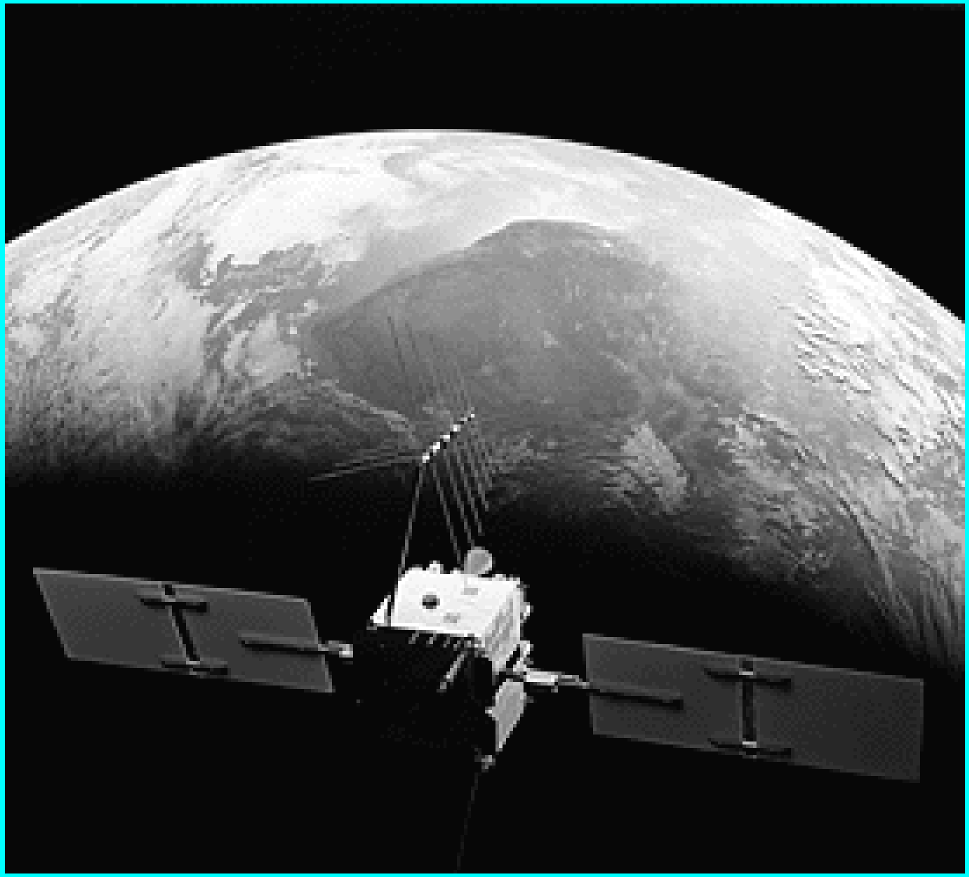
Space Mission Analysis



SPCE 5045

Administrative Items

- Text
- Course Overview and Description
  - Purpose
  - Learning Objectives
  - Topics
- Homework
- Exams
  - Mid-term exam
  - Final exam
  - Term Project
- Grading Policy

Course Purpose

- Familiarize the student with concepts fundamental to the field of space mission design, hardware development, implementation and operation

Overview

- Elements of space missions are examined including orbits, spacecraft systems, launch vehicles, re-entry, operations, and mission management. Emphasis is placed on understanding the underlying physical principles and the system engineering process used to select orbits, plan maneuvers, and accomplish preliminary design of spacecraft payloads/subsystems to meet mission requirements.

Course Description

- Emphasis in this <u>engineering</u> class will be on:
  - Mission requirements
  - Space environment considerations
  - Orbit and constellation considerations to meet mission objectives
  - Spacecraft subsystem design to meet mission objectives
    - Payload Design
      - Communications
      - Observation systems
    - Propulsion
    - Attitude determination and control
    - On-board data processing
    - Power supply
    - Thermal and structure issues

Course Description(concl.)

- The first part of the course will cover the mission requirements process.
- The second part of the course will focus on spacecraft and payload design to meet mission requirements.
- The third part of the course deals with launch and operations

Learning Objectives

- At the end of this course, you should be able to:
  - 1. Define the mission requirements process
  - 2. Apply the process to a hypothetical mission
  - 3. Specify spacecraft and payload design criteria
  - 4. Identify launch, early orbit operations and supporting missions

Administrative Items (cont.)

- Text:
  - Space Mission Engineering, The New SMAD; Wertz; ISBN 978-1-881883-15-9

- It can be ordered directly from the publisher, Astrobooks.com, at: http://www.astrobooks.com
- Or through Amazon, etc. The important detail is that it is “The NEW SMAD”, since there were previous editions titled “SMAD”.
- Last spring students had good luck calling Astrobooks.com directly at (310) 539-2306. Beware…the text weighs about 7 pounds so shipping might be somewhat expensive!!

Grading Policy

- Homework sets ➔ 25%
  - TBD number
- Mid-term exam ➔ 25%
  - Take-home
- Final exam ➔ 25%
  - Take-home
- Term project ➔ 25%
- Below is the grade scale used by our SPCE Department

A	A-	B+	B	B-	C+	C	C-	Etc.
100 - 95	94.9 - 90	89.9 - 87	86.9 - 84	83.9 - 80	79.9 – 77	76.9 – 74	73.9 - 70	

Schedule

Session	Topic	Text Ref.
1	**PART 1**: Introduction and Definition of Terms	Part 1; Ch 1-3
2	Space Mission Concept Definition	Ch 4-6
3	Introduction to Space Environment and Space Mission Geometry	Ch 7,8
4	Orbits and Astrodynamics	Chapter 9
5	Orbit Design (cont.)	Chapter 10
6	Financial aspects	Ch 11,12,13
7	***MID-TERM EXAM***	
8	**PART 2**: Spacecraft and payload design	Ch 14,15
9	Communications payloads	Chapter 16

Schedule (concl.)

Week	**Topic**	**Text Ref.**
10	Observation payloads	Chapter 17
11	Spacecraft subsystems 1,2,3	Ch 18,19,20
12	Spacecraft subsystems 4,5	Ch 21,22
13	Logistics, risk, alternative designs	Ch 23,24,25
14	**PART 3**: Launch ops, ground systems	Ch 26,27,28
15	Mission ops and EOL	Ch 29,30
	FINAL EXAM	
16	Turn in final exam and term project	

OVERVIEW

- The following slides present a top-level view of the material to be presented during the term. More in-depth study will occur <u>for specific topics</u> within this material.
- Requires familiarity with calculus; basic physics

OVERVIEW (cont.)

- Homework and exams may require use of computer tools (Excel; MatLab; Mathcad; etc.)
- The final exam will relate to items covered after the mid-term exam
- Slides; homework and exams will be disseminated by e-mail or posted on Canvas
- Web pages will include FAQs; misc. information, links, etc.

OVERVIEW (cont.)

- Term Project Guidelines:
  - Topic is your choice based on analytical tools developed in the class
  - Topic to be approved by instructor by week 10
  - Detailed scientific/engineering analysis of topic is required
  - Paper to be ~ 15 pages in professional format
  - Project is due by the time of final exam

Contact Information

- Who am I?
  - My name is James Torley; UCCS “Lecturer”
- Where am I?
  - I live in Colorado Springs
- Contact me?
  - You may send e-mail to me at:
    - jtorley@uccs.edu
  - You may call me at:
    - 1-719-339-0092
- Submit assignments <u>directly to my e-mail address</u>
  - I <u>ONLY</u> use Canvas for posting material and general “broadcast” items

Schedule

- Session 1
  - Review goals, learning objectives and topics
  - Assignment is to read chapters 1 and 2 of the text with the above emphasis in mind

Space Mission Analysis Chapter 1

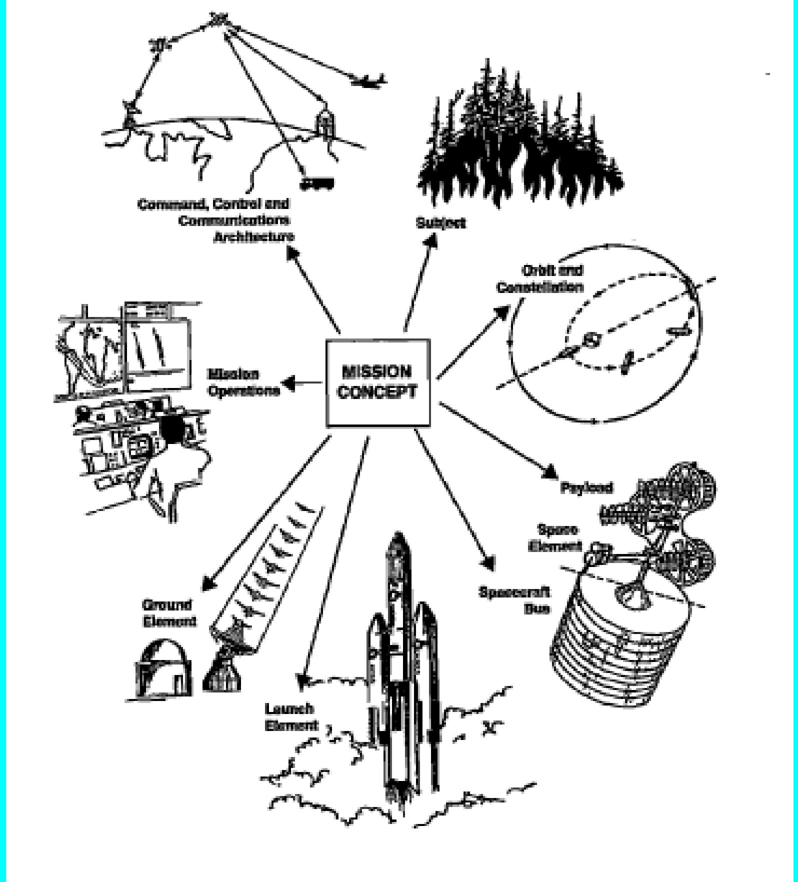


Fig. 1-3. **Space Mission Architecture.** All space missions include these basic elements to some degree. See text for definitions. Requirements for the system flow from the operator, end user, and developer and are allocated to the various mission elements.

Space Mission Analysis

- Chapter 1 of the text is at a very, very high level for this class. However, it sets the stage for much more detailed design discussions to follow.
- Be familiar with the TRL discussions for both hardware and software development as shown in Table 1-1
- NOTE: On the inside cover of the text is a website address and password to interactive tables, figures, etc. If you see a notation such as 

or 

attached to the tables and figures I have included in the weekly material that is the indication that you should refer to the interactive material in the text by following the instructions on the text cover.

Table 1-1. Technology Readiness Levels (TRLs) for DoD Hardware Development. [DoD, 2009]

TRL	Definition	Description	Supporting Information
1	Basic principles observed and reported.	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development (R&D). Examples might include paper studies of a technology's basic properties.	Published research that identifies the principles that underlie this technology. References to who, where, when.
2	Technology concept and/or application formulated.	Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative, and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies.	Publications or other references that outline the application being considered and that provide analysis to support the concept.
3	Analytical and experimental critical function and/or characteristic proof of concept.	Active R&D is initiated. This includes analytical studies and laboratory studies to physically validate the analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.	Results of laboratory tests performed to measure parameters of interest and comparison to analytical predictions for critical subsystems. References to who, where, and when these tests and comparisons were performed.
4	Component and/or breadboard validation in a laboratory environment.	Basic technological components are integrated to establish that they will work together. This is relatively "low fidelity" compared with the eventual system. Examples include integration of "ad hoc" hardware in the laboratory.	System concepts that have been considered and result from testing laboratory-scale breadboards. References to who did this work and when. Provide an estimate of how breadboard hardware and test results differ from the expected system goals.
5	Component and/or breadboard validation in a relevant environment.	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so they can be tested in a simulated environment. Examples include "high-fidelity" laboratory integration of components.	Results from testing a laboratory breadboard system are integrated with other supporting elements in a simulated operational environment. How does the "relevant environment" differ from the expected operational environment? How do the test results compare with expectations? What problems, if any, were encountered? Was the breadboard system refined to more nearly match the expected system goals?

Table 1-1. (Continued)

6	System/subsystem model or prototype demonstration in a relevant environment.	Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory environment or in a simulated operational environment.	Results from laboratory testing of a prototype system that is near the desired configuration in terms of performance, weight, and volume. How did the test environment differ from the operational environment? Who performed the tests? How did the test compare with expectations? What problems, if any, were encountered? What are/were the plans, options, or actions to resolve problems before moving to the next level?
7	System prototype demonstration in an operational environment.	Prototype near or at planned operational system. Represents a major step up from TRL 6 by requiring demonstration of an actual system prototype in an operational environment (e.g., in an aircraft, in a vehicle, or in space).	Results from testing a prototype system in an operational environment. Who performed the tests? How did the test compare with expectations? What problems, if any, were encountered? What are/were the plans, options, or actions to resolve problems before moving to the next level?
8	Actual system completed and qualified through test and demonstration.	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation (DT&E) of the system in its intended weapon system to determine if it meets design specifications.	Results of testing the system in its final configuration under the expected range of environmental conditions in which it will be expected to operate. Assessment of whether it will meet its operational requirements. What problems, if any, were encountered? What are/were the plans, options, or actions to resolve problems before finalizing the design?
9	Actual system proven through successful mission operations.	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation (OT&E). Examples include using the system under operational mission conditions.	OT&E reports.

Table 1-2. Technology Readiness Levels (TRLs) for DoD Software Development. [DoD, 2009]

TRL	Definition	Description	Supporting Information
1	Basic principles observed and reported.	Lowest level of software technology readiness. A new software domain is being investigated by the basic research community. This level extends to the development of basic use, basic properties of software architecture, mathematical formulations, and general algorithms.	Basic research activities, research articles, peer-reviewed white papers, point papers, and early lab model of basic concept may be useful for substantiating the TRL.
2	Technology concept and/or application formulated.	Once basic principles are observed, practical applications can be invented. Applications are speculative, and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies using synthetic data.	Applied research activities, analytic studies, small code units, and papers comparing competing technologies.
3	Analytical and experimental critical function and/or characteristic proof of concept.	Active R&D is initiated. The level at which scientific feasibility is demonstrated through analytical and laboratory studies. This level extends to the development of limited functionality environments to validate critical properties and analytical predictions using non-integrated software components and partially representative data.	Algorithms run on a surrogate processor in a laboratory environment, instrumented components operating in a laboratory environment, laboratory results showing validation of critical properties.
4	Module and/or subsystem validation in a laboratory environment (i.e.,software prototype development environment).	Basic software components are integrated to establish that they will work together. They are relatively primitive with regard to efficiency and robustness compared with the eventual system. Architecture development initiated to include interoperability, reliability, maintainability, extensibility, scalability, and security issues. Emulation with current/legacy elements as appropriate. Prototypes developed to demonstrate different aspects of eventual system.	Advanced technology development, stand-alone prototype solving a synthetic full-scale problem, or stand alone prototype processing fully representative data sets.

Table 1-2. (Continued)

5	Module and/or subsystem validation in a relevant environment.	Level at which software technology is ready to start integration with existing systems. The prototype implementations conform to target environment/interfaces. Experiments with realistic problems. Simulated interfaces to existing systems. System software architecture established. Algorithms run on a processor with characteristics expected in the operational environment.	System architecture diagram around technology element with critical performance requirements defined. Processor selection analysis, Simulation/Stimulation (Sim/Stim) Laboratory buildup plan. Software placed under configuration management. Commercial-off-the-shelf/ government-off-the-shelf (COTS/GOTS) components in the system software architecture are identified.
6	Module and/or subsystem validation in a relevant end-to-end environment.	Level at which the engineering feasibility of a software technology is demonstrated. This level extends to laboratory prototype implementations on full scale realistic problems in which the software technology is partially integrated with existing hardware/software systems.	Results from laboratory testing of a prototype package that is near the desired configuration in terms of performance, including physical, logical, data, and security interfaces. Comparisons between tested environment and operational environment analytically understood. Analysis and test measurements quantifying contribution to system-wide requirements such as throughput, scalability, and reliability. Analysis of human-computer (user environment) begun.
7	System prototype demonstration in an operational, high-fidelity environment.	Level at which the program feasibility of a software technology is demonstrated. This level extends to operational environment prototype implementations, where critical technical risk functionality is available for demonstration and a test in which the software technology is well integrated with operational hardware/software systems.	Critical technological properties are measured against requirements in an operational environment.
8	Actual system completed and mission qualified through test and demonstration in an operational environment.	Level at which a software technology is fully integrated with operational hardware and software systems. Software development documentation is complete. All functionality tested in simulated and operational scenarios.	Published documentation and product technology refresh build schedule. Software resource reserve measured and tracked.
9	Actual system proven through successful mission-proven operational capabilities.	Level at which a software technology is readily repeatable and reusable. The software based on the technology is fully integrated with operational hardware/ software systems. All software documentation verified. Successful operational experience. Sustaining software engineering support in place. Actual system.	Production configuration management reports. Technology integrated into a reuse "wizard."

Reference Material

- The following slide indicates some of the pertinent professional organizations dealing with space missions and design
- If you are not familiar with some of these organizations, I suggest you visit their web sites to learn more about them

Table 1-4. Major Astronautics Professional Societies

Get Info

Society	Comments	Website
AIAA = American Institute of Aeronautics and Astronautics	The largest American professional society with a major focus on astronautics. Holds national and regional conferences. Publishes both refereed journals and many books. AIAA technical committees create many of the standards used in the space industry. (See Sec. 6.6.)	www.aiaa.org
AAS = American Astronautical Society	The largest of the American societies devoted exclusively to astronautics and space exploration. (Note that another AAS = American Astronomical Society, is the largest astronomical organization is the US.)	astronautical.org
BIS = British Interplanetary Society	One of the oldest professional societies in astronautics. Publishes papers on topics, such as interstellar travel, that are more far-reaching than many of the other professional journals.	www.bis-spaceflight.com
IAF = International Astronautical Federation	The IAF is the principal worldwide organization for astronautics with an annual conference held at various locations throughout the World. The IAF is a collection of organizations, i.e., organizations not people are IAF members. Associated with the IAF, are the ***IAA*** = International Academy of Astronautics, which is a worldwide association of astronautics professionals, and the ***IISL*** = International Institute of Space Law, which focuses on legal and treaty issues in the exploration of space.	www.iafastro.com
IEEE = Institute of Electrical and Electronics Engineers	The world's largest professional technical society. Focused on electrical engineering, but does a great deal of work in astronautics, including publication of many relevant papers.	www.ieee.org
INCOSE = International Council on Systems Engineering	A relatively recent organization, founded in 1990, but with a strong interest in space systems engineering. Intended to be a focal point for the dissemination of systems engineering knowledge.	www.incose.org
SEDS = Students for the Exploration and Development of Space	An independent student-based organization (both graduate and undergraduate) with chapters at various universities around the World. Loosely affiliated with some of the professional space organizations. Runs both conferences and various local activities.	seds.org
NSS = National Space Society	Independent educational organizations formed from the merger in 1987 of the National Space Institute and the L5 Society. Dedicated to the creation of a spacefaring civilization.	www.nss.org

©2011 Microcosm Inc.

©2011 Microcosm Inc.

Table 1-5. Major Professional Journals in Astronautics.

	Comments	Abbreviation	Content
AIAA	*Journal of Spacecraft and Rockets*	JSR	Technical
	Journal of Guidance, Control, and Dynamics	JGCD	Technical
	Journal of Aerospace Computing, Information, and Communication	—	Technical
	Journal of Propulsion and Power	JPP	Technical
	Aerospace America	AA	Popular
AAS	*Journal of the Astronautical Sciences* (quarterly)	JAS	Technical
	Space Times (bi-monthly)	ST	Popular
BIS	*Journal of the British Interplanetary Society*	JBIS	Technical
	Spaceflight (includes a running chronology of space missions)	—	Popular
	Aviation Week and Space Technology (weekly)	Av Week	News
	Space News (weekly)	SN	News

©2011 Microcosm Inc.

Table 1-6. Representative Regularly Held Conferences in Astronautics

Get Info

Sponsor	Conference	Location	Date
AIAA	Aerospace Sciences Meeting	Florida	Jan
AIAA, FAA	Commercial Space Transportation Conference	Varied (US)	Feb
AIAA, ASME, ASCE, AHS, ASC	Structures, Structural Dynamics and Materials Conference	Colorado	April
AIAA	Atmospheric Space Environments Conference	Hawaii	June
AIAA, ASME, SAE, ASEE	Joint Propulsion Conference	San Diego	July
AIAA	Guidance, Navigation, and Control Conference	Varied (US)	Aug
AIAA	Modeling and Simulation Technologies Conference	Varied (US)	Aug
AIAA	Space 20(year) (largest of the AIAA conferences)	Varied (US)	Sept
AIAA	AIAA Aerospace Sciences Meeting	Varied (US)	Jan
AAS	Guidance and Control Conference	Colorado	Feb
AAS, AIAA	Space Flight Mechanics Conference	Varied (US)	Feb
AAS	Goddard Memorial Symposium	NASA GSFC	Mar
AAS, AIAA	Astrodynamics Specialist Conference	Varied (US)	July
AIAA (LA & Orange County Sections)	Reinventing Space (= Responsive Space Conference prior to 2011)	Los Angeles	Apr/May
IAF, IISL	International Astronautical Congress (IAC)	Varied (Worldwide)	Oct
Utah State University, AIAA	SmallSat Conference	Logan, UT	Aug

©2011 Microcosm Inc.

Next Week

- Catch up on your reading! I will have information dealing with the preliminary concepts discussed <u>through</u> Chapter 6.