# Introduction to Satellite Mission Design

## SPACE 310

## Fall 2023

## Revised: 19 Oct 2023 (Changes highlighted)


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**Lecture Times and Location:**

Tuesdays and Thursdays from 12:00 to 13:20

2424 CSRB

**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.

**Course Approach and Goals:**

This course involves lectures, tutorials and team project(s). In the team project(s), students work in the development of a satellite mission design. The main course goal is to provide students with an introduction to space systems engineering and project management with the objective to develop:

1. The ability to define requirements, design, and manage a small satellite mission, taking cost, schedule, environmental, and safety constraints into consideration;
2. The ability to work in a multidisciplinary team;
3. A good understanding of professional responsibility;
4. The ability to conceptualize and design small space missions;
5. The ability to engage in lifelong learning activities.

**Course Overview:**

The course is intended to introduce students to space mission design and small satellites technologies, including the processes by which system engineering decisions are implemented into the design of small satellite missions. Approaches to spacecraft design and tests are discussed.

The course covers the fundamentals of space mission design. Topics covered include: (1) Axiomatic design; (2) Space mission design; (3) Requirements development; (4) Satellite subsystems; (5) Power, mass, data, and financial budgets; (7) Thermal analysis; (8) Overview of orbits; (9) Overview of mission operations; and (10) Launch vehicles.

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

**Course Foundations:**

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, satellite bus design, and synthesis of solutions. Lectures, discussions, and tutorials 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.

**Required Textbook:**

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

*https://astrobooks.com/spacemissionengineeringthenewsmadsme-smadwertzeverettpuschellavailablespring2011softcover.aspx*

***Please buy the textbook*!**

**Useful Reference Books:**

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*

The Logic of Microspace *by R. Fleeter*

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

**Advised Prerequisites:**

1. ENGR 100 and ENGR 101;
2. Basic skills in Excel and Matlab.

**Homework and Final Examination:**

The objectives of homework and examinations 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 objectives are being achieved.

**Homework Assignments:**

Homework will consist of specific questions about requirements development, design, systems engineering processes, and satellite subsystems. Homework must be handed in electronically before midnight on the due date, unless specified.

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. <u>The write-up must be entirely your own</u>.

The use of generative AI is prohibited.

**Late Policy:**

Grades will very likely be reduced by at least 10% for any assignment turned in after the due date. Contact your instructor <u>*in advance*</u> if you anticipate having trouble meeting 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 unless extenuating circumstances have been discussed with one of the instructors.

**Final Examination:**

The final examination will consist of specific questions about the material covered in the course. You will have to complete it at home in a period of 50 hours.

**Final Grade:**

The final score will be computed by

SCORE = 0.05 QUIZ + 0.20 PEER + 0.25 (HMW + EXAM + PROJ),

where QUIZ is the average grade for all but 3 quizzes, HMW is the average grade of all Homework Assignments, EXAM is the average grade of the Examinations, PEER is the average grade of the Peer Evaluations, and PROJ is the average grade of the Project Presentation and the Final Project Report.

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

Grading Scale

| **Score** | **Grade** | **Score** | **Grade** |
|---|---|---|---|
| 100 | A+ | 77-79 | C+ |
| 93-99 | A | 72-76 | C |
| 90-92 | A- | 70-71 | C- |
| 87-89 | B+ | 67-69 | D+ |
| 82-86 | B | 62-66 | D |
| 80-81 | B- | 60-61 | D- |

Grades <60 are failing. Grading scale may be adjust slightly to align better with overall class performance.

**Complaints about Grades:**

We will go over the homework, project or exam 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 actively engaged during class, asking questions and participating in in-class activities.

**Tentative Course Timeline**

*Note: This timeline is subject to change as needed throughout the semester. Changes will mostly be shifts by 1-2 class periods to adjust for varying time needed for each topic.*

**August 29:** Course Philosophy and Class Deliverables

Introduction to Space Mission Engineering

**August 31: Introduction to Design**

Space Mission Communities

**September 5:** Introduction to Design (start at slide 12)
Introduction to class project

Space Mission Engineering Process (stopped on slide 13)

**September 7**: Space Mission Engineering Process

Space Mission Concept Definition

Space Mission Analysis and Mission Utility

**September 12:** Trades Studies Part 1

**September 14:** Trades Studies Part 2

Space Environment and Radiation

**Homework 1 Posted:** Design, Trade Study and Systems Engineering

**September 19:** Space Weather Faraday Cup (SWFC) intro and traceability [Chris Bert, CLaSP]

Formal Requirements Definition [Fernando Saca (SPRL)]

**September 21:** SWFC Requirements

Technology Readiness Level (TRL) [Fernando Saca (SPRL)]

**Homework 1 Due**

**September 26:** Space Mission Geometry

**September 28:** Space Mission Geometry: Sample Problems

**Homework 2 Posted: Space Environment and Requirements**

**October 3:** Orbits and Astrodynamics [Jon van Noord, SPRL]

**October 5:** Orbits and Astrodynamics [Jon van Noord, SPRL]

Space Environment

**October 10**: Cost Estimating

**Homework 2 Due**

**October 12**: Reducing Space Missions Cost and Schedule

**Homework 3 Posted: Geometry, Orbits and Cost**

**October 17**: **No Class** –Fall Study Break (Oct 17-18)

**October 19:** Overview of Spacecraft Design

**October 24:** Overview of Spacecraft Design (continuation)

**October 26:** Overview of Spacecraft Design (continuation)

**Homework 3 Due**

**October 31:** Overview of Spacecraft Design (continuation)

**November 2:** Initial project Presentations & Reviews

**November 7:** Overview of Spacecraft Design

Observation Payloads

**November 9**: Observation Payloads (continuation)

**November 14**: Observation Payloads (continuation)

**November 16:** Class Project Presentations

**Peer #1 Evaluation Due**

**November 21**: **No Class –Thanksgiving Break**

**November 23**: **No Class –Thanksgiving Break**

**November 28**: Course Review & Exam Overview

**Hints for the 50 Hours Examination**

**November 30**: **50 Hours Examination Released at 9 am (no class)**

**December 5**: **50 Hours Exam Due (no class)**

**December 7**: **No Class**

**Peer Evaluation #2 Due**

**Final Project Report (Slide Deck) Due**

**December 8 - 15**: **Exam Period**