Addition of a New Course: MAE4263 Space Flight Mechanics

Dear University Council,

Aerospace engineering program should cover both of aeronautical engineering and astronautical engineering, but the current undergraduate Aerospace Engineering (AE) program is not strong in the area of astronautical engineering that deals with orbital mechanics and space missions.

Therefore, it is proposed to create a new undergraduate course, entitled Space Flight Mechanics, and insert it into the undergraduate AE degree program as a required course. This course will be taught at the senior level during the spring semester. To accommodate this new course, it is proposed that Humanity/Social Science Elective be eliminated from the program.

This course was taught in Fall 2009 as a special topic in Aerospace Engineering, and all of the faculties in Aerospace Engineering believe that the proposed new course will enhance the current curriculum, particularly in finding a balance between astronautical engineering and aeronautical engineering.

Enclosed are the required forms for the proposed curriculum change, tentative course syllabus, course schedule, and comments from student who attended this course. Should you have any question or concern, please contact the proposer or any faculty member in Aerospace Engineering.

Sincerely,

Taeyoung Lee
Mechanical and Aerospace Engineering
taeyoung@fit.edu

Florida Institute of Technology
College of Engineering
Mechanical and Aerospace Engineering

February 23, 2010

Approved by College of Engineering Council
3-25-10

150 West University Blvd, Melbourne FL 32901-6975 • (321) 674-7058 • Fax: (321) 674-8813
COLLEGE: Engineering
DEPARTMENT: Mechanical and Aerospace Engineering

DEGREE LEVEL: Undergraduate
PROGRAM TITLE: Aerospace Engineering

TO BE INITIATED WITH CATALOG YEAR: 2011/2012
CHANGE REQUESTED FOR: Major program

EFFECTIVE DATE FOR CHANGE: 8/15/2011
NAMED TERM FOR EFFECTIVE DATE: Spring - Senior Year

Major/Minor Code: 7044

BRIEF DESCRIPTION OF REQUESTED CHANGES:
Attach a more detailed description and any supporting documentation.

Remove Humanities/Social Science Elective Class from the Spring Semester of the Senior Year.
Add MAE4263 Space Flight Mechanics to the Spring Semester of the Senior Year with prerequisites of MAE2082 Dynamics and MTH12201 Differential Equation / Linear Algebra.

Approvals: On completion of appropriate department approvals, submit form to Chair, Graduate Council, or Chair, Undergraduate Curriculum Committee, for approval below and forward to the Office of the Registrar.

Originator: [Signature] 3/22/10
Date: 3/22/10
Chair, Graduate Council
Date:

OR

Department Head/Major Program Chair: [Signature] 3-25-10
Date: 3-25-10
Chair, Undergraduate Curriculum Committee
Date:

REGISTRAR'S USE ONLY:

University Catalog
Academic Year:
Yes: ✔ No: ☐ Update completed: Date: Initials:

Extended Studies Division Catalog
Academic Year:  ☑ Yes: ☐ No: Update completed: Date: Initials:

University Alliance Catalog
Academic Year:  ☑ Yes: ☐ No: Update completed: Date: Initials:

CAPP / Degree Evaluation
Academic Year:  ☑ Yes: ☐ No: Update completed: Date: Initials:

Catalog / Policy Mgmt. System
Academic Year:  ☑ Yes: ☐ No: Update completed: Date: Initials:

DISTRIBUTION
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RGP-003/1100
Florida Institute of Technology

ADDING A NEW COURSE TO THE CURRICULUM

This course is available for student registration only after the approval process has been completed.

SUBJECT ____________________________ COURSE NO. ____________________________ CREDIT HOURS _______ TERM TO BE ADDED TO THE FILE ____________________________
(e.g., MSE) (e.g., 1301) (e.g., Fall 2010)

CLASS HOURS 45/semester LECTURE HOURS 45/semester LAB HOURS 0 CONTACT HOURS (CEU ONLY) ____________________________

DEPARTMENT ____________________________ SCHEDULE TYPE ____________________________
(e.g., Mechanical Engineering) (e.g., Lecture, Lab or Special Topics/Project)

☐ COLLEGE OF AERONAUTICS – 23
☐ COLLEGE OF PSYCHOLOGY AND LIBERAL ARTS – 25
☐ NATHAN M. BISK COLLEGE OF BUSINESS – 24
☐ COLLEGE OF SCIENCE – 26
☐ COLLEGE OF ENGINEERING – 1
☐ EXTENDED STUDIES DIVISION / NATHAN M. BISK COLLEGE OF BUSINESS – 90

COMPUTER TITLE Restricted to 25 characters, including spaces Space Flight Mechanics

CATALOG TITLE ____________________________

CATALOG DESCRIPTION OF COURSE Restricted to 350 characters, including spaces

Provides understanding of the motion of celestial objects and spacecraft under gravity. Includes analysis of the two-body and restricted three-body problems and orbital transfer using impulsive forces. Also includes designing interplanetary spacecraft trajectories for given specifications. Uses MATLAB for numerical analyses and dynamic simulation.

In addition, please attach a course syllabus and/or more detailed description.

RESERVATIONS

☐ Prerequisite MAE2082
☐ Corequisite ____________________________
Course Number ____________________________

☐ Prerequisite MTH2201
☐ Corequisite ____________________________
Course Number ____________________________

☐ Prerequisite ____________________________
☐ Corequisite ____________________________
Course Number ____________________________

ADDITIONAL RESERVATION *OR Instructor Approval*

(e.g., Major, Class Level, Department Head Approval)

If this course replaces a course currently offered in BANNER, please indicate old course information and the date/term the course may be removed from the system.

SUBJECT Alpha Prefix (e.g., MSE) ____________________________ COURSE NO. (e.g., 1301) ____________________________

APPROVALS: Upon completion of appropriate department approvals, submit form to Chair, Graduate Council, or Chair, Undergraduate Curriculum Committee for approval below and forward to Catalog Director.

Date 3/22/10

Originator ____________________________

Chair, Graduate Council ____________________________

Date 3/22/10

Department Head/Program Chair ____________________________

OR

Date 3/25/10

Dean of Associate Dean ____________________________

Chair, Undergraduate Curriculum Committee ____________________________

CATALOG DIRECTOR

These changes/additions have been made for the University Catalog/policy management system and entered into the BANNER term named above.

Date

Catalog Director ____________________________

REGISTRAR'S USE ONLY

SCORSE ____________________________ SCADTEL ____________________________ SCAPREQ ____________________________

SCARRES ____________________________ Operator Init. ____________________________ Date ____________________________

Florida Institute of Technology • Office of the Registrar

150 West University Boulevard, Melbourne, FL 32901-6975 • (321) 674-8114 • Fax (321) 674-7827

RGR-038-459
Proposal Summary

It is proposed to create a new undergraduate course, MAE4263 Space Flight Mechanics and insert it into the undergraduate Aerospace Engineering (AE) degree program as a required course. This course will be taught at the senior level during the spring semester. It will also be available for other degree programs as a technical elective. To accommodate this new course, it is also proposed that Humanity/Social Science Elective be eliminated from the program. These changes would go into effect with the 2011/2012 university catalog.

AE Faculty  The proposed changes were initiated by the AE faculty during their continual review of the AE program. At the faculty meeting held in September 2008, the AE faculty identified that they could increase the emphasis on the space side of aerospace engineering by offering courses in Astrodynamics or Spacecraft Dynamics and Control. As a result, the proposed course, Engineering Astrodynamics, was taught as a special topic course in Fall 2009.

The corresponding course materials (homework assignments and exams) were reviewed in the recent AE faculty meeting in February 2010. It is noted that the addition of this course would provide more balance between aeronautics and astronautics, and another advantage would be that the orbital mechanical portion of MAE4262 Rockets & Mission Analysis would be moved to Astrodynamics, freeing up time in MAE4262 for additional material. After further discussion, it is unanimously agreed that this course should be included in the AE curriculum as a required course.

ABET  According to the program criteria of ABET,

- Aeronautical engineering programs must demonstrate that graduates have a knowledge of aerodynamics, aerospace materials, structures, propulsion, flight mechanics, and stability and control.
- Astronautical engineering programs must demonstrate that graduates have a knowledge of orbital mechanics, space environment, attitude determination and control, telecommunications, space structures, and propulsion.
- Aerospace engineering programs or other engineering programs combining aeronautical engineering and astronautical engineering, must demonstrate that graduates have knowledge covering these areas – aeronautical engineering or astronautical engineering as described above.

But, the current undergraduate AE curriculum is not strong in the area of astronautical engineering that deals with orbital mechanics, attitude determination and control, and space missions: there is only one course, namely MAE4262 Rockets and Mission Analysis, that is partially related to orbit analysis. This has actually raised a question in the recent ABET program evaluation process, and a program evaluator recommended to add a new course in the area of astrodynamics as a required course.

Students  Students who took the proposed course in Fall 2009 were supplied with a survey that asked them questions about the need for a background in astrodynamics. The students' responses summarizing their responses are attached. In short, the majority of the students were very interested in taking an astrodynamics course, and they believed that it would substantially improve our undergraduate AE curriculum. They also rated the overall value of the course as it contributed to their learning to 5.00 / 5.00.

Undergraduate Core Requirements  According to the undergraduate course requirements in the university catalog, all students seeking a bachelor's degree are required to complete the following core requirements:

- Humanities (9 credit hours) including HUM 2051, HUM2052
- Social Sciences (3 credit hours)

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The current undergraduate AE curriculum satisfies all of the above core requirements, and additionally, it includes 3 credits for *Humanity/Social Science Elective* in the spring semester at the senior level. Therefore, the undergraduate core requirements will still be satisfied after the proposed curriculum change.

**Relevance to SPS3030 Orbital Mechanics**  The proposed course is composed of two parts, namely orbital mechanics and orbital maneuvers. The former part deals with the general motion of celestial objects under mutual gravitational potential, and the latter part is focused on the design and analysis of spacecraft maneuvers between orbits and planets including spacecraft attitude dynamics on an orbit. Throughout the class, numerical simulations based on modern computational tools are strongly emphasized. The instructor demonstrates the procedure of programming and numerical analysis during lectures. Students are required to do several programming assignments. For example, students should design a Mars exploration mission at the end of the class with numerical simulation.

It turned out that combining computational analyses with a real-world spacecraft mission design attracts AE students in astronomical engineering successfully. The department of physics and space science is offering a similar class, *SPS3030 Orbital Mechanics*, but it is more focused on orbit observation and orbit determination rather than spacecraft maneuvers or spacecraft attitude dynamics. The strong emphasis on spacecraft interplanetary trajectory design, attitude dynamics, and numerical studies distinguishes the proposed engineering astrodynamics course from orbital mechanics courses in the PSS department.

**Flow Chart**  The flow chart of the undergraduate AE curriculum will be updated as follows.

- **Current flow chart for the senior year**

<table>
<thead>
<tr>
<th>SEMESTER</th>
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<tbody>
<tr>
<td>FALL</td>
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<td>38</td>
<td>27,33</td>
<td>MME 3260 EXPERIMENTAL AERODYNAMICS</td>
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<td>29</td>
<td>MME 4242 AIRCRAFT STABILITY &amp; CONTROL</td>
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<td>32</td>
<td>MME 4262 ROCKETS &amp; MISSION ANALYSIS</td>
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<td>38,39</td>
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<td>32</td>
<td>MME 4261 AIR-BREATHING ENGINES</td>
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  | TOTAL | 33 |

- **Proposed flow chart for the senior year**

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  | TOTAL | 33 |
Course Syllabus

Prerequisites  MAE2082 Applied Mechanics: Dynamics, MTH2201 Differential Equations/Linear Algebra, Permission of Instructor

Catalogue Description  Provides understanding of the motion of celestial objects and spacecraft under gravity. Includes analysis of the two-body and restricted three-body problems and orbital transfer using impulsive forces. Also includes designing interplanetary spacecraft trajectories for given specifications. Uses MATLAB for numerical analyses and dynamic simulation.


Contents

- Orbital Mechanics
  - Dynamics of Point Masses [Chap. 1]
  - Two-Body Problem [Chap. 2,3]
  - Orbital Elements [Chap. 4]
  - Restricted Three-Body Problem [Chap. 3]

- Orbital Maneuvers
  - Impulsive Transfers [Chap. 6]
  - Relative Motion and Rendezvous [Chap. 7]
  - Interplanetary Trajectories [Chap. 8]

- Attitude Dynamics
  - Rigid Body Dynamics [Chap. 9]
  - Satellite Attitude Dynamics [Chap. 10]

References

- J. Danby, Fundamentals of Celestial Mechanics, Willmann-Bell, 1988
- R. Bate, Fundamentals of Astrodynamics, Dover Publication, 1971
- J. Prussing, Orbital Mechanics, Oxford University Press, 1993

Grading  Attendance 5%, Homework 35%, Midterm Exam 30%, Final Exam 30%

- Numerical simulations are required for several homework assignments.
- Students are required to design a Mars exploration mission at the end of class.
# Course Schedule

<table>
<thead>
<tr>
<th>Week</th>
<th>Materials</th>
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| 1    | Dynamics of point masses  
      | Newton’s law of motion, Newton’s law of gravity |
| 2    | Formation of the two body problem in an absolute-relative frame  
      | Numerical integration of ordinary differential equations |
| 3    | Analytical solution of the relative motion of the two body problem  
      | Conserved quantities, Kepler’s law of planetary motions |
| 4    | Types of orbits  
      | Characteristics of circular, elliptic, parabolic, and hyperbolic orbits |
| 5    | Orbital position as a function of time  
      | Numerical solution of nonlinear equations |
| 6    | Orbit in a 3D space, orbital elements  
      | Effects of Earth oblateness (Sun-synchronous orbit, Moniya orbit) |
| 7    | Midterm Exam  
      | Impulsive orbital maneuvers |
| 8    | Hohmann transfer  
      | Generalized Hohmann transfer |
| 9    | Phasing maneuver, Non-hohmann transfer  
      | Apse line rotation, Lambert problem |
| 10   | Interplanetary Hohmann transfer  
      | Rendezvous conditions |
| 11   | Method of patched conics  
      | Restricted three body problem |
| 12   | Rigid body kinematics  
      | Euler’s equation |
| 13   | Dynamics of a spinning top  
      | Stability of torque-free dynamics |
| 14   | Dual-spin spacecraft / coning maneuver  
      | Attitude stabilization |
| 15   | Final exam |
Students’ Responses

The followings are comments from students who attended the proposed class when it was offered as a special topic class in Fall 2009.

- “This should be a required course since there is very little astronautics in curriculum”

- “This class should be permanent”

- “I think this class should be included every year from now on. I learned a lot and this is why I became an aerospace engineer”

- “The class should be offered for everyone. It was my favorite class this semester”

- “This course should be included in the curriculum”

- “Strongly suggest making a required course for Aero Eng.”

- “Yes, course should be part of AE curriculum”