In Memoriam

(photo: NAE)

Rudolf E. Kalman

May 19, 1930 - July 2, 2016

Professor Rudolf Emil Kalman, formerly Graduate Research Professor and Director of the Center for Mathematical System Theory at the University of Florida in Gainesville, Florida and the chair for Mathematical System Theory at the Swiss Federal Institute of Technology (ETH) in Zurich, Switzerland, passed away peacefully at his home in Gainesville, Florida, on July 2, 2016, after a short but valiant fight with cancer. He was 86 years old. He is survived by his wife Constantina nee Stavrou, their two children Andrew and Elisabeth, and their families.

Starting in the early 1960's, Kalman's creative genius launched an era of transformative strides in systems science that enabled technological achievements that include the landing on the moon and GPS-enabled cellphones. Chief amongst his creations was the Kalman filter which resides deep inside almost every navigation system, sensor technology, and computer-controlled regulation device. The present special commemorative issue of the ASME Journal of Dynamic Systems, Measurement, and Control is dedicated to his memory and has been assembled to touch upon representative lines of research that spawned from his profound thought and to reflect upon his salient influence in so many facets of engineering and science.

Rudolf Emil Kalman was born in Budapest on May 19, 1930, the son of Otto and Ursula Kalman. The Kalman family left Hungary in 1943, during World War II, and emigrated to the United States. The family arrived in Youngstown, Ohio, in 1949. Kalman attended Youngstown College for three years before being admitted at Massachusetts Institute of Technology (MIT) to study electrical engineering. At MIT he received his bachelor's degree (S.B.) in 1953 and, under the guidance of Ernst Guillemin, his Master's degree in 1954. He pursued doctoral studies at Columbia University in New York City under the guidance of John Ragazzini and received his degree (D. Sci.) in 1957 by presenting his doctoral thesis on the subject of "Analysis and synthesis of linear systems operating on randomly sampled data."

After a brief stay at the IBM research laboratory in Poughkeepsie, NY, Kalman joined the Baltimore-based Research Institute for Advanced Studies (RIAS) of the Glenn L. Martin company in 1958, also referred to as Martin-Marietta, after a merger in 1961, and eventually Lockheed-Martin. The mathematical division of the institute was headed by the world-renowned mathematician Solomon Lefschetz and the institute distinguished itself as one of the world's premier centers of mathematical research. As it turned out, the impact of the institute was to be multiplied manyfold by the groundbreaking contributions of this newly hired young research mathematician, Rudolf Kalman. Shortly after Kalman joined RIAS he developed the Kalman filter. He worked out his idea in January 1959 and presented his famous publication, "A New Approach to Linear Filtering and Prediction Problems," in late March 1959 at a conference of the American Society of Mechanical Engineers. Entrenched viewpoints led to initial skepticism on Kalman's discovery and his second paper on the subject, "New Results in

Linear Filtering and Prediction Theory," coauthored with Richard Bucy, was initially rejected. However, soon afterwards, the transformative nature of Kalman's work was widely recognized. A visit by Kalman in the Fall of 1960 to Stanley Schmidt at the Ames Research Center of NASA in Mountain View, California, proved pivotal. Schmidt saw the potential impact of Kalman's discovery in the estimation and control problem of the Apollo project, the mission to the moon and back in the planning stages, and immediately set out to transition the discovery into an astronautical guidance system. The remarkable effectiveness of this new technology was duly publicized by Schmidt who credits the Apollo program for the conditions and funds that facilitated this glorious opening success of Kalman filtering[1].

Kalman filtering was just one of the many foundational contributions that Kalman laid out during the years at RIAS, from 1958-1964. His uniquely original approach to research shaped the field of control in the subsequent decades. His ability to see, through the maze of techniques and practices of the time, the emerging role of computers in engineering and science led him on a search for new foundations. Throughout, his taste for problems was guided by engineering relevance as well as mathematical elegance. During the First Congress of the International Federation of Automatic Control (IFAC) in Moscow, in 1960, in his paper "On the general theory of control systems," the young Rudy Kalman introduced the concepts of controllability and observability, their duality, and their relevance in control and estimation. Yet, in the same paper, in spite of the transformative nature of what he had just introduced, he underscored his view that the current "understanding of fundamental aspects of control remained superficial" and raised thought provoking questions on the nature of information that is needed to achieve desired control objectives. Kalman was on a mission to transform the field, and so he did. Today, more than half a centurly later, control theory and engineering relies heavily on the foundations he laid out, controllability, observability, realization theory, duality between control and estimation, separation principle, and many more.

After RIAS, Kalman was appointed Professor at Stanford University from 1964 until 1971, and subsequently the Graduate Research Professor and the Director of the Center for Mathematical System Theory at the University of Florida from 1971 until 1992. He stayed on at the University of Florida for another five years until retirement in 1997. Starting in 1973 and in parallel with his position in Florida he also held the chair of Mathematical System Theory at the Swiss Federal Institute of Technology in Zürich, Switzerland, which he held until his retirement in 1997. During his long career he produced a wealth of original contributions and ideas that have laid the seeds for many developments that followed. From sampled-data control systems, to stability theory, the structure of dynamical systems, optimization and many more, his manuscripts are gems, both in depth and style, and the contribution of his thought is timeless.

The breadth of his vision reached much further out into the foundations of the sciences. He sought to understand what information experimental data convey and was engrossed by the apparent sloppiness of how models are devised and treated in different fields. In his address to the Inamori Foundation on receiving the Kyoto prize, Kalman heralded the scope of System Theory to this end, and underscored his conviction that "scientific modeling is a deductive exercise, and not a creative act." His firm belief in a "prejudice-free" system theoretic perspective guided him through most of his life and he often emphasized how severely "under-developed" the subject of "system identification from noisy data" actually is, refering to this as "one of the most urgent scientific research problems of our day"[2]. His criticism: "Whenever a model is built, it is always proper to ponder the basic scientific question: Is the model really based on the data? Or is an artifact displaying the prejudices of its creator?" stands to lead future generations to reach the mountaintop that he sought.

Rudolf Kalman was elected member of the National Academy of Sciences (USA), the American National Academy of Engineering (USA), and the American Academy of Arts and Sciences (USA). He was a foreign member of the Hungarian, French, and Russian Academies of Sciences. He was awarded many honorary doctorates from universities around the world. He received numerous awards including the IEEE Medal of Honor in 1974, the IEEE Centennial Medal in 1984, the Inamori foundation's Kyoto Prize in Advanced Technology in 1985, the Steele Prize of the American Mathematical Society in 1987, the Richard E. Bellman Control Heritage Award in 1997, and the National Academy of Engineering's Charles Stark Draper Prize in 2008. President Obama personally honored Kalman with the 2008 National Medal of Science, the highest recognition the United States bestows for advancement in science, technology and innovation.

Rudolf Emil Kalman, the founder of the field of Mathematical System Theory and a giant in the field of Control, has left us. Until the very end of his life he continued tirelessly to seek out the truth and ponder about the physical world and the world of ideas that we live in. The immense contributions and the light of his thought will shine bright for generations to come. He is dearly missed by all those who had the privilege to know him.

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[1]Schmidt, S.F., "Kalman filter: Its recognition and development for aerospace applications," Journal of Guidance and Control, volume 4, issue 1, pages 4-7, January 1981

[2]Kalman R.E., "System identification from noisy data," Dynamical systems II, volume 210, 1982, pages 135-164, Academic Press, New York: presented at the International Symposium on Dynamical Systems, Gainesville, Florida, on February 25, 1981.