SYLLABUS

Satellite Engineering

16.851

Department of Aeronautics and Astronautics

Massachusetts Institute of Technology

Fall 2003

Configuration control
as of 9/3/2003

Professor David W. Miller

John E. Keesee

Table of Contents

1.0 General Description: 16.851 Satellite Engineering

The purpose of this course in Satellite Engineering is to provide the student with an introduction to the design of satellite subsystems. We will learn about subsystem functions and performance measures. We will discuss and practice evaluating tradeoffs of performance among alternative designs that may satisfy the required subsystem function and optimize higher-level system performance or cost requirements. We will also examine the environments and interfaces that impact satellite design, including launch systems and the space environment. We will discuss payloads in a general sense, with specific examples to highlight the payload's influence on other subsystem's design.

At the end of this course the student will have a fundamental understanding of the factors influencing subsystem design and will be able to evaluate the impact of tradeoffs between subsystem requirements on the performance and cost at the system level.

We will not design a satellite in this subject. Our focus is on an understanding of subsystems and their relationships. Instead we build a foundation upon which later subjects (e.g.16.89 Space System Engineering) design satellite systems. In those subjects you will use the skills and tools developed in this class to evaluate alternative designs at the system level.

We will, however, use a satellite system (or several systems) to provide a context for the subsystem discussions. These examples are useful because they provide realistic examples and highlight the challenges that drive tradeoffs in performance.

Some of the students in this course may already have some knowledge of specific spacecraft subsystems. While the overall format of the class is lecture, it is hoped that all will contribute to our discussions from their work and study experience.

Once again, the purpose of the course is for you to learn about satellite subsystems. If there is something you do not understand, ask about it. Discussions allow us to explore the subject and significantly improve our understanding.

1.1 Course Learning Objectives

By the end of the course the student will have demonstrated the ability to:

1. Understand the function of spacecraft subsystems.
2. Apply orbital mechanics formula and tools to spacecraft mission design.

3. Select appropriate launch systems and understand their affect on satellite and payload design and performance.
4. Evaluate spacecraft subsystem performance and trades
5. Estimate space system costs
6. Trade subsystem performance requirements to optimize higher-level system performance, cost, or weight.

2.0 ORGANIZATION

Satellite Engineering is a twelve (12) unit course consisting of three (3) hours of lecture, and nine (9) hours of homework per week. It is an H-level Graduate credit course. Classes are held on Mondays and Wednesdays from 1 pm to 2:30 pm.

Primary faculty for the course will be John E Keesee and Professor David W Miller. Additional Aeronautics/Astronautics department faculty may deliver some of the lectures since they are experts in particular subsystems and environments.

3.0 LECTURE AND HOMEWORK SCHEDULE.

Table 3.1 Lecture and Homework Schedule

	Topic	**Read-ing**	**Home-work**		**Topic**	**Home-work**	**Read-ing**
9/1/03	**Holiday**			9/3/03	Intro		
9/8/03	Launch Systems	SMAD 18		9/10/03	Orbital Mechanics	#1 handed out	SMAD 5,6,7
9/15/03	Orbital Mechanics	SMAD 5,6,7		9/17/03	Space Environ-ments	#1turned in	SMAD 8
9/22/03	**Holiday**			9/24/03	Power subsystem s	#2 handed out #1 eval turned in	SMAD 11.4
9/29/03	Attitude Determina-tion and control	SMAD 11.1		10/1/03	GPS/Navi gation	#2 turned in	SMAD 11.7
10/6/03	Propulsion	SMAD 17		10/8/03	Avionics	#3 handed out #2 eval turned in	SMAD 11.2, 11.3, 16
10/13/03	**Holiday**			10/15/03	Avionics	#3 turned	SMAD

						in	11.2, 11.3, 16
10/20/03		SMAD 11.7		10/22/03	Structures	#4 handed out #3 eval turned in	SMAD 11.6
10/27/03	Thermal, Ground Systems	11.5, 15		10/29/03	Communications, TT&C		SMAD 11.2, 11.3, 13
11/3/03	Optics, Payloads	SMAD 9		11/5/03	Systems	#4 turned in	SMAD 11.2, 11.3, 16
11/10/03	**Holiday**			11/12/03	Manufacturing and Test	#5 handed out #4 eval turned in	SMAD 12, 19
11/17/03	Software and Autonomy	SMAD 16		11/19/03	Software and Autonomy	#5 turned in	SMAD 16
11/24/03	Budgets, Costs, Ground Systems	SMAD 20		11/26/03		#5 eval turned in	SMAD
12/1/03	Integrated Concurrent Engineering			12/3/03	ISS operations		
12/8/03				12/10/03			

4.0 HOMEWORK

4.1 Problem sets

Homework for this class will be worked in teams who will be selected by the instructors and changed during the semester. Homework will be handed out every other Wednesday and will be due one week later. In some cases each team's homework problems may be unique. When homework is turned in you should make two copies of your work, one for the instructor and one for another team to evaluate. In the next week you will prepare an evaluation of the other team’s work.

4.2 Module Development

Most of the homework problems will require the coding of software modules. We suggest you use MATLAB to code these modules and will provide a tutorial to help you learn the programming language. We intend for these modules to be useful in future subjects (e.g. 16.89) or satellite system design work beyond your studies at MIT. The point of analyzing the other teams' work and receiving comments on your own is to help you build useful and effective tools. Your modules will very likely be used in 16.89 Space Systems Engineering.

The modules should mathematically capture the relationships between the discipline's inputs and outputs and in general relate subsystem performance and cost to the subsystem's requirements. When used in an integrated concurrent engineering context, you will be asked to determine how the subsystem performance or cost will change as a result of changes in the requirements. The module must be complex enough to capture the important relationships yet simple enough to provide outputs that make sense. You should ensure that your modules are appropriately documented with explicit definitions of input and output so that you and others will understand its structure in the 16.851 evaluation as well as future applications. You are likely to use this program again in the future or may need to use part of it in developing the solution to another problem. You might have to update it or correct errors. In any case, the faculty and the review team will grade it. Documentation is essential so that we can understand and give proper credit for your work. Good documentation would include:

1. Programmer's name
2. A concise requirements specification
3. Descriptions of problem inputs, expected outputs, constraints and applicable formula
4. A pseudo-code or flowchart for its algorithm (optional)
5. A source program listing
6. A hardcopy of a sample test run of the program
7. A user's guide explaining to nonprogrammer users how the program should be used (optional).

5.0 PORTFOLIO

One of the key products of this class is a personal portfolio. The portfolio provides both a personal reflection on the learning experience as well as a central collection of the tools and reference material from the course. The portfolio should contain:

1. Your learning objectives for the class.
2. Your reflections on the learning experiences with respect to the learning objectives.
3. All of the tools you developed, including particularly the software modules and the problem sets and their solutions you or others developed.
4. Web sites and reference material you found useful.
5. Whatever else would be useful for your review of the subject.

The portfolio format is up to you to choose but it should be well organized. It may be captured on paper or electronically in a computer file or on a web site. You will turn in the portfolio (or provide a url) for grading three times during the semester.

6.0 COMMUNICATIONS

6.1 Staff Meetings

The faculty and staff will meet every Monday at 10am to discuss the progress of the class.

7.0 GRADING

Grading for 16.851 is based upon the criteria shown in the following table. The percentage weights of each item and a brief description are provided. These grades will be reported to the students in their end-of-term grades as well as once near the middle of the term.

Table 7.0: Grading Categories and Weights

Criteria	Grader	Weight	Number
Class participation	Faculty	15%	26
Problem sets	Faculty	50%	5
Problem set reviews	Faculty	15%	2
Portfolio	Faculty	20%	3

8.0 RESOURCES

8.1 Textbooks

The following textbooks provide resource material for this course:

1) Required: Space Mission Analysis and Design (SMAD), Wertz & Larson, Third edition, Microcosm Press, 1999. Available at the Coop or on Reserve in the Aero-Astro Library.

2) Optional: Fundamentals of Space Systems, Pisacane and Moore, Oxford, 1994

3) Optional: Space Systems Engineering, Fortesque and Stark, John Wiley and Sons, 1995

4) Optional: Space Vehicle Design, Griffin and French, AIAA 1991

5) Optional: Communications Satellite Handbook, Morgan and Gordon, 1989

8.2 Satellite Tool Kit

Each student will be provided with a copy of Satellite Tool Kit®, an orbital analysis software package developed by Analytical Graphics, Inc. Each student will receive instructions on how to access the full capabilities afforded by MIT's educational license with Analytical Graphics, Inc. The STK program is yours to keep (although I would like you to return the CD to me once you have installed the software on your computer). The educational license will expire at the end of the course, terminating your access to the tools beyond the basic functionality. The free version of STK is always available by contacting AGI or on their web site at http://www.stk.com.

8.3 Satellite Design Websites

1. Small spacecraft www links
   http://www.rand.org/publications/MR/MR864/appxF.html
2. NASA Online Cost Models http://www.jsc.nasa.gov/bu2/models.htm

Notes