SYLLABUS

AME 532a: Flight Vehicle Stability & Control
Spring Semester, 2024
(Updated 2024-01-07)

John McArthur
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Course Sections: 28896R and 29066D
Course Unit: 3 Units
Prerequisite: AME 459, Flight Mechanics or equivalent is recommended preparation.
AME 451, Linear Controls or equivalent is recommended preparation.
(Or with a special approval by the Instructor)

Class Hours: Tuesday, 6:00 pm to 8:30 pm
Class Location: USC Building Two (SCT 1501K) and Online
Office Hours: Thursday, 5:00-7:00 pm – On Webex (see virtual meetings on class website)
And BY APPOINTMENT – call or email
We can meet in coffee shop or other location (depending on pandemic status)
We can meet virtually via phone and/or zoom
I will try to be available every Tuesday 5:00-6:00 as well, but no guarantees
Coordinate ahead of time to meet with me

Teaching Assistant: N/A

Course Background:
This course will cover the applications of control system design to aircraft and missiles. The class
assumes a basic understanding of fluid dynamics, along with a significant understanding of flight
vehicle performance and dynamics. The class will cover the development of fully non-linear 6 degree
of freedom simulators, linearization of the equations of motion, and the application of classical and
state space control design to contemporary aircraft designs. The class will employ Matlab/Simulink
(including the Control System Toolbox) to problems of inner loop control augmentation, outer loop
designs, and autonomous flight.

Course Components:
Students’ learning experience in this course will come from three (3) interrelated components:

- Textbook Reading

The class will use the textbook, ― Aircraft Control and Simulation, Third Edition, by Brian
L. Stevens and Frank L. Lewis. The class will focus on the later parts of the book which
covers control system and autopilot design. The earlier parts of the book covering
conventions, dynamics, aerodynamics, performance, and basic flight mechanics will be
briefly reviewed to ensure all students understand this background material. The majority of
the class will focus on chapters 4, 5 and 6 plus additional supplemental material.
• **Classroom Lecture**

Lectures will discuss the relevant theories, methodologies, processes, tools, and practice used in the aerospace industry to understand and analyze aerospace vehicle flight control. The lectures will cover Stevens and Lewis chapters 1-6 and will bring in additional material (i.e., PowerPoint slides), drawn from many reference books and technical papers.

• **Supplementary Reading and Projects**

Additional reading assignments from various reference resources will be given throughout the semester as additional required reading. All students are encouraged to prepare for the lectures by reading the assigned chapter and any additional required reading prior to the lecture. There will be one project assigned which consists of an autopilot design and verification.

**Office Hours:**

Office hours set above and also by appointment, before or after class. Make an appointment by phone, text or email.

**Required Textbook:**


**Recommended Reference Books:**

- *Linear System Theory and Design*, by Chi-Tsong Chen, Oxford University Press

The instructor may recommend additional reading materials and website reference resources during the semester whenever appropriate.

**Course Website:**

Students’ learning of this course is supplemented by use of the USC DEN Desire 2 Learn instruction system ([http://den.usc.edu/](http://den.usc.edu/)). All registered students have access to this website and should go to AME532. The course website structure is implemented to support the specific organization of the course instruction as described in this syllabus. All students should browse around the entire site to familiarize themselves with various areas and functions of this course website.

- Announcements -- important announcements of this course.
- Syllabus -- contains an up to date copy of the class syllabus.
- Assignments -- each homework and reading assignment will be posted along with dates for
quizzes and exams.

- Content – pdf copies of selected lecture material.
- Discussions – a place for the students to share their thoughts about interesting subjects with the class
- Groups -- all communication tools, including emails and roster.
- Websites – links to reference material.

Course Grading:
Students will be graded according to the following scheme:

- 10% -- Classroom/Lecture Participation
- 25% -- Homework
- 25% -- Project/Presentation
- 20% -- Mid-Term Exam
- 20% -- Final Exam

Each of the above grading components is described in more details below.

Grading Components:

- Classroom/Lecture Participation (10%)

The intent is for AME532 to be an involved class. Class participation is more than just counting the attendance (which is also important). The students are encouraged to ask questions, to complete reading assignments and to participate in discussions. This can be done during class, on-line, or via the homeworks and projects.

- Homework (25%)

Homework assignments will be posted on a regular basis. Students are expected to submit homework on time. Late homework will not be accepted unless there is a valid and credible excuse.

- Project (25%)

A project will be assigned early in the semester. The project objective will be to build a 6 degree of freedom simulator and visualization with student designed autopilot in the loop. This part of the project should be built through homework assignments each week. The project should have at least one unique element besides the homework built aspects that goes beyond what was required in the homeworks. The projects will be presented/demonstrated to the class during the final meeting of the semester, and a brief report on the project will also be written and submitted.

- Mid-Term (20%) and Final (20%) Examinations

Both the mid-term and the final will follow the same format. They will be open book, open note, and open matlab. But you should be aware that the book is big, and you’ll have lots of notes, and the tests have a lot of questions and work involved. So, spending time searching through the book and/or notes, or writing matlab scripts, is not a very good use of your time. You’ll need to be able to answer most questions without digging through your tools, just like
when you get to work at a job. While you can have your computer available, you are not allowed to have any internet searching available (google, bing, yahoo, etc) or any AI assistance (chatGPT, etc) or any other sort of outside help from human or non-human sources. Just Matlab.

Make-up exams will only be offered when there is proven need by the student. Should you have to miss your exams, an individual makeup exam will be scheduled with the instructor.

Academic Integrity:

"The Viterbi School of Engineering adheres to the University's policies and procedures governing academic integrity as described in SCampus. Students are expected to be aware of and to observe the academic integrity standards described in SCampus, and to expect those standards to be enforced in this course."

Students with Disabilities:

Any Student requesting academic accommodations based on a disability is required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP. Please be sure the letter is delivered to me (or to TA) as early in the semester as possible. DSP is located in STU 301 and is open 8:30 a.m. - 5:00 p.m., Monday through Friday. The phone number for DSP is (213)740-0776.
Course Schedule (subject to change):
The Instructor reserves the right to change this schedule and topics during the semester.

<table>
<thead>
<tr>
<th>Week No</th>
<th>Date</th>
<th>Class Subject</th>
<th>Text Chapter</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>24/01/16</td>
<td>NED/ECEF DCM. Purposes of DCM. 3D Rotations as Vector and Magnitude. Quaternions. Use of Quaternions. Time Varying Coordinate Systems.</td>
<td>1</td>
<td>HW 02 Assigned</td>
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<tr>
<td>3</td>
<td>24/01/23</td>
<td>Kinematics: Translational/Rotational. Translational Dynamics. Free Body Simulation in Simulink Example.</td>
<td>1, 2</td>
<td>HW 01 due HW 03 Assigned</td>
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<tr>
<td>4</td>
<td>24/01/30</td>
<td>Rotational Dynamics. Demo of Free Body Simulation with Visualization.</td>
<td>1, 2</td>
<td>HW 02 due HW 04 Assigned</td>
</tr>
<tr>
<td>5</td>
<td>24/02/06</td>
<td>State Equations. Non-Linear State Space Model. Linear State Space Model. Linearization (trim/linmod).</td>
<td>1, 2, 5</td>
<td>HW 03 due Project Progress Update 1 due HW 05 Assigned</td>
</tr>
<tr>
<td>6</td>
<td>24/02/13</td>
<td>Outputs. Wind and Stability Coordinate Systems. Actual &quot;wind&quot;. Forces and Moments from Static Aero. Control Surfaces. Model Layout</td>
<td>2, 3</td>
<td>HW 04 due</td>
</tr>
<tr>
<td>7</td>
<td>24/02/20</td>
<td>Forces and Moments from Moving Aero. Stall. More about Linearization (trim/linmod). Details of Simulation. Simulation Methods.</td>
<td>2, 3</td>
<td>HW 05 due HW 06 Assigned</td>
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<tr>
<td>8</td>
<td>24/02/27</td>
<td>Midterm Exam - First 1 hour Second part of class – Simulation Methods. Implementing the Simulation.</td>
<td>2, 3</td>
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<tr>
<td>9</td>
<td>24/03/05</td>
<td>Details on using Matlab's trim and linearization. General Dynamic Stability Analysis. Details on Trim/Linearize theory. Numerical Linearization. Unmodelled Dynamics. Modal Stability and Dynamics.</td>
<td>2, 3</td>
<td>HW06 due</td>
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<tr>
<td>10</td>
<td>24/03/12</td>
<td>SPRING BREAK</td>
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<td>12</td>
<td>24/03/26</td>
<td>Transfer Functions. Classical Controls. Role of the Autopilot and Intro to Modern Methods.</td>
<td>4, 5</td>
<td>HW 08 Assigned</td>
</tr>
<tr>
<td>13</td>
<td>24/04/02</td>
<td>Simple Roll Example (-D, P-D, and PI-D). Controllers with States. Eigenvalue Analysis. Linear Quadratic Regulators. Internal Rotating Components. Propeller Modelling.</td>
<td>4, 5</td>
<td>HW 07 due</td>
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<tr>
<td>14</td>
<td>24/04/09</td>
<td>Longitudinal Static Stability Analysis. Actuator Models. Decoupling Controllers and Eigenvector Control. Discrete Controllers.</td>
<td>5, 6</td>
<td>HW 08 due</td>
</tr>
<tr>
<td>15</td>
<td>24/04/16</td>
<td>Sensor Models. Estimators including LQE or Kalman Filters. Modelling for Motors and Batteries.</td>
<td>5, 6</td>
<td>Project Final Report (individual) due</td>
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<tr>
<td>16</td>
<td>24/05/07</td>
<td>Project Presentations</td>
<td></td>
<td>Project Presentations due and presented</td>
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Final Exam (two hours): 7:00 to 9:00 pm (typically, exact time TBD)