INTRODUCTION TO ENGINEERING DESIGN

AGENDA

Types of design

How design is interconnected

Activity – Experiences with bad design

Vocabulary of design

Activity – Applying the vocabulary of design

TYPES OF DESIGN

There are many different kinds of design, and they can be vaguely grouped into the following:

1. Aesthetic/artistic design
2. Product/industrial design
3. Engineering design

- Aesthetic/artistic design
  - E.g. – fashion, graphic, interior, fine arts, video games, etc.
  - Focus on the artistic merit, pleasing to the senses
- Product/industrial design
  - E.g. – product, industrial, architecture, UX/UI, etc.
  - Focus on pleasing the senses and on specific functions/objectives
- Engineering design
  - E.g. – chip design, gear design, thermal design, structural design, etc.
  - Focus on specific function to achieve objective

INTERCONNECTED DESIGN

All three types of design are interconnected, and good products happen when all types of design complement each other.

Example of good design – **Apple iPod**

- **Chip design** – allowed huge amounts of digital music to be stored in a small space
- **Industrial design** – created a form that accommodated the chip and battery requirements, while letting people own their music collection in a product they liked
- **Aesthetic design** – The aesthetics of the product allowed it to be integrated into people's lifestyles, to create new ways for people to enjoy music, created balance of convenience, privacy, and personal vanity

INTERCONNECTED DESIGN

Bad products are often created by a conflict of different kinds of design, even when individual elements are well-designed.

Example of bad design – **Google Glass**

1. **Chip design** – allowed camera, screen, and processing in a tiny space
2. **Industrial design** – packed the entire object into conventional looking glasses, at the corner to avoid blocking vision
3. **Aesthetic design** – integrated modern device into conventional item and fashion accessory

All 3 individual design elements are positive!

INTERCONNECTED DESIGN

Why was the product not successful?

1. Taking out a camera to shoot something memorable is socially acceptable, but do you want to have a camera always pointed at you?
2. Would you talk to someone who has a screen in front of their eyes at all times?
3. Glasses can be fashion accessories, but they are also meant to have a function. Without the pretense of a function, they are like bracelets. But people don't wear glasses in the same way as bracelets.

DESIGN VOCABULARY

Function – something a device/product is meant to do.	Glasses help you to see better.
Means – Method to make a function happen	Concavity/convexity in lenses are the means that allow glasses to help you see better
Form – Shape/structure of the product	Lenses are usually round, glasses have a frame to hold glasses, the frame loops over your ears

DESIGN VOCABULARY

Design objective – Feature/behavior you wish your design to exhibit

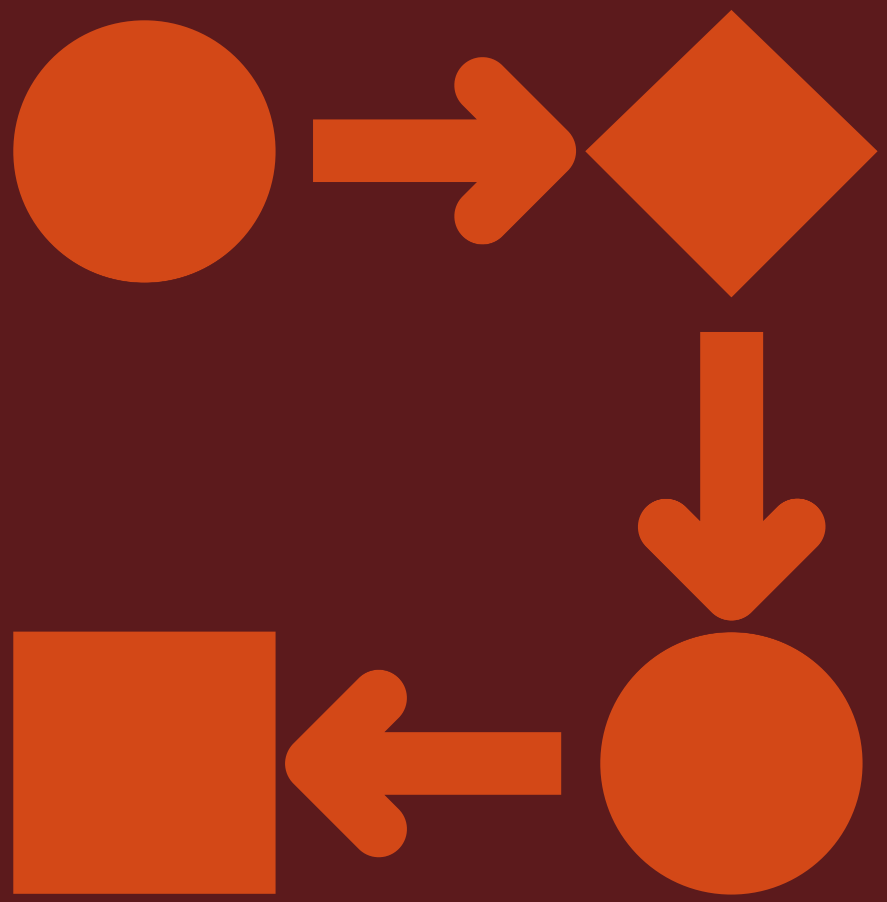
Design constraints – Limits/restrictions on the features/behaviors

Design possibilities – Different means to achieve design objective and/or get around design constraints

ENGINEERING DESIGN PROCESS

AGENDA

- What is the Engineering Design Process?
- What are the different stages of engineering design?
- What do the different stages of engineering look like?
- Activity – Wallet Design



ENGINEERING DESIGN

- Systematic process
- Refers more to function and means, than form
  - *But form, function, and means are interrelated*
- Has clear objectives and constraints
- Is an iterative process
- Meant to solve or satisfy human needs and wants

DESIGN VOCABULARY - RECAP

Function – something a device/product is meant to do.	Glasses help you to see better.
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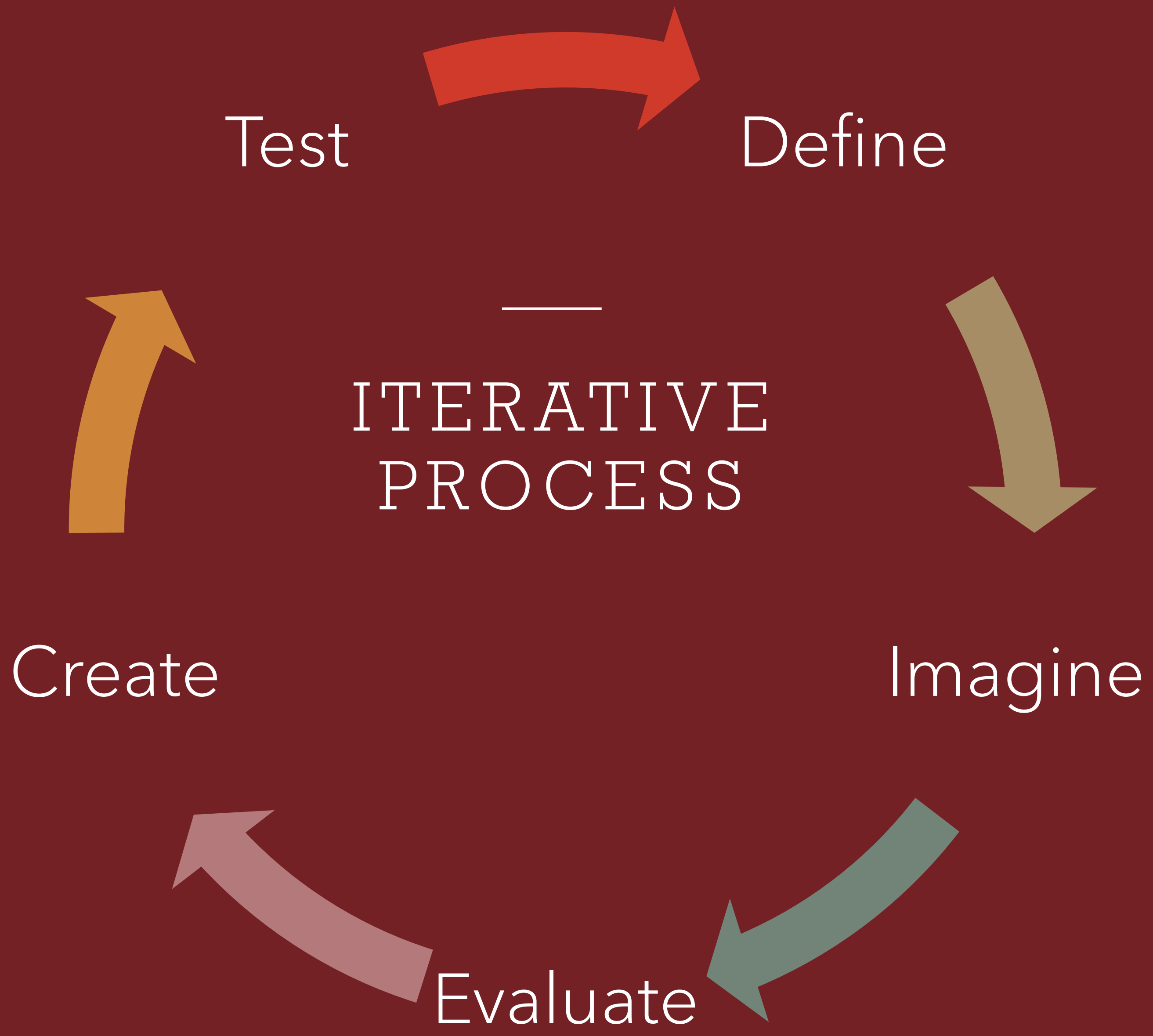
STAGES OF ENGINEERING DESIGN

- Define
- Imagine
- Evaluate
- Create
- Test


ITERATIVE PROCESS
Define
Imagine
Evaluate
Create
Test

STAGE 1 - DEFINE

What are you trying to solve?

- Often not straightforward; problems are interconnected but you don't have infinite time and resources

Relates directly to design objective

- People often confuse means and objective, but they are separate

End result is "Problem Statement"

- This problem statement is simple, focused, and intuitive

STAGE 1 - DEFINE

Engineering design objectives **are features/behaviors you wish your design to exhibit** and should have the following qualities:

- *S – Specific*
- *M – Measurable*
- *A – Attainable*
- *R – Relevant*
- *T – Timely*

Together, they are SMART goals

STAGE 2 - IMAGINE

- **Every design objective can be accomplished in multiple ways**
- Imagine the solution in as many different ways as you can
- Tempting to get attached to a single design
  - *But that is always a negative!*
- Communicate your ideas, be open to feedback

STAGE 2 - IMAGINE

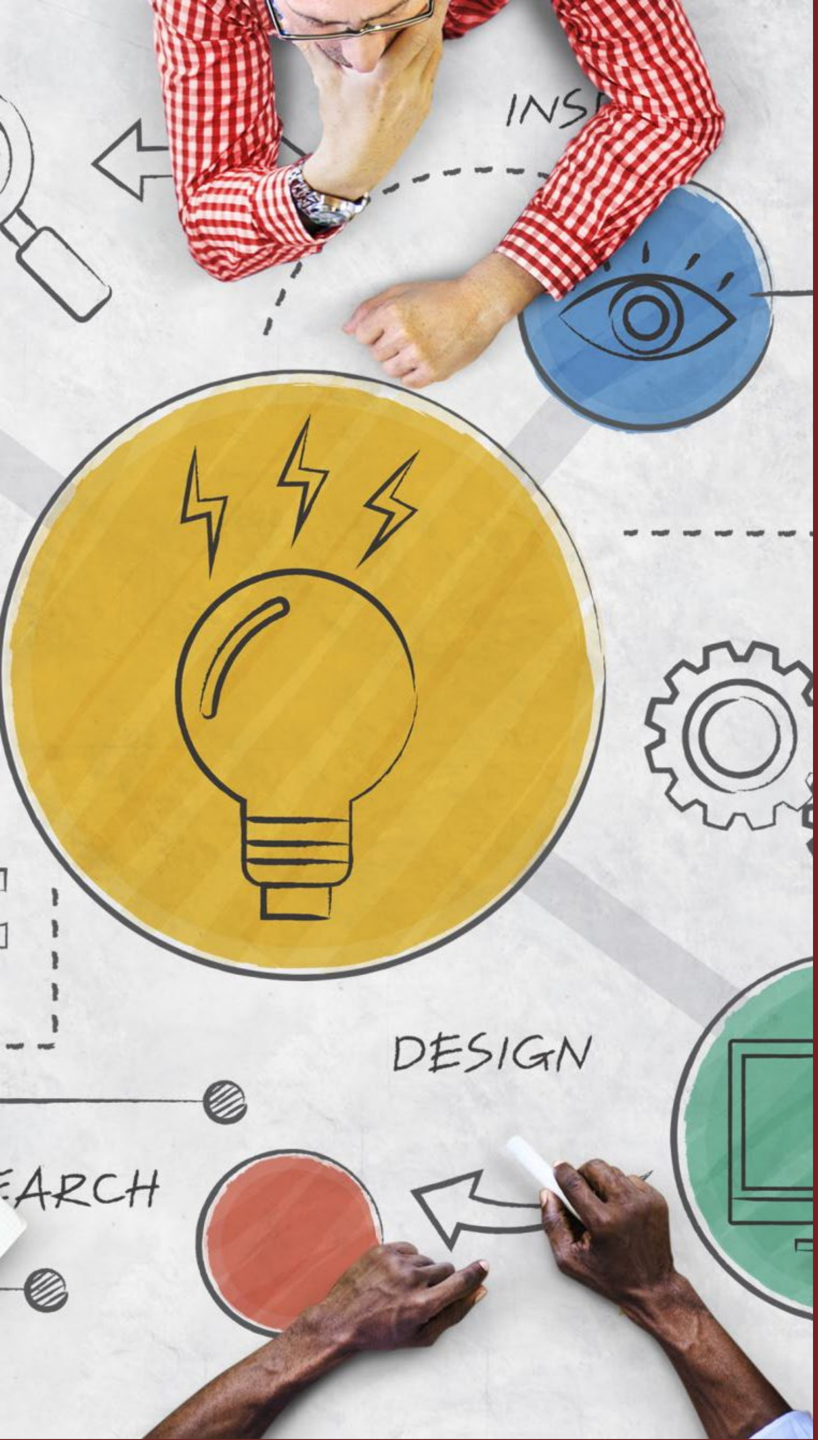
Creativity

- Think up new, radical designs
- Think of as many designs as you can
- Commit them to paper or other media

Communication

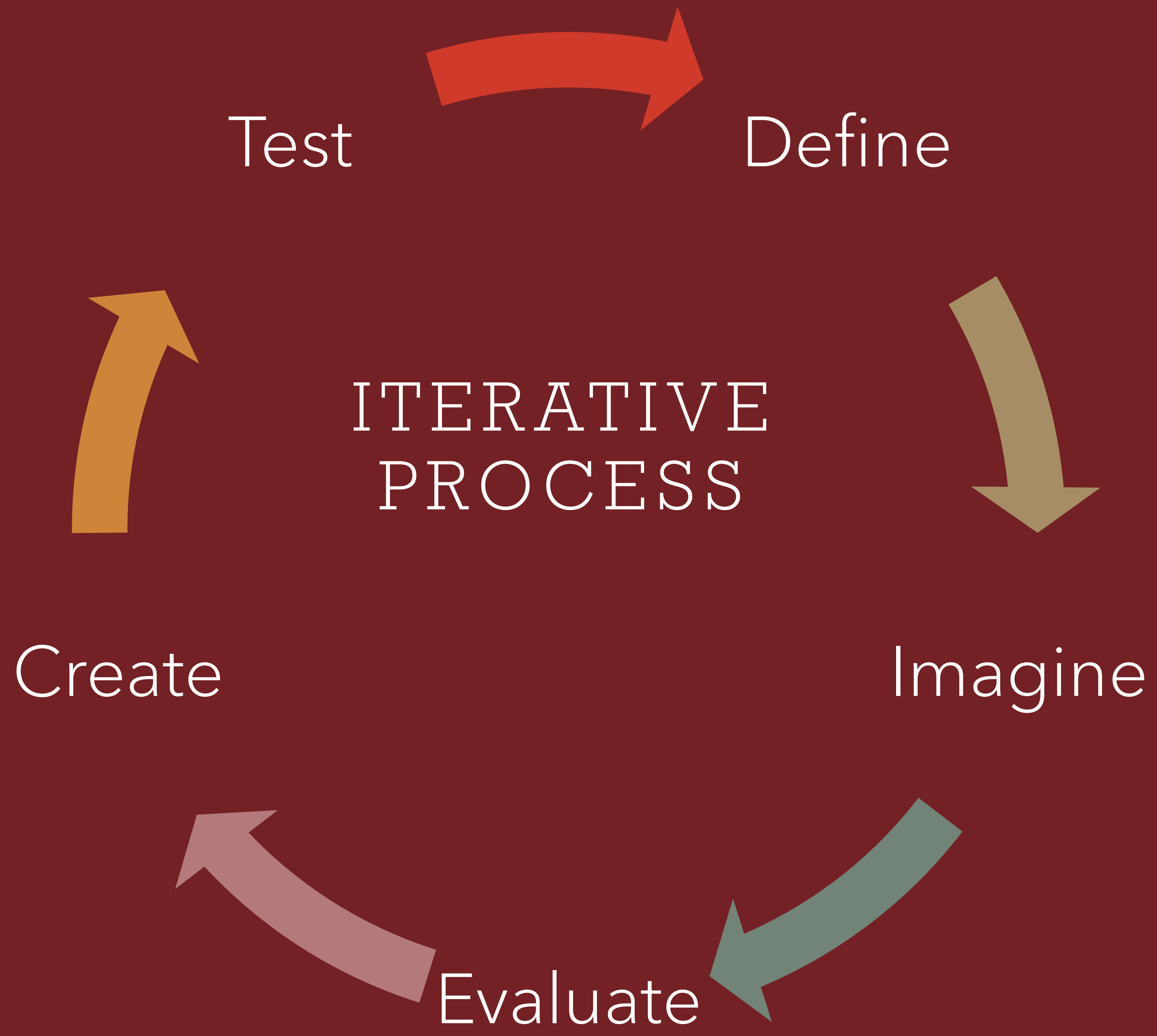
- Let others know of your ideas
- Seek out feedback
- Use drawings/diagrams liberally*

*Research has shown that spatial visualization abilities are directly linked to engineering skills



RECAP

- Engineering design is a systematic and iterative process
- Engineering design has five stages – define, imagine, evaluate, create, test
- Define – Figuring out the objectives, articulating them in a concise problem statement, listing out detailed objectives as SMART goals
- Imagine – Coming up with multiple design, communicating them, receiving feedback



ITERATIVE PROCESS
Define
Imagine
Evaluate
Create
Test

STAGE 2 - IMAGINE

To arrive at the final design

- Consider all the constraints (limits/non-negotiables) in your design
- Consider the potential ways you can achieve your design objectives (possibilities)

Formalize your design through metrics and specifications

DESIGN VOCABULARY

Metric – Standard/scale against which design objectives can be measured

Focal length of lenses is a metric in designing glasses

Specification – Performance levels/values for scales/standards in the metric

Value or range of focal length is the specification in glasses

STAGE 3 - EVALUATE

How do you know your design will work?

In what ways will your design work?

May work from manufacturing perspective

But not from economic or social perspective

How do you arrive at an *optimized* design?

Optimizing is balancing the different perspectives in your design

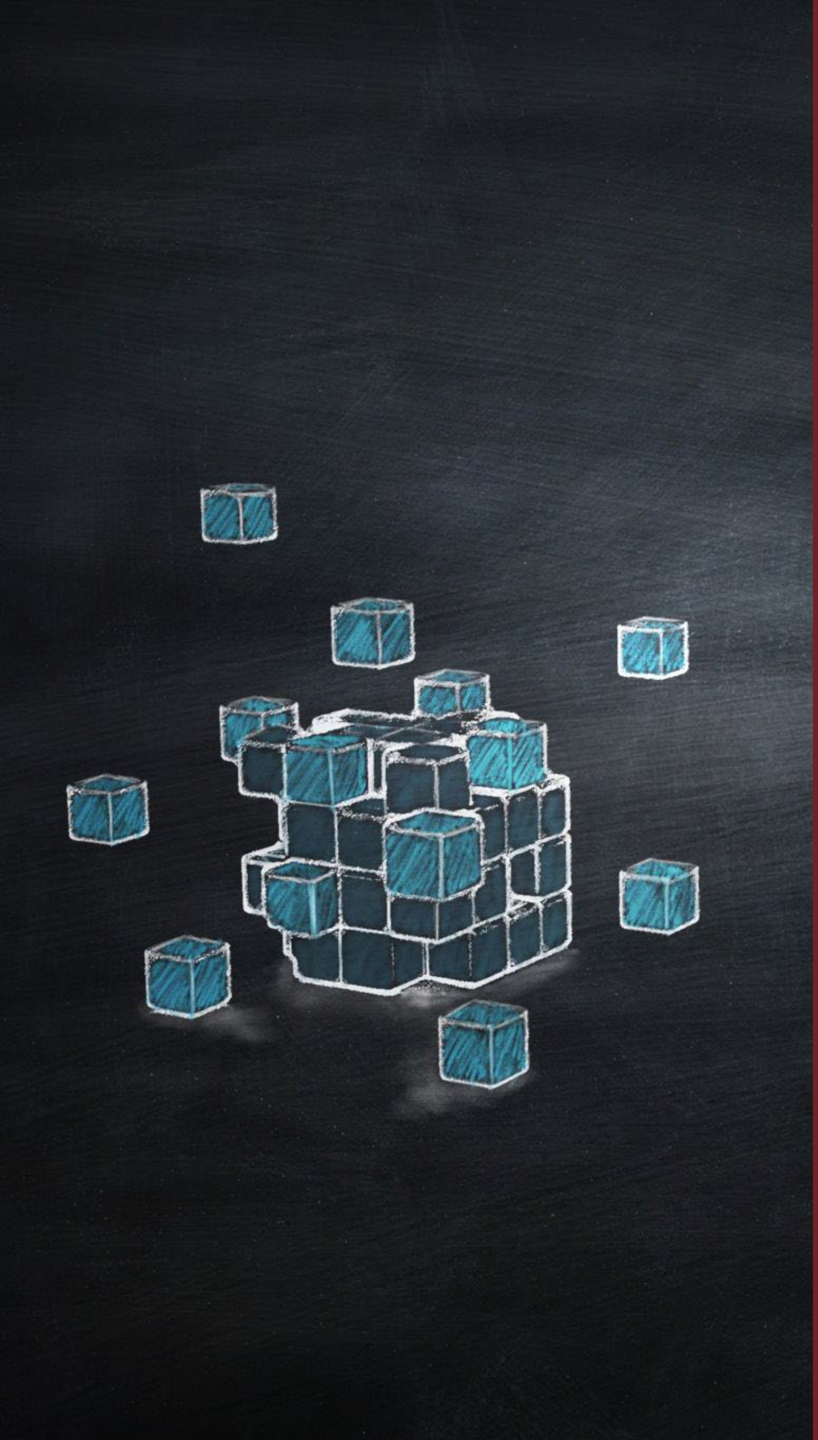
STAGE 3 - EVALUATE

- Use a *Decision (Pugh) Matrix* tool to check your design against the metrics and specifications you had developed
- Use the guide from the American Society for Quality (ASQ) below

Decision Matrix: Long Wait Time

Criteria → / ↓ Problems	Customer pain 5	Ease to solve 2	Effect on other system 1
Customers wait for host	High—Nothing else for customer to do 3 × 5 = 15	Medium—Involves host and bussers 2 × 2 = 4	High—Gets customer off to bad start 3 × 1 = 3
Customers wait for waiter	Medium—Customers can eat breadsticks 2 × 5 = 10	Medium—Involves host and waiters 2 × 2 = 4	Medium—Customer still feels unattended 2 × 1 = 2
Customers wait for food	Medium—Ambiance is nice	Low—Involves waiters and kitchen	Medium—Might result in extra trips to

https://asq.org/quality-resources/decision-matrix?srsltid=AfmBOoo_ISQQ_VE02I5ZFwVVnmygVzcAW1b3DZM20WQKIifJc5IdmhEu



STAGE 4 - CREATE

What are you creating?

- Final product
- **Prototype** – usually functional, at scale, often manufactured using different processes from the final product
- **Model** – functionality restricted, more focus on form, shows proof-of-concept, scaled down or up

STAGE 5 - TEST

- Testing may be for various purposes
  - *Functionality*
  - *Safety*
  - *Usability*
  - *Manufacturability*
  - *Other metrics*
- Tests need to be designed, and may used qualitative or quantitative metrics

Modeling Concepts

Models & Prototypes

Models - Scaled representations (smaller or larger) used to imitate behaviors and validate theories

Prototype – Usually at-scale representation, functions and looks like the final product, aiding in manufacturing and tooling

Common model types in engineering

- Diagrams/graphs/mathematical
- Computer-aided
- Physical

Physical & Computer-aided

Scaled Physical Models

Simulate designs at reduced or enlarged scales

Help visualize large structures (dams, highways, bridges)

Does not usually include all features/functions

Computer-Aided Modeling

Enables engineers to evaluate thousands of ideas rapidly

Reduces the number of physical models/prototypes to be built

Reduces material, manufacturing, and testing costs

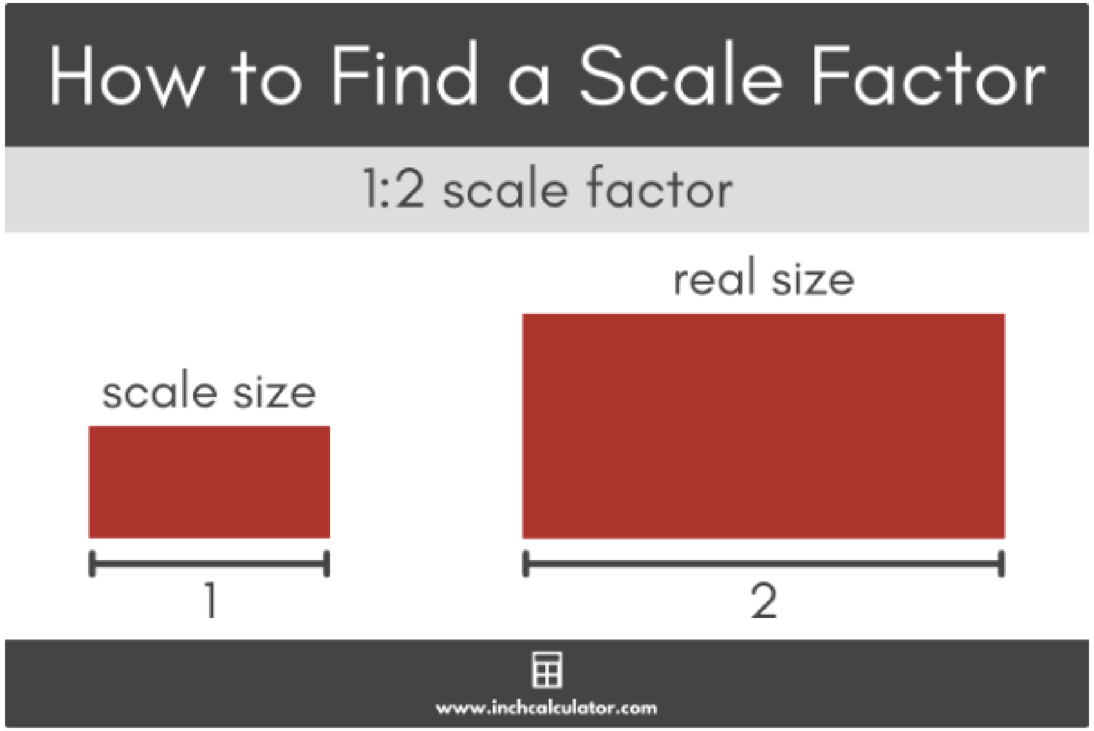
Scale Factor

Scale Factor Calculation

1. Use formula:

   Scale Factor = Scaled Size / Real Size

2. Simplify the fraction.
3. Rewrite as a ratio.
4. Choose an appropriate scale for the model.



Proof of Concept (POC) Model

Definition

- An initial model to validate the feasibility and potential of an idea, method, or product

Purpose

- To confirm that a concept/feature can be successful before extensive development

Characteristics

- Conducted during the ideation phase
- Involves a simple, undeveloped version of the desired outcome
- Helps identify unforeseen risks early in the process

POC vs. Prototype, Pilot, and Minimum Viable Product (MVP)

POC vs. Prototype

- **POC:** Tests viability; may not function fully
- **Prototype:** A working model demonstrating design and functionality

POC vs. Pilot

- **POC:** Initial validation of a concept.
- **Pilot:** Final testing phase with real customers before full-scale production.

POC vs. MVP

- **POC:** Assesses feasibility of an idea.
- **MVP:** A simplified product version with core features to test market interest.

https://formlabs.com/blog/proof-of-concept-poc/

Model Development Process

First three stages of design

- Get user input
- Imagine multiple designs
- Choose the best solution
- Create detailed drawings and notes
- Gather materials to build

Fourth and fifth stages of design

- Construct the model
- Test its functionality
- Evaluate results.

Improve the Design

- Analyze findings
- Refine the model for better performance.

Material and Tool Considerations

Material choice

- Materials used should align with technical, human, and aesthetic factors
- What kind of materials do you need
  - for structural integrity?
  - for other functional aspects?
  - for form and aesthetics?

Tools availability

- What tools are available to work
  - on structural materials?
  - on electrical components?
  - to manipulate mechanical components?

Model characteristics

Structural

Must withstand regular forces

Must carry other elements without major deformation

Mechanical

Must involve mechanisms and/or movements as part of the function/feature

Electrical

Must involve motors, or lights, or sensing as part of the function/feature

MATERIAL SELECTION

AGENDA

- What kind of materials do you see in everyday objects, and why are they used?
- How do you decide on which materials to use in a product?
- Activity – complete the bicycle PoC Build Plan

MATERIALS SELECTION PROCESS

- STEP 1: **Identify Function of Product**
- STEP2:
- STEP 3:
- STEP 4:

BICYCLES - FUNCTIONS

A bicycle is product – made from smaller product/sub-assemblies

What are the different sub-assemblies

Identify at least 3, possibly 4, sub-assemblies

What is the function of each sub-assembly?

BICYCLES - FUNCTIONS

- Bicycle = system of products
- We need to do a system analysis
  - Break the system into sub-systems
  - Figure out components that make up each sub-system
  - Analyze how each sub-system is assembled
  - Develop a way to integrate all sub-systems into system

BICYCLES - FUNCTIONS

- How do the functions depend on the type of bike?
  - Racing
  - Touring
  - Mountain
  - Commuter
  - Child’s
  - Beach

MATERIALS SELECTION PROCESS

- STEP 1: Identify Function of Product
- STEP2: **Determine required Material Properties**
- STEP 3: **Identify candidate Material(s)**
- STEP 4:

WHAT ARE MATERIAL PROPERTIES?

Mechanical	Strength, modulus, etc.
Physical	Density, melting point
Electrical	Conductivity, resistivity
Aesthetic	Appearance, texture, color
Processability	Ductility, moldability
Cost	Cost!

BICYCLES - MATERIALS

Each term has a scientific meaning, beyond their regular meanings!

- Frame – strength, hardness, color
- Wheels – strength, shape, shock absorption, durability against wear
- Chain and sprockets – Tensile strength, stiffness
- Seat, pedals, and handles – ergonomics, softness, gripping comfort
- Braking system – friction characteristics, tensile strength of brake wire

MATERIALS SELECTION PROCESS

- STEP 1: Identify Function of Product
- STEP2: Determine required Material Properties
- STEP 3: Identify candidate Material(s)
- STEP 4: **Select required Processing Method(s)**

MANUFACTURING

Can we actually make it?

- Key question which has a massive influence on materials selection
- What processes can be used to make each part?
- Are the processes economical, environmentally sustainable, safe for handling, etc.?

MANUFACTURABILITY

Can the materials be sourced easily?

Does the manufacturing process use standardized parts and tools?

Is it easy to maintain how one part fits into another, given that there will be some leeway in the measurements? (this is called tolerance).

Is the process environmentally sustainable, or wasteful? How much energy does it consume? How much waste product does it generate? Is the waste product toxic?