EE15N
The Art & Science of Engineering Design
Winter Quarter 2019

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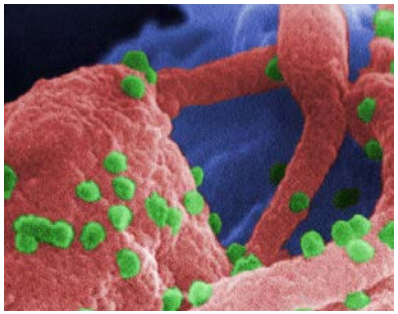
FEBUARY 6, 2109



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

MID-QUARTER STUDENT SURVEY NOW OPEN

- We want your

- 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.

LECTURE

FUNCTION & REQUIREMENTS

AFTER PRODUCT DEFINITION

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

FUNCTIONAL SPECIFICATIONS

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

Specifications

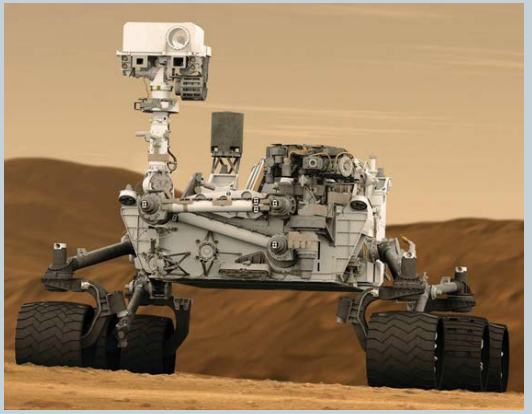
Metrics

IDEA

PRODUCT DEFINITIONS

FUNCTIONAL SPECIFICATIONS

PRODUCT



FUNCTIONS

- 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…

TYPES OF FUNCTIONS

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

TYPES OF FUNCTIONS (Cont)

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

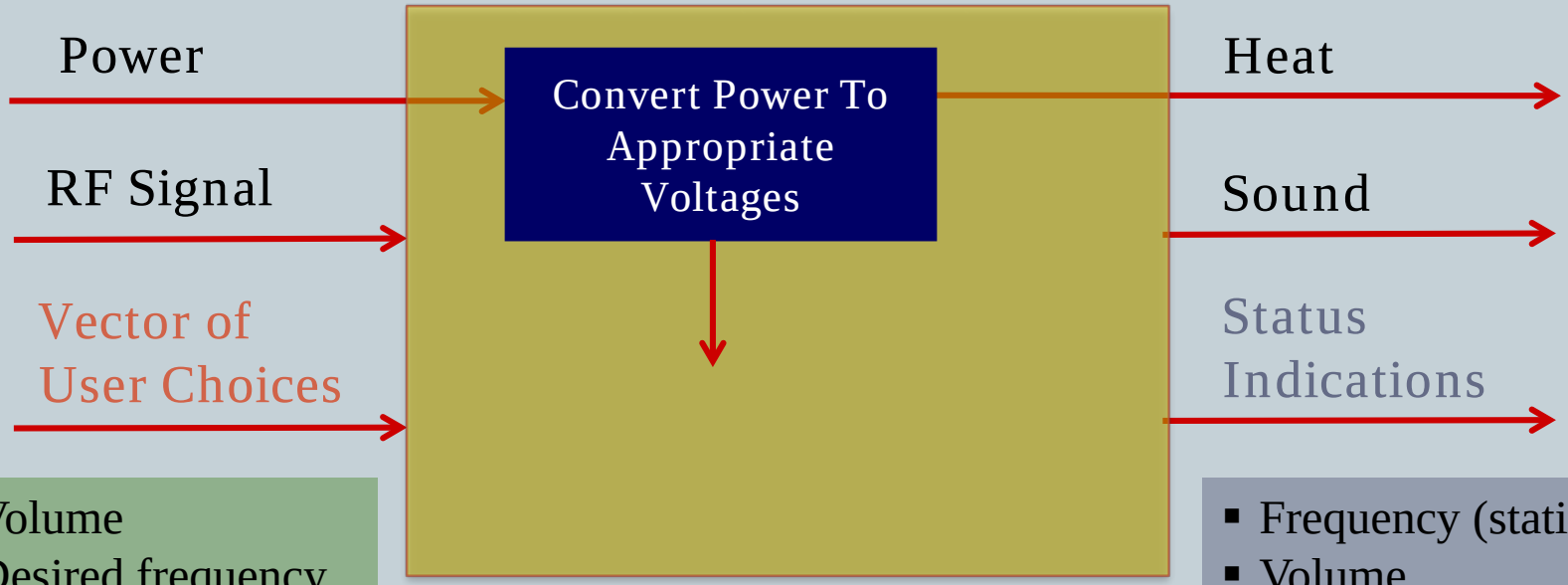
FUNCTIONAL ANALYSIS

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

FUNCTIONS IN A GLASS BOX



- Volume
- Desired frequency (station)

- Frequency (station)
- Volume
- Bass/Treble

REVERSE ENGINEERING

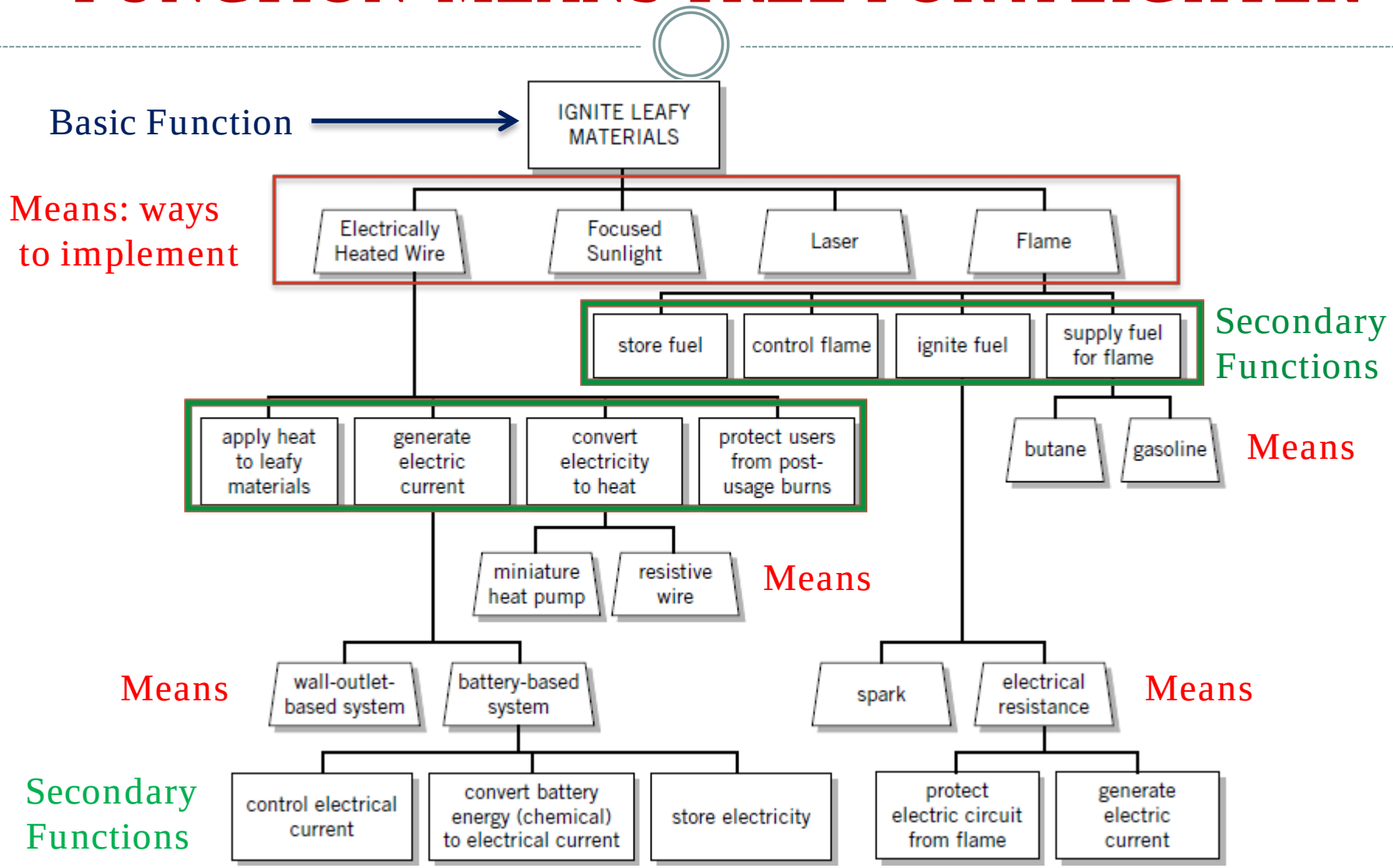
- We reverse engineer a device or system that does some or all of what we want our design to do
- Finding out how alternate designs work informs your design
- Reverse engineering consists of asking the following:
  - "What does this do?"
  - "How does it do that?"
  - "Why would you want to do that?"
- 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



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

TEAM 2 –REVISED PROJECT STATEMENT OF DANBURY ARM SUPPORT PROJECT

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 students 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 $\sigma=Mc/I$ does not exceed σ_{max}).

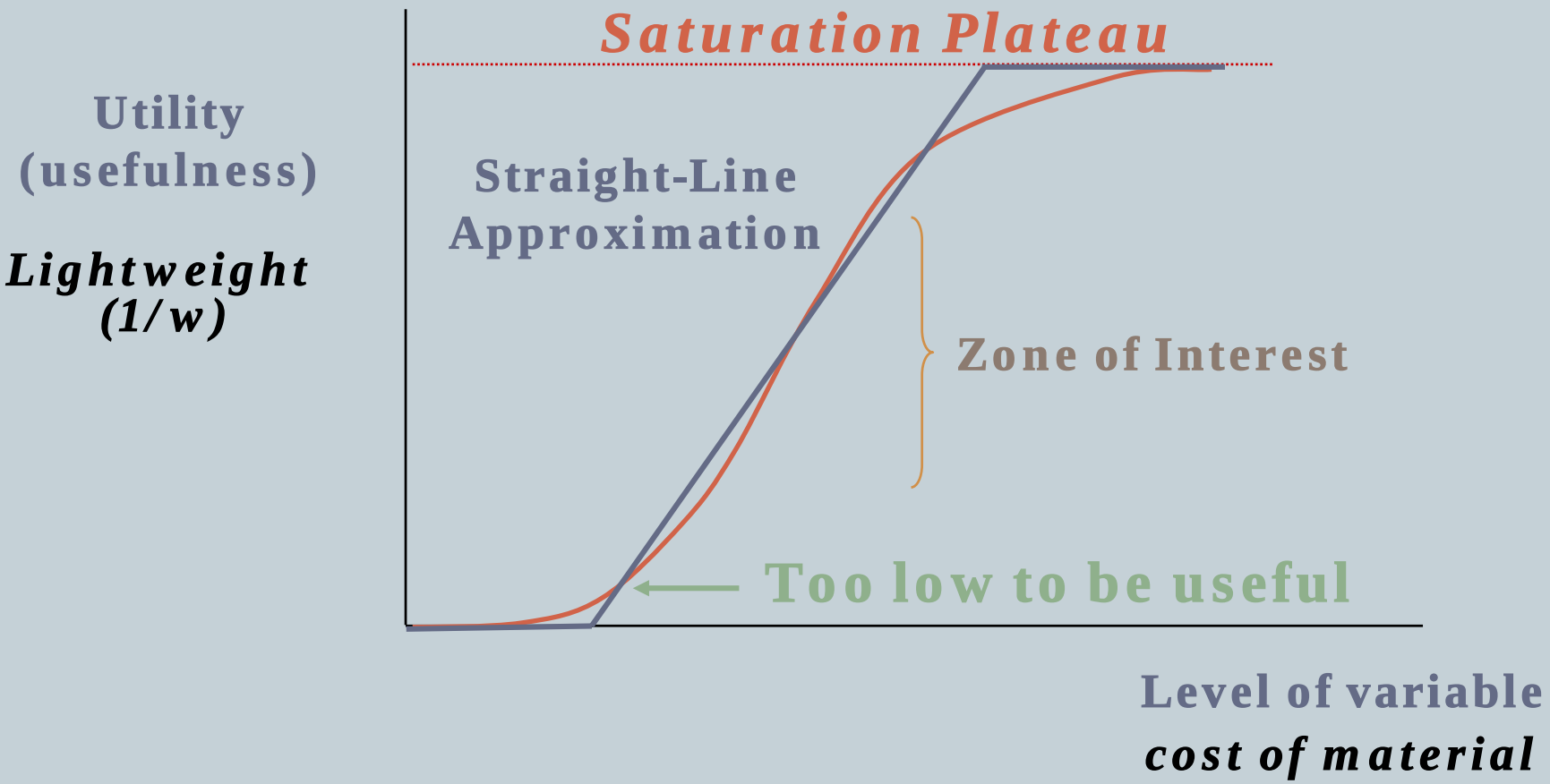
- Performance Specifications:

  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)



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?

TODAY'S SPEAKER

LAURIE YOLER