Course Overview/Systems Engineering

• Course Overview
  - Goals
  - Web-based Content
  - Syllabus
  - Policies
  - Project Content

• Tools of Systems Engineering
  - History
  - Project Organization
  - Task-based Management
Contact Information

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Goals of ENAE 483/484 (and 788D)

- Learn the basic tools and techniques of systems analysis and space vehicle design
- Understand the open-ended and iterative nature of the design process
- Simulate the cooperative group engineering environment of the aerospace profession
- Develop experience and skill sets for working in teams
- Perform and document professional-quality systems design of focused space mission concepts
Outline of Space Systems

• ENAE 483 (Fall)
  - Lecture style, problem sets and quizzes
  - Design as a discipline
  - Disciplinary subjects not contained in curriculum
  - Engineering graphics
  - Engineering ethics

• ENAE 484 (Spring)
  - Single group design project
  - Externally imposed matrix organization
  - Engineering presentations
  - Group dynamics
  - Peer evaluations
Web-based Course Content

• Data web site at spacecraft.ssl.umd.edu
  - Course information
  - Syllabus
  - Lecture notes
  - Problems and solutions

• Interactive web site at www.ajconline.umd.edu
  - Communications for team projects
  - Surveys for course feedback
Syllabus Overview

• Fundamentals of Spacecraft Design
• Level 1 Design: Vehicle-Level Estimation
• Level 2 Design: Systems-Level Estimation
• Level 3 Design: Component Detailed Design
Syllabus 1: Fundamentals of Space Systems

9/3 - Systems Engineering
9/5 - Space Environment
9/10 - Orbital Mechanics
9/12 - Engineering Graphics
9/17 - Engineering Ethics
9/19 - Engineering in Teams
Syllabus 2: Design Levels 1 and 2

- **Level 1: System-Level Parametric Design**
  - 9/24 - Rocket Performance
  - 9/26 - Parametric Analysis
  - 10/1 - Cost Analysis

- **Level 2: System-Level Parametric Design**
  - 10/3 - Mass Estimating Relations and Budgets
  - 10/8 - Advanced Costing Analysis
  - 10/10 - Reliability and Redundancy
  - 10/15 - Confidence, Risk, and Resiliency
Syllabus 3: Design Level 3

- Loads, Structures, and Mechanisms
  10/17 - Loads Estimation
  10/22 - Structural Analysis
  10/24 - Structures and Mechanisms Design

- Propulsion, Power, and Thermal
  10/29 - Propulsion System Design
  10/31 - Power System Design
  11/5 - Thermal Design and Analysis

11/7 - Midterm Examination

- Avionics Systems
  11/12 - Attitude Dynamics/Proximity Operations
  11/14 - Data Management; GN&C
  11/19 - Communications
Syllabus 4: Design Level 3 (continued)

• Crew Systems
  11/21 - Space Physiology
  11/26 - Human Factors and Habitability

11/28 - Thanksgiving Break
  12/3 - Life Support Systems Design

• Other Topics
  12/5 - Scheduling Margin

12/10 - Team Project 2 Presentations
Policies

• Grade Distribution
  - 30% Problems
  - 15% Midterm Exam
  - 10% Team Project 1*
  - 15% Team Project 2*
  - 30% Final Exam

* Team Grades

• Late Policy
  - On time: Full credit
  - Before solutions: 70% credit
  - After solutions: 20% credit
Projects for ENAE 483 - Fall 2002

Project Diana

- Minimum cost and time system for resuming human lunar exploration
- “Pathfinder” project to illustrate techniques and applications this term
- Single-person project (me!)
Projects for ENAE 483 - Fall 2002

• Team Project 1 (2-3 person teams)
  - Research a spacecraft from history (real or planned)
  - Prepare an engineering overview presentation
  - Emphasis on research and graphics skills

• Team Project 2 (4-5 person teams)
  - Perform preliminary design of a space vehicle
  - Should follow along with lecture syllabus
  - Presentations at end of term
  - Lead-in to ENAE 484
Team Project 1

- Intended to give you a start at systems engineering and group dynamics
  - Picking and operating in small teams
  - How to perform research
  - Engineering graphics
  - Technical presentation preparation

- Prepare a viewgraph presentation describing a space vehicle - Could be past, present, or planned for future, flown or unflown - but not science fiction! (Note: vehicles, not missions: e.g., “Apollo lunar module”, not “Apollo 17”)

- Details linked to course syllabus
Team Project 2

• Crew Rotation/Rescue Vehicle
  - Rotate crews to/from International Space Station
  - Based on ISS for emergency “bail-out”
  - Launch on Delta IV Heavy
  - Cost-effective compared to Space Shuttle

• Design process should proceed throughout the term

• Formal design presentations at end of term
Class Rosters

• ENAE 483
  – Aymergen, Cagatay
  – Baker, Meghan Briana
  – Beres, Matthew Christian
  – Bowen, Christopher L
  – Catlin, Kathryn Anne
  – Christy, Jason Thomas
  – Colville, Jesse Ryan
  – Edery, Avi
  – Frank, Wendy Elizabeth
  – Hintz, John Charles
  – Hollingsworth, Kirstin Mic
  – Hoskins, Aaron Bradley
  – Jones, Robyn Michelle
  – Langley, Alexandra Bliss
  – Long, Andrew Michael
  – Michael, Sadie Kathleen
  – Miller, William Martin
  – Moulton, Nathan Lee

• ENAE 483 (cont.)
  – Noyes, Thomas Vincent
  – Parker, John Michael
  – Pierson, Lynn Kathryn
  – Reilly, Jacqueline Marie
  – Richeson, Justin Arthur
  – Rodriguez, Eric Raymond
  – Sadorra, Oliver John
  – Silva, Ernest Surendra
  – Stamp, Gregory Carlton
  – Work, Christopher Eric
  – Yoshimura, Yudai

• ENAE 788D
  – Chauffour, Marie-Laure
  – Clough, Joshua Alan
  – Evanson, Justin J
  – Horne, Rebecca Leigh
  – Rodriguez, Arthur Steven
  – Shapiro, Elisa Gail
  – Shoup, Gregory James
Mars Scout-Class Mission

- Robotic mission to precede human mission
- Science objectives are to sample, survey, and verify surface environment as safe for human exploration mission, and to develop necessary infrastructure
- Develop to NASA requirements for Scout-class missions
- Design as a university-built mission
- Final output is a Scout proposal to NASA
Akin's Laws of Spacecraft Design - #3

Design is an iterative process. The necessary number of iterations is one more than the number you have currently done. This is true at any point in time.
Overview of Systems Engineering

• Developed to handle large, complex systems
  - Geographically disparate
  - Cutting-edge technologies
  - Significant time/cost constraints
  - Failure-critical

• First wide-spread applications in aerospace programs of the 1950’s (e.g., ICBMs)

• Rigorous, systematic approach to organization and record-keeping
The Space System Development Process

Pre-Phase A

Conceptual Design Phase
Development of performance goals and requirements
Establishment of Science Working Group (science missions)
Trade studies of mission concepts
Feasibility and preliminary cost analyses
Request for Phase A proposals
The Space System Development Process

Pre-Phase A

Phase A

Preliminary Analysis Phase
- Proof of concept analyses
- Mission operations concepts
- “Build vs. buy” decisions
- Payload definition
- Selection of experimenters
- Detailed trajectory analysis
- Target program schedule
- RFP for Phase B studies
The Space System Development Process

Pre-Phase A

Phase A

Phase B

Definition Phase

Define baseline technical solutions
Create requirements document

Significant reviews:

Systems Requirements Review
Systems Design Review
Non-Advocate Review

Request for Phase C/D proposals
The Space System Development Process

Pre-Phase A

Phase A

Phase B

Phase C/D

Development Phase
Detailed design process
“Cutting metal”
Test and analysis

Significant reviews:
- Preliminary Design Review (PDR)
- Critical Design Review (CDR)
- Test Acceptance Review
- Flight Readiness Review

Ends at launch of vehicle
The Space System Development Process

Pre-Phase A

Phase A

Phase B

Phase C/D

Phase E/F

Operations and End-of-Life

Launch

Check-out

Mission Operations

Maintenance and Troubleshooting

Failure monitoring

End-of-life disposal

Parametric Design
Principles of Space Systems Design
Requirements Document

- The “bible” of the design and development process
- Lists (clearly, unambiguously, numerically) what is required to successfully complete the program
- Requirements “flow-down” results in successively finer levels of detail
- May be subject to change as state of knowledge grows
- Critical tool for maintaining program budgets
Project Diana Mission Statement

Presidential address to a joint session of Congress, January, 2003:

“I believe this nation should commit itself to achieving the goal, before this decade is out, of returning humans to the lunar surface, for exploration and eventual permanent habitation.”
Level 1 Requirements

1) Perform a mission equivalent to a NASA J-class Apollo mission before January 1, 2010

2) No programmatic resources may be used for launch vehicle development

3) Any single mission shall have a 90% chance of mission success

4) Any single mission shall have a 99.9% chance of crew survival

5) The program will maximize the opportunities to engage and involve the U.S. and world public, especially K-12
Level 2 Requirements

1.1) At least two astronauts will form the lunar landing crew
1.2) Lunar surface stay time will be at least 72 hours
1.3) Lunar surface activities will be comparable to Apollo J missions
Level 3 Requirements

1.3.1) Landed lunar equipment mass will be TBD kg
1.3.2) Returned lunar sample mass will be TBD kg
1.3.3) Surface activities will include 3 EVAs of 7 hours duration each
Design is based on requirements. There's no justification for designing something one bit "better" than the requirements dictate.
Work Breakdown Structures

- Detailed “outline” of all tasks required to develop and operate the system
- Successively finer levels of detail
  - Program (e.g., Space Transportation System)
  - Project (Space Shuttle Project)
  - Mission (Earth-LEO Transportation)
  - System (Shuttle Orbiter)
  - Subsystem (Main Propulsion)
  - Assembly (High Pressure LOX Turbopumps)
  - Subassembly, Component, Part, ...
Akin's Laws of Spacecraft Design - #24

It's called a "Work Breakdown Structure" because the Work remaining will grow until you have a Breakdown, unless you enforce some Structure on it.
PERT Charts

- **Lecture 1**
  - **Task Title**: 1d
  - **Duration**: 1d
  - **Earliest Starting Date**: Tue 9/3/02
  - **Earliest Completion Date**: Tue 9/3/02
  - **Slack Time**: 0d

- **Homework 1**
  - **Duration**: 2d
  - **Earliest Starting Date**: Wed 9/4/02
  - **Earliest Completion Date**: Thu 9/5/02

- **Prepare for Lecture 2**
  - **Duration**: 2d
  - **Earliest Starting Date**: Wed 9/4/02
  - **Earliest Completion Date**: Thu 9/5/02
The Critical Path and Slack Time

Design Robot
4 w 0d
Tue 9/3/02 Mon 9/30/02

Build Head
6 w 0d
Tue 10/1/02 Mon 11/11/0

Build Body
4 w 10d
Tue 10/1/02 Mon 11/11/0

Build Legs
3 w 15d
Tue 10/1/02 Mon 11/11/0

Assemble
2 w 0d
Tue 11/12/02 Mon 11/25/0
The Critical Path and Slack Time

Design Robot
4 w 0d
Tue 9/3/02 Mon 9/30/02

Build Head
6 w 5d
Tue 10/1/02 Mon 11/18/02

Build Body
7 w 0d
Tue 10/1/02 Mon 11/18/02

Assemble
2 w 0d
Tue 11/19/02 Mon 12/2/02

Build Legs
3 w 20d
Tue 10/1/02 Mon 11/18/02
Cascading Slack Time

Design Robot: 4w 0d
Tue 9/3/02 Mon 9/30/02

Build Torso: 2w 10d
Tue 10/1/02 Mon 10/28/02

Build Legs: 3w 15d
Tue 10/1/02 Mon 11/11/0

Build Waist: 2w 10d
Tue 10/15/02 Mon 11/11/0

Build Head: 6w 0d
Tue 10/1/02 Mon 11/11/0

Assemble: 2w 0d
Tue 11/12/02 Mon 11/25/0
<table>
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<tr>
<th>ID</th>
<th>Task Name</th>
<th>Duration</th>
<th>Start</th>
<th>Finish</th>
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<tbody>
<tr>
<td>1</td>
<td>Design Robot</td>
<td>4 w</td>
<td>Tue 9/3/02</td>
<td>Mon 9/30/02</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Build Head</td>
<td>6 w</td>
<td>Tue 10/1/02</td>
<td>Mon 11/11/02</td>
<td>1</td>
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<tr>
<td>3</td>
<td>Build Body</td>
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<td>Mon 10/28/02</td>
<td>1</td>
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<td>Build Legs</td>
<td>3 w</td>
<td>Tue 10/1/02</td>
<td>Mon 10/21/02</td>
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<tr>
<td>5</td>
<td>Assemble</td>
<td>2 w</td>
<td>Tue 11/12/02</td>
<td>Mon 11/25/02</td>
<td>2, 3, 4</td>
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**Gantt Charts**
Akin’s Laws of Spacecraft Design - #23

The schedule you develop will seem like a complete work of fiction up until the time your customer fires you for not meeting it.
Akin's Laws of Spacecraft Design - #1

Engineering is done with numbers. Analysis without numbers is only an opinion.