KING FAHD UNIVERSITY

Department of Aerospace Engineering

AE426: Flight Dynamics

Instructor

Dr. Ayman Hamdy Kassem

What is flight dynamics ?

Is the study of aircraft motion and its characteristics.

- Is it safe to fly?
- Is the pilot comfortable with it?
- Would it do its mission?

Flight Dynamics AE426

Is Wright brothers flight on December 17, 1903 really the first successful flight?

These hieroglyphic was found on the walls in a temple at Abydos in Egypt.

Course Description: Introduction to stability, performance and control of fixed-wing aircrafts.

Prerequisites: AE 220

Textbook: Nelson, R. C., *Flight Stability and Automatic Control*, 2nd Ed., McGraw-Hill Co., 1998.
References: Etkin, B., and Reid, L. D., *Dynamics of Flight: Stability and Control*, 3rd Ed., John Wiley & Sons, 1996.

Instructor:

Dr. Ayman Kassem

Office Building 22 – Room 161

Class Schedule: SMW (1:10 – 2:00).
building 24 - room 149

Office Hours: SMW (2:00-3:00) or by appointment.

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Course objectives:

•To introduce students to the fundamental concepts of atmospheric flight dynamics.

•To allow students to analytically estimate static and dynamic stability derivatives.

•To enable students to study and predict aircraft performance.

•To allow students to study the stability of longitudinal and lateral motions using the linearized equations of motion.

•To enable students to control aircraft using the root locus method.

Course Outline	**Weeks (approximately)**
Introduction	1
Static Stability (Chapter 2)	2-4
Aircraft Equations of Motion (Chapter 3)	5-6
Aircraft Performance (Handouts)	7-8
Longitudinal Motion (Chapter 4)	9-10
Lateral Motion (Chapter 5)	11-12
Introduction to Control Theory (Chapter 7)	13
Aircraft Autopilot Design Using Control Theory (Chapter 8)	14-15
Review and final exam	16

Course outcomes:

Outcome#1: Students will demonstrate a good understanding of flight dynamics. (**Objectives 1-2**)

Outcome#2: Students will demonstrate a good understanding of flight performance, stability, and control. (**Objectives 2-5**)

Outcome#3: Students will demonstrate the ability to use MATLAB® as a tool for matrix manipulations and dynamic simulation. (**Objectives 2-5**)

Outcome#4: Students will demonstrate the ability to work as a team in a project, give a professional PowerPoint presentation and write a technical document. (**Objectives 1-5**)

Project:

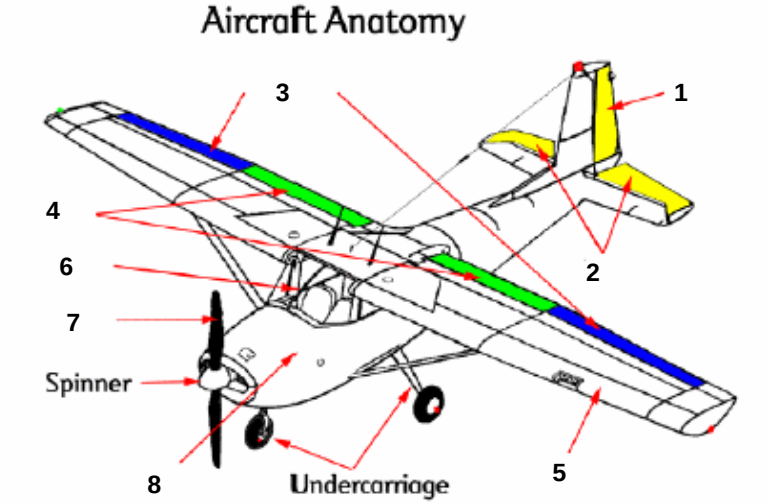
• You are required to evaluate the stability and performance characteristics of actual airplanes.

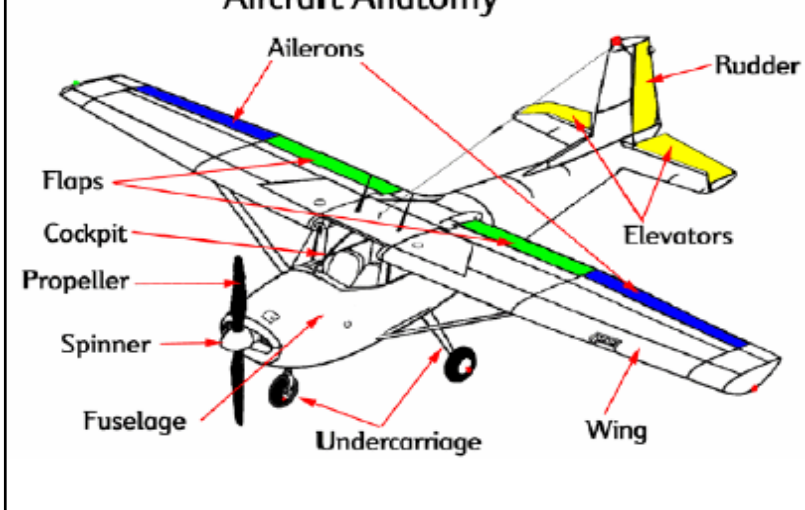
• Each team selects an airplane, obtains its geometric and inertia data, computes its stability derivatives, and studies the longitudinal and lateral-directional motions.

• submit work-in-progress report at mid-semester and make a final report and oral presentation at the end of the semester.

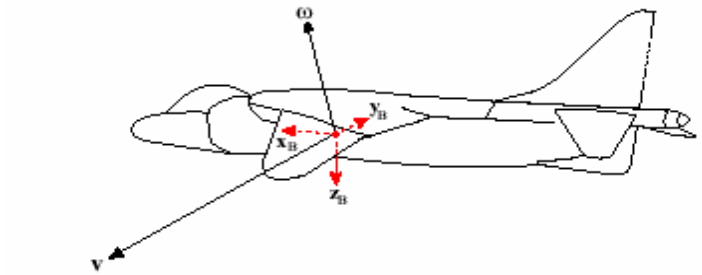
Evaluation Methods:

[1] Homework	10%
[2] Attendance	10%
[3] Midterm exam 1	15%
[4] Midterm exam 2	15%
[5] Project	20%
[6] Final Exam	30%





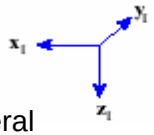
AXES (BODY and INERTIAL)

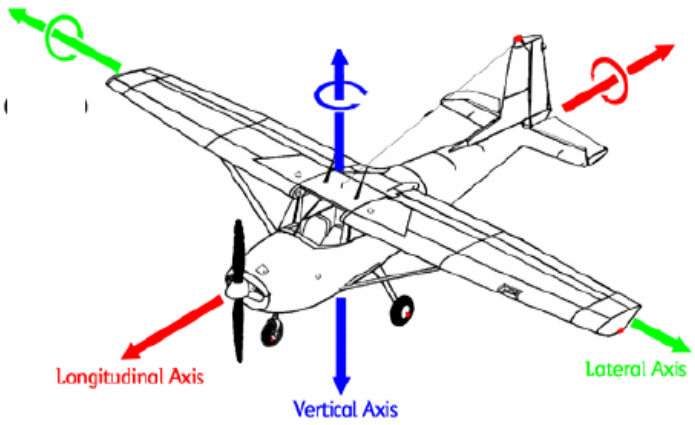


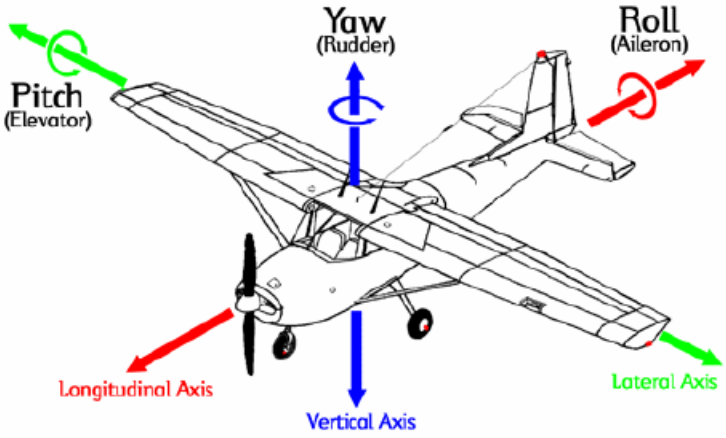
X_B pointing through the nose of the aircraft (longitudinal axis).

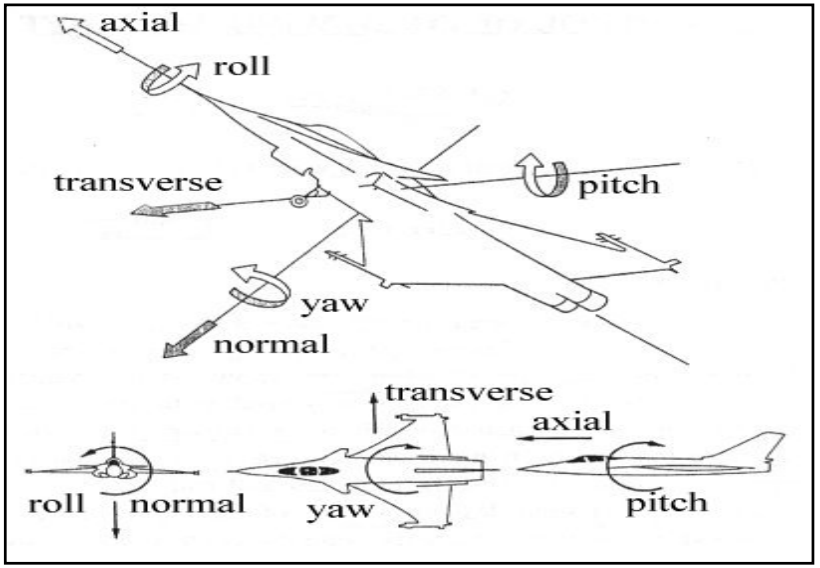
Z_B pointing down (directional axis).

Y_B pointing to the right wing (lateral axis).









Review of Aircraft Metrics

- Wing Area = S
- Wing Span = b
- Mean Chord = $\bar{c} = S/b = (c_t + c_r)/2$
- Root Chord = $c_0 = c_r$
- Tip Chord = c_t
- Taper Ratio = $\lambda = c_r/c_t$
- Aspect Ratio = $AR = b/\bar{c} = b^2/S$

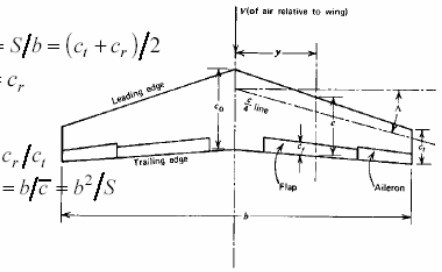


Figure 3.1 Top view of a wing planform.

Main Topics

- **Performance.**
- **Stability.**
- **Control.**

Main Topics

- **Performance.**
  - Customer related.
    - How high will it go ?
    - How Fast?
    - Fuel consumption?
    - Range?
- **Stability.**
- **Control.**

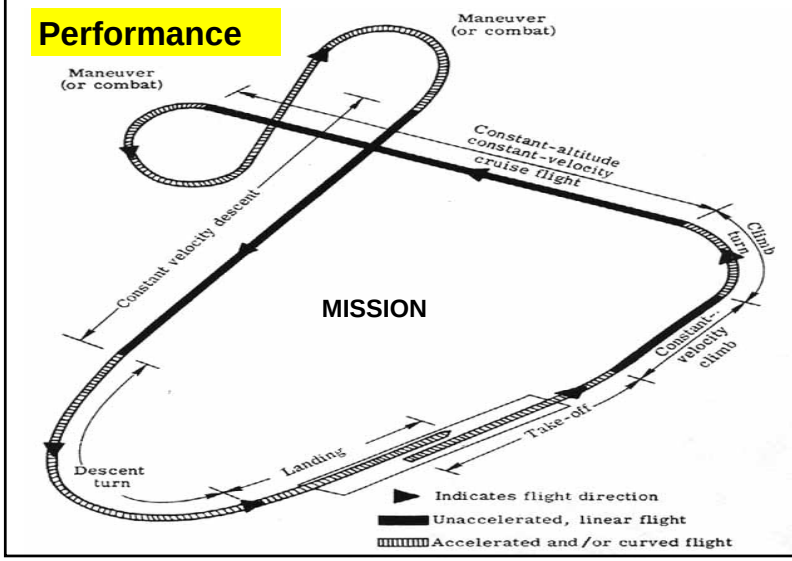
Main Topics

- **Performance.**
- **Stability (Static and Dynamic)**
  - Pilot related.
    - Is it stable?
    - Can it do this maneuver? How easy?
    - Flying qualities.
- **Control.**

Main Topics

- **Performance.**
- **Stability (Static and Dynamic).**
- **Control.**
  - Engineer related. (This is your work!!)
    - Control theories (classical and modern).
    - How to make the A/C stable?
    - Improving flying qualities.
    - Company secrets.

Performance



Performance

- It is how the aircraft will perform its job.
- what are Performance characteristics?
  - Range.
  - Rate of climb.
  - Take off and landing distances.
  - Flight path optimization.

Stability & Control

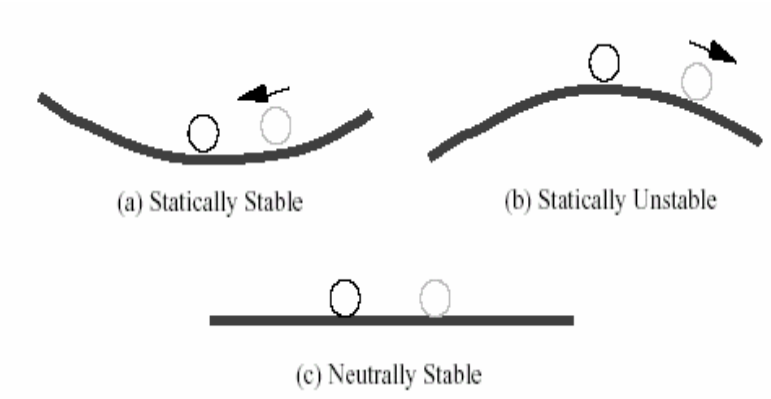
Stability

- Result of small disturbances from equilibrium which arise at ***random*** from external loads. It is categorized as ***static*** or ***dynamic***.
- Stability is a ***characteristic of the vehicle dynamics*** which is independent of the pilot's actions.

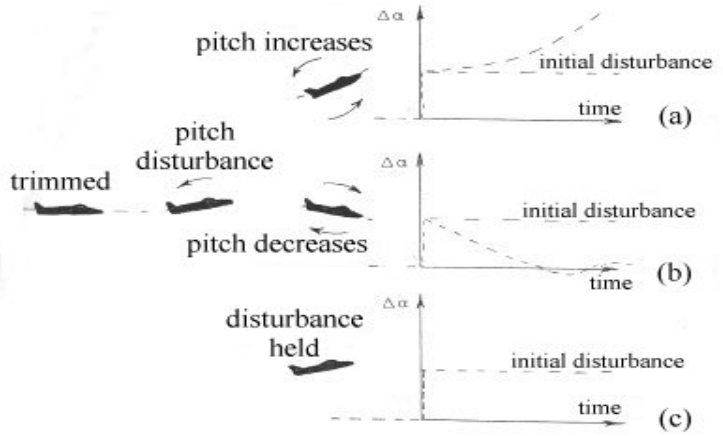
Control

- Response of aircraft to ***intentionally*** applied forces/moments which causes aircraft to deviate from initial equilibrium condition in a desired fashion.
- Control relates to a ***pilot's interaction*** with the aircraft.

Static Stability

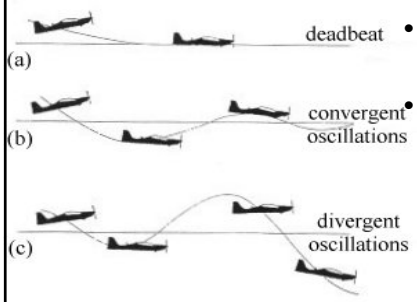


Longitudinal Static Stability



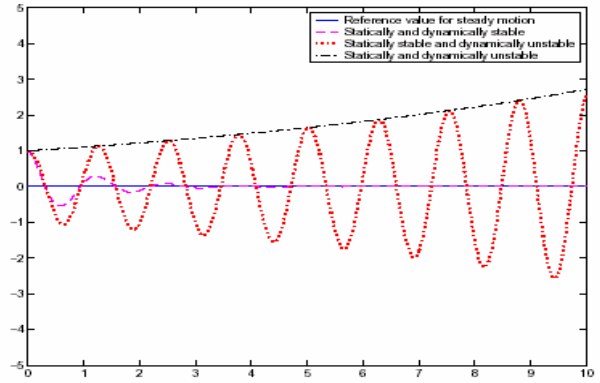
Dynamic Stability

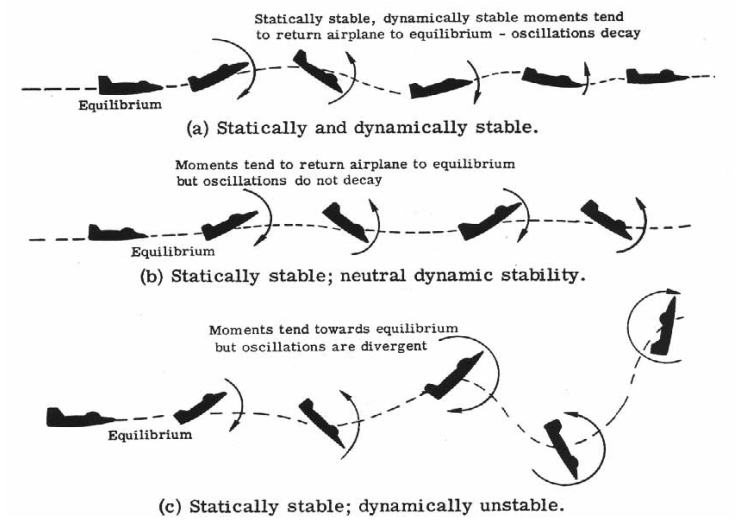
- For dynamic stability, motions have to be ***convergent*** or ***damped out***. (The vehicle will return to its original equilibrium condition after some interval of time and settle there).



- If divergent then dynamic instability exists.
- Cases (a) & (b) here are longitudinally dynamically stable, case (c) is longitudinally dynamically unstable (all are statically stable).

It is important to observe that a ***dynamically stable airplane must always be statically stable***. On the other hand, a ***statically stable airplane is not necessary dynamically stable***.





Our particular interest are the following questions:

- Can the aircraft perform its mission? How reliable?
- How much effort is required from the pilot ?
-

To do that we need to know :

- Aircraft anatomy especially controls (aileron, rudder, throttle, thrust vectoring, etc.) ***What parts do the job?***
- Aircraft equations of motions. ***How is it done?***
- Automatic control theory. ***How to do it better?***