OUTLINE

- Administrative Details:
  - Slides from guest speaker Laurie Yoler have been posted on Canvas and the EE15n website.
  - This week: Notes from Weekly Meeting.
  - Next week: Morphological Chart. Set of team member sketches for the Gallery Method. Notes from Weekly Meeting.
  - Make sure that documents are sent/accessible to both Andrea and My (Google doc links sent to us might be easiest)

- Lecture
  - Generating and Evaluating Design Ideas. Design for X.

- Speaker
  - Celia Oakley, Opener
GENERATING & EVALUATING DESIGN IDEAS

DESIGN FOR X
EVERYTHING SHOULD BE MADE AS SIMPLE AS POSSIBLE BUT NOT SIMPLER

Albert Einstein
FROM IDEA TO PRODUCT

Problem Statement

GENERATING

SELECTING

What gets built.
What is our problem statement?
Conceptualization of a space that incorporates all possible designs.

Juice Container Design Space

- Cardboard Box
- Plastic Bag
- Plastic Bottle
- Glass Bottle
- Aluminum Can
- Straw Hole
- Twistoff Cap
- Metal Cap
- Pullring
- Pushtab
KEY OBJECTIVES

- Allow users to locate bicycles on crowded bike racks
  - Both daytime and nighttime conditions
  - From at least 50 feet away
  - By using both auditory and visual elements
- Implement the solution using a device that is not bulky or heavy on the bicycle
- Implement the solution using a device that is no more than double the cost of existing bike lights
  - This price should account for lights, speakers, and remotes
**EXAMPLE OF DESIGN SPACE – S-LIGHT PROJECT**

### Light Set-Up
- Rotating Light
- Lights Around Outside
- Rotating Cover with Slit
  - Brightest, Ability to Customize, No moving parts

### Activation of Tracking System
- Whistle Recognition
- Voice Recognition
- Remote Control
  - 50 Foot Range, Convenient Size, No possibility of confusion

### Attachment
- Mounting Bracket
- Welding
  - Conventional, Cheap, Freedom to remove from bike
COMPLEX DESIGN SPACES

- A problem has a large design space if
  - The number of potential designs is large
  - The number of design variables and/or the number of values they can assume is large

- Artifacts with large design spaces
  - Airplanes
  - Buildings

By contrast, what has a small design space?
DESIGN SPACE DECOMPOSITION EXAMPLE: AIRPLANE

Airplane

- Passenger Compartment
  - Seats
  - Emergency Exits
- Fuselage
  - Overhead Bins
- Wings
- Kitchen
  - Seats
  - Windshields
- Cockpit
  - Controls
MORPHOLOGICAL CHART:
ORGANIZING FUNCTIONS & MEANS

- List of functions or features.
- List of different means of each function or feature identified.
- Assemble designs in the classic *Chinese Menu* style.

Morph chart due 2/20
TEAM METHODS (n members)

- **n:3:n-1 (in book it is 6-3-5):**
  - Each member writes 3 ideas.
  - n lists rotated among n-1 team members
  - Each member comments on each idea

- **C-sketch:**
  - Same as n:3:n-1 method, but rather than listing 3 ideas, sketch 3 pictures

- **Gallery:**
  - Each member does 1 sketch of a design idea
  - Sketches posted, then each discussed by team

Gallery sketches due 2/20
EXPANDING YOUR DESIGN SPACE

- Talk to experts that work on related designs
- Product literature on existing products
- Visionary/research papers and articles
- Design and legal codes
- Standards (often based on performance analysis available in the standards literature)
- WWW search
- Patent search (www.uspto.gov, google.com/patents, freepatentsonline.com)
- Benchmark existing products to evaluate how well they perform.
- Reverse engineer or dissect existing devices
**CONTRACTING YOUR DESIGN SPACE**

- Check for external constraints that affect the design
- Invoke and apply constraints
- Freeze the number of features and behaviors being considered
- Impose priorities on the list of features and functions
- Apply common sense to rule out infeasible ideas.
DIVERGENCE VS CONVERGENT THINKING

Divergent thinking:
- Try to remove limits or barriers on design ideas
- Think outside the box

Convergent thinking:
- Narrow design space to focus on best alternatives
- Know constraints & boundaries to converge on a solution within these limits

Think outside the box, but stay within the laws of physics!

http://www.senseandsensation.com/2012/03/divergent-convergent-thinking.html
SELECTING THE BEST DESIGN

- Now you have a number of feasible design alternatives
- How do you select the best design?
Want a design that best meets a client’s objectives

Use metrics to determine how well a design meets objectives

Should focus on client’s most important objectives

Designs that don’t meet constraints must be rejected

Methods for Design Evaluation via Metrics *(2 out of 3 due 3/1)*

- Numerical Evaluation Matrix
- Priority Checkmarks
- Best of Class Chart

Use Common Sense When Looking At Results!
Shows both constraints (upper rows) and objectives (lower rows) in the left-hand column

Eliminate designs that don’t meet constraints

Assign a score to each remaining design for each objective (pick a useful, differentiating scale like 1-10 or 1-100)

See if “best design” is clear from the scoring (best/equal in all areas)

Determine (with client) which design best meets ranked objectives
TABLE 8.1 A numerical evaluation matrix for the juice container design problem. Note that only three of the six objectives originally identified for this design are utilized here, in part because we think these three objectives are more important than the other three, and in part because we have metrics (and presumably data) for these three objectives.

<table>
<thead>
<tr>
<th>Design Constraints (C) and Objectives (O)</th>
<th>Glass Bottle, with Twist-Off Cap</th>
<th>Aluminum Can, with Pull-Tab</th>
<th>Polyethylene Bottle, with Twist-Off Cap</th>
<th>Mylar Bag, with Straw</th>
</tr>
</thead>
<tbody>
<tr>
<td>C: No sharp edges</td>
<td>×</td>
<td>×</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C: Chemically inert</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O: Environmentally benign</td>
<td></td>
<td></td>
<td>80</td>
<td>40</td>
</tr>
<tr>
<td>O: Easy to distribute</td>
<td></td>
<td></td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>O: Long shelf life</td>
<td></td>
<td></td>
<td>90</td>
<td>100</td>
</tr>
</tbody>
</table>
PRIORITY CHECKMARKS

- Simpler, qualitative version of the numerical evaluation matrix
- Rank objectives as high (3 checks), medium (2 checks) or low (1 check)
- Assign design a 1 if meets objectives well, otherwise a 0
- Scoring times number of checks yields total checks per objective

As with NEM, see if “best design” is clear from the scoring based on ranked objectives
A table titled "Priority Benchmark Chart" for the juice container design problem. The chart qualitatively reflects a client's values in terms of priority assigned to each objective, using the ordering in the PCC of Figure 4.4.

<table>
<thead>
<tr>
<th>Design Constraints and Objectives</th>
<th>Priority (✓)</th>
<th>Glass Bottle, with Twist-Off Cap</th>
<th>Aluminum Can, with Pull-Tab</th>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O: Environmentally benign</td>
<td>✓ ✓ ✓</td>
<td></td>
<td></td>
<td>1 ✓ ✓ ✓</td>
<td>0 ✓ ✓ ✓</td>
</tr>
<tr>
<td>O: Easy to distribute</td>
<td>✓</td>
<td></td>
<td></td>
<td>0 × ✓</td>
<td>1 × ✓</td>
</tr>
<tr>
<td>O: Long Shelf Life</td>
<td>✓ ✓</td>
<td></td>
<td></td>
<td>1 × ✓ ✓</td>
<td>1 × ✓ ✓</td>
</tr>
</tbody>
</table>
For each objective, assign scores to each design alternative

Scores start from 1 for the alternative that meets that objective best, increasing to 2 for second-best, and so on

Ties equally split their combined score, e.g. best 2 designs are each assigned \((1+2)/2=1.5\), 3 designs tied for second get \((2+3+4)/3=3\)

As with NEM, see if “best design” is clear from the scoring based on ranked objectives
A best-of-class chart for the juice container design problem. This chart presents the rank ordering of the metrics results for each acceptable design. Notice that in this case, the client and the designer will need to select between the winner for the highest objective, or a design that wins on both of the other ones.

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<tr>
<td>O: Environmentally benign</td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>O: Easy to distribute</td>
<td></td>
<td></td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>O: Long shelf life</td>
<td></td>
<td></td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Product</td>
<td>Description</td>
<td>Price</td>
<td>Store Options</td>
<td>Reviews</td>
</tr>
<tr>
<td>------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------</td>
<td>--------</td>
<td>---------------------</td>
<td>------------</td>
</tr>
<tr>
<td><strong>Welch's Juice Drink, Assorted</strong> - 24 pack, 10 fl oz bottles</td>
<td>Quench your thirst with Welch's juice. Thanks to this variety pack, you can sip on any flavor that suits your mood. Choose...</td>
<td>$21.96</td>
<td>from 10+ stores</td>
<td>143</td>
</tr>
<tr>
<td><strong>Little Hug Fruit Barrels Fruit Drink, Fruit Punch</strong> - 40 pack, 8 fl oz bottles</td>
<td>Nutrition Facts - Serving Size: 8 Fluid Ounce - Calories: 5 Calories from fat: 0 Total Fat: 0 g - Saturated Fat: 0 g...</td>
<td>$12.41</td>
<td>from 2 stores</td>
<td></td>
</tr>
<tr>
<td><strong>Honest Kids Organic Juice Variety Pack</strong> - 40 count, 6 fl oz pouches</td>
<td>From the children of the duo that created Honest Tea comes this organic juice drink from concentrate. Great tasting and not...</td>
<td>$10.98</td>
<td>from 5+ stores</td>
<td>167</td>
</tr>
<tr>
<td><strong>Apple &amp; Eve 100% Juice, Elmo's Punch</strong> - 8 pack, 4.23 fl oz boxes</td>
<td>Blend of 5 juices from concentrate with other added ingredients. No sugar added. 100% vitamin C. Calcium fortified. Daily...</td>
<td>$13.99</td>
<td>from 10+ stores</td>
<td>141</td>
</tr>
</tbody>
</table>
Where $X$ is an attribute:

- **Production**
  - Minimize cost of production (manufacture and assembly) and/or time to market while maintaining quality and low cost

- **Affordability**
  - True Cost = Initial Purchase Costs + Operating/Maintenance Costs over Life of Device

- **Long-term Use: Reliability**
  - Probability that a device will function under stated conditions for a stated measure of usage or time (mean time to failure)

- **Sustainability**
  - Life-cycle Assessment (LCA): Understand, analyze and document full range of environment effects of a product:
    - Considers design, manufacture, transport, sale, use, and disposal
GROUP ACTIVITY

Come up with 3 possible designs for a water bottle and pick the best one.
TODAY’S SPEAKER

CELIA OAKLEY
OPENER