NATIONAL ACADEMY OF SCIENCES

NORMAN CARL RASMUSSEN
1927–2003

A Biographical Memoir by

KENT F. HANSEN

Biographical Memoirs, VOLUME 86

PUBLISHED 2005 BY
THE NATIONAL ACADEMIES PRESS
WASHINGTON, D.C.

Norman C. Rasmussen

NORMAN CARL RASMUSSEN

November 12, 1927–July 18, 2003

BY KENT F. HANSEN

NORMAN CARL RASMUSSEN died on July 18, 2003, at the age of 75. He succumbed to complications of Parkinson's disease from which he suffered for many years. Norm was a remarkable scientist, engineer, and educator who made additions to nuclear physics, nuclear engineering, health physics, and risk analysis. In each of these fields he was a creative researcher who made important, lasting contributions. He first achieved recognition for his work in gamma ray spectroscopy and the quantitative determination of the nuclear composition of materials. Subsequently he worked on the analysis of radiation doses in survivors of the U.S. nuclear weapons testing programs of the 1950s and 1960s. His most influential work was in directing the Atomic Energy Commission study on nuclear safety, published as WASH 1400 but better known as the Rasmussen Report. This pioneering effort has evolved into the principle tool of risk assessment in the nuclear industry. His public service included the National Science Board, numerous National Academy of Sciences panels, and the Defense Science Board. However, to those of us privileged to know him well, our sense of loss is dominated by the loss of a wonderful colleague and friend who possessed a rich collection of delightful human characteristics.

EARLY YEARS

Norm was born on November 12, 1927, in Harrisburg, Pennsylvania. He grew up on a dairy farm as the fifth of six brothers. He attended public schools in the Hershey, Pennsylvania, school system. Besides being a student he had the multiple chores of a farm boy, an experience that greatly influenced his career. As a farm boy in the depths of the Great Depression he had to learn how to care for animals; how to service and maintain farm equipment; and how to build or repair farm buildings and facilities. The result was that he became very proficient in using his hands, and very motivated to use his intelligence. Finally, the experiences of his youth gave him a lifelong habit of hard work. His father died when Norm was in the eighth grade, and the family moved to near Gettysburg, where his grandparents helped in caring for the family. He graduated from high school in June 1945 and enlisted in the Navy. He was sent to the Great Lakes Naval training school, where he became an electronics technician. He served on active duty until August 1946, when he was honorably discharged.

With the help of the GI bill he enrolled in Gettysburg College in the fall of 1946. He majored in physics because his interest had been stimulated in high school. He came under the guidance of Prof. George Miller at Gettysburg College, who intensified Norm's interest in physics, and also encouraged Norm to go to graduate school. Upon graduation (cum laude) in June 1950 Norm enrolled in graduate school in physics at the Massachusetts Institute of Technology. Before leaving Gettysburg he met a young coed, Thalia Tichenor, who subsequently became his wife (in 1952) and lifelong soul mate.

At MIT he worked for Prof. Robley Evans in the Radioactivity Center, which Evans created and led. The work was

concerned with the field of experimental low-energy nuclear physics, including the determination of nuclear energy levels, radiation dosimetry, and the biological effects of radiation. It was in the fall of 1952 that I first met Norm. He was a teaching assistant in Prof. Evans's two-semester subject "Nuclear Physics," which I took as a senior in physics. Norm was always available to the students to help with understanding the material and in working the devilishly long homework assignments. One of my classmates and close friends subsequently became a research assistant in the Radioactivity Center, and I began to see Norm frequently outside the classroom. He was an avid sports enthusiast, both as a player and as a fan. We frequently shared despair over the fate of the Red Sox and the impact of the curse of the Bambino. (For readers not familiar with the curse, it began in 1920 when Harry Frazee, owner of the Red Sox, sold his star pitcher, Babe Ruth, to the New York Yankees for cash. Frazee subsequently used the cash to promote a Broadway flop, whereas the Yankees converted Babe Ruth to a hitter. And the rest is a well-known history of triumph for the Yankees and tragedy for the Red Sox.) Even in our later years together as faculty colleagues we would occasionally sneak off in the afternoon to go watch the Red Sox together.

ACADEMIC CAREER

Norm completed his Ph.D. in 1956, and his thesis was entitled "Standardization of Electron Capture Isotopes." This was a very creative experimental thesis involved in determining absolute nuclear decay rates. After graduation, Norm remained in the MIT Physics Department as an instructor. He also continued his experimental work in the Radioactivity Center. Norm's hands-on experience as a child made him an extremely versatile and creative experimentalist. In the 1950s the tools available for detection and measurements

were primitive. Norm was in the forefront of developing coincidence-counting techniques to measure decay schemes, which was the focus of his early papers.

At this time, the mid-1950s, MIT was building the MIT research reactor and expanding the program in nuclear engineering into a full department. Norm was invited to become an assistant professor in the new department to help in the creation of a curriculum that included experimental methods. He also became an important experimentalist using the new reactor. He was a key participant in the building of a 6-meter bent crystal spectrometer that was used for gamma ray spectroscopy studies for many years. He migrated from the determination of decay spectra to the use of spectra for measuring nuclear composition. This led him to a major program for the measurement of spent nuclear fuel composition, a matter of significant importance to the nuclear weapons programs where both tritium and plutonium were created in production reactors. This work also brought him international renown, as the International Atomic Energy Agency adopted his techniques for use in proliferation studies.

Although a magnificent experimentalist, he was also exceedingly creative in applying new technologies to nuclear spectroscopy problems. He was among the leaders in adopting the use of solid-state devices for photon detection and measurement. He was an important contributor to the development of lithium drifted germanium detectors. He also recognized the importance of data analysis and was the first spectroscopist to adopt the then-new fast Fourier transform to data analysis.

Part of his training and background was an appreciation of the importance of statistics to the analysis and interpretation of data. Robley Evans was very firm in training all his students to be careful and thorough in their analyses. This

training was reflected in Norm's work and laid the foundation for his subsequent appreciation of probabilistic risk assessment. It also made Norm an excellent poker player, a pleasure he pursued regularly and profitably.

One of Norm's closest colleagues and collaborators was Prof. Theos J. Thompson. Tommy came to MIT in 1957 to design the MIT research reactor. In 1966 Tommy began a special summer program in nuclear power plant safety. This program brought together leading experts in all aspects of safety, including reactor physics and engineering, materials problems, instrumentation and control issues, plant operations, modeling and simulation, and plant licensing. Norm was a participant in this program, and in 1969 he became the director when Tommy left to become an AEC commissioner. As a result Norm was in the position of being an experienced analyst with a deep understanding of most of the issues involved in nuclear power technology.

THE REACTOR SAFETY STUDY

The first civilian nuclear power plant, Dresden 1, went on line in 1959. This was followed by Yankee Rowe in 1960. The electric utilities began a rapid increase in plant orders and construction. The first large unit was at Oyster Creek in New Jersey and was a very large plant, over 650 MWe. The plant was ordered in 1963, construction was approved in 1964, and the plant went into commercial service in 1969. Another large plant, Nine Mile Point, also went into service in 1969. Thereafter growth was very rapid; four plants in 1970, four more in 1971, and eight plants in 1972. In 1973 U.S. utilities ordered 41 nuclear plants. Clearly the industry was growing, and attracting attention.

Opposition to nuclear power began to take shape in the 1960s, with the initial concern focused upon radiation from the plants and the effluents. Then the concern shifted to

safety and the consequences of large accidents. Interveners began to attack the licensing process and create expensive delays in plant construction and licensing. The plant designs were based upon the concept of the "maximum credible accident." Usually this took the form of a large rupture in a main coolant pipe, depriving the core of cooling water. Arguments in the courts and in the public arena were complicated because of the lack of quantitative assessments of the real risks associated with the plants. Senator John Pastore (Rhode Island) was the chairman of the Joint Committee on Atomic Energy, and in 1972 he wrote to James Schlesinger, head of the AEC, encouraging the AEC to undertake a study that addressed the issue. Schlesinger agreed and went about creating a large-scale project for that purpose. Because of the significance of the study it was felt that it should be led by someone outside the AEC itself. Norm's name emerged as a likely leader of the project based upon his association with the issue, his neutrality as an academic, and his scientific reputation. Norm agreed to head a multiyear, multimillion-dollar study.

He was very fortunate to have as a close collaborator, Saul Levine, who was then the deputy director of the Office of Research at the AEC. Together they began to review potential tools for risk analysis and encountered some classic work by Chauncey Starr and F. R. Farmer that suggested probabilistic approaches to address licensing and siting. Their work also considered the use of event trees to identify how things could go wrong, and then in using fault trees to develop quantitative evaluations of the likelihood of an accident. This was then to be followed by an assessment of the consequences of every failure (e.g., radiation release quantities, pathways to the environment, and effects upon population). Together Norm and Saul created a program to examine the risk associated with both major types of U.S.

reactors (i.e., the pressurized water reactor and the boiling water reactor). Their team ultimately involved a large number of analysts at the national laboratories, the utilities, and several universities.

The activities of the AEC were overseen by the Joint Committee on Atomic Energy (JCAE) of the U.S. Congress. The committee had a deep interest is the future of nuclear energy and the findings of the study underway. Norm was frequently called upon to testify before the JCAE. He was an extraordinary witness due to his great depth of knowledge, his ability to put complex issues in a comprehensible form, his obviously forthright presentations, and his wonderful sense of humor. At one hearing Senator Pastore was presiding. Norm was explaining the concepts of event trees and fault trees and how they were used. In the midst of his testimony the quorum bell rang. Senator Pastore interrupted Norm and explained that the committee members would have to leave in about 10 minutes. He asked Norm how much longer he would need to complete his remarks. Norm replied, "Senator, that depends upon how smart you are!" The staffers in attendance were all aghast, and Senator Pastore roared with laughter and suggested that the committee should adjourn promptly.

The study report, WASH 1400, was released in draft form in 1974, and the final version in October 1975. It was received with appreciation from the industry because it concluded that the risks to nuclear power were very low. Conversely the opponents attacked the report vigorously because the conclusion was unacceptable to them. There followed an extensive period of review, debate, and reassessment. Appreciation for the report grew after the Three Mile Island accident (TMI). The report had suggested that small breaks in piping were much more significant than the large break accident. TMI was in fact a small break. In the aftermath of

the accident the Kemeny Commission suggested that the methodology be used in risk assessment. The Nuclear Regulatory Commission had replaced the AEC as the regulator in 1975. After TMI the Nuclear Regulatory Commission began to use probabilistic risk assessment (PRA) for specific safety issues; for example, the issues regarding loss of offsite power to a station were analyzed and found to be significant, leading to new regulations. The commission went even further in the 1990s by deciding to use PRA for judging the impact of the usefulness of various safety regulations. Today the industry operates under what are called "risk informed regulations," which allow utilities to use PRA to adjust their service and maintenance activities. Partly as a result of these changes U.S. plants are now among the most productive in the world.

Norm received well-deserved recognition for this pioneering work. He was elected to the National Academy of Engineering in 1978 and to the National Academy of Sciences in 1979. In 1985 he was awarded the Department of Energy Enrico Fermi award, the most prestigious of all DOE awards. The Fermi award had a cash stipend of $100,000. A few weeks after receiving the award, Norm told me of his adventures with his new riches. He deposited the check at his bank and waited a few days to inquire at an ATM about his balance. He said he just wanted to see that much money in his account. The balance did not reflect the deposit. He waited another few days and tried again, and again the deposit wasn't shown. After a third trial and several weeks after making the deposit, he went to the bank personally to ask what had happened. The teller listened to his story and then patiently explained that the ATM screens only showed 5 digits before the decimal.

With the release of WASH 1400 Norm was involuntarily committed to becoming a public figure. He spent an incredible amount of time traveling the world explaining

the methodology, defending nuclear power, and helping develop the applications. He was always fair in his debates, never indulging in distortion, misrepresentation, or exaggeration. He was deeply appalled by the poor quality of some of the actions of some opponents. Most of all he was distressed by the unwillingness of some opponents to discuss issues offstage and off camera. He always tried to understand the nature of the opposition and how together the industry and the opponents might find constructive resolution. He kept on his wall a cartoon showing two figures separated by a deep, symmetric chasm. One character is saying to the other, "Come over to my side, the view is much clearer." He always tried to maintain a balanced perspective on the nuclear issue and did his best to convince others to do the same.

While maintaining his activities in the nuclear power arena he continued an active academic career. He was named head of the Nuclear Engineering Department in 1975 and served in that position for seven years. In 1983 he was named the McAfee Professor of Nuclear Engineering. During these years, he continued an active research program but with the focus now on risk assessment. He was highly sought after by students to be their thesis supervisor. The student grapevine was, and is, well attuned to the merits of various faculty members as advisors. Norm was one of the best in giving his students lots of time, attention, and moral support. He supervised over 60 graduate theses, and each of his graduates became a lifelong friend.

He was appointed by President Reagan to the National Science Board in 1982 and served for six years. He also served on the Defense Science Board from 1974 until 1978. He continued as a consultant to the Defense Science Board until his retirement in 1990. He retired from active teaching in 1994 in part due to his health.

THE MAN

Norm maintained a remarkably wide set of personal interests and activities. He was very good with his hands and pursued crafts with diligence and skill. He made much of the furniture for his home just for the shear joy of craftsmanship. He and his wife purchased land in New Hampshire on a small lake, and he cleared the land and built by himself a small home. He would visit barn sales throughout New England to find old beams and boards and incorporate these into his home. As part of his land clearing he purchased an abandoned bulldozer and restored it to operating condition. He then used the bulldozer to improve the road into his property and prepare a site for a sauna, which he again built by hand. He loved spending time in the summer on the lake. In the fall he would go up on weekends to cut wood for the stove and fireplace. And in the winter he used the home whenever he could arrange a ski trip to the mountains.

Perhaps my favorite tale of Norm has to do with his wood chopping one fall. He cut wood for most of a chilly October Saturday. After enough effort, he fired up his sauna to relax. After he had been inside long enough, he thought he might prove his Scandinavian roots by leaping into the lake. Knowing that this late in the season no one would be at the lake he ran out of his sauna in the buff, ran down the path to his dock, and pounding his chest and yelling like Tarzan he leaped into the lake. Only after becoming airborne did he note that two very frightened women were sitting in a rowboat fishing just off the end of his dock.

Norm was also very athletic and participated in all kinds of sports. He was particularly fond of skiing, and we always arranged our teaching schedules to have common days off to go skiing in the middle of the week. We also served

together on the Scientific Advisory Board of the Idaho National Engineering and Environmental Laboratory. We frequently managed to find time to ski in Utah or Wyoming on those trips.

Beyond sports Norm had a real passion for bird watching. Wherever he traveled he took binoculars with him in the hopes of having a few minutes to see new species. As part of his duties on the National Science Board he traveled to the South Pole. He made arrangements to be helicoptered over to the ice shelf in order to see emperor penguins. He was particularly fond of penguins and found this trip one of the most exciting of his life. After completing the trip, he gave a seminar in the Nuclear Department with a slide show that included the penguins. He appeared at the seminar dressed in a penguin costume, which created one of the lasting moments in the department's history. He also took a vacation to journey to the Priboloff Islands in order to see the unique species present there.

There is no doubt that the greatest individual inspiration in his life was his wife, Thalia. Together they shared the raising of two children: son, Neil, and daughter, Arlene. Subsequently they enjoyed together four grandchildren. Norm was blessed with intelligence, a strong work ethic, and a wonderful family life that was apparent to all who knew him.

Norm will be most remembered by the scientific community for his remarkable achievements in the area of nuclear power plant safety. Every nuclear plant around the world now has a tool that allows for the assessment of risks, and of means for improving the safety of plant design and operations. The Nuclear Regulatory Commission has used the results of his methods to assist in identifying new regulatory processes and procedures. The results are much greater insights into system design and performance. All new reactor concepts are influenced by the ability to examine their safety

in a quantitative way. Other technical areas are beginning to adopt the probabilistic risk assessment approach.

I WOULD LIKE TO THANK several colleagues and friends for their assistance in preparing this biography. Gordon Brownell, Frank Masse, and Costa Maletskos were with Norm in his early years in the Radioactivity Center and provided much valuable information. Prof. George Apostolakis was very generous in reviewing material regarding WASH-1400 and its impact on the industry.

SELECTED BIBLIOGRAPHY

1956

Standardization of Electron Capture Isotopes. Ph.D. thesis, MIT, Physics Department.

1960

With A. H. Kazi and H. Mark. Six-meter radium bent-crystal spectrograph for nuclear gamma rays. *Nucl. Phys.* 15:653.

With R. D. Evans. Isotopes: Radioactive measurement. In *Medical Physics*, ed. O. Glasser, pp. 338-341. Chicago: Yearbook Publishers.

1962

With M. Cohan. Analysis of radiations from spent fuel elements using a bent crystal spectrograph. *Trans. Am. Nucl. Soc.* 5:1.

1965

With J. A. Sovka and S. A. Mayman. The nondestructive measurement of burnup by gamma-ray spectroscopy. In *Proceedings of the International Atomic Energy Agency Symposium on Nuclear Material Management,* pp. 829-849. Vienna, Austria: International Atomic Energy Agency.

1966

With O. Oldenberg. *Modern Physics for Engineers.* New York: McGraw-Hill.

1967

With V. J. Orphan and U. Hukai. Determination of (n,g) reaction Q values from capture gamma-ray spectra. In *The Third International Conference on Atomic Masses.* University of Manitoba, Winnipeg, Canada.

The nondestructive analysis of spent reactor fuel by gamma-ray spectroscopy. In *Proceedings of the Symposium on Safeguards Research and Development.* Report no. WASH-1076, pp. 130-137. Argonne, Ill.: Argonne National Laboratory.

1969

With T. Inouye and T. Harper. Application of Fournier transforms to the analysis of spectral data. *Nucl. Instrum. Methods* 67:125-132.

1972

Nuclear detection methods. In *Preventing Nuclear Theft: Guidelines for Industry and Government,* eds. R. B. Leachman and P. Althoff, pp. 231-263. New York: Praeger.

1974

The United States Atomic Energy Commission study on the estimation of risks to the public from potential accidents in nuclear power plants. *Nucl. Saf.* 15(4):375-383.

The approach of the United States Atomic Energy Commission study to the public risks of power reactors. In *The Nuclear Controversy in the USA-II, an International Workshop.*

Nuclear power risks in the United States. In *Proceedings of the 1974 World Energy Conference.*

1975

Safety and risks of nuclear power. In *Proceedings of the International Symposium on Nuclear Power Technology and Economics* (under the auspices of the National Science Council with the co-sponsorship of the Institute of Nuclear Energy Research, the Taiwan Power Company, and the National Tsinghua University), pp. 601-620.

The safety study and its feedback. *Bull. At. Sci.* 31(7):25-28.

Reactor safety. *IEEE Spectrum* 12(8):46-55.

1977

The nuclear power controversy. *Nucl. Eng. Int.* 22:256.

With D. Rose. Nuclear power safety and environmental issues. In *Options for United States Energy Policy,* pp. 119-142. Institute for Contemporary Studies.

1979

Setting safety criteria. In *Proceedings of a Symposium of the American Academy of Arts and Sciences/Argonne National Laboratory: National Energy Issues—How do we Decide?* pp. 144-155. Argonne, Ill.: Argonne National Laboratory.

Chain reaction, nuclear. In *Encyclopedia of Science and Technology*. 5th ed., pp. 15-27. New York: McGraw-Hill.

1980

Setting safety criteria. In *National Energy Issues, How Do We Decide?* ed. R. G. Sachs, pp. 73-82.