OUTLINE

- Administrative Details – Due Tonight at Midnight:
  - Revised Problem Statement
  - Preliminary List of Project Roles & Tasks
  - Objective Tree
  - Weekly Project Meeting Notes

- Lecture
  - Function & Requirements

- Speaker
  - Laurie Yoler
We want your feedback!

Please complete our short online student survey:
- Opens: February 6th
- Closes: 11:59 p.m. on February 12th
- URL: https://vptleval.stanford.edu/auth/evaluation.php?id=16020

If response rate exceeds 85%, you will get special snacks for the Tesla field trip.
FUNCTION & REQUIREMENTS
Product Definition

- Translate and clarify client’s wants
- Identify limits – what can’t client have?
- Order client’s wants
- Metrics to measure success

What’s Next?

Functional Specification
What object must do to realize stated objectives
Device to be built of wood, reeds and taffeta. "A small model can be made of paper with a spring like metal shaft that after having been released, after having been twisted, causes the screw to spin up into the air."
Functions are things that designed object must do in order to be successful.

Statement of a function usually consists of an action verb and a noun.

When describing functions, use verb-noun combination that best describes most general cases.
FUNCTION OF A BOOKCASE

What is the function of a bookcase?

A Bookcase *add verb here* *add noun(s) here*

Now describe function of the following bookcases...
Basic functions:

- Specific work that designed object is intended to accomplish.

Let’s consider an Overhead Projector

Basic Function of Overhead Projector?

To Project Images
Secondary functions:

- Required secondary functions: needed for basic functions to be accomplished.
- Unwanted secondary functions: related to undesired byproducts of either basic or secondary functions.

**Required Secondary Functions of Overhead Projector?**
- Converting energy
- Generating light
- Focusing images

**Unwanted Secondary Functions of Overhead Projector?**
- Generating heat
- Generating noise
FUNCTIONAL ANALYSIS
TOOLS FOR ESTABLISHING DESIGN FUNCTIONS

- Enumeration:
  - Making a list of functions the design must perform

- Black Box/Glass Box:
  - Indicating system boundary
  - Showing all inputs and outputs
  - Focusing on how a group of inputs are transformed

- Function-Means Tree:
  - Several means of accomplishing the designs basic function(s) are listed
  - Subsidiary functions that result from these means are listed below them
  - Repeats each subsequent level

- Dissection & Reverse Engineering
FUNCTIONS IN A BLACK BOX

Convert RF Signal To Sound At Desire Level

Power → RF Signal → Vector of User Choices → Convert RF Signal To Sound At Desire Level

Heat → Sound → Status Indications
FUNCTIONS IN A GLASS BOX

- Power
- RF Signal
- Vector of User Choices

Convert Power To Appropriate Voltages

- Heat
- Sound
- Status Indications

- Volume
- Desired frequency (station)
- Frequency (station)
- Volume
- Bass/Treble
REVERSE ENGINEERING

- We reverse engineer a device or system that does some or all of what we want our design to do
- Finding out how alternate designs work informs your design
- Reverse engineering consists of asking the following:
  - “What does this do?”
  - “How does it do that?”
  - “Why would you want to do that?”
- These questions, and thoughts on how to improve the design, are the core of reverse engineering

How would you reverse engineer a drone?
FUNCTION-MEANS TREE

- Graphical representation of a design’s basic and secondary functions
- Tree’s top level shows basic function(s) to be met
- Each succeeding level alternates between showing:
  - Means (in trapezoids) by which the primary function(s) might be implemented
  - Secondary functions (in rectangles) necessitated by those means
FUNCTION-MEANS TREE FOR A LIGHTER

Basic Function: Ignite leafy materials

Secondary Functions:
- Electrically Heated Wire
- Focused Sunlight
- Laser
- Flame

Means (ways to implement):
- store fuel
- control flame
- ignite fuel
- supply fuel for flame

Secondary Functions:
- apply heat to leafy materials
- generate electric current
- convert electricity to heat
- protect users from post-usage burns

Means:
- miniature heat pump
- resistive wire

Secondary Functions:
- control electrical current
- convert battery energy (chemical) to electrical current
- store electricity
- protect electric circuit from flame
- generate electric current

Means:
- spark
- electrical resistance
OBJECTIVES VERSUS FUNCTIONS

- Objectives describe what object is:
  - Objectives detail attributes
  - Objectives are usually characterized with *are* & *be*

- Functions describe what object does:
  - Functions focus on input-output transformations
  - Functions are usually characterized by active verbs
The Danbury Elementary school of the CUSD has a student diagnosed with Cerebral Palsy (CP), a neuro-development impairment which causes disturbances of voluntary motor function. For this student, activities that require fine muscle movements, such as painting, writing, and eating, are particularly difficult because of impaired motor control and coordination. There is ample evidence indicating that this student paints more effectively when an instructor holds onto the lower portion of the upper arm (right above the elbow) and thus minimizes extraneous movements of the shoulder.

The school desires a device that can minimize the student’s involuntary shoulder movements and thus allow her to paint semi-independently. Such a device would ideally be applicable in other CP cases and must be easily implemented by an adult.
TEAM 2 – LIST OF FUNCTIONS OF DANBURY ARM SUPPORT PROJECT

- Attach to arm
- Attach to stabilizing point
- Dampen motion
- Allow for range of motion
- Provide comfort
- Provide adjustability
EXAMPLE: PROJECT S-LIGHT

PROBLEM STATEMENT

- Desire to improve the biking experience at Stanford University
- Students often emerge from crowded classrooms with rows of similar looking bicycles
- Students may have to try their keys in multiple locks until they locate their own bike
S-LIGHT 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
S-LIGHT
FUNCTIONS THAT DESIGN MUST PERFORM

- Display a light
  - Visible from 360 degrees around the bicycle
- Emit a sound
  - Loud enough to be heard in a crowded bike rack environment
  - Quiet enough so as not to disturb classrooms
- Remote should function from a distance of at least 50 feet away
DESIGN SPECIFICATIONS

- Articulate the attributes and behaviors of a design
- Provide a basis for evaluating the design
  - *Specs* are targets of the design process
- Formalize what the client or user wants in terms suitable for engineering analysis and design
3 TYPES OF SPECS

- **Prescriptive Specifications:**
  Specify values for attributes of the designed object (e.g. a safe ladder has a 6 inch step.)

- **Procedural Specifications:**
  Identify procedures for calculating attributes or behavior (e.g. a ladder step is safe if its bending stress \( \sigma = \frac{Mc}{I} \) does not exceed \( \sigma_{\text{max}} \).)

- **Performance Specifications:**
  Identify performance levels that signify the achieved desired functional behavior (e.g. a safe ladder step supports an 800 lb. Gorilla).
**PERFORMANCE SPECIFICATIONS REFER TO SEVERAL THINGS**

- **Prescriptive** performance specifications give values for attributes of the designed object
  - A safe ladder step must support an 800 lb gorilla

- **Interface** performance specifications indicate how the artifact must work with other artifacts or systems.
  - A portable electric guitar must have a standard plug

- **Detailed design** performance specifications are used to indicate how well a designed artifact is predicted to perform a function.
  - A water fountain will increase water efficiency by 25%
ATTACHING NUMBERS TO DESIGN SPECS (UTILITY PLOT)

Utility (usefulness)

Lightweight \((1/w)\)

Saturation Plateau

Straight-Line Approximation

Zone of Interest

Too low to be useful

Level of variable cost of material
SETTING PERFORMANCE LEVELS

Select variables within zone of interest

- Radio functions: convert RF signal to sound
  - Transform power from wall outlet
  - Filter out unwanted frequencies
  - Amplify signal
  - Output electrical signal to drive speaker(s)

- Performance levels (entail design tradeoffs)
  - Transform 110V power to 12V±.1V with power loss of no more than 3dBm
  - Filter frequencies outside the tuned FM radio band of 30 MHz with a minimum attenuation of –30dB.
  - Amplify signal within a range of 1-10 mW by 10dB
  - Output electrical signal at 12V ±.1V.
METRICS VS. PERFORMANCE SPECS

- Metrics apply to objectives
  - Allow designers and clients to assess the extent to which an objective is realized by a particular design
  - Metrics are typically associated with end performance goals
  - Metrics can be quantitative (e.g. weight, data rate, etc.) or qualitative (“ease of use”, elegance, etc.)

- Performance specs apply to functions
  - Specify how well functions are realized by a design
  - Can be considered constraints, since designs typically must meet their performance specs
YOUR TURN

What are the interface design boundaries and issues for the design and installation of a new toilet for a building?