AE-707: Module 1, Lecture 1: Introduction

Atri Dutta

Aerospace Engineering

COURSE OVERVIEW

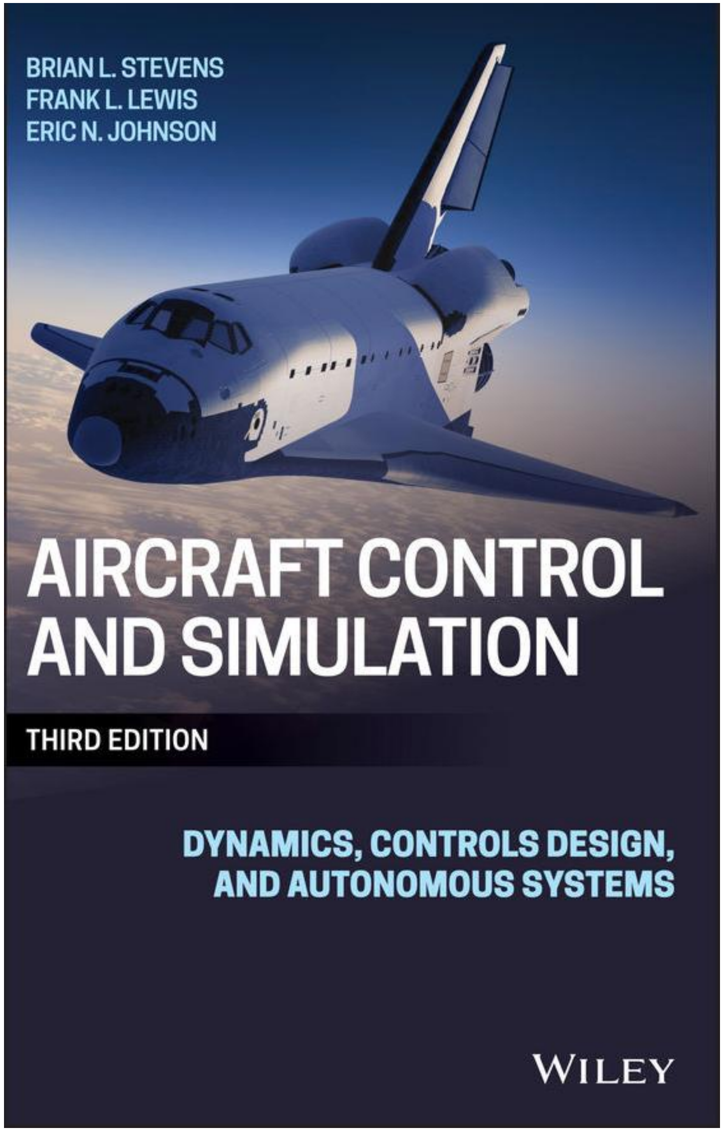
About the Course

- Required course for the Flight Dynamics and Control area of the AE MS/PhD program
- Topics covered
  - State-space model
  - Techniques: eigenvalues, eigenstructures
  - Robust control: accounting for uncertainties
  - Nonlinear control: feedback linearization
  - Applications: Mostly aircraft, a bit of spacecraft
- Pre-requisites

About the Instructor

- Atri Dutta (pronounced more like “Au”tri D“au”tt“o”)
- Background
- Office: WH 200-B
- Walk-in office hours: MW: 3 – 4 PM, T: 4 – 5 PM
- Email: atri.dutta@wichita.edu
- Phone: 316-978-5208

TEXTBOOK


BRIAN L. STEVENS
FRANK L. LEWIS
ERIC N. JOHNSON
AIRCRAFT CONTROL
AND SIMULATION
THIRD EDITION
DYNAMICS, CONTROLS DESIGN,
AND AUTONOMOUS SYSTEMS
WILEY

Performance Evaluation

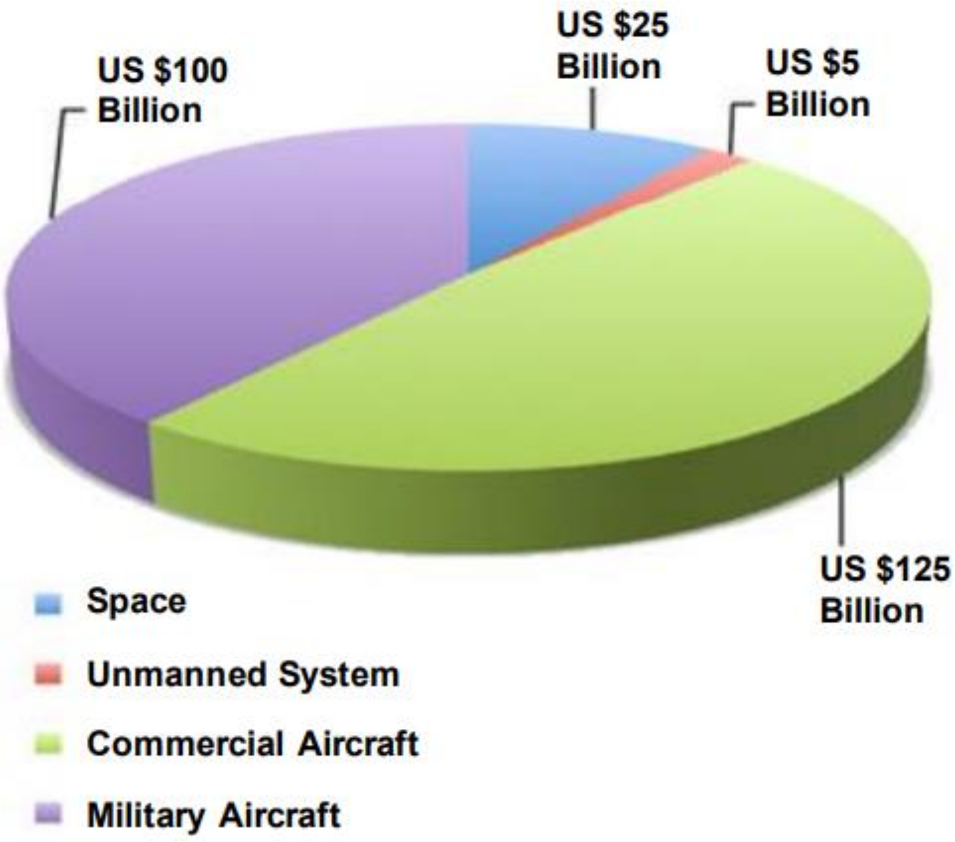
- Online quiz or assignment almost each week

- Three examinations: In person, closed-book, closed-notes, bring your own equation sheet and calculator (dates already posted in schedule)

- Exam questions designed to test concepts taught
  - Familiar problem statement
  - Problems solved in class or some variantion
  - Practice problems
  - Unfamiliar problem statement

Aerospace Control Systems

Aerospace Marketsize (2009 – 2019)



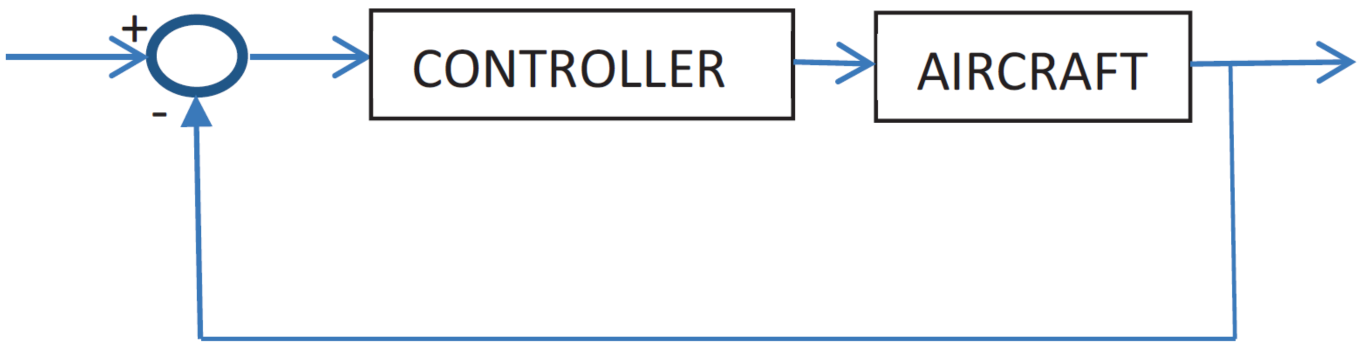
Aerospace Control Marketsize

- Aircraft demand will average around 1300 per year (Airbus and Boeing forecast 2009 – 2028); market value = $3 trillion
- UAVs spending double over the next decade, from $4.4 billion annually to $8.7 billion annually (Teal Group, 2009), market value = $62 billion
- Cost of GNC in an aircraft = 12% of total cost
- Cost of GNC in a satellite = 8 − 15% of the total cost
- The market for control technology is estimated at about $225 billion for aviation, $25 billion for space applications, and $5 billion for UAVs.

Ref: http://ieeecss.org/sites/ieeecss.org/files/documents/IoCT-Part1-01Aerospace.pdf

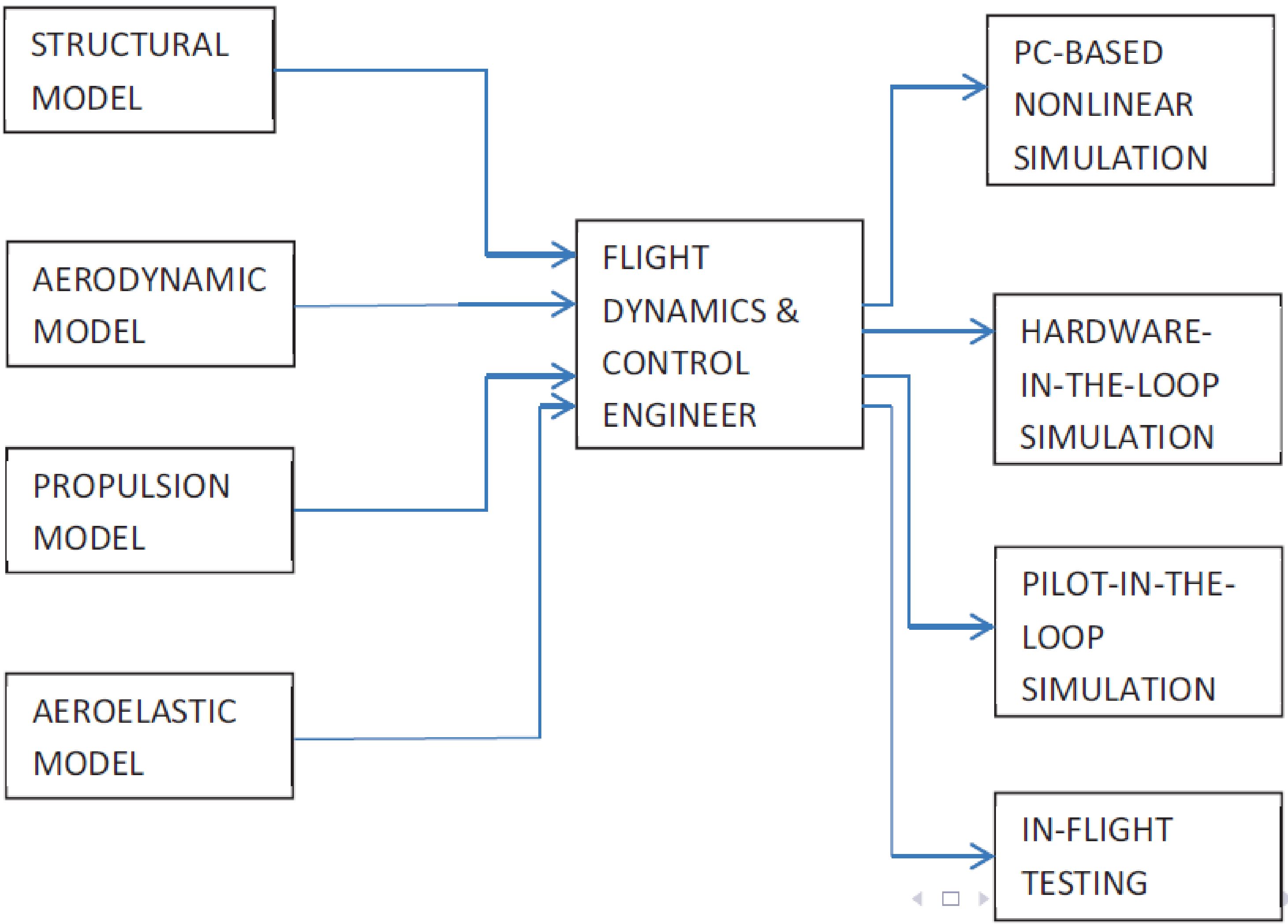
What is Control System? (1 of 2)

What is a Control System? (2 of 2)

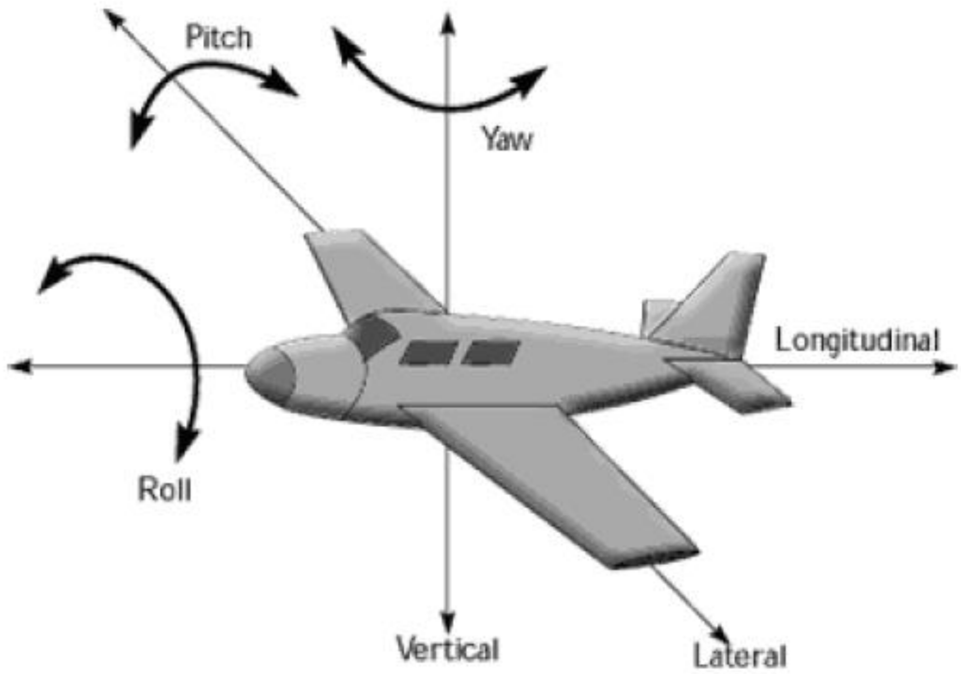


- Dynamic system that can be modified
- Desired behavior
- Actual behavior
- Corrections to the behavior of the dynamic system

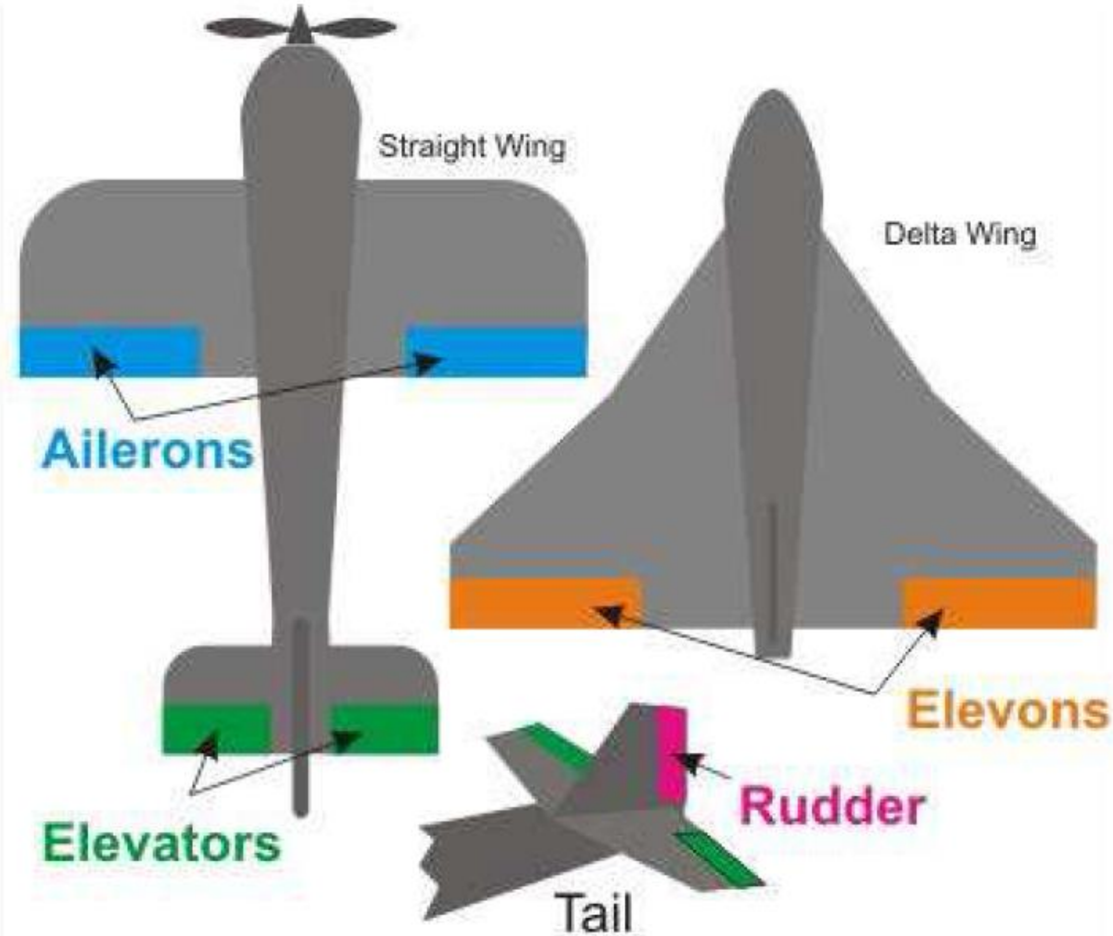
ROLE OF A CONTROL ENGINEER



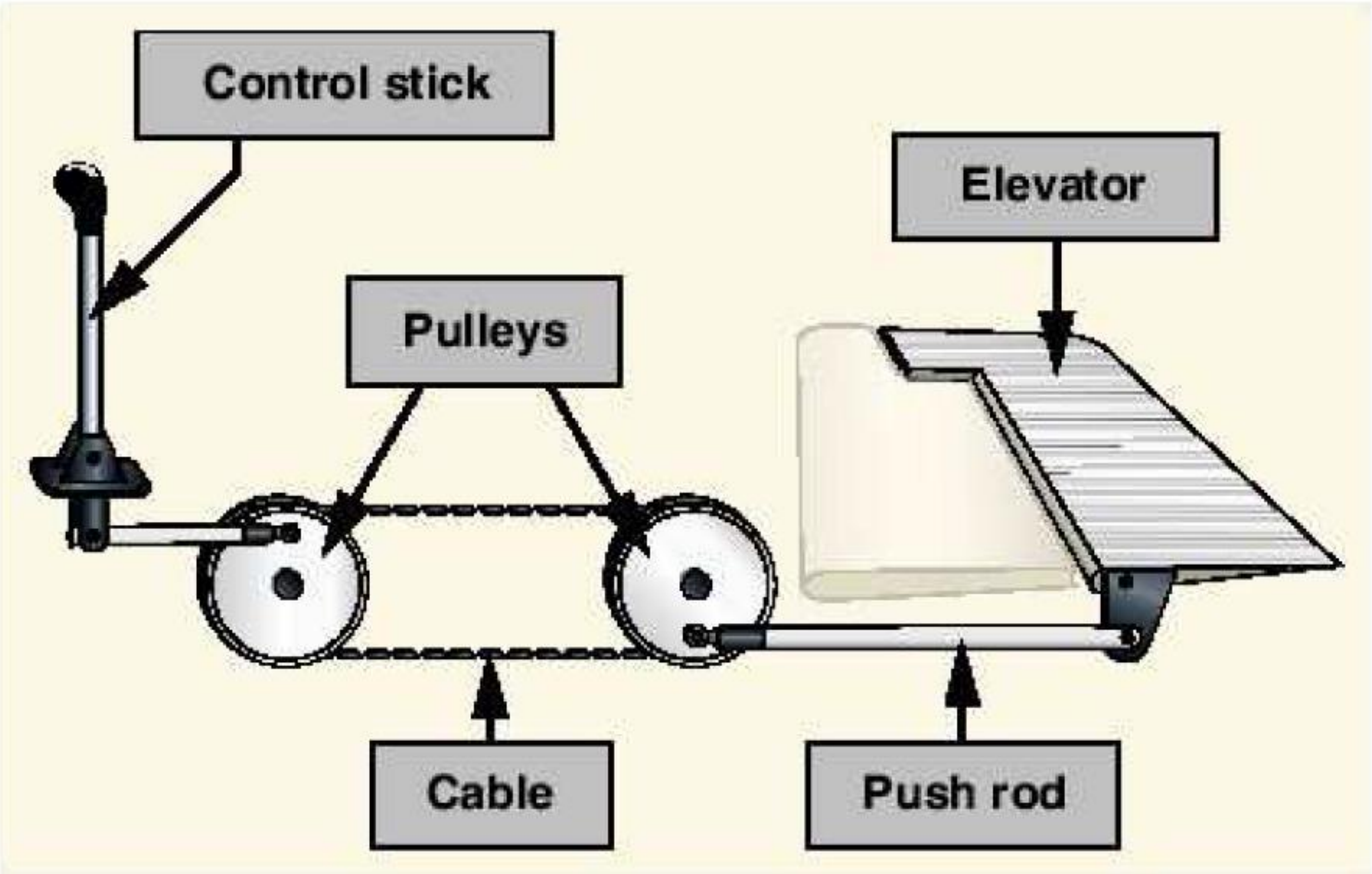
AIRCRAFT ATTITUDE ANGLES



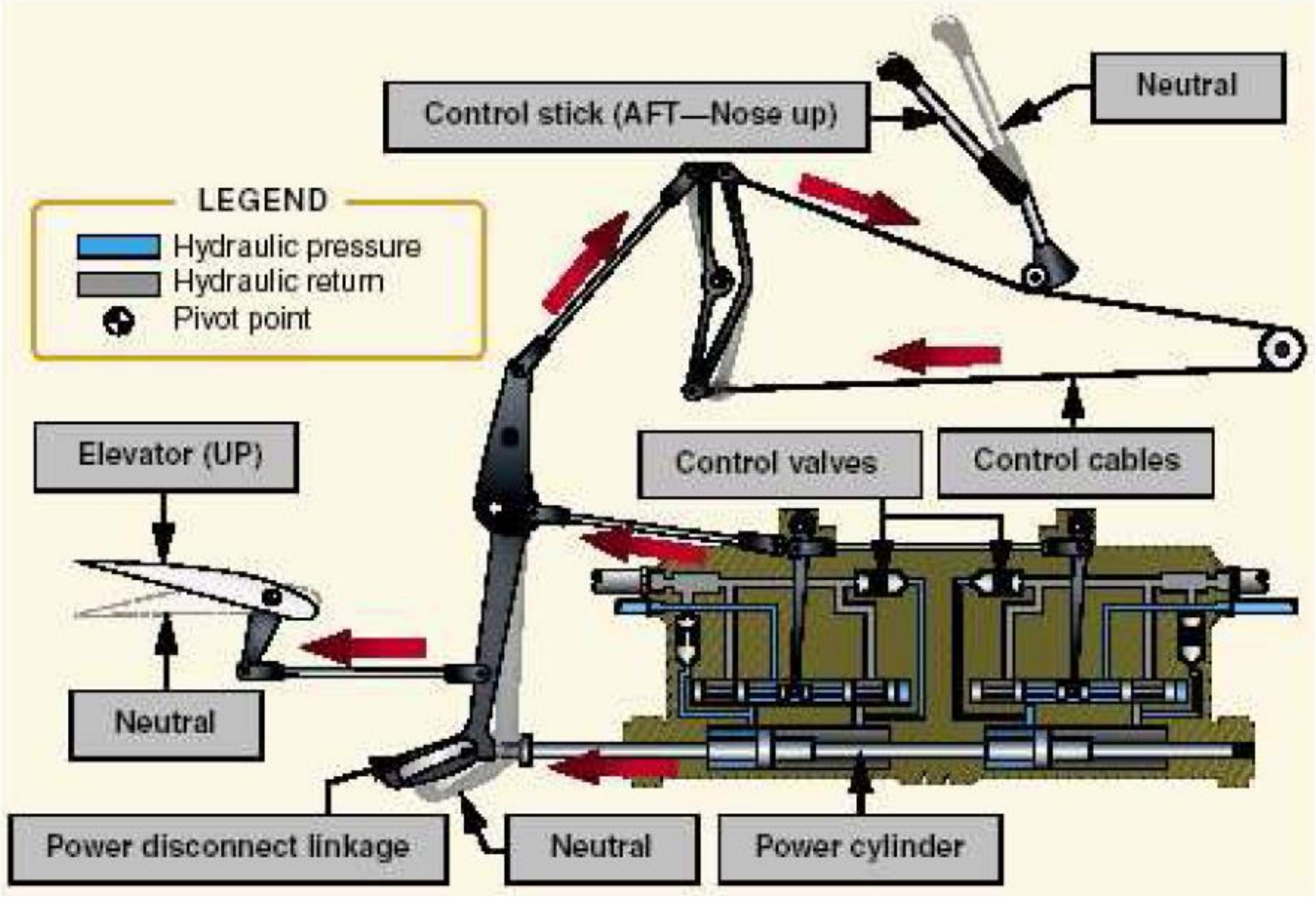
Aircraft Control Surfaces



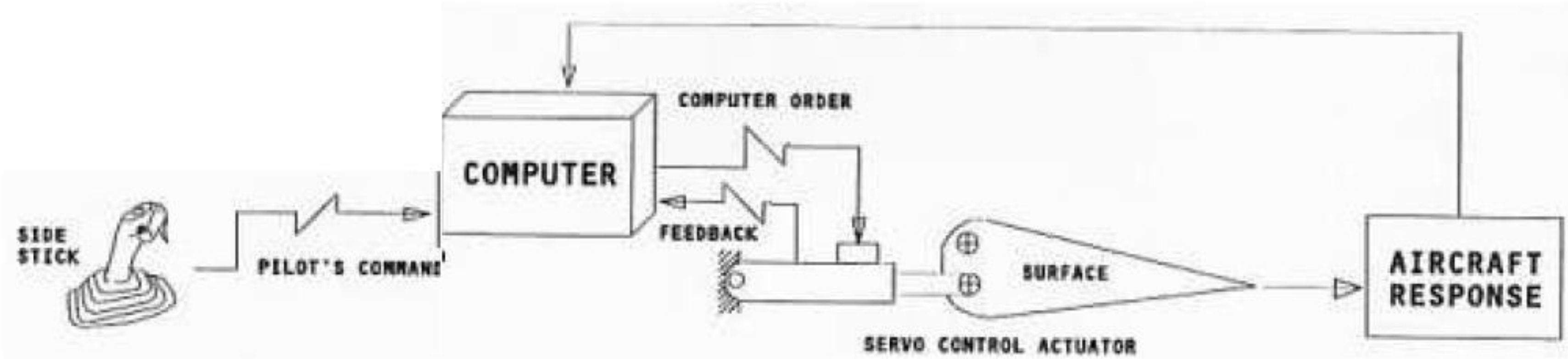
Mechanical Flight Control System



HYDRO-MECHANICAL FCS



FLY-BY-WIRE FCS



- Advantage: weight savings due to removal of mechanical linkages; allows use of different controller in different flight conditions
- Apollo program served as the catalyst for using fly-by-wire technology in aerospace applications!

History of FBW Use in Aircraft

- 1972: F-8 crusader jet fighter
- 1988: A320 series by Airbus (passenger aircraft)
- 1995: Boeing B-777
- 2007: Dassault Falcon 7X (business jets)
- Use in rotorcraft more recent
  - Sikorsky S92, Bell Relentless 525, Eurocopter
  - V-22 Osprey, Agusta-Westland AW609 (tilt-rotors)

Mathematical Models for Dynamic System

Linear Control Design

- What is a linear system?

- State-space model

$$\dot{\underline{\boldsymbol{x}}}(t) = \boldsymbol{A}(t)\underline{\boldsymbol{x}}(t) + \boldsymbol{B}(t)\underline{\boldsymbol{u}}(t)$$

$$\boldsymbol{A} \in \mathbb{R}^{n \times n}$$

$$\boldsymbol{B} \in \mathbb{R}^{n \times m}$$

- Feedback controller

$$\underline{\boldsymbol{u}}(t) = \boldsymbol{K}(t)\underline{\boldsymbol{x}}(t)$$

$$\boldsymbol{K} \in \mathbb{R}^{m \times n}$$

Nonlinear Control Design

- What is a nonlinear system?

$$\underline{\dot{\boldsymbol{x}}}(t) = \underline{\boldsymbol{f}}\left(t, \underline{\boldsymbol{x}}, \underline{\boldsymbol{u}}\right), \quad \underline{\boldsymbol{x}}(t_0) = \underline{\boldsymbol{x}}_0$$

$$\underline{\boldsymbol{x}} \in \mathbb{R}^n$$

$$\underline{\boldsymbol{u}} \in \mathbb{R}^m$$

- Feedback control

$$\underline{\boldsymbol{u}}(t) = \underline{\boldsymbol{u}}(\underline{\boldsymbol{x}}(t))$$

Challenges in Control Design

- Challenges
  - Unmodeled dynamics
  - Output may not have all state information
  - Feedback corrupted by noise