UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE & ENGINEERING

Memorial Tribute to

WALTER MURRAY WONHAM

University Professor Emeritus
The Edward S. Rogers Sr. Department of Electrical & Computer Engineering

October 31, 2023

Be it resolved –

> THAT the Council of the Faculty of Applied Science & Engineering record with deep regret the death on May 14, 2023 of Professor Walter Murray Wonham

Professor Walter Murray Wonham was a giant in the field of control systems and garnered international attention for his work. In addition, he was polylingual; a bibliophile; a sailor, skier and tennis player; and he held a great love for traditional Chinese literature and poetry.

Murray was born in 1934. He married Anne Wonham (née Hale) and has two daughters, Cynthia and Marjorie. After graduating high school in Montreal, Murray studied Engineering Physics at McGill University, earning his degree in 1956. He followed that with a PhD in Control Engineering from the University of Cambridge in 1961.

Beginning in the 1960s, he worked with several institutions, including those at Purdue University and Brown University, as well as NASA. During this time he furthered his research on stochastic filtering and control, developing the 'Wonham filter' — cited today by researchers in quantum systems — along with new results on Matrix Riccati equations and the separation theorem of stochastic control, now found in textbooks around the world. Murray's research then changed focus, turning to linear multivariable control, and in 1967 he was the first to prove the famous pole assignment theorem, which has become a staple of undergraduate courses on state space control, including courses in the ECE department.

By 1970, Murray had moved back to Canada, taking a position in U of T as a faculty member in the Systems Control Group in the then-named Department of Electrical Engineering. Early in his U of T career, he pioneered the geometric approach to linear time-invariant (LTI) systems and developed the internal model principle. His success produced a new level of understanding along with valuable tools, but it also opened up new problems, inspiring a generation of control theorists to try and replicate in the nonlinear domain what Murray had achieved in the linear.

It was clear with each of Murray's research publications that he was a deep thinker and visionary. This culminated in 1979 with "arguably one of the best books ever written in control theory," says ECE Professor Manfredi Maggiore, referring to *Linear Multivariable Control: A Geometric Approach*, which was subsequently issued in three editions and translated into Russian and Chinese. The running joke, originated by Murray's former student and collaborator Professor Emeritus Bruce Francis, is that you could teach an entire graduate course out of the book's Chapter 0: 'Mathematical Preliminaries.'

In the spring of 1979, Murray taught Peter Ramadge, now a professor at Princeton University, who remembers the elegant simplicity Murray wielded to resolve fundamental concepts and important questions: "It was something that deeply resonated with me," says Ramadge. He also recalls Murray enjoying the occasional lunch with students a local Chinese restaurant. Many came away from these lunches with a better understanding of what makes good research and how to think about research problems.

In the 1980s, Murray initiated the field of supervisory control of discrete-event systems along with Ramadge (who had become his doctoral student). Professor Shahin Hashtrudi Zad of Concordia University, looking back on the years as Murray's student, notes his signature insightfulness, how he could find connections other researchers overlooked: "Professor Wonham's work showed that the two theories, geometric control and supervisory control, share a lot of similarities, especially from an algebraic point of view."

Murray's thinking in this area was eventually outlined in books, the first published in 2005 with Chuan Ma, a second in 2015 with Kai Cai. For many years Murray's graduate course notes on this topic were made available for free online and have greatly influenced generations of researchers. Eventually, in 2019, they became his final book, co-authored again with Kai Cai, entitled *Supervisory Control of Discrete-Event Systems.*

During his time at U of T, Murray held visiting lectureships across the globe, including academic institutions and universities in the United States, China, Germany, India and Mexico. Combining his research work with his love of travel gave him great pleasure, and he would regale everyone on his return of his adventures with host students. In 1996 Murray was appointed University Professor, and he retired in 2000 as University Professor Emeritus at U of T.

Throughout his life, Murray received a plethora of awards and recognitions. He was made a Fellow of the Royal Society of Canada and a Life Fellow of the Institute of Electrical and Electronics Engineers (IEEE). He was a Foreign Member of the U.S. National Academy of Engineering and an Honorary Professor of Beihang University, then-known as the Beijing University of Aeronautics and Astronautics. In 1987 he received the IEEE Control Systems Science and Engineering Award and in 1990 he was the Brouwer Medallist of the Netherlands Mathematical Society. After retirement, he remained an active and engaged researcher and supervisor of graduate students. In 2020 he was awarded the Giorgio Quazza Medallist of the International Federation of Automatic Control.
Murray was a true gentleman whose pursuit of truth was an aesthetic one, a principle he embraced in all facets of his life. His door was always open with a note that read simply "knock and enter,"

and his brilliance and his teaching shaped many students into leaders in their fields. Jonathan Ostroff of York University says, “He demanded my best academic work but also had a gracious understanding of my personal life,” a sentiment echoed by Murray’s colleague and Professor Emeritus Raymond Kwong: “I have lost not only an outstanding colleague but also a personal friend.” Murray will be deeply missed by all those who knew him.

Be it further resolved –

> THAT this tribute to Professor Walter Murray Wonham be inscribed in the minutes of this Council meeting, and that copies be sent to his family as an expression of the respect and gratitude of the members of this Council.

Prepared by Professor and Chair Deepa Kundur, Professors Phil Anderson, Mireille Broucke, Raymond Kwong, Manfredi Maggiore, Jonathan Ostroff (York University), Khoman Phang, Peter Ramadge (Princeton University), Luca Scardovi, Shahin Hashtrudi Zad (Concordia University) and Safwat Zaky.