SPACECRAFT DESIGN

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Course Description
Aero 401 is referred to as the Capstone Design Experience in the Aerospace Engineering Department. In particular, Aero 401 Spacecraft Design is the first semester of a two semester design sequence that involves the design of a spacecraft based on explicit goals, objectives, and constraints. The class requires that students utilize the knowledge and skills gained during their undergraduate studies to design a spacecraft to accomplish a specific function specified in a Statement of Work. Utilizing accepted principles of Systems Engineering and Project Management, students will work together in teams to design a spacecraft that can perform the desired function and satisfy the stated requirements.

Prerequisites: Aero 302, 303, 306, 351, 421

Meeting Times: MW 4:10 - 5:25, HRBB
TR 11:00 - 12:25, HRBB

Learning Outcomes

1) Students will be able to apply the basic Systems Engineering processes and how they apply to spacecraft design (ABET Outcomes 3, 10, 12, and 16),
2) Students will be able to apply the technical skills learned in the undergraduate curricula to real world problems in what may be less than ideally applicable situations (ABET Outcomes 1, 2, 3, 4, 10, 12, 13, 14, 18, 19, 20, and 21),
3) Students will work in a controlled team environment for a sustained length of time (ultimately, two semesters) during which they will be able to evaluate both the positives and negatives of personal dynamic interactions (ABET Outcomes 7 and 8),
4) Students will be able to cultivate improved communications skills – both written and verbal – through regular written reports and presentations (ABET Outcomes 5 and 6),
5) Students will be able to analyze non-technical design drivers such as cost, safety, federal regulations, schedules, federal budget constraints and evaluate their relative effect on design efficiency and cost (ABET Outcomes 9 and 16),
6) Students will be able to define the technical issues involved in spacecraft mission design and assess their comparative effects on spacecraft design, schedule and cost (ABET Outcomes 5 and 6),
7) Students will be able to explain the basic technical issues involved in spacecraft fabrication and testing (ABET Outcomes 13, 14, and 18),
8) Students will be able to utilize and describe the basic industry standard design and review procedures as practiced by NASA and the Air Force (ABET Outcomes 3, 10, and 12),
9) Students will be able to apply sound testing principles to conduct simple, small-scale experiments in order to prove a concept, substantiate analysis, or investigate an unknown phenomenon and then analyze and interpret the resulting test data (ABET Outcomes 13 and 14).

Course Rationale
The goals of the Aerospace Engineering Department at Texas A&M University may be stated as follows: 1) provide a comprehensive aerospace engineering education that develops in students the fundamental skills necessary for the design, synthesis, analysis, and research development of aircraft, spacecraft, and other high technology flight systems; and (2) prepare students for the aerospace engineering profession and related fields by developing in them the attributes Required to contribute successfully to society and the engineering profession both now and in the future. The Capstone Design experience exemplified by the Aero 401/402 cycle of classes is designed to concentrate on the second objective above: preparing the students for the world in which they will work once they graduate.

The engineering community, in many ways, has remained unchanged from previous decades: it is a fast paced environment that, above all else, requires technically proficient engineers. There are however, at least two aspects of engineering that have changed significantly in the past 10-20 years. There is now a much larger dependence on teamwork and the influence of the principles of systems engineering. The graduate who is well-grounded in the technical skills of his or her major will always be in demand. However, in addition to technical capabilities, the student who graduates with a clear understanding of the systems engineering process and views teamwork as the standard way of doing business will automatically enter the workforce with a distinct advantage. Thus, to be relevant in today’s world, the Capstone Design experience must, as accurately as possible, reflect the environment the students will encounter when they report for work. Through the application of systems engineering processes to guide the utilization of the technical skills they spent the first three years of their undergraduate life acquiring, the students will gain a much better appreciation for the design process and its interdependencies, as well as the strengths (and limitations) of teamwork. In addition, this approach allows the students to learn about leadership – both what it means and what it doesn’t mean.
Expectations of Students

1) All activities should be consistent with the Aggie Code of Honor: "An Aggie does not lie, cheat, or steal or tolerate those who do".

2) Working with others is of paramount importance, not only in this class, but in your career. During this class cycle you will be on teams for an extended time and it is crucial that you work and play well with others. As a general rule, a team with fractious relationships will not perform well.

3) All students are required to attend all classes. In the event circumstances prevent a student from making it to class, it is vital that the student contact me prior to the class in question to explain the reason for missing the class and make arrangements to obtain class materials and/or assignments.

4) All students are expected to be on time if at all possible. (Admittedly, sometimes the large distances of the A&M campus make this difficult.) If you are going to be chronically late due to a long hike from a previous class, alert me to the possibility and enter as unobtrusively as possible. If you know you are going to be late, alert me ahead of time. Likewise, if you need to leave early.

5) Similarly, all assignments are expected to be completed and turned in on time. Once again, if there are extenuating circumstances that prevent the student from completing the assignment, the student shall contact me prior to the assigned due date and explain the need for an extension.

6) Positive Attitude, defined as enthusiasm, initiative, industriousness, diligence, etc., is expected in this class, just as it will be expected by your future boss. If you find it difficult to be genuinely enthusiastic, either learn to fake it, or at the least, don’t be disruptive (and possibly consider whether this is a good career choice).

7) Class participation is strongly encouraged. The modus operandi in this design class will be for me to treat the students as engineers. Engineers comment, argue, disagree, and ask questions. It is not a passive occupation and I will expect the students to do the same.

8) As a corollary of treating the students as engineers, it stands to reason that I will also treat the students as adults. It is the student’s responsibility to respond as adults; for after all, you are.

9) Cell phones will be turned off in class (including mine).

University Support Services

In the event that students encounter personal or academic issues, there are several avenues that can be utilized to resolve such problems and avert potential harm, either personally or academically. For questions or issues related to the course, the first person you should talk to is the professor or instructor who is teaching the course. In the case of this Aero 401 section, I can provide a limited amount of tutoring or help arrange for more extensive support. In addition, I am willing to provide mentoring for those interested career development. The university, however, has established formal programs that are applicable to a wide range of situations. Here are a few examples of these services currently available at Texas A&M:
Programs for Academic Success Skills (PASS) The goal of PASS Programs is to provide students with an opportunity to develop knowledge, skills, and attitudes that will enhance their study and test taking abilities while decreasing anxieties related to academic performance. Services include individual and group counseling, assessment of study behaviors, screening for learning disabilities, an extensive collection of self-help resources, and weekly workshops on a variety of study skills topics.

Career Counseling and Testing Services Group and individual career counseling services will help you make informed vocational plans, choose a major, or plan for graduate study. Professional counselors provide testing, groups, and individual counseling to help you learn about your interests, abilities, personality, values, and various career options. The professional counselors can also assist you with an extensive library of pamphlets, computer programs, and other resource materials in the Academic & Career Resource Center.

Personal Counseling Personal counseling is a process that facilitates self-discovery and growth, and most students at one time or another can benefit from personal counseling. Counseling can help improve self-confidence, relationships, academic performance, and decision making for your overall well-being. The SCS provides individual, couple, and group counseling for concerns that are common among students.

Self-Help, Outreach, and Consultation Includes educational and informational presentations, workshops, and programs, consultation to faculty, staff, and organizations about student needs, and access to the SCS virtual library of self-help articles and information sheets.

Stress Management & Biofeedback Training Stress and anxiety have many causes and can impact us in different ways. Relaxation techniques can help us learn to manage our stress better. Biofeedback uses specific relaxation techniques designed to manage stress & anxiety more effectively.

Crisis Intervention If you find yourself in a crisis situation you may come to the Student Counseling Service (room B103 of Cain Hall, (979.845.4427) for crisis intervention anytime during business hours 8:00 AM to 5:00 PM Monday through Friday. After 4 PM or on weekends, you may call the Help Line at 979.845.2700(V/TTY), or go to the nearest hospital emergency room.

Expectations Students Can Have of the Professor Students should expect their professor to:

1) Prepare a well-organized, detailed syllabus and follow it. The professor should always bring a complete set of notes to class and be prepared to lecture on the materials thoroughly and efficiently.
2) Be enthusiastic about teaching. Students should feel welcome when seeking help for academic or personal problems.

3) Be clear and accurate when answering student questions. Homework assignments should be clear and to the point.

4) Be current with advances in his field of expertise. Students should expect the professor to introduce the latest research and technological advances into the classroom in order to better prepare them for the future.

5) Give assignments regularly to reinforce class material. Assignments should be challenging and relevant to class discussions. Students should expect the professor to provide the tools and knowledge necessary to finish the assignments successfully and on time. Students should expect tests and assignments to be graded promptly and include constructive comments.

6) Have a sense of humor that makes the class fun to attend and provides a level of dynamics to the class that helps maintain the interest of the students.

7) Treat all students equitably. Students should expect to be graded according to their performance and efforts.

How to Succeed in this Course
To succeed in this course students should:

1) Attend class and participate.
2) Be prepared when you come to class.
3) Display initiative – don’t wait for me to think of everything.
4) Ask questions. Challenge me if you think I’m wrong or misleading.
5) If you need help, ask. If I don’t know the answer, I will find someone who does.
6) Work at teamwork. Not everyone is congenial. Learn to accomplish a goal in spite of personality differences.

Textbook and other Resource Materials
The primary textbook for this course is: Space Mission Engineering: The New SMAD, First printing, 2011, edited by Wertz, James R., Everett, David F., and Puschell, Jeffery J.


Other publications that will prove useful include the following:

Grading:

<table>
<thead>
<tr>
<th>Grading Scheme</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Team Presentations</td>
<td>50%</td>
</tr>
<tr>
<td>Midterm Report</td>
<td>10%</td>
</tr>
<tr>
<td>Attendance</td>
<td>5%</td>
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<tr>
<td>Dependability</td>
<td>5%</td>
</tr>
<tr>
<td>Class Participation</td>
<td>5%</td>
</tr>
<tr>
<td>Team Function</td>
<td>25%</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td><strong>100%</strong></td>
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</tbody>
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Office Hours (719A H.R. Bright Building)
- Monday and Wednesday: 1:00-3:30
- Tuesday and Thursday: 9:00-11:00

Course Project Overview for 2013
The project for this semester is very ambitious: design a human-crewed space exploration vehicle capable of traveling to a near earth asteroid (NEA), station-keep with the asteroid, and obtain samples to return to earth. Twelve humans must be kept alive and healthy (physically and psychologically) for a year or more. In addition, artificial gravity will be maintained at a level necessary to prevent skeletal degradation, protection from dangerous radiation particles will be provided, and atmospheric pressure within the habitats will be maintained at approximately 14.7 psi. There are, of course, many other facets of this project and they will be defined in the beginning of the course.

This Aero 401/402 series will also be ambitious in another aspect: Aerospace Engineering students will be joined by a group of students from the Electrical and Computer Engineering Department who will participate in the design of the spacecraft. The operational approach will be to divide the work along disciplinary lines such that the students from each department will contribute to the project in ways that are congruent with their disciplinary skills. This approach is consistent with industry and will provide students with an enhanced educational experience.

Course Topics
There are three primary objectives of the Aero 401 design class:
1. The first is to provide an open-ended, realistic design challenge in space systems that demands the creative efforts of students and replicates as closely as possible the design
processes and teamwork that are the prevailing norms in the aerospace community today.

2. In addition to offering realistic design projects, the work of the student teams receives a critical review from external evaluators – using prevailing, community-wide standards.

3. Finally, to execute detailed design using the most up-to-date and customer-validated interdisciplinary, integrated design software.

As a capstone design course, Aero 401 Spacecraft Design will rely heavily on the fundamental principles of Systems Engineering and Project Management. Therefore, the first few weeks of the semester will be dedicated to lectures defining, explaining, and illustrating the various facets of Systems Engineering principles as they are applied to the design and development of spacecraft. Obviously, given the time constraints of a semester, the depth of coverage will be necessarily limited. Nevertheless, the student will understand the importance of the systems engineering approach to spacecraft design and be familiar with the processes and how to apply them. The following is tentative list of topics to be covered and important milestones:

1. **Systems Engineering Basics**
   a. System Engineering is a logical structured engineering approach for formulating the problem and transforming the customer need into a useful capability throughout its entire life cycle.
   b. Students learn by applying this “logical” design process (including requirements definition, preliminary design, evaluation and assessment, and component design) to the design of a spacecraft system.

2. **Project Management**
   a. Project management is about creating an environment conducive to successfully completing critical projects
   b. Project management is a method and mindset…a disciplined approach to managing chaos

3. **Documentation and Configuration Management**
   a. Documentation is the memory of a project
   b. Configuration Management is its conscience; i.e., it ensures consistency

4. **Requirements Definition**
   a. Transforms customer’s desires into statements that can be used to define a design solution

5. **The Project Life Cycle Process**
   a. Categories, or phases, that define the work required to successfully accomplish a project

6. **Project Statement of Work**
   a. Provided to the student teams
   b. Defines what the customer wants

7. **Project Teams**
   a. Selection of Project Managers, Deputy Project Managers, and Technical Leads
   b. Students work in a controlled team environment where they learn about the positives and negatives of personal dynamic interactions.
8. Requirements from Statement of Work  
   a. Student teams will derive requirements from the Statement of Work
9. Concept Development per Team  
   a. This is where the majority of the semester will be spent.
10. Design of Thermal Control Systems  
    a. Maintain temperatures within given specifications
11. Propulsion Systems  
    a. What kinds of systems are needed?  
    b. How much thrust and propellant
    a. Where am I (nav)  
    b. Where am I going (guidance)  
    c. How do I get there (Control)
13. Electrical Power Systems  
    a. How much power is required  
    b. Where does it come from  
    c. How is it managed
14. Telemetry, Command, and Data Handling  
    a. Sending data to earth  
    b. Using data efficiently  
    c. Receiving and executing commands  
    d. Storing data efficiently
15. Telecommunications  
    a. Communication between earth and spacecraft  
    b. Onboard communications  
    c. Ship to ship communications
16. Regenerative Life Support  
    a. Food, water, air recycling  
    b. Waste removal  
    c. Radiation protection
17. Cost Estimating and Budget Control  
    a. How much is it going to cost to build  
    b. Living within your means
18. Weekly Oral Reports  
    a. Cultivate improved communication skills, both in writing and in presentations
19. Mid-term Written Reports
20. PDR Preparation
21. PDR Presentation

General Order of Semester Activities
The following is a general outline of activities for Aero 401. The timing and order may change, 
but these activities will occur by the end of the semester.

1. January 2013
a. Introductions  
b. Project overview  
c. Begin Statement of Work  
d. Team assignments  
e. System Engineering Lectures  
f. Finalize Statement of Work  
g. Guest Lectures  

2. February 2013  
a. Begin Subsystem Lectures  
b. Mission Concept Review (MCR)  
c. System Requirements Review (SRR)  
d. Guest Lecture  
e. Mission Definition Review (MDR) to an invited Review Board  
f. Begin Team Reports  
g. Begin one free class per week available for project work  

3. March 2013  
a. Guest Lecture  
b. Spring break  
c. Plan remainder of the semester  

4. April 2013  
a. Begin wrapping up technical activities for the semester  

5. Begin preparing for Preliminary Design Review (PDR)  
6. Begin two class days per week available for project work  
7. End Team Reports  
8. PDR preparation  
9. PDR Dry Runs  
10. PDR  

Americans with Disabilities Act (ADA) Policy Statement  
The Americans with Disabilities Act (ADA) is a federal anti-discrimination statute that provides comprehensive civil rights protection for persons with disabilities. Among other things, this legislation requires that all students with disabilities be guaranteed a learning environment that provides for reasonable accommodation of their disabilities. If you believe you have a disability requiring an accommodation, please contact Disability Services, in Cain Hall, Room B118, or call 845-1637. For additional information visit http://disability.tamu.edu.  

A Personal Statement about Academic Honesty:  
Beyond the fundamental belief of civilized society that cheating is wrong, there are very real consequences of dishonest behavior that can destroy careers, lives, and families. It may seem like quite a leap to go from plagiarism or taking credit for someone else’s work to a ruined career, but they are linked. If you are willing to compromise your integrity for something as inconsequential as a better grade – and you are repeatedly successful – it’s a small step to
continuing this behavior in your professional life where the rewards are more tangible. After all, it works. Or does it?

Engineers are expected to be technically competent; but there is an additional aspect of engineering that is equally important: trust. In class, I make a conscious decision to trust you and, until given a reason not to, will continue to do so. Likewise, if he or she is smart, your boss will trust you. It’s important to understand that your boss doesn’t trust you to never make a mistake. He or she is trusting that you will not “fudge” the data to tell the story you know the boss wants to hear. In the short term that may seem to be acceptable, but when discovered – and it is always discovered – not only will you be called to account, but your boss will also be in trouble because he or she believed in you. At that point trust is broken and your career is in trouble.

I cannot overemphasize the importance of your reputation for integrity. In the aerospace industry, we often work on vehicles that transport human beings. From experience I can tell you that the loss of a crew is a devastating event. Even if you did everything correctly and was in no way responsible, it shakes you to the core. But think how you would feel if you had compromised – even slightly – some of the data used to prove it was safe to fly? As a result, it is paramount that, to the best of your ability, everything you do be not only of the highest quality but also that you are willing to stand behind your work. Any doubts about your integrity will relegate you to a supporting role – if you’re lucky.

In addition to its value to you, it is also important to understand that your reputation for integrity is very fragile. It can be damaged by one momentary lack of judgment. Nineteenth century author Ernest Bramah put it this way, “A reputation for a thousand years may depend upon the conduct of a single moment”. If you haven’t thought about it before, begin the habit of guarding your reputation in this class. Dishonesty does not go unnoticed. You may think your actions are hidden, but your teammates will know and once destroyed, trust is very difficult to rebuild.

**Philosophy of Teaching**

I have come to the teaching profession rather late in life. Many years ago I gave up working on a Ph.D. to go to work at NASA. While I thought several times about picking up my doctoral studies, I couldn’t make myself suspend working in the space program for the time it would have taken to finish my Ph.D. As a result, even though I don’t have a Ph.D. I feel that I have very significant experiential information to pass along to young people about to enter the workforce. You already know the technical information you need to succeed at NASA, or Boeing, or SpaceX, or wherever. A great deal of the information I will share with you over the course of two semesters will not be found in textbooks; but I think you will find it to be valuable data that you can use to help guide you in your career.

I was a division chief at the Johnson Space Center in the Engineering Directorate for the last 10 years of my career. My biggest successes involved helping my employees excel and then
making sure they were rewarded. I consider teaching this course an extension of that. It isn’t about me. I have a desire to do the best I can to prepare you for the real world and if possible, give you a leg up as you enter your career track.

My objective is to run this class as close to an engineering organization as possible. I will treat you as engineers – for all intents and purposes that is what you are. I will treat you with respect and trust, unless you prove to me that I cannot, and I expect the same in return. I am not a micro-manager, but I also expect things to be done when I ask for them. We can discuss extenuating circumstances, but it shouldn’t be habitual.

Ultimately, my goal is to extract your very best during this course cycle. But this is your class and you will only get out of it what you put into it. I don’t have any competing research projects so you are my primary responsibility. If you will work with me, we can make this a fitting finish to your undergraduate experience.