MAE4160/4161/5160 – Spacecraft Technologies and Architectures

Spring 2016, 3-4 credits
Kimball B11
Lecture: Mon/Wed/Fri 10:10-11:00

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Grading:	Letter

I. Rationale:

This course is a survey course in contemporary space technology from subsystems through launch and mission operations, all in the context of spacecraft and mission design. It focuses on the classical subsystems of robotic and human-rated spacecraft, rockets, planetary rovers, and habitats, as well as on contemporary engineering practice.

Topics covered include subsystem technologies and the systems-engineering principles that tie them together into a spacecraft architecture. Subsystem technologies discussed include communications, thermal subsystems, structure, spacecraft power, payloads (remote sensing, in-situ sensing, human life support), entry/descent/landing, surface mobility, and flight-computer hardware and software. A brief review of the theory and practice of guidance/navigation/control space propulsion is provided, with the assumption that students have already encountered this material in the prerequisite courses (MAE 3060 or 4060).

MAE 4161 also includes a senior-design project option that fulfills the undergraduate requirement in this area.

MAE 5160 (4 credits) includes an in-depth design activity suitable for M.Eng. study (but that does not meet that Meng project requirement).

II. Course Aims and Outcomes:

Specific Learning Outcomes:

By the end of this course, students will:

- understand, at a higher systems level, space missions and systems, and how the space environment and mission requirements drive spacecraft design;
- understand the basic fundamentals of spacecraft subsystems, including propulsion, attitude determination and control, power, structures, thermal, communications, and command and data handling;
- understand typical practices for designing space systems in a contemporary context of US commercial space and government agencies;
- be able to simulate a spacecraft in operation at the level of a Preliminary Design Review (PDR) using state of the art tools, and identify and characterize subsystems for a preliminary spacecraft design.

III. Format and Procedures:

The course has a theoretical component based on lectures, homework assignments, and two quizzes, and a practical component based on a semester-long project. The project consists of architecting a complete spacecraft system with appropriate subsystems, with designs supported by parametric analysis and simulation. This project will be matured throughout this semester, through a sequence of design reviews meant to resemble aerospace industry practice.

MAE 4160 students (3 credits) engage in a 3-4 person space-system design project, with a single final report authored by all team members.

MAE 4161 students undertake this project within such a team but with the reporting expectations of a senior-design project, namely a 20pp, separate report that documents each MAE 4161 student's design.

MAE 5160 students (4 credits) conduct an in-depth study of a space-technology problem that is integrated with one of these team design projects and forms part of the team's report.

IV. Course Requirements:

1. Project Design Documents and Presentations: This course mimics U.S. industry and government practice in documenting spacecraft system architecture and analysis details in written reports and presentations that correspond to key decision points in the lifecycle of a spacecraft. The lectures will include discussion of all aspects of this lifecycle. However, a single semester is simply not enough time to walk through a full-scale design process for a realistic system, regardless of size or complexity. So, design reports in this class require that the design be analyzed up to the "Preliminary Design Review" stage and include a plan for completing work up to the "Critical Design Review" stage. Additional work—e.g. completing more detailed analysis, building prototypes, etc.—is optional and is at the discretion of the student.

The summary below is meant as an overview. Each assignment will include more detail and will draw from material provided in lecture:

- **SRR Document**: The System Requirements Review establishes the correctness of key requirements for the space system, including performance, functionality, and design processes. This written document will be approximately 10 pages, consisting of precisely articulated requirements at the level of the mission, space and ground segments, and high-level subsystems.
- **SDR Document**: The System Design Review is a milestone that confirms that the system architecture is solving the right problem: that the requirements are reflected in the basic choices that comprise the spacecraft to be analyzed in greater detail. The document to be completed is a roughly 10 page summary that explains the big picture: images of the spacecraft, high-level diagrams, the concept of operations, and a mission timeline.
- **PDR Presentation**: The Preliminary Design Review documents the analyses that demonstrate the spacecraft as architected can feasibly meet the requirements. More detailed analysis will have to be performed before the spacecraft's components can be procured or built, but after PDR, there is no longer a question that the story holds

together. At this point some "long-lead items" might be procured for a real spacecraft; so, some insight into possible vendors is required at the PDR level. This presentation will be scheduled for a time/day near the end of the semester and will offer an opportunity for the students on the team to receive critiques that can be incorporated into the Final Design Report. MEng students' detailed design material should be included in this presentation.

- **CDR Plan**: The Critical Design Review marks the end of design and analysis and the beginning of fabrication/procurement, assembly, integration, and testing. Unique to this class, the CDR plan required here is a 5 page document that summarizes what analyses will be required if the project were to continue to CDR.
- **Final Design Report**: This design report might be called a "PDR Analysis Book." It documents the details of the analysis presented at PDR. It takes the form of a design report, which begins with describing high-level requirements, the mission and spacecraft architectures that meet these requirements, and post-PDR activities. It is meant to stand on its own but likely will incorporate most of the material already submitted during the semester. Creating this report should be more of an exercise in organization of existing work into the form of a report and verifying completeness than generating new material. There is no specific length requirement.

2. <u>Homework</u>: There will be 6 homework assignments containing theory questions and problems based on the material seen in class. See Schedule document on Blackboard for due dates. All homework is due at 10:10am on the due date and must be submitted through the Blackboard assignment feature.

Homework assignments will be given a numerical grade from 0 to 100. **There will be no extension on homework assignments irrespective of the excuse. Instead, we will drop the lowest homework assignment grade at the end**. This should provide enough flexibility. Please use this option wisely.

Work submitted late but within one week of the due date/time will receive 50% of the credit they would have received if on time. For fairness to all students and administrative simplicity, no homework late by more than one week will be accepted. Feel free to submit early.

Consulting with classmates on homework is encouraged, even recommended. However, each student must turn in his or her own work, with no intentional duplication of other students' work. You will not learn the material and will be unprepared for the quizzes if you merely copy others' homework.

3. <u>Quizzes</u>: There will be 2 in-class quizzes. The quizzes will be individual, open books and open notes but no access to internet. They will consist of questions similar in nature and difficulty to those used in the homework assignments. See Schedule document on Blackboard for the dates.

V. Grading Procedures:

(a) 25% Final Design Report
(b) 20% 2 Quizzes (10% each)
(c) 15% Homework (2.5% each)
(d) 10% Final PDR Presentation

(e) 10% SRR Report
(f) 10% SDR Report
(g) 10% CDR Plan

For the grades that involve group activity, individual grades are assigned on the following basis:

- Each design document is assigned a single grade X. Criteria for grading each document will be provided along with the specifics of the assignment. The total points (T) available to the N members of the team is given by T = X * N.
- The default is that each student receives the grade given to the group's document. This distribution of points would reflect the case where each student contributes similar quality and quantity of work.
- Students are asked to identify which portion of the reports they worked on. The TA's and professor's assessment of these sections may alter the distribution of points among the team members so that each student's grade differs from the overall document grade, keeping T constant.
- Each student is asked to assess each team member's contributions (quality, quantity, timeliness, etc.), and the total points are redistributed if it's clear from these assessments that some students deserve more credit than others.

All grades will be posted to the Blackboard web site. All grading appeals must be made to the TA in writing with justification (including references to lecture notes or readings) within one week after graded material is returned. The entire homework will be re-graded, not merely the part in question. So, a regrade by the TA may raise or lower the score.

VI. Academic Integrity

Each student in this course is expected to abide by the Cornell University Code of Academic Integrity. Any work submitted by a student in this course for academic credit will be the student's own work.

The student is encouraged to turn to the TAs, professors, and other students for help in understanding the general approach to solving homework assignments. However, after sharing ideas, getting, and/or giving help, each student must work through each assignment completely and by himself or herself, without the use of any material that originated with any other person (except for team project work).

For team project work, all team members are expected to review all sections of what the team submits because the grade will be shared.

Should copying occur, both the student who copied work from another student and the student who gave material to be copied will both automatically receive a zero for the assignment. Penalty for violation of this Code can also be extended to include failure of the course and University disciplinary action.

During examinations, you must do your own work. Talking or discussion is not permitted during the examinations, nor may you compare papers, copy from others, or collaborate in any way.

Any collaborative behavior during the examinations will result in failure of the exam, and may lead to failure of the course and University disciplinary action.

For further information on Cornell's Code of Academic Integrity see: http://cuinfo.cornell.edu/Academic/AIC.html

VII. Accommodations for students with disabilities
In compliance with the Cornell University policy and equal access laws, I am available to discuss appropriate academic accommodations that may be required for student with disabilities. Requests for academic accommodations are to be made during the first three weeks of the semester, except for unusual circumstances, so arrangements can be made. Students are encouraged to register with Student Disability Services to verify their eligibility for appropriate accommodations.

VIII. Inclusivity Statement
We understand that our members represent a rich variety of backgrounds and perspectives. The Sibley School is committed to providing an atmosphere for learning that respects diversity. While working together to build this community we ask all members to:

- share their unique experiences, values and beliefs
- be open to the views of others
- honor the uniqueness of their colleagues
- appreciate the opportunity that we have to learn from each other in this community
- value each other's opinions and communicate in a respectful manner
- keep confidential discussions that the community has of a personal (or professional) nature
- use this opportunity together to discuss ways in which we can create an inclusive environment in this course and across the Cornell community

IX. Tentative Course Schedule (*May change to accommodate guest presenters & student needs*)
See Schedule on Blackboard.

X. Resources

- **Required textbook**: Space Mission Engineering: The New SMAD (Space Technology Library, Vol. 28, Microcosm Inc., July 2011 Edition, ISBN: 1881883159. (Available at the Cornell Store and for $75.00 via

  http://astrobooks.com/spacemissionengineeringthenewsmadsme-smadwertzeverettpuschellavailablespring2011softcover.aspx

- Course Packet: Lecture notes and readings posted on Blackboard site

Blackboard site: http://www.blackboard.cornell.edu.

The course site is named MAE 4160 Spacecraft Technology&Systems Selva Valero, D.

Optional materials:

- Fortescue et al., Spacecraft Systems Engineering (Wiley, 2011).
- Griffin and French, Space Vehicle Design, 2nd Ed., (AIAA, 2008).