NORMAN C. RASMUSSEN

1927–2003

Elected in 1977

"Contributions to applied radiation detection, the development of quantitative methods of risk assessment, and nuclear safety."

BY KENT F. HANSEN

NORMAN CARL RASMUSSEN died July 18, 2003, at the age of 75. He succumbed to complications of Parkinson's disease, from which he suffered for many years. He was a remarkable, creative scientist, engineer, researcher, and educator who made important, lasting contributions to nuclear physics, nuclear engineering, health physics, and risk analysis.

Norm first achieved recognition for his accomplishments 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 US nuclear weapons testing programs of the 1950s and 1960s.

His most influential work was in directing the Atomic Energy Commission (AEC) study on nuclear safety, published as WASH 1400 but better known as the Rasmussen Report. This pioneering effort evolved into the principal tool of risk assessment in the nuclear industry.

His public service included the National Science Board, numerous National Academies panels, and the Defense Science Board.

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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

Born November 12, 1927, in Harrisburg, Pennsylvania, Norm, the fifth of six brothers, grew up in the depths of the Great Depression on a dairy farm and attended Hershey public schools. In addition to his schoolwork he had the multiple chores of a farm boy, an experience that greatly influenced his career. He learned how to care for animals, service and maintain farm equipment, and 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. And 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 near Gettysburg, where his grandparents helped care for the children. He graduated from high school in 1945 and enlisted in the Navy, which sent him 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.

That fall, with the help of the GI bill, he enrolled in Gettysburg College, where he majored in physics because his interest had been stimulated in high school. He came under the guidance of George Miller, who intensified his interest in physics and encouraged him 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. But before leaving Gettysburg he met a young coed, Thalia Tichenor, who in 1952 became his wife and lifelong soul mate.

At MIT Norm worked for Robley Evans in the Radioactivity Center, which Evans created and led. The focus was on 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 met Norm. He was a teaching assistant in Prof. Evans' two-semester course on nuclear physics, which I took as a senior in physics. Norm was always available to help students understand the material and with the devilishly long homework assignments.

When one of my classmates and close friends became a research assistant in the Radioactivity Center, 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 curse of the Bambino.[1] In our later years as faculty colleagues we would occasionally sneak off in the afternoon to go watch the Red Sox together.

Academic Career

Norm completed his PhD in 1956, with a very creative experimental thesis titled "Standardization of Electron Capture Isotopes," focused on determining absolute nuclear decay rates. After graduation he remained in the MIT Physics Department as an instructor while continuing his experimental work in the Radioactivity Center.

His 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, MIT was building its Nuclear Research Reactor and expanding the program in nuclear engineering into a full

[1] 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 long history of triumph for the Yankees and tragedy for the Red Sox.

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.

In addition to being a magnificent experimentalist, Norm was 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, and 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 Theos J. (Tommy) Thompson, who came to MIT in 1957 to design the research reactor. In 1966 Tommy began a special summer program in nuclear power plant safety, bringing together experts in all aspects of safety—from reactor physics and engineering to materials problems, instrumentation and

control issues, plant operations, modeling and simulation, and plant licensing. Norm was a participant in the program, and in 1969 became the director when Tommy left to serve as 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 US civilian nuclear power plant, Dresden 1 (in northern Illinois), went online in 1959, followed by Yankee Rowe (in western Massachusetts) in 1960. The electric utilities began a rapid increase in plant orders and construction. The first large unit—over 650 MWe—was at Oyster Creek in southern New Jersey. 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 (in upstate New York), also went into service that year. Thereafter growth was very rapid: four plants in 1970, four more in 1971, and eight in 1972. In 1973 US utilities ordered 41 nuclear plants. The industry was growing—and attracting attention.

Opposition to nuclear power had begun to take shape in the 1960s, with concern focused initially on radiation from the plants and effluents and then on 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 on 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), chair of Congress's Joint Committee on Atomic Energy (JCAE), wrote in 1972 to James Schlesinger, head of the AEC, encouraging the AEC to undertake a study to address the issues. 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. Norm's name emerged as a likely leader of the project based on his association with the issue, his neutrality as an academic, and his scientific reputation. Norm agreed to head the multiyear, multimillion-dollar study.

He was very fortunate to have as a close collaborator Saul Levine, deputy director of the AEC's Office of Research. 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 fault trees to develop quantitative evaluations of the likelihood of an accident. This was to be followed by an assessment of the consequences of every failure (e.g., radiation release quantities, pathways to the environment, and effects on population). Norm and Saul created a program to examine the risk associated with both major types of US reactors (pressurized water and boiling water). 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 JCAE, which had a deep interest in the future of nuclear energy and in the findings of the study. Norm was frequently called on to testify before the JCAE. He was an extraordinary witness thanks to his great depth of knowledge, his ability to put complex issues in a comprehensible form, his forthright presentations, and his wonderful sense of humor.

At one hearing with Senator Pastore presiding, Norm was explaining the concepts and use of event trees and fault trees. 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 on how smart you are!" The staffers in attendance were all aghast, but Senator Pastore roared with laughter and suggested that the committee 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 of nuclear power were very low. It was vigorously attacked by opponents 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 (TMI) accident. The report had suggested that small breaks in piping were much more significant than a large break accident, and TMI was in fact a small break. In the aftermath of the accident the Kemeny Commission[2] suggested that the method be used in risk assessment.

The US Nuclear Regulatory Commission (USNRC) replaced the AEC in 1975, and after TMI it began to use probabilistic risk assessment (PRA) for specific safety issues. For example, issues associated with 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 to judge 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 US 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 the National Academy of Sciences in 1979. In 1985 he received the Department of Energy's Enrico Fermi award, the most prestigious of its honors.

The Fermi award had a cash stipend of $100,000 and a few weeks after receiving it 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

[2] John G. Kemeny, president of Dartmouth College, chaired the President's Commission on the Accident at TMI.

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 into the bank to ask what had happened. The teller listened to his story and then patiently explained that the ATM screens showed only 5 digits before the decimal.

With the release of WASH 1400 Norm was involuntarily committed to being 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 fair in his debates, never indulging in distortion, misrepresentation, or exaggeration. He was 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 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 keep 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 became head of MIT's 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, and Norm was one of the best, giving his students lots of time, attention, and moral support. He supervised more than 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 was a

member of the Defense Science Board from 1974 to 1978 and continued as a consultant until his retirement in 1990. He retired from active teaching in 1994 in part because of his health.

Norm will be most remembered by the scientific community for his remarkable achievements in nuclear power plant safety. Every nuclear plant around the world now has a tool that allows for the assessment of risks and for improving the safety of plant design and operations. The USNRC has used the results of his methods to assist in identifying new regulatory processes and procedures, resulting in 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.

The Man

Norm maintained remarkably broad personal interests and activities. He was very good with his hands and pursued crafts with diligence and skill—he made much of the furniture in his home just for the sheer joy of craftsmanship.

He and Thalia purchased land in New Hampshire on a small lake, and he cleared the land and by himself built a small home. He would visit barn sales throughout New England to find old beams and boards and incorporate them into his house. As part of his land clearing he purchased an abandoned bulldozer, restored it to operating condition, and used it both to improve the road in to his property and to prepare a site for a sauna, which he again built by hand. He loved spending time in the summer at this house 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 a chilly October Saturday of wood chopping. 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, 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 frightened women were sitting in a rowboat fishing just off the end of his dock.

Norm was 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, and frequently managed to find time to ski in Utah or Wyoming on those trips.

Beyond sports Norm had a passion for bird watching. Wherever he traveled he took binoculars in the hope 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, where he made arrangements to be helicoptered over to the ice shelf in order to see emperor penguins—he was particularly fond of them and found this trip one of the most exciting of his life. Afterward 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 the Pribilof Islands in order to see the unique species there.

Norm was blessed with intelligence, a strong work ethic, and a wonderful family life that was apparent to all who knew him. There is no doubt that the greatest single inspiration in his life was his wife, Thalia. Together they raised two children, Neil and Arlene, and later enjoyed four grandchildren.

Author's Note

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