EE15N
The Art & Science of Engineering Design
Winter Quarter 2019

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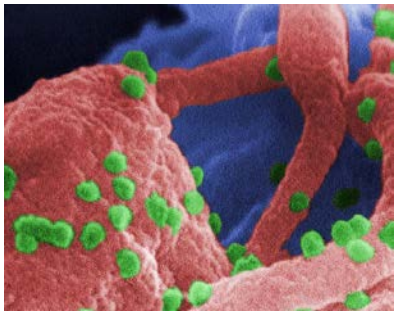
FEBUARY 13, 2019



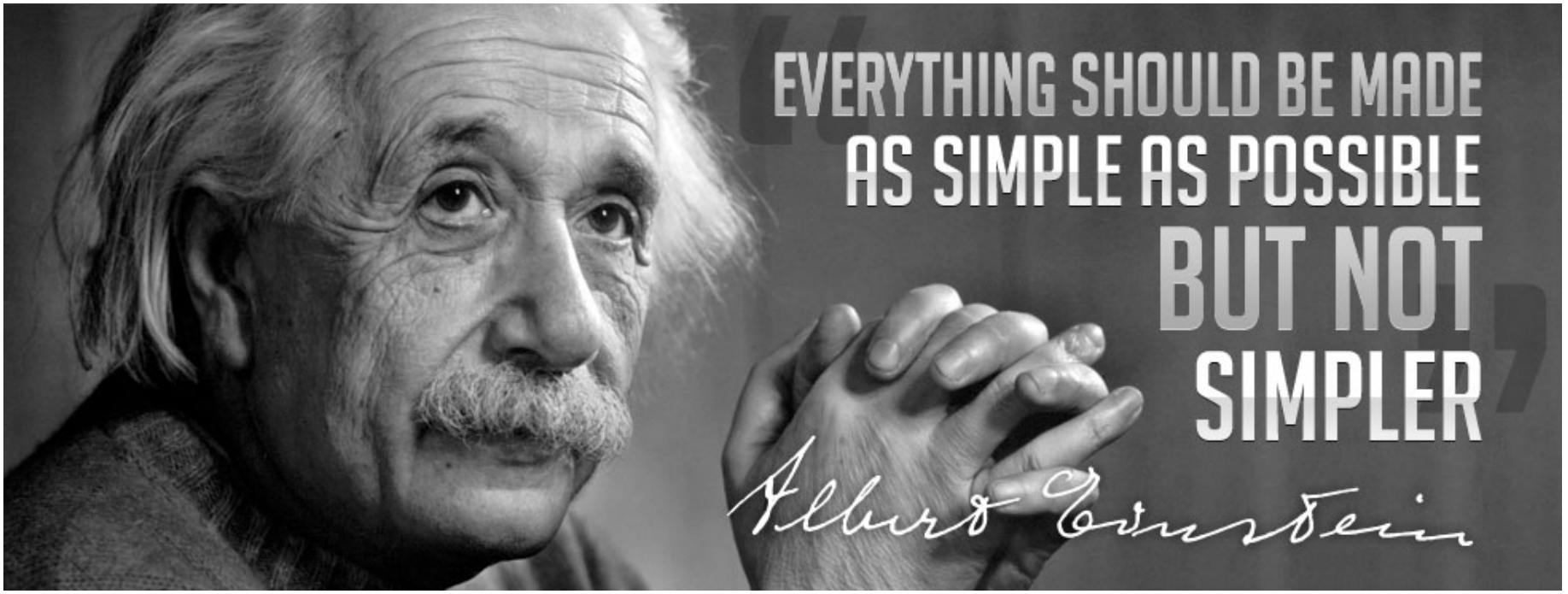
OUTLINE

- 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

LECTURE

GENERATING & EVALUATING DESIGN IDEAS

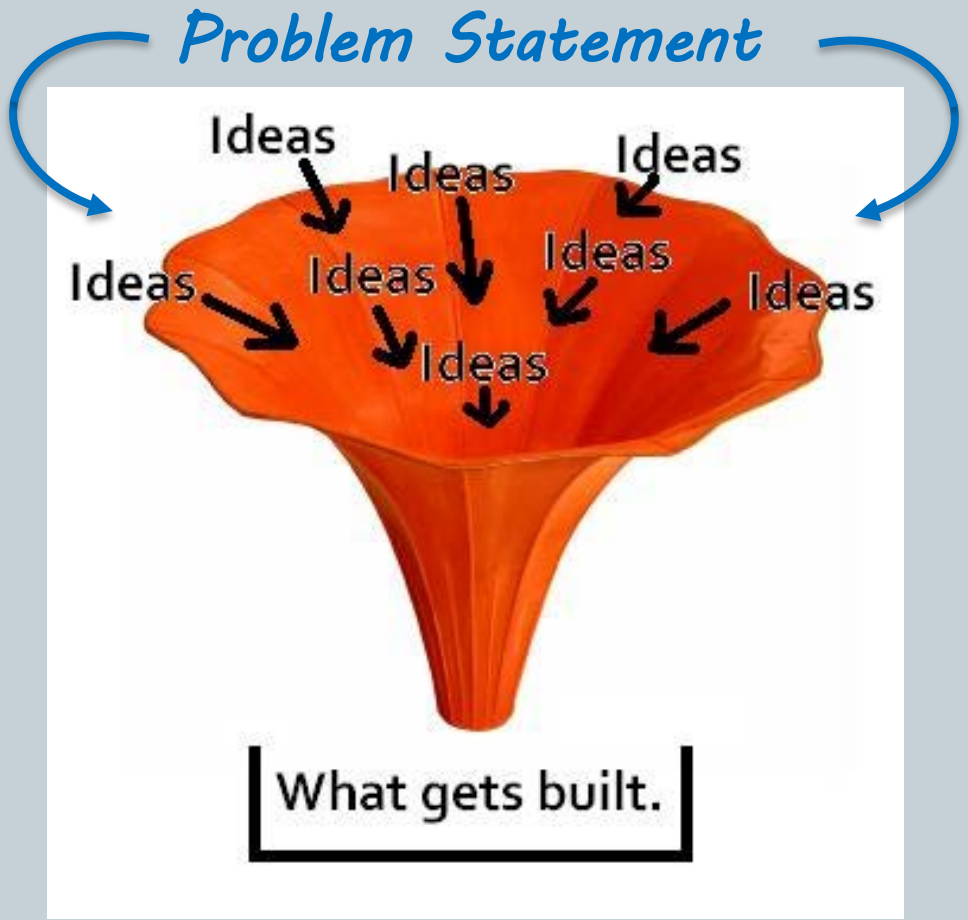
DESIGN FOR X


EVERYTHING SHOULD BE MADE
AS SIMPLE AS POSSIBLE
BUT NOT
SIMPLER
Albert Einstein

FROM IDEA TO PRODUCT

GENERATING

SELECTING

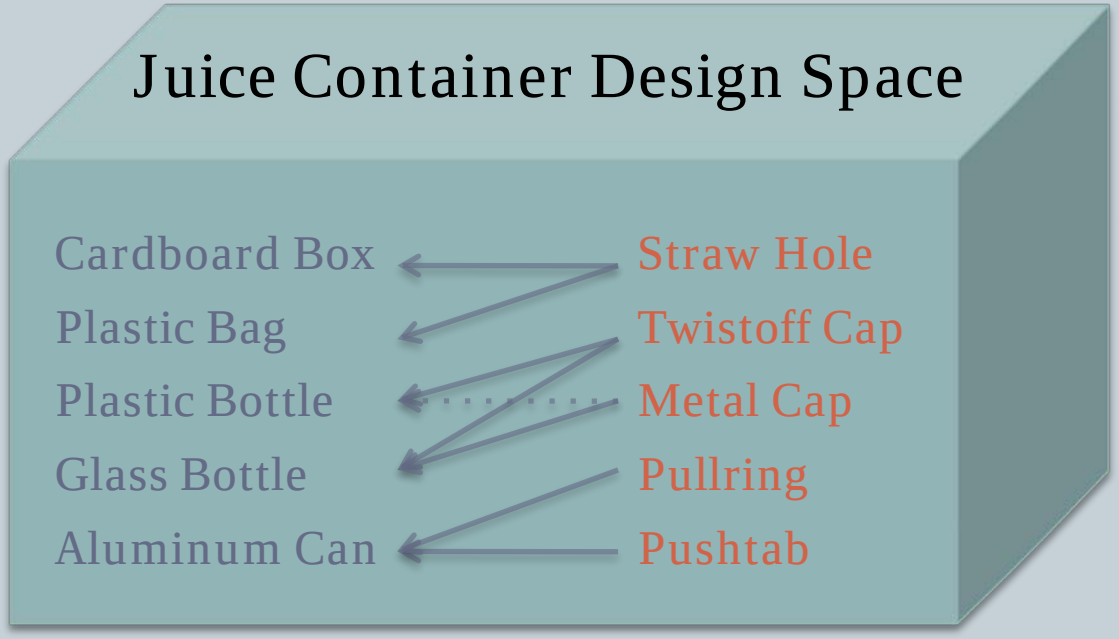


CHILDREN'S JUICE CONTAINER

What is our problem statement?

DESIGN SPACE OF JUICE CONTAINER

Conceptualization of a space that incorporates all possible designs.



S-LIGHT PROJECT

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

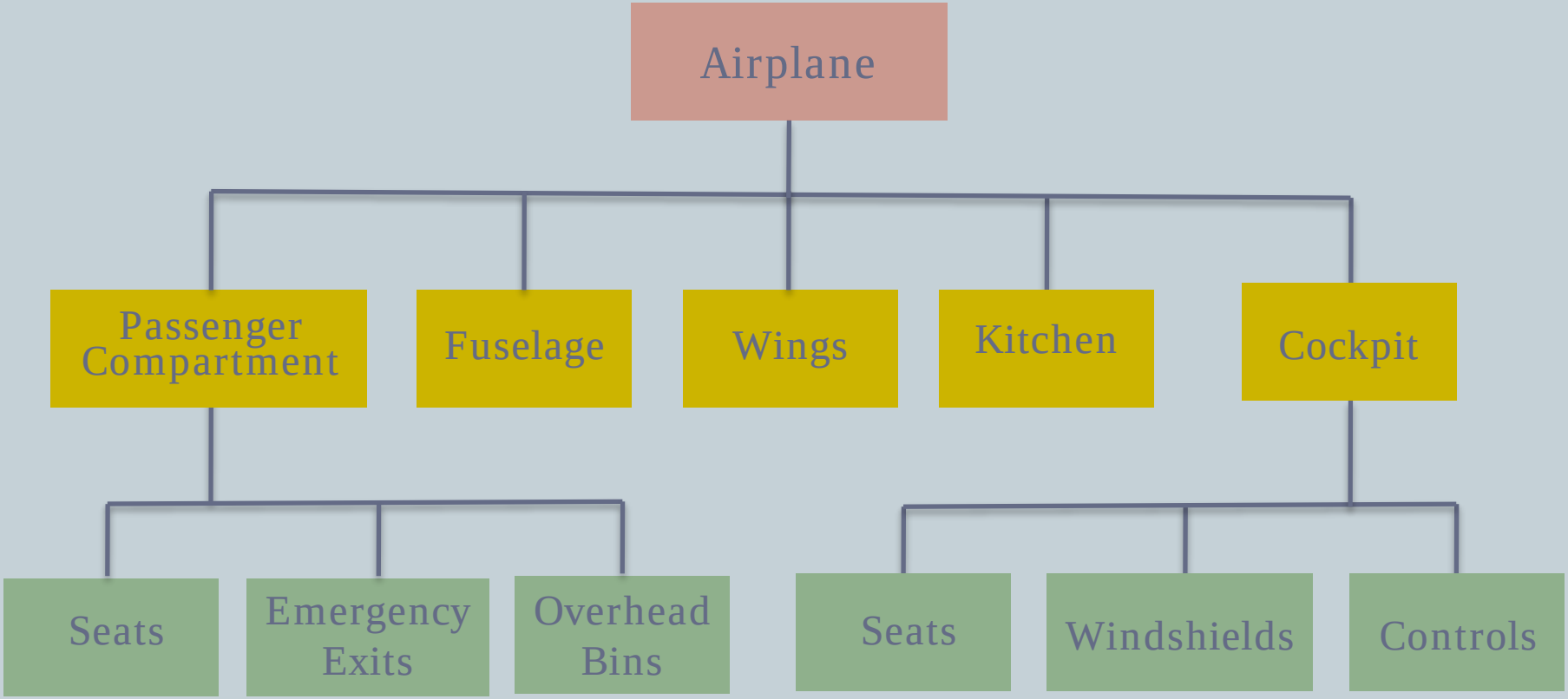
COMPLEX DESIGN SPACES

- 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
  - …

} ***How do their design spaces differ?***

By contrast, what has a small design space?

DESIGN SPACE DECOMPOSITION EXAMPLE: AIRPLANE



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.

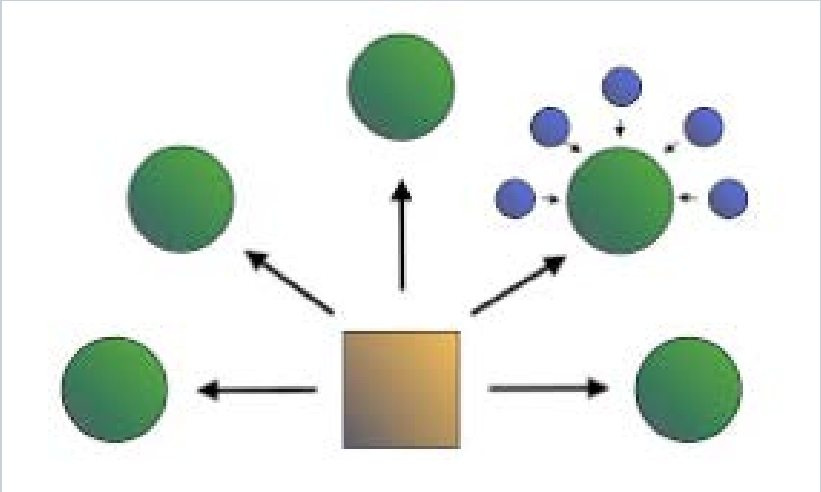
DIVERGENCE VS CONVERGENT THINKING

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?

APPLYING METRICS TO OBJECTIVES TO 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!

NUMERICAL EVALUATION MATRIX

- 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

NUMERICAL EVALUATION MATRIX – JUICE CONTAINER EXAMPLE

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

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

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

PRIORITY CHECKMARKS – JUICE CONTAINER EXAMPLE

TABLE 8.2 A *priority benchmark chart* for the juice container design problem. This chart qualitatively reflects a client's values in terms of the priority assigned to each objective, so it uses the ordering in the PCC of Figure 4.4

Design Constraints and Objectives	Priority (✓)	Glass Bottle, with Twist-Off Cap	Aluminum Can, with Pull-Tab	Polyethylene Bottle, with Twist-Off Cap	Mylar Bag, with Straw
C: No sharp edges		×	×		
C: Chemically inert					
O: Environmentally benign	✓✓✓			1 × ✓✓✓ ✓✓✓	0 × ✓✓✓ ●●●●
O: Easy to distribute	✓			0 × ✓ ●●●●	1 × ✓ ✓
O: Long Shelf Life	✓✓			1 × ✓✓ ✓✓	1 × ✓✓ ✓✓

BEST OF CLASS CHART

- 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

BEST OF CLASS CHART – JUICE CONTAINER EXAMPLE

TABLE 8.3 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

Design Constraints (C) and Objectives (O)	Glass Bottle, with Twist-Off Cap	Aluminum Can, with Pull-Tab	Polyethylene Bottle, with Twist-Off Cap	Mylar Bag, with Straw
C: No sharp edges	*	*		
C: Chemically inert				
O: Environmentally benign			1	2
O: Easy to distribute			2	1
O: Long shelf life			2	1

EXAMPLES OF CHILDREN'S JUICE CONTAINER

Welchs Juice Drink, Assorted - 24 pack, 10 fl oz bottles

$21.96 from 10+ stores

★★★★½ 143 product reviews

Quench your thirst with Welch's **juice**. Thanks to this variety pack, you can sip on any flavor that suits your mood. Choose ...

Welch's · Orange · Grape · Pineapple · Fruit Punch · Fruit · No Sugar Added · 10 ounce · Juice Blend · 24 Pack

Little Hug Fruit Barrels Fruit Drink, Fruit Punch - 40 pack, 8 fl oz bottles

$12.41 from 2 stores

Nutrition Facts - Serving Size : 8 Fluid Ounce - Calories : 5Calories from fat : 0Total Fat : 0 g - Saturated Fat : 0 g ...

8 ounce

Honest Kids Organic Juice Variety Pack - 40 count, 6 fl oz pouches

$10.98 from 5+ stores

★★★★½ 167 product reviews

From the **children** of the duo that created Honest Tea comes this organic **juice drink** from concentrate. Great tasting and not ...

Organic · 6 fl oz

Other size options: 6.75 Fl. Oz., 32 Count ($15)

Apple & Eve 100% Juice, Elmo's Punch - 8 pack, 4.23 fl oz boxes

$13.99 from 10+ stores Also available nearby

★★★★½ 141 product reviews

Blend of 5 **juices** from concentrate with other added ingredients. No sugar added. 100% vitamin C. Calcium fortified. Daily ...

Apple & Eve · Fruit Punch · Fruit · Boxes · No Sugar Added · 4.2 ounce · 8 Pack · Multi-pack

DESIGN FOR X

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