff, and Pines. Haensel's insight was not only that alumina, a Lewis acid, could physically support dispersed platinum but also that the unsaturated hydrocarbons formed by the platinum could be isomerized to rings on the acidic alumina. He established this key synergism by testing both the supported catalyst and physical mixtures of platinum and alumina, where the contact with intermediates was not intimate.

Another major advantage of Haensel's process was that it generated large amounts of hydrogen. In addition to the economic value of the hydrogen, its production helped to remove much of the sulfur and other contaminants found in petroleum. Hydrogen generation, therefore, is an important step in making the Platforming process a much more environmentally friendly process than any previous refining technique. Gasoline produced by the Platforming process also has a higher octane value than gasoline produced using older methods. Higher-octane fuels burn much more cleanly and efficiently, reduce knocking, and improve mileage and engine performance.

In addition to cleaner, cheaper fuel this process generated a higher yield of aromatic hydrocarbons—the raw materials used in the manufacture of plastics. This created the base for the modern plastics industry, which previously relied on the processing of coal tar, a very environmentally unfriendly process. Through catalytic reforming chemistry, more than 200 billion pounds of aromatic hydrocarbons are produced each year.

It could be concluded that Haensel was the inventor of catalysis with supported nanoparticles of platinum, although that word was coined much later. It is now one of the buzzwords in materials science; few people realize that in heterogeneous catalysis, nanoparticles have routinely been used for six decades thanks to the work of Vladimir Haensel.

The Achievement's Worldwide Impacts

Each of us benefits daily from the fruits of Vladimir Haensel's work. The engineering breakthrough of the Platforming process has helped shape our economy in many ways, from the inexpensive processing of high-grade fuels to the production of plastics in a more environmentally sound way. These advances have directly and indirectly contributed to many of the world's industries. We can easily take for granted the abundance of low-cost, high-efficiency fuels without realizing that the ability to economically transport food, medicine, industrial supplies, and even our mail is very much dependent on Haensel's invention.

Indeed, the Platforming process has reduced the United States' reliance on foreign oil, has broadened the long-term energy outlook for the world, and has saved billions of dollars in transportation costs. The United States has over 190 million cars, trucks, and buses that consumed nearly 132.9 billion gallons of gasoline each year. They serve the bulk of the nation's transportation needs, bring families together, and deliver food and medicine. A gallon of reformed high-octane gasoline produced through the Platforming process can provide 35 percent more mileage than previous methods as well as much higher performance. The savings in natural resources and costs to the consumer are tremendous.

At the time of this writing, the United States spends, on average, $123 billion per year to buy gasoline. The estimated cost of operating an automobile in the United States was about 46¢ per mile; of that, the cost of gasoline and oil was only 6¢. World consumption of oil was 66 million barrels per day, of which the United States accounts for roughly one-fourth.

Vladimir Haensel Returns to Teaching

After serving as vice president for science and technology at UOP, Haensel joined the faculty at the University of Massachusetts, Amherst, in 1980 as professor of chemical engineering. He continued to teach at the university and also served as a consultant to UOP until his passing.

Known across campus as "Val," he was an influential figure at UMass Amherst, both as a teacher and as an advisor to students, faculty, deans, and chancellors. He took particular pride in two elective courses he taught to mixtures of undergraduate and graduate students: Catalysis and Energy Conversion Processes, and Industrial Chemistry. His style was Socratic, often aided and abetted by his wife, Hertha Skala Haensel, former director of physical chemistry and surface science at

UOP. Following preparative study, the students launched into spirited discussion, punctuated by anecdotes, stories, and occasional apples from the teacher in recognition of new insights.

He also cherished the chance to work with undergraduate and graduate students in the lab, exploring new science with them and sharing his experience and research philosophy. The company contributed directly to this activity by creating a Vladimir Haensel/UOP research scholarship fund, which sponsors research by undergraduates.

Haensel served as a board member of the Petroleum Research Fund, 1979–1982; chair of the US-USSR Technology Exchange in Chemical Catalysis, 1976–1979; US State Department Representative to the International Scientific Forum in Hamburg, Germany, 1980; chair of the advisory committee, Industrial Science and Technology Innovation of the National Science Foundation, 1982–1985; and a member of the board of directors of Heico Corporation.

He authored more than 120 scientific and technical papers, and was granted over 145 US patents and 450 foreign patents. He was elected to the National Academy of Sciences in 1971 and the National Academy of Engineering in 1974. Among his many awards and honors was the National Medal of Science from President Nixon on October 10, 1973. He was also the first recipient of the National Academy of Sciences' Award for Chemistry in Service to Society in 1991. In 1994 he was awarded the Chancellor's Outstanding Teacher Award from the University of Massachusetts, Amherst. In 1997 he was selected by the National Academy of Engineering to receive the Charles Stark Draper Prize.

Haensel is survived by his wife, Hertha Skala Haensel, who lives in Amherst. His daughter, Kathee Webster, lives in Virginia Beach, Virginia. Before his passing, Haensel was investigating the use of hydrogen as a fuel.

THE AUTHOR THANKS the following individuals for memories, documents, and other resources that were vital to the completion of this memoir: Hertha Skala Haensel, Phillip Westmoreland, George Lester, Alan Wilks, and Mary Good.

R. RICHARD HEPPE

1923–2015

Elected in 1982

"For continued significant contributions to aerodynamics, design, and disciplined technical management of numerous military and commercial aircraft developments."

BY SHERMAN N. MULLIN
SUBMITTED BY THE NAE HOME SECRETARY

R. RICHARD HEPPE, retired vice president of Lockheed Corporation and last president of Lockheed California Company, died January 18, 2015, in Cupertino, California. He was 91 years old.

Dick was born March 4, 1923, in Kansas City, Missouri. His family moved to San Mateo, California, in 1930 and he was a dedicated Californian for the rest his life. He was educated at Stanford University, receiving a bachelor of science degree in mechanical engineering in 1944 and a master of science in aeronautical engineering in 1945. He was elected to Phi Beta Kappa, Tau Beta Pi, and Sigma Xi. He was a graduate student at California Institute of Technology from 1945 to 1947.

Dick joined Lockheed Aircraft Corporation in 1947 in Burbank, California, as an aerodynamics engineer and remained at Lockheed for the remainder of his long career. The same year he was recruited Lockheed employment was reduced to 14,500, down from its World War II peak of over 90,000. He would play a major role in its modernization, expansion, and technology leadership.

Initially, as a member of the advanced design organization, he worked under the general direction of Clarence L. "Kelly" Johnson, the chief research engineer. He immediately participated in designing competitive high-performance aircraft, an endeavor that would highlight his Lockheed career for the next 41 years. He was a creative engineer, assertive, a skilled mathematical analyst, and a polished writer and speaker. His management hero was and remained Harvard liberal arts graduate Robert E. Gross (1897–1961), visionary chairman of Lockheed (1932–1961).

Dick's career trajectory included piston engine–powered airliners, turboprop commercial and military aircraft, supersonic fighter aircraft, and unique helicopters, and culminated with pioneering stealth aircraft. Much of this effort was intensely stimulated by US Cold War defense strategy and national priorities.

One of his early assignments was development of the *Super Constellation*, the last Lockheed airliner powered by piston engines. It was a commercial success both domestically and internationally, and also produced for the Air Force and Navy.

Starting in 1952 Dick made a major contribution to the design and development of F-104 jet fighter aircraft, the first designed to fly at Mach 2. In 1958 it set a new world speed record: 1,404 miles per hour. A total of 2,578 F-104 aircraft were produced by Lockheed and licensed manufacturers in allied countries.

Dick was involved in developing three large turboprop propelled aircraft: the C-130 Hercules military transport, the Electra commercial airliner, and the P-3 Orion maritime patrol aircraft.

When development of a large supersonic passenger aircraft was given a high national priority in 1963 Dick was assigned as chief engineer of what became Lockheed model L-2000 supersonic transport (SST). He was very disappointed when Boeing won that intense competition in 1967 and then surprised when the program was canceled in 1971.

From the viewpoint of Heppe and Lockheed, losing the SST was a blessing in disguise. In 1967 Dick's career focus changed significantly. Competing for the development of a new US Navy carrier-based antisubmarine aircraft, he led the preliminary design and proposal effort, with Lockheed winning the competition in 1969. This resulted in the S-3A Viking aircraft program. Dick was promoted to director of engineering for military aircraft. S-3A aircraft development and production of a fleet of 187 aircraft was completed in nine years, a unique accomplishment. This effort also initiated Dick's long involvement in the development of digital computer-based, software-controlled avionics systems.

Dick became vice president for Navy programs in 1974, and then advanced to vice president and general manager, government programs. Staggering problems on the L-1011 TriStar commercial airliner program drove Lockheed to near bankruptcy in 1971 and continuing major financial losses. The organization Heppe led was for a decade the most successful part of the Lockheed California Company and a significant factor in Lockheed's avoiding bankruptcy. This effort included developing major avionics systems improvements of the P-3C maritime patrol aircraft, incorporating them in production, and retrofitting them into the existing fleet.

In the 1970s, under Heppe's leadership, the company's international programs expanded. Australia and the Netherlands purchased fleets of P-3C Orion maritime patrol aircraft. In 1976 he led the team that won the new maritime patrol aircraft competition in Canada, resulting in the CP-140 Aurora aircraft program. Lockheed entered into a P-3C aircraft licensed production agreement with Kawasaki Aircraft in Japan, resulting in a fleet of 100 patrol aircraft. Lockheed-designed maritime patrol and antisubmarine aircraft fleets remained the most capable and widely used by the US Navy and many allied countries well into the twenty-first century.

In 1981 Heppe became a vice president in the Lockheed Skunk Works, focusing on transitioning the secret F-117 stealth fighter aircraft from development to production. He also became involved in the development and production of advanced low observable technology. The F-117 achieved initial combat operational capability in 1983. He then focused on leading the preliminary design of a stealthy Mach 2 twin engine fighter aircraft to compete in the emerging Air Force Advanced Tactical Fighter competition.

In 1984 Dick became president of Lockheed California Company, which had major plants in Burbank and Palmdale, California. The ill-fated L-1011 commercial airliner program had been terminated in 1981 and the much smaller company was rapidly recovering. He continued to focus on the Advanced Tactical Fighter and led the formation of a Lockheed-Boeing–General Dynamics team to compete.

October 31, 1986, marked another high point in Heppe's career: The Air Force selected Lockheed and Northrop as winners of the first round of the Advanced Tactical Fighter competition. The F-22 team Dick helped create was activated, with him as a member of the executive committee.

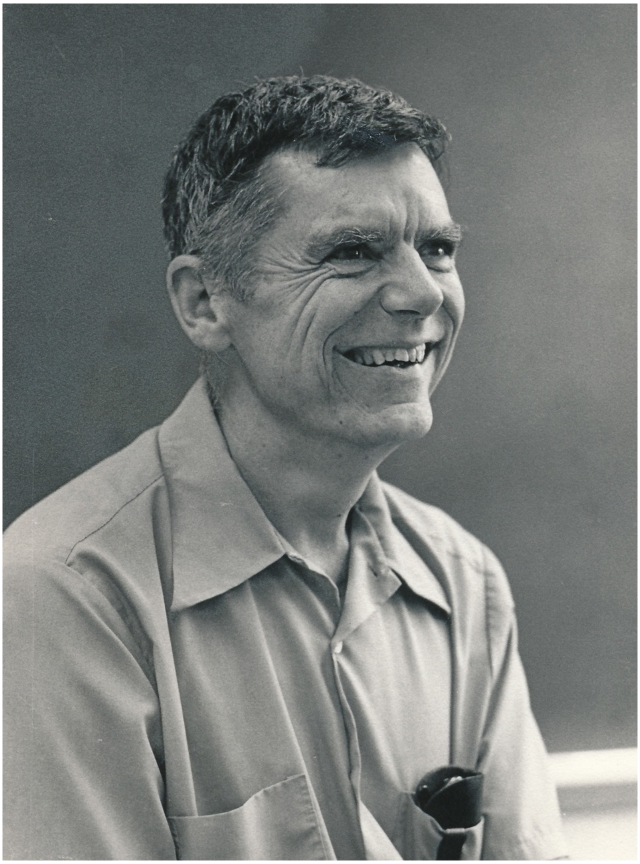
The summer of 1987 brought a unique event in Dick's career and Lockheed history. The management of the Lockheed-Boeing–General Dynamics F-22 fighter aircraft team concluded that their F-22 fighter design was not competitive. Dick led an intense three-month redesign effort, staffed by the best engineers from the three companies, creating the F-22 fighter as it is known today—the most combat-capable fighter aircraft in the world.

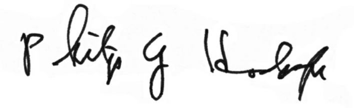
Dick retired from Lockheed in 1988. However, he continued as a consultant on the F-22 fighter aircraft program through December 1990, when prototype aircraft flight testing was successfully completed and a competitive production proposal was submitted. The final high point of his career was in April 1991, when the Lockheed-led F-22 team was announced the winner of the Air Force Advanced Tactical Fighter competition.

Long an active member, Dick was elected a fellow of the American Institute of Aeronautics and Astronautics (AIAA). The AIAA also presented him with the Reed Aeronautics Award (1986), its highest professional award for an aeronautical engineer. In 1979 he received the Admiral Charles E. Weakley Award from the National Security Industrial Association for contributions to US antisubmarine warfare capability.

Dick Heppe was one of the most creative, accomplished, and versatile aeronautical engineers of the twentieth century. As a demanding leader he set high standards. Besides his technical prowess he was a gifted, forceful manager, widely recognized for his frankness and integrity. He believed deeply that engineering was a noble profession and conducted himself accordingly. He was both a thinker and a doer and always surrounded himself with similar individuals.

Dick was a happily married and devoted family man. For decades he and his wife Pat's favorite vacation and getaway spot was the Napili Kai Beach Resort on Maui. Dick was predeceased by Patricia Kennedy Heppe, his wife of 57 years, and his son Bruce. He was survived by sons David (Jody) and Mark (Tari), daughter Janice, five grandchildren, and four great-grandchildren.





PHILIP G. HODGE

1920–2014

Elected in 1977

"Leadership in the development of methods for the analysis and design of structures stressed beyond the yield point."

BY ROBERT PLUNKETT

PHILIP GIBSON HODGE, professor emeritus of mechanics at the University of Minnesota, died of natural causes on November 11, 2014, in Sunnyvale, California.

Philip was born in New Haven, Connecticut, on November 9, 1920, to Philip Gibson Hodge, a New York publisher and Foreign Service officer, and Muriel Miller Hodge. He received a BA in mathematics from Antioch College in 1943. Immediately after getting his degree he married Thea E. Drell and joined the Merchant Marine, where he began by teaching basic math to radio operators, then shipped out as a mariner for the duration of World War II. After discharge he enrolled in the graduate program in applied mathematics at Brown University, where he studied under the guidance of William Prager. As part of his studies, he and Dr. Prager developed the basic foundation for the rigorous analysis of perfectly plastic solids. Together they wrote *Theory of Perfectly Plastic Solids*, the first of Philip's five books. *Theory* was published in 1951, and to this day it remains the ultimate authority in its field.

After receiving his PhD in 1949 he taught mathematics at the University of California, Los Angeles, as an assistant professor. His most engaging memory at that time was that he converted a member of the football team from a physical education major to one in mathematics! He was next appointed associate professor of applied mechanics at Brooklyn Polytechnic Institute in 1953, then professor of mechanics at the Illinois Institute of Technology in 1957, where he led a vigorous graduate school program in the theoretical aspects of solid mechanics. His final position was as professor of mechanics at the University of Minnesota, as of 1971. There he joined three other NAE members in a rather small department. They and the other members of the department faculty conducted a strong program in solid mechanics, fluid mechanics, and analytical dynamics. During his tenure, he was known as a very effective and well-liked teacher at both the undergraduate and graduate levels. From his retirement in 1991 to his death, he was professor emeritus of the University of Minnesota and visiting professor emeritus at Stanford University.

Philip wrote over 100 papers published in peer-reviewed journals. His extensive research on continuum mechanics methods applied to plastic materials resulted in five well-known books: the one previously mentioned, coauthored with Dr. Prager; another coauthored with J.N. Goodier, a well-known researcher in the theory of elasticity; and three others of his own that covered various aspects of continuum mechanics.

Both his education and early research in applied mathematics revolved mainly around the secure foundation of mathematical analysis and partial differential equations. However, earlier than many, he realized that the advent of fast digital computers had changed the field drastically. As early as the 1970s many of his papers included work on both the formulation and solution of finite element analysis problems in the field. He also found these techniques to be particularly useful for the vexing engineering problems of design by limit analysis. Limit analysis is a multiparameter exploration technique. It is dedicated to the development of efficient methods to directly determine estimates of the collapse load of a given structural model, without resorting to iterative or incremental analysis. It is based on a set of theorems, limit theorems, which in turn are based on the laws of conservation of energy and other laws descriptive of material behavior. It is widely used for the design of large civil engineering structures, such as buildings and bridges. His contributions here were recognized by the American Society of Civil Engineers (ASCE) with its award of the Theodore von Karman Medal in 1985.

During his career in research and education, in addition to his five books, his published papers, and over 30 graduate students, he made many contributions to the leadership of professional societies. He was technical editor of the American Society of Mechanical Engineers (ASME) *Journal of Applied Mechanics* for five years and served on many ASME committees, including five years on the executive committee of the Applied Mechanics Division, several years on the ASME Nominating Committee (including as its chair), and several years on the Honors Committee, in addition to several other societywide committees. His greatest contribution to our profession may have been his 18 years as secretary of the US National Committee on Theoretical and Applied Mechanics—he served in that position longer than any other secretary. During that time he was also a delegate to the International Union for Theoretical and Applied Mechanics General Assembly and later a member-at-large.

His contributions were recognized by many awards and honors, including the ASME Medal (1987) and honorary membership (1977), as well as awards from ASCE and the Russian Academy of Science.

In addition to his many contributions to engineering, Philip was an avid outdoorsman. He was a hiker, camper, backpacker, cross-country skier, and marathoner until long after his retirement. He was proud of his two Boston Marathons and of having finished first in the Senior Section of the Twin Cities Marathon. He slowed down a little only when his knees began to bother him in his late sixties and his doctor warned him, "You can run now or walk later!" He was an opera aficionado and wrote published opera reviews until fairly recently. His wife Thea had been a senior software executive for Cray Computers while they lived in Minneapolis. She preceded him in death by several years. He leaves three children: Susan E. Hodge, Philip T. Hodge, and Elizabeth Hodge Kelly, and many grandchildren and great-grandchildren.

John C. Houbolt.

JOHN C. HOUBOLT

1919–2014

Elected in 1990

"For the concept of lunar-orbit rendezvous in lunar exploration and sustained contributions to structural dynamics, aeroelasticity, aircraft loads and orbital mechanics."

BY DENNIS BUSHNELL

JOHN CORNELIUS HOUBOLT was born in Altoona, Iowa, on April 10, 1919. He grew up on a dairy farm in Joliet, Illinois, and earned BS (1940) and MS (1942) degrees from the University of Illinois in civil engineering and a PhD (1957) in technical sciences from the ETH in Zurich.

After early positions in civil engineering for the city of Waukegan and the Illinois Central Railroad, he entered on duty at the National Aeronautics and Space Administration (NASA; then NACA) Langley Research Center in 1942 in the Structures Research Division, conducting research on the stability and dynamics of aircraft structures. Within a short time compared to most such promotions he was made the associate division chief of the Dynamic Loads Division in 1949, serving until 1961, when he was appointed chief of the prestigious Theoretical Mechanics Division, researching special problems of space flight including rendezvous, communication satellites, launch vehicle dynamics, and other "hard problems." His wife Mary said, "He was always scribbling equations. He wrote equations on grocery bags, envelopes and even the sides of the bathtub while taking a bath."

In 1963 he left NASA and joined the Aeronautical Research Associates of Princeton, which was founded and led by Coleman Dupont Donaldson, the editor of the *Princeton Series* that documented the state of the art in aerospace at the time across the board. He served from 1963 to 1975 as senior vice president, researching and applying concepts in aeroelasticity, structures, flight mechanics, systems analysis, and guidance and control. In 1975 he rejoined NASA Langley Research Center, where he served as chief aeronautical scientist until he retired from government service in 1985. After retirement he served as a private consultant.

John Houbolt taught throughout the 1945–1963 time period for the graduate extension of both the University of Virginia and Virginia Polytechnic Institute, instructing in mathematics, elasticity, vibration, and flutter. He is the author of some 140 technical reports, was an exchange scientist with the Royal Aircraft Establishment in Farnborough, England, in 1949, and received a Rockefeller Public Service Award for graduate study at the ETH. He received the NASA Exceptional Scientific Achievement Award in 1963, the first American Institute of Aeronautics and Astronautics (AIAA) Structures, Structural Dynamics and Materials Award in 1968, and the University of Illinois Distinguished Civil Engineering Alumni Award in 1969 and Illini Achievement Award in 1970, and was selected as the 1989 Peninsular Engineer of the Year and elected to the National Academy of Engineering in 1990. The AIAA awarded him the Dryden Research Lecture Award in 1972 and made him an honorary fellow in 1975. He was awarded honorary doctorate degrees from the ETH in 1975, from Clarkson University in 1990, and from the University of Illinois, Urbana-Champaign in 2005. He served the NATO Advisory Group for Aerospace Research and Development (AGARD) for more than 20 years giving lectures, as a member of panels, and chairing working groups. He served on the US Air Force Scientific Advisory Board for some 20 years and served in many capacities in support of AIAA. He received the ASME "Spirit of St. Louis" Medal in 2000. The street in front of Joliet Junior College, which he attended, was renamed Houbolt Road.

John Houbolt was married, had three daughters, and was a private pilot with multiple-engine rating. His wife remembers her husband "had many interests with aeronautics and space flight at the top of the list; but skeet and trap shooting, flying, sailing, water skiing, and snow skiing ranked near the top, too. He, also, especially enjoyed woodworking, working with mechanical items like clocks and watches, and electronic things and was always available to take care of such things around our home or for neighbors up and down the street. He thoroughly enjoyed helping people. When some items had no parts available, he made the parts, so he could do the job. For the fun of it, he taught himself how to pick locks and was able to get an elderly woman back into her apartment on the third floor when surrounding college students were about to scale the exterior of the building to climb into a window! With his newfound talent, he also rescued a friend's fur coats from a safe she had had built into her home. Our cars and often those of neighbors were well taken care of by John. There seemed to be nothing that he couldn't fix."

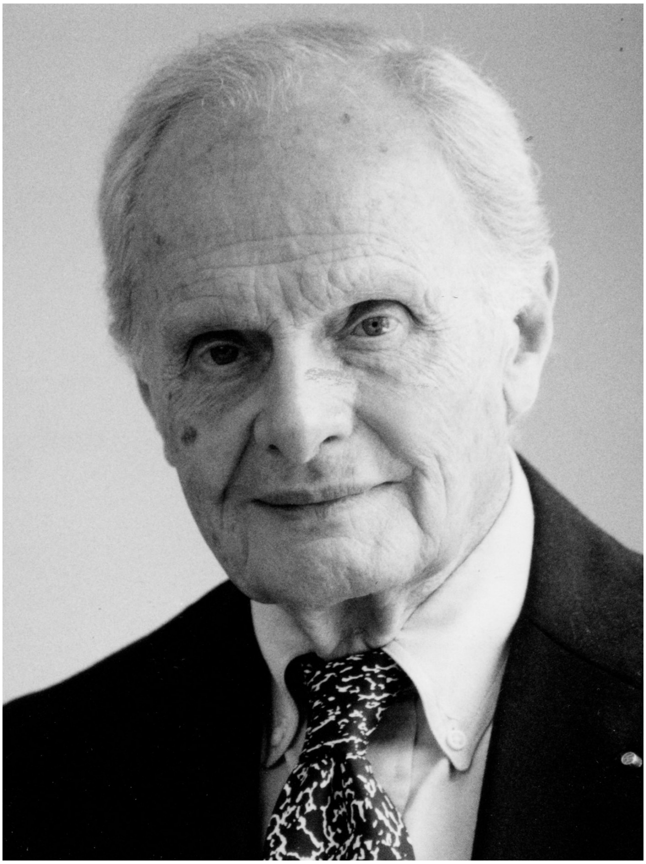
John Houbolt's most important technical contribution in the societal context, the one for which he is best known, is his analysis and efforts to convince NASA of a better way to land on the moon in the Apollo program. John was a member of the Lunar Mission Steering Group and had been studying the technical aspects of space rendezvous starting in 1959. There were at the time, in the early 1960s, three major approaches to sending humans to the moon—directly from the Earth, after Earth orbit, and from lunar orbit. John studied and amassed arguments in favor of the third approach, called lunar orbit rendezvous (LOR), which he calculated was less costly and the only approach that could meet President Kennedy's goal of reaching the moon by the end of the decade. He referred to this as the Chevrolet versus the Cadillac option. In a private letter to an incoming NASA administrator he stated, "Do you want to go to the Moon or not?... Why is a much less grandiose scheme involving rendezvous ostracized or put on the defensive? I fully realize that contacting you in this manner is somewhat unorthodox, but the issues at stake are crucial enough to all of us that an unusual course is warranted." John prevailed, the Apollo program adopted his lunar rendezvous approach, and the program successfully, safely landed on, and returned humans from, the moon within the decade of the 1960s as specified by presidential order.

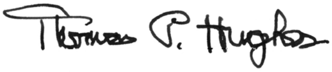
John received many plaudits for his lunar orbital approach to the Apollo project, including, after his death, an extensive speech from the Illinois congressman in the congressional record. NASA Administrator George Low stated, "It is my strongly held opinion that without the lunar rendezvous mode, Apollo would not have succeeded; and without John Houbolt's letter, we might not have chosen the lunar orbit rendezvous mode." John's concept was hailed by space historians as "Langley's most important contribution to the Apollo program." The Joliet Illinois Historical Museum has a permanent exhibit dedicated to John Houbolt and his family entitled "The Soaring Achievements of John C. Houbolt."

In addition to his Apollo contributions, John conducted pioneering and seminal research in most of the discipline fields within both aeronautics and space flight including gust analysis, torsional analysis for rotary wing blades, flutter, impact loading, and finite element methods.

John combined superb conceptual and detailed technical capabilities with the clearheadedness to envision application issues and the drive to prevail, a very effective combination. Working with John was an absolute joy; he was an extraordinarily clear thinker whose technical arguments were well grounded and presented in an easily understandable manner. Today, as NASA is again faced with the quandary of how to send humans to another place in space, this time to Mars, we are faced with the same three options: Mars direct, from Earth orbit, or from Mars orbit, plus others such as utilizing a moon (Earth's moon or a Mars moon) or Lagrange points.

If only we had John Houbolt's sage advice for this critical decision for the future of our space program.





THOMAS P. HUGHES

1923–2014

Elected in 2003

"For contributions to, and the effective dissemination of, the history of technology."

BY JOEL MOSES

THOMAS PARKE HUGHES (September 13, 1923–February 3, 2014) was widely regarded as the nation's preeminent historian of technology. He was 90 years old at the time of his death. He helped found the Society for the History of Technology (SHOT) and received its highest honor, the Leonardo da Vinci Medal, in 1985.

Tom is best known for his analyses of the design, building, and management of large-scale engineering systems, such as electric power networks and the ARPANET/Internet. He wrote, "Technology is messy and complex.… In its variety, it is full of contradictions, laden with human folly, saved by the occasional benign deeds, and rich with unintended consequences" (*Human-Built World: How to Think about Technology and Culture*; University of Chicago Press, 2004). Tom wanted to distinguish between the drive for simple explanations sought by scientists and the complex reality of many aspects of large-scale engineering systems.

His biography of Elmer Sperry (*Elmer Ambrose Sperry: Inventor and Engineer*; Johns Hopkins University Press, 1971) won SHOT's Dexter Prize as the best history of technology book of the year in 1972. *Networks of Power: Electrification in Western Society, 1880–1930* (Johns Hopkins University Press, 1983) won the Dexter Prize in 1985. Here Hughes contrasts the manner in which electric power networks arose in major cities in Britain, Germany, and the US. His emphasis is on differences in which power systems were designed as a result of differences in the social systems in which they were embedded. A major theme in his books was the creative genius, scientific achievements, engineering feats, managerial expertise, and entrepreneurial risks needed in designing and managing large-scale technological systems.

American Genesis: A Century of Invention and Technological Enthusiasm, 1870–1970 (Viking, 1989) was a finalist for the Pulitzer Prize in History in 1990. In it Tom suggested that technology played a greater role in shaping America than political achievement or free enterprise. The American genesis was the creation of the modern technological nation. *Rescuing Prometheus* (Pantheon, 1998) explored the creation of large technological systems, including SAGE, ARPANET/Internet, and Boston's Central Artery/Tunnel. Hughes edited two volumes with his wife, Agatha Hughes: *Lewis Mumford: Public Intellectual* (Oxford University Press, 1990) and *Systems, Experts, and Computers: The Systems Approach in Management and Engineering, World War II and After* (MIT Press, 2000).

Tom was born in Richmond, Virginia. After a stint in the Navy during World War II, he received a bachelor's degree in mechanical engineering in 1947 and a PhD in modern European history in 1953, both from the University of Virginia. His thesis was on the Great Exhibition in London and the Glass Palace, clearly in the history of technology area, but he taught Russian history at Mary Baldwin College. In the following years he increasingly transformed himself from a historian of modern Europe to a historian of technology, the field that he helped create. As can be imagined, academics, especially in the arts and sciences, viewed this new field with suspicion. For more than a decade Tom had short-term appointments at various colleges and universities, including MIT (1963–1965).

In 1966 he was named visiting associate professor at Johns Hopkins University, but he still had not written a significant book. Alfred Chandler, the great business historian, urged him to write one. Tom wrote his biography of Elmer Sperry while he was at Southern Methodist University in the early 1970s. That book made the cover of *Science* and led to several tenure offers. In 1973 the University of Pennsylvania appointed Tom to its Department of History and Sociology of Science. At the time of Tom's appointment the department was itself likely viewed by the faculty of arts and sciences with reservations.

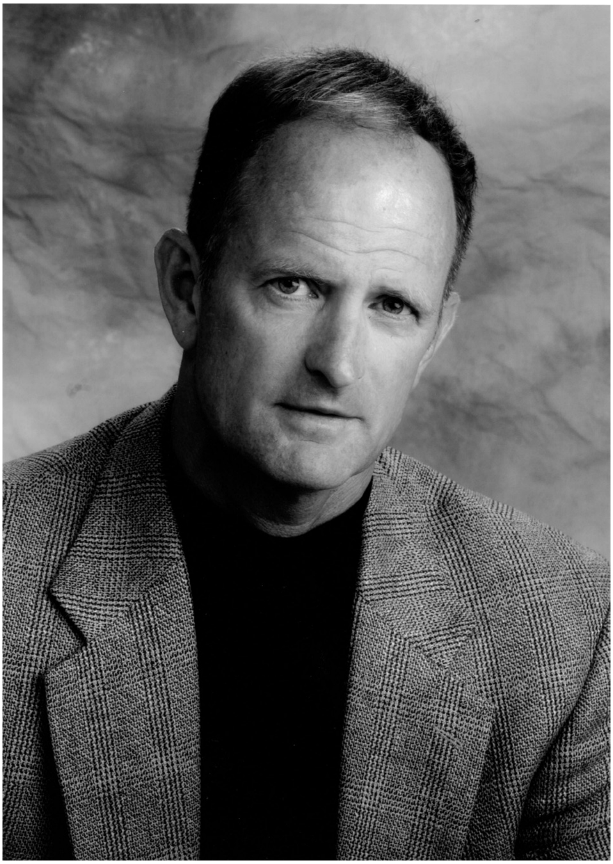
Twenty-five years later the department was arguably a jewel in Penn's crown, largely due to the luster created by Tom. He served as chairman in 1977–1980. He was appointed Andrew W. Mellon Professor of History and Sociology of Science in 1987 and served until his retirement in 1994 when he became Andrew W. Mellon Professor Emeritus. Thereafter he was also appointed distinguished visiting professor at MIT.

He was elected a fellow of the American Academy of Arts and Sciences, a member of the American Philosophical Society, and a foreign member of the Royal Swedish Academy of Engineering Sciences. Among his many honors, he received an honorary doctorate in engineering from the Royal Institute of Technology in Sweden, and an honorary doctorate in humane letters from Northwestern University.

When Tom was hired by the University of Pennsylvania in 1973, he and Agatha looked for a house in Philadelphia. Tom was surprised that an iconic house by the well-known modern architect, Robert Venturi, was for sale. This was a house that Venturi designed for his mother, Vanna Venturi. It is called "Mother's House." Venturi's wife and partner, Denise Scott Brown, told the *Philadelphia Inquirer* that, after they bought the house, Tom and Agatha often invited them back to have Thanksgiving dinner in it. Tom, she said, "was a very loving person—he always gave me a kiss, which I called his 'Southern gentleman' kiss."

Tom was indeed a Southern gentleman, with a warm heart and a friendly personality, and he was very supportive to his many friends and students.

Tom's wife and collaborator, Agatha Hughes, died in 1997. Survivors include their son, Lucian Hughes, daughter, Agatha H. Hughes, four grandchildren, and Tom's long-time partner, Mary Hill Caperton.



CHARLES V. JAKOWATZ JR.

1951–2015

Elected in 2003

"For innovations in synthetic-aperture radar-image processing critical to military applications and environmental monitoring."

BY C. PAUL ROBINSON

CHARLES V. JAKOWATZ JR. was an outstanding engineer who spent his entire working career at the Sandia National Laboratories in Albuquerque. His technical creations and those of the team of talented scientists and engineers he assembled and led are amazing developments in technology. His classified and unclassified advances of an esoteric tool for remote sensing and observations, called synthetic aperture radar[1] (SAR), include many pioneering creations that won major awards for their ingenuity. As well, some of the inventions have been judged to be of overwhelming importance to the national security of the US (and the world). These inventions and new technologies are considered some of the most

[1] Radar works by sending out microwaves that bounce off objects, with the reflected waves—captured by an antenna—allowing images that are limited only by the size of a rigid antenna you can fly to create images of what's out there. SAR works by firing pulses of more than 1,000 per second, correlating a plane's flight path very precisely by integrating these pulses—effectively creating a much longer antenna—that allow much higher-resolution images to be created. This maximum correlation length for accurately determining the flight path is dubbed the *synthetic aperture*. Rather than images that are limited by the wavelength of the radar wave itself, a variety of postprocessing techniques can improve the resolution for returned waves with far greater precision. They also allow one to detect changes in subsequent images.

important advances ever created for national security or for arms control monitoring and verification, with a growing list of ingenious and game-changing applications still emerging.

Among the notable quotations of Sir Arthur C. Clarke, author of *2001: A Space Odyssey*, was his judgment that "Any sufficiently advanced technology is indistinguishable from magic." Such a descriptor seems very appropriate for several of the major advances that Jack Jakowatz and his team achieved. They are remarkable feats of engineering. He and his team perfected the use of SAR devices, which already enjoyed the unique advantage of providing very high-resolution imagery for surveillance through fog and clouds as well as at night. In addition, as is often the case, some of the very best achievements of Jack's team resulted in very diverse arrays of new and unforeseen capabilities, whose existence and ultimate performance have enabled new and important as well as some highly secretive applications. These should be expected to remain under tight classification restrictions for a very long time, which motivated me to request to write this memorial, so that I can give witness to the great importance of Dr. Jakowatz's enduring legacy of contributions to our nation's security.

The productivity of these advances has been widespread across many diverse fields of application such that aspects of some can be openly discussed. These representative advances provide tangible witness of a larger body of ingenious technologies that have been created. For example, in the mid-1990s, Dr. Jakowatz and his team developed a system to rapidly create images in near real time (and in three dimensions) over large expanses of land through processing of controlled pairs of images that can be created at great distances and in any weather. Using high-speed computers to create computer visualizations—with accuracies better than 1 foot—provides images of great clarity. These efforts enable new possibilities for earthquake predictions and warnings by precise monitoring of ground fault slippages over great distances. The 3D nature of these processed images has given birth to very accurate topographical maps, taken from aircraft or satellites, that have already proved invaluable for studying glacier motions and changes. This technology also holds great promise to predict impending floods or to detect the groundswell precursors that often precede volcanic activity.

Massive databases—generated in a similar manner—have enabled unique change detection methods that can be employed over wide areas. These are useful to spot and follow events over time and highlight even minute details—of small or large changes—between successive images, to monitor suspected (but prohibited) activities for proliferation prevention, to monitor border areas between combat troops, and to generally assess the damage resulting from either military hostilities or adverse natural events.

In 1996 Dr. Jakowatz was awarded an E.O. Lawrence Award—one of the Department of Energy's top prizes—for achievements that advance the use of SAR to detect exceptionally small changes in landscape. The award read: "For fundamental work in signal analysis and image processing and its applications to national security, specifically, through overhead detection and identification of weapons of mass destruction." Since 1990 Jack had served as the manager of the Sandia Radar Signal Processing Group. He displayed his exceptional but usual modesty in accepting the award, as he said, "I am both honored and flattered to receive this award. But I would like to make it clear that a single person doesn't make these contributions by himself. I see this as an award for my many Sandia colleagues who together have done a tremendous amount of good work."

In 1990 a patent was issued to Dr. Jakowatz and two of his colleagues for the invention of the SAR autofocusing technique. Called the phase gradient autofocus, it is a very compelling advance. This trio also received an R&D 100 Award for their work when the autofocus advancement was judged one of the top 100 best technical contributions in the US that year.

Besides the many responsibilities of the programs he led, Jack always wanted to "give back" to subsequent generations through teaching. From 1978 through 1993 he served as an adjunct professor in the College of Engineering at the

University of New Mexico, where he taught both graduate and undergraduate courses. And as the power and importance of the new SAR technologies grew and became recognized in the defense and security communities, Jack was tireless as he traveled the nation to teach short courses to government and industrial entities.

An unexpected but singular accomplishment came when Dr. Jakowatz and his team were granted permission to write and publish a book on many of their important unclassified accomplishments. They completed and published a massive (429-page) volume entitled *Spotlight-mode Synthetic Aperture Radar: A Signal Processing Approach* (with Daniel E. Wahl, Paul H. Eichel, Dennis C. Ghiglia, and Paul A. Thompson; Springer, 1996). This important book was quickly published in both hardback and paperback, and soon entered its second printing. It has been cited 864 times in books and technical papers.

Jack's personal history reflects both his solid Midwest upbringing and a longstanding family passion for engineering. He was born on March 5, 1951, in Urbana, Illinois, where his father was completing his PhD in electrical engineering at the University of Illinois. Jack then spent his early years in Schenectady, New York, with the family moving to Kansas when his father became dean of engineering at Wichita State University. Jack chose Purdue University for his own college training, earning a BS in 1972, an MS in 1974, and a PhD in 1976, all in electrical engineering. His doctoral research work—still cited today—addressed issues of improving images obtained by computerized axial tomography (CAT) scans using either x-rays or ultrasound.

Jack began work on national security issues immediately on his arrival at the Sandia National Laboratories in 1976. In the mid-1980s, when a problem arose in SAR imagery, Jack's background in 3D images, along with his novel mathematical insights, resulted in revolutionary improvements. Jack then started building the very powerful research and development team that he led and mentored until his retirement in 2014.

Jack and his wife thrived in Albuquerque and had two daughters. Jack found time in his busy life to engage in many forms of athletic activity: cycling, swimming, running, weightlifting, golf, and racquetball. With his characteristic sense of humor he would say "anything worth doing is worth overdoing"—a sentiment that is all too evident in the way he approached his work life as well.

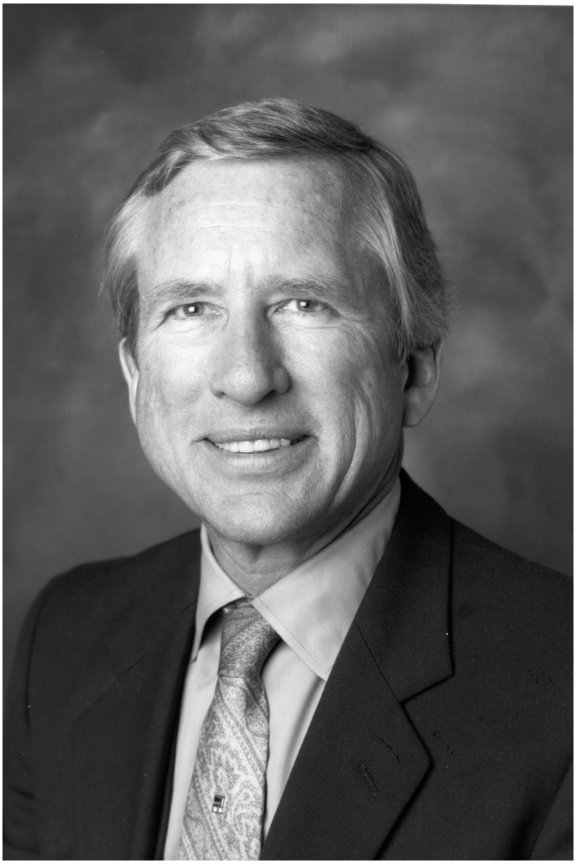
In 2003 Jack achieved the highest award that can come to a US engineer when he was elected to membership in the National Academy of Engineering. He continued his leadership role of his talented research team at Sandia, including a branching of portions of the work into Sandia's Systems Research Center. He retired in October of 2014, having completed 38 years of providing "exceptional service in the national interest." His death on February 7, 2015, ended a ten-year battle he had been waging with heart disease.

His wife Carol wrote

> As incredibly accomplished as Jack was in his professional life, his daughters Amy and Courtney would argue that he was perhaps an even more accomplished father. His dedication to his family was unwavering. Jack encouraged, supported and inspired all of his daughters' professional, athletic and personal dreams. He never missed a single swim meet or cross country event. He ever was (and ever will be) cheering for them in all aspects of their lives. Jack would often say that he loved his daughters and his wife of 43 years, Carol, more than his own life.

How should we best remember Jack Jakowatz? Earlier this year there was a very popular movie, "American Sniper," in which the lead character tells a military psychologist, regarding his accomplishments, that he would like to be remembered only for "the large number of people whose lives were saved because of my actions." That is a legacy that Jack Jakowatz certainly deserves, as the number of American servicemen and women, as well as Allied forces, whose lives have been saved is very large because Jack's technologies were deployed. His and his team's efforts have been key to the detection and elimination of a large variety of battlefield threats that previously had produced very high numbers of deaths and casualties.

One story that characterizes Jack, the man, so well is the way in which he always encouraged the next generation of engineers; his own words seem the most fitting to close this tribute: "Not only can you make the world a better place, but [engineering] is a fascinating field. If you can find a job where you are driving to work and you *want* to be there that day because it's going to be interesting—you can learn something, you can teach something, you can do a meaningful piece of work for the country—man, you've got it made! You won't have to work a day in your life because your job won't be work. Engineering affords a chance for people to do that."



HR Johnson

H. RICHARD JOHNSON

1926–2012

Elected in 1973

"Contributions to the development of microwave tubes and to engineering management."

BY TERRY O'LAUGHLIN
SUBMITTED BY THE NAE HOME SECRETARY

HORACE RICHARD JOHNSON, cofounder, president, and chief executive officer of Watkins-Johnson Company and a member of the National Academy of Engineering for 39 years, passed away on December 9, 2012, at the age of 86.

Johnson was born in Jersey City, New Jersey, on April 26, 1926. His family moved to Teaneck, NJ, when he was one. He attended public schools and was a member of Boy Scout Troop 107, rising to the rank of Eagle. In summers, he worked at the Camp No-Be-Bo-Sco near the Delaware Gap National Recreation Area as a counselor and telephone repairman when he was 15 and 16. He passed the amateur radio license exam with coaching by his father, who was licensed as W2DOZ, and received the call sign W2SZX while in high school. An early affinity for science led him to declare his desire to be an electrical engineer while still a teenager.

Admitted to Cornell University at 16, Johnson entered the US Navy V-12 officer training program while still a freshman. He enlisted as an apprentice seaman in July 1943. He graduated with a bachelor of electrical engineering with distinction in February 1946. Briefly assigned to the *USS Montpelier* as an ensign after the war ended, he transferred to inactive reserve one month before becoming a graduate assistant in physics at Cornell.

In fall 1947, at the age of 21, he was awarded an all-expenses-paid electronics research laboratory fellowship at the Massachusetts Institute of Technology based on his record at Cornell and recommendations from professors like Richard P. Feynman. On an American Youth Hostel bicycle trip with his MIT roommate Franco Bosinelli in 1949, he met his future wife Mary Louise Kleckner. They were married the following summer. He published six papers in *Physics Review* and completed his PhD in physics at MIT with a thesis in microwave spectroscopy in 1952.

After graduation, Johnson turned down a Fullbright fellowship and borrowed money from his parents to move his young family to the West Coast. They settled in Westchester, California, as Johnson became a member of the technical staff at Hughes Aircraft in Culver City. Within four years he had published ten more papers, received honorable mention in the 1955 Eta Kappa Nu outstanding young engineer competition, and was appointed manager of the microwave tube department. While working on a problem with traveling wave tubes he was befriended by fellow Hughes engineer Dean Watkins who left shortly after they met to join the faculty of Stanford University.

In August 1957, Johnson attended a conference at Stanford and met Watkins for lunch. Watkins proposed starting a traveling wave tube company to capitalize on innovations he was developing in the labs at Stanford. In October, Watkins called Johnson to inform him that he had raised $1 million from the Kern County Land Trust to start the company. The Watkins-Johnson Company was incorporated on December 6, 1957.

Starting small with Watkins as president and Johnson as vice president, they hired three employees and settled into a cramped two-room, 400-square-foot office at 535 Ramona Street in Palo Alto. Johnson initially shouldered most of the burden for getting the new company on its feet, working six days per week while Watkins retained his appointment at Stanford and worked for Watkins-Johnson on Tuesdays, Thursdays, and Saturdays. After a short while, Stanford invoked its limits on outside consulting and Watkins chose to step down to adjunct professor.

The initial Watkins-Johnson board of directors included titans of engineering such as William Hewlett and Frederick Terman. Terman remained on the board most of his life and was a major stockholder. David Packard served as a mentor helping the fledgling Watkins-Johnson develop a corporate culture that inspired innovation, productivity, and loyalty in a manner similar to methods developed at Hewlett-Packard. Judging from the annual employee reunions that continue more than a decade since Watkins-Johnson ceased to exist, they succeeded.

The company's first income came from Hewlett-Packard as an $80,000 contract to build six Helitrons, an octave bandwidth tunable microwave oscillator invented by Watkins. A Navy contract to develop a 100,000-watt pulsed traveling wave tube soon followed. Johnson worked long hours generating contracts, writing proposals, recruiting people, and managing the expansion of the business.

The company's initial products were backward wave tubes, which were a crucial component in radar systems, test equipment, and other applications requiring frequency agile microwave power, and traveling wave tubes, which were used primarily in microwave receivers, especially for military applications such as reconnaissance, surveillance, and jamming.

Watkins-Johnson was profitable from the start, netting $80,000 on sales of $500,000 in its first year of operation. In August 1958, the young company moved into a 13,000-square-foot building at 3333 Hillview Avenue as the first tenant in the new Stanford Research Park. Johnson recalled the new building was cavernous for the ten or so employees who moved over from Ramona Street.

Watkins-Johnson's first acquisition started when Watkins heard that Ray Stewart, who had learned microwave tube construction as a technician at Stanford under Watkins, was looking to sell his business and retire. Watkins-Johnson purchased Stewart Engineering by floating an IPO through Hayden Stone in 1963.

Stewart was the first of a series of shrewd acquisitions that moved Watkins-Johnson to the forefront of the industry. Both

Watkins and Johnson saw the potential of the furnaces Stewart had designed for tube manufacture and restructured the facility. The new Stewart Division made steady improvements to furnace design and maximized the efficiency of tube production. The profitability of Watkins-Johnson expanded dramatically, netting a profit of $3.2 million on sales of $31.3 million four years after this acquisition and just ten years after the company was founded.

Watkins-Johnson produced many remarkable microwave devices. Perhaps the most notable today are the WJ-1280 and WJ-1290 traveling wave tubes which power the radio transmissions from Voyager 1 and are still functioning perfectly 38 years after launching from Earth, now sending data back from outside our solar system.

As technologies evolved, Watkins-Johnson continued as an industry leader in the development and production of microwave devices. It expanded into yttrium-iron-garnet (YIG), gallium arsenide (GaAs), thin-film, and thick-film radio frequency devices, and it designed, built, and sold the equipment necessary to manufacture these components.

Watkins-Johnson's preeminence in the field was largely due to its recruiting and mentoring programs. Unlike most companies, which sent human resources or recruiting specialists, Watkins, Johnson, and other top management returned to their alma maters and visited a few other elite colleges to personally interview degree candidates. Those that passed muster were invited to spend a day in the plants shadowing other engineers and managers and being seduced by the attractive climate of what would later be called Silicon Valley with its close proximity to the mountains and the ocean. In this way both sides of the recruiting effort knew what they were getting.

Once hired, new engineers were partnered with experienced hands and bestowed responsibility early in their careers. Engineers who moved up to management were required to attend training seminars conducted by experts from the American Management Association. This hiring, placement, and promotion structure served to nurture generations of talented engineers. Many former engineers refer to the company as WJ University because of this emphasis on developing young talent. Work experience at Watkins-Johnson was a valued entry on the curriculum vitae of many young engineers.

The academic tone was enhanced by several publications popular in the industry beginning with the *WJ Technical Bulletin* in 1959, through the *WJ Tech Notes* published from 1974 to 1991 and finally the *WJ Technical Times*. The company hosted open houses and symposia, with attendant presentations and publications on their technological innovations.

Johnson's greatest accomplishments are likely to go unheralded because of his firm's deep connections and service to national security. The most visible aspect was Johnson's ten years of service to the National Security Agency as a member of the Scientific Advisory Board. He was also a member of the Association of Old Crows. Beyond this, only bits and pieces of the scope and value of his service and that of the Watkins-Johnson Company to the intelligence community have become public.

In addition to producing microwave devices and manufacturing equipment, Watkins-Johnson gathered enough resources and divisions to begin developing systems. The successful development of the lowest-noise traveling wave tubes enabled them to build sensitive microwave receiving equipment that led the industry in performance. The name Watkins-Johnson became all but synonymous with the highest-quality radio receivers and receiving systems, products much in demand throughout the Cold War.

Watkins-Johnson electronic intelligence receivers became integral to the efforts of American intelligence agencies to understand and map the progress and extent of missile, space, and radar development behind the Iron Curtain. These systems were installed on ships and planes and in secret listening posts ringing the Soviet Union. The electronics were tweaked and upgraded constantly so that as much information could be gleaned as technologically possible.

Another important part of Watkins-Johnson's reputation in national security work stems from the 1967 acquisition of Communication Electronics, Inc., then a small surveillance equipment company in Rockville, Maryland. Founded in 1960 by Ralph E. Grimm and independently owned, Communication Electronics had been growing rapidly. The demand for its sensitive and dependable nonmicrowave equipment mushroomed during the early days of the Cold War and was outstripping the company's ability to raise capital for further expansion.

Johnson courted and befriended Grimm and adroitly handled the acquisition of Communication Electronics. With the infusion of resources and blending of their previously separate areas of radio frequency expertise, this new division of Watkins-Johnson quickly began to dominate the design and production of radios and systems for vital signals intelligence and communications intelligence national security work. This equipment sold in large quantities to allied countries all over the world, creating an international reputation for Watkins-Johnson.

One of the first jointly developed projects was the once deeply classified QRC-259, a wideband militarized receiver system designed to intercept and unpack signals from a range of sources. This system successfully integrated the microwave expertise of the parent company with the extensive lower-frequency experience of this new subsidiary.

Watkins-Johnson's value to national security also stems from facilities it operated first on the East Coast and later on the West Coast much like Lockheed's fabled Skunk Works. These plants developed special projects in cooperation with various intelligence agencies. Much of the work done in these facilities remains classified because the equipment produced is too closely linked to specific national security activities.

The majority of the company's business until the late 1980s was for the Department of Defense and related agencies. As the Cold War wound down, Watkins-Johnson's defense work stalled and expansion of the semiconductor division, particularly chemical-vapor-deposition systems, came to dominate the portfolio. The company expanded to become the third largest producer of this equipment in the world. A significant portion of its remaining defense income came from components and radar subsystems produced for the advanced medium-range air-to-air missile and from the Communication Electronics Division through its work for intelligence agencies.

Competition in the semiconductor equipment industry proved too fierce for the company to continue expanding in this area. This, in close combination with an ill-fated attempt to transition the engineering staff and expertise from surveillance radios into the nascent wireless telecommunications business, left the company vulnerable by the mid-1990s. Johnson was pleased that when rumors of a hostile takeover surfaced, the company was able to maximize its value to shareholders and keep most of its employees working as divisions were spun off and the Watkins-Johnson Company ceased to exist.

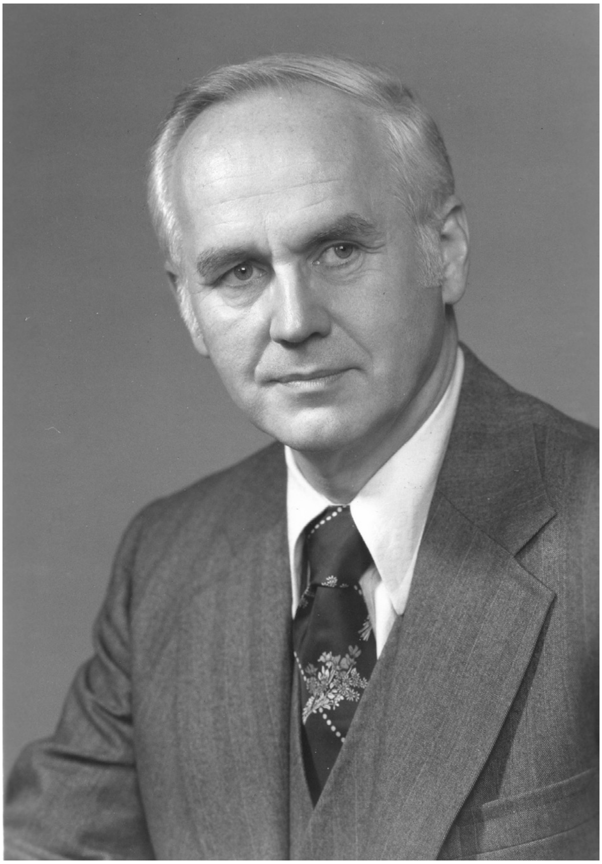
Dick Johnson is widely remembered by his former employees as an affable and dynamic boss, especially in comparison to his reticent but equally brilliant partner Dean Watkins. Johnson's employees recount numerous anecdotes of his personal interest in their lives and their well-being. The company created and supported employee recreational and social activities that were avidly attended and employee reunions that have outlasted the company and now the founders.

Over the years Johnson served the engineering community in many capacities: as a lecturer at Stanford and UCLA, on the board of the American Electronics Association, and on the Advisory Council for the engineering programs at Cornell University. He was named a fellow of the Institute of Electrical and Electronics Engineers in 1962. He became a member of the National Academy of Engineering in 1973. He was at various times a member of the Electron Devices Society, American Physical Society, Research Society of North America, Volunteers for International Technical Assistance, as well as Gamma Alpha, Sigma Xi, Phi Kappa Phi, and Tau Beta Pi.

In the community, Johnson was well known for his service. He maintained his boyhood connection to the Boy Scouts, participating with his sons and serving ten years on the board for the Stanford Area Council with three as president. He was a board member of United Way and a member of the

Commonwealth Club of California. He worked toward establishing a hands-on science museum in Silicon Valley and continued to be active with science fairs long after amazing and aiding his children with science demonstrations. He worked to improve housing, transportation, and educational opportunities in the area through the Santa Clara County Manufacturing Group.

An active man favoring tennis and downhill skiing throughout his life, Johnson also enjoyed the serenity of his Bow Bay vacation home on Lake Tahoe. He personally maintained woodlands around the house, cutting and splitting his own firewood. He loved to sail the lake and explore the surrounding High Sierras. He remained an active amateur radio operator after his move to California, becoming K6BZA and conversing across the continent with his father in New Jersey on mornings when ionospheric conditions were favorable. He is survived by his wife Mary Louise, 2 daughters, 3 sons, 15 grandchildren, and 6 great-grandchildren and the many employees who revered working for the company he cofounded.



Howard Kehrl

HOWARD H. KEHRL

1923–2013

Elected in 1985

"In recognition of his outstanding contributions to the advancement of automotive science and engineering."

BY JAY WETZEL

HOWARD HARMON KEHRL was born on February 2, 1923, in Detroit. He was raised by his mother Martha, who had emigrated from Germany. The Great Depression was a very challenging time for the family. Having an affinity for cars and all things mechanical distinguished Howard at an early age. He enjoyed fast cars in his teens and supported himself in school by selling the cars he had rebuilt.

Howard the Student

Howard was an excellent student and earned a scholarship to Wayne State University. While there he met Mary Katherine Maloney, the love of his life, and they would marry a few years later. Howard left Wayne State to enlist in the Navy during World War II. He was commissioned an ensign after completing the Naval Officers Training Program. He taught an engineering course in the Notre Dame Midshipmen's School. He graduated from Illinois Institute of Technology with a bachelor of science degree as well as the Midshipmen's School in 1944 as part of the Naval Officers Training Program. He received a master of science degree in engineering mechanics from the University of Notre Dame in 1948. While there, he also taught engineering subjects.

Howard the Professional: Engineer and Executive

Kehrl joined General Motors in 1948 as a college graduate in training with the Research Laboratories and a year later he became a research engineer. He was transferred to the Cadillac Motor Car Division Tank Plant in Cleveland in 1951 as a senior project engineer and later was appointed assistant staff engineer. In 1954, he joined the engineering department of the Chevrolet Central Office in Detroit and subsequently served as development engineer, design engineer, and director of the Engineering Laboratories. During that period, General Motors sponsored him as a Sloan Fellow at the Massachusetts Institute of Technology, where he achieved his master's degree in industrial management.

Kehrl was appointed manager of quality control at Chevrolet in 1961. He was transferred to Oldsmobile as assistant chief engineer in 1964 and was named chief engineer in 1969. He was appointed general manager of Oldsmobile on May 25, 1972, and was elected a vice president of General Motors and named to the administration committee on June 5.

On November 5, 1973, Kehrl was appointed group executive in charge of the Car and Truck Group. One year later, he became executive vice president in charge of the General Motors technical and planning staffs, and was elected to the board of directors and the executive committee. He was given added responsibility for the overseas group in August 1978, and in August 1979 was elected to the finance committee. Two years later, he was elected vice chairman in a major restructuring of the General Motors leadership. As vice chairman, he had jurisdiction over the corporation's technical staffs, operating staffs, and public affairs groups. He also served as a member of the corporation's ten policy groups and its finance, executive, and administration committees. He served in that position until December 31, 1986, when he elected to retire.

Howard, the Man I Knew

I joined the Pontiac Division of General Motors in 1963 as an engineer in training and met Mr. Kehrl, who personally took time to welcome all the newly hired engineers. He was a tall statuesque person with a military-like posture and piercing eyes, and as he reached out to shake my hand, his military persona melted away, a big smile appeared, and he reflected compassion and warmth as he put all of us newbies at ease. With tremendous energy and knowledge, he shared his experiences as a long-ago new hire, the two-year training program upon which we were about to embark, the current and future state of automotive technology, and the potential career paths that were available for us. Within an hour he laid out our future and assured all of us that we had made the correct decision to join the GM team.

While Howard's career was on the GM fast track, he was definitely the right person at the right time for all his assignments. He played a key role in the rebirth of the auto industry during the postwar era, the start of the horsepower race, new technology for manufacturing and engineering leading to productivity and product improvements, the adoption of the catalytic converter and unleaded fuel, carburetors replaced by fuel injection, powertrain and vehicle systems managed by onboard computers, the oil embargo, new government agencies for clean air and auto safety, and new regulations driving engineers and scientists to discover potential technology and affordable practical solutions. Howard played a major role in guiding GM in these exciting and hectic years.

I was very blessed to have worked closely with Howard during the time he was the executive vice president in charge of the General Motors Technical Center, while I was the chief engineer at Pontiac and later the cofounder and VP of engineering for the Saturn Car Company. Much later I was appointed a GM VP in charge of GM's Technical Centers including chairmanship of the Engineering Vice Presidents Committee, positions once held by Mr. Kehrl.

My observations of Mr. Kehrl as the man are as follows: Howard was a first-class gentleman. I will always remember him for his welcoming smile that was always genuine, his unlimited energy, and his enthusiasm that was very contagious. Howard was always willing to lend a helping hand while instilling a team-based can-do mindset.

Howard was a passionate leader who loved the automobile, the customer, and all aspects of the business enterprise of creating, manufacturing, and retailing the General Motors family of vehicles. He had a very special talent for discovering the best in people and then nurturing their special talent for the good of the program, the team, and the individual. He created excitement at all levels of employee contribution up and down the organization and across all aspects of the business. His special approach in dealing with people created individual pride in the execution of their responsible tasks within a team-driven program. By using encouragement and appreciation, Howard was always able to get everyone to do their best. When people or teams approached him with an opportunity, he would show his interest by listening intently, asking a few questions, and then replaying the proposal back to the team with a few of his own additions in a manner that energized everyone's passion to act upon it.

Howard understood the importance of networking as a means of mentoring many of us to take the correct path in carrying out our responsibilities within GM and the industry and he was always eager to acknowledge others for their contribution to the effort. He put excitement back into the ownership experience of a General Motors vehicle by bringing all aspects of the business together as one team on a common mission. As a result, styling took the lead, engineering delivered the performance promised by the look, manufacturing built in the quality and reliability, and sales, advertising, and marketing delivered the message to the market.

Howard was definitely a role model for all of us to follow—a professional who mentored rather than pontificated, an encourager, and a good friend to many. He demonstrated by personal example that the competitive pressures of the automotive business could be kept in check when integrity, humor, willingness, and appreciation were added to one's daily outlook. These represent some of the special gifts that Howard so willingly gave to so many of us.

Howard Takes His Talents to a Place Beyond the Grasp of Human Understanding

Howard Harmon Kehrl passed away peacefully at age 90 on October 1, 2013, at his home in Rancho Palos Verdes, California. He and Mary were happily married for 67 years and raised four children. Howard dedicated his retirement to the enjoyment of his family.

Anthony Kelly

ANTHONY KELLY

1929–2014

Elected in 1986

"For pioneering research in the development of strong solids and composite materials."

BY ARCHIE HOWIE
SUBMITTED BY THE NAE HOME SECRETARY

ANTHONY KELLY, a seminal figure in the development of composite materials and a reforming vice chancellor at the University of Surrey, died on June 3, 2014, at the age of 85.

Tony, as he was generally known, was born in Hillingdon, West London, on January 25, 1929. His father, Group Captain Vincent Gerald French Kelly, who was of Irish descent, taught mathematics to pilots in the education service of the Royal Air Force. Tony's scientific promise became apparent at the age of 13 in Presentation College, Reading, when he successfully corrected a physics teacher's work on the blackboard. Since Presentation College did not have a sixth form, he had to develop his own habit for intensive study and teach himself enough physics, chemistry, geography, and geology to take the University Intermediate Examination and win an open scholarship in science at the University of Reading.

Tony's doctoral research was carried out between 1950 and 1953 at the Cavendish Laboratory, Cambridge, in Sir Lawrence Bragg's famous crystallography group. Although his formal supervisor was W.H. Taylor and he had intermittent guidance from Bragg, his main mentor was Peter Hirsch, who had been largely responsible for setting up the x-ray microbeam equipment and exploring its use to investigate the structure of deformed metals. Bragg had realized that a sufficiently small x-ray beam might illuminate only a few of the subgrains in the mosaic structure of a deformed metal so that instead of the usual diffuse diffraction rings, spotty rings would result, giving information about subgrain sizes, their orientations, and strains. Tony admired Bragg's philosophy more generally, feeling that in later years this aspect of the great man's achievement with its emphasis on experimental data and astute simulation of dislocation behavior with bubble rafts was seriously underrated by comparison with his supervision of the research on DNA and other biomolecules.

Three significant advances came out of Tony's own work. First, he moved from x-ray reflection to transmission with thin samples with about ten times less exposure time. Second, the thin samples could then be deformed in controlled tensile tests at a known stress rather than by rolling. Third, to improve the spatial resolution of the diffraction method, he switched, in joint work with Peter Hirsch and Jim Menter, to the use of transmission electron diffraction. With hindsight it can be seen that these were crucial steps toward the successful electron microscope imaging of dislocations in thin crystals that took place in Cambridge just three years after Tony left.

The next few years were spent shuttling between the UK and the US. Tony spent one year at the University of Illinois, then a year with Alan Cottrell in Birmingham, followed by three years as a founding member (assistant then associate professor) with Morris Fine in the new Department of Materials Science at Northwestern University. Although his own research continued to focus on x-ray diffraction and deformation of metals, this experience broadened Tony's outlook so that he was invited by Cottrell to join him in Cambridge teaching a course in ceramics.

The years 1959–1967 were probably the most productive period of Tony's research career. He caught up very swiftly with electron microscopy, using it to study both deformation-induced and radiation-induced defects in magnesium oxide and graphite. With Robin Nicholson he wrote an enormously influential review of dispersion hardening of metal alloys. This was perhaps the first clear demonstration of his remarkable ability to digest and systematize an immense amount of data. On the more theoretical side, with his research student W.R. Tyson and Cottrell he investigated the conditions for a crystal to fail by pure fracture. Their approach involved not just the elastic properties but also the surface energy relevant in crack formation and so for many years this was a useful intermediate between the simplest theory depending only on Poisson's ratio and vastly more complex atomic simulations of cracks and defects.

A still more influential result emerging as a fusion of these interests was Tony's work on the deformation and mechanical properties of composites. With Tyson he investigated the behavior of brittle tungsten wires in a plastic copper matrix. Their discovery of the fiber pullout failure process provided the first explanation of an important deformation mechanism and the source of large work of fracture and hence toughness. The experimental data and their analysis also showed that at sufficient volume fraction the fibers could produce a significant increase in strength. With another research student, George Cooper, a second failure mechanism was then discovered for composites with a brittle matrix having a fracture strain less than the fibers. This proved to be the first manifestation of the multiple-fracture phenomenon later investigated in more detail by Tony and his team at the National Physical Laboratory (NPL).

With all this research activity, Tony remarkably found time to produce a couple of important books. *Strong Solids* (Clarendon Press, 1973) provided comprehensive analysis of the strength of a whole variety of crystals both perfect and imperfect together with the first analysis of composite mechanical properties and production methods. In *Crystallography and Crystal Defects* (with Geoffrey Groves; Addison Wesley, 1970), he brilliantly addressed a problem that he had noticed as a research student—the remarkable gulf between the crystallography used in structure determination of perfect crystals and the rudimentary understanding of most scientists studying the crystal defects. Both of these books have gone through several editions.

Tony moved in 1967 to NPL first as superintendent of the Materials Division and then as deputy director. The NPL not only had more extensive facilities for composite fabrication but also provided a better interface to defense institutions and industry for him to disseminate his ideas about composites and get closer to active development programs. With the team he built up there the most significant accomplishment was an in-depth investigation of the multiple-fracture mechanism and its role in the properties of fiber-strengthened ceramics, particularly concrete. He got still closer to industry when seconded for two years to Imperial Chemical Industries as part of a government-academia-industry task force.

In 1975 Tony was appointed vice chancellor (effectively CEO) of the University of Surrey—the previous Battersea Polytechnic which had just moved to a new site in Guildford. Almost immediately he had to face up to very severe financial cuts which required drastic economies. He persevered, however, in building up the research activity in the new institution and campaigned most vigorously on its behalf. At a meeting of vice chancellors in Downing Street he was apparently told by Margaret Thatcher, "You can have money for a readership, Dr. Kelly, but not for a professorship—like it or lump it." Against these odds he succeeded brilliantly, leading the way in the UK for universities to get a larger share of their income from nongovernment sources. His most spectacular achievement was to create a Research Park at the University of Surrey and furthermore to keep its development in-house so that it is now a major resource for the university. Although he ruffled a few feathers, the University of Surrey had become one of the two most successful of the former Polytechnics in the UK by the time he retired in 1995. Equally remarkably, Tony was able to maintain his research activity during these 18 years of heavy administration. The flow of publications that emerged from the vice chancellor's office included not only works of scholarship such as encyclopedias, where he was contributor as well as editor, but also reports of his continuing efforts to explain composite behavior in terms of the geometry and properties of the constituents. There was even some experimental work on the packing of fibers using raw spaghetti! Sailing became his major means of relaxation in these years.

In retirement Tony moved back to Cambridge, renewing his connection with Churchill College where he had been a founding fellow in 1960. The college became even more important to him after the death of his wife Christina whom he had first met as a student in Reading. Tony's style could switch between emollient and abrasive and she was adept at dealing with this. Later on he suffered from arthritis and was able to get direct experience of our success in mimicking nature with hip and knee joints. Despite all this his energy and sense of humor did not desert him. Distrusting some of the forecasts of climate change he got the support of 40 of its fellows to send a petition to the Royal Society persuading it to make some changes in its public stance. Most of all he strove to keep open the window that he had created between academic research and composite technology.

Tony held the UK national honors of Commander of the Order of the British Empire (1988) and Deputy Lieutenant, Surrey (1993). He was a fellow of the Royal Society and its Bakerian Lecturer (1995), a fellow of the Royal Academy of Engineering and winner of its President's Medal (2011), president of the Institute of Materials, Mining and Metallurgy, and an honorary fellow of the Institute of Linguistics; he held honorary degrees from the Universities of Surrey, Birmingham, Reading, Hanyang (S. Korea), and Navarra (Spain). In the UK he served as both member and chairman of the Engineering Requirements Board and of the Joint Standing Committee on Structural Safety of the Institutions of Civil and Structural Engineers.

Tony's enthusiasm and endurance were widely admired as were his magnificent hospitality and munificence. As a devout Catholic throughout his life he supported many good causes and was made a Papal Knight. He leaves behind four children—Marie-Clare, Paul, Andrew, and Steve—together with seven grandchildren.

THEODORE C. KENNEDY

1930–2012

Elected in 1999

"For leadership and innovation in advancing the nation's construction industry."

BY EARL DOWELL

THEODORE CLIFFORD KENNEDY, an international leader in the construction industry and former CEO and chairman of the board of BE&K, died May 8, 2012, in Birmingham, Alabama, at the age of 81.

Ted was born in McKeesport, Pennsylvania, on May 26, 1930, to Theodore Keith Kennedy and Catherine Gratzer Kennedy. His father was an ironworker with Rust Engineering Company and as a young boy Ted worked alongside his father as "water boy." Ted attended high school in Front Royal, Virginia, and graduated from Duke University in 1952 with a bachelor of science degree in civil engineering. After graduation, he joined Rust Engineering Company, leaving for two years to serve his country in the US Navy Seabees.

In 1972, he and two colleagues, C. Peter Bolvig and William F. Edmonds, left Rust to form BE&K. They began their business with a simple philosophy—to support their clients, their employees, and their community. In 2008 before being acquired by KBR, Inc., BE&K had become one of the nation's largest privately held engineering and construction firms.

Under Ted's leadership, BE&K was recognized as an industry leader promoting Merit Shop construction, which increases employment opportunities as it trains union and independent construction craft workers at the same time. This method increases the efficiency on the job site and encourages innovative solutions. BE&K was the first construction company to arrange for childcare facilities on construction sites, thus recruiting and training women in the workforce. Its Child Development Center, BEKare, received the NOVA Award in 1991. BE&K was chosen by *Fortune* magazine as one of the 100 best work places in America. Ted worked with union and non-union employees to increase construction safety, productivity, and ethics throughout the construction industry. BE&K was awarded a STAR safety designation by the US Department of Labor's Voluntary Protection Program.

Both he (1994) and BE&K have been honored as inductees into the Alabama Engineering Hall of Fame for their outstanding accomplishments in the field of engineering and construction. In 1981 and 1989, *Engineering News-Record* magazine recognized Ted as a "Man Who Made His Mark," and again in 1999 they recognized him as "one of the top 125 industry leaders within the past 125 years."

He served as national president of Associated Builders and Contractors in 1980 and on the Contractor's Advisory Committee for the Business Roundtable for 14 years, and was chairman of the Construction Industry Institute in 1988.

His honors and awards include Duke University's Pratt School of Engineering Distinguished Alumnus Award in 1981; the First Crystal Vision Award from the National Association of Women in Construction for his role in the promotion of women in construction; Finnish Decoration of the Knight, First Class, of the Order of the Lion of Finland for his work as the Honorary Consul of Finland in Alabama from 1993 to 2003; the Carroll H. Dunn Award of Excellence by the Construction Industry Institute (1988); the Walter A. Nashert Constructor Award by the American Institute of Constructors; induction into the Alabama Academy of Honor in 2005; Contractor of the Year, Associated Builders and Contractors (1989, 1991); the "Cornerstone Award" by the Associated Builders and Contractors; and Employer of the Year, National Association of Women in Construction (NAWIC). He was inducted into the Paper Industry International Hall of Fame in 2008 having been a member since 1972. The National Academy of Construction established the Ted C. Kennedy Award in 2011 in his honor.

In community affairs, he served on the Community Foundation of Greater Birmingham board and as board chair of the Housing Enterprise of Central Alabama. He was also a commissioner with the Housing Authority of the Birmingham District. In education, he served on the Alabama Commission on School Performance and Accountability; as a member of the Board of Directors of the A+ Education Foundation; as chairman of the National Board of Directors for INROADS, Inc., a national career development organization for minority youth; and as chair of the A+ College Ready board, a statewide initiative to establish advanced placement programs in Alabama's public schools. He was also known for his work with the Children's Hospital of Alabama and the Birmingham Civil Rights Institute.

He was elected a member of the National Academy of Engineering (NAE) in 1999. For the NAE he served as chair and member of the Executive Committee for Section 04 (Civil Engineering), as a member of the Board on Infrastructure and the Built Environment and the Awards Committee as well as on numerous ad hoc National Research Council studies.

Ted was a great leader and ambassador for Duke's Pratt School of Engineering; his love for Duke and the Pratt School was apparent to all who met him. He had been a member of Duke's Engineering Dean's Council and Board of Visitors since 1985, serving as the chair of the board for many years. In 2005, the Theodore C. Kennedy Professorship was established to support engineering faculty in the Pratt School of Engineering.

He was a family man who especially enjoyed family vacations in the Adirondacks, skiing in North Carolina, or time at the beach. He was an avid fly fisherman, trekking to Canada annually for salmon fishing, and one year caught a 40-pound Atlantic salmon.

Ted is survived by four daughters, two sons, and four grandchildren.

Ted understood that it is really all about the excellence of your people; he was a leader and a gentleman that others admired and were grateful to follow.

GLENN F. KNOLL

1935–2014

Elected in 1999

"For contributions and technical leadership in the field of ionizing radiation detection and application."

BY DAVID WEHE
SUBMITTED BY THE NAE HOME SECRETARY

GLENN FREDERICK KNOLL, professor emeritus of nuclear engineering and radiological sciences at the University of Michigan, died April 20, 2014, at the age of 78.

He was born on August 3, 1935, to Reverend Oswald and Clara Bernthal Knoll. He earned a BS in chemical engineering from Case Institute of Technology in 1957, master's from Stanford University in 1958, and PhD in 1963 at the University of Michigan, where he joined the faculty.

A gifted teacher and brilliant researcher, Dr. Knoll was a mentor and role model for generations of students. Colleagues claimed they made careers out of his innovative ideas by turning them into applications in their fields such as nuclear medicine, radiography, oil well exploration, nuclear physics, environmental stewardship, and homeland security.

From 1979 to 1990 Professor Knoll chaired the Department of Nuclear Engineering, whose size and prestige, under his leadership, matured to its current level. After returning to the faculty ranks, he initiated a new research field of room-temperature semiconductor radiation detectors and led this effort until tapped to serve as the interim dean of engineering (1995–1996). He then returned to his true calling, teaching and research, until his retirement in 2001.

Former University of Michigan president and colleague James Duderstadt said, "Glenn Knoll left his legacy for science with a half century of world leadership in nuclear measurement. But he was also fun-loving and kind, he took young faculty and graduate students under his wing."

Dr. Knoll's contributions have been recognized widely. In addition to his election to the National Academy of Engineering, he was inducted as a fellow of the Institute of Electrical and Electronics Engineers (IEEE), the Institute of Medical and Biological Engineering, and the American Nuclear Society (ANS). He was also honored with the Glenn Murphy Award of the Nuclear Engineering Division of the American Society for Engineering Education (1979), the ANS Arthur Holly Compton Award in Education (1991), the IEEE Career Outstanding Achievement Award, and the IEEE Third Millennium Medal.

He participated in the formulation of post-9/11 planning through ideas published in the 2002 National Research Council report *Making the Nation Safer: The Role of Science and Technology in Countering Terrorism*.

Dr. Knoll enjoyed the technical fraternity of colleagues and travelled internationally to participate in their lives. He served as an International Atomic Energy Agency reviewer of international programs and taught his radiation detection course on every continent but one. As editor of the journals of his field, he was universally known and respected. His textbook, *Radiation Detection and Measurement* (Wiley, 4th ed., 2010), remains the standard reference of the field after four decades and is available in multiple languages.

On the day of his death Dr. Knoll was as active as ever, reviewing proposals and writing white papers to meet imminent deadlines. He sent final ideas for the June 2014 Symposium on Radiation Measurements and Applications (SORMA), the international conference that he launched nearly 50 years ago.

In talking with former colleagues and students it became clear that Dr. Knoll had a playful, competitive spirit. A man of innumerable talents he enjoyed travelling, music and singing in the glee club, and driving his Harley-Davidson. He played softball on the Nuclear Nine (as a solid third baseman) and had a passion for fencing, paddleball, and racquetball. He also enjoyed a monthly game of poker.

Recollections of Son Thomas F. Knoll

My Dad introduced me to nearly every part of my life, from my profession to my hobbies. He was an engineer, which he described to me as using math and science to make useful stuff, and gave me my first introduction to all three.

My family used to take many long car rides together. At least they seemed long to a little kid sitting in the back of the car. We travelled back and forth from Ann Arbor to Frankenmuth to visit my grandparents, and during the summer we spent a week or two at my grandparents' cottage on Houghton Lake. To pass the time on these car rides, my Dad would make up math problems for me to try to solve in my head. They started out as simple arithmetic problems—multiplying two-digit numbers together, etc.—and as I got older they progressed to problems in algebra and geometry.

Eventually I got good enough at solving these problems that Dad could no longer make up problems in his head that were hard enough to challenge me. But the math teaching did not stop then, and we switched over to pencil and paper. He taught me the basics of differential calculus when I was 13.

When Dad was writing the first edition of his textbook, I was able to pay him back for some of his math instruction by solving some equations for his book, including a fourth-degree polynomial that still appears in the current edition.

He also introduced me to science. One strong memory I have is a night at the cottage on Houghton Lake, which is far enough from big cities that the view of the stars at night can be spectacular. On one clear night he took me out on the dock, and using a flashlight as pointer taught me the constellations, which I remember to this day.

He kept all his issues of *Scientific American* magazine organized by year in cardboard library shelf boxes. I spent many hours learning science by reading them while growing up.

Only recently did the availability of digital online archives convince him that it was OK to throw them out.

The third part of engineering is "making stuff." One my favorite memories is of Dad taking me to see one of the greatest feats of engineering ever, the Saturn V rocket, and the launch of Apollo 17. He took me along to a conference in Miami and afterward we drove up to Cape Kennedy to watch the launch. The minimum age for the VIP viewing area next to the vehicle assembly building was 16. I was only 12 at the time so he told me to "act old." I was lucky that by that time I was nearly six feet tall, so nobody called us on it.

In the basement of our house he built a wood shop, which he taught all three of his sons to use. I have fond memories of making furniture together, including a couple of pieces that are still in my mom's house.

I started to make model airplanes, at first plastic miniatures like Dad used to make and later radio-controlled gliders. This started a lifelong love of aviation. As a hobby, I have a pilot's license and fly my own airplane.

My dad taught me how to play golf, a game I love playing. This is one subject where he was probably not the world's best teacher. While I eventually got good enough to beat him, I'm fighting a slice that I think I copied from his swing.

But the greatest influence he had on my life was in my profession. He provided my first introduction to computer programming. I remember a Saturday afternoon at a computer lab watching him write a simple computer program in FORTRAN to compute mortgage interest. He showed me the printout of the program and explained the steps. He said I would probably be good at computer programming. He was right.

The other part of my profession that he introduced me to was photography. He gave me an Argus rangefinder camera when I was about 10, and taught me to develop film and make prints in a darkroom we built together in the basement. I combined my knowledge of computer programming and photography when John and I created Adobe Photoshop.

So I can honestly say that I owe the start of nearly everything in my life to my Dad. Thank you, Dad.

Recollections of Son John A. Knoll

Dad was a great man. A man of great warmth and goodness, humor, generosity, and of course an immense intellect. He was a man who was extraordinarily productive with a powerful work ethic. He set the bar very high, and every day I aspire to live up to his example.

I owe much of who I am today to the influences of the household in which Mom and Dad raised me. My brothers and I grew up in a loving and stable environment, one that encouraged curiosity, experiment, and creative expression.

What we learned from Dad, both by example and direct tutorship, was that it was possible to succeed at almost any endeavor if you were willing to make the investment and do the work. Dad behaved as though there were no fields that were beyond our abilities to master. We learned to question assumptions, be skeptical, and not accept the status quo.

I've been living in California for 34 years now and I work with many people from all over the world. One thing I've noticed from a thousand conversations is that people who grow up in cold climates develop indoor hobbies. Growing up in Ann Arbor, Tom and Pete and I had a lot of indoor hobbies. More than half of those began by observing Dad engaging in one of them. We'd take an interest, try it ourselves, and they would become our hobbies too.

For me, five hobbies I picked up from Dad led pretty directly to the career I've so happily engaged in my whole life.

Model Making

Dad used to build model kits of World War II aircraft. He was very good at it. They were beautiful and captivating with lots of intricate detail. I was fascinated by them and started trying to learn that skill. It took me nearly a decade to be any good at it, but eventually I got to be good enough that I worked professionally as a model maker for the first four years of my film career.

Still Photography

Dad built a darkroom in our basement and taught us the basics of photography, including how to develop film and make prints. A favorite memory of mine is when he bought me my first really good camera. I had learned on a super-bare-bones camera and was ready for something more sophisticated.

We went to the local camera shop where we browsed the selection. The salesman, seeing a 14-year-old kid, kept showing us simple starter cameras that didn't have the features I wanted. Looking down into the case, I spotted a camera that looked like it had everything I wanted: full manual, various automatic settings, double exposure mode, etc.

"What about that one?" I asked.

"Oh, you don't want that camera. You'd have to be a nuclear physicist to use that camera!"

Needless to say, that was the camera we bought. I loved it. It served me well for 25 years.

Electronics

When an appliance like a television broke we would take it to the basement workshop and fix it. I learned the basics of analog circuitry that way and developed a great interest in digital electronics that I still dabble in today.

Computer Programming

In the spring of 1978 Dad got an Apple][computer that he used for developing and testing signal processing algorithms. It was this really cool and exotic bit of high technology right there in our house. He showed us how it worked and encouraged us to learn how to use it. Boy did I ever take advantage of that!

That early exposure and encouragement led pretty directly to a lifelong passion for writing software tools and pushing the limits of using computers for creative expression. It also led pretty directly to my getting involved with Thomas in the development of Photoshop.

Making Stuff in the Shop

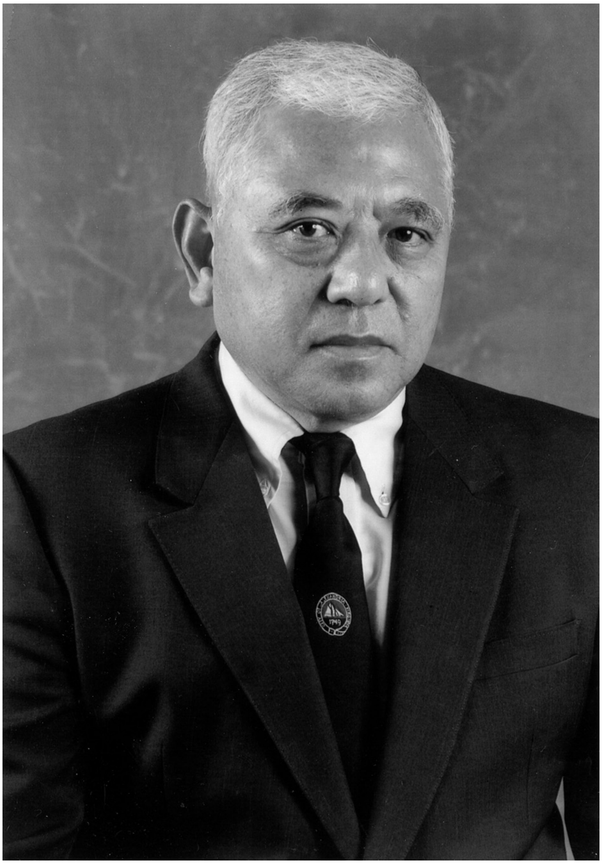
Dad had a nicely equipped workshop in the basement. He used it to fix things, build some really nice furniture, and generally engage in a lot of DIY. We got recruited to help on the bigger projects. That had a pretty big effect on me, too. I got to be very comfortable around woodworking and metalworking tools and learned that making things for yourself wasn't a big deal. Again, this has served me very well in my professional life.

All of those hobbies came together in what I ended up doing for the last 35 years in visual effects for film. I've seen a lot of success in film, but so much of it came directly from Dad's influence and example. Glenn is still very much alive in who I am, how I approach problems, and how I see the world.

When someone they love dearly passes, a lot of people express regrets about all the things they didn't get to say, the events they wish that person had been there to share, the regrets that they didn't make a greater effort to include them in their lives. I have none of those regrets. Dad knew how much we loved him. He was there to share in all of the most important events of our lives, and it was wonderful.

Glenn married Gladys Hetzner on September 7, 1957, and she survives, as do their three sons: Thomas Frederick, of Pacific Palisades; John Andrew (Jennifer), of San Rafael, CA; and Peter Glenn (Carola), of Andover, New Jersey. He delighted in grandchildren Andrew, Hannah, Harlow, Lisa, Alexander, and Jane. Also surviving are a brother, Alan Knoll (Ruth); sister, Marie Kaiser; in-laws, Judith and David Berger, Virginia and Wayne Hatwich; and many nephews and nieces.

We have lost a legendary friend and colleague.



RIKI KOBAYASHI

1924–2013

Elected in 1995

"For advances in the knowledge and measurement of the thermodynamic and transport properties of natural gas liquids and gas hydrates."

BY GEORGE J. HIRASAKI

RIKI KOBAYASHI, Louis Calder Professor Emeritus in Chemical Engineering at Rice University, died on July 19, 2013. He was known as Riki by his graduate students, although students from Japan respectfully call him "sensei."

Riki was born to Misutaro and Moto Kobayashi on May 13, 1924. Misutaro was a mechanical engineer in Japan who came to San Francisco in 1904. After the earthquake of 1906, Misutaro moved to the Saibara colony in Webster. In 1913 Moto came to America as a "picture bride." Riki's father raised Satsuma oranges in Webster and planted cucumbers between the orange trees. Once when the orange trees froze, the cucumbers saved his business. My father told me that he once visited Riki's father to discuss cucumber culture. Riki told me that our families are related by marriage in Japan. My grandmother's maiden name was Kobayashi, but then Kobayashi is a common family name in Japan.

Riki graduated from Rice University (then known as the Rice Institute) in 1944 with a BS in chemical engineering when he was 19 years old. He graduated with a PhD from the University of Michigan in 1951 and immediately joined the faculty of the Rice Institute. His thesis advisor was Donald Katz. Riki was one of the coauthors with Katz on the *Handbook of Natural Gas Engineering*, published in 1959 (McGraw-Hill). He was also a coauthor with Rice professor Tom Leland of the chapter on "Thermodynamics" in the *Handbook of Chemical Engineering*, the bible for the chemical engineering profession. Riki coauthored with Kuy Song and Dendy Slone the chapter on "Phase Behavior of Water/Hydrocarbon Systems" in the *Petroleum Production Handbook* (1987), and he coauthored with Patsy Chappelear and Harry Deans the chapter on "Physico-Chemical Measurements by Gas Chromatography" in *Applied Thermodynamics* in 1968. He authored approximately 200 journal articles.

When I was considering Rice for graduate school, my father said to look up one of the Kobayashi boys on the faculty at Rice. I got an appointment with Riki and he told me to come to Rice for my graduate studies. I did not apply elsewhere. I remember Riki as one of the young faculty members who would throw a football with his students.

At that time the Chemical Engineering Department was well known for the "Riki boxes" for measuring thermodynamic and transport properties at cryogenic conditions. These were complex instruments to measure properties of fluids at low temperatures for separation of components of natural gas. The instruments were surrounded by a "box" to hold the refrigeration coolant while making measurements but could be lowered when working on the instrument. The data from this technology are now used to liquefy natural gas for transportation of natural gas from places like the Middle East and Australia to markets in Europe and Asia.

Riki's interest in gas hydrates spanned his entire professional career, beginning with his PhD research and continuing even after he retired. At the time of his PhD research, gas hydrates were known as the ice-like material that would plug up natural gas pipelines. I visited him in the 1980s and he was conducting a graduate seminar on how to produce natural gas from methane hydrate deposits below the permafrost. At that time hardly anyone was thinking about producing natural gas from hydrates. In 2013 Japan did a successful production test of natural gas from marine deposits of methane hydrates off the coast in the deep waters of the Nankai Trough.

Riki was a pioneer in using nuclear magnetic resonance (NMR) to measure the diffusion coefficient of hydrocarbon fluids. In the 1960s he was working on NMR with Raph Dawson and Fouad Khoury. When I joined the faculty in 1993, Riki encouraged me to do NMR research. He gave me piles of literature, dating back to 1948, to get me up to speed on the NMR science. His dream was to discover the unifying connection between viscosity, diffusivity, and thermal conductivity with the NMR T_1 and T_2 relaxation times. He was hoping to use the principle of corresponding states to unify these properties. We were awarded a research grant by the National Science Foundation and Sho-Wei Lo earned her PhD showing that methane in live oil relaxed by the spin-rotation mechanism rather than the dipole-dipole interactions as was commonly assumed at that time. Subsequently, Shell, Schlumberger, and Marathon donated NMR spectrometers to Rice to encourage us to continue the research.

Perhaps more than any other living individual, Professor Kobayashi has provided the engineering database for the natural gas industry. He received the first Donald L. Katz Award from the Gas Processors Association (GPA) in 1985. This award "was initiated to recognize outstanding accomplishments in midstream research and technology, and/or for excellence in engineering education." His work was characterized in a 1987 American Institute of Chemical Engineers (AIChE) symposium in his honor as "one of the century's most prolific and lasting efforts in thermodynamic and transport properties." He had the vision to pioneer (1) the measurement of hydrocarbon vapor–water–gas hydrate equilibrium; (2) the use of gas chromatography to measure vapor-liquid and vapor-solid equilibria, phase transitions, and molecular diffusivity; (3) the use of laser light scattering to measure properties in the critical region; and (4) the use of NMR relaxation measurements to determine the connection between diffusivity and viscosity with NMR relaxation times through the corresponding state principle of thermodynamics. His exceptionally high quality pressure-volume-temperature (PVT), vapor-liquid equilibria (VLE), and viscosity data have become the standard of the industry for the development of correlations and have found immediate use by industry. His low-temperature VLE data have permitted the design and development of the turbo-expander plant, the most prevalent process in the gas industry. Recent industrial applications of his data include (1) design of CO_2 processing facilities for enhanced oil recovery, (2) design criteria for dehydrating natural gas in North Slope and North Sea production to prevent hydrate formation, and (3) water content criteria for gas transmission in the proposed Alaskan Gas Pipeline.

Riki was elected a member of the National Academy of Engineering in 1995. He was a fellow of AIChE and the American Institute of Chemists and a member of the Academy of Medicine, Engineering and Science of Texas, the Japan Institute of Chemical Engineering, the American Institute of Mining, Metallurgical, and Petroleum Engineers, and the American Chemical Society. He was awarded the Outstanding Engineering Award at Rice University in 1985 and the Albert Einstein Medal from the Russian Academy of Natural Sciences in 2010.

Riki's legacy at Rice University is remembered by the Riki Kobayashi Graduate Fellowship in Chemical Engineering. This is a perpetual fellowship from an endowment raised by Riki's friends, associates, and former students who want to recognize Riki and the impact he had on their lives and careers.

I miss Riki—he was my teacher, fellow professor, and a family friend. He is survived by his wife Lee, two sons, two stepdaughters, and three grandchildren.

Charles C. Ladd

CHARLES C. LADD

1932–2014

Elected in 1983

"For developing unifying principles governing clay behavior and innovative design procedures related to soft ground construction."

BY W. ALLEN MARR

Civil engineering lost an icon and Geo-Legend with the passing of CHARLES CUSHING LADD III, age 81 (born November 23, 1932), at his home on August 4, 2014. Professor Ladd was renowned as a gifted teacher (with a style emulated by many former students who became faculty members) and innovative researcher on advanced technical topics in geotechnical engineering, particularly the engineering properties of soft clays. He was internationally sought after to consult on complex and difficult civil projects involving soft ground.

Among his numerous professional achievements, Professor Ladd was elected to the National Academy of Engineering in 1983. He was the recipient of many research awards from the American Society of Civil Engineers (ASCE), including the Walter L. Huber Civil Engineering Research Prize (1969), the J. James R. Croes Medal (1973), the Thomas A. Middlebrooks Award (2002), the Norman Medal (1976), and the Karl Terzaghi Award (1999). In 1995 he was elected to distinguished member of ASCE. In 2013 he was awarded the ASCE Outstanding Project and Leaders (OPAL) Leadership Award for his contributions to engineering education, an accomplishment of which he was most proud. He also contributed his time and expertise to a number of ASCE committees, among them the Committee on Curricula and Accreditation, the Geotechnical

Engineering Division's publications committee, the Awards Committee, and a committee dealing with soil properties. He also served as a member of the Geo-Institute's Board of Governors. He also received the C.A. Hogentogler Award (1990) from the American Society for Testing and Materials.

Professor Ladd was an inspiring, committed teacher, legendary for his attention to detail, focused thinking, and integrity. His lectures in soil mechanics and soil behavior were meticulously prepared, accompanied by his handwritten notes bearing his initials and revision dates in the upper right-hand corner of each sheet. Chuck challenged his students to rise to high levels of performance and determination.

One of his most important contributions was the development of SHANSEP, an acronym for stress history and normalized soil engineering properties, which is widely used for evaluating the undrained stability of construction on and in soft clays. This work grew out of a consulting project in Japan in 1960 involving oil storage tanks constructed on deep soft soils and evolved into 50 years of research and practice with major contributions on the effects of anisotropy, sample disturbance, and strain rate on stress-strain-strength behavior of clay soils.

Chuck received a bachelor of arts (cum laude) in mathematics and physics from Bowdoin College in 1955, and a bachelor of science in building engineering and construction from MIT the same year. He continued on at MIT to earn a master of science in civil engineering in 1957 and doctor of science in soil engineering in 1961. He joined the MIT faculty in 1961 and served continuously until he retired in 2001 as the Edmund K. Turner Professor of Civil and Environmental Engineering. He served as instructor, assistant professor, associate professor, full professor, acting head of the Geotechnical Division, chair of the Civil and Environmental Engineering Department's Committee on Graduate Studies, director of the Center for Scientific Excellence in Offshore Engineering, and graduate admissions officer.

Chuck was the patriarch of a large, tightly knit family. He and his late wife, Carol, enjoyed taking their family on winter cruises and treating their extended family to yearly summer vacations. He and Carol were famous for hosting Christmas parties where he would serve his signature "punch" concoction. He loved his students and colleagues, often inviting them to attend family functions, celebrations, and holidays. Up until his hospitalization on August 1, he had been spending much of his time happily working on a book on soil behavior and a challenging soft clay embankment stability problem for a proposed new airport in Mexico City.

He was a devoted husband of 55 years to the late Carol Ballou Ladd, who died in 2009. He is survived by children Melissa Northrup of Boxborough, MA; Charles C. Ladd IV and his wife Marcia of Mountain Top, Pennsylvania; Ruth McGraw and her husband James of Essex, MA; Matthew Ladd and his wife Annette of Little Compton, Rhode Island; nine grandchildren; and three great-grandchildren. He also left his fiancée, Elaine Burkley of Sudbury, Massachusetts, and his brother and sister-in-law, Richard and Linda Ladd of Albuquerque.

FREDERICK F. LING

1927–2014

Elected in 1977

"Contributions to the understanding of friction and wear, metal cutting and forming, and the dysfunction in human joints."

BY VAN C. MOW

FREDERICK FONGSUN LING, a distinguished professor of mechanical engineering and one of the most influential tribologists of the twentieth century, died on November 8, 2014, in New York City at the age of 87. He dedicated his professional life to the study of friction, lubrication, and wear of materials, bringing an interdisciplinary approach to improving manufacturing productivity.

Dr. Ling was born in Qingdao, China, on January 2, 1927. He received a BS degree in civil engineering from St. John's University, Shanghai, in 1947. Soon thereafter, he left for the US on a Ford International Scholarship to Bucknell University, where he earned a BS in mechanical engineering in 1949. Because of the ongoing civil unrest in China at the time, Dr. Ling did not return to his home country but continued his studies at the then Carnegie Institute of Technology (now Carnegie Mellon University) for an MS in mechanical engineering (1951), followed by a DSc in mechanical engineering. His doctoral dissertation, entitled "An Investigation of Sliding Friction and Interface Temperature between Two Dry Metallic Surfaces," was completed in 1954. He began his deep involvement in research on surface mechanics and tribology during his graduate studies.

Following his DSc, he was appointed assistant professor of mathematics at Carnegie Institute of Technology. Two years later, he joined the Department of Mechanics at Rensselaer Polytechnic Institute, where he served as chair from 1967 to 1974. In 1974, he was appointed chair of the newly established Department of Mechanical Engineering, Aeronautical Engineering & Mechanics, serving as chair until 1986. He held the title of William Howard Hart Professor of Rational and Technical Mechanics from 1973 to 1988.

During his time at Rensselaer, Dr. Ling introduced many graduate students to the field of tribology, and in 1990 was named Distinguished William Howard Hart Professor Emeritus. After retiring from Rensselaer, he became a visiting professor in the Department of Mechanical Engineering at Columbia University for four years and also served as director of the Columbia Engineering Productivity Center. From 1990 to 1992, he was president of the Institute of Productivity Research in New York.

In 1992, Dr. Ling began a 10-year tenure at the University of Texas at Austin, where he held the Earnest F. Gloyna Regents Chair in Engineering, Department of Mechanical Engineering, and the position of associate director for engineering, Center of Manufacturing Systems. In 2002, he became the Earnest F. Gloyna Regents Chair Emeritus in Engineering. He retired to New York City where he continued to serve as editor in chief of Springer-Verlag's *Mechanical Engineering Series* until 2011.

Professor Ling authored the seminal texts *Surface Mechanics* (Wiley Interscience, 1973) and, with W.M. Lai and D.A. Lucca, *Fundamentals of Surface Mechanics with Applications* (Springer-Verlag, 2002). He wrote or coauthored more than 100 scientific publications and numerous other books. In the preface to Springer's *Mechanical Engineering Series*, he stated, "Mechanical engineering, an engineering discipline borne of the needs of the industrial revolution, is once again asked to do its substantial share in the call for industrial renewal. The general call is urgent as we face profound issues of productivity and competitiveness that require engineering solutions, among others…." In his life's work, Dr. Ling strived to meet that challenge, lecturing widely on friction, lubrication, and wear in manufacturing and material systems and leading research teams on projects for government agencies such as the Air Force Office of Scientific Research, the National Aeronautics and Space Administration, and the National Science Foundation. He established research with companies such as the Ford Motor Company, General Electric, and IBM, and initiated research collaborations with tribologists in government and university laboratories, both domestic and foreign.

Among his numerous honors and awards, Dr. Ling received the coveted Senior Postdoctoral Fellow Award from the National Science Foundation in 1970 and the American Society of Mechanical Engineers (ASME) Mayo D. Hersey Award in 1984. He was elected to the National Academy of Engineering at the age of 50. In 1998, ASME recognized his lifetime service to engineering with its honorary membership for "advancing the field of tribology through engineering research and applications in machine systems."

A modest, patient, and optimistic man, nothing delighted Dr. Ling more than helping his students and colleagues advance their careers. He instilled a strong tradition of leadership in tribology and mechanical engineering communities; that tradition is being carried on by a large number of former students and colleagues whose careers were influenced greatly by Professor Frederick F. Ling.

He is survived by his wife of 60 years, the former Linda Kwok, three children, and four grandchildren. His daughter Erica shared the following observations.

Song of the Tiger

My father was a reserved, modest man who led by example and did not like to stand on ceremony. He introduced himself simply as Fred Ling. My brothers and I were known as The Kids. But we were just the nucleus of his family. He embraced and took great pride in the achievements of his engineering students and colleagues, and the honor of which our father was most proud was election to the National Academy of Engineering, at the age of 50.

Dad was born in the Year of the Tiger, the third of five sons and one daughter of Helen C.Y. Wong, an educator and a doctor, and Frank F.C. Ling, an engineer, who met while pursuing degrees at the University of Michigan in the early 1920s. When Dad left Shanghai to study at Bucknell University, he was only 20 and had always intended to return to China. Because of historical events in China, he never saw his mother and father again—but their example clearly inspired Dad's notable career and commitment to education, research, and service in engineering. Those born in the Year of the Tiger are said to be born leaders—courageous and energetic, competitive yet capable of great generosity. Dad was all of those things, yet he was also gentle, whimsical, and artistic.

Throughout his life, Dad took delight in solving problems and fixing, designing, and building things. Dad's only surviving brother, Wilfred C. Ling, tells a story about Dad at the end of World War II, when he and a friend dismantled a US Army jeep, rebuilt the engine and body, and resold it to the associate headmaster of St. John's Middle School.

Dad made me my very first dress, a red jumper from one of his shirts. He designed and built pieces of furniture shortly after my parents were married. Linda Kwok and Fred Ling, both born in China, formed an unlikely pairing—she, mercurial and impulsive, and he, tenacious and deliberate—yet they complemented each other for more than six decades, and raised their three children in Troy, New York. Dad became a naturalized citizen in 1962, Mom in 1966.

Dad taught my brother Alfred, who inherited his ability to fix anything, how to use hand and power tools, and his use of Dad's drafting tools no doubt led him to a career in architecture. While that mechanical facility eluded me, I too became an architect. It is interesting Dad should beget two architects, as he was in some ways himself a frustrated architect. He designed the house we lived in at 30 Mellon Avenue in Troy, which featured a courtyard plan characteristic of traditional Chinese houses, an atrium, minimalist landscaping, and solar panels way back in the 1970s.

When he wasn't building things, Dad loved to read, mostly biographies and history, and passed on an appreciation of history, especially about the Second World War, to my brother Arthur. Arthur remembers fondly the times Dad and he talked about famous historical figures and events and spent many a night watching old World War II movies together. Yet of even more interest to Dad was our family history, which Arthur recalls Dad telling, for example, at the kitchen table while drawing pictures of the old family home in Qingdao. Dad also was captivated by music, especially opera, and loved to sing. His former colleagues at Rensselaer Polytechnic Institute remarked that Dad would look for any excuse to have a singalong. Occasionally he would pull out his harmonica, and once he even stepped up to play with a jug band at a pumpkin farm.

I am very much like my father, in appearance and in temperament. He used to call me perpetual motion, but that's how I remember him. Industrious and energetic, he was always busy thinking, doing, or traveling.

Dad relished travel, especially in Eastern Europe during the era of détente, and took full advantage of the chance to experience different cultures and languages. Lucky was the child who sat next to him on an airplane during his frequent flights, for Dad invariably would fold and present the gift of an origami bird or frog.

One of Dad's greatest pleasures later in his life was being a grandfather to Alfred and Molly's sons and to Stephen's and my daughter. Following Chinese tradition, he was known as Yeh-yeh to Frank, Timothy, and Edward and as Gong-gong to Thea.

Grandson Frank carries on the origami tradition, far surpassing Yeh-yeh in the complexity of the designs he creates. Thea, who inherited his peripatetic gene, remembers Gong-gong singing her lullabies and how very generous he was. Tim embodies Dad's whimsical, fun-loving side, a dimension not seen by too many others. Eddie is studying mechanical engineering, which would have pleased his Yeh-yeh greatly. He and Frank love cars, just like their father and grandfather, and share that enviable gift of being able to fix anything.

Late in life, Dad's mental gifts began to fail him, yet he remained courteous and generous, and to the end, he seemed comforted by music and would hum to let us know things were okay. Dad often noted the role of serendipity in his life. He made the most of those opportunities during a long and rewarding life, far from his beginnings in Qingdao but ever true to the principles by which his parents lived. Elizabeth Doocey, Dad's longtime executive assistant at Rensselaer Polytechnic Institute, described Fred Ling well: he was a gentle man and a gentleman.

Erica H. Ling, for The Kids
October 19, 2015

ROBIN MILNER

1934–2010

Elected in 2008

"For fundamental contributions to computer science, including the development of LCF, ML, CCS, and the pi-calculus."

BY TONY HOARE AND GORDON PLOTKIN

ARTHUR JOHN ROBIN GORELL MILNER, a founding father of theoretical computer science, died of a heart attack on March 20, 2010.

Robin was born to Muriel (née Barnes-Gorell) and John Milner (a colonel in the British Army) in Yealmpton near Plymouth in South Devon on January 13, 1934. He attended the historic English private school Eton College, where he developed his love of mathematics. He spent his two years of compulsory military service in the Royal Engineers, ending as a second lieutenant. He entered King's College, Cambridge, as a scholar, obtaining the highest honors in mathematics; then he spent his final year studying philosophy. He had no secondary degree until the later awards of honorary doctorates at 10 leading universities in Europe.

His first year of employment (1959–1960) was as a mathematics teacher at Marylebone Grammar School. He then joined a major British computer manufacturer, Ferranti Ltd., to work as a programmer. In 1963 he was appointed a lecturer in mathematics and computing at the City University, London, where he acquired his lifelong interest in automata theory, programming languages, artificial intelligence, and the relationship of logic with computation. These topics formed the essential mathematical basis and motivation for his subsequent researches.

He left London in 1968 to begin a period of full-time research, first at the University in Swansea, Wales, and then at Stanford University, California. In 1973, he was appointed as a lecturer in computer science at Edinburgh University. With Rod Burstall, Matthew Hennessy, and Gordon Plotkin, he founded and then served as the first director of the world-famous Laboratory for Foundations of Computer Science. In 1990–1994 he resumed full-time research, supported by a senior fellowship from the national funding agency SERC. He moved to Cambridge University in 1995 as head of the Computing Laboratory, and retired in 2001, after 2 years as a research professor there.

Robin's research interests always lay at the very foundations of computer science. His theories were embodied directly in highly original computer programs written by him and his colleagues. They served initially as research and educational tools. His colleagues then contributed to the extension, standardization, and reengineering of the tools in support of an even wider community of researchers. Eventually Robin's ideas and the tools evolved into general-purpose design automation tools for software engineers. This progression foreshadowed the development of the current culture of open-source software.

A prime example of this progression was his implementation (beginning at Stanford, but mostly at Edinburgh) of an automated reasoning tool for Dana Scott's logic for computable functions (LCF). The experience of implementation led him to the design and implementation of the first practical functional programming language, ML (metalanguage). It incorporated the Hindley-Milner algorithm for inferring and checking the types of all the terms of the language, while allowing the programmer to declare new polymorphic types to suit the needs of different applications. His own application was the generation of logical proofs, whose validity was also ensured by type checking. These successful features of ML were widely reproduced in many subsequent proof engines that are now in widespread use, as both industrial and research tools. Examples are Mike Gordon's and John Harrison's versions of

HOL (higher-order logic), both used as design tools in the electronics industry.

Throughout his career at Edinburgh, Robin explored the foundations of concurrent and distributed programming. Each of his major projects repeated the progression described in the previous paragraphs. They represent three major milestones in the broadening of our understanding of the practice and study of concurrency.

The first milestone was his novel formulation of a calculus of communicating systems (CCS). This opened a new area of computer science research, which culminated in industrial-strength tools for design of interactive (cyberphysical) systems (for example, Kim Larsen and his colleagues' UPPAAL). He introduced the efficiently mechanized concept of bisimulation as a definition of the equivalence of programs; informally interpreted, it showed that for every pair of nonequivalent programs there is a test or experiment capable of revealing their difference. This is an elegant formal expression of a philosophical principle common to both scientific theories and engineering specifications.

His next accomplishment was the pi-calculus, which models dynamic reconfiguration of communication channels between concurrent processes, and defines a notion of structural equivalence in terms of algebraic axioms and proof rules. He was looking for a canonical calculus of concurrent computation, which would underlie not only CCS but also functional programming and even Turing machines. The pi-calculus has been applied to a diverse range of problems, including computer security and biological modeling.

Finally, in his retirement he continued to work on a new "bigraphical" model for reactive systems. He proposed it as a unifying foundation for a wide range of calculi, including the pi-calculus. It was the subject of his last book, and a full discharge of his lifetime commitment to the idea that computer science is a science as fundamental as physics, with the same power to change and be changed by mathematics.

Robin's services were in repeated demand for the comparative assessment of the research and teaching of the universities in the UK, which provided a basis for differential allocation of government funds. He was the editor of no fewer than five journals in theoretical computer science. In 1990, he was founding chairman of the UK Distinguished Dissertations scheme in computer science, and in 2002 a founding member of the UK Computing Research Committee (UKCRC), which was later adopted by the British Computer Society as the core of its academic branch.

From 2003 he was joint leader with Tony Hoare of a series of discussions in the UK, working toward agreement on long-term goals for computer science research, including the possibility of Grand Challenge projects. It was inspired by the completion in that year of the Human Genome Project, and it later secured sponsorship by the UKCRC. Robin identified most strongly with the challenge posed by the prospect of ubiquitous computing which has now been realized by Data Centres and the Internet of Things. He proposed that the scientific understanding of the associated problems could be met by a structured hierarchy of mathematical models, similar to those which have been astonishingly successful in all established branches of science, and which have served as the foundation of effective design automation tools in all branches of engineering. The search for such models has intensified and continues to this day.

Robin was the recipient in 1991 of the A.M. Turing Award in recognition of his work on LCF, ML, CCS, and full abstraction, an important foundational concept in the study of programming language semantics. Other leading awards were the (British) Computer Society Technical Award for the development of Standard ML (1987), the ACM SIGPLAN Programming Languages Achievement Award (2001), the Royal Medal of the Royal Society of Edinburgh (2004), and the Distinguished Achievement Award of the European Association for Theoretical Computer Science (2005).

In 1988 he was elected as a founding member of the Academia Europaea, fellow of the Royal Society, and Distinguished Fellow of the British Computer Society. He was later elected to fellowships of the Royal Society of Edinburgh (1993) and of the ACM (1994), and received a foreign membership of the Académie Française des Sciences (2005). In 2006–2007 he was awarded the Blaise Pascal Chaire Internationale de Recherche, which he held at the Ecole Polytechnique.

Robin's publications included *Edinburgh LCF: A Mechanised Logic of Computation* (with Mike Gordon and Chris Wadsworth; Springer, 1979), *Commentary on Standard ML* (with Mads Tofte; MIT Press, 1991), *The Definition of Standard ML* (with Robert Harper, David MacQueen, and Mads Tofte; revised edition, MIT Press, 1997), *A Calculus of Communicating Systems* (Springer LNCS, 1982), *Communication and Concurrency* (Prentice Hall, 1989), and *The Space and Motion of Communicating Agents* (Cambridge, 2009).

Robin bore his genius and his distinctions lightly. To his students, his followers, his colleagues, and his scientific rivals he extended his gentle kindness and his generous friendship. He was always a pleasure to be with.

Robin's idea of relaxation included household repair and embellishment. He possessed a comprehensive collection of woodworking tools, with which he made elegantly shaped handles for string-pull light switches, special-purpose shelving in his home, and even a new handle for a fridge. His most unusual product was a new wooden dial to replace the broken plastic dial of an old rotary dial phone. Each finger hole was lovingly sanded smooth.

In his student days, Robin played the oboe, cello, and piano, and considered a career in music. It was at a music camp in 1963 that he met his wife, the violin teacher Lucy Moor. They both loved music throughout their lives, and Lucy played the viola in an enduring and popular amateur string quartet. Robin died only a few days after her funeral. He was also predeceased by his son Gabriel. He is survived by his sister June, daughter Chloe (with daughter Amy), and son Barney (with daughter Jade).

JOHN B. MOONEY JR.

1931–2014

Elected in 1988

"For pioneering development of effective systems and techniques for manned operations to the full depth of the oceans."

BY DON WALSH

JOHN BRADFORD MOONEY JR., whose leadership made the US Navy a global leader in undersea technology and deep ocean operations, died in Austin, Texas, on May 30, 2014, at the age of 83.

Brad was born in Portsmouth, New Hampshire, on March 26, 1931. From his New England heritage he developed a love of the sea at an early age. As a young man, he became involved with scouting, eventually achieving the rank of Eagle Scout.

After graduating from high school in 1949 he won an appointment to the US Naval Academy. While at Annapolis he was active in sailing and cross-country track competitions. Graduating with the class of 1953, he served two years in surface ships.

Next he entered Submarine School at New London, Connecticut, in 1955 for the 6-month training course. After graduation he served in three submarines in the Atlantic and Pacific Fleets from 1955 to 1964.

In 1964 Brad's undersea career took a new and unusual direction. He was ordered to duty as the officer in charge of the Navy's bathyscaph *Trieste II*. This would be his first command in his 34-year-long naval career.

The two-person *Trieste II* was capable of diving to 20,000 feet (6,000 m) to access 98 percent of the seafloor in the world ocean. At the time it was one of two deepest-diving manned vehicles in the world. The French Navy had the other.

The deep submersible program was based at the Navy Electronics Laboratory (NEL) in San Diego from 1958 to 1964. Its mission was to support oceanographic research for the NEL scientists and those from other institutions.

However, the Submarine Force decided that *Trieste II* could be best used for highly classified recovery missions and related work tasks. Lieutenant Commander Mooney was assigned the very delicate task of moving the *Trieste II* program from the research and development community to the Submarine Force command in San Diego.

Ultimately he played a major role in the establishment of a new Navy command at San Diego. Submarine Development Group One would be the first organization that consolidated all of the Navy's deep diving programs. Its assets included several submersibles, the Man in the Sea (e.g., Sea Lab) program, and the *Baya* (SS-318), a specially configured diesel submarine used for acoustics research.

As the O-in-C of *Trieste II*, Brad's first major mission was investigating the nuclear submarine *Thresher* (SSN-593) wreck site. In late April 1963 *Thresher* was lost with all hands in the North Atlantic 220 miles (354 km) east of Boston. The wreckage was found in 8,200 feet (2,500 m) of water in 1963 by the first *Trieste*. In the summer of 1964 *Trieste II* did a second series of forensic dives there. Brad piloted several of the dives.

In recognition of his pioneering work with *Trieste II*, Brad was designated US Navy Deep Submersible Pilot #5 in 1964.

In January 1966, a hydrogen bomb was lost in the sea near Palomares, Spain, at a depth of 2,550 feet (880 m). Commander Mooney was temporarily ordered to assist the Navy task group that searched for 80 days before recovering it.

In 1966, after two years as commander of the *Trieste II*, he was ordered to the submarine *Menhaden* (SS-377) as commanding officer. During his time as captain, the ship operated in the Eastern Pacific and made two six-month deployments to the Far East including the Vietnam war zone.

After his command tour, Brad was ordered to the Pentagon to organize a new office within the Office of the Chief of Naval Operations (OPNAV) that would have oversight of all the Navy's deep submergence activities. His title was deep submergence programs coordinator. He served in this capacity from 1968 to 1971.

His skills were put to the test in May 1969 when the nuclear submarine *Scorpion* (SSN-589) was lost with all hands near the Azores Islands. The water depth was about 12,000 feet (3,700 m). *Trieste II* was deployed from San Diego on board a floating drydock for the long tow to the Azores. While Commander Submarine Development Group One was mission commander, Brad provided the coordination link between Navy headquarters in Washington and the afloat task group.

In 1971 Brad was ordered back to San Diego as the chief staff officer (#2 position) at Submarine Development Group One. While Submarine Development Group One was now a fairly mature organization, it benefited greatly from Commander Mooney's years of operational experience with deep submergence systems at sea as well as headquarters expertise gained while in OPNAV.

In 1972 Captain Mooney received orders to become the commanding officer of the Naval Station in Charleston, South Carolina, a major shore command. He returned to the Navy's deep submergence community in 1975 when he was ordered back to Washington, DC, as the deputy director of the Deep Submergence Systems Division in OPNAV.

In 1977 he was given another major shore command, the Naval Training Center in Orlando, Florida. His time there was less than a year as he was selected for promotion to rear admiral later that year.

His first flag officer posting was director of the Total Force Planning in the Office of the Chief of Naval Operations. He finally got back into ocean science and technology work when he was appointed oceanographer of the Navy in 1981 with additional duty as naval deputy at the National Oceanic and Atmospheric Administration (NOAA) in the Department of Commerce.

After two years as oceanographer he was appointed the 15th chief in charge of the Office of Naval Research. He served from 1983 to 1987. From 1982 to 1987 he was also chairman of the board and the editorial committee at the 135-year-old US Naval Institute, an educational forum for the naval professions.

Rear Admiral Mooney retired from the Navy in 1987 having served for 34 years. About half of his career was associated with Navy-related science and technology programs ranging from the bottom of the sea to the edge of space.

During his long naval career, Brad's outstanding contributions were recognized by two awards of the Legion of Merit medal, three Meritorious Service Medals, and two Navy Unit Commendations.

In civilian life he did not slow down. He became a consultant on ocean-related issues to many organizations. Among others, he advised marine programs at universities such as Texas A&M, the University of New Hampshire, and Florida Atlantic University.

Brad was elected to the National Academy of Engineering in 1988 and was a member of Section 12 (Special Fields and Interdisciplinary Engineering). He also served in several capacities with the National Research Council and was a member of the Marine Board from 1991 to 1994.

In January 1989 he was appointed president and managing director of the Harbor Branch Oceanographic Institution (HBOI) at Fort Pierce, Florida. He left HBOI in March 1992.

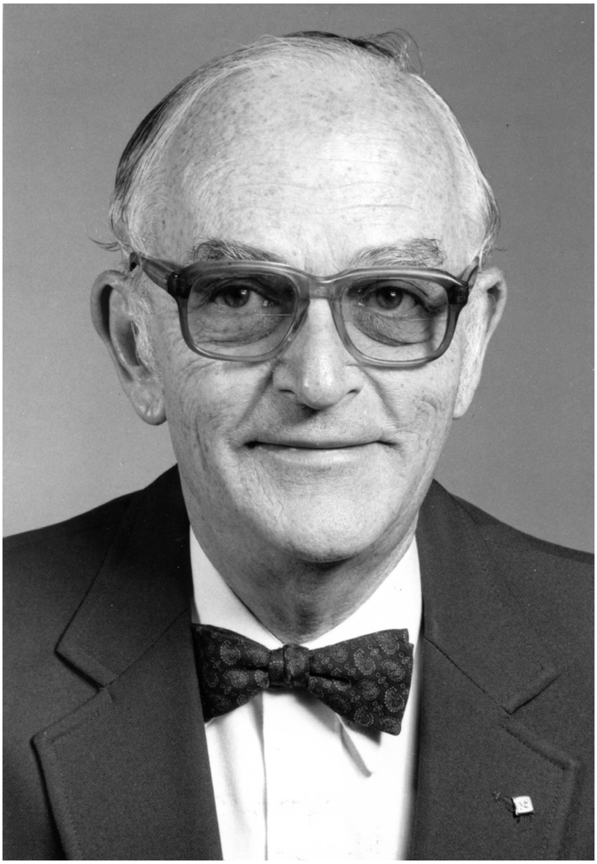
From 1991 to 1992 he was the elected president of the Marine Technology Society (MTS) for a two-year term. In 1999 MTS recognized his contributions to ocean engineering with its highest honor, the Compass Distinguished Achievement Award.

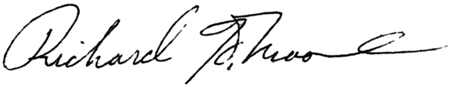
In 1995, the prestigious Explorers Club elected Brad Mooney as a fellow in recognition of his early deep ocean explorations.

Through the mid-2000s Brad continued advisory committee work with the NRC and the Naval Research Advisory Committee. By the end of the decade he had mostly retired to his home in Austin, Texas.

Brad Mooney is survived by his wife of 24 years, Jennie Marie "Jay" Mooney; daughters and sons-in-law, Melinda

Jean and Timothy Thomas of Mansfield, TX, Pamela and George Greenleaf of Wilmington, North Carolina, and Jennifer Joan and Dave Mattingly of Ashburn, VA; stepsons and wives Devitt and Corine Adams of Cape Cod, Massachusetts, and Darryl and Katie Adams of Austin, TX; and 12 grandchildren.





RICHARD K. MOORE

1923–2012

Elected in 1989

"For pioneering achievements in radar remote sensing of the land and oceans from air and space platforms."

BY JOHN MOORE AND GLENN E. PRESCOTT
SUBMITTED BY THE NAE HOME SECRETARY

RICHARD K. MOORE, Distinguished Professor Emeritus at the University of Kansas and one of the most noted scientists in the field of radar remote sensing, died on November 13, 2012, at the age of 89. At the time of his death, Moore was widely recognized as a pioneering researcher in the radar remote sensing of the Earth, having had a prominent role in the founding research that defined this field. He spent more than 30 years as an electrical engineering faculty member at the University of Kansas (KU), where he founded the interdisciplinary Radar and Remote Sensing Laboratory. He continued to work until the year of his death, maintaining an office at KU with the Center for Remote Sensing of Ice Sheets (CRESIS).

Richard, or Dick as he was generally called, was born in St. Louis, Missouri, on November 13, 1923, to Louis D. and Nina M. Moore. He lived in the family home in Kirkwood through university graduation. His avid interest in ham radio led him to study electrical engineering at Washington University in St. Louis where he received his BS in 1943.

He worked for RCA in Camden, New Jersey, as a radar engineer after graduation, where he met and married Wilma Schallau, also an engineer, in 1944. He joined the Navy that same year and served as an electronics and radar officer on the USS *Rehoboth* in the Pacific. In 1946, upon separation from the

Navy, he attended graduate school at Washington University, St. Louis. His master's thesis, in which he developed a very low frequency (VLF) antenna for submarines, was judged to be of doctoral quality, and he moved to Cornell to complete that work, while also researching tropospheric and ionospheric propagation. His son John wrote that when he was working on his doctorate, his work and the resulting thesis (development of the VLF antenna) became classified material. This meant he could not work on it during his regular work as a graduate student and could not even discuss it. Hence, he did research on tropospheric and ionospheric propagation as his public research and a way to earn money to raise his family and, of course, because of his interest in it dating from the start of his ham radio avocation. Upon receiving his PhD from Cornell in 1951, he moved his young family to Albuquerque and worked at Sandia Corporation while lecturing at the University of New Mexico (UNM). In 1955 he became chairman of the Electrical Engineering Department at UNM, remaining until 1962. He was offered the Black and Veatch Distinguished Professorship at the University of Kansas that year and he moved to Lawrence, Kansas.

Two years after arriving at KU, Dr. Moore established the interdisciplinary Radar and Remote Sensing Laboratory (RSL) with support from the National Aeronautics and Space Administration (NASA) and the Army. RSL pioneered the use of short-wavelength (microwave) radar systems for satellite-based remote sensing. He worked at RSL until his retirement in 1994. After retirement, he continued to conduct sponsored research projects until 2004. In the 30 years he spent at the University of Kansas, he developed powerful tools that transformed weather forecasting and climate change monitoring. His research resulted in scientific instruments being placed aboard NASA and other agency satellites for collecting data and improving understanding of the oceans and the atmosphere.

Dr. Moore, in addition to serving his country in the Navy, performed classified research and served on classified government committees in the areas of defense and national intelligence throughout his career, including the CIA's MEDEA committee and the National Research Council Advisory Committee on Undersea Warfare.

Richard Moore was indeed one of the world's most respected leaders in remote sensing. In 1957, before the US had even launched its first satellite, he coauthored a research paper that described how radar could map the Earth from orbit. He recognized the remote sensing potential of synthetic aperture radar (SAR) attached to a low-flying aircraft. Six years later, he was helping NASA launch the first generation of communications and weather satellites.

Moore developed the concept of wind-vector scatterometry, with his colleague Bill Pierson, and the concept of scanning synthetic aperture radar (ScanSAR). Cal Swift, in his preface to a special issue of *IEEE Transactions of Antenna and Propagation in Radio Oceanography*, published in January 1977, stated that the persistence of Moore and Pierson in advocating the wind-vector scatterometry in spite of less-than-encouraging results from previous experiments has led to the development of more accurate aircraft and spacecraft instruments. These instruments were used to collect data under a variety of wind conditions and prove a concept that eventually resulted in satellite measurements of ocean winds. Now wind-vector data obtained from microwave scatterometers on satellites are being used in numerical weather forecasting.

The wind scatterometer helped revolutionize weather forecasting by mapping wind fields over remote oceanic regions. This radar identifies hurricanes, typhoons, and cyclones in the early stages of formation and monitors wind speed and other factors that influence weather. In addition, the ScanSAR concept was used in the Shuttle Imaging Radar mission for mapping the surface topography of the Earth, and wide-swath imaging was used in both the RADARSAT and ENVISAT satellites. The ScanSAR concept will continue to be used in forthcoming satellite radar missions.

Dr. Moore received many accolades during his career. He was made a fellow of IEEE in 1962 for contributions to electromagnetic propagation, and he was named a life fellow of the IEEE in 1993. He was awarded an Outstanding Technical Achievement Award by the IEEE Council on Oceanic Engineering in 1978; that same year, he received the Alumni Achievement Award from his alma mater, the Washington University School of Engineering and Applied Science. In 1982 he received a Distinguished Achievement Award from the IEEE Geoscience and Remote Sensing Society, and he was awarded the IEEE Centennial Medal in 1984.

In 1989 he received the Irvin Youngberg Award in the Applied Sciences from the University of Kansas, and in 1993 he was named a fellow of the American Association for the Advancement of Science. His most prestigious awards were given in 1995 when he was honored with the Italian Center for Remote Sensing Award and the Australia Prize for Remote Sensing, given to a pioneer in the field of microwave-based satellite remote sensing, and a prolific inventor of new remote sensing devices that helped revolutionize mapping and monitoring of the Earth's surface.

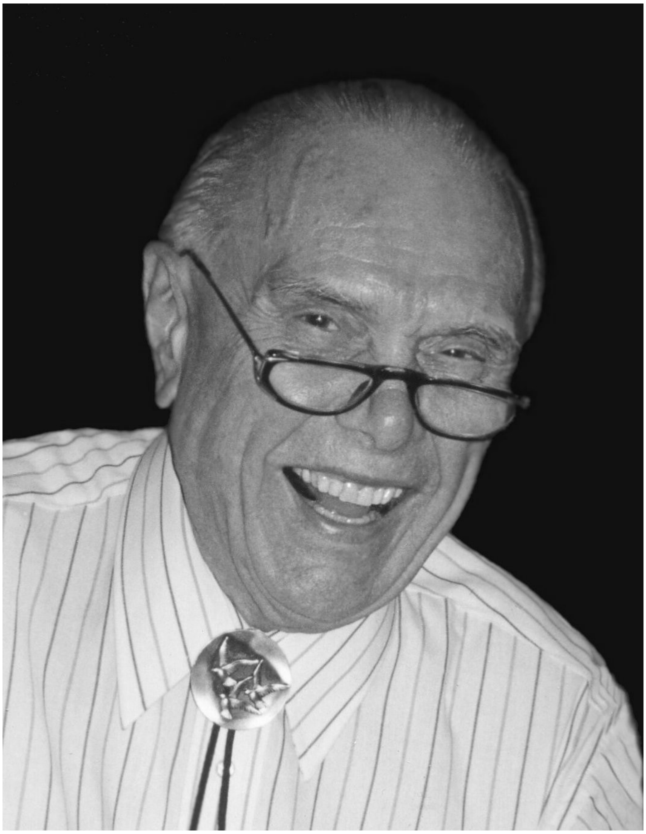
Dick's other professional interests and activities included the American Association of University Professors, American Society of Engineering Education, Geoscience and Remote Sensing Society, Antennas and Propagation Society, Aerospace & Electronic Systems Society, Education Society, American Geophysical Union, International Union of Radio Science (URSI), and chairman, International Commission F.

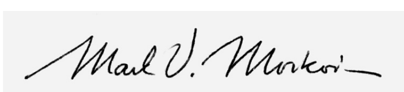
In his personal life, Dick was active in the community, regularly attending meetings of the Kiwanis Club, the Endacott Society (KU retirees association), and the Military Officers Association of America. His interest in amateur radio (W0GYS) was a lifelong love. He sponsored the University of Kansas Amateur Radio Club (K0KU) and served as its faculty advisor until he retired. He was an avid traveler, visiting every continent, either for science or personal interest. He was active in First Presbyterian Church and gave generously to many charities.

As an educator and scholar, Dick Moore had an incredible impact on his colleagues and students at the University of Kansas. During his career, he authored or coauthored

10 books—including the foundational three-volume work on radar remote sensing, *Microwave Remote Sensing: Active and Passive,* with Fawaz Ulaby and Adiran Fung (Artech House Publishers, 1986)—and over 300 journal articles and conference publications; nearly all of these publications were the result of research conducted with his graduate students. He served as a graduate advisor for more than 100 students during his tenure at KU. During the late 1960s and early 1970s KU graduated more radar engineers that any university in the US, and Dick was responsible for that. These engineers and researchers went on to build or help build world-class radar research programs at the Universities of Michigan, Texas, Oklahoma, and Kansas.

For his dedication to the students of the university, Dick was awarded the Louise Byrd Graduate Educator Award in 1984. He and his wife also established the Richard K. & Wilma S. Moore Thesis Award to honor the best graduate thesis and doctoral dissertation in the Electrical Engineering & Computer Science Department.





MARK V. MORKOVIN

1917–2014

Elected in 1987

"For contributions to the understanding of instability, transition, and turbulence through outstanding research and distinguished written reviews of the field."

BY ELI RESHOTKO AND WILLIAM S. SARIC

MARK VLADIMIR MORKOVIN, after a remarkable and productive life as an aeronautical engineer and educator, died in Oak Park, Illinois, on October 18, 2014, at the age of 97.

He was born in Prague, Czechoslovakia, on July 25, 1917, to a Russian father and a Czech mother, the youngest of three sons. He was baptized as Vladimir Morkovin. He completed his elementary and secondary education at the Gymnase Réal Français de Prague. After graduating in 1935, he joined his father, who had emigrated to the United States in 1926, in Los Angeles. Based on his schooling in Prague, he was admitted to the University of Southern California (USC) with junior standing in mathematics and physics. He had to learn English very quickly! While at USC he acquired the nickname "Mark," which he adopted as his first name. After graduating from USC in 1937, he became a graduate assistant in mathematics at Syracuse University, leading to a master's degree in mathematics in June 1938. He then became a teaching assistant in mathematics at the University of Wisconsin, Madison. In 1938, in Madison, he met Alva Heup and married her in February 1940. In May 1941, he became a US citizen. In 1941–1942 he was an instructor in mathematics at Michigan State University. He completed his PhD thesis in absentia and was awarded his PhD in applied mathematics with a minor in physics from the

University of Wisconsin in June 1942. He spent the next year at Brown University as a Rockefeller Research Fellow and also was an instructor in civil engineering.

In 1943 Morkovin joined Bell Aircraft as a research aerodynamicist to help in the design of high-speed aircraft. At that time transonic flight was without theory and there was little in the way of reliable experimental information. Mark and the group, with analysis and some guesswork, estimated the lift, drag, and moment coefficients in the transonic regime and were very happy when flight tests of the Bell X-1 aircraft verified the essential correctness of their work. Mark was very proud of his part in the design of the first aircraft to break the sound barrier.

In 1946 he spent part of a year as project manager with the Office of Naval Research during which he organized applied mechanics reviews. In February 1947 he joined the aeronautical engineering faculty of the University of Michigan in Ann Arbor. He enjoyed his work at the University of Michigan, but after a while found that in his enthusiasm, he had overcommitted himself and his personal and family life suffered.

When an opportunity arose for teaching and research at the graduate level with essentially no administrative duties, he joined the Department of Aeronautics at Johns Hopkins University in Baltimore in the summer of 1951. He maintained a relationship with Hopkins as a lecturer even while from 1958 to 1967 he was a principal research scientist with the Baltimore Division of the Martin Marietta Corporation. It was during this period that his concentration on issues of turbulence and transition intensified. In 1956, he published the paper "Fluctuations and Hot-Wire Anemometry in Compressible Flows," where he laid out the procedures for implementing hot-wire anemometry and the proper interpretation of the data. These procedures are in use to this day. In 1962 he conceived and published the Morkovin hypothesis, "that for moderate Mach numbers compressibility effects do not influence the dynamic behavior of turbulence directly, and the principal effect of high speeds is felt through the change in fluid properties."

In the fall of 1967, Mark moved to the Illinois Institute of Technology (IIT) as professor of mechanical and aerospace engineering. Within one year he devoted his considerable energies to establishing lectures on boundary-layer transition and turbulence heretofore not taught, revising the undergraduate fluid mechanics curriculum using the new series of National Science Foundation films and film strips, and modernizing the wind tunnel facilities. The Mechanical Engineering Department had just moved into a new building and he was determined to make use of every available space, which resulted in the eponymous Mark V. Morkovin Wind Tunnel. These efforts were instrumental in attracting to the department a new generation of graduate students (Hassan Nagib, Thomas Corke, Unmeel Mehta, and Ahmed Naguib, among others) who are still having an impact on fluid mechanics today. The spirit of his efforts laid the foundations for Nagib and Corke to build the National Diagnostic Facility—a world-class, low-turbulence wind tunnel at IIT. From 1968 to 1973, he attracted and managed a major program funded by the Department of Defense through the Air Force Office of Scientific Research under the THEMIS congressional initiative. This further helped establish IIT as a world leader in fluid mechanics. Periodically, Mark would publish written reviews of some aspect or other of turbulence and transition. Mark retired from IIT in 1982, becoming professor emeritus. He nevertheless remained very active in transition research.

From the mid-1950s onward, Mark made a habit of visiting laboratories in the US and abroad to both lecture on and learn of the ongoing work in turbulence and transition. In 1969 he was a member of a small committee that recommended to the National Aeronautics and Space Administration (NASA) the formation of a Transition Study Group, which was founded in 1970. Initially the group was composed of researchers from the various government laboratories. Reshotko, by virtue of being on the NASA Aeronautics Advisory Committee at the time, was also appointed to the group and became its chairman. Mark was quite disappointed not to be made a member of the group but was kept informed of the group's activities. In 1974, the group presented a series of papers at a session of an American Institute of Aeronautics and Astronautics meeting and Mark was the reviewer of all the papers for their publication a year later.

When the Transition Study Group became less formal (after NASA the group had no consistent sponsor), membership was opened up and Mark became a major contributor to the group's activity. A preliminary measure of his contribution was that the group's meetings ran twice as long with him as without him. His real contribution was as the conscience of the group. He was the sounding board for many of our ideas, good or bad. He never hesitated to question what we did and in the process sharpen our understanding. If any of us thought that we understood a particular point, he would reach into his briefcase and pull out a figure that represented a counterexample.

In this period of time, Mark set out to write the definitive book on boundary-layer transition. With his wife, Alva, as his typist and editor, he wrote drafts of many chapters and circulated some of them for comments. The problem was that the field was moving faster than he could compose and therefore many chapters could not be kept up to date. Many of us suggested that he simply date each chapter. He did not accept our suggestion and in the end there was no book. Later on he concluded this activity by giving a week-long series of lectures at various research centers featuring the many figures from his lectures over the years that he could put together in a somewhat coherent form.

In the early 1990s, Mark visited the Institute for Computer Applications in Science and Engineering (ICASE) at NASA Langley and became aware of a new theoretical formulation of stability issues. Knowing that Reshotko would be visiting ICASE a few weeks later, he advised him strongly to find the appropriate papers and read them. While at ICASE Reshotko met a young researcher, Peter Schmid, who was completing his doctorate in Sweden and who showed him his work. On reading Schmid's papers, Reshotko realized that his work was about "transient growth." Peter Schmid was then invited to the next meeting of the Transition Study Group to give a tutorial on his work. It was clear to us that we had to incorporate his approach to our understanding of the "paths to transition." This led Mark, Thorwald Herbert, and Reshotko to try to absorb the implications of "transient growth" on the transition process and on features that we had described as "bypasses." The result was a roadmap diagram that Reshotko presented at an American Physical Society meeting in 1994 under the authorship of Morkovin, Reshotko, and Herbert. This likely was Mark's last publication and is referred to often in the subsequent stability literature.

Mark's wife Alva died in 1998. He is survived by sons Michael and Gregory, and two grandsons. Mark Morkovin was a cherished colleague and a true friend.

TOSHIO MURA

1925–2009

Elected in 1986

"For initiating and promoting micromechanics to bridge the gap between metal physics and engineering mechanics."

BY LEON M. KEER

TOSHIO MURA, a leader in the development and promotion of the field of micromechanics to bridge the disciplines of metal physics and engineering mechanics, died on August 9, 2009, at the age of 83.

Toshio Mura, second son of Shinzo and Chie Fujii, was born in Ono, a small port village of Kanazawa, the capital of Ishikawa Prefecture, Japan, on December 7, 1925. Among the locals, the Fujiis are well known as brewers, having a long history in the area. Kanazawa is an old city on the coast of the Sea of Japan, where traditional culture is proudly maintained and appreciated. In Japan, given names often reflect what parents wish their children to be or to become. "Toshio" is written in three characters. "To" stands for outward or abroad, "shi" determination or will, and "o" a man. Thus "Toshio" means a man who is not confined and sets his eyes on the world. Surely, Mura did not disappoint his parents.

After graduation from the Kanazawa Second Middle School (Kanazawa Ni-chu) in 1941, Mura entered the Fourth Imperial High School (Shi-ko).

Although militarism prevailed during this period, students in imperial high schools felt a traditionally observed liberal atmosphere there. Mura must have enjoyed this atmosphere, although at the same time feeling the pressure required to prepare for higher education. The imperial high schools, which were terminated after the conclusion of World War II, had been established to rear those chosen young who would be leaders in society.

In 1944, during the most difficult time of the war, Mura went to the Imperial University of Tokyo to read aeronautical engineering. After the war, his department was dissolved and changed to the Department of Applied Mathematics at the University of Tokyo. Fascinated by applied mathematics and with the encouragement of faculty members, he pursued his graduate study under the supervision of Tsuyoshi Hayashi in 1949. At that time the department had many outstanding scientists. Among those who had a particular influence upon Mura, either consciously or subconsciously, Kazuo Kondo and Sigeiti Moriguti must be mentioned. The title of his PhD dissertation was “Study on Thermal Stresses.” His work in the dissertation turned out to be one of the earliest papers on the dynamic wave of thermal stresses.

As a graduate student, Mura also began his teaching career as a mathematics professor at Meiji University, where he met and worked with his lifelong friend, Nobuo Kinoshita. Their joint paper, “On the Boundary Value Problem of Elasticity,” which was published during his tenure at Meiji University (1956), agitated some Russian mathematicians in the field of integral equations. At the graduate school, Mura was introduced to his future wife, Sawa, by her sister, Sumi, who had worked in the Department of Aeronautical Engineering. Sawa was the second daughter of Tetsuichi and Hanae Ozaki. During the courtship, Mura often visited the Ozakis and Sumi fondly recalls that he praised Sawa’s cooking. They married in 1953 and their first daughter, Miyako, was born in 1955.

Seizing an opportunity, in 1958 Mura went to Northwestern University’s Department of Materials Science in Evanston, Illinois, to work with John O. Brittain. While at this department, Mura conceived the idea of the periodic distribution of dislocations, which was documented in a paper and published later in the *Proceedings of the Royal Society of London* in 1964, where, for the first time, the Fourier method was used to obtain the elastic field of dislocations. In 1961 by encouragement of Morris E. Fine, Toshio joined the Department of Civil Engineering at Northwestern as assistant professor. The pleasant but stimulating atmosphere brewed by his colleagues—John Dundurs, Jan D. Achenbach, and I—also encouraged him. Dundurs and Mura obtained the elastic fields of dislocations parallel to a cylindrical inhomogeneity (1964). Mura and I analyzed a penny-shaped crack with a plastic zone by solving an integral equation, Mura's first paper concerned with a crack (1963).

In 1963 Mura succeeded in expressing the elastic field of a curved dislocation in a line integral, now known as Mura's formula (1963). He further explored the line integral expression to obtain an equation, readily applicable to any medium without using the Green's function, requiring no differentiation and involving only computable integration. In his book *Micromechanics of Defects in Solids* (Springer, 1st edition, 1982), Mura showed that this expression can also reproduce the formulas developed by L.M. Brown, J. Lothe, R.J. Asaro, D.M. Barnett, and J.P. Hirth. Mura and his student, D.R.J. Owen, applied the line integral formula to obtain stress fields of often observed but complexly shaped dislocations (1967). The 1963 paper is also noteworthy for introducing the concept of a dislocation flux tensor, which is useful when the dynamic motion of dislocations is examined. The dislocation density and flux tensors were applied to continuum plasticity theory. Believing that a stress appearing within the framework of continuum plasticity was the sum of external and dislocation stresses, Mura published a series of papers, in the late 1960s, along these lines that emphasized the distribution and stress of dislocations (1967, 1968).

The pioneering work of J.D. Eshelby appears to have inspired and stimulated Mura, as seen in his studies of static and dynamic fields of dislocations in anisotropic media and in dislocation pile-ups. As can be inferred from the preface to *Micromechanics of Defects in Solids*, Mura regards Eshelby's work on inclusions and inhomogeneities (1957) as being the most important and fundamental. Using the Fourier integration method, they extended Eshelby's celebrated ellipsoidal inclusion theory to an anisotropic medium and proved that the stress and strain fields in an ellipsoidal inclusion are uniform. In 1970 Kinoshita joined Mura at Northwestern University. Mura and his student P.C. Cheng derived the stress and strain fields outside an ellipsoidal inclusion with general eigenstrains in an anisotropic medium. In this work they recovered, in an elementary manner, the expressions for the jumps of distortion and stress at an interface with discontinuously changing eigenstrains, the expressions that were first obtained by R. Hill and later discussed by L.J. Walpole in conjunction with the jumps of polyharmonic potentials.

Mura also interacted with experimentalists, who eagerly sought his advice and aid on issues of mathematics and mechanics. In particular, Morris E. Fine and his students in Northwestern's Department of Materials Science and Engineering benefited from this interaction in their studies of the fatigue of alloys. Mura also gained insight into material properties and structures by the interactions with these materials scientists.

Toshio became professor emeritus at Northwestern in 1996, and the Toshio Mura Graduate Fellowship Fund was established that year.

Because of his attachment to his native country, Mura invited many visiting scholars from Japan. Some were taught, educated, and trained in mechanics; some continued in Japan the research begun at Northwestern. For all of them, Toshio and Sawa's house in Wilmette, Illinois, was their second home.

In addition to his membership in the National Academy of Engineering Toshio Mura received many awards based on his scientific achievements. In 1992 he received the Materials and Mechanics Award from the Japan Society of Mechanical Engineers, for his contributions to modeling in applied mechanics. In 1998 he was awarded the Order of the Rising Sun, Gold Rays with Neck Ribbon by Emperor Akihito, Japan. He and Mrs. Mura were invited to a special party hosted by Emperor Akihito in the Akasaka Royal Garden, Tokyo, on October 14, 1999.

Toshio was survived by his wife, Sawa (who died in 2014), two daughters, Miyako and Nanako, their daughters' husbands, Steve Izzo and Vince Kwasniewski, and four grandchildren, Courtney (1984), Stephanie (1986), Kyle (1992), and Eric (1995).

This biography was excerpted in part from a tribute to T. Mori published in *Micromechanics and Inhomogeneity: The Toshio Mura 65th Anniversary Volume* by G.J. Weng, M. Taya, and H. Abe (Springer, 1989), with additions from M. Taya, University of Washington.

THOMAS J. MURRIN

1929–2012

Elected in 1984

"For his innovative and far-sighted contributions to both industry and government in the fields of productivity and quality improvement."

BY ANGEL JORDAN

THOMAS JOSEPH MURRIN, a native of New York City, was born on April 30, 1929, and died on January 30, 2012. Married to Marie "Dee" (Coyne) Murrin, deceased on September 11, 2013, he is survived by Kathleen Murrin, Jeanne Wilkinson (Jack), Mary Murrin Lampl, Cecilia Minnock (Patrick), Theresa Murrin, Heidi Murrin (Jeff Miller), Thomas J.C. Murrin (Karen), and Claire Murrin Hudac (Mark); grandchildren Colleen, Carolyn, Patrick, Thomas, Paul, Liam, Ian, Madilyn, Catherine, Sean, Darrah, and Aidan; and great-grandchildren Luke, Adelle, and Declan.

Murrin received a bachelor of science degree in physics from Fordham University in 1951 where he was a starting tackle under Coach Vince Lombardi; he did graduate work at several universities.

Recruited to the Westinghouse Electric Corporation as a graduate student in 1951, Murrin initially worked as a manufacturing/materials engineer. Over the next 36 years, he served in various positions with Westinghouse, including European manufacturing representative based in Geneva, Switzerland; corporate vice president of manufacturing; senior vice president of the Defense and Public Systems Group; and president of the Public Systems Company. He retired in 1987 as president of the firm's highly regarded Energy and Advanced

Technology Group—an organization with nearly $5 billion in annual sales. As a member of the Westinghouse Management Committee from 1974 until his retirement, quality and productivity improvement were elevated to key corporate initiatives under his guidance. During his Westinghouse career, he traveled to more than 40 countries.

Building on his extensive foreign travel and study of industrial operations, Murrin served as a US delegate to the NATO Industrial Advisory Group, headquartered in Brussels. He was a member of the Defense Policy Advisory Committee on Trade (DPACT) of the Department of Defense and served as chairman of DPACT's Subcommittee on Trade Relations with Japan.

He was the first chairman of two prestigious advisory committees to the federal government, the board of overseers of the Commerce Department's Malcolm Baldrige National Quality Award and the Defense Department's Defense Manufacturing Board. He was a member of the President's Commission on Industrial Competitiveness, and chairman of the board of governors of the Aerospace Industries Association.

Murrin served for 18 months as deputy secretary of the US Department of Commerce, nominated by President George H.W. Bush and confirmed by the US Senate. At the Department of Commerce, he was deeply involved in a variety of executive activities, including the 1990 Decennial Census, the Malcolm Baldrige National Quality Award and its initial application in the Commerce Department, the modernization of the National Weather Service, and the new Advanced Technology and Manufacturing Center Programs. As acting secretary for Secretary Mosbacher, Murrin attended cabinet and other top-level meetings with President Bush, Vice President Quayle, and other senior federal government executives.

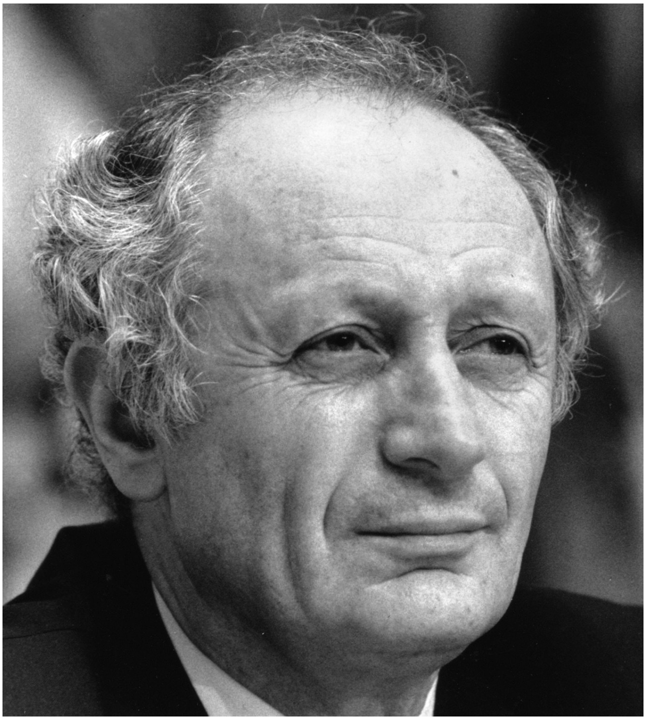
Thomas J. Murrin was named dean of Duquesne University's A.J. Palumbo School of Business Administration, effective January 1991. At Duquesne's Business School, he helped to develop innovative programs to distinguish its teaching and research—particularly in the increasingly important field of global competitiveness and economic growth. In 1993 and 1994, faculty-industry study trips were made to Japan and Germany, and in 1995 to Nicaragua and the Dominican Republic.

During his earlier involvement with educational institutions, Murrin was Distinguished Service Professor of Technology and Management at Carnegie Mellon University, chairman of the board of trustees of Duquesne University, and a member of the board of trustees of Fordham University and national board of Cities in Schools. Together with Raj Reddy and the author of this tribute, he founded and supported in 1979 the Robotics Institute at Carnegie Mellon University, now regarded as one of the largest and most prestigious institutes of its kind in the world.

After returning to Pittsburgh, he continued to promote quality and competitiveness initiatives as a member of the executive committee of the DC-based Council on Competitiveness and as a board member of several organizations, including Motorola and the Duquesne Light Company. Tom became a nationally recognized proponent of total quality management in academe, with numerous invited presentations across the country.

As part of Murrin's community service activities in Pittsburgh, he led a successful fundraising effort at Mercy Hospital, where he was chairman of the board for nine years, and participated in similar efforts for Duquesne University and United Way. He was the honorary chairman of several successful fundraising drives and cochaired the Cities in Schools fundraising effort.

Among Murrin's honors are the Order of Merit, Westinghouse Electric Corporation; the Annual Achievement Award in Business and the Encaenia Award, Fordham University; the National Leadership Award, American Productivity Center; the James Forrestal Memorial Award and Excellence in Manufacturing Award, National Security Industrial Association; election to the National Academy of Engineering; the Manufacturing Management Award, Society of Manufacturing Engineers; Hall of Fame, Cardinal Hayes High School; honorary doctor of management science, Duquesne University; appointment as a fellow of the World Academy of Productivity Science; the 1994 Pittsburgh Man of the Year Award in Education; and, in 1995, an honorary doctorate of humane letters from Fordham University.



YURI A. OSSIPYAN

1931–2008

Elected in 1993

"For contributions to materials science and engineering and leadership in international cooperation and understanding."

BY EUGENE SHCHUKIN

YURI ANDREEVICH OSSIPYAN died September 10, 2008.[1] He was born February 15, 1931, in Moscow into an intelligent and very warm family. In 1955 he graduated from the Moscow Institute of Steel and Alloys, Department of Metallurgy Engineering, and began his research work at the Institute for Metal Physics of the Central Research Institute of Ferrous Metallurgy. At the same time, he took theoretical courses at the Faculty of Mechanics and Mathematics of Lomonosov Moscow State University. In 1962 he defended his thesis under the guidance of Georgy V. Kurdyumov.

In 1962–1963 he was deputy director for research at the Crystallography Institute of the USSR Academy of Sciences. His outstanding talents as both scientist and founder of departments and institutions soon became evident in the formation and development of the Institute of Solid State Physics (ISSP) of the USSR Academy of Sciences (Chernogolovka, Moscow region). From 1963 to 1973 he was the ISSP's deputy director for science, and in 1973–2002 director of the institute, after which he continued his work as ISSP's scientific leader.

[1] His name is also spelled Osip'yan, following the Russian orthography Осипьян.

Ossipyan devoted his scientific life to progress in solid-state physics. He published more than 200 scientific papers on the theory of phase transitions, the physics of strength, the physics of electric and magnetic phenomena in semiconductor physics, optics, and other areas.

In the second half of the 1950s, ideas and experimental methods of the theory of dislocations presented in the work and famous books of Alan Cottrell, William T. Read, John J. Gilman, Egon Orowan, and other Western scientists were met with great interest in Russia by researchers in crystallography and then in materials science. Ossipyan took a very active and productive part in this broad area. Especially impressive are his pioneering studies of interactions between dislocations and electric fields. His precise studies in this important research area were further developed by Albert R.C. Westwood and his team in the United States, and by Vladislav I. Savenko and Dina I. Leikis in the USSR.

In the early 1960s Ossipyan discovered an unexpected and interesting dislocation phenomenon, now known in scientific literature as the photoplastic effect, and made advances in studying the electroplastic effect. In collaboration with his students, he observed the presence of charge on dislocations in A2B6 semiconductors and the existence of clusters of broken valent bonds in the dislocation cores in silicon, and did research on the electron spin resonance and spin-dependent recombination at dislocations.

His elegant experiments with high-frequency conductivity led to discovery of the quasi-one-dimensional electron bands associated with dislocations and combined electron resonance on dislocations in silicon. His research also showed the magnetic field effect on the plastic deformation in superconductors, along with the strong influence of the state of the electron system on plastic deformation. Thus, both the electric field effect on the movement of dislocations through crystal and, in turn, the effect of dislocations on changing the electronic properties of a system in plastically deformed crystals were analyzed. Since those first experiments with electron spin resonance on ruptured bonds, a powerful method for semiconductor quality control has been developed—electron paramagnetic resonance (EPR) spectroscopy of defects in semiconductors.

Such studies led to successful achievements in the physics of dislocations in semiconductor crystals. The work of Ossipyan and his scientific school obtained broad recognition and made valuable contributions toward promoting Russian research in this field of solid state physics to a leading position.

In 1972 Ossipyan was elected a corresponding member of the Academy of Sciences of the USSR and in 1981 he became a full academician. For his research in the physics of dislocations, he was awarded in 1984 one of the highest honors in physics, the Lebedev Gold Medal of the USSR Academy of Sciences, and in 1988 he received the Karpinskii International Prize and Gold Medal. In 2005 he received the highest award of the Russian Academy of Sciences, the Lomonosov Grand Gold Medal, for fundamental contributions to the physics of dislocations in solids and opening photoplastic effect.

Ossipyan demonstrated his talent as a leader in organizing and directing the USSR state program on high-temperature superconductivity. At the ISSP, he led a series of studies of the structural and physical properties of crystals in high-temperature superconductors, particularly of the characteristics of magnetic flux in superconductors, and of conductivity anisotropy. Under his leadership, research in these areas gained recognition and credibility, and in his various senior positions in the Presidium of the Russian Academy of Sciences he made essential contributions to the organization of research.

He was both a distinguished authority and an amazing teacher. Thanks to his activity at the ISSP, departments were established in solid state physics at the Moscow Physical-Technical Institute and in physical chemistry at the Moscow Institute of Steel and Alloys. For many years, he led undergraduate and upper-level lecture courses, and he chaired solid state physics at the Moscow Physical-Technical Institute until his last days; under his guidance, many future successful Russian scientists defended their dissertations. Later, he participated in the establishment of the Physicochemical Department at Moscow State University.

His work was internationally recognized. He was elected as a foreign member of the National Academies of Bulgaria, the Czech Republic, Hungary, Poland, the US National Academy of Engineering, and the International Academy of Astronautics, and he took part in leading the International Union of Pure and Applied Physics (IUPAP). In his homeland he was given the honorary title of Hero of Socialist Labor (1986) and the Order "For Merit to Fatherland" (1999).

Yuri's parents, Andrey and Berta Ossipyan—his well educated, wise father and his good, hospitable mother—inoculated their son with the perfect qualities of openness and readiness to help, hard work and responsibility, curiosity, and love of knowledge. Despite defective heart valves, he successfully mastered boxing, and one event in his life became well known: he dispersed a band of hooligans menacing a young woman.

Yuri Ossipyan dedicated himself to development of the ISSP, the search for promising researchers and staff, permanent attention to their successes and needs, and maintaining the highest level of scientific research. The ISSP is now one of the leading Russian academic institutions in physics and an excellent scientific center, with a broad spectrum of research in condensed matter physics and materials science.

His attributes—to overcome difficulties and mistakes; to meet conflicts with unexpected results; and to fight and conquer, to never surrender, but to use force only when necessary—accompanied him all his bright life.

Yura was a bright presence. A shining memory of him will be preserved in the hearts of all who knew him.

LAWRENCE T. PAPAY

1936–2014

Elected in 1987

"For outstanding leadership in pioneering the research, development, and commercialization of electric power generation utilizing alternative and renewable technologies."

BY MAXINE SAVITZ AND PETER BLAIR

LAWRENCE T. PAPAY, pioneer and outstanding industry executive and leader in the research, development, and commercialization of electric power generation technologies, died on July 28, 2014, after a long struggle with Parkinson's disease. He was 77.

Larry was born in Weehawken, New Jersey, on October 3, 1936, the youngest of four sons, to Joe and Elizabeth Papay. He was raised in Montvale, NJ, in the house his father built when he was a boy. Larry excelled as a student and athlete in high school and went on to receive a BS in physics from Fordham University in New York City. After graduation in 1958 he attended Officer Candidate School and served four years as a naval officer teaching in the Nuclear Power School at Mare Island Naval Shipyard. At the christening of a nuclear submarine in 1959, Larry met his wife Carol on a blind date. They were married in Carol's home state of Ohio on New Year's Eve in 1960 and resided in Vallejo, California, until Larry began graduate school.

In 1963 Larry and Carol, with daughter Lisa and son Greg born in 1961 and 1963, respectively, returned to the East Coast, this time to Cambridge, Massachusetts, where Larry worked toward an MS (1965) and ScD (1968) in nuclear engineering from MIT. Daughter Diane joined the family in 1965 and, upon completion of his doctoral studies, Larry took the family to begin a prestigious Atomic Energy Commission (AEC) postdoctoral fellowship at the European Commission's Joint Research Centre, Centro Comune di Ricerca Euratom, in Ispra, Italy. Larry and the family returned to Italy many times throughout the rest of his life.

After completing his AEC fellowship, Larry returned to California to begin his remarkable 21-year career at Southern California Edison Company (SCE) where he ascended to leadership posts in research and development, engineering, power transmission distribution operations, power generation, nuclear power, system planning, and ultimately senior vice president. He was an industry leader and pioneer in SCE efforts in the 1970s and 1980s to commercialize new electric power–generating technologies, including renewables, coal gasification, geothermal energy, cogeneration, and many others, literally beginning a transformation of the electric utility business in the process—a transformation that continues apace today. Larry's pivotal role in this transformation led to his election to the NAE and to involvement in many national policy committees and other activities that shaped the future of the utility industry.

In 1991 Larry joined Bechtel Corporation where he became a partner and the senior vice president and general manager of Bechtel Technology and Consulting, where he was responsible for monitoring emerging technologies and developing new businesses, principally in the energy sector, employing those technologies, including technological developments that impacted existing business lines as well as the rapidly growing engineering and construction businesses at Bechtel.

From 2000 to 2004 Larry served as sector vice president for the Integrated Solutions Sector, SAIC, where he was responsible for business involving the integration of technology in the energy, environment, and information areas for a variety of governmental and commercial clients worldwide.

From 2004 to his death in 2014, Larry finished his working career as CEO and principal of PQR, LLC, a management consulting firm specializing in managerial, financial, and technical strategies for a variety of clients in electric power and other energy areas.

Larry's wide-ranging expertise placed him in high demand for professional societies, boards of directors, and other activities including service as general chair of American Nuclear Society meetings and National Science Foundation panels, and chair of the California Council on Science and Technology and of the SLAC Policy Committee. He was also active in the Association of Edison Illuminating Companies, the Atomic Industrial Forum as a member of the board of directors, the California Business Roundtable, the California Power Pool as chairman of the executive committee, the US Department of Energy's Energy Research Advisory Board, Secretary of Energy's Laboratory Operations Board, the Department of Homeland Security Science and Technology Advisory Committee, the National Renewable Energy Laboratory as a member of the board of directors, the Congressional Office of Technology Assessment Solar Advisory Panel, and numerous others.

Larry's service to the NAE, including as a member of the NAE Governing Council, and to the National Research Council (NRC) spanned 28 years. He chaired major Academy studies such as the 2006 Committee on Alternatives to Indian Point for Meeting Energy Needs and the 2009 Committee on America's Energy Future Panel on Electricity from Renewables. He served on many study committees such as those addressing US-China Cooperation on Electricity from Renewables (he chaired the US committee), Panel on Energy Facilities, Cities and Fixed Infrastructure, the major study on Science and Technology for Countering Terrorism, an Assessment of Resource Needs for Fuel Cell and Hydrogen Technologies, and the Committee on the Prospects for Inertial Confinement Fusion Energy Systems. He served on numerous NRC oversight committees as well, such as the Board on Energy and Environmental Systems, the Nuclear and Radiation Studies Board, the Commission on Engineering and Technical Systems, and the Division on Engineering and Physical Sciences. Finally he served on important organizing and selection committees, such as the Organizing Committee for the National Academies Summit on America's Energy Future and the selection committee for the NAE Charles Stark Draper Prize.

Larry's service was so highly sought not only because of his expertise and experience but also because of the generous spirit and gracious manner he brought to all his activities. In 2008 Fordham University established the Papay Science Award to honor the spirit he brought to the science and engineering enterprise.

Larry was also a generous volunteer in the California communities where he and his family lived. Some of his favorite experiences included coaching Little League, fundraising for school and civic causes, and serving as an Arcadia Planning Commissioner. Leisure activities he most enjoyed were reading, listening to music, and wine collecting as well as biking, skiing, and traveling with family and friends.

Larry is survived by his wife Carol; children Lisa, Greg, and Diane; and five grandchildren, as well as his brothers Joe, Gene, and Ray.

NORBERT PETERS

1942–2015

Elected in 2002

"For contributions to the field of combustion modeling of turbulent flames and the development of chemical kinetic mechanisms for hydrocarbon oxidation."

BY FORMAN WILLIAMS

NORBERT PETERS, internationally recognized for his scientific and engineering contributions to advances in combustion and the fluid dynamics of reacting flows, died on July 4, 2015, at the age of 72. He was on vacation with his family in France when he experienced a sudden and severe heart attack; medical help came too late, and he died just two days later. He was seemingly in great health, lively, as sharp as ever, always full of ideas with big plans and in a good mood, and scientifically very active, not having lost any of his unbelievable energy and unstoppable scientific curiosity.

Norbert was born July 10, 1942, in Linz, Austria. He grew up in Dortmund, Germany, and finished high school there in 1962, having spent a year at a Florida high school in the United States. Before starting his university studies he worked for six months in a program of practical engineering in a German-Indian collaboration at the Rourkela steel plant in India. He studied mechanical engineering at the Technical University of Karlsruhe and received a "prediploma" in 1965. Subsequently, he continued his studies at the Technical University of Berlin and received a diploma in chemical engineering in 1968. He then studied economics in Paris (Bourse d'État Français during a year at the École Pratique des Hautes Études), where he also published a paper in 1969 on French poetry. He then returned to Berlin, where he received his PhD in 1971 for his work on chemically reacting boundary layers, completing his habilitation in 1975, on the topic of thermodynamics and the theory of chemically reacting flows. He advanced from a research assistant to an assistant professor in Berlin.

Norbert moved to RWTH Aachen University in 1976 as a professor in the Institute for Mechanics and became a full professor and director of the Institute for Applied Mechanics in 1987. Through his efforts, this institute became the Institut für Technische Verbrennung (the Institute for Combustion Technology). In 2001 he accepted a 1-year full-professor appointment at Stanford University but returned to Aachen after that. Although he retired as director of his institute in 2013 (succeeded by Heinz Pitsch), he continued his research and teaching in the institute unabated.

Norbert left a strong mark in combustion science with his seminal and foundational contributions to the theory of flames and flame asymptotics, reduced chemical kinetics and surrogate fuels, turbulent combustion, and the theory of turbulence. While his research included experiments, his focus was on theory and simulation. This research was always characterized by a deep physical understanding, engineering intuition, and the application of systematic mathematics-based analysis; his theoretical work was based on first principles and was always intended to result in practical models for simulation and analysis of real-world technical combustion systems. For example, he regularly attended meetings of the Society of Automotive Engineers and contributed discussions of technological advances.

He began his scientific career working on inert and reacting laminar and turbulent boundary layers during his PhD and habilitation. In the early 1970s he made the transition from reacting boundary layers to combustion, focusing on analysis and numerical simulations, and published an early paper on simulations of a methane-air diffusion flame with full chemistry as early as 1975. His paper on the theory of heterogeneous combustion instabilities of spherical particles at the Fifteenth International Combustion Symposium, published in 1975, forcefully demonstrated his unsurpassed abilities and preferences for extracting useful physical understanding by simplified mathematical methods, as is made clear from the comments on that paper, published in the volume. During that time, Norbert came across the work of Amable Liñán, especially the 1974 paper on the structure of diffusion flames, which deeply impressed Norbert and inspired some of his early asymptotics investigations, shaping his views on nonpremixed combustion. In 1980 he spent a sabbatical at the University of California, San Diego (UCSD), where he started a long-term collaboration with the UCSD combustion group and established important interactions with the fluid-mechanics faculty there. During that stay, he also developed the flamelet model for nonpremixed combustion, based on asymptotic analysis. Both the steady flamelet model and the representative interactive flamelet model for unsteady processes are now among the most used models for nonpremixed combustion in technological combustion systems.

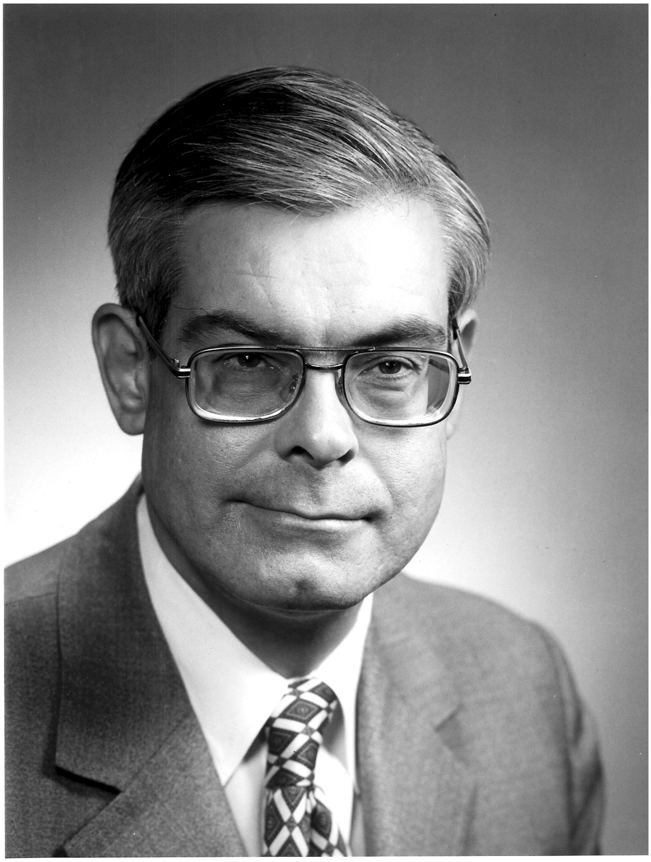
Norbert was one of the few combustion scientists with substantial contributions in both turbulent combustion and chemical kinetics. After addressing, for example, NO formation in turbulent diffusion flames, in the 1980s he developed reduced mechanisms based on steady-state assumptions. While this technique had been known for a long time, it had never been applied to complex reaction systems, and Norbert developed a formalism for systematic reduction. This was an important, seminal step, since only these reduced mechanisms allowed for a systematic analysis of the structure of flames. The combination of the reduction techniques and asymptotic analysis led to one of Norbert's most influential contributions in combustion science, the analysis of the structure of laminar premixed methane-air flames. This work includes the two-, three-, and four-step reduced mechanisms for methane flames, which clearly reveal the layered flame structure and represent the first application of rate-ratio asymptotics, a new and innovative asymptotic approach having much greater versatility than the previously existing activation-energy asymptotics. For the first time, this led to a quantitative understanding of the structure of premixed flames based on multistep chemistry, and it engendered many later studies of premixed and diffusion flames based on similar techniques.

In the 1990s Norbert shifted his focus to premixed turbulent combustion, developing the theory for turbulence-flame interactions, models for the turbulent burning velocities, and numerical simulation techniques based on level sets, resulting in the so-called *G* equation, which he clarified and extended for use in turbulent-combustion modeling. One of his major findings was that flamelet-related behavior extends beyond the Klimov-Williams boundary into what he called the thin-reaction-zones regime, where reaction zones remain intact but turbulence affects the transport in preheat zones. Without his identification of this new regime, in which most practical applications reside, resulting now in continuing work, investigations of regime diagrams would have been severely restricted. In 2000 he published his book entitled *Turbulent Combustion*, the clearest and most complete existing exposition of that subject, treating diffusion and premixed as well as partially premixed flames—the book remains today the most authoritative source of information available on the topic. More recently, much of Norbert's original research was in turbulence theory, where he introduced the concept of dissipation elements that leads to a description of small-scale turbulence, and which again has been strongly influential for many researchers. While this work is very fundamental, it was his trademark to use this new theory in applications, for example, in predictions of mega-knock in turbocharged spark-ignition engines.

Norbert's scientific productivity was always on an upward swing. In total he generated on the order of 500 publications, and in 2010 alone he produced 26—an average of one every 2 weeks, which may be hard to comprehend. And he was in the midst of making further landmark advances, which his collaborators should be able to bring to fruition. He had an incredible excitement for science and was always ready to share his latest ideas, to a point where it was nearly impossible to talk with him and not know everything about his most recent theories. Norbert leaves us with many questions in turbulence and combustion science, for a number of which he would have provided unique answers characterized by his inimitable special way of thinking and tackling outstanding scientific challenges.

Norbert was a member of the North Rhine-Westphalian Academy of Sciences, and he received the Gottfried Wilhelm Leibniz Prize in 1990, a very prestigious research award in Germany, the Harry L. Hornig Memorial Award and the Arch T. Colwell Merit Award of the Society of Automotive Engineers, and the Zeldovich Gold Medal from the Combustion Institute in 2002. He also was awarded honorary doctoral degrees from the Université Libre de Bruxelles, the Technical University of Darmstadt, and ETH Zurich. He was a deputy editor of *Combustion and Flame* from 1982 to 1998, one of the founding editors for *Flow, Turbulence and Combustion* from 1998 to 2002, and an associate editor of the *Journal of Fluid Mechanics* from 2002 to 2007. He also served as a member of the board of directors of the Combustion Institute and organized several combustion summer schools in Aachen, and participated more recently in Princeton and European combustion summer schools. Earlier he had organized a series of International Workshops on Mathematics in Combustion, hosting the first in Aachen in 1979; he recognized the need to bring international mathematically oriented researchers together for exchanges of ideas to advance the science, which was notably effective through the eleventh workshop, held in 1991, after which international communications had progressed to a point at which these workshops were no longer needed and so were discontinued.

Besides being dedicated to science and engineering, for which he had marvelous abilities, Norbert was a very decent and considerate individual who was always fun to be with. He is survived by his wife, Cordula, their two young sons, and a daughter and two sons by his previous marriage. He will be greatly missed, both as a person and as an engineering scientist.



ROBERT PRICE

1929–2008

Elected in 1985

"For pioneering achievements in applying statistical communication theory to radio communication, radar astronomy, and magnetic recording."

BY THOMAS KAILATH

ROBERT PRICE, a communications scientist, died December 3, 2008, at the age of 79 in Lexington, Massachusetts, where he had resided for more than 50 years.

Bob was born on July 7, 1929, in Ft. Washington, north of Philadelphia, and studied at the William Penn charter school, one of the oldest private schools in Philadelphia. Following his AB degree in physics in 1950 from Princeton, and a short stint at Philco Labs in Philadelphia, he joined the MIT Lincoln Laboratory and simultaneously enrolled at MIT, where Robert Fano suggested the topic that would lead to his ScD dissertation, "Statistical Theory Applied to Communication Through Multipath Disturbances" (MIT RLE Technical Report 266, September 1953).

Bob's thesis contains a number of channel capacity calculations and some results on optimal receivers. The latter material is further developed in Price (1956), where in the (later extensively studied by others) problem of the detection of Gaussian signals in additive white Gaussian noise, Bob made a very important observation. The main computation requires the evaluation of a double integral of a quadratic function of the received signal, with a weighting function obtained as the solution of an integral equation. The required computations will be fairly complicated in any physical problem but it is a characteristic of Bob's work that he sought to find a physical interpretation of the mathematical formulas.

It was well known that the detection of a deterministic signal in additive white Gaussian noise involved cross correlation between the received waveform and the deterministic signal. This would not work when the signal is random, but studying his formulas, Bob noticed that the computation could be regarded as a cross correlation between the received waveform and a least mean squares estimate of the random Gaussian signal. In actual applications even such an estimate would be difficult to compute, but he pointed out that it would be possible to use intelligent approximations to obtain a useful estimate. This now celebrated "estimator correlator" principle has been found to be of value in many problems, but it found relatively quickly an application in the development of the famous "Rake" multipath-embracing receiver, done together with his close friend and colleague Paul Green (Price and Green 1958).

For years, Price and Green had worked together at Lincoln Laboratory on different aspects of a noise modulation and correlation (NOMAC) system. Following ideas put forward in information theory by Claude Shannon, Jerome Wiesner, director of the Research Laboratory of Electronics (who later became science advisor to President Kennedy and then president of MIT), proposed building a system that transmitted wideband (pseudo)random signals detected by the use of correlation between the received signal and the transmitted (pseudo)random signal. NOMAC was put into service by the Army Signal Corps under the name F9C. One of the systems was deployed in Germany at the time of the Berlin blockade. But in the field, it was soon found that NOMAC's performance was seriously affected by the presence of multipath propagation (signals arriving at the receiver after multiple reflections via a randomly varying fading channel). How to mitigate this deterioration was the topic suggested by Fano for Price's doctoral research.

The Rake receiver consists of several "fingers" with different delays, which look like a rake, hence the name. It took advantage of the multiple signals to enhance the signal strength, combining the signals from the different fingers with the right weights to undo the multipath effects. The Rake receiver concept, first used for ionospheric communications, has been applied in a variety of areas such as underwater communications, analysis of seismic signals, and, as described below, planetary radar astronomy. Most significantly, the success of modern mobile phones relies heavily on the rake concept, with almost every cell phone implementing a Rake receiver.

As the rake paper by Price and Green (1958) got more attention, questions were raised about the very large bandwidth of the transmitted signals: A bandwidth of 10 kHz was used to support a single 60-word-per-minute teletype channel! But the reason could not be revealed at the time, because the main purpose of the system was its antijamming function.

NOMAC and Rake were examples of what came to be called spread-spectrum (SS) systems. Two papers by Robert Scholtz (1982, 1983) gave a comprehensive history of early spread-spectrum communications, supplemented by a fascinating paper by Price (1982), "Further Notes and Anecdotes on Spread-Spectrum Origins."

This is a good point at which to mention some notable characteristics of Bob's work. He took great pleasure and pride in diligently seeking out and acknowledging all, even potential, prior references, and paid close attention to motivation and clarity of exposition. The just-cited paper is a wonderful example.

Bob was also extremely generous in his interactions with others, as I and many others gratefully acknowledge. His long-time colleague at Lincoln Laboratory, Paul R. Drouilhet, wrote in the IEEE obituary for Bob: "In addition to pursuing his own research, Dr. Price always assisted those who worked around him, and was the source of many ideas helpful to his colleagues." As one testimonial among many, I quote from a letter written to me by Robert Scholtz of the University of Southern California, concerning his papers (Scholtz 1982, 1983):

> Price was recruited to help me…, and that is when I experienced Bob's bulldog tenacity first hand. He thoroughly researched all leads to SS history, especially through the patent office records which I believe were available in Boston Public Library at the time, and interviewed many engineers on the East Coast who worked on SS. He got the librarian at Sperry Research to cull through archives for anything related to it. Every week or two I would get a very thick envelope of selected pages from documents related to SS with Bob's annotations written all over them or notes stapled to them. These typically were followed by phone calls, often on weekends, starting in the late afternoon and usually ending 4–6 hours later! Somewhere I remember him indicating that he had run up enormous phone bills at Sperry on this research project (thousands of dollars). I vividly remember one night (after one of these calls) waking bolt upright after a dream in which Bob was running me down with a steamroller!

Because of this extensive help, Scholtz invited Bob to be a coauthor, but characteristically, Bob declined.

However, there is one historical nugget that Bob had dug up in the course of those discussions, which he told Scholtz he wanted to reserve for his own supplement (Price 1982). Following a lead from his sister, Bob tracked down a 1942 patent by Hedy K. Markey and composer George Antheil for a secrecy system employing frequency hopping. Of Hedy, Bob wrote, "growing up in Austria, the only child of a prominent Vienna banker had shown, at age 16, a flair for innovation by letting herself be filmed in total nudity when starting in the Czech-produced classic, 'Ecstasy' (the 5th of her many motion pictures)." In 1938, Hedy left behind her husband and secured a seven-year contract from Metro-Goldwyn-Mayer, under the stage name Hedy Lamarr. When Bob discovered that she was now living in New York he arranged an interview, for which he had to be first screened by a lawyer. Bob was very happy with the meeting and secured an autographed photograph of Hedy Lamarr (figure 2 in Price 1982). There are many other nuggets in Bob's fascinating paper—it is a wonderful read.

Bob's contributions to both the technology and the history of secure communications became widely known and highly respected. He was invited to the opening of the Cabinet War Rooms in London for his research into the secret wartime telephone conversations between Roosevelt and Churchill. Another historical nugget is a long two-part interview with Claude Shannon, the founder of information theory.[1] Price had a special connection with Shannon, because when Shannon went out of town, Bob and a couple of his friends had rented Shannon's home on the lake in Winchester, MA.

With the success of Rake under their belts, Price and Green began to look around for new challenges. One arose quite fortuitously. On completion of his doctoral research, Price had applied for and received a Fulbright Fellowship to spend a year at the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Radio Physics division in Sydney. Here he was part of a team that found the strength of the 327-MHz spectral resonance of deuterium in our galaxy to be anomalously weak—a result of some cosmological significance. Fifteen years later this experience led to an interesting lunchtime conversation between Price and Green about a book on radio astronomy by Pawsey and Bracewell of the CSIRO (*Radio Astronomy*, Oxford Clarendon Press, 1955). The book noted that radar astronomy might be able to get better results in studying planets than was possible via existing optical techniques.

Successful radar bounces off the moon had actually been achieved in 1946 by groups in New Jersey and Hungary. But going beyond the moon would require much more powerful transmitters and more sensitive receivers. A powerful radar had recently been built by Lincoln Laboratory at the MIT Haystack Observatory atop Millstone Hill in nearby Westford, and Price and Green wondered if it could be used to bounce signals off the planet Venus! Rough "paper napkin" calculations cast doubt on these hopes, but it was allayed when Robert Kingston joined the discussions. He had just built a

[1] Available at www.ieeeghn.org/wiki/index.php/OralHistory:Claude_E._Shannon.

relatively new, quite sensitive solid state microwave receiver called a maser (microwave amplification by stimulated emission of radiation).

In February 1958 Price and Green collected almost 59 hours of radar reflections from Venus. As anticipated, none of the echoes was above the receiver noise level and so the data had to be averaged over multiple runs in order to improve the signal-to-noise ratio. For this, the data were digitized onto magnetic tape and fed into a solid state digital computer at Lincoln Laboratory. Price then closeted himself for several months in a basement office, in effect doing pioneering work in what later came to be called digital signal processing. (I remember Price excitedly communicating that in the digital domain he could easily get excellent approximations to the physically unrealizable "boxcar" analog filter.) In March 1959 Lincoln Laboratory announced that it had bounced radar waves off Venus (Price et al. 1959), and a year or so later the Jodrell Bank Observatory in England announced that it had confirmed the results. Attempts by a group led by the famous Soviet radio scientist V.A. Kotelnikov gave further confirmation.

Nevertheless, Price and Green decided to repeat the experiment in 1961, taking advantage of power improvements at the Millstone radar. Unfortunately, very careful analysis failed to confirm the earlier results—a stunning disappointment. A little later, the first unambiguous direct detection of echoes from Venus was announced by a team at the Jet Propulsion Laboratory (JPL) in Pasadena, California, using a much more powerful transmitter at its Deep Space Instrumentation Facility.[2] Despite his obvious regrets, Price later took comfort from the fact that the template matching methodology he had introduced enabled astronomers, many years later, to make a new confirmation of Einstein's theory of general relativity. He was also proud that he had made the first synthesis of optimum radar-radiometric signal processing techniques,

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[2] Much more on all this can be found in an official NASA history (Butrica 1996), chapter 2 of which records comments by Price and Green on how the error had arisen and provides interesting background on the JPL experiment.

employing the theoretically best mix of pre- and postrectification filtering, which is significant for other sensors and in communications applications (Price and Green 1960, Price 1968).

Bob published several other important papers before he left Lincoln Laboratory in 1965. An article in 1958 showed that the cross correlation of a random process with its nonlinearly distorted version is, for many processes, proportional to its autocorrelation, thus expanding on the Bussgang (1952) theorem, which proved it for Gaussian noise. The consequence is that computation of an autocorrelation function becomes much easier, because instead of full multiplication, multiplying by just +1 or −1 was sufficient. In 1998 Bob's paper was recognized with an IEEE Information Theory Society Golden Jubilee Award for an outstanding result in the area of stochastic processes. A related efficient analytical tool, dubbed "Price's back door," appears in a book by Nelson Blachman (1982, p. 89).

Bob was always fascinated with special functions (friends referred to him as Bessel Bob) and took particular pleasure in evaluating difficult integrals arising in his work and that of his friends. In addition to the example at the end of his 1956 paper, a particularly notable example is his closed-form solution to a long-standing statistical problem in the analysis of variance (Price 1964). And as a private consultant, around 1988, Bob developed a novel statistical treatment of interference and jamming based on a new series of hypergeometric functions having superior numerical convergence properties.

He left Lincoln Laboratory in 1965 to become a research scientist and manager at the newly established Sperry Research Center in Sudbury, MA, from 1965 to 1983. He applied modern communications methods to digital recording, inventing digital equalization filtering techniques, which led to the quadrupling of data storage density (Price et al. 1978), and scotching "clever ideas" contradicting theoretical limits. This work led to several important patents.

In 1983, when the Sperry Center closed (and became Unisys), Bob was invited to become chief scientist at M/A-COM Government Systems in Lexington, where he worked for five years before leaving to become a research scientist at the

Raytheon Research Division (1988–1993). There he focused on variations and improvements on existing fast Fourier transform (FFT) algorithms (see, e.g., Proakis and Manolakis 1992, pp. 729–730). Notably, he used FFTs to create new nonlinear FM chirp waveforms for radar pulse compression; versions of this waveform have been adopted for international air traffic control. After 1993 he remained active as an independent consultant and testified in a number of patent cases.

Dr. Price received many honors. He received the Edwin Howard Armstrong Achievement Award of the IEEE Communications Society in 1981, and was elected to the NAE in 1985. He was a member of Phi Beta Kappa and Sigma XI; a Fulbright Fellow, CSIRO Radio Physics Division (1953–1954); member, Commission C (Signals and Systems), US National Committee, International Union of Radio Science (URSI; 1959); and fellow, IEEE (1962), "for contributions to communication system theory and its use in radar contact with Venus." He served on the advisory committee of the Department of Electrical Engineering and Computer Science at Princeton University (1971–1977).

His later hobbies included collecting exotic foreign currency and banknotes, such as German marks and Japanese currency used in occupied Malaya. He also did projects such as building a burglar alarm system for his home and a Heathkit color TV receiver, but his wife, the former Jennifer Martin (whom he had met on a ship returning from Australia in 1954), says that his main hobby was his work.

Bob and Jennifer were married in England in 1958 and celebrated their 50th anniversary on April 19, 2008. He is also survived by three sons—Stephen L. Price of Huntington Station, New York, Colin L. Price of North Andover, MA, and Edmund H. Price of Wayland, MA—and four grandchildren.

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ALLEN E. PUCKETT

1919–2014

Elected in 1965

"Outstanding contributor to aerodynamics and guided missile engineering."

BY ANTHONY J. IORILLO

ALLEN E. PUCKETT, pioneering aerospace engineer and chairman emeritus of Hughes Aircraft Company, died on March 31, 2014, surrounded by his family in his home in Pacific Palisades, California. He was 94.

Allen led the Hughes Aircraft Company's growth to the forefront of the country's defense electronics, telecommunications, and space industry. After retiring in 1985, he continued to contribute to the profession as a lifetime trustee at the University of Southern California (USC).

Born July 25, 1919, in Springfield, Ohio, Allen enrolled at Harvard University at age 16. In the summer between his freshman and sophomore years he worked as a ranch hand at his cousin's ranch in Montana, an experience he credited with changing his life and fostering a lifelong love of the outdoors and horsemanship.

In 1939 he earned his bachelor of science degree, graduating summa cum laude, and in 1941 he earned his master's degree. That same year, he began his PhD studies at the California Institute of Technology at the invitation of renowned professor and aeronautical engineer Theodore von Kármán.

While working at the Guggenheim Aeronautical Laboratory at Caltech, Allen helped design a new supersonic wind tunnel, the first of its kind in the country. Later, he produced the calculations that led to the development of delta wing theory, which predicts the aerodynamics of supersonic aircraft and continues to be applied in the production of modern aircraft. This work formed the basis for his landmark PhD thesis, "Supersonic Wave Drag of Thin Airfoils."

When the United States entered World War II Allen received orders to report for duty, but shortly before he was scheduled to leave for flight training he learned that he had been discharged from the Army Air Corps. Unbeknownst to him, von Kármán had written directly to the secretary of war, making the case that Puckett would be much more valuable to the war effort by continuing his research at Caltech.

In addition to many influential technical papers, Allen cowrote the seminal textbook *Introduction to Aerodynamics of a Compressible Fluid* with Caltech professor Hans Liepmann and coedited *Guided Missile Engineering* with Simon Ramo. Allen's name became a familiar one to those of us who studied these works. He had made his mark in academia, and he was just 30 years old.

After Allen completed his PhD in aeronautics in 1949, Ramo recruited him to build the aerodynamics department at the fledgling Hughes Aircraft Company. He joined the firm that year and, over the course of his nearly four-decade tenure at Hughes, rose steadily through the ranks, eventually becoming president in 1977 and CEO and chairman of the board in 1978.

One of his most valuable contributions came in the mid-1950s when Howard Hughes created the Howard Hughes Medical Institute (HHMI), endowing it with all the shares of the company. Without the possibility of employee equity participation, many, including Ramo, left to strike out on their own in a well-chronicled exodus. The Defense Department threatened to cancel all of its contracts if the management turmoil was not resolved. The still young Allen held his team together and took the initiative to recruit and propose the seasoned engineering executive L.A. ("Pat") Hyland to lead the company. After some hesitation, Howard Hughes agreed. Together, Hyland, as general manager, and Allen, as technical leader, stabilized the company and set the standards for the rest of its life. When Hyland retired and announced Allen as successor, he good-humoredly remarked that Allen had displayed uncommon acumen when he hired his boss.

By now Allen had shifted his focus to the burgeoning field of electronics and was a primary force in establishing the company's status as the country's leading defense electronics supplier. Hughes equipment could be found on virtually every air, land, sea, and space vehicle in the US and NATO inventory and in every air defense and communications installation. The ubiquitous laser was pioneered in the company's research laboratory.

Allen also promoted the development of the first geosynchronous satellite, which relayed live television coverage of the 1964 Tokyo Olympics, marking the first time the Games could be seen in real time on several continents. He encouraged the company's rise to the forefront of worldwide commercial satellite sales. And he oversaw Hughes' deployment of the country's largest private fleet of satellites, providing service that enabled the growth of the US cable television industry. (Hughes' later creation of DIRECTV was a natural extension of this effort.) For his crucial contributions to geostationary communication satellites Allen received the National Medal of Technology, the nation's highest honor for technological achievement, in 1985.

Under his leadership, Hughes also participated in the National Aeronatics and Space Administration's Surveyor program, constructing unmanned spacecraft that explored the feasibility of lunar landings and transmitted images of the surface of the moon back to Earth. These missions paved the way for the Apollo program. Allen later remarked that the Surveyor program was one of his most memorable and valuable accomplishments.

By the time Allen retired in 1987, Hughes had grown to more than 80,000 employees and was the largest employer in California. It had also become one of the largest technical forces in the country, employing 20,000 engineers. Under Allen's guidance, the company established graduate and undergraduate fellowships at major engineering schools across the country. The Hughes Fellowship Program was the largest program of its kind, and many of us in the Academy are beneficiaries.

The Hughes Aircraft Company no longer exists. It was sold by HHMI to General Motors shortly before Allen retired and has since been subdivided and resold in pieces. Of course this saddened Allen, but he derived great satisfaction in knowing that the asset he nurtured made HHMI one of the world's largest foundations and the nation's largest private supporter of academic biomedical research. In his nineties, he still kept track of HHMI Nobel Prize winners.

Having been elected to the USC board of trustees in 1983, Allen continued his lifelong support of education after he retired. He played an integral role in USC's growth and development and significantly contributed to the university's academic progress.

"Allen touched all those who work, study, and teach at USC through his insightful guidance and remarkable generosity," said USC president C.L. Max Nikias. "Over the course of his three decades of distinguished service as a trustee, he worked to advance the vitality of our university, and his efforts continue to be felt throughout the USC community. We will all miss him very much."

Allen remained especially committed to the advancement of the USC Viterbi School of Engineering and provided invaluable support to the school through his philanthropic giving and visionary leadership. He held a research faculty appointment in engineering and served as a member of the school's board of councilors. In 1978 the school recognized his prowess as an industry leader by naming him the inaugural recipient of its Engineering Management Award.

"Allen was a titan of industry and a brilliant scholar who inspired all of us with his far-reaching contributions," said Yannis C. Yortsos, dean of USC Viterbi.

In addition to his elections to the NAS and NAE, Allen was awarded the French Legion of Honor and received many other accolades. Among them were Caltech's Distinguished

Alumnus Award, the Lawrence Sperry Award from the American Institute of Aeronautics and Astronautics, the Lloyd V. Berkner Award from the American Astronautical Society, the Brandeis University Award for Distinguished Achievement in the Field of Technology, the Frederik Philips Award from the Institute of Electrical and Electronics Engineers, and the Medal of Honor from the Electronics Industries Association. He served on numerous company boards and government advisory committees.

He also strove to support future generations of technological leaders and gave generously to his alma maters in support of research and scholarship. Together with his wife, Marilyn, he endowed the Allen E. and Marilyn M. Puckett Professorship in the Harvard School of Engineering and Applied Sciences. At Caltech, he established the Allen and Marilyn Puckett Professorship and provided funding for the Puckett Laboratory of Computational Fluid Dynamics.

An avid competitive yachtsman and cruising sailor, Allen participated in regattas around the world and was regarded as a legend in the sailing community. He brought his technological expertise to this arena as well, helping to develop some of the first computer programs for navigation and performance analysis.

He loved the outdoors on land as well. Over the years, he hiked extensively in the Sierra Nevada and the Swiss Alps. He was particularly proud of his summiting of California's Mt. Whitney via the difficult "mountaineer's route."

As his children observed in their eulogy, "He did not climb every mountain, but he did reach for some of the highest. He was a lover of music, and an exceptionally graceful dancer. He enjoyed playing the ukulele and the saxophone, and could sing a rousing sea shanty. The number of lives he touched is truly beyond measure, and he will be deeply missed by all who knew him and those who loved him."

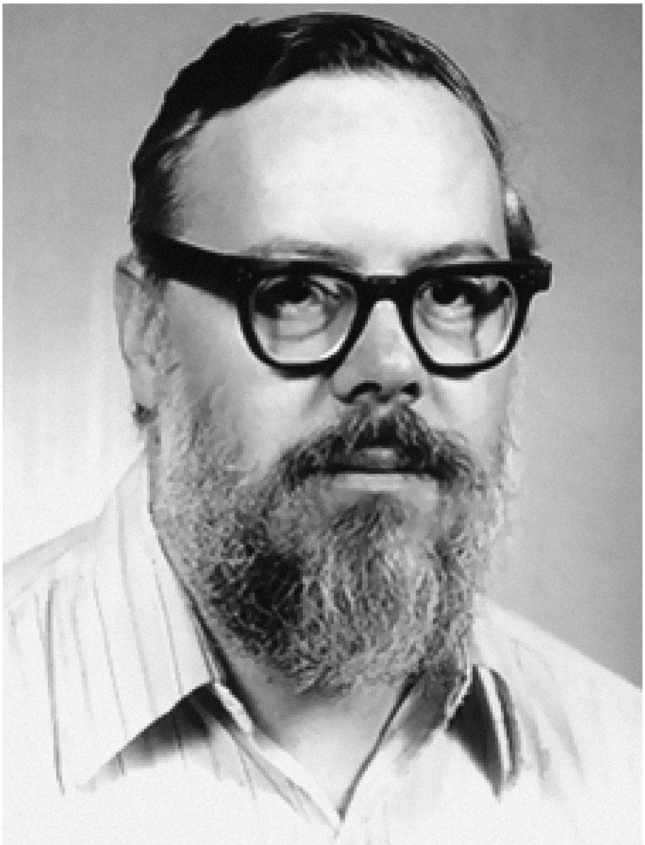
Allen is survived by Marilyn, his wife of 50 years; their two children Margaret Puckett Harris (Russell) and James R. Puckett; three children from his first marriage to Betty Jane Howlett (deceased), Allen Weare Puckett (Laura), Nancy

Puckett Grant (Jeff), and Susan Puckett Prislin. He is also survived by six grandchildren and 14 great grandchildren.

By any measure, Allen lived a full and remarkably productive life. He was a consummate scholar, leader, and, above all, a gentleman. Thankfully, he was able to enjoy the fruits of his labor until late in life, and he had the comfort of leaving a thriving and loving family.

He will be remembered fondly by those of us in the Academy fortunate enough to have experienced his wise counsel, generous spirit, and friendship.

The author wishes to acknowledge the help he received from the family, Caltech, and the obituary of the University of Southern California.



DENNIS M. RITCHIE

1941–2011

Elected in 1988

"For development of the 'C' programming language and for co-development of the UNIX operating system."

BY BRIAN W. KERNIGHAN

DENNIS M. RITCHIE, creator of the C programming language and cocreator of the Unix operating system, died on October 12, 2011, at the age of 70.

Dennis was born in Bronxville, New York, on September 9, 1941. His father, Alistair E. Ritchie, worked for many years at Bell Laboratories in New York City and then Holmdel, New Jersey. The family moved to the nearby town of Summit when Dennis was quite young. He attended school there, then went to Harvard University for undergraduate and graduate degrees in physics and applied mathematics; his PhD thesis topic (1968) was subrecursive hierarchies of functions. Explaining his career path, he once said, "My undergraduate experience convinced me that I was not smart enough to be a physicist, and that computers were quite neat. My graduate school experience convinced me that I was not smart enough to be an expert in the theory of algorithms and also that I liked procedural languages better than functional ones."

Dennis joined Bell Labs in 1967 as a member of the technical staff in what soon became the Computing Science Research Center. For the first few years, he worked on the Multics project, a joint venture of the Massachusetts Institute of Technology, General Electric, and Bell Labs that planned to build a large time-sharing computer utility. Multics proved too ambitious, and when it became clear that it would not live up to its goals in a timely fashion, Bell Labs withdrew from the project in 1969, leaving Dennis and his colleagues with experience in innovative operating system design, an appreciation of implementation in high-level languages, and a chance to start over with much more modest goals.

The result was the Unix operating system and the C programming language.

Unix had its origins with Kenneth Lane Thompson's early experiments in building an operating system on a small castoff computer; he was soon joined by Dennis, and the two of them created the first recognizable version in late 1969. In addition to the operating system itself, Dennis wrote a significant amount of supporting software as well as documentation that made it possible for others to use the new system.

The C programming language dates from very early in the 1970s. It was based on Dennis's experience with high-level languages for Multics implementation, but much reduced in size because computers of the time had very limited capacity; there simply was not enough memory or processing power to support a complicated compiler for a complicated language. This enforced minimality accorded well with Ritchie's and Thompson's preference for simple, uniform mechanisms. C was a good match as well for real computer hardware; it was clear how to translate it into good code that ran efficiently.

C made it possible to undertake something that had never been done successfully before: writing an entire operating system in a high-level language. By 1973, Unix had been converted from its original assembly-language form into C. This made it much easier to maintain and modify the system. It also enabled another giant step, moving the operating system from its original PDP-11 computer to other computers with different architectures. Because most of the system code was written in C, porting the system required not much more than porting the C compiler.

Dennis was a superb technical writer, with a spare elegant style, deft turns of phrase, and often with flashes of dry wit that accurately reflected his personality. His book *The C*

Programming Language, coauthored with Brian Kernighan, was first published in 1978 (Prentice Hall). Universally known as "K&R" after its authors, it is still a standard reference and has been translated into more than two dozen languages. Dennis's original C reference manual formed the basis of the ANSI/ISO standard for C that was first produced in 1988. Without doubt, some of the success of C and Unix can be attributed to Dennis's skill in producing well-written explanatory documents.

With Thompson, Dennis received many honors and awards for his work on C and Unix, including the IEEE Emmanuel Piore Award (1982), the Association for Computing Machinery (ACM) A.M. Turing Award (1983), the ACM Software Systems Award (1983), the NEC C&C Foundation Prize (1989), the IEEE Richard W. Hamming Medal (1997), the National Medal of Technology (1999), and the Japan Prize for Information and Communications (2011).

After successfully avoiding any management role for many years, Dennis finally yielded and became head of the Software Systems Department at Bell Labs, where he was responsible for the group of researchers who were building the Plan 9 operating system, an attempt to reclaim the simplicity of the original Unix while unifying some of its disparate mechanisms. Dennis stepped down from management and retired officially in 2007 but continued to come to Bell Labs every day until his death.

Dennis was modest, kind, unassuming, and generous, always giving credit to others while downplaying his own contributions. A typical example is found in the acknowledgment section of his 1996 retrospective on the evolution of Unix: "The reader will not, on the average, go far wrong if he reads each occurrence of 'we' with unclear antecedent as 'Thompson, with some assistance from me.'" Dennis was a giant of computing. Most of the world's computers run Unix or Unix-like systems, and much of the world's software is written in C or in languages derived from it. He is greatly missed.

Dennis is survived by sister Lynn, brothers John and Bill, and their families.

HERBERT B. ROTHMAN

1924–2015

Elected in 1990

"For outstanding contributions to the design and rehabilitation of hundreds of bridges of all types and for exceptional contributions to the understanding of wind effects of complex structures."

BY MATTHYS LEVY

HERBERT BERNARD ROTHMAN, an exceptionally talented and versatile engineer and expert in aerodynamic analysis of suspension bridges, died on July 26, 2015. A native New Yorker, Herb was influenced by his father and uncle, who were both architects/engineers, but was drawn to the engineering side by a talent for mathematics. As a young man he had polio and fought to strengthen his legs, an experience that drove him to always strive to succeed no matter what challenge he faced. I remember that whenever we were together, he always took the stairs, three steps at a time, and avoided the elevator, all to assure himself that his legs were as strong as ever.

After graduation from Rensselaer Polytechnic Institute and a brief stint at another firm, he joined Ammann & Whitney (A&W) in 1945. There he met Boyd Anderson and Milton Brumer, both of whom were to have a major impact on his career. From Brumer he learned to apply a methodical approach to problems, which served him well whenever he was challenged to find solutions to difficult bridge problems, and from Anderson he learned how to analyze structures of all types. Early on, he also learned to articulate complex concepts in simple ways and to look for solutions out of the ordinary. In his 32 years with Ammann & Whitney, where he rose to become the firm's chief bridge engineer, he developed a solution for failing bridge anchorages of the Triborough Bridge, initiated the first cable inspection of the Golden Gate Bridge, and spent a couple of years in France providing engineering for American bases around that country where he pioneered the use of precast concrete for hangars and dormitories. Back in the United States, Herb worked on what was at the time the longest suspension bridge in the world, the Verrazano Narrows Bridge. He was also the designer for Philadelphia's Walt Whitman Bridge, the Oakland Coliseum, Massachusetts Institute of Technology's thin concrete shell Kresge Auditorium, the Society Hill Tunnel in Philadelphia, the General Manuel Belgrano cable-stayed concrete bridge in Argentina, and a large radio telescope. In addition, he developed a matrix algebra system that was a precursor for modern stress analysis systems.

Clients generally developed a long-lasting respect for Herb's engineering acumen as exemplified by the many projects that George Schoepfer, chief engineer of the Triborough Bridge and Tunnel Authority, entrusted to him first when he was at A&W and later when he joined Weidlinger Associates.

In 1977 Herb, having met Paul Weidlinger while consulting for the John Hancock tower in Chicago, was invited to join Weidlinger Associates (WAI) as a principal, to start a bridge and transportation design division. One of his first projects at WAI was the stiffening of the Bronx Whitestone Bridge that had exhibited potentially dangerous oscillations under certain wind conditions. He conceived of a 94-ton tuned mass damper that was fitted between the stiffening girders and designed to protect the bridge in the event of a 100-year storm. He later improved the aerodynamic behavior of the bridge by installing lightweight fiber-reinforced polymer fairings that would stabilize the bridge for winds up to 120 mph, thus ensuring stability for a more than 100,000-year return period as well as returning the bridge to its original sleek profile. During his 30 years with WAI, Rothman participated in the rehabilitation and strengthening of the Manhattan Bridge and many of the other New York area bridges, as well as designing the largest single-cell cofferdam.

The Manhattan Bridge, a suspension bridge linking Manhattan to Queens, was particularly challenging. A subway line rode on tracks located on one side of the bridge. Every time a train crossed the bridge, the truss/deck structure would twist, a condition that had existed ever since the bridge's construction in 1909. As a result, steel elements would crack and had to be constantly repaired. Herb devised a solution creating two torsionally stiff tubes, one on each side of the bridge, by adding lateral elements to the two-level deck and stiffening the girders of the existing bridge. This resisted the twisting motion and essentially eliminated cracking of members.

One of his last major projects was the design of the new east span of the San Francisco–Oakland Bay Bridge. The project was developed as a competition between a cable-stayed and a suspension bridge to replace a cantilever bridge that was insufficiently earthquake resistant. Herb had the task of developing the suspension concept, preferred by the community and academics because it was more visually compatible with the suspension spans on the west side. Rather than arriving at a conventional suspension bridge with anchorages at both ends, Herb proposed a self-anchored suspension bridge in which the cables connect to the deck rather than to difficult to construct anchorages. A secondary benefit was its increased resistance to the area's high seismic forces. This bridge, which was recently completed, is the world's longest self-anchored suspension bridge. At the time of his retirement, he was the chairman of WAI.

Rothman was an avid sailor and took a number of cruises to Nova Scotia on his 44-foot Cambria (the last of many sailboats he owned) that he would describe as occasionally challenging when the wind suddenly grew to gale proportions. He hated to use the engine and when becalmed, his passengers would be retching over the side while he waited for the wind to pick up. The only time he willingly used the engine was one July 4th in New York Harbor to avoid a near collision when the USS *Iowa*, with President Reagan aboard, bore down on his prime viewing position. Friends and colleagues, such as his partner Ron Mayrbaurl, were often invited to crew with him. An unfulfilled ambition of his was to sail around the world.

Herb was always open to new experiences and when I offered to fly him down to Washington for a meeting we were to attend, he enthusiastically accepted. If there was any trepidation on his part when he saw the single-engine plane, I did not see it. The morning flight in a clear blue-sky day was spectacular with practically infinite visibility. After a successful meeting we took off in the afternoon from National Airport and had just passed Baltimore when the door on Herb's side popped open and vibrated with a roar from the slipstream. Herb tried valiantly to pull the door shut but when that proved impossible, I landed at a small airport. As the plane slowed Herb was finally able to close and lock the door. We immediately took off again and completed the flight without further excitement. Of course, Herb never again flew with me.

He published numerous papers and articles on such diverse topics as matrix analysis, suspension bridges, and cofferdams and was the keynote speaker at professional conferences. He was recognized for his accomplishments and received the John A. Roebling Medal from the Engineers' Society of Western Pennsylvania and the Thomas Fitch Rowland Prize from the American Society of Civil Engineers. In 1993 the Institute for Bridge Integrity and Safety named him Bridge Engineer of the Year. He was also a member of a number of professional societies.

Throughout his life, Herb was very close to his family, his wife Joan, and their two daughters, Betty and Jane. He also helped raise his granddaughter, Becky, and lived to meet his great-granddaughter. In his hometown of Laurel Hollow, he served as deputy mayor and highway commissioner.

Andrew P. Sage

ANDREW P. SAGE

1933–2014

Elected in 2004

"For contributions to the theory and practice of systems engineering and systems management."

BY WILLIAM B. ROUSE

ANDREW PATRICK SAGE, professor and founding dean emeritus of the Volgenau School of Engineering at George Mason University, died October 31, 2014.

Born on August 27, 1933, in Charleston, South Carolina, Andrew Sage received his BS in 1955 in electrical engineering at the Citadel, the Military College of South Carolina, his MS in 1956 in electrical engineering from the Massachusetts Institute of Technology, and his PhD also in electrical engineering in 1960 from Purdue University. He received honorary doctor of engineering degrees from the University of Waterloo in 1987 and from Dalhousie University in 1997.

Dr. Sage started his academic career in the early 1960s as associate professor at the University of Arizona where, among other things, he did research on the electronic simulation of biological clocks and bistable circuits. From 1964 to 1967, he was professor of electrical engineering at the University of Florida, Gainesville. From 1967 to 1974, he was chair of the Information and Control Sciences Center at the Southern Methodist University in Dallas and chair of the Electrical Engineering Department. From 1974 to 1984 at the University of Virginia, he was professor of engineering science and systems engineering as well as associate dean of engineering. He joined George Mason University in 1984 as founding dean of the School of Information Technology and Engineering, later renamed the Volgenau School of Engineering. In May 1996 he was elected founding dean emeritus of the school and appointed a university professor.

Dr. Sage wrote or edited over 20 books and was editor of the John Wiley Series on Systems Engineering and Management. He edited the *IEEE Transactions on Systems, Man, and Cybernetics* from January 1972 through December 1998, and also served a two-year period as president of the IEEE SMC Society. He played an instrumental role in establishing the *INCOSE Journal of Systems Engineering* in 1997 and served as the journal's editor in chief until 2013. He was also coeditor of *Information-Knowledge-Systems Management*.

In addition to his NAE membership, Dr. Sage was elected a fellow of the Institute of Electrical and Electronics Engineers (IEEE) for "Contributions to engineering education, and to the theory of systems, identification, estimation, and control," the American Association for the Advancement of Science, and the International Council on Systems Engineering.

In 1970 he received the Frederick Emmons Terman Award from the American Society for Engineering Education, and in 1994 the Donald G. Fink Prize from the IEEE and a Superior Public Service award for his service on the CNA Corporation Board of Trustees from the US Secretary of the Navy. In 2000 he received both the Simon Ramo Medal from the IEEE in recognition of his contributions to systems engineering and an IEEE Third Millennium Medal, and in 2002 an Eta Kappa Nu Eminent Member Award and the INCOSE (International Council on Systems Engineering) Pioneer Award. In 2007 he was elected as a charter member of the Omega Alpha Association International Honor Society for Systems Engineering. In 2010 he was recognized by Purdue University School of Electrical and Computer Engineering as Outstanding Electrical Engineer. In 2014 he was an honoree for the Academy of Engineers at the Citadel School of Engineering.

He is survived by his wife of 52 years, Laverne G. Sage, and their children and spouses: Theresa A. Sage and husband Mike Beahan, Karen M. Sage and husband Brent Johnson, and

Philip A. Sage and wife Mary M. Sage, and two grandchildren, Nathan A. Sage and Evan A. Sage. His family said he would be remembered by his relatives and many friends worldwide for his warm and inviting attitude and his perseverance.

THORNDIKE SAVILLE JR.

1925–2014

Elected in 1977

"Leadership, vision, and innovation in the field of coastal engineering."

BY CHIANG C. MEI

THORNDIKE SAVILLE JR., former director of the Coastal Engineering Research Center, Army Corps of Engineers, and a leader of the coastal engineering profession in the United States, died on November 5, 2014, at the age of 89.

Saville, known as Thorn to his colleagues and friends, was born on August 1, 1925, in Baltimore, Maryland, into a family of distinguished hydraulic engineers. His father, Thorndike Saville Sr., served from 1930 to 1969 first on the Beach Erosion Board (BEB), which was part of the Civil Works Program of the US Army Corps of Engineers, and then on the Coastal Engineering Research Board.

Saville went to Harvard University for a year before joining the Army in 1943. As a weather observer during World War II, he collected meteorological data first along the Atlantic seaboard and later in the Pacific, including New Guinea and the Philippines. After the war he returned to Harvard to complete his undergraduate degree in civil engineering in 1947, then went on to graduate school at the University of California, Berkeley, where he earned his master's degree and studied and conducted sediment transport physical modeling tests under the direction of Joe Johnson.

Upon graduation, he was hired by Major General Glen Edgerton in 1949 to work on an assignment studying sediment and water movement in the Mission Bay, San Diego. In 1950 he moved to BEB at the Dalecarlia Reservoir in Washington, DC. When BEB became a part of the Coastal Engineering Research Center (CERC), Saville was appointed chief of its Research Division, whose missions were then expanded from beach erosion to deep water processes and the stability of navigation structures.

In 1971 Saville was appointed technical director, a position he held until his retirement in 1981. Among his personal achievements, he conducted larger-scale stability of rock experiments, testing and verifying Hudson's formula (an equation used by coastal engineers to calculate the minimum size of riprap) in the large wave tank available only at the CERC. As director he was in charge of conceiving, planning, and conducting projects for various Corps districts as well as coordinating research programs with universities on coastal engineering. The central mission was to provide better understanding of shore processes, wind waves, tidal inlets, storm surges, and current as they apply to navigation improvement, flood and storm protection, beach erosion control, and effects of construction on the ecology of US shorelines.

During his long and distinguished tenure, CERC produced the *Shore Protection Manual*, which has become the standard reference for coastal engineering design the world over. Another major accomplishment is the establishment of the Field Research Facility in Duck, North Carolina, recognized throughout the world as the premier research laboratory for developing the scientific foundations and engineering tools required to support sound coastal development.

Saville authored more than 75 publications in the field of hydraulics, including three BEB Technical Memoranda in 1953: *Accuracy of Hydrographic Surveying In and Near the Surf Zone* (with Joseph M. Caldwell), *Wave and Lake Level Statistics for Lake Erie*, and *Wave and Lake Level Statistics for Lake Ontario*. He held many key positions advising the engineering profession and the government on the coastal environment. He was a member of the American Shore and Beach Preservation Association and served on its board of directors until 1997. He also served as a member of the Coastal Engineering Research Council of the American Society of Civil Engineers (ASCE) Coasts, Oceans, Ports, and Rivers Institute.

Among numerous honors, Saville was elected an ASCE fellow and awarded the society's Walter Huber Research Prize in 1963 and the John G. Moffatt-Frank E. Nichol Harbor and Coastal Engineering Award in 1979. In addition he was a professional engineer, fellow of the Washington Academy of Sciences, and longtime active member of the World Association for Waterborne Transport Infrastructure.

Thorndike Saville Jr. is survived by his wife Janet Foster Saville, daughters Sarah Saville Shaffer and Jennifer Saville, son Gordon Foster Saville and his wife Bei Huang Saville.

Thorndike Saville Jr. was a giant in his profession, and a leader who served with dedication and distinction for the protection and improvement of the nation's coast. He will be missed.

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ROBERT S. SCHECHTER

1929–2014

Elected in 1976

"Pioneering studies of surface chemistry directed to engineering applications over a broad spectrum including bioengineering, environmental protection, and energy."

BY LARRY W. LAKE, STEVE L. BRYANT, THOMAS F. EDGAR, GARY A. POPE, MAURICE BOURREL, AND WILLIAM R. ROSSEN

ROBERT SAMUEL SCHECHTER, a brilliant teacher, scholar, researcher, mentor, and leader, died October 8, 2014. He was a world-renowned chemical and petroleum engineer with great accomplishments in both disciplines. He made major contributions to the areas of fluid mechanics, transport phenomena, surface phenomena, optimization, variational principles, oil-well stimulation, and enhanced oil recovery. He inspired countless others to carry on research in these and other areas. He was a great person with a great sense of humor, had a generous and helpful nature, was a wonderful colleague and a role model for all, with the highest professional and ethical standards, and was admired and respected by all who knew him. He was an outstanding chairman of both the Chemical Engineering Department and the Petroleum Engineering Department at the University of Texas at Austin (UT).

With 202 refereed articles, 27 book chapters, and five books, two others edited, codeveloper of the spinning drop tensiometer, Bob Schechter was the equal of ten of his peers. His creativity and contributions earned him much recognition: election to the National Academy of Engineering in 1976, the Chevalier de l'Ordre des Palmes Académiques from the prime minister of France in 1980, the Billy and Claude R. Hocott Distinguished Engineering Research Award in 1984 (the first awarded), the Joe J. King Professional Engineering Achievement Award in 1991, the John Franklin Carll Award from the Society of Petroleum Engineers in 1994, and designation in 2009 as one of the *Journal of Petroleum Technology*'s Legends of Production and Operation. In 2014 he was posthumously recognized as a distinguished professor, the only non-UT alumnus to be so recognized.

At the University of Texas, where Bob had a 35-year career, he excelled in all three areas required of a faculty member. He was an excellent teacher; even his most difficult classes were in demand and he was always willing to take on and develop new classes. He was above all an excellent researcher. He and his colleague Bill Wade invented the Joint Industry Project (JIP) to fund university research. JIPs, in one form or another, have been emulated many times and form the backbone of chemical and petroleum engineering research support.

A man of such achievement cannot be memorialized by one pen. The following accounts are from a former student, friends, and colleagues.

Steve Bryant writes: Bob was greater than the sum of his parts. He was inquisitive, compassionate, always willing to help colleagues, especially the younger ones, witty without being offensive, friendly, always willing to share ideas, and never too busy to talk science. I never heard him say a bad thing about anyone.

On the occasion of being named an Improved Oil Recovery Pioneer, Bob wrote an elegant little speech in which he pointed out the common origin of many important scientific discoveries: a moment when someone said, "Hmmm. That's interesting." This, he claimed, was usually said when an experiment had not turned out as anticipated. An unimaginative scientist says nothing of the sort when this happens; usually she or he is simply annoyed. A great researcher testing a hypothesis will have expectations about the outcome of an experiment. He (in the old days scientists were usually "he") will therefore be alert to the unexpected. When nature does something more subtle or more complicated or even contrary to what was expected, a valuable opportunity is at hand: the opportunity to learn something. Sometimes that opportunity turns into a discovery, once in a while into a paradigm shift. But the eventual "ah-ha" moment on which the documentaries focus always starts with a bemused, sotto voce utterance of "that's interesting." I wish someone had preserved Bob's speech; it would rank with Medawar's meditations on the scientific method.

Bob's point was that serendipity plays no small role in the advance of science, and that while incremental progress might follow a reasonably linear path, major advances usually have an element of randomness or luck or coincidence that takes the work down a quite different path. But—and this is crucial—Bob was also saying that the random is not sufficient. The event must be observed by a brain prepared to notice, by an intellect prepared to wonder, by a mind prepared to think long enough to realize that something interesting might indeed have happened. Bob instilled an appreciation of the power of this approach to research. I am forever grateful for that gift, not least because it makes the whole enterprise of research fun. Poetically, it opens the possibility of research being a creative enterprise, more similar to the fine arts than many people realize—an activity in which relationships emerge between previously unconnected concepts, objects, or phenomena.

Saying "that's interesting" is a powerful tool for a researcher. Bob's day-to-day definition of an interesting problem was easily stated: a problem for which the solution or explanation was not obvious. Given that problems he regarded as obvious are nothing of the sort for most of us, his criterion was certainly a sufficient condition. So among my proudest moments were visits long after I graduated during which he deemed interesting some scientific question that I had raised.

Bob's other great gift was my first peek behind the curtain where science actually gets done. The history of ideas usually celebrates inventors and discoveries with linear story arcs—a progression with a beginning, a middle, and an end. The scholarly literature devotes all its pages to accounts of explanations that are consistent with observations, steadily building on prior work to create the majestic edifice of science. This approach gives the impression that science itself is a linear and rational series of steps. This is of course bogus, though this only becomes clear with experience.

Unlike the lesson about the importance of saying "hmmm, that's interesting," this gift was inadvertent, I think. A good deal of my PhD work was in pursuit of a physical and mathematical demonstration of something that we were sure was true, but couldn't prove. After months of this pursuit Bob suggested that I try to apply the second law of thermodynamics to the problem. It seemed to me this would just make a complicated problem even more complicated. But his insight was legendary, and if he thought this might work, I would have been a fool not to wrestle with this idea until the problem capitulated.

In the event it was I, not the problem, that capitulated. It took a while to work up the nerve to tell him I couldn't figure out how to make the second law tell us anything useful. Schechter's reverence for Gibbs, the father of thermodynamics, was well known, and an admission of defeat involving the second law seemed unlikely to be well received. To my surprise, he simply said "well, it was worth a try." It dawned on me that day that even legends like Bob Schechter didn't have everything figured out in advance.

In hindsight—and journal articles are always written in hindsight—it appears that the authors knew what they were doing each step of the way. The role of accident and serendipity is never discussed, since the blind alleys and wrong hunches don't contribute to the explanation and should not take up space in the journal. But quite often the actual path was tortuous and jumpy and involved wrong turns, backing up, and going around in circles.

Bob suggested applying the second law of thermodynamics not because he knew it would work, but because it was not an obvious thing to do, and sometimes the "out of left field" idea turns out to be useful. Sometimes . . . but not every time. It was an enormous relief to discover that in science, as in baseball, legends did not have to hit a home run every time they came up to bat. They instead needed to be willing to swing at a pitch, knowing that, if they missed, it was not the end of the world.

Certainly, with experience the batter/scientist develops better and better intuition about what the next pitch/hypothesis should be. And people like Schechter have a gift for making connections and simplifying assumptions and other tricks that speed up the research process enormously. But even so, sooner or later it comes down to being willing to say "let's try this and see what happens."

Bob had that willingness, which, combined with curiosity and intelligence and insight and perseverance, took him to the top of his profession. Part of his enduring influence is that he let so many students and colleagues in on the secret to success.

Throughout his career Bob was a witty, robust intellectual. Maurice Bourrel writes: When I met Bob for the first time in 1977, I immediately recognized I was going to learn a number of things from this man. A few months later, this proved to be true. Including in totally unexpected domains.

One day, he came to me and said, "I'm going to give you your first lesson in squash." I was in my 30s at that time, playing soccer regularly, running—in good shape! I looked at this big strong man, with his thick glasses, his unique way of walking (I refer to the clap-clap of his large shoes beating the ground), and said to myself: "Ha! I'd like to see that." And see I did. I went out of the court exhausted, very badly defeated.

A few weeks later, he came again and said, "I'm going to give you your second lesson in squash." I had practiced in the meantime, and said to myself, "Ha! Now we'll see!" I did a little bit better: I won 2 games, against 7.

I have to say, however, that I could see Bob was struggling to breathe and obliged to rest from time to time.

The day after, he had his heart surgery. This indeed devalued my performance in my own eyes.

This is how I learnt squash, and humility.

Gary Pope writes: Bob served as chair of petroleum engineering from 1975 to 1978 and hired me as an assistant professor in 1977. The dean appointed Bob, one of the top professors in the entire university, to rebuild the department. Bob did more than that. He transformed it. He led the department with great vision and energy. It is because of his great leadership and vision that the department is what it is today.

The ideal departmental chair is a great teacher, world-class researcher, and strong leader. He was all of those things and more. He was always fair, treated everyone equally, and encouraged and promoted all of his colleagues. He also had the stature needed to do the job. Based on his outstanding research accomplishments, he had already been elected to the National Academy of Engineering, the highest engineering honor in the country. He also had the great respect of his faculty colleagues, the UT administration, and the petroleum industry. This enabled him to recruit and retain outstanding petroleum engineering faculty members, several of whom were also elected to the NAE later in their teaching careers at UT.

He was adored by the students he taught. They in turn have taught other students and led other departments and companies, among other achievements. His impact was huge and lasting. It set the course of the department for decades. We are what we are because of Robert S. Schechter. We and the world owe him tremendously for this great achievement.

Bill Rossen writes: In the summer of 1989 I came to the University of Texas at Austin as an assistant professor. That summer I attended the Gordon Conference on Flow in Permeable Media and told several people about my move. Twice during that conference people came up to me saying essentially the same thing: "I hear you are going to the University of Texas? Bob Schechter teaches there. Bob Schechter *is the nicest man I ever met*."

At one ceremony Bob was receiving a major award from the UT College of Engineering; I think it was the Joe King Award for research. When he started his remarks upon receiving the award, he started by saying that he was thought of as a big shot around UT, but in Austin he was known as Mary Ethel's husband. I have always admired that gracious opening, and have tried to follow its excellent example (though never under circumstances quite that august).

The welcome mat at Bob and Mary Ethel's front door said, enigmatically, "At this house live one very nice person and one old grouch.” I never found out which was alleged to be the old grouch. . . .

For many years Bob hosted an annual evening at the UT Faculty Center in celebration of the birthday of J. Willard Gibbs (“father of thermodynamics”) on Gibbs’ birthday in February. To enter the party one had to be able to define entropy—but one didn’t have to be able to give a lecture on it. (My wife Janice, with her PhD in English literature, duly learned the definition and joined the party one year.)

In addition to socializing, there was a special activity each year. One year we saw a demonstration of the principle illustrated in the National Commitee for Fluid Mechanics Films feature “Low-Reynolds-Number Flows,” showing the reversibility of the flow if diffusion is limited. There were two coaxial vertical cylinders, perhaps 12 and 18 inches in diameter, with glycerin filling the gap in between. The inner cylinder could rotate, and the outer cylinder was fixed. (The apparatus had been brought to UT years earlier by Bob Hermann, a professor in mechanical engineering who had come from General Motors’ labs. He had had it built there after seeing, and being much impressed by, the fluid mechanics film.)

At the party, Bob placed a large dot of blue-dyed glycerine on the surface between the cylinders. (In the movie, they write “Re << 1” there.) The inner cylinder was rotated about two revolutions: the dot first stretched and then disappeared in about the first half-revolution. Then the inner cylinder was rotated back. In the last half-revolution the dot reappeared, first stretched, and then back in its original shape. It was like a magic trick, or a miracle.

One year I was invited to provide the activity. I had heard that if someone spills red wine on a carpet, one should shake salt on it: the red wine is drawn in among the salt grains by capillary action and one can vacuum up the salt, leaving the carpet unstained. I brought a scrap of carpet, poured a bit of red wine on it, and poured on salt. The salt turned pink, but enough red wine stayed below to stain the carpet. Sadly, another great theory bit the dust.

At his office, Bob was interested in discussing anything about research. At his home he was always a gracious host when I would visit in his later years. He was interested in everything—his visitors' activities, their research, anything. When he had trouble with his eyes in his later years (a detached retina?), he reported to friends that the problem had to do with the van der Waals interactions between the two surfaces. Nothing was beyond the reach of his interest.

Academics features individuals with, uh, healthy egos. Bob, however, was always gracious in academic controversies. In one case, fresh out of grad school and working at Chevron, I found that in one of his papers his student had incorrectly tried to find the simultaneous optimum of two functions (solubilization ratio and adsorption in surfactant flooding, I think). It turns out this is a standard problem in economics (maximizing utility while minimizing spending), and I wrote to Bob, showing him the solution from an economics textbook. I didn't know Bob personally then, but I was much impressed with his gracious reply when I wrote.

I didn't attend Bob's classes, of course, but I believe he imbued his students with a vivid sense of humor. One day his lecture was not going smoothly. Then the star pupil in his class (I forget his name—let's call him Smith) seemed to be joining the class in the critical questioning. Bob called out, "Smith, have you turned against me too?"

I am proud to have known a man as intellectually sharp, hard-working, inquisitive, and personally gracious as Bob Schechter. He was one in a million!

A line from *Hamlet* says it best; Shakespeare, writing of the prince's father, says

> "He was a man, take him for all in all,
> I shall not look upon his like again."

REINHARDT SCHUHMANN JR.

1914–1996

Elected in 1976

"Contributions to the science of extractive metallurgy and applications to process analysis and design."

BY DOUGLAS W. FUERSTENAU AND MYSORE DAYANANDA

REINHARDT SCHUHMANN JR. died July 7, 1996, at his home in West Lafayette, Indiana, at the age of 81. He was a highly respected teacher and metallurgical engineer who made numerous seminal contributions to the processing of ores for mineral recovery and to the pyrometallurgical production of metals.

He was born on December 16, 1914, in Corpus Christi, Texas, and received his high school education in Long Beach, California. After studying for two years at the California Institute of Technology he moved to the Missouri School of Mines at Rolla, where he received his BS degree in metallurgical engineering in 1933 at the age of 18. He apparently inherited his interest in chemistry and metallurgy from his father, who was a chemistry professor. Upon graduation, he went to work for a gold mining venture near Pitkin, Colorado, where he helped build and operate the stamp mill for the Roosevelt Mine. Shu, as he was called by those who knew him, thought that this was the last stamp mill to be built in the United States. Because of financial difficulties due to the Depression, the mine soon closed and he then enrolled at the Montana School of Mines in Butte to pursue a graduate degree. In those years, Butte was the world center of copper mining and his time there spawned his lifelong interest in copper production metallurgy.

At the Montana School of Mines, Schuhmann studied under Professor Antoine M. Gaudin (an NAE founding member). There he conducted a groundbreaking investigation of the mechanism by which a flotation collector strongly interacts with the surface of chalcocite, an important copper sulfide mineral. He earned his MS in metallurgical engineering from the Montana School of Mines in 1935 and then enrolled as a doctoral student in the Metallurgy Department at the Massachusetts Institute of Technology (MIT), where his research was a self-directed, pioneering experimental investigation of the kinetics of flotation of minerals. For this he designed a small-scale continuous flotation cell with which he delineated how operating variables control the rate at which hydrophobic mineral particles attach to air bubbles and are recovered in the froth. In fact, that research was the first of its kind, and an important topic that has been pursued by numerous others ever since. He received his ScD degree in 1938.

Schuhmann joined the MIT faculty as an instructor in 1938 and rose through the ranks of assistant and associate professor by 1945. During those years, he worked mainly in the areas of comminution and flotation and published several papers in the field of mineral dressing. A classic paper concerned the size distribution of particles produced in comminution, widely known as the Gaudin-Schuhmann size distribution. He was a coauthor of the *Textbook of Ore Dressing,* published by McGraw-Hill in 1940.

During World War II, he was heavily involved with programs to improve the flotation recovery of tin from Bolivian ores, the strategic source of tin at that time. During the period 1945–1947, he served as the associate director, MIT Raw Materials Project (Manhattan District), and was involved in research in the extraction of uranium from its ores. Upon the retirement of Process Metallurgy Professor Carl Hayward, Schuhmann moved into that area, expanding his research interests to include thermodynamics of high-temperature processes for metal extraction and phase equilibria in multicomponent, multiphase systems. He wrote major papers on the thermodynamics of copper smelting and iron-silicate slags in the early 1950s. He wrote a second textbook, *Metallurgical Engineering* (Addison-Wesley, 1952), in which he expounded the unit processes approach to extractive metallurgy. In 1955 he published a brilliant analysis and application of the Gibbs-Duhem equation for ternary systems, which became highly recognized in the area of thermodynamics of solutions, the kinds of complex solutions found in molten slags encountered in smelting operations.

After 16 years at MIT, he moved to Purdue University in 1954 as professor of metallurgical engineering and chairman of the Division of Metallurgical Engineering in the School of Chemical and Metallurgical Engineering. In 1959 the Metallurgical Engineering Division became the School of Metallurgical Engineering, with Professor Reinhardt Schuhmann Jr. as its first head. As founding head of the school, his leadership was crucial in laying the sound foundation for both the undergraduate curricula and the graduate research programs in the 1950s and 1960s. He served in that capacity until 1964, when he stepped down and accepted a distinguished professorship with the title of Ross Professor of Engineering. In 1966–1967 he was the Battelle Visiting Professor at the Ohio State University and in 1977 the Kroll Visiting Professor at the Colorado School of Mines. He retired in 1980 and as distinguished professor emeritus continued his scientific interactions with the faculty on the Purdue campus.

Shu was a teacher par excellence, a researcher of enviable insight and inquiry, and an engineer with incredible capacity to translate his insights into industrial applications. He was a teacher of teachers in classical thermodynamics; he inspired students to seek solutions to problems by seeking the right information, by framing the right questions, and by applying the appropriate scientific laws and engineering principles. In other words, he focused on the student's problem-solving potential. Both undergraduate and graduate students held him in very high regard. His research interests covered a wide spectrum—from mineral dressing and extraction of ferrous and nonferrous metals to theoretical analysis and practical applications of classical and irreversible thermodynamics, from sulfur fixation in coal gasification to energy and environmental conservation. Professor Schuhmann often stated that he enjoyed moving back and forth between small-scale laboratory experiments and large-scale industrial processing, demonstrating that the same scientific ideas apply in both cases.

As a proof of creative engineering, he and his colleagues owned five US patents; these led to industrial breakthroughs in the areas of oxygen sprinkle smelting of sulfide ores and the commercial production of lead by the Queneau-Schuhmann-Lurgi (QSL) process. The QSL process utilizes oxygen converters for the direct and continuous production of lead from sulfide ore concentrates and has been adopted by Lurgi Chemie and Huttentechnik GmbH of Germany with plants throughout the world (Germany, Australia, Canada, China, and Korea). This one-step process, which can treat all grades of lead concentrates and also secondary raw materials, replaces the former two-step sinter oxidation and blast furnace reduction operations.

Shu was a recipient of many awards and honors; these include the Extractive Metallurgy Division Best Paper Award (1957) and EMD Lecturer (1965) of the Metallurgical Society (TMS, renamed the Minerals, Metals and Materials Society); the James Douglas Gold Medal, American Institute of Mining, Metallurgical and Petroleum Engineers (AIME) (1970), and Mineral Industry Education Award (1975); the Extractive Metallurgy Science Award, TMS (1977); recognition as a charter fellow of the Metallurgical Society of AIME (1963); fellow of the American Society for Metals (ASM) (1972); and member of the National Academy of Engineering (1976). He was very active in many professional societies including TMS and the Iron and Steel Society of AIME, ASM, the American Society for Engineering Education, the American Chemical Society, and Sigma Xi; and he held numerous committee chairmanships.

In November 1986, the Reinhardt Schuhmann International Symposium on Innovative Technology and Reactor Design in Extractive Metallurgy was held in Schuhmann's honor in

Colorado Springs to recognize his many contributions in the areas of extractive metallurgy and thermodynamics. The symposium was sponsored by engineering societies from eight countries and Shu's contributions were noted by his peers in the Foreword to the publication, as follows:

> It is now more than thirty years since the publication of Professor Schuhmann's epoch-making series of papers on the fundamentals of copper smelting. This work set the foundation for much of the fundamental work in this area. Professor Schuhmann's many other achievements range from a brilliant manipulation of the Gibbs-Duhem equation to derive what is now known as the Gibbs-Schuhmann equation, to co-invention, with Professor P.E. Queneau, of the Q-S-L Process and the Oxygen Sprinkle Smelting Process. The Q-S-L Process has been extensively piloted on a 240 tonne per day demonstration unit and is now ready for commercialization. It is expected that this process will revolutionize lead smelting technology.

In 1988 a research laboratory in the School of Materials Engineering was named the Reinhardt Schuhmann Jr. Laboratory to honor the founding head of the school for all his contributions over the years. In 1993 Professor Schuhmann received an honorary doctorate from Purdue University for his various contributions. This honor not only recognized his technical activities but also said:

> Shu played a major role in many of Purdue's activities since the 1950s. He started the materials area at Purdue and was the founding head of the school. His talents were recognized in many arenas in that he also was one of the founding members of the University Senate; his people skills were called into play in the late 60s when he was on the firing line of the student unrest of the times. In many ways Shu has left his mark on people who came in contact with him throughout his career. This legacy is perhaps the most lasting and most important of all of his contributions.

First at MIT and then at Purdue, Professor Schuhmann advised the research of numerous graduate students for their master's and doctoral degrees. These students, who have had significant careers in industry, academia, and government, are an important part of Shu's legacy.

Shu was a loving family man with two daughters, Martha and Alice, and three grandchildren. He considered his wife, Betsy Hancock Schuhmann, whom he married in 1937, as the one who inspired him and kept him in line, as she was quite involved in reading, studying, and discussing politics. His favorite sports were tennis and hiking in the Colorado mountains with Betsy. Six years after him, Betsy Schuhmann died on July 3, 2002, at the age of 86.

HARRIS M. SCHURMEIER

1924–2013

Elected in 1983

"Imaginative and careful engineering leadership that assured success in bold explorations of the solar system."

BY JOHN R. CASANI

HARRIS McINTOSH SCHURMEIER died November 23, 2013, after an exciting and distinguished life. He was one of the founders of American planetary exploration, contributing both his engineering and leadership skills to that enterprise. He was also a founder of the discipline of systems engineering.

Bud was born on July 4, 1924, in St. Paul, Minnesota. He became interested in flight at a young age and spent many hours designing and building model airplanes. His sister Betty Lu Christensen recalls that, in his efforts to have the lightest planes possible, he made a "skin" for them from a film floated on the water in the bathtub then dried on wire circles made of coat hangers. The rooms of their house were filled with these wire hangers. His brother Bob remembers that in his teens Bud built a wind tunnel out of cardboard to test his model planes.

His enthusiasm for flying led him to serve as a pilot in the US Navy during World War II and to pursue an aeronautical education. He earned his BS in mechanical engineering in 1945, MS in aeronautical engineering in 1948, and professional engineering degree in aeronautical engineering in 1949, all from the California Institute of Technology. His first job after graduation was with the Southern California Cooperative Wind Tunnel in Pasadena, operated for a consortium of aircraft manufacturers by Caltech.

He moved to the Jet Propulsion Laboratory (JPL) in 1949, where he served as an engineer in the laboratory's wind tunnel section. JPL had just begun operating a 12-inch supersonic tunnel, and Bud's job was calibrating it. The laboratory was also beginning to design a 20-inch hypersonic tunnel, which proved his first design challenge. The hypersonic tunnel's test section had to be cooled, and he had to figure out how to cool it while preserving flow quality.

In 1959 he was asked by Robert J. Parks to become the deputy manager for the Sergeant short-range ballistic missile JPL was developing for the US Army. But that task did not last long. JPL underwent a major reorganization that year in order to prepare itself for its movement out of the missile business and into space exploration, and Schurmeier was asked to create a new systems division in 1960.

He told an interviewer in 1970 that his intent for the division had been to have "all the trajectory work and analytical navigation work . . . preliminary design and the design integration of the spacecraft, the job of integration of the spacecraft to the launch vehicle, the responsibility for carrying out the system testing and launch operations and flight operations . . . all in the systems division." Unlike JPL's other technical divisions, the systems division had no hardware responsibility. Other parts of the laboratory remained responsible for manufacturing subsystems; the systems division was responsible for ensuring all the pieces would work together, and then proving that they did once delivered.

Creating the systems division was a complex undertaking that he had not finished when Parks asked him take over JPL's floundering Ranger project in 1964. Project Ranger was aimed at delivering a series of lunar impact spacecraft to the Moon, with early missions carrying scientific instruments such as a seismometer, while later ones carried high-resolution television cameras. But the first five missions had failed in one way or another, leading to great pressure from the National Aeronautics and Space Administration (NASA) to fix the project's problems.

"But man," Schurmeier recalled, "you couldn't stand any more [problems]. The atmosphere was such that it wouldn't accept that. You were going to be much more rigorous with everything, and much more thorough in the testing and that kind of thing. And you were going to take it slower and be that much surer of every step before you went on. And that's what we did." Schurmeier's first Ranger, Ranger 6, was nearly successful—the spacecraft worked perfectly, but, unknown to his team, its camera system had shorted out during launch, and the flawless flight ended without the precious images.

Bud had brought a couple of cases of champagne on ice to JPL to celebrate Ranger 6's success, but after the failure and inevitable press conference quietly took them home, "took them out of the water, glued the labels back on, put them back into the cases, set them aside, went to bed for a couple of hours, came into work and we started up the problem of figuring out what happened."

He brought the champagne back for Ranger 7's encounter with the Moon on July 31, 1964. That mission was, finally, entirely successful. Both of the remaining Rangers in the program were also complete successes, and Schurmeier then became project manager for the Mariner Mars 1969 project, which launched two spacecraft to Mars in February and March 1969. Though one vehicle suffered a battery explosion just before its flyby, both completed their photographic missions, imaging about 20 percent of the red planet's surface.

Bud's next assignment was as project manager for the mission once known as Mariner-Jupiter-Saturn 1977 (or MJS77), but for most of its life as Voyager. Under his tenure, Voyager started out as a "Grand Tour," with four long-lived spacecraft to be launched in 1977 and 1979 to reach Jupiter, Saturn, Uranus, Neptune, and Pluto. But as a cost-cutting measure, it was reduced to two less-ambitious spacecraft launched in 1977 to visit only Jupiter and Saturn, with one to be retargeted at Saturn's giant moon, Titan, via a gravity assist at Saturn. Schurmeier's project team retained key elements of the design needed for the more distant planets though, enabling one of the vehicles to eventually visit Uranus and Neptune anyway. Both Voyagers were still operating in 2014.

Before the Voyagers' launch, he was again asked to take on a new challenge, heading JPL's civil technology branch, and later the laboratory's reentry into defense technologies. During the 1970s, a federal initiative known as Research Applied to National Needs (RANN) pursued technologies intended to benefit the general population. RANN was implemented by the National Science Foundation and run by another ex-NASA engineer, Alfred Eggers, but drew on the technical resources of several federal agencies, including NASA/JPL. The laboratory performed transportation, solar and geothermal energy, civilian telecommunications, medical, and even wastewater treatment research under RANN. Bud was promoted to assistant laboratory director for civil systems in April 1976 and ran this enterprise and its successor at JPL, Defense and Civil Programs, until his retirement on November 1, 1985.

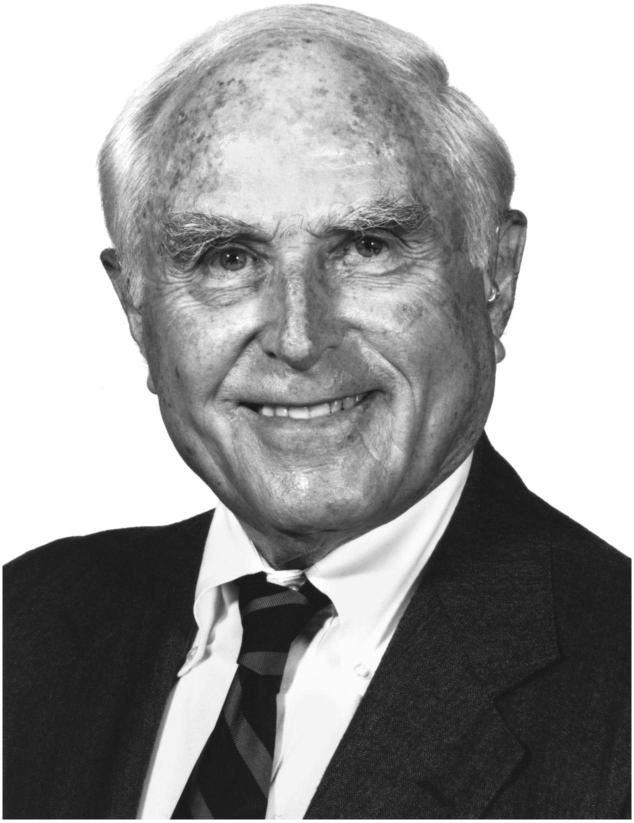
Postretirement, Bud maintained his connections to aerospace engineering through service on the Galileo project standing review board and on the William M. Keck Observatory project review board. He also headed two projects for the Planetary Society, its Mars Balloon and Mars Rover efforts, and chaired the review board for the Society's "Cosmos 1" project, intended to fly a solar sail in space.

He was elected to the National Academy of Engineering in 1983, a fellow of the American Institute of Aeronautics and Astronautics in 1973, and a member of the Supersonic Tunnel Association, the American Association for the Advancement of Science, and Sigma Xi.

President Lyndon Johnson presented him with the NASA Exceptional Scientific Achievement Medal in 1965; he received the NASA Exceptional Service Medal in 1969 and the NASA Distinguished Service Medal in 1981; he was twice presented the Astronautics Engineering Award by the National Space Club, in 1965 and in 1981; and he delivered the American Institute of Aeronautics and Astronautics annual von Kármán Lecture in 1974.

Bud was a licensed pilot, flight instructor, and avid soaring/motor glider enthusiast throughout his life. He was also a surfer, a skier, and a sailor. He took up avocado farming after retiring from JPL and served as a utilities commissioner for the City of Oceanside.

He was married to Bettye Jo, whom he met when he went to work for the wind tunnel project, in 1949. They were married for 60 years when she preceded him in death in 2009. He is survived by Ben (brother), Robert (brother), and Betty Lu (sister), and his children, Harris, Sydne, and Dennis. His seven grandchildren are Mac, Lindsey, Jenna, Bryce, Lauren, Jake, and Brenden. Bud's granddaughter Lauren is currently in a doctoral program for planetary geology at the University of Illinois at Chicago.



Ascher H. Shapiro

ASCHER H. SHAPIRO

1915–2004

Elected in 1974

"Contributions to fluid mechanics research and education."

BY ROGER D. KAMM
SUBMITTED BY THE NAE HOME SECRETARY

ASCHER H. SHAPIRO, a leader in the field of compressible fluid flow, one of the early pioneers in biomedical fluid mechanics, and a dedicated educator, died on November 26, 2004, at the age of 88.

He was born in New York City on May 20, 1916, son of Lithuanian immigrants, and grew up there. When it came time to attend university, he initially chose City College of New York, but after several years migrated to the Massachusetts Institute of Technology (MIT), where he stayed for his entire career. He received his SB degree in 1938 and ScD in 1946, and then moved through the ranks: laboratory assistant in 1938, instructor in 1940, assistant professor in 1943, associate professor in 1947, and professor in 1952. He became chair of the MIT faculty in 1964, but stepped down in 1965 to become head of the Department of Mechanical Engineering, a position he held until 1974, when he attained the highest honor bestowed on MIT faculty, Institute Professor.

Ascher's research focused on high-speed flight, turbomachinery, and power production during the first 25 years of his career. During that period, he was a member of the Lexington Project to evaluate the concept of a nuclear-powered aircraft and director of the Atomic Energy Commission's Project

Dynamo to study the prospects for using nuclear energy for electricity generation.

Ascher was a prolific and gifted author of textbooks. A major achievement was his publication of a two-volume text, *The Dynamics and Thermodynamics of Compressible Fluid Flow* (Wiley, 1953 and 1954), which is still in print today and has been translated into many languages. It served for many years as the "bible" of compressible fluid flow, and the care and precision with which it is written reflected Ascher's deep dedication to education. In addition, his book *Shape and Flow: The Fluid Dynamics of Drag* (Anchor Books/Doubleday, 1961) presented a lucid description of boundary layers and drag on bodies of various shapes, written in a manner that made it widely accessible.

Another example of Ascher's dedication to education was the series of films on fluid dynamics produced by the National Committee for Fluid Mechanics Films, which Ascher founded in 1961. These films became classics, and for many students were the means by which they obtained a fundamental grasp of underlying physical concepts of fluid flows. When completed, there were 39 videos in the collection, several of which Ascher scripted and appeared in, others featuring the leading figures of fluid mechanics of the time from around the world. According to Ronald Probstein, Ford Professor of Engineering Emeritus in MIT's Department of Mechanical Engineering and fellow member of the MIT Fluid Mechanics Lab, "Producing those films was one of the joys of his life."

In the early 1960s, Ascher's research made a decisive turn from compressible flow to the nascent field of biomedical fluid mechanics. His pioneering works addressed such issues as peristaltic pumping in the intestine and design of an intra-aortic balloon pump, a device developed by a Boston-based company and used for many years to provide temporary assist to patients in heart failure. In the early 1970s, Ascher published a series of seminal papers on flow in collapsible tubes, drawing on his background in compressible flows and the similarity in form of the governing equations. These led to important contributions to our understanding of blood flow in the low-pressure venous circulation, and the use of external pneumatic compression to prevent deep vein thrombosis and of high-frequency ventilation to maintain gas exchange in prematurely born infants suffering from respiratory distress syndrome.

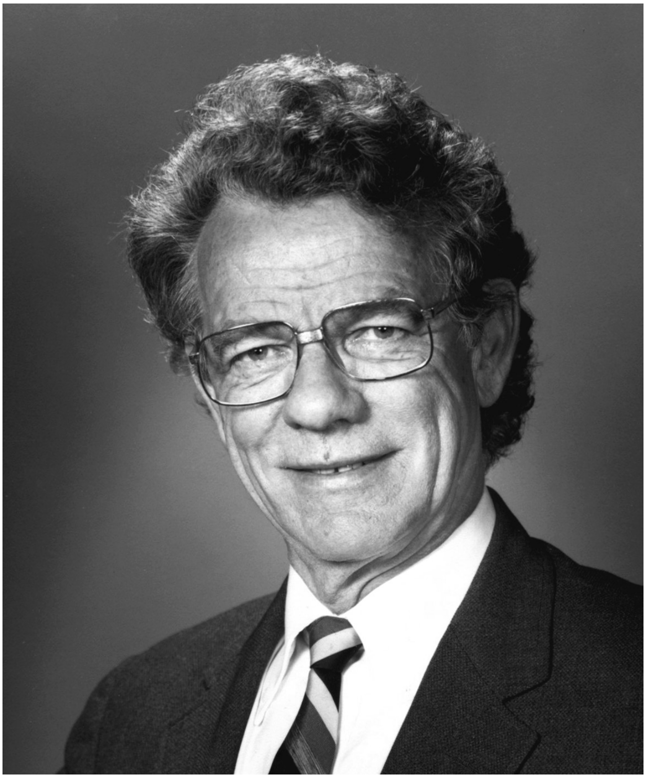
For his accomplishments in research and education, Ascher was recognized by numerous awards and honors. From the American Society of Mechanical Engineers, he received the Charles Russ Richards Memorial Award for outstanding achievement by a young researcher in 1960, and the Worcester Reed Warner Medal in 1965 for "outstanding contribution to the permanent literature of engineering." In recognition of his educational contributions, he was awarded the Lamme Medal in 1977 from the American Society for Engineering Education. He was elected to the National Academy of Sciences in 1967 and the National Academy of Engineering in 1974. He had a long association with the Technion, the Israel Institute of Technology, where he received an honorary doctorate and served on the board of governors for 20 years.

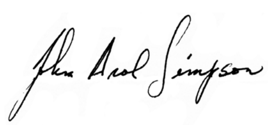
In Ascher's "other" life, he was a patron of the arts, especially the Boston Symphony Orchestra, which he attended regularly. When he could not attend himself, he generously passed his tickets on to his appreciative students, and I was pleased to be a beneficiary of his generosity. He was a gentle individual but did not shy away from speaking his mind in his interactions with either students or colleagues. His comments were always astute and reflective of his deep understanding of the fundamental concepts of fluid mechanics. He was held in the greatest respect by all who came to know him.

His daughter Mary Handel says:

> The essay has enlightened me regarding my father's academic activities. He was so devoted to his children and grandchildren and their activities that I was not thoroughly aware of how he spent his time at MIT. He was always available to be with us and never seemed pressed for time. His hobbies of gardening, squash, and the archeology of Israel also gave him great pleasure.

Ascher was survived by his third wife Kathleen, who passed away in 2011, and three children, Peter, Martha, and Mary. By daughter Mary, he had two grandchildren, Jonathan and Valery.





JOHN A. SIMPSON

1923–2011

Elected in 1988

"For creativity and innovation in developing a unique computer-controlled research facility for studying fully automated manufacturing."

BY JOHN W. LYONS

JOHN AROL SIMPSON, former director of the Manufacturing Engineering Laboratory at the National Institute of Standards and Technology (NIST), died December 6, 2011, in Falls Church, Virginia. He was 88 years old. He is survived by his wife Arlene, a son, and three grandchildren.

John was an electron physicist, a metrologist, and an expert in factory automation. He devoted most of his working life to these three areas while serving at the National Bureau of Standards (NBS)—later named the National Institute of Standards and Technology. Born in Toronto on March 30, 1923, he served in the US Army during World War II and then attended Lehigh University in Bethlehem, Pennsylvania, where he received BS (1946), MS (1948), and PhD (1953) degrees in physics.

While working on his PhD degree he was also employed at NBS in the Electron Physics Section led by L.L. Marton. This group studied a number of electron analogs of optical systems. His thesis was on an electron interferometer, work he described as very difficult both theoretically and experimentally. Subsequently he worked on a high-resolution electron spectrograph in association with Ugo Fano of the University of Chicago. The NBS group grew in size and became "one of the most active electron physics groups in the world."[1] Dr. Simpson later became section chief.

During this time the bureau was very much focused inward; precision measurements advanced apace. Ernest Ambler and his colleagues performed the critical set of experiments demonstrating that parity is not always conserved. These experiments supported the theoretical work of Chen Ning Yang and Tsung-Dao Lee at Columbia University that earned them the Nobel Prize in Physics in 1957. Later work by Russell Young, also a metrologist at the Bureau, laid the foundation for the 1986 Nobel Prize in Physics to Gerd Binnig and Heinrich Rohrer for the scanning tunneling microscope. Young's device—the Topografina—showed the way but the needed technology to make it practical had not yet been developed. This was an exciting time for high-precision metrology; John Simpson was there.

When need for change arose in the Metrology Division of NBS, Dr. Simpson was assigned, in 1975, as acting division chief (then renamed the Mechanics Division) to restructure and modernize it. He became expert in the details of fundamental measurement science. He told amusing stories about the international standard of mass held in a vault at the International Bureau of Weights and Measures in Paris and the copies distributed to the nations who had signed the Treaty of the Meter. It was and is an artifact made of a platinum-iridium alloy and has a nasty habit of changing in mass very slightly over long periods of time. Simpson felt along with most knowledgeable people that all the measurement standards should be traceable to immutable laws of nature. Developments in physics during his time at NBS included discoveries in quantum physics including the maser, the laser, and the Josephson effect. Applying these and other developments in physics, all of the international units of measurement except the kilogram were tied to these laws. Only the kilogram has defied attempts to replace it.

[1] Interview with John Simpson, The Oral History Program, National Institute of Standards and Technology, May 20, 1993.

Measurement of length (the meter) is done with lasers. When making measurements at the micrometer level and below there are some uncertainties that have to be addressed. John talked about the problem of determining exactly the edge of a solid object. It can be thought of most basically in terms of the extension of the molecular orbitals extending from surface atoms but this doesn't help much with making a laboratory measurement. The measurement is done optically by observing diffraction at the edge. John considered the problem as an exercise in metaphysics. He was a great fan of Robert Pirsig's books on the metaphysics of quality, especially *Zen and the Art of Motorcycle Maintenance* (William Morrow & Company, 1974).

In a reorganization of NBS in 1978 Dr. Simpson was named the first director of the Center for Manufacturing Engineering and Process Technology, a group that included the mechanical engineering program from his earlier division and chemical engineering from other parts of the bureau. There was not enough compatibility between the mechanical and chemical pieces and the new center was divided in two: the Center for Chemical Engineering and the Center for Manufacturing Engineering (CME, later the Manufacturing Engineering Laboratory) with John Simpson as director. The relatively new technology of robotics, formerly in the computing center, was added to CME. Thus was NBS's new effort in manufacturing technology born.

One of the many accomplishments of this period was improving the accuracy of coordinate measuring machines. Simpson and his colleagues devised a means of establishing an independent set of lasers such that the actual position of the machine's probe could be established independent of the machine's indicators. The deviation so measured was then fed into the machine's software and the true position determined and displayed. The result was a computer-controlled self-correcting measuring machine. This work improved the accuracy substantially and, since the team had determined that the machine errors are repeatable, this characterization only had to be made on occasion rather than with each measurement.

The result has since been incorporated in the manufacture of coordinate measuring machines.

The experience with coordinate measuring machines led to the realization that this same approach could be applied to numerically controlled manufacturing machines, namely, self-correcting devices incorporating on-machine metrology and applying software adjustments to the machines' controls. This approach quickly evolved into studying an ensemble of machine tools in an automated environment. The result was the NBS Automated Manufacturing Research Facility (AMRF).

At that time the NBS also had one of the early programs in robotics. Dr. Simpson incorporated that effort in the AMRF, thereby enabling a fully automated flow of material from raw material storage through various machines fed by robots to finishing and final metrology, also fed by robots. To accomplish this required a software control architecture and various standards for describing material properties and for enabling interfaces between disparate machines with their own proprietary software. The control architecture, developed by James Albus, was based on an earlier model of the human cerebellum. Refinements of this approach are widely used in today's automated systems. Thus the AMRF was based on the physics of materials, metrology, robotics, and computer engineering. The lasting results of this work were control architecture, product description standards, and techniques for interconnecting all sorts of computer-controlled machines and devices.[2]

John Simpson's AMRF program was a pioneering effort that attracted a great many guest researchers from universities and industry. It also attracted the attention of the Congress in the person of Senator Ernest Hollings of South Carolina. His interest, in turn, led to the reauthorization of NBS, changing

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[2] For a detailed history of the AMRF including several appendices that list sponsors, numbers of companies, and universities that sent guest workers to the program, see Joan M. Zenzen, *Automating the Future: A History of the Automated Manufacturing Research Facility 1980–1995*, Diane Publishing Company, Darby, PA, March 2001. This is a reprint of NIST Special Publication 967, available from the NIST Information Center in Gaithersburg.

its name and incorporating increased emphasis on technology in support of the American economy. It became clear to Dr. Simpson that large companies in the United States were quite capable of handling this technology, but the vast majority of small companies were not. Dr. Simpson and his colleagues adapted NBS's method of achieving efficiencies in delivering services to state and local governments through a cascading chain of laboratories. Measurement assurance was achieved through NBS/NIST calibration support. Dr. Simpson proposed establishing demonstration facilities out in the states where the new technology could be brought before small companies. The idea was adopted and became the Hollings Manufacturing Extension Partnership in 1989. Beginning with three centers, the program now has 400 centers and field offices with 1,300 staff in the 50 states. In this way, Simpson's manufacturing automation program turned NBS outward, offering full-blown integrated automated process technology to US industry. This in turn led to the reauthorization of NBS as NIST, calling for more emphasis on working with US industry in support of the national economy.

John Simpson was an interesting character and fun to be around. He was a good storyteller and had many tales about the early days of his 48 years of government service—he was dean of the staff when he retired. On snow days he would bring his cross-country skis to work and make the rounds of NIST's considerable acreage. He was an avid bicyclist and led a group of like-minded staffers on the roads of NIST. One day he was thrown over the handlebars and suffered a fairly serious shoulder injury, but that didn't deter him from continuing his noon-day rides.

John's broad range of expertise in the various components of NBS/NIST was rare at the time; we shall not likely see such breadth of experience in a single individual again. His career spanned the evolution of NBS into NIST; his work provided the impetus for the increased attention to transitions of NIST technology to the private sector. He was a key player in the history of the institution.

ERNEST T. SMERDON

1930–2014

Elected in 1986

"For contributions resulting in more effective use of limited water resources for worldwide food production and resource conservation."

BY JOHN E. BREEN

ERNEST THOMAS SMERDON, Engineering Dean Emeritus of the University of Arizona and a visionary leader in engineering education as well as in water resource conservation, died on August 11, 2014, at the age of 84.

Ernest, or Ernie as he was generally called, was born in a farm home on January 19, 1930, in Ritchey, a very small village in the Missouri Ozarks. During his formative initial 17 years on the farm in Ritchey, he learned from his parents the value of hard work, honesty, and the importance of always doing one's best. Throughout his subsequent far-reaching career, colleagues greatly respected Ernie for his emphasis on these virtues. They made him a highly effective leader. In every subsequent office that he occupied, Ernie always kept a painting of the river valley and water-powered grain mill at Ritchey to remind him of the interconnection of water and farming that was to be the great part of his life's work.

At 17, Ernie enrolled in the Agricultural Engineering Department of the University of Missouri in Columbia, receiving a BS in engineering in 1951. That was an extremely important year in his life. Besides completing his baccalaureate degree, he also married Joanne Duck, who became an active partner in many of his later administrative roles and provided constant support to Ernie throughout his career.

With the Korean War under way in 1951, he accepted a commission in the US Air Force and, after a year of meteorology training at the University of Washington, served as a meteorologist from 1951 to 1955, part of the time stationed in Greenland. His meteorological training expanded his agricultural engineering interest. When he left the Air Force in 1955, he returned to the University of Missouri for graduate school with a major in agricultural engineering and a minor in civil engineering. He conducted extensive laboratory studies in hydraulics and hydrology, receiving an MS in 1956 and a PhD in 1959 with emphasis in water resources and irrigation engineering.

Upon completion of his graduate work, Ernie joined the faculty of Texas A&M University as an associate professor of agricultural engineering. In 1962 he was promoted to professor of agricultural engineering and in 1964 he became a professor of civil engineering and director of the Texas A&M Water Resources Institute. During this period, he was a consultant and panelist for early efforts to develop teaching and research programs in renewable natural resources for both the National Research Council (NRC) and the US Department of Agriculture.

In 1968 he became chair of the Agricultural Engineering Department of the University of Florida. He was assistant dean for research there from 1974 to 1976.

From 1976 to 1982, Ernie was vice chancellor for academic affairs of the University of Texas System. In this demanding position he served on the screening committee for presidents of four campuses including the flagship campus, UT Austin. His colleagues praised him for his vision, diplomacy, and honesty.

In 1982 Dr. Smerdon became professor of civil engineering and director of the Center for Research in Water Resources at the University of Texas at Austin. In 1983 he added a professorship in natural resource policy studies in the LBJ School of Public Affairs. In 1987 he was named the Janet S. Cockrell Centennial Chair in Engineering following his 1986 election to the National Academy of Engineering. While at Texas, he served on numerous water-related task forces that developed programs for both water quality and quantity throughout the state.

In 1988 Dr. Smerdon made his last academic move when he became vice provost and dean of the College of Engineering and Mines at the University of Arizona in Tucson. In this important leadership role, held until 1997, his attention turned to more global issues in the education of engineers and particularly the career-long education of engineers for lifelong learning. He led efforts to shift education for engineers to a more futuristic mode recognizing the rapid development and changes in the technological fields.

Ernie's emergence as a leading contributor in hydrology and water resources was recognized by the American Geophysical Union, which sponsored his hydrology lectures at 15 prominent universities, and by a number of consultancies for the US Agency for International Development, advising roles for developing nations, and participation in NRC panels on environmental issues.

In 1982 he received the Missouri Honor Award for Distinguished Service in Engineering. In 1989 his landmark contributions to irrigation engineering were recognized by the American Society of Civil Engineers (ASCE) Irrigation and Drainage Division (outstanding journal paper) and Royce J. Tipton Award. Also in 1989 the American Water Resources Association gave him the Icko Iben Award for promoting understanding and communication between disciplines involving water resources. He served as president of the American Society for Engineering Education (ASEE) and of the ASEE Deans of Engineering Committee. In 1994 he was elected a Distinguished Member of ASCE and in 2003 his alma mater, the University of Missouri, awarded him an honorary doctorate of science degree.

Upon retirement from the Arizona deanship, Ernie accepted an assignment as senior education associate in the Engineering Directorship of the National Science Foundation. He also participated in NAE committees such as the Academic Advisory Board, the Committee on Technology Options in a Global

Economy, the Steering Committee for Engineers of 2020, and the Capacity of the US Engineering Research Enterprise.

In recognition of his lifelong devotion to improving engineering education, he was selected to receive the ASCE OPAL Leadership Award for Education in 2008 and in 2006 the Union of Pan American Engineering Society's Golden Vector Award, only the fifth US citizen to be so honored. The University of Arizona named the Ernest T. Smerdon Engineering Academic Center in his honor.

Dr. Smerdon is survived by his loving wife of 63 years, Joanne, and children Tom, Kathy, and Gary. He is also survived by 10 grandchildren, four great-grandchildren, and a sister.

Ernie will not be forgotten by anyone who had the opportunity to know him. Much of his legacy is to be found in the great body of professionals impacted with his infectious leadership. He was truly a hard worker.


Thor L. Smith

THOR L. SMITH

1920–1999

Elected in 1990

"For pioneering studies of the basic engineering properties of elastomers and glassy polymers."

BY DONALD R. PAUL

THOR L. SMITH, a well-known polymer scientist and retiree from IBM Almaden Research Center, died on September 6, 1999, at age 79 in Los Altos, California.

Thor was born June 11, 1920, in Zion, Illinois, where he grew up. He attended Wheaton College and received a BS in chemistry in 1942; he obtained an MS in physical chemistry from the Illinois Institute of Technology in 1944. He then went to the University of Wisconsin, where he worked under John D. Ferry and in 1948 received a PhD in physical chemistry specializing in polymers. His industrial career began immediately thereafter.

He first worked for Hercules Inc., in Wilmington, Delaware (1948–1954). In 1954 he moved to California, where he joined the Jet Propulsion Laboratory and did extensive research on solid rocket propellants, elastomers, rheology, and viscoelasticity. He served as a section chief (1956–1959) and then worked at the Stanford Research Institute (SRI) until 1968. He was named an SRI Fellow in 1964. He took a brief excursion into academia at Texas A&M University as professor of chemistry in 1968.

Thor returned to California in 1969 and began his career in the IBM Research Division. He worked in the Polymer Sciences and Technology Department until his retirement in 1990. He was involved in basic research in polymer science and made a considerable impact in IBM technology in the areas of plastics and elastomer materials. He continued his interests in viscoelastic properties, rheology, strength, and toughness of elastomers and other filled materials. Later in his career he did important work in the area of glassy polymers.

Thor's significant and lasting contributions to the literature on polymers have affected how these materials are incorporated into products. Some of the underlying principles from his work have been included in textbooks on polymers and become part of the essential fabric of the field.

Mechanical behavior was a central theme throughout his career. His early work focused on rubbery polymers and key issues related to their use in solid propellants for rocket motors. This led to the clever elucidation of the now famous "failure envelope" of rubbery materials and involved recognizing the applicability to failure behavior of time-temperature superposition principles from linear viscoelasticity.

His later work on the glassy state of polymers focused on their response to mechanical stress, motivated by issues related to the use of polymers in electronics and magnetic storage of information; but, again, basic principles emerged that influenced the field in more general ways. Specifically, he showed that mechanical stress affects molecular packing and mobility in the glassy state. One significant consequence of this is that the rate of sorption or permeation of small molecules such as water or gases is increased. Another consequence is that stress accelerates the rate of physical aging of glasses (i.e., their slow approach to a thermodynamic equilibrium state). These phenomena are factors affecting the stability and reliability of magnetic tapes for information storage and must be appreciated for high-performance systems.

In every case, Thor's research was conducted with characteristic thoroughness and keen insight. Corresponding excellence is found in his more than 80 research publications in highly respected journals in the field. They have been widely read and used and some are regarded as classics.

Thor was active in numerous professional organizations including the American Chemical Society (Rubber, Polymer

Chemistry, and Polymer Materials: Science and Engineering Divisions), American Physical Society (fellow), Society of Plastics Engineers (SPE), and British Society of Rheology. He served as president (1967–1969) and vice president (1965–1967) of the Society of Rheology. He chaired the Gordon Research Conference on Elastomers in 1968 and the Winter Gordon Research Conference on Polymers in 1980. He served as a member of the board of trustees of Gordon Research Conferences (1978–1984) and chair in 1982.

He was a member of the NRC's Evaluation Panel for the Polymers Division of the National Bureau of Standards (1974–1977) and National Materials Advisory Board Committees on Adhesion of Rubber to Steel (1971–1972) and on Science Base for Materials Processing (1978–1980). He chaired the Joint Army-Navy–Air Force Panel on the Physical Properties of Solid Propellants (1959–1961).

Thor received the prestigious Bingham Medal of the Society of Rheology in 1978 and the SPE Research Award in 1983. He received an Outstanding Innovation Award from IBM in 1978. He gave numerous invited lectures, including the G. Stafford Whitby Memorial Lectures at the University of Akron in 1974. He served on the editorial advisory boards of the *Journal of Polymer Science: Polymer Physics Edition* and *Polymer Engineering and Sciences*.

Thor Smith was a real gentleman who upheld high personal and professional standards with great dignity. He was highly respected by colleagues in the polymer field.

At the time of his death he was survived by his wife, Darlene Smith, and sons Theodore Lowe Smith and Glen E. Smith.

ELIAS SNITZER

1925–2012

Elected in 1979

"Invention of the glass laser and the fiber-optics laser."

BY ANTHONY J. DEMARIA

ELIAS SNITZER, a modest giant in the field of lasers and fiber optics technology for over 50 years, died on May 21, 2012. He was 87 years old.

Eli, as he was called, was born in Lynn, Massachusetts, on February 27, 1925. He graduated from Tufts University with a BS in electrical engineering in 1945, and an MS and PhD in physics from the University of Chicago in 1950 and 1953. He joined the faculty of Lowell Technology Institute in 1956. In 1958 his career was stalled when he was subpoenaed to appear before the House Un-American Activities Committee of the United States House of Representative because he had been involved in left-wing politics as a student at the University of Chicago. Consequently, he lost his teaching job at Lowell Institute of Technology. His case was taken up by the American Association of University Professors and some years later the case was settled in his favor.

American Optical Company hired him and he began his work on Nd:glass lasers and glass fibers. In 1961 he published the theoretical description of optical modes in glass fibers. Shortly thereafter he reported the first operation of the glass laser. This report came soon after the report of the operation of the world's first laser, the ruby laser at Hughes Research Center in 1960. Eli followed the ruby laser announcement with the first reported operation of a glass laser and later with the first report of a fiber laser and amplifiers. These inventions have played an important role in the development of lasers and fiber optics technologies in optical communications and in scientific research.

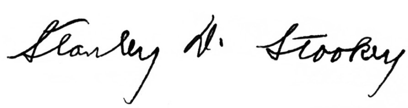
Eli remained at American Optical as director of corporate research until 1977 when he joined United Technologies Research Center (UTRC) as manager of photonics technology. At UTRC he was responsible for lasers, integrated optics, fiber optics, fiber sensors, and laser radar, to name a few, and instrumental in the initiation of the UV side-writing of the fiber Bragg gratings program.

In 1984 he joined Polaroid where he directed programs in fiber and integrated optics for communication, sensors, and photographic instrumentations. He invented the double-clad fiber laser, which has found extensive applications in fiber communication.

In 1989 he joined the Ceramic Sciences Engineering faculty at Rutgers University where he continued to teach and to conduct research in fiber laser amplifier and glass Bragg gratings until his retirement. He also led the development of the praseodymium fluoride glass fiber amplifiers and the development of mask fabrication for Bragg grating.

He was elected fellow of the Optical Society (OSA) in 1964 and awarded its Charles Hard Townes Award (1991) and John Tyndall Award (1994), the IEEE Photonics Society Quantum Electronics Award (1979), the Otto Schott Research Award (1999), and the Rank Prize for the invention of the cladding-pumped fiber laser (2000). He was named a life fellow of the IEEE and elected to the NAE in 1979. The American Ceramic Society honored him with the Morey Award for glass science in 1971 and as the inaugural recipient of the Stookey Award given for a lifetime of innovative contributions in research on new materials and processes involving glass. In 2012, IEEE recognized his work with a milestone plaque placed outside the American Optical Research Center in Southbridge, MA.

In addition to his distinguished professional career, Eli Snitzer was a devoted father and family man. He was the beloved husband of the late Shirley (Wood) Snitzer and loving father to five children, Sandra, Barbara, Peter, Helen, and Louis, ten grandchildren, and five great-grandchildren. He was an avid tennis player and enjoyed all activities by the water. He was also a proud veteran of the US Navy.



S. DONALD STOOKEY

1915–2014

Elected in 1977

"Invention of glass, ceramics and photo sensitive glasses."

BY CORNING INCORPORATED
SUBMITTED BY THE NAE HOME SECRETARY

STANLEY DONALD STOOKEY, whose 1952 discovery of glass ceramics led to one of the most successful product lines in Corning Incorporated's history, died November 4, 2014. He was 99 years old and lived in Pittsford, New York.

Dr. Stookey was born May 23, 1915, in Hay Springs, Nebraska. His family moved from Nebraska to Cedar Rapids when he was five. Some of his favorite childhood memories were of family fishing trips to Minnesota—a hobby that he continued to enjoy throughout his life.

He earned his bachelor's degree in chemistry and mathematics from Coe College in Cedar Rapids in 1936 and his master of science in chemistry from Lafayette College in Easton, Pennsylvania, in 1937. The glass industry was an unknown territory to Dr. Stookey when he began looking for jobs in 1940 with his newly defended PhD dissertation in physical chemistry from the Massachusetts Institute of Technology (MIT). Although Dr. Stookey didn't consider himself one of the top scholars in his graduating class, he was excited about finding a job that gave him a chance to explore. The problem was, in 1940, scientific frontiers seemed to be few and far between: few real secrets seemed to be left in what he called the "conventional sciences of chemistry and physics." When J.T. Littleton and William Chittenden Taylor from Corning showed up at

MIT looking to fill three positions, Stookey considered glass for the first time.

He was invited to interview at Corning as a candidate for a position as a glass technologist, overseeing melting research in the production department under Corning's chief engineer Walter Oakley. His record at MIT had not prompted Littleton the physicist or Taylor the chemist to think of him initially as a candidate for the fundamental research slot—investigating opal glasses. But somehow at the end of his visit, Stookey had convinced Littleton to hire him for the research position at an annual salary of $2,500 per year.

After Dr. Stookey joined Corning, he immersed himself in exploratory research, studying the complex chemistry of oxidation and its effects on the color of glass as it changes temperatures—discoveries that helped lead to the development of photosensitive glass. From there, he led the development of Fotoform® glass—a composition that allowed chemicals to, in effect, punch minuscule holes in glass. The application had potential for use in the nascent color television tube market.

He secured his place in Corning folklore in 1952 when he put a Fotoform disc into a furnace set at 600 degrees Celsius. The furnace malfunctioned and the temperature rose to 900 degrees Celsius. Expecting to find a molten mess in the furnace, Dr. Stookey instead discovered an opaque, milky-white disc. He removed it from the furnace, but his tongs slipped and the disc bounced unbroken on the floor, clanging like a piece of steel. "It crystallized so completely that it could not flow," he later wrote, "and was obviously much stronger than ordinary glass."

While the formation of this first piece of glass ceramics was "a lucky accident," Dr. Stookey said, he followed up with years of rigorous research. Ultimately, he confirmed his belief that nucleation—the critical first step in the crystallization process—could initiate a host of new crystalline materials from glass. Corning patented the material as Pyroceram® glass ceramics, the basis for the CorningWare® line that became a staple in the consumer cookware world for decades.

That innovation, along with other breakthrough exploratory research in the areas of photochromics and photosensitive glass, earned Dr. Stookey the National Medal of Technology and Innovation in 1987, a place in the National Inventors Hall of Fame in 2010, and a host of other prestigious recognitions. He earned 60 US patents over the course of his career. Corning's top award for its own leaders in exploratory research is named in Dr. Stookey's honor.

Dr. Stookey was elected to the National Academy of Engineering in 1977. He was a member of Sigma Xi, the British Society of Glass Technology, and American Chemical Society, a fellow and Distinguished Life Member of the American Ceramic Society, a fellow of the American Institute of Chemists, and a Rotary Club member in Corning.

He was honored with many awards throughout his career, including the John Price Wetherill Medal of the Franklin Institute (1953 and 1962); Coe College Alumni Award of Merit; Ross Coffin Purdy Award of the American Ceramic Society; Toledo Glass and Ceramic Award; Inventor of the Year Award, George Washington University; Award for Creative Invention of the American Chemical Society; Eugene C. Sullivan Award, Corning Section, American Chemical Society; Beverly Myers Achievement Award of the Educational Foundation in Ophthalmic Optics; Phoenix Award of the Glass Industry; Achievement Award of the Industrial Research Institute; Samuel Giejsbeek Award of the Pacific Coast Sections, American Ceramic Society; and Distinguished Inventor Award, Central New York Patent Law Association.

He retired from Corning in 1978 but continued to consult in its laboratories, especially on glass manufacturing processes and photosensitive glass. In addition, he continued to mentor both young and experienced scientists at the company many years after he retired.

Besides his contributions to Corning's innovation portfolio, Dr. Stookey was dedicated to community service—in particular, issues facing the elderly population in Corning. In the early 1970s, he helped lead a task force that eventually resulted in the construction of the Dayspring housing complex in Corning.

On a personal level, Dr. Stookey considered his family his finest achievement. He lived life fully, appreciative of his family and dear friends. He enjoyed fishing close to home and around the world on adventurous trips. He fished for marlin and sailfish off of Mazatlán, Cozumel, and squaretail trout in Quebec. Other fishing expeditions took him to the Arctic Circle on Great Bear Lake and Makokibatan Lake in Northern Ontario. He also traveled to Europe, the Caribbean Islands, the Orient, and Katmandu.

Dr. Stookey is survived by two sons and their spouses, Dr. Robert A. (Sally) Stookey of Pittsford, NY, and Donald B. (Beth) Stookey of Utica, NY, and several grandchildren and great-grandchildren. He was predeceased by his wife Ruth and daughter Margaret A. Zak.

G. Russell Sutherland

G. RUSSELL SUTHERLAND

1923–2014

Elected in 1984

"For outstanding contributions to agricultural mechanization resulting in mankind's assurance of food and fiber to the end of this century."

BY RON LEONARD

GLENN RUSSELL SUTHERLAND's distinguished career with Deere & Company began in 1949 after graduation with a master's degree in agricultural engineering with honors from the University of Wisconsin.

Russ spent the majority of his career in factory product engineering units of Deere & Company at Ottumwa and Des Moines, Iowa. His uncanny ability to conceive improvements to the hay and forage harvesting products earned him numerous patents and distinguished him at Deere's Ottumwa Works. These skills earned him management positions with responsibility for the design of several major machine lines manufactured there.

In 1963 he received a promotion and transfer to the Deere Des Moines Works as senior division engineer for cotton harvesters, and soon was promoted to manager, product engineering, for all products at that unit. Deere had long trailed International Harvester in sales of cotton pickers and strippers. Under Russ's leadership the Des Moines Works cotton harvesting machines rapidly improved in performance and durability to become market leaders over the competition.

Russ oversaw a broad range of products, from cotton pickers and strippers to adjustable-width row unit corn heads, farmstead grain dryers, stack wagons for hay harvesters, new tillage implements, and row unit heads for combines that harvested soybeans. Product sales and market share records reached new heights. Farming practices were changing rapidly as farmers responded to the challenge to increase production and adjusted their farming practices as required. During his 28 years at the Ottumwa and Des Moines units Russ held 27 patents for agricultural equipment.

His leadership extended beyond specific product designs. He was also a great developer of managerial talent. Engineers who worked in Deere's Ottumwa and Des Moines units benefited from his direct influence. They learned that his personality was unassuming and his guidance exemplified humility and gentleness. Summed up, his approach was just to state the facts clearly and honestly, then expand your thinking to consider new and different approaches to the design.

In 1977 Russ was appointed director of product planning at the Deere & Company Worldwide headquarters in Moline. His successful experiences with products at Deere units were put to good use in this assignment. In 1984 he was appointed vice president, engineering, and in April 1986 he assumed the position of vice president, engineering and technology.

During his time at Deere & Company, Russ championed the movement to desktop computing systems for product engineering functions. During the 1970s and 1980s, desktop digital design software and hardware underwent revolutionary changes as new modeling and analysis software were linked together. His leadership ensured that Deere engineering systems were state of the art.

Russ brought insight rather than information to the job. He was challenging but not demanding, practiced leadership with a smile, was an innovator not a follower, and was a mentor for both product and people development. His election to the NAE in 1984 was a fitting recognition of his accomplishments. He also served as a director of the American National Standards Institute.

The Deere & Company bulletin announcing Russ's retirement in 1987 included the following summary of his contributions to the company: "Each of us in our career hopes to make a positive difference in the Company through our efforts. Russ Sutherland is one who has made a positive difference. His influence has been felt in new product programs, development of engineering computer networks and systems, and the encouragement of entrepreneurial efforts at selling manufacturing technology developed within John Deere. Those of us who have worked with Russ know how much his wise counsel is sought and respected."

His 90 years of life began in his parents' farm home in Waukau, Wisconsin, on December 20, 1923, and ended with his death on June 11, 2014, at home in Mariposa, California, surrounded by his family. His life journey included attendance at Foote Rural School (a one-room schoolhouse) and graduation from Berlin, Wisconsin, High School. While working his way through the University of Wisconsin, his engineering studies were interrupted during World War II when he was called to active duty. He finished Midshipman School in Ithaca, New York, in March 1945 and married his high school sweetheart Leone there before reporting to a Miami naval base. Following his tour of duty as an engineering officer on board a ship in the Pacific they were reunited at the University of Wisconsin when Russ resumed his engineering studies.

After retirement from Deere in 1987, he and Leone moved to their dream home in Bella Vista, Arkansas, where he served on the property owners association board of directors and enjoyed golfing and boating. In 2000 they moved to Mariposa, where he volunteered for the Museum and History Center and was a member of the American Legion. He enjoyed traveling, gardening, working with tools to repair things, and researching the genealogy of his Scottish ancestry. Their family included sons and daughters-in-law Keith and Nancy Sutherland of Cedar Rapids, Iowa, and Glenn and Kathy Sutherland of Midpines, CA, five grandchildren, and nine great-grandchildren.

In remembering him at his death his family wrote, "Throughout this 90 year journey, there has been one constant: the character of Russ Sutherland. Despite his many achievements, he always has exemplified humility, gentleness, and above all, integrity. He always put family first, despite the many demands of his career. He led and taught with quiet encouragement and by example. His was a life well lived."

JOHN J. TAYLOR

1922–2013

Elected in 1974

"Contributions to the application of theoretical methods to nuclear shield and reactor design."

BY WILLIAM J. PERRY

JOHN JOSEPH TAYLOR, a pioneer in nuclear energy and former vice president of Westinghouse and the Electric Power Research Institute, died on December 9, 2013, at the age of 91.

John was born in Hackensack, New Jersey, on February 27, 1922. He graduated from St. John's College in 1942 and went on to serve as a Lieutenant (jg) in the Navy. After his naval service he did graduate work at Notre Dame, where he was awarded a master's degree in mathematics in 1947. He was awarded an honorary doctorate from St. John's College in 1947. On leaving college he went into the nuclear industry and never looked back, making his mark as a world leader in that field and the related field of electric power.

He started his career in nuclear power with the Kellex Corporation, but in 1952 moved to the Westinghouse Electric Corporation, where he held a series of increasingly responsible positions in nuclear power, in time becoming the vice president and general manager responsible for the corporation's nuclear power plant business. During this period Westinghouse became one of the preeminent companies in the world in the field of nuclear power.

During his career at Westinghouse John had management positions, in turn, for the development of nuclear reactors for naval submarines, reactors for commercial electric generating plants, and breeder reactors. In short, he held senior management responsibilities for some of the most critical nuclear programs in our nation during the Cold War. As John approached the mandatory retirement age for senior managers at Westinghouse, he was the general manager for all of Westinghouse's commercial nuclear power plants, and he was not ready to retire.

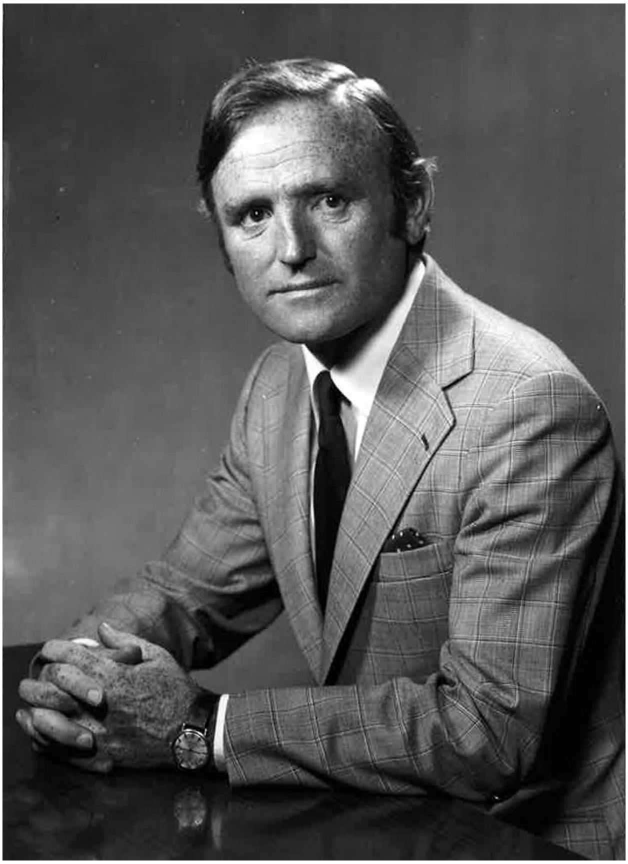
So in 1981, after a remarkably distinguished career spanning 31 years, he left Westinghouse and went to the Electric Power Research Institute (EPRI) in Palo Alto, California, where he became the vice president of nuclear power. He served at EPRI for another 14 years, retiring in 1995 at the age of 73. When John was at Westinghouse, he focused on the technology and management of nuclear reactors; at EPRI he drew on his broad background to explore policy implications of nuclear energy. A typical product of his EPRI work was the paper "Reactor Accidents: A Global Reassessment of Consequences," one of several dozen papers he wrote while at EPRI—in addition to the more than 30 technical papers he authored or coauthored on technical aspects of nuclear reactors while at Westinghouse.

While John's career in the nuclear reactor field was quite broad, it is fair to say that he was especially preeminent in the field of nuclear safety and efficiency, including the safe disposal of excess plutonium. Indeed, he was probably the leading American in this field and was internationally known for his seminal analysis of the Three Mile Island nuclear accident. His outstanding work in the nuclear safety field led him to be nominated for the prestigious Enrico Fermi award, as well as the Smythe award.

During his long and distinguished career, he was honored with many awards, including the Walter H. Zinn Award (American Nuclear Society), the George Westinghouse Gold Medal (American Society of Mechanical Engineers), and the Order of Merit (Westinghouse Electric Corporation). He was elected to the National Academy of Engineering, a fellow of the American Nuclear Society and American Association for the Advancement of Science, and a member of the American Physical Society. He served on many committees of the NAE and the National Research Council, and was chair of the Electric Power/Energy Systems Engineering Section. He served as an unpaid consultant to the International Atomic Energy Agency and to several US government agencies, including the Department of Energy, and often testified to the Congress.

John's modesty belied a lifetime of remarkable achievement serving his country. His career of achievement in more than 50 years in nuclear design, nuclear safety, and nuclear policy is unique in the world. But beyond the overachiever was a warm and generous human being. He was a caring friend to many of us, but was most at home with his family, to whom he was entirely devoted. Lorraine, his beloved wife of 67 years, died several years before John.

He is survived by a son and daughter-in-law, John B. and Allyn Taylor, a daughter and son-in-law, Nancy T. and Paul Gray, a daughter and son-in-law, Susan and Paul DeMuro, as well as six grandchildren, one grandson-in-law, and two great-grandchildren. They will all miss him, as will his many friends; indeed, we will never see his like again.



GARETH THOMAS

1932–2014

Elected in 1982

"Pioneering work in the application of transmission-electron microscopy to materials science and engineering."

BY RON GRONSKY
SUBMITTED BY THE NAE HOME SECRETARY

GARETH THOMAS, world leader in the application of electron microscopy to engineering materials analyses and longstanding distinguished member of the Berkeley faculty, died on February 6, 2014, in Oegstgeest, the Netherlands, at the age of 81.

Gareth was born in Maesteg, a small town in the south of Wales historically known for its iron and coal industries, on August 9, 1932. He spent his childhood attending primary and secondary schools in Maesteg while developing his athletic skills in both cricket and rugby. Ever the strong competitor, he sought and earned early admission to nearby Cardiff University, completing his bachelor of science degree in metallurgy with first class honors in 1952. He immediately began his graduate studies at the University of Cambridge, St. Catherine's College, and, while still playing competitive rugby, completed all requirements for the PhD degree by 1956.

In 1958 Gareth married Elizabeth Cawdry and soon after moved to the United States, working briefly for a time in consulting roles for the aluminum industry, then, in 1960, accepting appointment as a visiting assistant professor of metallurgy at the University of California, Berkeley. As he would later tell his colleagues, "it was easy to plant roots in Berkeley." He took a special liking to the Bay Area, immersing himself in

Berkeley's community of scholars, strong rugby tradition, and culinary delights, finding special pleasure in short road trips to the nearby Napa Valley. Gareth and Elizabeth established their residence on Summit Road, at the top of the Berkeley hills, with a spectacular view of San Francisco Bay. True to form, he quickly joined the regular ranks of the professoriate the following year (1961), weathering the turmoil of the Free Speech Movement (1964) while launching his successful research portfolio and establishing more than enough momentum to attain the rank of full professor in 1966.

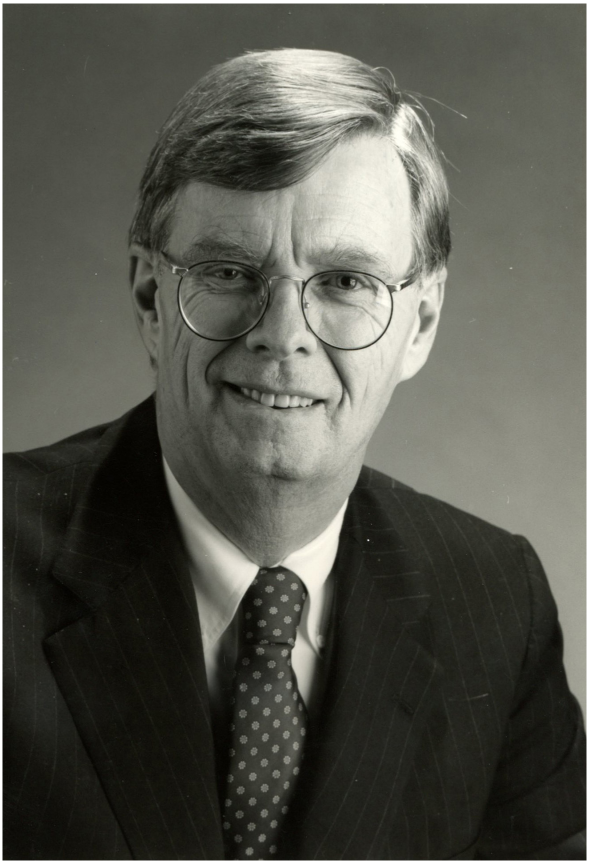
Professor Thomas's research career began at Berkeley with a small electron microscopy lab in the basement of the Hearst Memorial Mining Building. Teaming with colleagues locally and from around the world, he worked diligently to establish the relationship between the internal structure of materials and their properties, bringing new understanding of engineering performance and how it might be optimized. He trained scores of graduate students and postdoctoral scholars in the nuances of electron microscopy, published a widely used textbook on the subject, and continued to grow his collection of electron microscopes beyond the confines of his campus space.

In 1976 Gareth and two colleagues, Robert Glaeser (Berkeley) and John Cowley (Arizona State University), proposed the creation of a National Center for Electron Microscopy to be housed on a new site at the Lawrence Berkeley National Laboratory. The idea eventually won favor with the Department of Energy, becoming a line item in the congressional budget of 1980. The NCEM was officially established in 1983, and Gareth served as its scientific director until 1991. His legacy is cemented at NCEM, along with over 500 technical publications and 10 patents, encompassing a lifetime of achievement in the development of engineering materials.

His tireless work ethic also earned him a multitude of awards, from the Institute of Metals (London) National Undergraduate Student Prize in 1953, to ASM International's Gold Medal in 2001, with numerous honorary memberships and degrees from a host of international institutions in the intervening years, including memberships in both the NAE (1982) and NAS (1983). Gareth's talents in leadership were also recognized by his appointments and elections to the presidency of the Electron Microscopy Society of America (1975) and the International Federation of Societies for Electron Microscopy (1986). He gave freely of his time in service to the profession on the TMS-AIME Board of Directors (1978), as chairman of the *Acta Metallurgica* board of governors (1982), on the National Research Council, and as editor in chief of *Acta Materialia* and *Scripta Materialia*. He also served a year at the helm of the Technology Transfer Centre at the Hong Kong University of Science & Technology, Kowloon (1993) and as chief technology officer of the specialty alloy company MMFX® Steels, which licensed one of Gareth's patents for high-strength corrosion-resistant ferrous steels.

Former students and colleagues also recall Gareth's zest for life outside of the lab. He enjoyed a succession of sports cars, skiing, opera, an exquisitely well-appointed wine cellar (enabling many memorable wine tastings for his research group), sports (the San Francisco Giants, San Francisco 49ers, and, of course, the Rugby World Cup), and travel, the last of these inducing his graduate students to calculate his "mean elevation above sea level" during an especially busy semester! He is still missed and recalled fondly during all of the annual electron microscopy society meetings around the world.

Above all, Gareth wanted to be remembered as a loving husband, father, and grandfather. His first wife Elizabeth died in 2007. He is survived by his wife Annelies, son Julian, daughter-in-law Kimberly, and two grandchildren.



PAUL E. TORGERSEN

1931–2015

Elected in 1986

"For developments in simulation and gaming concepts, and for leadership in industrial engineering and engineering education."

BY ERIC SCHMIDT

When entering the Virginia Tech campus from the north side of the town of Blacksburg, you pass under a broad arch. The structure, encased in blocks of grey dolomite-limestone also known as Hokie Stone, is inscribed with the university's motto, *Ut Prosim* (That I May Serve). The arch also serves as an enclosed connection from the library to the Advanced Communications and Technology Center across the street, also known as Torgersen Hall. The arch is the Torgersen Bridge. In addition to providing a link to the library, the Torgersen Bridge is an open study area, occupied by students 24 hours a day, seven days a week. The iconic structure welcomes freshmen to campus on their first day of class. They pose in front of it in their caps and gowns on graduation day. Literally and symbolically, the Torgersen Bridge is a bridge to knowledge, as was Paul Torgersen himself.

PAUL ERNEST TORGERSEN passed away on March 29, 2015, at the age of 83, just 10 months after teaching his last engineering class. He was born on October 13, 1931, on Staten Island, New York. His legendary affection for athletics helped launch his academic career as he attended Lehigh University on a tennis scholarship (he once ranked 8th in the nation in doubles), graduating with a bachelor's degree in industrial engineering in 1953. He went on to earn an MS and PhD at

Ohio State. In 1954, he married Dorothea (Dot), with whom he would spend the next 60 years. After teaching at Ohio State and Oklahoma State, he arrived at Virginia Polytechnic Institute and State University in 1967 as professor and head of the Department of Industrial Engineering. Virginia Tech quickly became home—a place that engaged his love of teaching, dedication to his discipline, passion for athletics, and spirit of service. He remained true to those principles as a professor, dean, and eventually president of the university.

I first knew Paul as a neighbor. My father, Wilson Schmidt, was the head of the university's Department of Economics, and our family lived next door to Paul and Dot and their children, Karen, Janis, and James. Paul and my father borrowed each other's tools and shared a chainsaw. I mowed the Torgersens' lawn. Our families were close, but Paul was much more than a good neighbor. He was also a kind and thoughtful mentor who took an interest in the future of a young man considering a career in engineering. Though I did not attend Virginia Tech, I was one of the many students who benefited from his wisdom and guidance. We remained close through the years, and I greatly valued his friendship.

Paul's legacy in the arena of engineering and higher education is one of service, growth, and vision. As dean of the College of Engineering at Virginia Tech, he led the college to national prominence, establishing more than 40 endowed professorships. During his 20-year tenure, the college moved from the bottom 10 percent in national rankings for research to the top 10 percent.

As president, he advanced diversity at the university, hiring the first woman to serve as senior vice president and provost, and the first female deans of the College of Architecture and Urban Studies and the College of Human Resources and Education. He appointed the university's first African American vice president to lead the newly created Office of Multicultural Affairs.

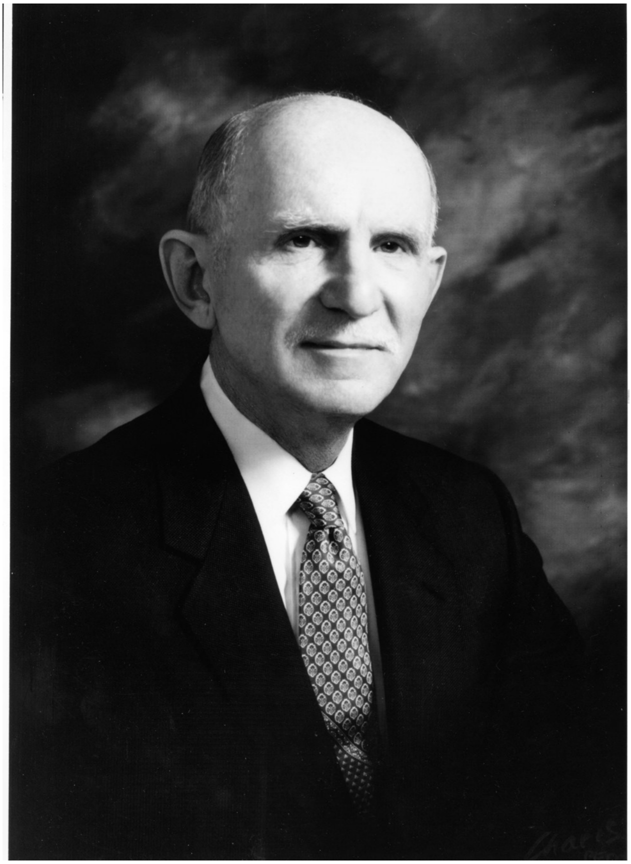
He promoted athletic excellence as a means to advance the university's national profile and to increase opportunities for students. As president, he was often absent from the president's box at football games, electing instead to watch from the sidelines.

A champion of technology, he set the stage for Virginia Tech's evolution to an advanced twenty-first-century research university. He advocated the construction of the Advanced Communications and Information Technology Center and the Virginia Smart Road. He supported the development of broadband technology and the university's first Internet home page. He was the first Virginia Tech president to use email and a laptop computer.

He sought to advance research and technology not solely for the sake of growth and advancement but for the difference it could make in the lives of people. For Paul, the human equation was the most important part of education. Regardless of the position he held at the university, he refused to relinquish his face-to-face connection with students. He taught throughout his career, even teaching a class every semester as president, and continued to teach following his retirement—a total of 58 continuous years in the classroom at Virginia Tech.

Paul's professional accomplishments and honors in the field of engineering include appointment to the Virginia Governor's Task Force on Science and Technology, the 1992 Virginia Engineering Educator of the Year Award, and recognition as a fellow of the Institute of Industrial Engineers and the American Society for Engineering Education. He authored several books and served on the editorial boards of *Journal of Engineering Education*, *Journal of Industrial Engineering*, and *AIIE Transactions*. He was elected to the National Academy of Engineering in 1986 and generously gave his time to the organization. He served on multiple NRC committees and councils, including the Commission on Engineering and Technical Systems; the Coordinating Council for Education; the Committee for the Study of Quality Assurance Mechanisms for the University Transportation Centers Program; the Academic Advisory Board; the Committee on Engineering Education; the Greatest Engineering Achievements of the 20th Century Selection Committee; the Charles Stark Draper Prize Committee; the NAE Council; the Committee on Science, Engineering and Public Policy; and the Committee on the Federal Science and Technology Budget.

Paul Torgersen excelled in everything he did or was asked to do, and he did so with quiet humility, grace, and humor. He was a powerful advocate for everything he held dear, including his university and his students. During his time as dean and president of Virginia Tech, Paul signed 62,191 diplomas, and I know from personal experience he was a positive influence on the lives of thousands more who benefited from his wisdom and foresight. His legacy will continue to connect us to our future, like the "bridge to knowledge" on the Virginia Tech campus that bears his name. As you prepare to pass under the Torgersen Bridge and enter the campus, the arch frames eight stone pylons rising in the distance representing the university's core values, values exemplified by Paul's life: brotherhood, *Ut Prosim,* leadership, loyalty, sacrifice, honor, service, and duty.



Walter K. Victor

WALTER K. VICTOR

1922–2012

Elected in 1990

"For theoretical and practical engineering contributions to satellite and interplanetary command, tracking, navigation, radar, and radio science systems."

BY JOHN R. CASANI AND CHARLES ELACHI

WALTER K. VICTOR, known as Walt, was born in the Bronx, New York, on December 18, 1922. He graduated with a bachelor of science degree in mechanical engineering from the University of Texas. He was a B-25 pilot in the US Army Air Corps during World War II (May 1943–May 1947), with the rank of 1st Lieutenant, and a flight instructor. After the war he worked in radio engineering before joining the Jet Propulsion Laboratory (JPL) as a research engineer. He was hired into the lab's missile radio guidance section to work on the MGM-29 Sergeant missile in 1953.

Walt's first major contribution to space technology was in the development of CODORAC, which stands for coded Doppler radar communications system. Intended to be part of the Sergeant missile's guided system, it employed pseudo-noise techniques to make the missile guidance unjammable. After the Army chose not to use CODORAC for Sergeant, though, one part of the technology, the phase-locked loop, became the basis of the Microlock tracking and communications system for the United States' first satellite, Explorer 1.

In 1958 Walt became manager of JPL's Communications Systems Research section, aiding Eberhardt Rechtin in planning a worldwide network for spacecraft communications. The following year, JPL began building the large antennas for what was then called its Deep Space Information Facility, first at Goldstone in California and later in Woomera, Australia, and Johannesburg, South Africa, for tracking and communicating with deep space missions.

In 1960–1961 Walt was involved in two other important experiments. He was the project engineer for JPL's role in the Project Echo experiment, in which radio signals from one 26-meter antenna at Goldstone were relayed to another via a large, orbiting mylar balloon. He was also codirector of JPL's Venus radar experiment, which used the same pair of antennas to make the first real-time detection of radar signals bounced off Venus in March–May 1961. This experiment refined the length of the astronomical unit and proved that the laboratory would be able to receive the faint signals from spacecraft near Venus.

In 1963 Walt became chief of JPL's Telecommunication Division and in 1967 deputy assistant laboratory director for the Office of Tracking and Data Acquisition. He held the latter position until 1976. During that time, the Deep Space Information System, renamed Deep Space Network (DSN) in 1963, grew to include seven 26-meter and three 64-meter antennas. Walt also led its transition from analog to digital transmission, reception, and data processing. In 1969 he conceived a substantial reorganization and upgrading of the DSN to improve its performance. He also led the organization through geographic changes, closing the Woomera station and moving its tasks to Tidbinbilla, near Canberra; opening a station outside Madrid, Spain; and eventually shutting down the Johannesburg station.

One key concept that Walt imposed and maintained at the Deep Space Network was that of the Goldstone Duplicate Standard. That meant ensuring that the Australian and Spanish DSN stations were physically and functionally similar to Goldstone to simplify acquisition, training, and maintenance. Another was that of continuous research aimed at incremental improvements in performance.

In 1976 Walt was transferred away from telecommunications and became deputy assistant laboratory director, Office of Technical Divisions. In 1978 he was promoted to assistant laboratory director for planning and review, responsible for the laboratory's quality assurance and reliability programs. And in 1985 he was assigned the task of consolidating the laboratory's computing operations as assistant laboratory director for computing and information services. He retired in 1988.

Richard Mathison, who worked with Walt for more than 20 years, remembered him as a "superb engineer, a strict technical disciplinarian, and a hard but excellent coach. At times, he could be brutally critical. But he always took very good care of his people." Similarly, Douglas Mudgway wrote of him that "Victor elicited great respect from his coworkers, at both JPL and NASA Headquarters, by virtue of his unequivocal commitment to excellence in every problem, task, or project he addressed." And University of Southern California (USC) Professor Solomon Golomb, who was deputy section chief of the Telecommunications Research Section under Victor from 1960 until he left for USC in 1963, said that "Victor was a consummate engineer who thoroughly cross-examined everyone who worked for him to be sure they had overlooked no detail in the systems or subsystems they were assigned to design and build. As a result, we knew that if Victor was in charge of a project, it was sure to succeed."

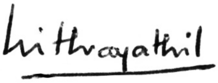
Walt was an intensely private man who did not socialize and who refused any sort of retirement ceremony after 35 years at JPL. His one hobby was pipe organs, in which he became a local expert.

His daughter Trudy wrote that another hobby was flying. He flew his Cessna airplane across the country from Burbank, California, to New York in 1956 with his young family on board. She also noted that he was a religious man and shared "his devotion and love of music" with his family and close friends.

He was a member of Sigma Xi, a fellow of the Institute of Electrical and Electronics Engineers elected in 1974, elected to the National Academy of Engineering in 1990, and in 1992 he shared the NEC C&C Prize, which is awarded for outstanding contributions in the fields of semiconductors, computers, or telecommunications, with Eberhardt Rechtin and Andrew Viterbi. He was a corecipient of a NASA Space Act Award in 1963 with Rechtin for his pioneering role in developing the Deep Space Network, and in 1977 he received the NASA Exceptional Service Medal.

Walt died July 25, 2012. He is survived by his children, Trudy Victor Elardo, Daryl Victor, and Walter Victor, five grandchildren, and four great-grandchildren.

The authors wish to acknowledge that the research for this tribute was done by Erik Conway, the JPL historian.



JOHN J. VITHAYATHIL

1937–2011

Elected in 2000

"For the invention of thyristor-controlled series capacitor system and advancement of high voltage direct current (HVDC) transmission technology."

BY ARUN PHADKE

JOHN JOSEPH VITHAYATHIL passed away peacefully on May 24, 2011, at his Portland home surrounded by his wife and children after a long and courageous battle with lung cancer. John was born in Trivandrum, Kerala, India, on February 17, 1937, to Joseph and Theresiamma Vithayathil. Throughout his life, John's wisdom and intellect were exceeded only by his caring and kindness for his family and friends and his unmatched love for his wife Rani.

John received his BSc degree in electrical engineering from Trivandrum Engineering College and his PhD from the Indian Institute of Science in 1967. Impressed by his doctoral dissertation related to high-voltage/direct current power transmission, the Bonneville Power Administration (BPA) offered him an engineering position in Portland, Oregon. John brought his family to Portland in 1967 and for nearly 45 years he and Rani called the Portland/Vancouver area home where they raised their four children.

After 20 years, John retired from the government and worked as an independent consultant for nearly 25 years. Internationally recognized as an expert of high-voltage direct current transmission, he also made key contributions to high-voltage alternating current transmission, including the invention of the Rapid Adjustment of Network Impedance (RANI) scheme, which he named after his beloved wife. John was awarded several patents throughout his professional career and received numerous distinctions and awards, including being named an IEEE fellow. His highest professional honor came in 2000 when he was inducted into the National Academy of Engineering.

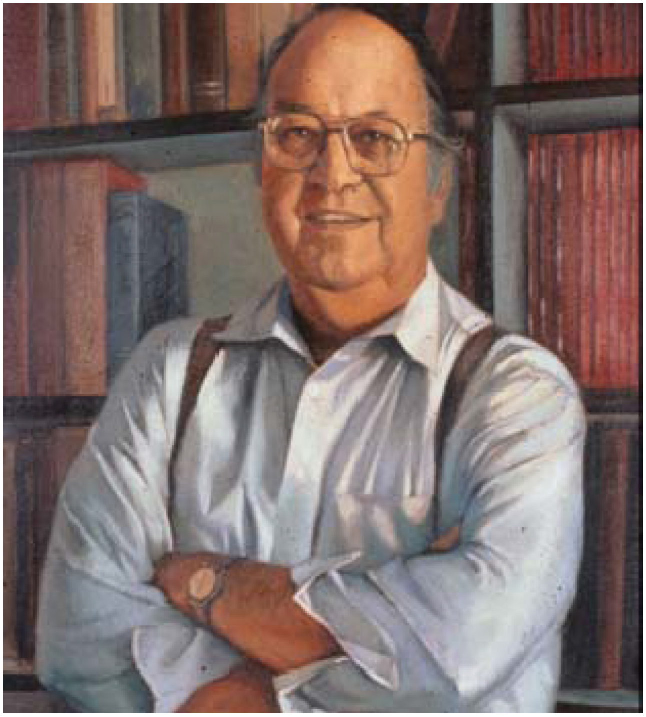
John was a mentor and friend to many engineers—including myself—who remember fondly his dedication to the profession and his desire to promote good research whenever he came across it. My own connection to John came about because of his enthusiastic support of the emerging field of synchronized phasor measurements in power systems, and his unstinting backing of this activity at Virginia Tech. I well remember how he met and overcame opposition from some well-known engineers in his company and staunchly defended this emerging technology as being worthy of BPA's backing. This technology has now become a key ingredient of the modern power system monitoring and control activities throughout the world.

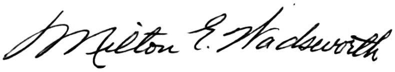
One of the clearest evidences of the high regard in which he was held by his peers was the technical collaboration between him and the renowned power engineering expert Edward Kimbark. Later Dr. Kimbark asked John to collaborate with him on writing many technical papers and textbooks on the subject of high-voltage direct current transmission.

John was a valued instructor for many courses offered by the University of Wisconsin–Madison. In this activity he collaborated with Willis Long of Wisconsin, who shares these memories: "The year was probably 1975. I had met John earlier at BPA when with his assistance I was building an EMTP model of the Pacific HVDC Intertie. He contacted me at the University of Wisconsin where I was then on the faculty. A group of engineers from Zaire were planning to visit BPA for a few weeks of training. An HVDC transmission system was to be built in Zaire to supply electrical energy for their copper mining operation. I said certainly and a team of 10 young engineers arrived with John on a Monday morning. He and I shared the lecturing, and UW Professor Dan Reitan aided us by setting up exercises on the university's HVDC physical simulator. The students greatly enjoyed the week and were a pleasure to be around. Probably 20+ years later I was at the Apollo HVDC station near Johannesburg, South Africa. An engineer came up to me and informed me that he had been in that class. I did not recognize his name until he told me that he had resumed using his Christian name after moving from Zaire to postapartheid South Africa. A second memory of John relates to a joint research contract on HVDC projects. John contacted me about supporting a research project on active filters for HVDC converter stations. I had a graduate student just at the point of needing a good project and he was happy to take it on. The student was most impressed by having an expert of John's stature be part of his research project."

In his younger days, John was an avid field hockey and soccer player, serving as captain for his college soccer team. As time went by, he enjoyed taking his wife on trips around the world and playing bridge with friends. But for John nothing matched the joy of being a grandfather, or Appapen, to his grandchildren. Annual family trips to the beach or central Oregon were the highlight of the year for the entire family.

John is survived by his loving wife of 46 years, Rani; daughter Mariamma, her husband Jacob, and their children Paul and John; son Jose; daughter Rose, her husband Steve, and their children Megan and Christopher; daughter Theresa, her husband Brett, and their children Catherine and Joseph; sisters Mary and Sister Maria Theresia; and brothers Paul, Antony, and Francis. He was preceded in death by his parents and his brothers Joseph and Cardinal Varkey Vithayathil.





MILTON E. WADSWORTH

1922–2013

Elected in 1979

"Contributions in the field of hydrometallurgy."

BY J. BRENT HISKEY AND GARRY WARREN

MILTON ELLIOT WADSWORTH passed away at home on January 31, 2013. At the time of his death he was a distinguished professor emeritus of metallurgy at the University of Utah. He left a positive impact on thousands of people over his lifetime and during his over half century of dedicated academic service.

Milton E. Wadsworth, affectionately known as Milt, was born February 9, 1922, in Salt Lake City to Thomas Guy Wadsworth and Agnes Flockhart Wadsworth. He attended Lowell Elementary, Roosevelt Junior High, and East High School, all in Salt Lake City. After graduating from high school in 1939 he enrolled in the University of Utah and while taking a course in spring flowers of the Wasatch he met the love and center of his life, Mirian Bailey. Both in the US Army, they were the first couple married in uniform at the Fort Douglas Chapel on November 19, 1943.

After serving as an infantry officer in the US Army during World War II, Professor Wadsworth began a lifelong relationship with the University of Utah, where he received his bachelor of science degree in metallurgical engineering in 1948 and his PhD in metallurgy in 1951. His thesis supervisor was Melvin A. Cook. Another important mentor and colleague at the university was Henry Eyring.

During his graduate studies Dr. Wadsworth worked as a part-time instructor in the Department of Metallurgical Engineering and upon graduation was appointed assistant professor. One of the early courses he taught was mineral dressing for chemical engineers. Early in his career he conducted pioneering research on the hydrolytic and ion pair adsorption processes in flotation. This work was recognized by an American Institute of Mining, Metallurgical, and Petroleum Engineers (AIME) Best Paper Award in 1957. Parallel to his interests in mineral processing and flotation, his research activities included work sponsored by the US Atomic Energy Commission on properties and processing of colloidal thoria and thoria gel. At about the same time he developed an interest in the emerging field of hydrometallurgy. He is recognized as one of the first academicians to bring science and engineering fundamentals to the study of hydrometallurgy.

Dr. Wadsworth had a keen intellect and a superb ability to interpret complex processes such as chemical thermodynamics, reaction kinetics, and phase equilibria in interesting and often humorous ways that were easily understandable. He loved to share his sense of humor and could on a moment's notice break into an impromptu tap dance to the enjoyment and amazement of those watching. He had an infectious personality.

Milt was the consummate teacher, inspiring intellectual curiosity and creativity in students at all levels. His influence extended to all dimensions of life and he was especially encouraging to his former graduate students, many of whom have gained international recognition in academia, business, and government careers. His impact as an educator was acknowledged nationally by AIME in 1981 when he received the Mineral Industry Education Award. His appointment as a distinguished professor of metallurgical engineering (1983) at the University of Utah, in part, recognized his excellence in teaching and the value of his teaching to the university. In 1989 the Minerals, Metals and Materials Society (TMS) presented him with its Educator Award for his many professional contributions.

Dr. Wadsworth served the University of Utah with distinction as a dedicated administrator for many years. He performed duties as the chair of the Department of Metallurgical Engineering for two separate terms (1955–1966) and (1974–1976). During these periods, the department flourished and solidified its international reputation in mineral processing and extractive metallurgy. He also held the position of associate dean in two colleges, the College of Engineering (1973–1974) and the College of Mines and Earth Sciences (1983–1991). In addition to his distinguished professorship (1983) mentioned earlier, he was the 1986 University of Utah recipient of the Rosenblatt Prize for Excellence in teaching, research, and administration. It is equally important to recognize the respect and esteem his students, colleagues, and friends had for him. Through their efforts, the University of Utah Milton E. Wadsworth Endowed Scholarship Fund was established in 2012. Students and faculty in the Department of Metallurgical Engineering will continue to benefit from this endowment.

Milt's research achievements in hydrometallurgy are quite impressive and cover a truly amazing range of topics. His early work in hydrometallurgy featured a number of studies involving high-temperature, high-pressure liquid-solid reactions. He and Frank Forward at the University of British Columbia are considered the fathers of modern-day pressure hydrometallurgy. In 1963 he and Franklin T. Davis organized the first International Hydrometallurgy Symposium in Dallas, Texas, and edited the symposium volume, *Unit Processes in Hydrometallurgy*. This symposium sponsored by the AIME has been the flagship hydrometallurgical conference in the world ever since. To Milton's and Franklin's credit, the series of seven monographs is a living legacy of advances in hydrometallurgy theory and practice. In recognition of his contributions, Dr. Wadsworth was the honoree at the fourth International Symposium on Hydrometallurgy in 1993 sponsored by the Society of Mining, Metallurgy and Exploration (SME)/TMS of AIME in Salt Lake City.

Milt was a forerunner in the application of absolute reaction rate theory and understanding of the role of electrochemical phenomena in hydrometallurgical reactions. Numerous seminal papers on these themes were authored by him and his students over the years. Particularly noteworthy are the papers dealing with the electrochemical nature of metal dissolution and deposition processes, especially the electrochemistry of conducting and semiconducting ore minerals. He was one of the first to recognize the importance of fundamental electrochemical processes in the dissolution of the sulfide minerals. This enhanced understanding of the leaching behavior of such economically significant minerals as chalcopyrite. During his distinguished research career, he published more than 155 technical and scientific papers and was awarded five US patents.

Dr. Wadsworth had an excellent working relationship with the minerals and metallurgical industries. He was particularly close to efforts to improve copper extraction and recovery from low-grade resources and the application of hydrometallurgical methods in the treatment of copper sulfide concentrates. During the 1970s, he served as a technical advisor for the Kennecott Copper Corporation task force on copper dump leaching. This association resulted in a number of important fundamental research projects. He was also closely involved with the development of Anaconda's concentrate enrichments process. He brought a keen understanding of the role of reaction kinetics to these industrial projects.

In 1968 Milt, Mirian, and their family began a love affair with world travel. Milton was asked by the Ford Foundation to set up a graduate program at the University of the Philippines (UP). With five unmarried daughters and the family labrador, Milt and Mirian moved to Manila for a two-year assignment. He held the position of professor of metallurgy from 1968 to 1970. Under Dr. Wadsworth's guidance the Ford Foundation project was very successful and he was presented with a Special Service Award by the UP Office of the President. The UP Department of Mining, Metallurgical and Material Engineering currently offers BS and MS degrees in metallurgical engineering and a PhD in materials science and engineering. The metallurgical engineering program is identified by the Commission of Higher Education of the

Philippines as a Center of Excellence. The University of Utah was the beneficiary of a number of outstanding students from the Philippines as a result of Milt's tenure there.

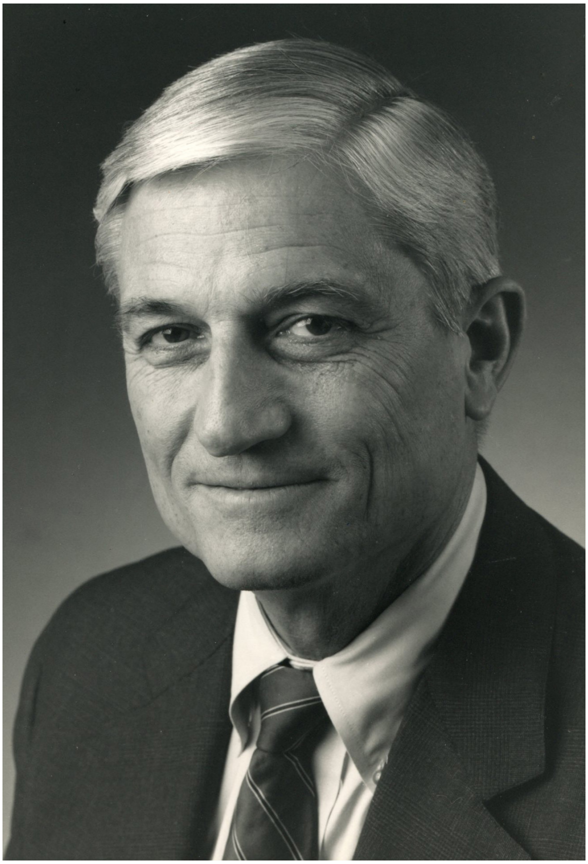
The impact and importance of his extensive research contributions were recognized during his career with numerous awards and honors. He was the recipient of four Best Paper Awards presented by the AIME. He was the recipient of the 1978 AIME James Douglas Gold Medal "For his distinguished contributions to extractive metallurgy in research and education, exemplified by his fundamental understanding and teaching of the hydrometallurgy of nonferrous metals." Other major awards include the 1984 Antoine M. Gaudin Award of SME and the inaugural Milton E. Wadsworth Award of SME given in 1993. He was recognized by the state of Utah in 1987 with the Governor's Medal for Science and Technology. He was the recipient of honorary doctorate degrees from the University of Liège, Belgium (Honoris Causa, 1979); the Colorado School of Mines (doctor of engineering, 1990); and the Central South University of Technology, China (doctor of engineering, 1995).

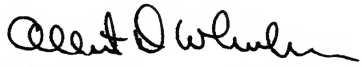
His professional society accomplishments were principally with AIME and its member societies TMS and SME. He joined AIME in 1947 and exhibited exemplary service to the institute throughout his career. He achieved the grade of TMS fellow in 1976 and the rank of SME distinguished member in 1978. He served as TMS president in 1983 and as AIME president in 1991. During his year as AIME president the institute completed two important projects. One was the development of a major educational activity aimed at improving the technological literacy of junior high school students through a series of videos entitled "Transformations: Science, Technology and Society." The second was the development of an AIME position paper on energy and the environment that was presented to various individuals, government agencies, and institutions. He was named an honorary member of TMS-AIME in 2009. Dr. Wadsworth was also an active member of the American Society of Metals (ASM) International, achieving the designation of fellow in 1987.

Milt's main avocation centered on his family. He loved being a father and grandfather. His travels with his family are legendary. He enjoyed a number of pursuits and hobbies. He had a passion for motorcycles, and he and Mirian would frequently ride great distances on their motorcycle to attend a meeting or just for pleasure. However, his principal creative activity was woodworking. He was a skilled carpenter, and lovingly remodeled their nineteenth-century ancestral home over the course of 30 years.

Dr. Milton E. Wadsworth will be remembered as a true intellectual and consummate teacher and for his wonderful sense of humor. He leaves a legacy of world-class scholarly research and dedicated academic service. His contributions go far beyond his impact on metallurgical engineering, beyond the fraternity of scientists and engineers. He was an excellent spokesperson for the beauty and elegance of metallurgy and science in general. All who listened benefited from his wisdom and understanding. The world is a better place because of his impact on so many people.

He is survived by daughters Kathryn Davis, Jane Wadsworth, Amy Wadsworth (David Richardson), Leslie Wadsworth-Smith (Alan Smith), Margaret Morrison (Richard), and 19 grandchildren. He was preceded in death by daughter Cristine Blanch, sons-in-law Thomas Blanch and Jon Davis, and grandchildren Collin Davis, Ellen Marie Morrison, and Laura Elizabeth Blanch. His dear wife of 70 years, Mirian Bailey Wadsworth, passed away on October 17, 2014.





ALBERT D. WHEELON

1929–2013

Elected in 1970

"Basic contributions to ballistic missile guidance, to radiowave propagation and communication, and to national security."

BY HANS MARK

ALBERT D. WHEELON died on September 27, 2013, and the nation lost one of its most talented practitioners of science, engineering, and management. Bud and I were almost exact contemporaries—we were both born in 1929, he on January 18 and I six months later. I met Bud for the first time in the spring of 1951 when we were graduate students at the Massachusetts Institute of Technology (MIT). Bud was about a year and a half ahead of me at MIT, receiving his PhD in 1952, and mine came in 1954. We were both in the Physics Department but he worked in the Research Laboratory for Electronics and I was in the Laboratory for Nuclear Science. Thus, I was not very close to Bud at that time but it was clear to all of us in the Physics Department that he was a superb student who would go on to great achievements.

Dr. Wheelon went to work at a newly established company founded by Simon Ramo and Dean Wooldridge in 1952. The mission of the Ramo-Wooldridge Corporation was to help the US Air Force develop the Intercontinental Ballistic Missile program. These weapons eventually were to become the land-based deterrent force of "Minuteman" missiles. Bud Wheelon participated in the mission of the company, but he also developed a very important scientific program. This was to study the detailed interactions between the atmosphere and electromagnetic radiations. He published some seminal papers on this subject that proved to be very useful in calculating the propagation of radar and other electromagnetic radiations used for communications in the atmosphere. In addition, during his years at Ramo-Wooldridge (in 1958 it became TRW) he was an active adjunct professor at the University of California, Los Angeles.

In 1962 the director of Central Intelligence, John McCone, asked Bud to join the agency to become the first deputy director of Central Intelligence for Science and Technology. It was an auspicious time for Bud to be in that position because it gave him the opportunity to display his extraordinary capability as a superb engineer and a resourceful manager. This was the time when Lockheed's Skunk Works was headed by the legendary Clarence (Kelly) Johnson. Two unique reconnaissance aircraft were being built there, the supersonic SR-71 Blackbird, which was built to avoid being shot down because of speed (Mach 3), and the U-2 because of the altitude it could reach. Bud was the person in charge of the organization in the government to see to it that these programs would see the light of day and to make sure that they were employed effectively. Later he would play the same role with Corona and subsequent reconnaissance satellites.

In 1966 Bud left the government to accept an executive position at the Hughes Aircraft Company. He was recruited to Hughes by then CEO Alan Puckett, who assigned Bud to run a newly formed unit, the Space and Communication Group (often called SCG). This unit consolidated all of the nascent space activities at Hughes. Bud quickly formed a simple but effective organization with four major divisions: the Commercial Systems Division, NASA Systems Division, Defense Systems Division, and a supporting Technology Division that provided hardware and people to the three systems divisions. This gave Hughes a starting point for a newly growing space business. Over the next 15 years, under Bud's leadership, the SCG organization became a major player in the world's space program. Between 1970 and 1985 the three major business units of SCG achieved numerous successes.

The Commercial Systems Division became the dominant player in the rapidly growing communication satellite marketplace. In addition to highly successful Intelsat programs, a series of spin-stabilized satellites tailored for national systems opened up new markets. Companies in the United States, Indonesia, Canada, Australia, Brazil, and Mexico all bought SCG satellite systems. Like all good new markets, new and tough competitors emerged, but Hughes maintained a greater than 50 percent market share.

Some very powerful and creative strategies were developed by Bud and his team during this period; probably foremost was combining commercial and government programs under one leadership, which permitted cross fertilization of technologies and management processes as well as balanced workloads. These strategies combined with technology innovations led to the continued growth of SCG over the following decades. Ultimately many of these strategies were copied by competitors but none implemented them as effectively as SCG. This success was a team effort under the strong leadership of Bud. He met every morning for about an hour with the SCG leaders. Every Friday he would review the status of all programs with the program managers. He was a hands-on boss.

The most significant strategic move under Bud's leadership of SCG was the decision to form a subsidiary, Hughes Communications, to provide satellite services to commercial customers. In addition to manufacturing satellites, Hughes would arrange to obtain the necessary licenses and financing to launch, operate, and market the satellites directly to commercial customers, sometimes in competition with companies such as Intelsat or AT&T that were buying satellites directly from SCG. This strategy, though risky, was very successful and ultimately led to major new Hughes businesses such as DIRECTV.

In 1972, when I was director of the NASA Ames Research Center, we were given the task by NASA Headquarters to develop a program to explore the planet Venus. We engaged Donald Hunten and Richard Goody as the principal investigators to develop a strategy. We wanted to learn about the circulation of the atmosphere of Venus and to make a map of the planet. We arranged for a competitive procurement process among satellite companies. The Hughes SCG NASA Division won the competition because Bud Wheelon was able to take one of the commercial satellites off the production line, cut the cylindrical spacecraft in half perpendicular to the axis of the satellite, and thereby create two smaller satellites. One of these would become the carrier of four atmospheric entry vehicles that would measure the motions of the atmosphere, and the second carried the imaging radar that made the map of the planet. In this way, we were able to completely meet the objective of the program at a modest cost. This was an example of the way Bud Wheelon operated. He had developed a profitable satellite system for communications and then, with an imaginative change, used the same vehicle to obtain some important scientific information.

In 1977 I was selected to be director of the National Reconnaissance Office (NRO). One of the documents that I was given was a "Legacy Report" written by Bud in 1977 to explain what was done during his tenure in office and also to make some predictions. I was astounded by the accuracy with which he listed what would happen in the technology during the 11 years since he had written the document. Real-time imaging was already in the works, and I was the director of the NRO when we launched the first real-time imaging satellite, so I knew something about it. In addition, Bud predicted radar imaging satellites and two still classified systems, all of which are now deployed. The Hughes SCG Defense Systems Division was heavily involved in this enterprise after he joined Hughes.

In 1985 Alan Puckett retired and Bud was promoted to take his place as president and CEO of Hughes Aircraft Company. The SCG continued to thrive and grow, a reflection of Bud's excellent succession planning and personnel development. Bud was truly an outstanding business executive as well as scientist.

Bud Wheelon left the Hughes Aircraft Company in 1988 following the purchase of the company by General Motors. He spent a year at MIT as the Hunsaker Professor lecturing on what he had learned about the management of engineering projects. He applied his scientific talents to study in great detail and write a comprehensive treatise on this subject.

Bud secured an appointment at the National Environmental Technology Laboratory in Boulder, Colorado, as a visiting scientist. This provided him with an "intellectual home" because there were excellent library facilities and knowledgeable people with whom he would be associated. He also moved to a small estate in Montecito, a suburb on the eastern side of Santa Barbara, in 1990. It was here that he studied and wrote his monumental treatise, *Electromagnetic Scintillation*. There are two volumes: *Geometric Optics* and *Weak Scattering* (a third volume was not finished). I used these books when I was working on the behavior of laser beams traversing the atmosphere.

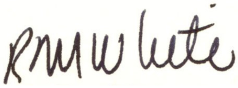
I remember visiting Bud and his wife Cicely a number of times during the 2000s. We always had wide-ranging discussions, and I was always amazed by the books he was writing—their breadth and exquisite explanations with many details.

I was not aware of Bud's illness; he never mentioned it to me. What was very important was that before he died, the National Academy of Engineering could inform him that he had been awarded the Simon Ramo Founders Award for Outstanding Achievements and Innovations in Engineering. It is altogether fitting that Bud holds this award named after his first mentor.

Bud was married twice; his first wife, the former Nancy Helen Hermansen, died in 1980, and his daughter, Elizabeth Wheelon, died in 2006. Bud's sister Marcia survives him, as well as his second wife, the former Cicely Evans, daughter Cynthia Wheelon, and a grandson.

Bud Wheelon was a "man for all seasons" because he had so many talents. I had a hard time writing this tribute because of our long friendship that developed over more than 64 years. I miss Bud and mourn his passing. My prayers are with him and I am sure that God holds him in the palm of His hand.

The author thanks Steven Dorfman for contributing to this tribute.



ROBERT M. WHITE

1923–2015

Elected in 1968

"Development of methods of weather forecasting; leadership in the evolution of the World Weather Watch System."

BY RICK ANTHES, JESSE AUSUBEL, D. JAMES BAKER, EUGENE BIERLY, ROBERT CARNAHAN, ROBERT CORELL, RICHARD HALLGREN, BRUCE GUILE, HARLEY NYGREN, JOHN PERRY, WILLIAM SALMON, AND ROBERT SCHONING

ROBERT MAYER WHITE, first administrator of the National Oceanic and Atmospheric Administration (NOAA), passed away on October 14, 2015. He provided visionary leadership in the National Weather Service, University Corporation for Atmospheric Research (UCAR), National Academy of Engineering (NAE), and National Research Council (NRC), and profoundly shaped the institutional structure of today's environmental science and services. He is survived by his beloved wife Mavis and children Richard and Edwina (Nina).

Bob White was born February 13, 1923, in Boston. He and his brother Theodore, the noted historian of American politics, rose from poverty through that city's fine public schools and distinguished universities, a characteristically American accomplishment in which Bob took justifiable pride. He received his bachelor's degree in geology from Harvard University and both his master's and doctorate in meteorology from the Massachusetts Institute of Technology. He served as a captain in the US Air Force from 1942 to 1945.

After completing his doctorate in 1950, he became chief of the large-scale processes group at the Air Force Cambridge

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Research Laboratory. In 1959 he joined the Travelers Weather Research Center in Hartford, Connecticut. When the Travelers Research Corporation was established in 1961, he became its president, eventually leading a staff of 150. With the late Thomas F. Malone, he pioneered private sector weather services in the United States.

White came to Washington in 1963 as director of the US Weather Bureau, one of the last appointments made by President John F. Kennedy. From the very beginning of his government service, Bob believed that all the federally funded meteorological services should present a united front. His efforts led to the establishment of the Office of the Federal Coordinator for Meteorology and Supporting Research and his appointment as the first federal coordinator.

Continuing his campaign for coordination and consolidation of environmental service organizations, he guided the establishment of the Environmental Science Services Administration (ESSA), which combined the US Weather Bureau with the US Coast and Geodetic Survey and the upper atmospheric research program of the National Bureau of Standards. Under his direction, ESSA ushered in the expanded use of satellite and computer technology and modernized the nation's weather warning and ocean monitoring systems.

He then led ESSA's transformation to the National Oceanic and Atmospheric Administration (NOAA) and served from 1970 to 1977 as its first administrator, steering NOAA toward a strong scientific research agenda and an active role in conservation issues. White himself helped create and implement legislation supporting conservation and environmental quality, such as the 1972 Marine Mammal Protection Act (MMPA) and Coastal Zone Management Act, the 1973 Endangered Species Act, and the 1976 Fisheries Conservation and Management Act (FCMA).

NOAA was charged with interpretation and management of the very broad congressional directives in these and other laws. Within a few years the FCMA changed the way many fisheries were managed worldwide. The MMPA addressed the critical need to reduce the killing by domestic commercial fishermen of porpoises, seals, and sea lions, a highly sensitive and controversial issue that was eventually resolved through White's efforts. Similarly, the Endangered Species Act impacted many government agencies and a host of species—and set off never-ending controversies among users, watchers, and protectors of living things. Wolves, polar bears, eagles, and countless other creatures large and small can now qualify for protection. Again, White played a key role in the act's early implementation.

In his capacity as head of NOAA, White served as US permanent representative to the World Meteorological Organization (WMO) from 1963 to 1978, beginning a vigorous leadership role in international environmental affairs. He made crucial contributions to the development and implementation of the World Weather Watch, the backbone of global exchange of weather data; the Global Atmospheric Research Program (GARP), devised by WMO and the International Council of Scientific Unions (ICSU) in response to President Kennedy's call for enhanced research in weather and climate; and the International Decade of Ocean Exploration (IDOE), which massively advanced understanding of the world's oceans. GARP led to the 1979 Global Weather Experiment, which greatly accelerated weather forecast model development and advanced forecasting capabilities. With White's support, GARP evolved into the ongoing World Climate Research Program.

In 1977, increasingly concerned about the accumulation of greenhouse gases, climate change, and its pervasive effects on society, White decided that he could be more effective outside NOAA. He took a newly created position at the National Research Council as head of the Climate Research Board (CRB), where he focused on climate programs in the federal agencies in an effort to develop an effective national climate program.

Also in 1977, he became president of Joint Oceanographic Institutions, where he led the international phase of the Ocean Drilling Program with the drill ship *Glomar Challenger*. Using his skills in both science and diplomacy he successfully transitioned what had been a national program to an international five-partner activity. He held that position until 1980, when he became president of UCAR, the only person to head both of the country's leading atmospheric and oceanographic institutions. Among his achievements at UCAR, he broadened its funding base beyond the National Science Foundation (NSF). New trustees from industry and business were brought in, encouraging a wider range of research on the atmosphere, climate, and their impacts on society.

In 1979 he organized and chaired the first World Climate Conference in Geneva, where he gave a far-sighted keynote speech projecting the possible consequences of human-induced warming of the Earth. The conference raised awareness of the potentially serious consequences of climate variability and change and prompted the initiation of focused climate research programs in the United States and many other nations.

As president of the NAE (1983–1995), White rapidly enhanced its status and stability. As NRC vice chair, he energetically raised funds for institutional initiatives such as the Arnold and Mabel Beckman Center in Irvine, California. He guided NRC advisory studies on a broad range of environmental issues, including stratospheric ozone depletion, acid deposition, loss of biodiversity, nuclear energy, radioactive wastes, the potential for waste reduction, and capacity building in developing countries. He was instrumental in laying the foundation for the international Council of Academies of Engineering and Technological Societies. This independent, nonpolitical, nongovernmental international organization would probably not have been successful without his involvement.

In 1996 White founded the Washington Advisory Group (WAG), recruiting founding members who included three former presidential S&T advisors, a former NSF director, and a former director of the National Institutes of Health, among others. Over the 14-year life of the company it did interesting and important work for a broad range of public and private entities, both in the United States and overseas. According to his colleagues, WAG simply would not have existed without Bob's tireless energy, the loyalty he showed—and earned from—his colleagues, and his love of creating new enterprises.

Bob White received a multitude of awards and honors, including the Tyler Prize for Environmental Achievement (1992) from the University of Southern California, the Charles E. Lindbergh Award for technology and environment (1990), the International Meteorological Organization Prize (1980), the Charles Franklin Brooks Award (1979) from the American Meteorological Society (AMS), the Rockefeller Public Service Award for Protection of Natural Resources, and in 1976 both the Smithsonian Institution's Fontaine Maury Medal for Contributions to Undersea Exploration and the International Conservation Award of the National Wildlife Federation. He was elected a fellow of five national and international scientific organizations, a member of the French Legion of Honor, and received eight honorary doctorates. He served a term as AMS president in 1980, and was vice president of the Marine Technology Society.

Meticulously scheduled and punctual, he was a virtuoso chairman whose meetings started on time and ended early while leaving no agenda item unresolved and no participant unheard. As a manager, he invited and took in ideas and advice, welcomed dissent and informed criticism, and made unhesitating but never uninformed decisions. And he always had time for lunches at favorite haunts, usually with a who's who of luminaries in science, government, and international organizations.

But his achievements were based equally on his personal qualities that over the years created a loyal and loving tribe of colleagues throughout the world. Anyone who ever worked *for* Bob forever after worked *with* him. Moreover—unusually in today's world—he seemed to have no enemies.

The overarching theme of White's distinguished career in science and government was leadership, characterized by his deep understanding of science, boundless energy, organizational genius, adamantine integrity, and ceaseless industry. He also remained a proud weatherman at heart, always excited by new technology, new problems, and new achievements in the field's science and the services it provides.

Above all, Robert M. White was a visionary builder—not of edifices or dams or bridges but of solid, substantial, and enduring organizations based on sound science and vital societal needs. Today's national and international institutions that coordinate and focus science, provide atmospheric and oceanic data for research and operational support, link science and government, and provide vital environmental services were powerfully sculpted by this remarkably talented, dedicated, and fine man.

MAX L. WILLIAMS JR.

1922–2013

Elected in 2003

"For fundamental developments in fracture mechanics and for providing guidance to industry and government that has facilitated technology transfer."

BY K.L. (LARRY) DEVRIES
SUBMITTED BY THE NAE HOME SECRETARY

MAX L. WILLIAMS JR., a pioneer and leader in fracture mechanics, passed away on September 18, 2013. He was 91.

Williams was born in the Aspinall neighborhood of Pittsburgh on February 22, 1922. Twenty years later, he would obtain his bachelor's degree at the Carnegie Institute of Technology in Pittsburgh. He entered the US Air Force as a captain and an aircraft maintenance engineer in 1943 before earning his MS (1947), engineer's degree (AE; 1948), and PhD (1950), all in aeronautics, from the California Institute of Technology. He then went from lecturer to tenure-track professor of aeronautics.

Early in his academic career, Williams was internationally renowned as a pioneer in fracture mechanics. His identification of the universal nature of the stress field at the tip of a crack became the cornerstone for the field of fracture mechanics through the development of the single most important parameter controlling fracture. He was a prime contributor to introducing the solid rocket motor industry—then dominated by chemical engineers—to viscoelastic, structural failure analysis. Even today you can open any number of fracture mechanics books to find M.L. Williams referenced. In addition, he was the founding and long-time editor in chief of the premiere journal on fracture mechanics, the *International Journal of Fracture*.

Fracture mechanics is in part a mature field thanks to his pioneering work. No structural fracture/failure analysis could be conceived without his contribution; he even pioneered the extension of these concepts to the mechanics of earthquake generation in the 1950s and to adhesive joints in the 1960s. During the height of the Cold War, Williams was instrumental in developing the tools for the failsafe operation of solid propellant rocket motors (e.g., Polaris, SRAM, and Minuteman), which made the national defense and space efforts viable.

For example, the influence of those developments concerning the mechanical behavior of polymeric materials was felt through the Richard Feynman analysis of the O-ring seals in the Challenger disaster. Williams' influence is also felt throughout the engineering field where mechanical applications of polymers in today's engineering environments are involved.

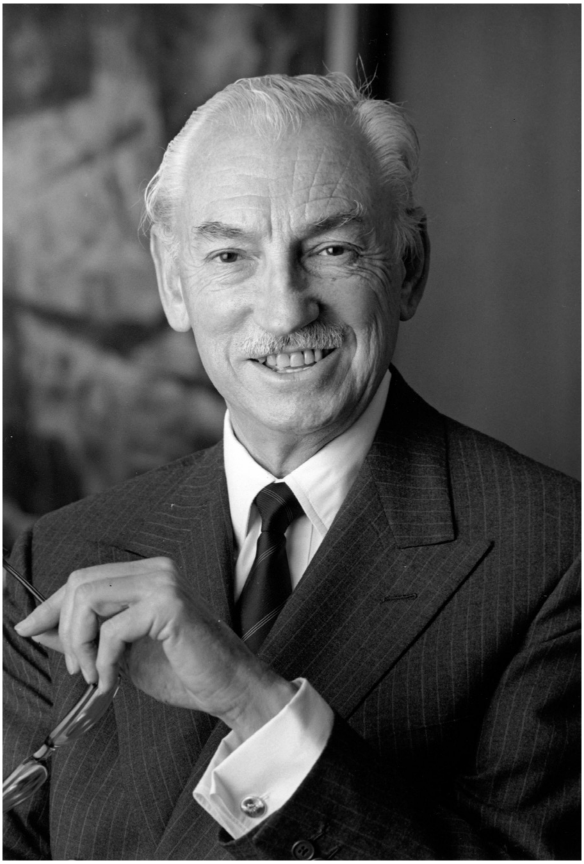
Williams left the research culture of Caltech to become dean at the University of Utah College of Engineering in 1965. He was an effective but demanding dean, making a number of improvements and important faculty hires as well as focusing on research and graduate studies. Under his administration, the Departments of Computer Science, Bioengineering, and Materials Science and Engineering were added to the college. He also created a need-based scholarship program for underrepresented students.

In 1973 Williams resigned from the University of Utah as well as from much of his personal research to accept the position of dean of the School of Engineering at the University of Pittsburgh, where he was also a professor until 1985. Later, he became more involved as an advisor for government agencies.

Throughout his career, he demonstrated a firm belief in practical, hands-on engineering. He was a registered engineer and had a major influence in guiding national programs of defense research, saving millions of dollars by judiciously supporting, criticizing, or phasing studies and programs. His practical insights transitioned into engineering management through guidance of over 20 engineering startups, which depended critically on mature engineering judgment.

Elected to the NAE in 2003, Williams was a consummate lecturer and held many appointments nationally and internationally. His national impact is memorialized through his involvement in numerous government committees ranging from the US Department of State to NASA and the Office of Science and Technology Policy.

Dr. Williams is survived by his loving wife of 46 years, Mel; children Gregory and Richard Williams and Christine Mann; and stepchildren Pamela Allande, Marilyn Shupe, and Walter McKinney.



ALEJANDRO ZAFFARONI

1923–2014

Elected in 1997

"For contributions to human health care through creating and forging collaborations between the scientific and engineering disciplines."

BY HOWIE ROSEN

ALEJANDRO ZAFFARONI, an innovator in drug delivery systems and biotechnology and generous humanitarian, died peacefully at home on March 1, 2014, in Atherton, California. He was 91. Dr. Zaffaroni was widely regarded as a visionary who left a positive impact on the lives of millions through the invention of innovative medical technology.

He was born in Montevideo, Uruguay, February 27, 1923. He studied medicine in his home country and was accepted to pursue a PhD in biochemistry at Harvard. He was also awarded a scholarship through the Institute of International Education in 1945 to study at the University of Rochester. He took a US military cargo ship to New York in the waning days of World War II and, after visiting both universities, he decided to attend Rochester as it offered him his own laboratory and the freedom to pursue his interest in biochemistry and steroid research. His research at Rochester resulted in the development of the "Zaffaroni technique," a method using paper chromatography to isolate steroids. It became an essential analytical tool and led to the first synthesis of cortisone by scientists at Upjohn Company. He received his PhD in biochemistry in 1949.

In 1951, after finishing a National Institutes of Health fellowship, he turned down multiple job offers in academia and with major pharmaceutical companies to join a small, privately held Mexican chemical company, Syntex S.A. In 1956, after just five years, he was elected executive vice president and director of Syntex Corporation. He played a key role, beginning in 1962, in bringing Syntex to the United States and establishing it as the first pharmaceutical company on the West Coast. He led the transformation of the firm into a global pharmaceutical corporation that pioneered the development of therapeutic corticosteroids and the birth control pill. Eventually he became president of Syntex Laboratories and director of research.

In 1968 he left Syntex to found ALZA Corporation (the name is formed from the first two letters of his first and last names). ALZA pioneered new technologies for drug delivery. Most drugs at the time were administered through simple pills or injections. The concept of "drug delivery" was so novel that one pharmaceutical executive thought that ALZA's product was a fleet of trucks. As part of the negotiations of Dr. Zaffaroni's departure from Syntex, he offered Syntex a 25 percent stake in the new startup. In 1969, it became the first US company to go public without revenues or positive earnings. The new methods developed by ALZA included transdermal patches for nicotine, nitroglycerin, fentanyl, and scopolamine (first marketed in 1981); insertable devices (first marketed in 1974); and an oral controlled release system (OROS for oral osmotic) that was licensed to Pfizer for a cardiovascular drug and became its first billion-dollar therapeutic when introduced in 1991. OROS technology was used in more than ten other commercial products.

ALZA was the first of Dr. Zaffaroni's nine companies built around novel technologies and 130 patented processes for drug delivery, high-speed genome scanning, drug discovery, and innovative materials development for a wide variety of industries. These companies have produced a multitude of successful platform technologies from which further medicines, devices, and materials have been developed. For example, Affymetrix, a company he cofounded in 1991, was a pioneer in developing DNA chips, more formally known as microarrays. Those chips revolutionized genetic studies, allowing many genes to be analyzed at once. They are now widely used in studies aimed at finding genetic variants linked to different diseases.

Dr. Zaffaroni attributed his legendary productivity to his many talented colleagues and the highly collaborative work culture he encouraged. His colleagues have recalled him as a supportive supervisor who often gave significant responsibility to young people, some fresh out of college. There are two themes that permeated Dr. Zaffaroni's career—the absolute requirement to create an environment where individuals had freedom to innovate and the vision to see the intersection between seemingly disparate technical fields.

Building on the success of his entrepreneurial pursuits, Dr. Zaffaroni and his wife Lida gave generously to humanitarian causes. The Zaffaroni Foundation has provided grants for medical research, higher education, scholarships, and the construction and ongoing support of the Moldaw-Zaffaroni Clubhouse of the Boys and Girls Clubs of the Peninsula located in East Palo Alto, CA.

The $10 million endowed Alejandro and Lida Zaffaroni Scholarship and Fellowship Program at Stanford University, which is partly funded by gifts from donors who credit Dr. Zaffaroni with providing inspiration, mentorship, and friendship throughout their careers, provides students, especially those from Latin America, with undergraduate scholarships and graduate fellowships. The Zaffaronis were also major donors to the Lida and Alejandro Zaffaroni Breast Imaging Center at the Stanford Cancer Center.

Numerous awards and honors are a testament to Dr. Zaffaroni's accomplishments. Notably, he was awarded the National Medal of Technology and Innovation, the nation's highest honor for technological achievement, bestowed by President Bill Clinton (1995). Other prominent honors include induction into the National Inventors Hall of Fame at the Smithsonian Institution (2012), the Woodrow Wilson Award for Public Service (2008), the Biotech Hall of Fame Award from the Life Sciences Foundation, the Biotechnology Heritage Award from the Chemical Heritage Foundation and the

Biotechnology Industry Organization (2006), the Bower Award for Business Leadership from the Franklin Institute (2005), the Gregory Pincus Award from the Worcester Foundation (2005), the Winthrop-Sears Medal from the Chemists' Club (2004), the UCSF Medal from the University of California, San Francisco (2002), first recipient of the Lester Center Lifetime Achievement Award from the University of California, Berkeley's Haas School of Business (1998), the Chemical Pioneer Award from the American Institute of Chemists (1979), and the President's Award from the Weizmann Institute of Science (1978).

Dr. Zaffaroni's professional associations included, in addition to the NAE, the National Academy of Sciences (1977) and the Institute of Medicine (1978). He was also a member of the Beckman Center for Molecular and Genetic Medicine Advisory Council at Stanford University, the Stanford University Hospital Board of Directors, the Division of Biological Sciences Advisory Council at Harvard University, the Massachusetts Institute of Technology Sustaining Fellows, and fellow of the American Association for the Advancement of Science, American Academy of Arts and Sciences (1973), and American Academy of Pharmaceutical Research and Science (1973).

Dr. Zaffaroni is survived by his wife Lida, son Alejandro and daughter-in-law Leah, daughter Elisa, and two grandchildren, Alejandro Peter and Charles A. Zaffaroni.

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APPENDIX

Members	Elected	Born	Deceased
William F. Allen	1986	June 22, 1919	September 21, 2014
Charles A. Amann	1989	April 21, 1926	March 10, 2015
Frederick T. Andrews	1988	October 6, 1926	September 15, 2013
Albert L. Babb	1972	November 7, 1925	October 22, 2014
James E. Bailey	1986	February 28, 1944	May 9, 2001
Richard H. Battin	1974	March 3, 1925	February 8, 2014
Ted B. Belytschko	1992	January 13, 1943	September 15, 2014
Arthur E. Bergles	1992	August 9, 1935	March 17, 2014
J. Robert Beyster	1989	July 26, 1924	December 22, 2014
Hendrik B.G. Casimir	1976	July 15, 1909	May 4, 2000
Subrata K. Chakrabarti	2002	February 3, 1941	January 23, 2009
Esther M. Conwell	1980	May 23, 1922	November 16, 2014
Eugene C. Figg Jr.	2001	August 4, 1936	March 20, 2002
Vladimir Haensel	1974	September 1, 1914	December 15, 2002
R. Richard Heppe	1982	March 4, 1923	January 18, 2015
Philip G. Hodge	1977	November 9, 1920	November 11, 2014
John C. Houbolt	1990	April 10, 1919	April 16, 2014
Thomas P. Hughes	2003	September 13, 1923	February 3, 2014
Charles V. Jakowatz Jr.	2003	March 5, 1951	February 7, 2015
H. Richard Johnson	1973	April 26, 1926	December 9, 2012
Howard H. Kehrl	1985	February 2, 1923	October 1, 2013
Anthony Kelly	1986	January 25, 1929	June 3, 2014
Theodore C. Kennedy	1999	May 26, 1930	May 8, 2012
Glenn F. Knoll	1999	August 3, 1935	April 20, 2014
Riki Kobayashi	1995	May 13, 1924	July 19, 2013
Charles C. Ladd	1983	November 23, 1932	August 4, 2014
Frederick F. Ling	1977	January 2, 1927	November 8, 2014
Robin Milner	2008	January 13, 1934	March 20, 2010
John B. Mooney Jr.	1988	March 26, 1931	May 30, 2014
Richard K. Moore	1989	November 13, 1923	November 13, 2012
Mark V. Morkovin	1987	July 25, 1917	October 18, 2014
Toshio Mura	1986	December 7, 1925	August 9, 2009
Thomas J. Murrin	1984	April 30, 1929	January 30, 2012
Yuri A. Ossipyan	1993	February 15, 1931	September 10, 2008
Lawrence T. Papay	1987	October 3, 1936	July 28, 2014

continued next page

Members	Elected	Born	Deceased
Norbert Peters	2002	July 10, 1942	July 4, 2015
Robert Price	1985	July 7, 1929	December 3, 2008
Allen E. Puckett	1965	July 25, 1919	March 31, 2014
Dennis M. Ritchie	1988	September 9, 1941	October 12, 2011
Herbert B. Rothman	1990	May 27, 1924	July 26, 2015
Andrew P. Sage	2004	August 27, 1933	October 31, 2014
Thorndike Saville Jr.	1977	August 1, 1925	November 5, 2014
Robert S. Schechter	1976	February 26, 1929	October 8, 2014
Reinhardt Schuhmann Jr.	1976	December 16, 1914	July 7, 1996
Harris M. Schurmeier	1983	July 4, 1924	November 23, 2013
Ascher H. Shapiro	1974	May 20, 1916	November 26, 2004
John A. Simpson	1988	March 30, 1923	December 6, 2011
Ernest T. Smerdon	1986	January 19, 1930	August 11, 2014
Thor L. Smith	1990	June 11, 1920	September 6, 1999
Elias Snitzer	1979	February 27, 1925	May 21, 2012
S. Donald Stookey	1977	May 23, 1915	November 4, 2014
G. Russell Sutherland	1984	December 20, 1923	June 11, 2014
John J. Taylor	1974	February 27, 1922	December 9, 2013
Gareth Thomas	1982	August 9, 1932	February 6, 2014
Paul E. Torgersen	1986	October 13, 1931	March 29, 2015
Walter K. Victor	1990	December 18, 1922	July 25, 2012
John J. Vithayathil	2000	February 17, 1937	May 24, 2011
Milton E. Wadsworth	1979	February 9, 1922	January 31, 2013
Albert D. Wheelon	1970	January 18, 1929	September 27, 2013
Robert M. White	1968	February 13, 1923	October 14, 2015
Max L. Williams Jr.	2003	February 22, 1922	September 18, 2013
Alejandro Zaffaroni	1997	February 27, 1923	March 1, 2014