MAE 482 - Flight Simulation for Aircraft Safety

SYLLABUS

Fall Semester 2018

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Course description: Introduction to flight modeling and simulation tools for aircraft health management through analysis and accommodation of abnormal flight conditions.

Course main topics:
- Definition of the aircraft health management concept;
- Description of upset flight conditions and their effects on aircraft dynamics and aerodynamics;
- Principles of modeling aircraft sub-system abnormal conditions ;
- Design of simulator tests for abnormal condition analysis;
- Dynamic signatures and impact on performance of aircraft actuator, sensor, propulsion, and structural failures;
- Impact of upset environmental condition on aircraft performance;
- Introduction to system fault detection;
- Introduction to control schemes for accommodation of aircraft sub-system abnormal conditions.

Textbook:
No textbook is required. Handouts will be provided with relevant material.

Pre-requisites:
MAE365 Flight Dynamics or consent of instructor.

Recommended:
Prior experience with Matlab® and Simulink®.
Course objectives:
- Description of aircraft health management systems;
- Review of the most common abnormal flight conditions for fixed and rotary wing aircraft;
- Analysis of causes and dynamic effects of abnormal flight conditions;
- Assessment of dynamic signatures and impact on performance of abnormal flight conditions through simulation and tests using PC-based simulation and a 6-DOF motion-based flight simulator;
- Overview of general methodologies for abnormal flight conditions detection and accommodation through automated control laws.

Learning outcomes:
At the end of this course, the students should be able to:
- Explain the role, motivation, and means of aircraft health management systems;
- Describe the general conditions and effects of the most frequent abnormal flight conditions;
- Analyze the effects of abnormal flight conditions on aircraft control, handling qualities, and performance;
- Design and perform tests on PC-based and motion-based flight simulators followed by data processing and interpretation for the analysis of dynamic signatures and impact of abnormal flight conditions on performance;
- Describe the most commonly used methods for fault detection and accommodation and explain their principles.

Course structure:
1½ hour lectures and laboratory sessions - TR 2.00-3.15pm in ESB 953 – Flight Simulation Lab. Motion-based flight simulator tests may be scheduled at different times.
Help/problem sessions - if necessary.
Office hours: TR 3.30-5.30 pm. If necessary and possible, individual appointments at different times may be scheduled.

Web Site Access:
Use your MIX account to access the eCampus system at http://ecampus.wvu.edu/. Lecture notes, handouts, homework, additional material, and announcements will be posted there. Your grades will be posted
there as well. E-mail sent from eCampus will be forwarded to your MIX account. Check your e-mailbox frequently.

**Homework/ Simulation Analysis Reports:**
Homework/Simulation Analysis Reports are individual assignments unless they are specifically assigned as a team/group effort. Homework/Simulation Analysis Reports are due at the beginning of the class on due date. Late submissions are penalized 10% credit per day. Note: all simulation analyses are performed using desktop computer simulation tools and/or the WVU 6 – DOF motion-based flight simulator. There will be 5 simulation labs and 2 homework assignments for this course.

**Tests/Quizzes:**
There will be 3 announced tests and 2 announced quizzes, but no final exam. The tests will consist of designing simulation experiments with pre-determined objective (e.g. detect and analyze an actuator failure), perform them, and analyze the results. The quizzes will have a standard format including questions and problems that the student is expected to answer/solve.

**Attendance:**
You are strongly encouraged to attend lectures, although it is not mandatory. If you miss a class, you are responsible for the material covered in class, irrespective of your absence. It is strongly discouraged to miss a test, quiz, or a lab session. Unless you notify me in advance of the scheduled activity time, I may not generate a makeup. Students must attend all lab sessions and perform all simulation analyses for a passing grade.

**Grading:**
Tests 7% each = 21%  
Quizzes 6% each = 12%  
Homework 6% each = 12%  
Simulation analyses 11% each = 55%  
A= 90% - 100%  
B= 80% - 89.99%  
C= 70% - 79.99%  
D= 60% - 69.99%  
F= <60%

Neatness and clarity are important for all assignments.

**Academic Integrity Statement:**
The integrity of the classes offered by any academic institution solidifies the foundation of its mission and cannot be sacrificed to expediency, ignorance, or blatant fraud. Therefore, I will enforce rigorous standards of academic integrity in all aspects and assignments of this course. For the detailed policy
of West Virginia University regarding the definitions of acts considered to fall under academic dishonesty and possible ensuing sanctions, please see the Student Conduct Code at: http://studentlife.wvu.edu/office_of_student_conduct/student_conduct_code. Should you have any questions about possibly improper research citations or references, or any other activity that may be interpreted as an attempt at academic dishonesty, please see me before the assignment is due to discuss the matter.

**Inclusivity Statement:**
The West Virginia University community is committed to creating and fostering a positive learning and working environment based on open communication, mutual respect, and inclusion. If you are a person with a disability and anticipate needing any type of accommodation in order to participate in this class, please advise me and make appropriate arrangements with the Office of Disability Services (293-6700). For more information on West Virginia University's Diversity, Equity, and Inclusion initiatives, please see http://diversity.wvu.edu.

**Copyright Notice**
All course materials, including lectures, class notes, quizzes, exams, handouts, presentations, and other materials provided to students for this course are protected intellectual property. As such, the unauthorized purchase, sale, or distribution of these materials may result in disciplinary sanctions under the Campus Student Code.
Tentative Course Schedule

**Week #1:**
I. Aircraft health management – definition and motivation. Selected examples of aviation accidents and their causes.
II. Introduction to WVU simulation tools. HW#01.
   Design of a flight simulator experiment.

**Week #2:**
I. Airplane and rotorcraft actuator failures: types, effects, and modeling.
II. Simulation Lab #01. Assess and analyze the dynamic effects of aircraft actuator failures.

**Week #3:**
I. Simulation Lab #01 (cont’d).
II. Simulation Lab #01 (cont’d).

**Week #4:**
I. Aircraft sensor failures: types, effects, and modeling.
   Aircraft propulsion failures and structural damages.
II. Test #01 – Design and perform a test in the WVU motion base flight simulator to detect and analyze an actuator failure.

**Week 5:**
I. Simulation Lab #02. Assess and analyze the dynamic effects of aircraft sensor failures.
II. Simulation Lab #02 (cont’d).

**Week 6:**
I. Simulation Lab #03. Assess and analyze the dynamic effects of aircraft propulsion system failure and structural damage.
II. Test #02 – Design and perform a test in the WVU motion base flight simulator to detect and analyze a sensor failure

**Week 7:**
I. Simulation Lab #03 (cont’d).
II. Environmental upset conditions: atmospheric turbulence, wind and wind shear, icing.

**Week 8:**
I. Test #03 – Design and perform a test in the WVU motion base flight simulator to detect and analyze a propulsion failure or damage on main structural components.
II. Simulation Lab #04. Evaluate the impact of environmental upset conditions on pilot workload and pilot+aircraft performance.

**Week 9:**
I. Simulation Lab #04 (cont’d).
II. Parameter identification and estimation – a conceptual overview.

**Week 10:**
I. Parameter identification and estimation – a conceptual overview (cont’d). Quiz #01.

**Week 11:**
I. Introduction to system fault detection.
II. Introduction to system fault detection (cont’d).
**Week 12:**  
I. Aircraft sub-system abnormal condition detection, identification, and evaluation.  
II. Aircraft sub-system abnormal condition detection, identification, and evaluation (cont’d).

**Week 13:**  
I. Simulation Lab #05. Experimenting the use of abnormal condition detection schemes based on parameter identification.  
II. Simulation Lab #05 (cont’d).

**Week 14:**  
Thanksgiving break.

**Week 15:**  
I. Introduction to automatic accommodation of aircraft sub-system abnormal conditions. Control architectures with fault tolerant capabilities  
II. Introduction to artificial intelligence techniques. Quiz #02.

**Week 16:**  
I. Introduction to artificial intelligence techniques. (cont’d).  
II. Final discussions and conclusion. HW #02.