EE497 Senior Design

Design for Engineers

Grzegorz Chmaj
Introduction

- Goals of today’s class:
  - Get familiar with the design process
  - Project selection
  - Requirements specification
  - Concept generation and evaluation
  - Functional decomposition
Source

Ralph M. Ford, Chris S. Coulston, “Design for Electrical and Computer Engineers”
## Motivation

<table>
<thead>
<tr>
<th></th>
<th>Stanley Screwdriver</th>
<th>HP DeskJet Printer</th>
<th>VW Beetle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Production Volume</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sales lifetime</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># parts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Development time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Development team</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Development cost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production investment</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Motivation

<table>
<thead>
<tr>
<th></th>
<th>Stanley Screwdriver</th>
<th>HP DeskJet Printer</th>
<th>VW Beetle</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Annual Production Volume</strong></td>
<td>10,000</td>
<td>4 million</td>
<td>100,000</td>
</tr>
<tr>
<td><strong>Sales lifetime</strong></td>
<td>40 years</td>
<td>2 years</td>
<td>6 years</td>
</tr>
<tr>
<td><strong># parts</strong></td>
<td>3</td>
<td>200</td>
<td>10,000</td>
</tr>
<tr>
<td><strong>Development time</strong></td>
<td>1 year</td>
<td>1.5 years</td>
<td>3.5 years</td>
</tr>
<tr>
<td><strong>Development team</strong></td>
<td>6</td>
<td>175</td>
<td>1,600</td>
</tr>
<tr>
<td><strong>Development cost</strong></td>
<td>$150K</td>
<td>$50 million</td>
<td>$400 million</td>
</tr>
<tr>
<td><strong>Production investment</strong></td>
<td>$150K</td>
<td>$25 million</td>
<td>$500 million</td>
</tr>
</tbody>
</table>
What is Engineering Design?

**Engineering design** is the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics, and engineering sciences are applied to convert resources optimally to meet a stated objective. Among the fundamental elements of the design process are the establishment of objectives and criteria, synthesis, analysis, construction, testing, and evaluation. [ABET]
Design process is the set of steps that a designer goes through, with jumping back and forth between steps:

- Define the Problem
- Do Background Research
- Specify Requirements
- Brainstorm Solutions
- Choose the Best Solution
- Do Development Work
- Build a Prototype
- Test and Redesign
Science and Engineering

Engineering design process differs from the Scientific method. Both these groups have different goals:

- Engineers create new things
- Scientists study how nature works
Science and Engineering

Scientific Method

1. Ask a Question
2. Do Background Research
3. Construct a Hypothesis
4. Test with an Experiment
5. Procedure Working?
   - No
   - Yes
   --- Analyze Data and Draw Conclusions
   - Results Align with Hypothesis
   - Results Align Partially or Not at All with Hypothesis
   --- Communicate Results

Engineering Method

1. Define the Problem
2. Do Background Research
3. Specify Requirements
4. Brainstorm, Evaluate, and Choose Solution
5. Develop and Prototype Solution
6. Test Solution
   - Solution Meets Requirements
   - Solution Meets Requirements Partially or Not at All
   --- Communicate Results
--- Based on results and data, make design changes, prototype, test again, and review new data.
Process design models

Two kinds of design models:

- **Prescriptive** – define how the models should work, how they could be performed. Establish rules, guidelines, behavior – that if followed, then would lead to desired process performance

- **Descriptive** – track what actually happens in processes, describe how they work and what are their properties
Prescriptive design model

Diagram:

1. Identify Problem & Needs
2. Determine Requirements
3. Do requirements satisfy needs?
   - Yes
   - No
Descriptive design model

Diagram:
Design model examples

VLSI design process:

- Specification
- System Architecture
- Logic Design
- Circuit Design
- Layout

Prescriptive or descriptive?
Design model examples

Embedded system design process:

Prescriptive or descriptive?
Software design process:

Prescriptive or descriptive?
Why to care about?

The importance of design process:

- How much does it cost to correct problems as process proceeds?

![Graph showing cost to implement changes vs. project lifetime. The cost increases exponentially as the project lifetime progresses.]
Conclusions:

- Engineering design is an iterative process.
- Design problems are open-ended with many potential solutions.
- Design processes represent best practices for realizing a system.
- Design processes may be prescriptive or descriptive.