**Spacecraft Technology**

**AERO/SPACE 582**

**Fall 2021**

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**Honor Code:**

The CoE Honor Code holds that students are honorable and trustworthy people and encourages them to behave with integrity in all phases of university life. Examinations will not be proctored, but the instructor or his representative will always be available to answer questions. At the end of each homework assignment, test and examination, the students must write the Honor Pledge “I have neither given nor received unauthorized aid on this homework, test or examination, nor have I concealed any violations of the Honor Code” and sign their name under it. The complete Honor Code is available at: <https://ossa.engin.umich.edu/honor-council/>

**Course Approach and Goals:**

The course involves mentors and guest lectures from other departments, industry, and National laboratories. Students participate from the conception to the completion of spaceflight projects. The main course goal is to provide students with the basic understanding of systems engineering and the design of spaceflight missions with the objective to develop:

1. The ability to define requirements, design and test spaceflight missions and their subsystems, taking cost, schedule, environmental, ethical, and safety constraints into consideration;
2. The ability to thrive in multidisciplinary teams;
3. A good understanding of ethical and professional responsibility;
4. The ability to design and integrate space systems;
5. The ability and desire to engage in lifelong learning activities.

**Course Overview:**

The course is intended to introduce the students to spacecraft technology and the processes by which technology and system engineering decisions are implemented into the design of spaceflight missions. The course provides an overview of critical tools supporting spacecraft development, with emphasis on top-level system designs. Strategic approaches to spacecraft designs are discussed.

 The course begins with a brief overview of systems engineering and the processes used to design spaceflight systems. It follows the axiomatic design process and the system engineering processes used by NASA. The course then focuses on the specific design of particular space systems conducted as a team project. The design includes orbit analysis, requirement definition, subsystem bus design, budget management, and detailed system analysis. This includes modeling of both engineering and budgetary performance, as well as technological impacts of engineering based decisions. An important aspect of the course is the development of teamwork similar to what occurs in industry.

**Course Structure:**

Lectures are structured around the modern design process common to all engineering disciplines. In particular, the importance of clear and well-thought conceptual ideas in the earliest phases of the design process is emphasized. The course focuses on the development and capture of requirements, analysis, spacecraft bus design, and synthesis of solutions. Lectures, discussions, and laboratory sessions are structured around the following themes:

1. **Systems engineering practices**: overview of the design of spaceflight systems.
2. **Problem definition**: definition of the engineering problem.
3. **Requirements**: quantitative definition of the project requirements.
4. **Concept generation**: collection and categorization of a large number of conceptual designs to solve the engineering problem.
5. **Concept evaluation**: quantitative evaluation of each conceptual design.
6. **Convergence**: reduction of the number of conceptual designs by merging the best ideas of selected designs.
7. **Concept selection**: identification of the best conceptual designs for detailed design and analysis.
8. **Detailed design and trades**: analysis of the best concepts using quantitative methods.
9. **Subsystem prototyping**: subsystem prototyping and tests with demonstration of critical concepts.
10. **Project wrap-up/transition**: documentation of the design in detail for use by future student teams.

**Class Hours and Location:**

Mondays, Wednesdays and Fridays from 2:30 to 4:30 pm

2246 Climate and Space Research Building (CSRB)

**Office Hours:**

Mondays and Wednesdays from 1:30 to 2:30 pm

Any other time by appointment

**Required Textbook:**

Space Mission Engineering: The New SMAD *by J. R. Wertz et al.*

**Useful Textbooks:**

Axiomatic Design: Advances and Applications *by**Nam Pyo Suh*

INCOSE Systems Engineering Handbook *by Walen et al.*

Observation of the Earth and its Environment *by H.J. Kramer*

Space Vehicle Design *by Michael D. Griffin and French*

**Prerequisites:**

1. Basic skills in Matlab and Excel programming.
2. Basic skills in Mathematics including introductory knowledge of Partial Differential Equations.
3. Basic physics at Engineering Undergraduate Level, including Mechanics and Electrodynamics.
4. Basic skills in space system analysis software, such as CAD, I-DEAS, STK, and Radiation analysis programs are desirable but they will be developed in this course.

**Homework and Final Examination:**

The objectives of homework and the final examination are:

1. To measure the students' ability to use the knowledge acquired in the course.
2. To provide feedbacks to the teacher on how well the course's long-range objectives were achieved.

**Homework Assignments:**

Homework will consist of specific questions about key systems engineering processes, and spacecraft technology.Homework must be handed in electronically before midnight on the due date.

**Homework Policy:**

Grades will be reduced by at least 10% for any homework turned in after the due date. After the answer sheet is handed out (usually one week after the due date) 50% of the grade will be deducted from a late homework. It is absolutely *not* permitted to consult answer sheets for help. Some collaboration on doing homework is encouraged, but each student must work out the answers on their own and the solutions they hand in must be individually prepared. When in doubt, write an honest note at the top of your assignment saying who you worked with and how much. Rule of thumb: < ¼ of your effort may be jointly if you don't mention a collaborator, < ½ if you do mention the collaborator. The write-up must be entirely your own.

**Final Examination:**

The final examination will consist of specific questions about key systems engineering processes, orbit analysis and spacecraft design and integration. You will have to complete it in a period of 100 hours. This is our famous “100 hours Examination.”

**Final Grade:**

The final score will be computed by

     SCORE = 1/4 (HMW + EXAM + PEER + PROJ),

where HMW is the average grade of all Homework Assignments, EXAM is the grade of the Examination, PEER is the average grade of the Peer Evaluations, and PROJ is the average grade of the Project Presentations (mid-term and final presentation) and the Final Project Report.

The final grade will be based on the grading displayed scale below.

|  |  |
| --- | --- |
| **Score** | **Grade** |
| 90-100 | A |
| 80-90 | B |
| 65-80 | C |
| 50-65 | D |
| < 50 | E |

**Complaints about Grades:**

We will go over the test of any student who brings a written paragraph describing his/her concerns. However, the review might affect the grade either positively or negatively.

**In Class Participation:**

The mastering of the basic concepts and ideas to be presented in this course requires the students to participate actively in class. Therefore, we expect students to be active and ask and answer questions during lectures.

**Tentative Course Outline**

**August 30:** **Course Philosophy** **and Class Deliverables**

**Introduction to Axiomatic Design**

**Lab.:** No Lab

**September 1: Space Environment & Radiation**

                        **Lab.:**No Lab

**September 3: Overview of Potential Class Projects**

 **2:30 pm Orbital Debris Removal Mission, Northrop Grumman**

 **3:00 pm Mars Weather Mission, Harris Corporation**

 **3:20 pm Mars Radio Occultation Mission, JPL**

 **TBD…**

                       **Lab.: Class Projects Selection (Led by the GSI)**

**September 6: No Classes -Labor Day**

            **Lab.:**No Lab

**September 8: Introduction to Requirements and Specifications**

 **Work Breakdown Structure (WBS)**

                          **Lab.:**No Lab

**Homework 1 Posted:**SMAD and Orbits

**September 10: Introduction to Space Systems Engineering**

**Lab.: Introduction to STK Tutorial (CSRB Comp Lab)**

**September 13: SMAD 1**

                          **Lab.:**Project Discussion

**September 15: SMAD2**

                          **Lab.: Brief Class Project Updates**

**September 17:  Space Systems Engineering by Steve Battel**

                          **Lab.:**No Lab

**September 20: Analyses of Alternatives**

                          **Lab:**No Lab

**September 22: Communication Systems’ Link Budget by Brian Gilchrist**

                          **Lab.:**No Lab

**September 24: Resume Writing and Interview Techniques**

            **Lab.: Radiation & Power Tutorial (CSRB Comp Lab)**

**September 27: Thermal Systems**

                    **Lab.:**No Lab

                    **Homework 1 Due**

**September 29: Introduction to Space Electronics by S. Battel**

 **Power Systems**

**Lab.:**No Lab

**Homework 2 Posted:**Radiation, Communication & Power

**October 1**: **Communication Systems**

 **Ground Systems**

                   **Lab.:**No Lab

**October 4**: **Design Principles and Goddard’s GOLD Rules by Steve Battel**

                    **Lab.: SolidWorks Tutorial (CSRB Comp Lab)**

**October 6**: **Command and Data Handling (C&DH) Systems**

                     **Lab.:**No Lab

**October 8: Electromagnetic Compatibility (EMC) & Electromagnetic**

**Interference (EMI) by Steve Battel**

                     **Lab.:**No Lab

**October 11: Attitude Determination and Control Systems (ADCS)**

                     **Lab.:** Project Work

**October 13: Concept of Operations (ConOps)**

                      **Lab.: Brief Class Projects Updates**

**Homework 3 Posted:**ADCS and Thermal

**Homework 2 Due**

**October 15: Margin Management**

                     **Lab.:**Project Work

**October 18: No Classes – Fall Study break**

                     **Lab.:**Project Work

**October 20: Flight Computers**

 **Effective Proposals**

                     **Lab.:**Project Work

**October 22**: **Effective Presentations**

 **Example of Project Presentation**

**Lab.:**No Lab

**Homework 3 Due**

**October 25**: **Class Project Presentations**

                      **Lab:**No Lab

**October 27: Class Project Presentations**

                      **Lab.:**No Lab

**Peer Evaluation Due**

**October 29: Class Project Presentations**

                      **Lab.:**No Lab

**Peer Evaluation Due**

 **November 1**: **Overview of Orbital Mechanics**

                        **Lab.: Overview of the 100 Hours Examination**

**November 3**: **Anomaly Detection and Recovery**

                        **Lab.:**Project Work

**November 5**: **100 Hours Examination Released at 9 am**

**November 8**: **100 Hours Examination**

**November 10**: **100 Hours Exam Due at 5 pm**

**November 12**: Project Work

                        **Lab.:**Project Work

**November 15**: **Parts Selection & Qualification for Space Programs**

                         **Lab.:**Project Work

**November 17**: **Atmospheric Drag in Space Systems by A. Ridley**

                         **Lab.:**Project Work

**November 19**: **Space Systems Safety**

            **Lab.:**No Lab

**November 22**: **No Classes – Pre-Thanksgiving**

                         **Lab.:**Project Work

**November 24**: **No Classes –Thanksgiving**

                         **Lab.:**No Classes

**November 26**: **No Classes –Thanksgiving**

                         **Lab.: No Classes**

**November 29**: **Venus Exploration**

                      **Industry Advisory Board Meeting**

                      **Lab.:**Project Work

**December 1**: Project Work

**December 3**: Project Work

**December 6**: **Final Class Project Presentations**

**December 8**: **Final Class Project Presentations**

**December 10**: **Final Class Project Presentations**

**Final Project Report Due**

**Peer Evaluation Due**

**December 13**: **Examinations**

**December 15**: **Examinations**

**December 17**: **Examinations**

**Sunday December 19, Commencement**