Lecture 3:
Information Gathering:
Reverse Engineering

Outline:

- INTRODUCTION TO REVERSE ENGINEERING
- THE TEARDOWN PROCESS
- BILL OF MATERIALS
- DETERMINING PRODUCT FUNCTION:
  - SOP (SUBTRACT AND OPERATE PROCEDURE)
  - FORCE FLOW DIAGRAMS
The “General” Design Process Model

**Identify Need**
- Talk with Client
- Project Goals
- Information Gathering

**Problem Definition**
- Problem Statement
- Information Gathering
- Design Objectives (quantifiable/measurable)

**Conceptualization**
- Brainstorming
- Drawing/Visualization
- Functional Decomp.
- Morphologic Chart

**Preliminary Design & Planning**
- Prelim. Specifications
- Prelim. Analysis
- Decision Making
- Gantt Charts & CPM

**Detailed Design**
- Detailed Analysis
- Simulate & Optimize
- Detail Specifications
- Drawings, GD&T

**Prototyping**
- Prototype Fabrication
- Concept Verification

**Testing/Evaluation**
- Evaluate Performance
- Are Objectives Met?
- Iterate Process Steps 2 - 7 as needed

**Report/Deliver**
- Oral Presentation
- Client Feedback
- Formal Design Report

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**Introduction to Reverse Engineering**

Definition of Reverse Engineering as it pertains to products or physical systems: the process of systematic examination of a product to learn and understand its principle of operation, its functions, and design.

Reverse Engineering seeks to uncover:

- Principle of operation
- Device functions and sub-functions
- Are customer needs satisfied?
- Company’s business practices and strategies
Introduction to Reverse Engineering

Reverse Engineering is a useful activity because:
1. Maintain competitive standing in latest technologies
2. Evaluation of product's performance (benchmarking)
3. Discover opportunities to improve upon competitor's products
4. Product analysis can strengthen "knowledge base" of examiners

Possible Pitfalls of Reverse Engineering:

Reverse Engineering

Reverse engineering is an important and legitimate business practice for all product development companies. It allows your company to:
1. Estimate costs of competitor's products
2. Plot trends among previous models/versions
3. Make predictions on market direction
4. Assess environmental impact and recyclability
5. Ensure competitors are not infringing on your IP
Reverse Engineering: The Process

Clearly define the goal/purpose of the reverse engineering activity.
- What are the goals of the activity?
- What is expected to be uncovered?

The Reverse Engineering Process, from reference [1].
1) List the Design Issues
2) Prepare for Product Teardown
3) Examine the Distribution Method
4) Disassemble, Measure and Analyze Product
5) Create a Bill of Materials

The Reverse Engineering Process: List the Design Issues

Clearly define the scope of the activity. Presumably, your design team is reverse engineering a competitor’s product, in order to produce a superior product, and gain market share.

In this context, by reverse engineering, you seek to determine:
- What are the problems/limitations of the design?
- What are the great features/functions of the design?
- Is this product part of a family of similar products?
- Are any online reviews/customer feedback available?
The Reverse Engineering Process:
Prepare for Product Teardown

Identify and list all the tools needed for the product teardown. This may include:
- Camera or Video Recorder
- Disassembly tools (screwdriver, pry bar, **)
- Calipers and ruler
- Multimeter
- Documentation method (log-book, or computer)

** Do Not use destructive test procedures! No saws, cutters, and hammers! You want to carefully disassemble, and ultimately re-assemble the product. You will gain knowledge from both disassembly and re-assembly.

The Reverse Engineering Process:
Examine the Distribution Method

A very important (and often overlooked aspect) of a product, is its distribution method. Take time to understand how this product moves through the supply chain (manufacturer to retailer to consumer), and if it has been properly designed for this. Consider the following aspects:
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The Reverse Engineering Process:
Disassemble, Measure and Analyze Product

To be effective, this step must be coordinated with photography, measurement, and testing (as needed).
Also, this process should be non-destructive, so that re-assembly is possible.
The steps are:
- Take apart the assembly
- Take pictures to create an exploded-view collage of images.
- Take measurements
- Perform tests
- Re-assemble the product when finished.

In some cases, destructive testing may be necessary. (NOT FOR MECH350!). However, this should occur at the end of the analysis.

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The Reverse Engineering Process:
Create Bill of Materials (BOM)

Form a Bill of Materials (BOM) using a spreadsheet program.
Information that is useful for your BOM may include:
- Part Name
- Quantity
- Dimensions, and Mass
- Material, Finish, or Colour
- Manufacturing process used,
- Purpose/Function of part
- Cost estimate per part
- Other notes

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When reverse engineering a product, one of the goals is to determine how the product functions. In other words, how it achieves its purpose, given the multitude of components within.

For simple products, this may be self-evident.

However, for complex products consisting of a dozen or more parts and sub-assemblies of parts, determining function can be tricky.

The SOP method is a systematic way to help you determine the function of a product, and also to determine if a product is over-designed.

The SOP [1] method directs you to remove a single component from a product, and then evaluate how that product performs without it.

The SOP method entails the following 6-Step procedure:

1) Disassemble (subtract) one component of the system.
2) Operate the system through its full range
3) Analyze the effect
4) Deduce the sub-function of the missing component
5) Replace the component and repeat the procedure n-times, where n is the number of components in the system.
6) Document the results in a table, or a function tree diagram.
Additional Notes on Subtract and Operate Procedure (SOP)

- The SOP method is also a great way to look for opportunities for component elimination, due to over-design.
- For Step 1: The order of the procedure may be dictated by the disassembly process. Also, it should now be evident why you cannot use destructive disassembly, since it would invalidate the SOP.
- For Step 2: Try to operate through the full range, to the greatest practical extent. Specifically, if the product objectives can be met.
- For Step 3 & 4: Testing and experiment may be necessary to achieve this step.
- For Step 5: Note that complex products are often a collection of “sub-assemblies”, each of which may be further disassembled if necessary. For example, a motor, a gear train, a switch, a battery, are all sub-assemblies.

Reverse Engineering: Force Flow (Energy Flow) Diagrams

- Another useful method to determine how a product operates, and the purpose of its sub-components, is to create a Force Flow Diagram.
- Force Flow Diagrams are a systematic way to help you determine combination between components and their interaction.
- FFDs represent the transfer of force through a product’s components.
Reverse Engineering:
Force Flow (Energy Flow) Diagrams

How to create a FFD:
- The components are symbolized as nodes using circles.
- The component name appears in the circle.
- The forces are drawn as arrows connecting the components in which the force transfer takes place.
- More than one arrow can enter or terminate into a node.

Example of a FFD for a paperclip [1]:

[Diagram of a paperclip showing force flow between the hand, lever arm 1, lever arm 2, and clip.]

Figure 6.8.
Example of a FFD for a Stapler [1]:

\[\text{Image of a Stapler} \]

Stapler is dis-assembled, and all constituent parts are illustrated [1]:

\[\text{Diagram of Stapler parts} \]
Reverse Engineering:
Force Flow (Energy Flow) Diagrams

FFD for a Stapler [1]:

References:

For further information, consider the following references:
