AN ALL TOO BRIEF TRIBUTE TO DUANE MCRUER

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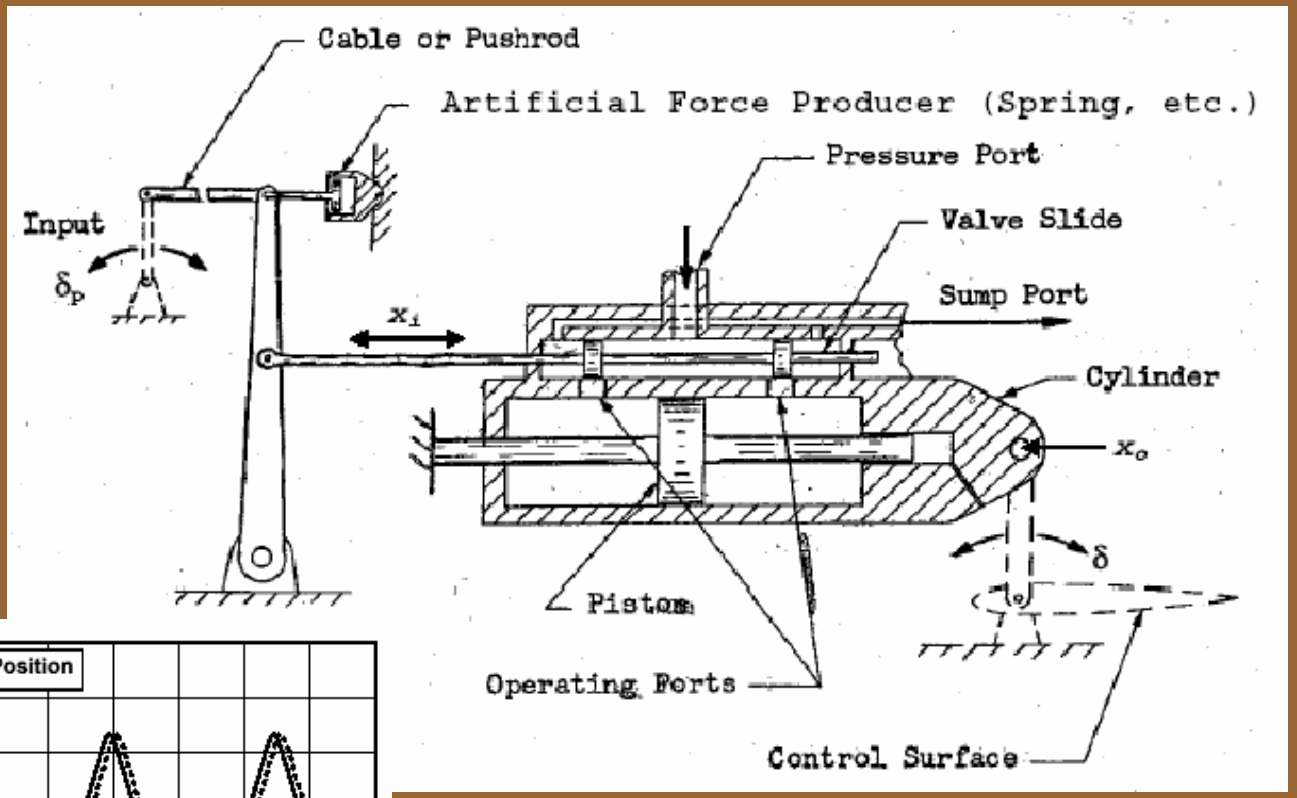
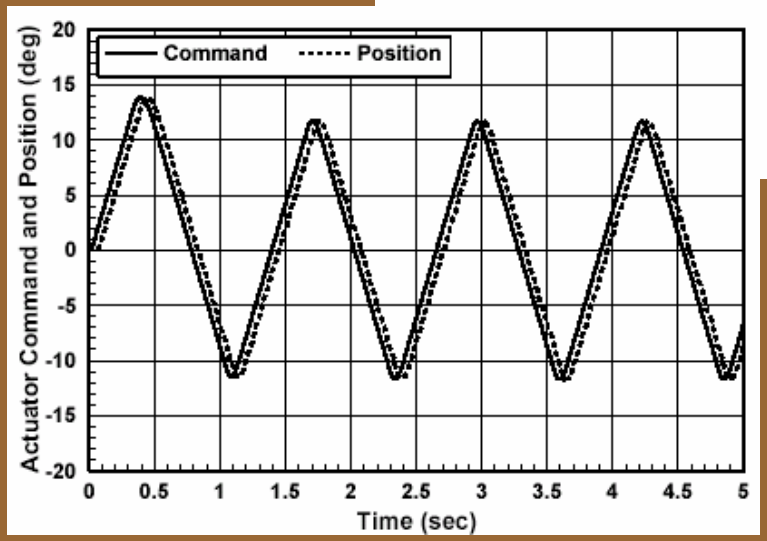
Aerospace Control & Guidance Systems Committee
Meeting No. 99

Boulder, CO
28 Feb. – 2 March 2007

THE NORTHROP YEARS
--Technical Chief of Flight Control--

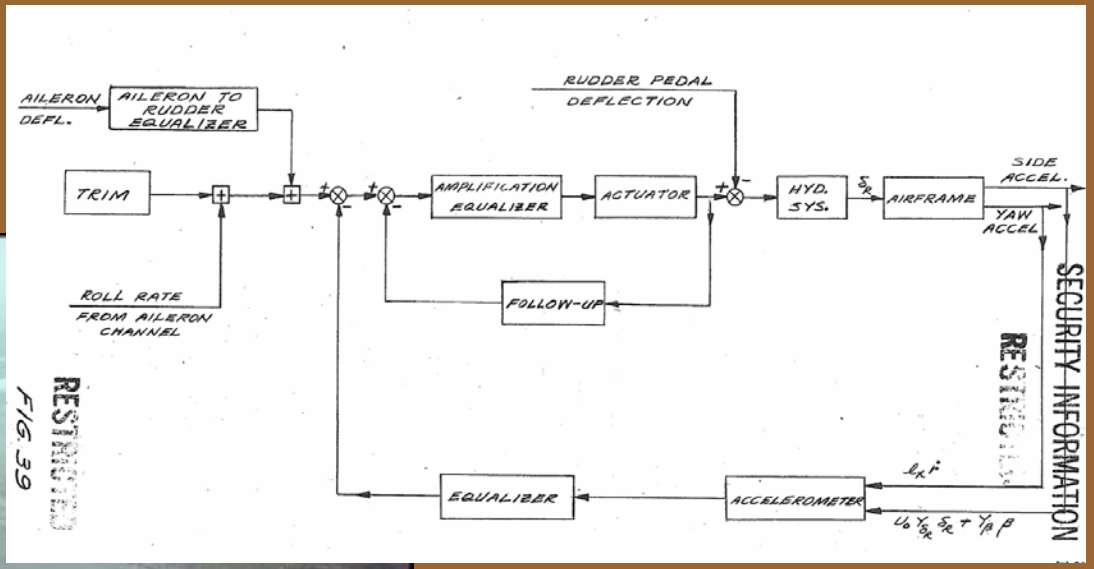
XP-89 – FULLY POWERED CONTROLS





Valve-Bottoming Response

F-89D: SIDESLIP STABILITY AUGMENTOR



US Patent #2,833,495,
May 6, 1958

CONTROL SPECIALISTS, INC.

- First post-Northrop endeavor
- Northrop developed an enormously talented cadre of engineers
- Corporate intent of new CSI was “Big Systems” problem solving activities
- Advancing the state of the feedback systems art
  (follow up from BuAer manuals)
- Applied research in vehicle dynamics, aerodynamics, and control systems
- Development of products, paid for by consulting
- Eventually acquired by Kelsey Hayes

ADVANCING THE ART OF FLIGHT CONTROLS

RYAN X-13

- Unusually advanced stability augmentation system (e.g., discovered lateral phugoid)

RYAN Q-2 Drone

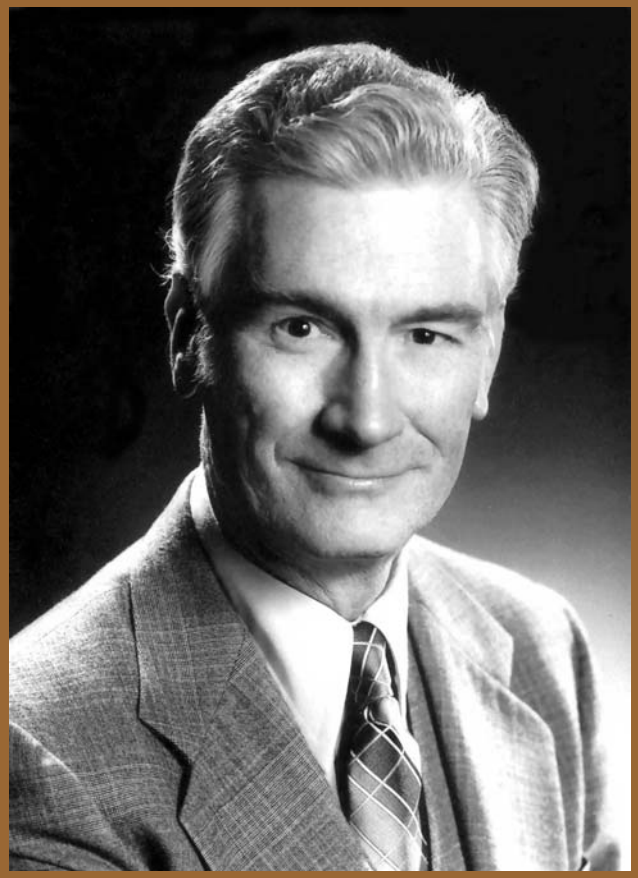
- Aileron-only control
- Lear F-5 servos
- Tilted rate gyro

EARLY MAJOR CONTRIBUTIONS

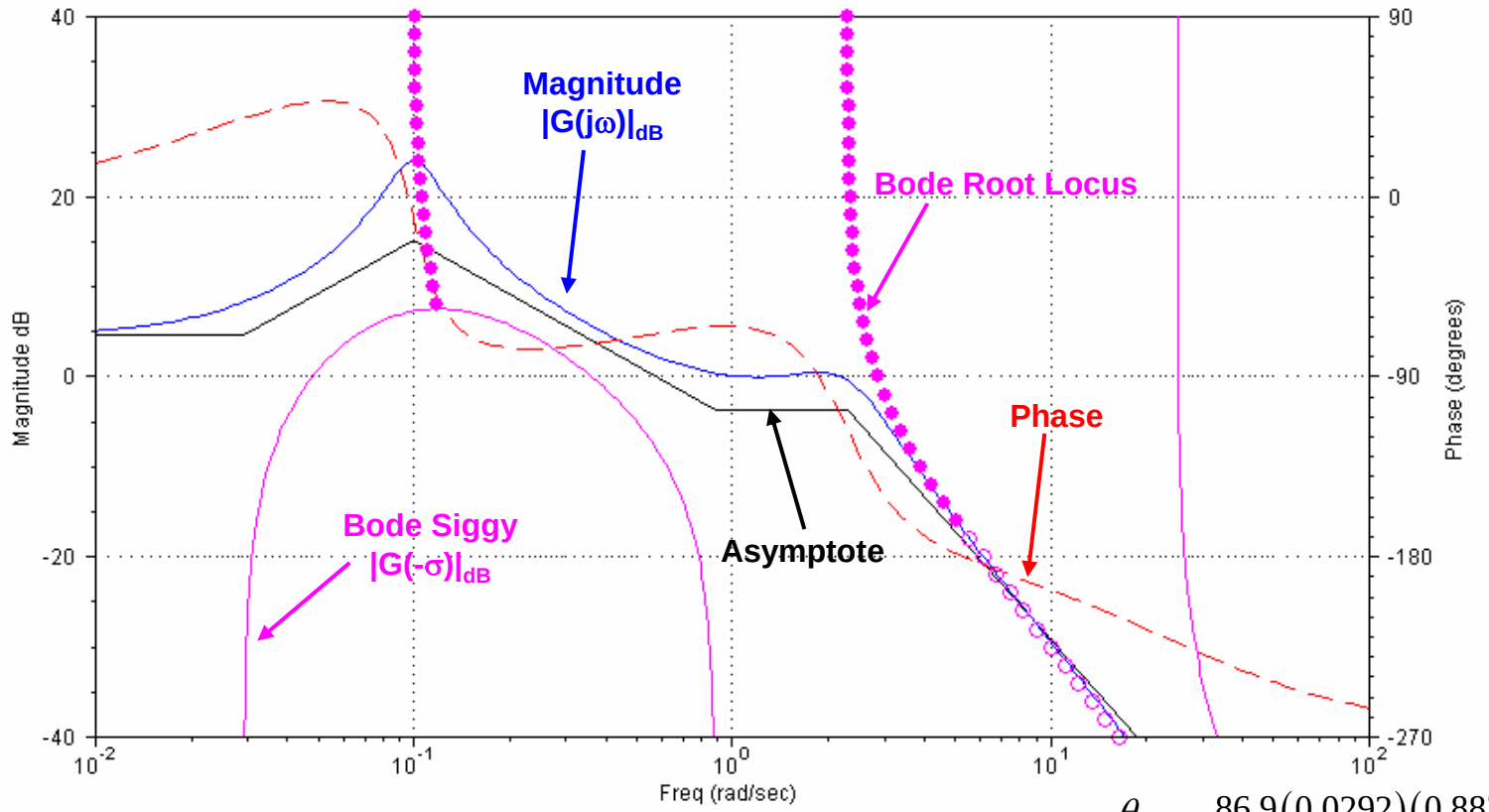
- U.S. Navy Bureau of Aeronautics Series on Analysis and Synthesis of Flight Control Systems:
  - *Methods of Analysis and Synthesis of Piloted Aircaft Flight Control Systems*, BuAer AE-61-4-I, March 1952.
  - *Dynamics of the Airframe*, BuAer AE-61-4-II, September 1952.
  - *The Human Pilot*, BuAer-62-III, August 1954.
  - *The Hydraulics System*, BuAer AE-61-4-IV, March 1953.
  - *The Artificial Feel System*, BuAer AE-61-4-V, May 1953.
- Major Starts (Greatly influenced later STI activities):
  - Human Pilot Dynamics
    (Dynamic Response of Human Operators, WADC TR-56-524)
  - Aircraft Configuration Design Sensitivities
    (Approximate Airframe Transfer Functions and Application to Single Sensor Control Systems, WADC TR-58-82)

SYSTEMS TECHNOLOGY, INC.

- President: 1957-1995
- Short List of Contributions:
  - Advanced Flight Control Design & Analysis Techniques
  - Man-Machine Systems and Human Operator Dynamics
  - McRuer's Crossover Law
  - Vehicle Handling Qualities
  - PIO Comprehension, Analysis, & Prevention
  - Ground Vehicle Dynamics and Driver Control
  - Manual Control Display System Design
  - Neuromuscular System Dynamics
  - Impaired Operator Behavior

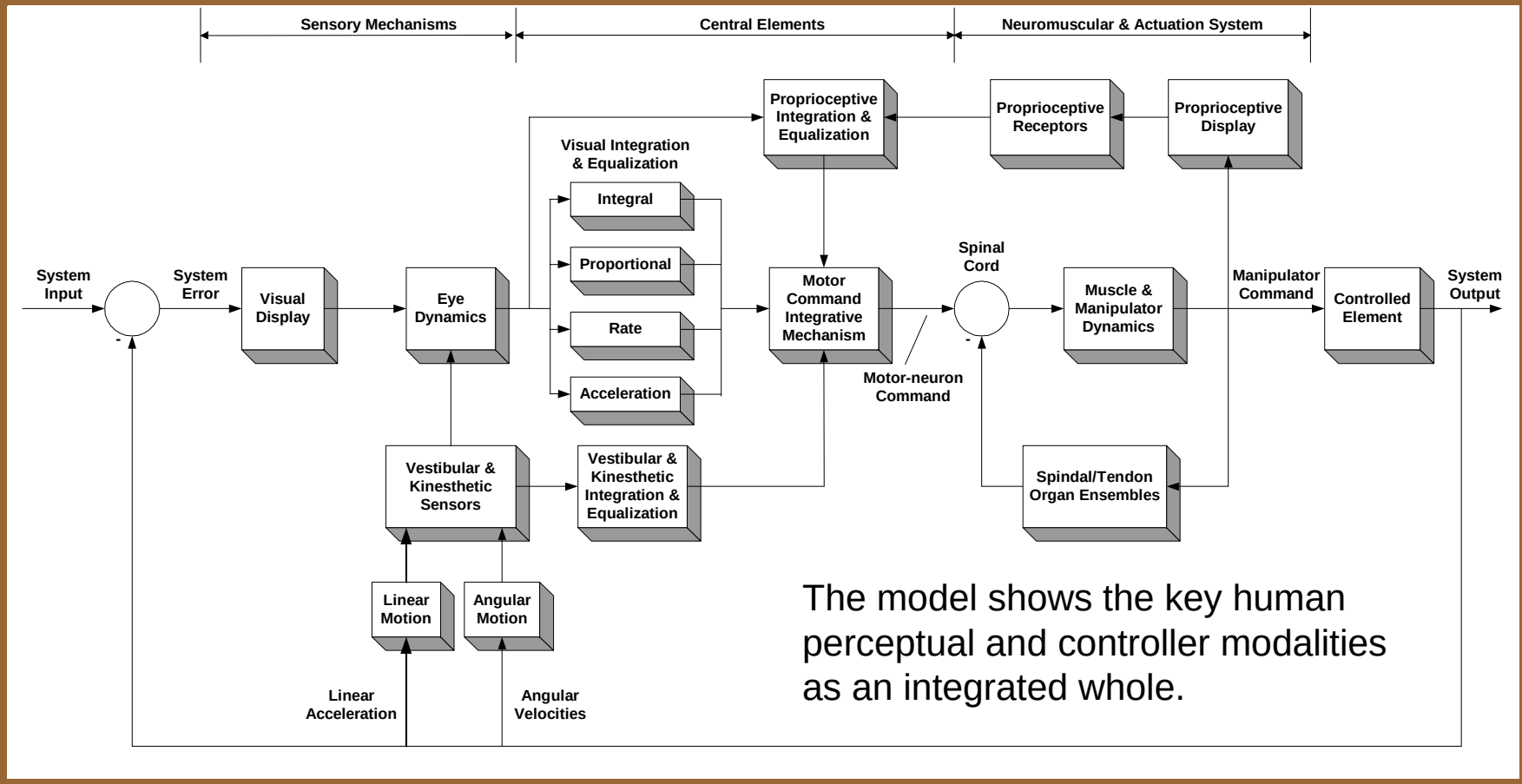


FREQUENCY DOMAIN DESIGN & ANALYSIS:
THE BODE-SIGGY/BODE ROOT LOCUS PLOT



X-15 Pitch Attitude TF: $\frac{\theta}{\delta} = \frac{86.9(0.0292)(0.883)}{[0.19, 0.1][0.366, 2.3](25)}$

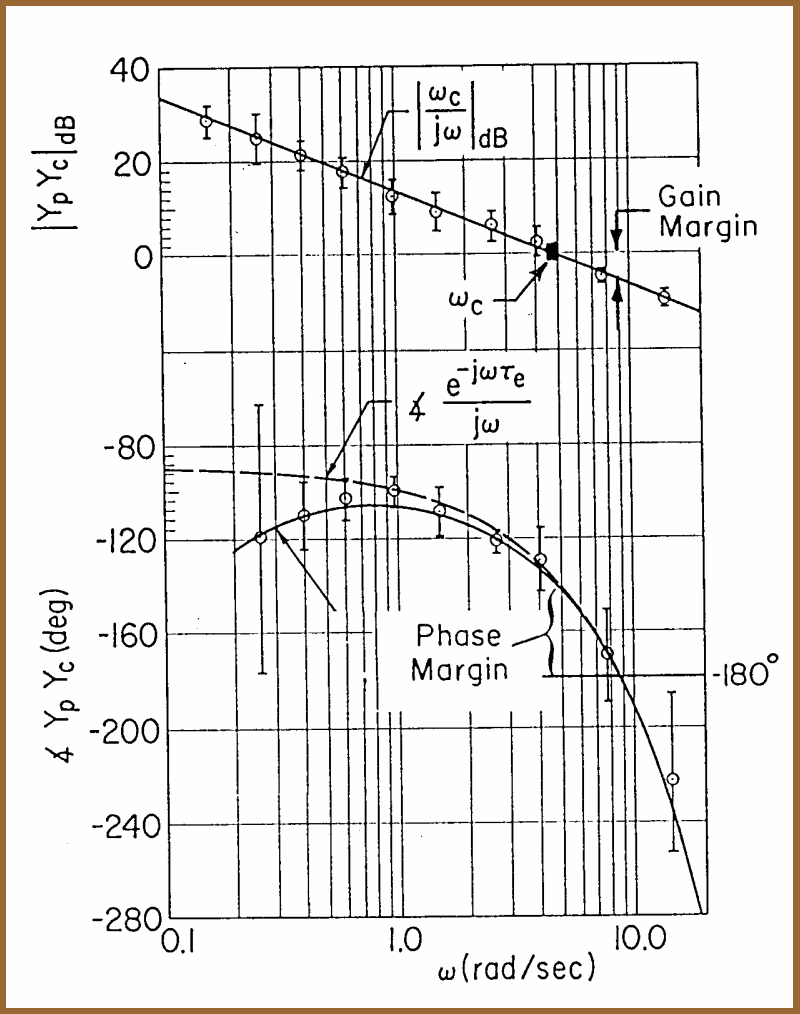
THE STRUCTURAL ISOMORPHIC HUMAN OPERATOR MODEL



THE CROSSOVER MODEL

- McRuer's Law:
  - For compensatory tracking, the pilot will act on the controlled element in such a way that the magnitude of the open-loop transfer function, Y_pY_c, will be approximately K/s (in frequency domain, $\omega_c/j\omega$) around the region of crossover

$$\underbrace{Y_p}_{\text{Pilot}}\ \underbrace{Y_c}_{\text{Vehicle}} \doteq \frac{\omega_c e^{-j\omega\tau_e}}{j\omega} \quad ; \quad \text{near } \omega_c$$

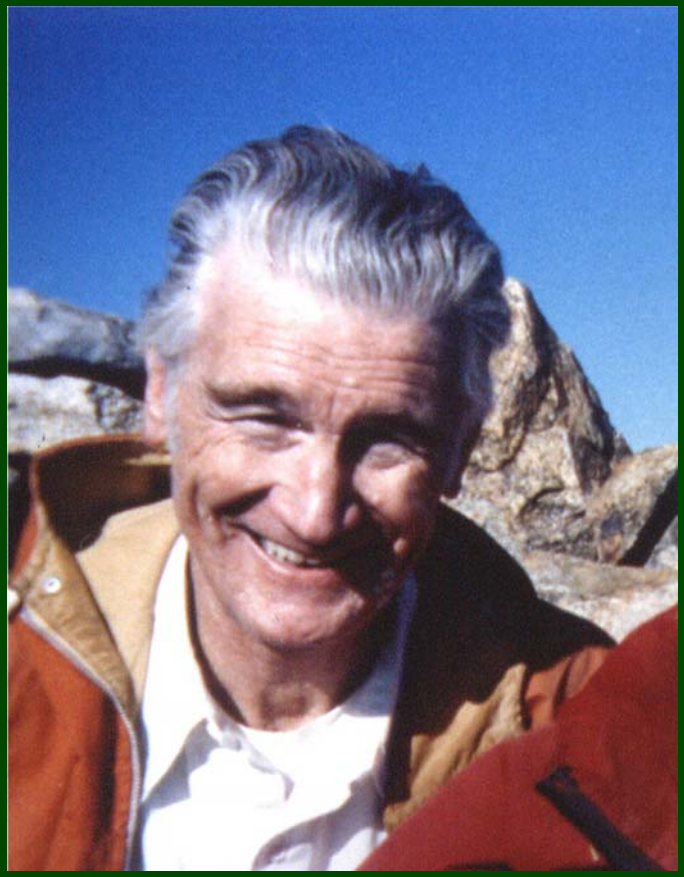


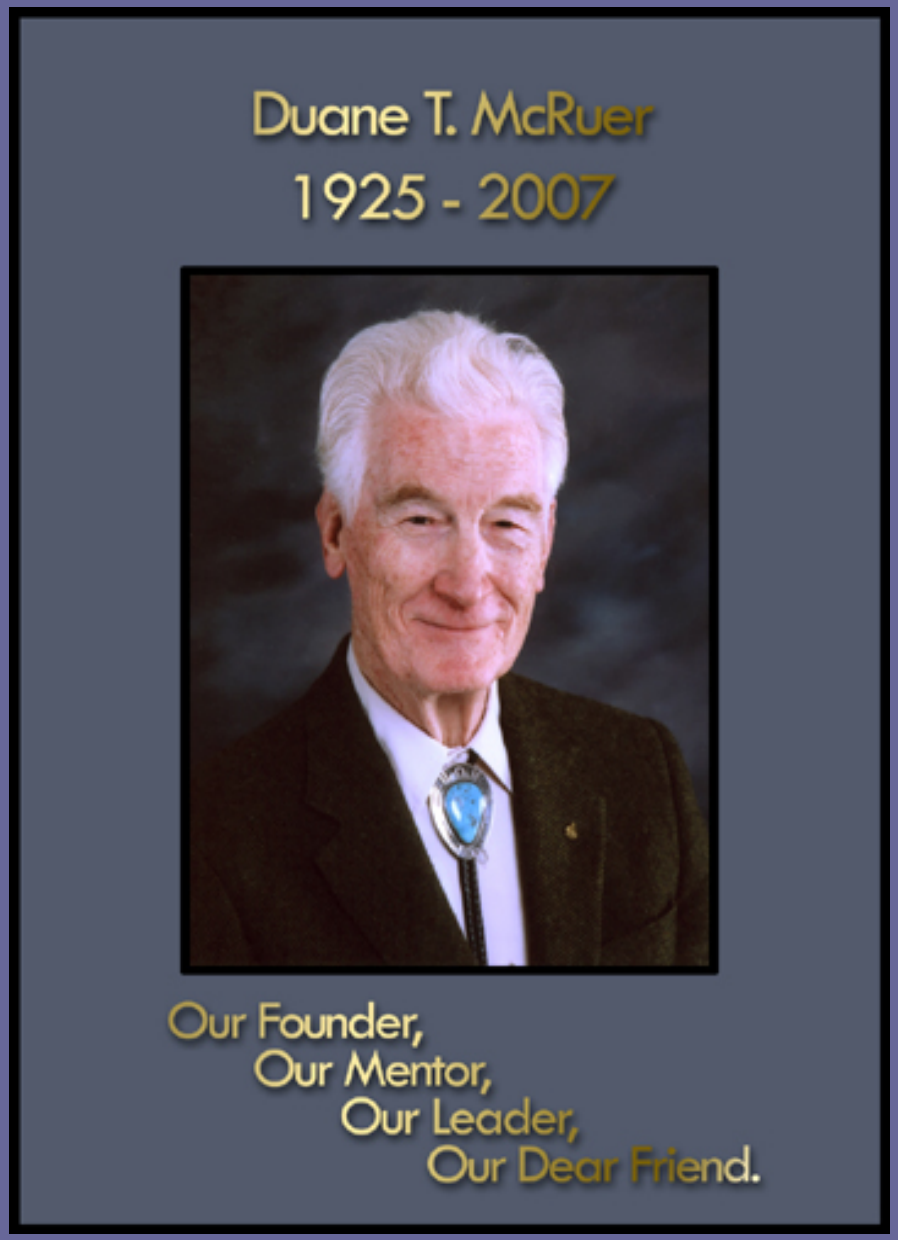
CAREER OVERVIEW

- Major Publications
  - *Aircraft Dynamics and Automatic Control*, Princeton University Press, Princeton, New Jersey, 1973.
  - *Analysis of Nonlinear Control Systems*, Wiley, 1961; reprinted Dover, 1971.
  - Over 130 archival technical papers and reports
- Societies
  - Member of National Academy of Engineering
  - Fellow/Honorary Fellow of IEEE, AIAA, SAE, HFES, American Association for the Advancement of Science, and California Council on Science and Technology
- Awards
  - Louis E. Levy Gold Medal of the Franklin Institute for theoretical analysis and empirical applications of systems engineering techniques to human control dynamics, 1960.
  - Mechanics and Control of Flight Award of the American Institute of Aeronautics and Astronautics for "outstanding accomplishment in the conception, development, and application of an analytical theory of aircraft handling qualities," 1970.
  - Alexander C. Williams, Jr. Award from the Human Factors Society for "outstanding contributions to several major system designs," 1976.
  - California Institute of Technology Distinguished Alumni Award for "outstanding achievement in his field," May 21, 1983.
  - NASA Distinguished Public Service Medal for “an exemplary record of personal service and leadership that has contributed maturely to the space and aeronautical missions of NASA," March 12, 1991.
  - SAE Aerospace Engineering Leadership Award “For his contributions as a pioneer and industry leader in the field of Aerospace Control Systems Engineering for the past 50 years.” September 30, 1998.
  - AIAA Aerospace Guidance, Navigation, and Control Award, 2004.

SIERRA CLUB ACTIVITIES

- Member of Angeles Chapter since 1962
- Climbed all 297 mountains in Sierra Peaks List
- Reached high points in 49 states
- Climbed 97 mountains in Desert Peaks List twice
- Received Angeles Chapter's Lifelong Service Award in 1998




Duane T. McRuer
1925 - 2007
Our Founder,
Our Mentor,
Our Leader,
Our Dear Friend.