



*James McKee*

## DUANE T. MCRUER

1925–2007

Elected in 1988

*“For pioneering application of guidance and control theory and to experimental man-machine interactions.”*

BY ARTHUR E. BRYSON AND JASON SPEYER

**D**UANE T. MCRUER, a guiding force in the development of modern aircraft flight control technology and founder and former president of Systems Technology, Inc. (STI), died on January 24, 2007, at his home in Manhattan Beach, California.

“Mac,” as he was affectionately called, was born in Bakersfield, and received his B.S. degree in mechanical engineering in 1945 from the California Institute of Technology (Caltech). He then joined the U.S. Navy and quickly rose to Lieutenant (j.g.) in charge of the CIC and Fighter Direction School on San Clemente Island, where he also worked on antisubmarine techniques. Upon discharge from the Navy he returned to Caltech and received an M.S. degree in electrical engineering in 1948. From 1948 to 1954 he worked for Northrop Aircraft, Inc., where he became the technical chief of flight control. There, he pioneered new techniques for controlling high-speed aircraft, where in particular he made aircraft stability augmented hydraulic and fly-by-wire controls practical. Simultaneously, he took night courses at the University of California, Los Angeles (UCLA) in aeronautics, controls, mathematics, psychology, and neural physiology. He was the first to apply theories, well understood in academia, to aircraft flight control and stability augmentation systems. He developed the automatic “sideslip stability augments,”

for which he holds four patents. These stability augmenters reduced the uncomfortable swaying motions that were present in early commercial aircraft, such as the “Dutch roll” present in the early Boeing 707, and were first applied to the F-89D. These innovations were the forerunners of current flight control systems.

From 1954 to 1957 he was president and chief engineer of Control Specialists, Inc. There he advanced the state of the art in systems as well as applied research in vehicle dynamics and aerodynamics. A particular accomplishment was the RYAN X-13, an experimental vertical takeoff and landing aircraft flown in the 1950s. The main objective of the project was to demonstrate the ability of a pure jet to vertically take off, hover, and transition to horizontal forward flight and then vertically land. An unusually advanced stability augmentation system was developed to address the lateral phugoid mode.

In 1957, with his wife Betty and Irving Ashkenas, Mac started Systems Technology, Inc. (STI) where he was president and technical director until he retired in 1993 and was chairman of the board until his death in 2007. STI grew from a small engineering consulting company into a prime contractor to the U.S. government and a consultant to industry recognized internationally. Some of Mac’s accomplishments during his tenure at STI are advanced flight control design and analysis techniques; man-machine systems and human operator dynamics; McRuer’s crossover law; vehicle handling qualities; pilot-induced oscillations (PIO); comprehension, analysis, and prevention; ground vehicle dynamics and driver control; manual control display system design; neuromuscular system dynamics; and impaired operator behavior.

Mac was a principal contributor to the theory of human operator control of vehicles and the mathematical modeling of man-machine systems. He pioneered the fundamental principle known as McRuer’s Law, according to which for compensatory tracking, the pilot will act on the controlled element in such a way that the magnitude of the open-loop transfer function, the pilot transfer function times the plant transfer function, will be approximately an integrator around the region of the

crossover frequency, whose experimental gain is the crossover frequency. Mac performed pioneering work on the phenomena of PIO in which a pilot's efforts to control an aircraft can make the overall man-machine system unstable. Many aircraft have encountered PIO in their development and operations. As a final example of the innovative atmosphere of STI, a flying model of a pterodactyl was created in cooperation with Paul MacCready, president of AeroVironment, and paleontologists, in which great pains were taken to anatomically reproduce the original flying qualities of this flying reptile, that is, the head produced directional stability. A movie was generated for the Smithsonian Institution in which the pterodactyl was dramatically brought back to life.

These ideas were disseminated by Mac to a generation of engineers in a series of 10 books; the most popular were *Analysis of Nonlinear Control Systems* (Wiley, 1961), *Aircraft Dynamics and Control* (Princeton University Press, 1973), and *Mathematical Models of Human Pilot Behavior* (North Atlantic Treaty Organization, Advisory Group for Aerospace Research and Development, 1974). He was an adviser to the government serving on committees of the U.S. Department of Defense, Department of the Air Force, and National Aeronautics and Space Administration (NASA) Advisory Council and on the Space Shuttle Flight Readiness Review Board. He also served on many National Research Council committees, including chairing the following: Aeronautics and Space Engineering Board (1990–1994); Space Station Engineering Design Issues (1988–1989); Aeronautical Technologies (1990–1992); and Effects of Aircraft-Pilot Coupling on Flight Safety (1995–1997).

JoAnn Clayton Townsend, director of the Aeronautics and Space Policy Board (1990–1997), remembers that in addition to his technical genius and accomplishments, Duane McRuer was an informed and effective aerospace policy expert. He became an advocate of government investment in basic research, that is, long-term research of a type not likely to be undertaken by industry. He was an active participant and leader in many studies that defined and recommended government spending priorities.

Mac began his service on the National Research Council's Aeronautics and Space Engineering Board (ASEB) in 1997 with participation in a decadal study recommending priorities in advanced space technology, and from 1990 to 1995 he led studies that advised NASA, Congress, and federal agencies regarding directions for national investments in technology. He was persuasive in briefing the content of ASEB studies to members of Congress, NASA, the Federal Aviation Administration, and the U.S. Department of Defense.

Mac was especially interested in guidance, navigation and control systems, and the interfaces between humans and aeronautics and space vehicles. He chaired the ASEB 1995–1997 seminal study on the effects of aircraft-pilot coupling and flight safety as well as the earlier Panel on Information Sciences and Human Factors. He also led ASEB's Workshop on Space Station Engineering Design Issues and follow-on space station studies. These included peer-reviewed letters to the NASA administrator regarding the use of a space station as an engineering research facility and various program evaluations. During these years, he volunteered a great deal of his time and energy to providing the best technical information available to Congress and relevant government agencies for policymakers to apply to their decision-making processes.

He was a fellow of the Institute of Electrical and Electronics Engineers and the Society of Automotive Engineers. He was an honorary fellow of the American Institute of Aeronautics and Astronautics. He was proud to be named one of Caltech's Distinguished Alumni in 1983.

Mac received many awards, including the Louis E. Levy Gold Medal of the Franklin Institute in 1960. The AIAA presented him with the Mechanics and Control of Flight Award in 1970 and the Aerospace Guidance Navigation and Control Award in 2004. He was a recipient of the NASA Distinguished Public Service Medal in 1991.

A man of wide interests, Mac climbed Half Dome at Yosemite National Park when he was only 12. He joined the Sierra Club in 1963 and became an enthusiastic mountaineer as well as an outstanding leader of the Sierra Peaks Section

of the Angeles chapter and served as its chair in 1976. He had an obsession with "lists." He finished climbing all three lists of the Angeles Chapter including Sierra Peaks, Desert Peaks, and Hundred Peaks sections. In addition to receiving all the awards available from the Angeles Chapter, in 1997 he was given the Sierra Club's Oliver Kehrlein Award. This was the Sierra Club's top honor for outings leadership. Mac's love of the mountains and finishing lists involved climbing more than 1,500 mountains in California, Nevada, and Arizona as well as all the high points in every state in the United States except Alaska. His great contribution to the Sierra Club was the development of hundreds of other leaders. His skills as an organizer in the outings program are legendary.

In addition to aeronautics, he knew a lot about European/ U.S. history and geology. He enjoyed sharing his knowledge with his fellow climbers around evening campfires and on the trail.

He was a mentor both at work and on the trail, having an encouraging word for everybody and showing an interest in what they were doing. Mac was a great engineer/entrepreneur and a kind, generous friend.