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?

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

Prerequisites: AE 220


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.
Email  Akassem@kfupm.edu.sa

### 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 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](#))

### Course Outline

<table>
<thead>
<tr>
<th>Course Outline</th>
<th>Weeks (approximately)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Static Stability (Chapter 2)</td>
<td>2-4</td>
</tr>
<tr>
<td>Aircraft Equations of Motion (Chapter 3)</td>
<td>5-6</td>
</tr>
<tr>
<td>Aircraft Performance (Handouts)</td>
<td>7-8</td>
</tr>
<tr>
<td>Longitudinal Motion (Chapter 4)</td>
<td>9-10</td>
</tr>
<tr>
<td>Lateral Motion (Chapter 5)</td>
<td>11-12</td>
</tr>
<tr>
<td>Introduction to Control Theory (Chapter 7)</td>
<td>13</td>
</tr>
<tr>
<td>Aircraft Autopilot Design Using Control Theory (Chapter 8)</td>
<td>14-15</td>
</tr>
<tr>
<td>Review and final exam</td>
<td>16</td>
</tr>
</tbody>
</table>
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).
Main Topics

- Performance.
- Stability.
- Control.

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

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

• 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

(a) Statically Stable  (b) Statically Unstable  (c) Neutrally Stable

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?*