EAS 6939c – Spacecraft Attitude Estimation & Control (3 credits) - offered spring of even years

*** Syllabus (a.k.a. our contract for the semester) ***

COURSE INSTRUCTOR: Dr. Riccardo Bevilacqua, MAE-A 308, bevilr@ufl.edu, 352-392-6230. Office hours: Wednesday 9am-12pm.

CLASS WEBSITE: canvas and http://www.riccardobevilacqua.com/teaching.html

CLASS MEETS: MWF period 6 (12:50 p.m. - 1:40 p.m.) in CHE 237.

TEACHING ASSISTANT/S: TBD.

PRE-REQUISITES: EAS4510 Astrodynamics (or equivalent undergrad astro class if coming from non-UF undergrad) or EAS6939 Advanced Astrodynamics, and EML5215 Analytical Dynamics, all with at least B grade.

COURSE OBJECTIVES: By the end of this course, you should be able to do the following:

1. Choose appropriate attitude control system for a specific spacecraft mission.
2. Choose appropriate attitude navigation system for a specific spacecraft mission.
3. Choose key parameters for the algorithms operating the systems above.
4. Translate software for attitude determination and control systems into real-time executables for hardware implementation.

COURSE DESCRIPTION: This class rigorously develops the concepts, mathematical procedures, and methods associated with estimation and control of the attitude of a spacecraft. The class will introduce the main types of sensors and actuators used in spacecraft, how to process data coming from sensors, and how to command the actuators. Topics include Kalman and Extended Kalman Filtering, control methods based on Momentum Exchange Devices (Reaction Wheels, Control Moment Gyroscopes), and control methods based on thrusters. The students will be exposed to hardware-in-the-loop experiments to perform estimation and control on ground-based spacecraft simulator platforms. The 3 take-home homeworks will incrementally build a Simulink model to be then compiled and tested on real hardware.

The table below provides a tentative schedule for this course. Key deliverable are highlighted.

TOPIC	**week**
Review of spacecraft rotational mechanics	1
Introduction of flexible elements to spacecraft rotational equations – **HW1**	2
Reaction Wheels control	3
Control Momentum Gyroscopes control	4

Variable Speed Control Momentum Gyroscopes control – **HW2**	5
Thruster-based control	6
Exam 1 (end of week)	7
Review of Kalman Filtering and Extended Kalman Filtering	8
Star trackers and Sun sensors	9
Inertial Measurement Units and Gyros – **HW3**	10
Exam 2 (end of week)	11
Simulink and Simulink coder for generation of executables	12
Implementation of compiled homeworks into real-time executable	13
Experiments in the laboratory	14
Final report on experiments	15

TEXTBOOK/SOFTWARE: Notes taken in class should be sufficient. Suggested:

1. Spacecraft Attitude Determination and Control, Wertz.
2. Space Vehicle Dynamics and Control, Bong-Wie.
3. Fundamentals of Spacecraft Attitude Determination and Control, Markley and Crassidis.
4. Spacecraft Momentum Control Systems, Leve, Hamilton, Peck.

You must have access to MATLAB and Simulink. More requirements may arise during the semester.

HOMEWORKS, EXAMS, AND REPORT: the homeworks count 10% each, the exams 25% each, and the final report 20%.

MIDTERM SURVEY: A voluntary mid-term survey will be provided. To incentivize your participation, the survey will be valued as 5% **bonus**.

GRADING POLICY: The grading scale is as follows, and it is not flexible:

A: 94 to 100

A-: 90 to 93.99

B+: 85 to 89.99

B: 80 to 84.99

B-: 75 to 79.99

C+: 70 to 74.99

C: 65 to 69.99

C-: 60 to 64.99

D+: 55 to 59.99

D: 50 to 54.99

D-: 45 to 49.99

E: Less Than 45

CLASS ATTENDANCE AND MAKE UP POLICY: Students are expected to attend all meetings. There will be no early/late exams. Please make your travel arrangements according to the exam dates specified in the syllabus. The general rule is no make-up exams and no rescheduling of exams to other times.

Requirements for class attendance and make-up exams, assignments, and other work in this course are consistent with university policies that can be found at: https://catalog.ufl.edu/ugrad/current/regulations/info/attendance.aspx.

The students remain completely responsible for timely communications with the instructor.

STUDENTS WITH DISABILITIES: Students with disabilities requesting accommodations should first register with the Disability Resource Center (352-392-8565, www.dso.ufl.edu/drc/) by providing appropriate documentation. Once registered, students will receive an accommodation letter which must be presented to the instructor when requesting accommodation. **Students with disabilities should follow this procedure as early as possible in the semester. In other words: immediately at the beginning.**

CHEATING POLICY: absolutely zero tolerance. Your examinations must be completed completely independently. If anyone is caught having worked together on an exam or having used an unauthorized source, the penalty is an automatic failure of the course.

Cheating breaks the mutual trust between instructor and student. Cheating will invariably result in an automatic "E" grade and the incident will be reported to the University.

Familiarize with the concept of plagiarism as well – plagiarized work is cheating.

UF students are bound by The Honor Pledge which states, "We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honor and integrity by abiding by the Honor Code. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: "On my honor, I have neither given nor received unauthorized aid in doing this assignment." The Honor Code (http://www.dso.ufl.edu/sccr/process/student-conduct-honor-code/) specifies a number of behaviors that are in violation of this code and the possible sanctions. Furthermore, you are obligated to report any condition that facilitates academic misconduct to appropriate personnel. If you have any questions or concerns, please consult with the instructor or TAs in this class.

Students should also familiarize with the Code of Ethics for Engineers: http://www.nspe.org/resources/ethics/code-ethics

ONLINE STUDENTS COURSE EVALUATION: Students are expected to provide feedback on the quality of instruction in this course by completing online evaluations at

https://evaluations.ufl.edu. Evaluations are typically open during the last two or three weeks of the semester, but students will be given specific times when they are open. Summary results of these assessments are available to students at https://evaluations.ufl.edu/results/.

The instructor will also provide a midterm evaluation form to the students, to monitor the development of the class, and make necessary adjustments, when possible. I value your input, and that is why I am giving you an incentive to complete this optional survey at mid-semester. See also grading policy for points assigned to this survey.

CLASS DEMEANOR EXPECTED BY THE INSTRUCTOR: I have little tolerance for students who are repeatedly late to class, cell phone ringing, text messages beeps, and any behavior that may be distracting both students and instructor. Offenders will be asked to leave the classroom, and the lecture will not resume until they comply. If they do not comply, the lecture will be given for granted and the instructor will move on.

Also, I will not be eating while teaching (obviously!), and I expect you not to eat in class.

Contact information for the Counseling and Wellness Center: http://www.counseling.ufl.edu/cwc/Default.aspx, 392-1575; and the **University Police Department**: 392-1111 or 9-1-1 for emergencies