Exam: April 7

- Closed book, closed journal, closed neighbor, open mind
- 4” x 6” reference card allowed
- Timed
- Short Answer questions
- Covers the course learning objectives
  - www.coe.montana.edu/engr310
“...systematic, intelligent generation and evaluation of specifications for artifacts whose form and function achieve stated objectives and satisfy constraints.”

-Dym & Little, 2004
Design in Engineering is:

- Ill-structured → cannot apply a formula
- Open-ended → >1 solution possible
- Complex
- Must integrate many pieces.
- Must integrate with environment
An Engineering Design Process

Client Need

Problem Definition

Conceptual Design

System-level Design

Detail Design

Design Communication

Final Design
Problem Definition

client’s statements

Gather information to develop a statement of client wants in engineering terms:

1. Clarify objectives
2. Establish user requirements
3. Identify Constraints
4. Define desired functions

statement of:
objectives
constraints
requirements
functions
Who Sets Objectives and Constraints?

client

motivates
design

creates
design

designer

uses
designed
artifact

user
First step

client

designer

user

Who are they?
Clarify the Design Problem

- Observation
- Interviews
- Researching existing solutions

→ Comprehensive list of desired characteristics
Most initial attribute lists are a mix of:

- Objectives
- Constraints
- Functions
- Means (or implementations)
Objective Tree

Helpful to organize objectives into a hierarchy.

Add Constraints (but differentiate).
No functions or means!
Functions & Specifications

**Functions** = what system must do to achieve objectives

**Functional Specifications** = how well system must do it

Also called “performance specifications” or “functional requirements”
Black Box Approach

Inputs
- Energy
- Material
- Information

Main Function

Outputs
Divide Functions into Subfunctions

Main Function

Subfunction A ➔ Subfunction B ➔ Subfunction C ➔ Subfunction D

Dashed line connects Subfunction A and Subfunction D.
Generate concepts of candidate designs:

5. Establish design specifications
6. Generate ideas
Functional Specifications

How well must the design accomplish the functions?

– Measurable
– Solution neutral
– Things client/users care about
“Zone of Interest”
Common Mental Blocks

- Perceptual: define problem too narrowly
- Fixation: can’t get past one idea
- Emotional: anxiety, fear of failure, frustration
- Cultural: social patterns that blind us to possible solutions
- Environmental: distractions, poor atmosphere
Conceptual Blockbusting

- First step is to recognize them.
- Second, use structured techniques to break out of your current thinking pattern.
Where do new ideas come from?

- Adaptations of existing ideas to new contexts
  - Generalize the problem, look for others’ solutions
- Combining existing ideas
- Analogy
Technique 1: Brainstorming

• List all ideas
  – individually first, then as a group

• No criticism or evaluation!
  – encourage crazy, outlandish ideas
  – have fun!!
## Technique 2: Morphological Chart

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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</thead>
<tbody>
<tr>
<td><strong>Accept Beans</strong></td>
<td><strong>Lid</strong></td>
<td>Door</td>
<td>Gravity chute</td>
<td>...</td>
</tr>
<tr>
<td><strong>Contain Beans</strong></td>
<td><strong>Canister</strong></td>
<td><strong>Bag</strong></td>
<td>Vacuum</td>
<td>...</td>
</tr>
<tr>
<td><strong>Grind Beans</strong></td>
<td><strong>Rotating blade</strong></td>
<td><strong>Mortar &amp; pestle</strong></td>
<td>Opposing discs</td>
<td>...</td>
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<tr>
<td><strong>Etc.</strong></td>
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Technique 3: Group Brain-writing

1. Decide on problem to be addressed
2. Silently, each person generates 3 ideas.
   1. Sketches + labels (minimum of words)
3. Rotate ideas to person on the right.
4. Build on the ideas just passed to you
   1. for a set period of time.
5. Repeat until ideas reach originator.
6. Review, discuss, evaluate, combine.
   1. post on the wall
7. Choose a subset to carry forward.
“Pick Best and Iterate” Approach

generate concepts

pick one

synthesize

analyze

improve
“Controlled Convergence” Approach

generate concepts

Look at sets of design ideas...

...and eliminate the worst.
(rather than pick the best)
Design Convergence...

...isn’t usually smooth.
## Evaluation Matrix

<table>
<thead>
<tr>
<th>Criteria</th>
<th>A</th>
<th>B</th>
<th>C</th>
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<tbody>
<tr>
<td>a)</td>
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<td>b)</td>
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<td>d)</td>
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</table>
System-level Design

specs + design alt’s

- Identify principle attributes of leading design concepts:
  7. Establish system architecture
  8. Model and evaluate alternatives
  9. Converge to best alternative
System-level Design

- Identify subsystems of the concept
- Investigate alternative configurations
- Think through interface issues, in detail
  - between subsystems
  - with user
  - with environment
- Choose configuration based on the best interfaces
Block Diagram

- Identifies key subsystems and interfaces

- Battery
  - Electrical Hardware:
    - Voltage Regulator Circuit
    - 4 Relays
  - 12V

- Microprocessor
  - 3.3V
  - "Pop-up" Signal

- Solenoid (4)
  - Actuation Pulse
  - Release Latch

- Mechanical Target Module
  - Selects skill game
  - Swing target into view
  - Release Latch
  - Support
  - Shoots target down to relatch

- User
  - Ground
System Architecture Plan

• Adds interface details to block diagram
Refine and add detail to final design:

10. Create detailed drawings, etc.
11. Optimize through analysis
12. Review design.
Design Communication

proposed fabrication specifications

Document fabrication specifications and justification

final fabrication specifications

client report
Iteration

Client Need

Problem Definition

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Detail Design

Design Communication

Final Design

validation

feedback
The Process is Not Linear!

- Phases tend to overlap in practice
- Applications repeat on different:
  - subproblems
  - levels of abstraction
- Problem definition tasks appear in some form in each phase
A Project Management Framework

- Project Definition
- Project Planning
- Project Tracking & Control
The Project Triangle

Schedule

Cost

Performance
Project Risk Chart

Amount of Risk

Probability

A
B
C
D
E
F
G
H
Project Planning Approach

• Project Manager Sets Multiple "Hard" Milestones
Building the Plan

1. Develop work breakdown structure (WBS)
2. Define length for each task
3. Define dependencies
4. Assign resources
5. Review for over-allocation
Stages of Team Development

- Forming
- Storming
- Norming
- Performing
Feedback: An essential element of design reviews

- Work Product
- Critique

revise
PAUSE Principle

Prepare – get the facts, generate options
Affirm – the relationship
Understand – the others’ issues
Seek – mutually beneficial options
Evaluate – Have we satisfied the major concerns?
Conflict Management Strategies

Avoidance
Compromise
Attack

Constructive Engagement

Creative Solutions
Keys to Effective Meetings

• Prepare ahead of time.
• Have a written agenda.
• Agree on meeting’s objectives.
• Start on time.
• Document decisions made.
• Don’t leave without an action plan.
• Establish ground rules.
• Appoint a facilitator.
Five Sets of Teamwork Skills

1. Interpersonal communication and collaboration
2. Understanding & communicating trade-offs and empathy for diverse perspectives
3. Planning/organization and accountability/reliability
4. Common goals/shared outcomes and conflict management, resolution
5. Willingness to learn and inclusive decision-making
Why do design projects fail?

1. Misunderstanding what the customer needs.
2. Committing to a solution too early.
4. Poor system architecture, especially interfaces.
5. Poor planning.
Good Luck on Monday!