Engineering Faculty Document No.: 6-00
Date: September 19, 2000

TO: Faculty of Schools of Engineering

FROM: Faculty of the School of Aeronautics and Astronautics

SUBJECT: Change in Course Title and Description of Course Content

The Faculty of the School of Aeronautics and Astronautics has approved the change in the course title and description of the course content listed below. This is a result of dividing the current AAE 451 into two courses as outlined in this proposed EFD and the proposed EFD 5-00, AAE 450 – Spacecraft Design. This action is now submitted to the Engineering Faculty with a recommendation for approval.

FROM:
AAE 451 Design I
Sem. 1 and 2, class 2, lab 3, cr. 3 (7 A&E).
Prerequisite: AAE 334, 352, and 372.

Lectures on the philosophy of design. Laboratory work on the synthesis of preliminary design of one of the following: flight vehicle (airplane, missile, or space vehicle), creative product, or experimental research study.

TO:
AAE 451 Aircraft Design
Sem. 1 and 2, class 2, lab 3, cr. 3
Prerequisites: AAE 251, 334, 340, 352, 364, and 372
Corequisite: AAE 421
Senior students perform a team-based aircraft design, requiring application of the education and skills developed in the aerospace curriculum. Aircraft mission requirements include engine cycle selection and airframe/engine integration, performance, stability and control, structures, human factors, avionics, sensors and manufacturing processes. The teams present oral and written reports on their designs.

Reason:
Students may take either aircraft design or spacecraft design to fulfill the capstone design requirement. Having separate course numbers is a necessary part of the School's astronautics initiative.

APPROVED FOR THE FACULTY
OF THE SCHOOLS OF ENGINEERING
BY THE COMMITTEE ON
FACULTY RELATIONS

CFR Minutes #929

Date 10/11/00

Chairman CFR C. D. Sutton

Thomas N. Farris, Professor and Head
School of Aeronautics and Astronautics

AAE 451

Aircraft Design

1. **Justification:** Students may take either aircraft design or spacecraft design to fulfill the capstone design requirement. Having separate course numbers is a necessary part of the School's astronautics initiative.
2. **Course Description:** Senior students perform a team-based aircraft design, requiring application of the education and skills developed in the aerospace curriculum. Aircraft mission requirements include engine cycle selection and airframe/engine integration, performance, stability and control, structures, human factors, avionics, sensors and manufacturing processes. The teams present oral and written reports on their designs.
3. **Level:** Senior
4. **Prerequisites:** AAE 251, 334, 340, 352, 364, and 372
   Corequisite: AAE 421

   Necessary Background:

   a. Expertise in aerodynamics, structures, propulsion, flight mechanics, and control systems.

   b. Introductory design experience.

   c. Programming ability.
5. **Course Instructors:** T. Weisshaar, D. Andrisani, II
6. **Format:** Five contact hours per week are scheduled, two as lecture and three as lab. However, during the first part of the semester, four to five lecture hours are used each week. Later, the time is divided between lectures, conferences and presentations.

7. Course Mission & Objectives:

Mission: To provide a challenging opportunity to demonstrate technical competence, critical thinking, creativity, teamwork and communication skills by synthesizing a complex multidisciplinary airplane design in which the performance requirements of vehicle subsystems are balanced to achieve good overall vehicle performance.

Primary Objectives

1. Provide a challenging, realistic, team-based aircraft design experience that requires human creativity, organization, customer-focused synthesis, component integration and effective application of the education and skills developed in the aerospace curriculum.
2. Understand the open ended, iterative nature and unique tasks associated with aircraft design, engine cycle selection and airframe/engine integration. These include creative exploitation of component synergism, performance, stability and control, structures, human factors, avionics, sensors and manufacturing processes.

3. Employ advanced engineering analysis tools to describe performance characteristics and optimize a viable aircraft/engine design with special emphasis on design integration and consolidation of technical interests, experiences and skills required for design synthesis.

8. Validation & Reporting requirements

The student teams are required to use several different levels of estimation tools to verify that their design has a high probability of meeting customer expectations. In the case of the design/build team, the reporting requirements are reduced because they have a design that will or will not work. Teams will submit reports that have a specified set of sections that will meet customer requirements and are encouraged to improve on and to exceed this set of requirements.

9. Grade Assessment Method:

The final report is developed in pieces during the semester and graded for content, organization and clarity. These scores and scores on presentations and participation form 50% of the student grade. The final report is viewed as the final exam and 50% of the grade results from this team report. In addition, each team member is required to submit a team member evaluation to identify the most valuable members of the team. Additional points are awarded as the result of these evaluations.

10. Principal References (not limited to) (in alphabetical order):

Abbott, I.H. and Von Doenhoff, A.E, *Theory of Wing Sections Including a Summary of Airfoil Data*, Dover Publications, Inc., 1949, 1959.

Anderson, J.D., Jr., *Introduction to Flight*, McGraw Hill Book Company, 1989.

Hale, F. J., *Introduction to Aircraft Performance, Selection and Design*, John Wiley & Sons, 1984.

Hoak, D. E., *USAF Stability and Control DATCOM*, Air Force Flight Dynamics Laboratory, published in nine volumes or sections, Volume 4 is the most useful.

Lan, C-T., and Roskam, J., *Airplane Aerodynamics and Performance*, Roskam Aviation and Engineering Corporation, 1980.

Mattingly, J.D. Heiser, W.H., and Daley, D.H., *Aircraft Engine Design*, AIAA, 1987.

McCormick, B.W., *Aerodynamics, Aeronautics, and Flight Mechanics*, John Wiley and Sons, Inc., 1995.

Niu, M.C-Y., *Airframe Structural Design*, Conmilit Press, 1988.

Pugh, S., Total Design - *Integrated Methods for Successful Product Engineering*, Addison-Wesley, 1990.

Raymer, D.P., *Aircraft Design: A Conceptual Approach*, AIAA, 1989.

Roskam, J., *Airplane Design, Parts I-VIII*, Roskam Aviation and Engineering Corporation, 1986.

Roskam, J., *Airplane Flight Dynamics and Automatic Flight Controls, Part I*, Roskam Aviation and Engineering Corporation, 1979.

Selig, M.S., Donovan, J.F., and Fraser, D.B., *Airfoils at Low Speeds*, H.A. Stokely, Publisher, 1989.

Stinton, D., *The Design of the Airplane*, BSP Professional Books, 1983.

Torenbeek, E., *Synthesis of Subsonic Airplane Design*, Delft University Press, 1982.

Witford, R., *Design For Air Combat*, Jane's Publishing, Inc., 1987.

Version 1: Design-Build-Test - Dominick Andrisani II

This course involves designing, building and flight testing a small aircraft. The basic goal of the course is to design an aircraft that works, i.e. that satisfies the mission requirements in flight. In this endeavor, theory and mathematics meet Mother Nature in the real world. Students develop an appreciation for the benefits and limitations of analytical design methods. Robustness and safety margins become critically important, as the real world is a cruel teacher. Realistic constraints are a fundamental part of the design-build-test experience. For many students this is the first time they have built anything with their newly acquired engineering skills. No previous aircraft building experience is required.

OUTLINE

1. Understanding of Mission Requirements
- Applicable engineering design standards
- Realistic constraints
2. Preliminary sizing
- Wing area
- Propulsion system
3. Design refinement
- Wing planform (section, taper, sweep, dihedral, etc.)
- Fuselage (length, diameter, etc.)
- Weight and balance
- Structural design (loads analysis, spars, wing box, etc.)
- Empennage and control surfaces
- Propulsion system details
- Preliminary design reports
4. Mission simulation and performance verification
5. Design iterations
6. Critical Design Review (oral and written reports)
7. Build a prototype (three weeks)
8. Flight test the prototype
9. Document and report results (oral and written reports)

Version 2: Aircraft System Synthesis – Terrence A. Weisshaar

This course begins with a loosely defined project of current interest to the aerospace industry. In the past these projects have included supersonic business jets, large capacity transports, military cargo transports and high altitude reconnaissance aircraft. Students are challenged to define the project fully and develop a precise mission statement, as well as a functional requirements description, by surveying the literature and contacting professionals in the aerospace industry and at government laboratories. The Spring 2000 project was to develop an unmanned high altitude aircraft to be used by the U.S. Air Force for intelligence, surveillance and reconnaissance (ISR). Partners were the U.S. Air Force Air Vehicles Directorate of the Air Force Research Laboratory and Allison Engines. At the same time, one class team was tasked with developing a flying model of a design that replicated fundamental problems to be addressed by the "paper" designs. In this case it was low Reynolds number flow and containment of a large antenna that dominated the geometric configuration.

Teams are organized during the first week. Later, disciplinary teams are developed to address specific disciplinary technical issues such as performance, aerodynamic, structures, stability and control and propulsion. These teams consider methodology, approaches, tools and interactions with other disciplines and submit reports. The disciplinary team members then return to their multi-disciplinary teams with knowledge sufficient to execute the project. The following tasks are assigned during the semester.

1. In response to an RFP (with some ill-defined customer needs) develop a mission statement and functional requirements of the design and its components. Develop a QFD "House of Quality" and use a structured approach to requirements definition. Present the mission statement and list of requirements to the industrial/governmental customer for evaluation. Modify as necessary to provide traceable requirements.

2. Create 10 concepts that satisfy the requirements. These concepts consist of 3views and a description of how they address the functional requirements. During the time that the 10 concepts are being reduced to a single concept, the disciplinary teams are organized and prepare their reports. After 1 week, narrow this list of 10 to 3.

3. Perform a constraint analysis and identify design drivers and critical interface interactions. Estimate weight and drag to identify engine requirements. Choose the final concept.

4. Identify candidate engines and identify design features of these engines.

5. Size the design using spreadsheets developed for this purpose. The component weights and component drag must be calculated and their impact on the design identified.

6. Refine the design by iteration and address requirements. Document progress by written and oral reports presented each week.