AE 3531
Control System Analysis and Design

Health and well-being

- Georgia Tech and the School of Aerospace Engineering understand that many students experience stress through a variety of academic, financial and personal experiences. We value you and want to make you aware of resources available to you should you need them. Your well-being and mental health are important, and we are here for you.

- Center for Assessment, Referral and Education (CARE) https://care.gatech.edu/
- Campus Police (any emergency): 404-894-2500 http://www.police.gatech.edu/
- Counseling Center:404-894-2575 https://counseling.gatech.edu/
- Dean of Students Office:404-894-6367 https://studentlife.gatech.edu/
- Georgia Crisis and Access Line:800-715-4225
- National Suicide Prevention Lifeline:
  - 800-273-TALK (8255) https://suicidepreventionlifeline.org/
- Crisis Text Line: Text HOME to 741741
- VOICE: Victims Survivor Support:
  - 404-385-4464 (or 4451) http://healthinitiatives.gatech.edu/well-being/voice
- Stamps Health Services https://health.gatech.edu/contact

Other resources:

- Office of Disability Services
- Georgia Tech Honor Code
- Student-Faculty Expectations Agreement
- VI. Scholastic Regulations, I. Course Requirements

Course structure, expectations

- We will follow the USG/Georgia Tech general health/COVID-19 protocols, etc.
- Grading will be based on HW assignments, a midterm exam, as well as a final exam
- We will adhere to the Georgia Tech honor code

Course overview

- Professor Chance McColl, PhD chance@gatech.edu | (404) 290-8841 (cell).
- Dr. McColl is a Professor of the Practice at Georgia Tech (2015-present).
- Dr. McColl has 30+ years' experience as an aircraft structural loads engineer. He serves as Vice President of TDA (Technical Data Analysis, Inc.; Virginia, Maryland, and Georgia) and oversees TDA's loads engineering (fixed wing, rotary wing, UAS) and software development efforts for US military (USN, US Army, USAF) and govt (NASA, NOAA), international (Australia, Canada, Germany, Norway, Greece, Netherlands, Portugal, South Korea) and industry (General Atomics, Sikorsky, Northrop Grumman, Sierra Nevada Corporation, etc.).
- Dr. McColl has been with TDA since 2001. Prior to that, he was a lead loads engineer, both at Boeing and Lockheed Martin.
- Dr. McColl received his BS in Aerospace Engineering from the University of Colorado at Boulder and his MS and PhD in Aerospace Engineering from Georgia Tech. Dr. McColl has served as co-chair of the Georgia Aerospace Policy Working Group and as a member of the Georgia UAS Working Group.
- Over the past 21+ years, Dr. McColl has taught numerous aircraft external loads and aeroservoelastic control courses for clients such as the US Navy, USAF, General Atomics Aeronautical Systems, Sierra Nevada Corporation, and Korean Aerospace Industries.

Course details

- **Expectations**
  - **Georgia Tech Honor Code**
  - See "***Course structure, expectations***", above
  - All lectures will be recorded and posted to Canvas immediately thereafter
  - You're responsible for: (1) all material discussed in lectures; (2) all material posted to Canvas
  - Pre-req: System Dynamics
  - **Matlab will be used**
  - Homeworks/exams will be posted / submitted / graded via Canvas
- **Textbook: *Control System Analysis and Design (4th ed.)*, Ogata** (ISBN: 9780131424623)
- Acknowledgements: course content includes a few sources, but primarily Ogata (we'll be moving around quite a bit in Ogata)
- Some notes will be provided electronically (e.g., some textbook annotations); others will be hand-written in lecture; you'll be required to copy/screenshot these yourself

Grading scheme

A/B/C/D = 90/80/70/60

- 50% Homework
- 25% Midterm exam*
- 25% Final exam*

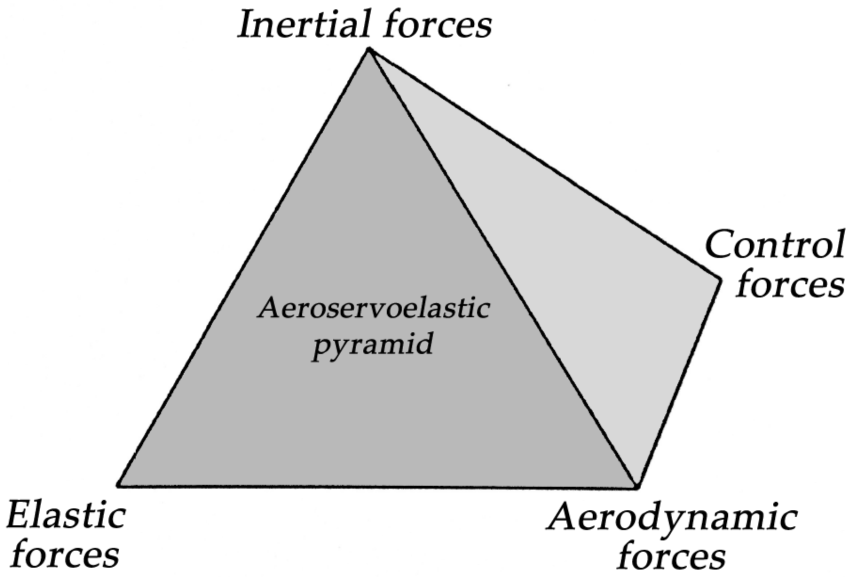
*** Both exams will be take-home and open book/open notes/partially Matlab-based (more details to follow)**

- I always add one point
  - An 89 becomes a 90 (A)
  - An 88.5 becomes an 89.5 (B)
  - A 79 becomes an 80 (B)
  - A 78.9 becomes a 79.9 (C)
  - etc.
- **Beyond that, no further grade changes made**

- All homeworks will be submitted electronically via Canvas
  - **You have 1 week from receipt of graded homeworks and the midterm exam to discuss any grade changes; after that 1 week, all grades are final**
- Some (but not all) notes will be provided electronically (e.g., some textbook annotations)

Objectives

- Obtain the basic theory and practice of control system analysis and design
- Focus on aerospace applications
- **Big picture:** aeroservoelasticity (ASE): the interaction between inertial forces, aerodynamic forces, a flexible (elastic) aircraft structure, and a **control system**
- Automatic control system (ACS) used for:
  - Aircraft handling and stability
  - Flight performance and ride quality throughout the flight envelope
  - Loads reduction and service life improvement
  - Examples: autopilot for altitude hold; yaw damper for lateral-directional control



Learning outcomes

Students will gain a mastery level understanding of:

1. Analysis of Controlled Linear SISO Systems
2. Design of Controlled Linear SISO Systems

Students will gain exposure to:

1. Analysis of Controlled Linear MIMO Systems
2. Design of Controlled Linear MIMO Systems
3. Relevant Application to Aerospace Systems

Eight (8) key concepts for this course

(1) Time domain, s-domain/ frequency domain
- Laplace transforms; inverse Laplace transforms
- Expressing / assessing system response in the complex plane $(s = \sigma + j\omega)$

(2) Open-loop - to- closed loop systems
- “Closing the loop”
- Canonical form(s)

(3) System transfer functions
- Open-loop, closed-loop
- System zeros, poles
  System gains

(4) System stability
- Static
- Dynamic
- Relative

(5) Root locus analysis
- System stability assessment
- Pole placement

(6) Controller, compensator design
- System stability; time domain (including transient and steady-state response), frequency domain performance
- Steady-state error / system accuracy assessment
- PID controllers; lag-lead compensators

(7) Bode, Nyquist analyses
- Open-loop, closed loop system stability assessment
- Gain margin, phase margin, etc.

(8) Modern control
- State-space domain
- Controllability; observability
- State feedback / pole placement
- State observers
- Optimal control

Things I expect you to understand prior to this course

- The following provides a list of things I expect you to understand prior to this course
  - *If any of the following topics are ones you wish to review, I have posted a full series of lectures from AE 3530 you may use: AE 3530 lectures for review (by topic)*

1. Laplace transforms, inverse Laplace transforms
2. Transfer functions in the Laplace ("s") domain
3. Zeros, poles of system transfer functions; visualization on the complex plane. Intro to stability as shown on the complex plane
4. Recognition of $\omega_n, \zeta, \omega_d$ for 2nd order systems; discussion of ζ (underdamped vice critically damped/overdamped)
5. Transient vs steady-state response
6. Use of Matlab for Laplace domain / time domain analysis, including Matlab's tf(), impulse(), step(), residue()
7. Concepts such as max overshoot, rise time, settling time, etc. for step input
8. State-space formulation
9. Bode analysis, including custom Matlab code for |G| (dB) and phi (deg) vs omega, as well as computations for bandwidth, cutoff frequency, gain crossover frequency, phase crossover frequency, gain margin, and phase margin
10. Eigen analysis for physical systems: how to extract eigen values (including relationship to natural frequencies for systems with mass/stiffness) and mode shapes

Homework, exams

Course homework

- All course assignments and exams (take-home midterm and final exam) will be submitted electronically via Canvas
- No AI

Exams

- This course will use not use digital proctoring for exams. However, the following are required of students:
  - Students must have a broadband internet connection
  - Students must have a secure, private location to take an exam
  - Students must have a reliable scanner (e.g., phone-based app like **Tiny Scanner**) to quickly scan in their work for Canvas homework or exam submission
  - Students must have a downloaded, installed copy of Matlab
  - Students will potentially be asked to provide a picture ID and take a picture of themselves via a webcam as part of the exam process
  - No AI