ENGR 310

Lecture 20
4 April 2008

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

What is Engineering Design?
“…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
- Designer creates design
- User uses designed artifact

First step

Who are they?

- Client
- Designer
- User

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

Outputs

Main Function

Divide Functions into Subfunctions

Subfunction A → Main Function → Subfunction B → Subfunction C → Subfunction D

Conceptual Design

- 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”

Utility vs. Level of Variable

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>
</tr>
</thead>
<tbody>
<tr>
<td>Accept Beans</td>
<td>Lid</td>
<td>Door</td>
<td>Gravity chute</td>
<td>...</td>
</tr>
<tr>
<td>Contain Beans</td>
<td>Canister</td>
<td>Bag</td>
<td>Vacuum</td>
<td>...</td>
</tr>
<tr>
<td>Grind Beans</td>
<td>Rotating blade</td>
<td>Mortar &amp; pestle</td>
<td>Opposing discs</td>
<td>...</td>
</tr>
<tr>
<td>Etc.</td>
<td></td>
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</tbody>
</table>

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

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

Look at sets of design ideas...

Design Convergence...

...isn’t usually smooth.

Evaluation Matrix

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Alternatives</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>a)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>b)</td>
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<tr>
<td>d)</td>
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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

Table

<table>
<thead>
<tr>
<th>System-level Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identify principle attributes of leading design concepts:</td>
</tr>
<tr>
<td>7. Establish system architecture</td>
</tr>
<tr>
<td>8. Model and evaluate alternatives</td>
</tr>
<tr>
<td>9. Converge to best alternative</td>
</tr>
</tbody>
</table>

Diagram

- Identifies key subsystems and interfaces
System Architecture Plan

- Adds interface details to block diagram

Electrical Circuit

Battery 12v

Voltage Regulator Circuit

Microprocessor

Pwr Port B

Bit 0

Bit 1

Bit 2

Bit 3

12v

3.3v

Proposed Fabrication Specifications

Detail Design

Client Need

Problem Definition

Conceptual Design

System-level Design

Detail Design

Design Communication

Final Design

Validation

Iteration

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

20%  40%  60%  80%  100%
Probability

Amount of Risk

10  8  6  4  2

A  B  C  D  E  F  G  H

Project Planning Approach

• Project Manager Sets Multiple “Hard” Milestones

Effort per Week

HM1  HM2 Schedule  HM3  Final

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!