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ME4182 & ME4723 *(other disciplines welcome!)*

Common Studio Session for Week #5

Date 09/19/2022

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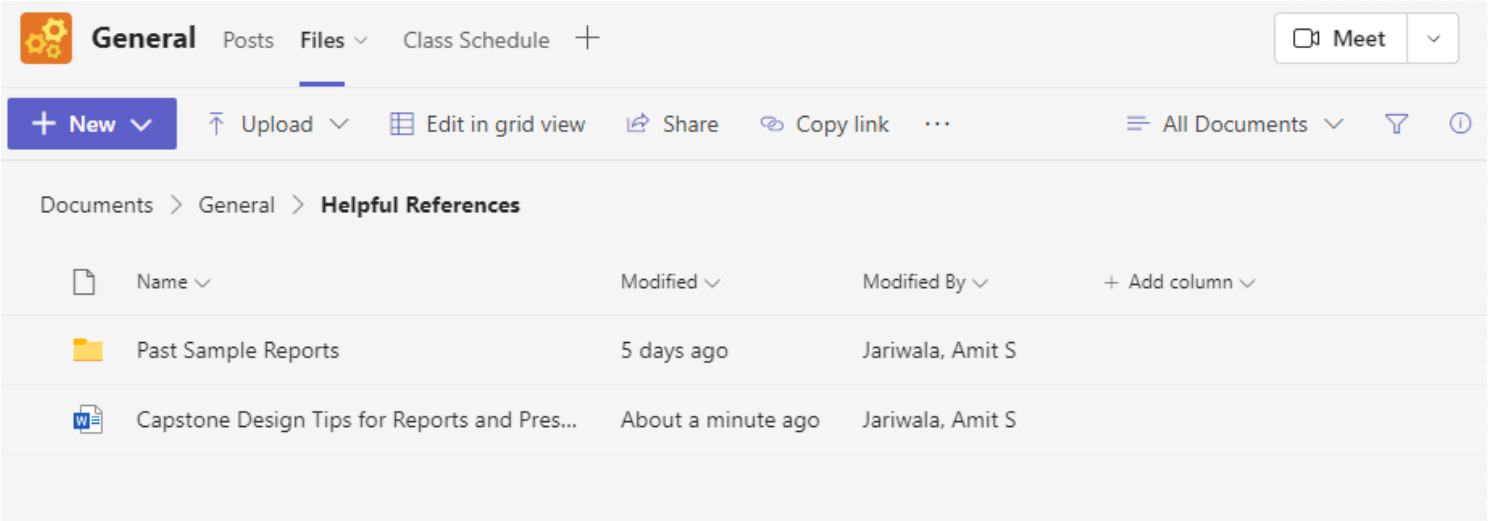
Join at slido.com
#JB-007

ⓘ Start presenting to display the joining instructions on this slide.

Recap/Reminders

- ALL Links, SLIDES and VIDEOS are posted here: http://mecapstone.gatech.edu/students
  - Additional resources added on MS Teams



- Plan for today:
  - Discussion on Prototyping
  - Hear from recent alumni
  - Reimbursement process
  - Assignment Announcement
    - 1-minute video submission by ALL teams on October 10

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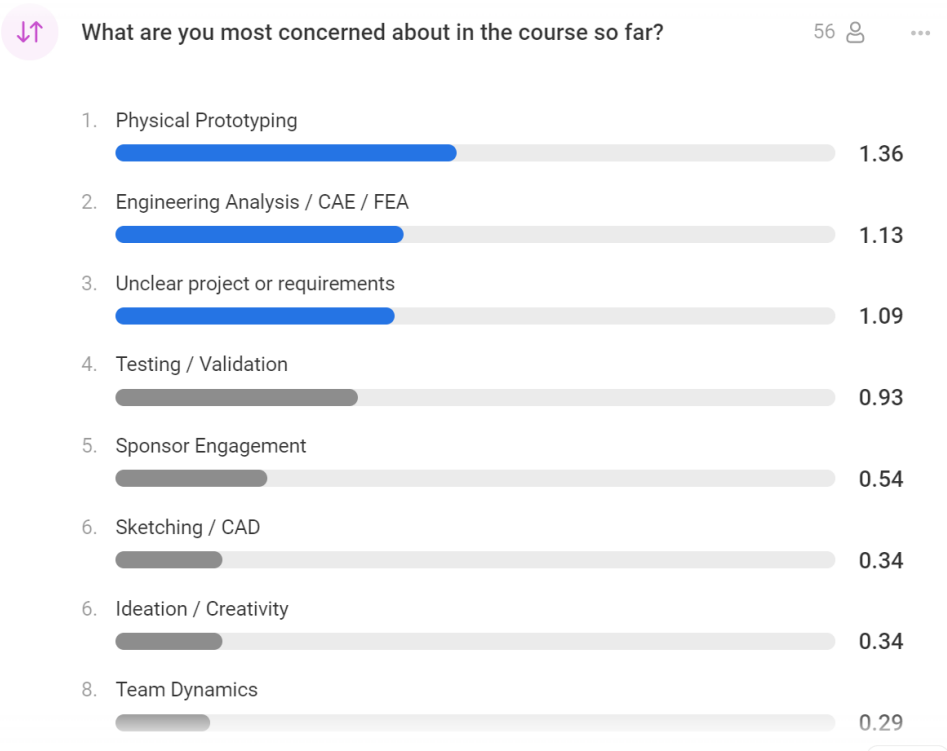
What are you most concerned about in the course so far?

ⓘ Start presenting to display the poll results on this s



Equipment Available to You!

- MyDAQs
- cDAQs
- BNC Cables
- PCB Cables
- Light Meter
- Voltage Input Modules
- Accelerometers
- Thermo-Anemometer + IR
- Infrared Camera
- Sound Level Meter

- **Check with me before you purchase electronics**
- How do I check the inventory?
  - https://mecapstone.gatech.edu/equipment
  - Teams message or email Jacob Blevins
- jacob.blevins@me.gatech.edu

Story of an Inventor

http://Dyson.com/

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Story of an Inventor

"I made 5,127 prototypes of my vacuum (over 15 years) before I got it right. There were 5,126 failures. But I learned from each one. That's how I came up with a solution. So I don't mind failure."

"By 2,627, my wife and I were really counting our pennies,… By 3,727, my wife was giving art lessons for some extra cash."

- James Dyson

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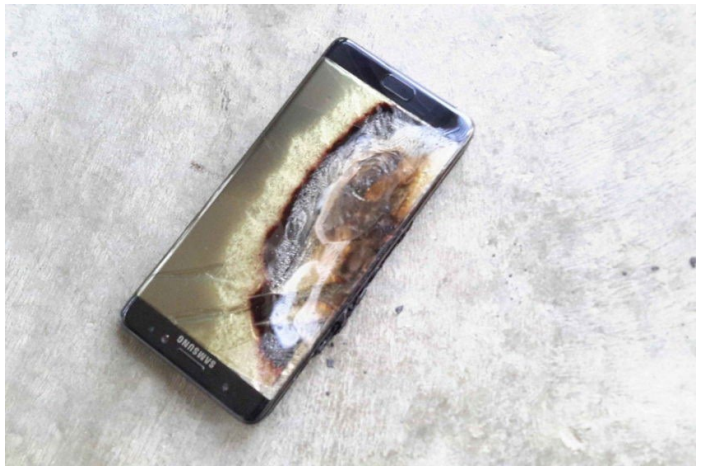
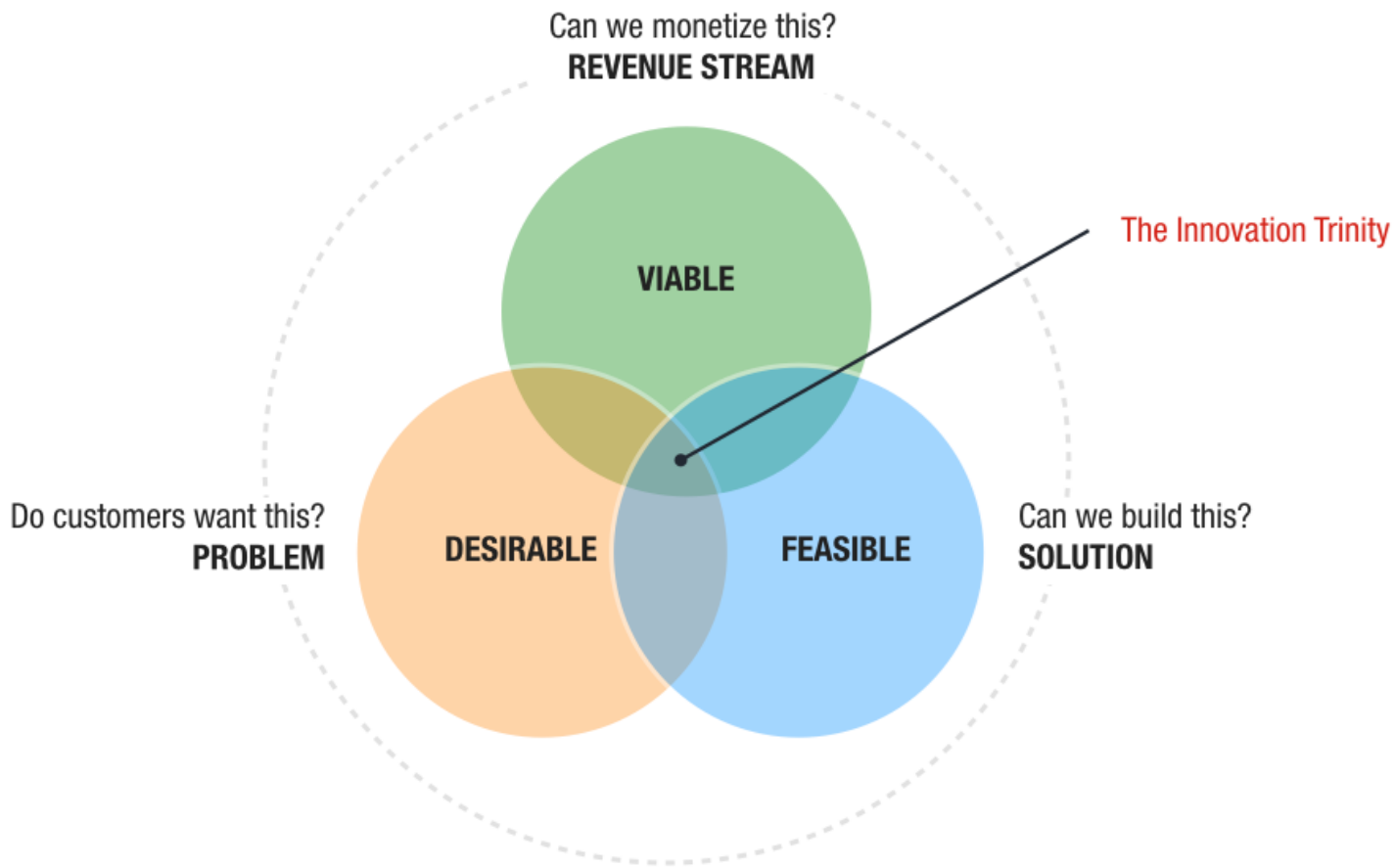
http://www.dennyyou.com/2018/06/04/james-dysons-5217-prototypes-before-he-invent-first-cyclone-vacuum-cleaner-dc01/

What is common?



https://www.engadget.com/dysons-electric-car-n526-085341772.html
https://dantealvaradoleon.medium.com/product-launches-an-analysis-of-the-samsung-galaxy-note-7-an-explosive-launch-65adb459f2eb
https://www.marketing91.com/coca-cola-brand-failure/
https://www.cnn.com/2021/03/03/tech/spacex-starship-sn10-test-flight-scn/index.html

What is Innovation?



Modification from IDEO's Innovation Framework

https://blog.leanstack.com/lean-startup-or-business-model-design-or-design-thinking-is-the-wrong-question-f84216fad869

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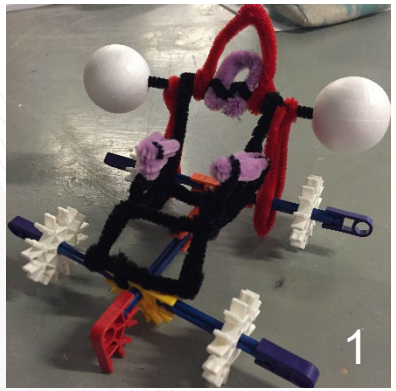
What causes design failures?

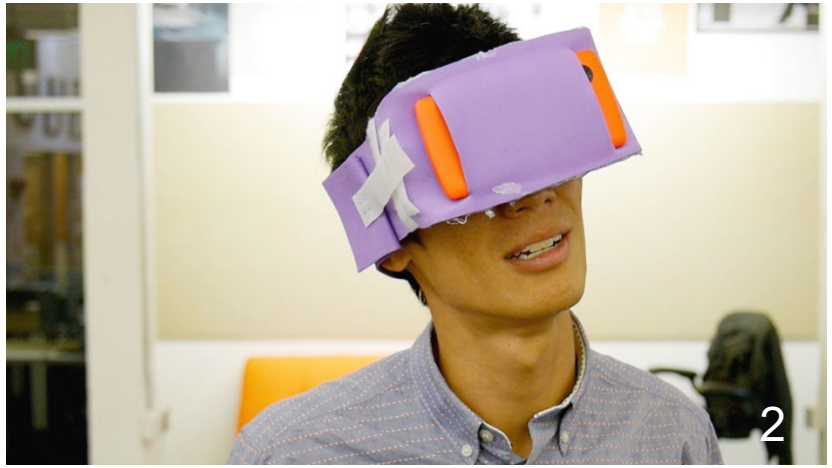
- Failure to understand user needs (NO Desirability)
  - “Discover” the customer
  - Identify Functional Requirements (FR)
  - Develop Design Specifications
- Failure to perform (NO Feasibility)
  - Solution fails in service
  - Not enough analysis or testing
- Failure to realize (NO Viability)
  - High cost
  - Not practical to manufacture

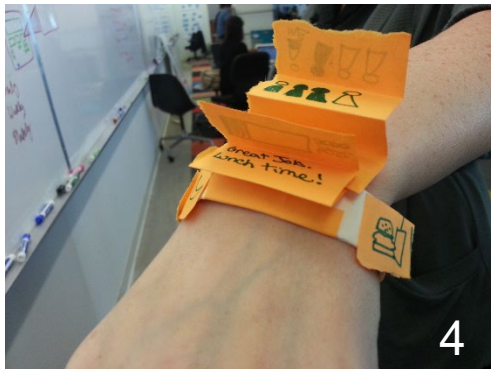
Prototypes reduce Innovation Risks

- Desirability
  - **Identify** key requirements and preferences that impact end-user
- Feasibility
  - **Confirm** if solution meets desired functionality and performance
- Viability
  - **Validate** if the end product is economically feasible and manufacturable

Are these Prototypes?







Yes, they can be simple!

Are these Prototypes?

Yes, they can be sophisticated

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Discuss with your team and define the term, "Prototype" in your own words. One response per team

ⓘ Start presenting to display the poll results on this slide.

What is a Prototype?

A design representation of some aspect such as form/fit or function of a design

Prototypes can be classified as a stage of the design process; they can also be described as a tool to further product development.

Discussion

?

Q1. Imagine your design goal is to build an excavator shown on the right. Would you build the items on the left as a prototype?

Segue into design project processes

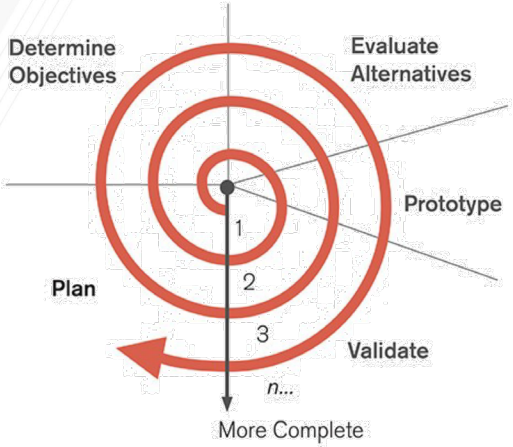
- Agile
  - Focused on refinement through iteration
  - More qualitative
  - Classically associated with Industrial Design
  - **FIND** what to build

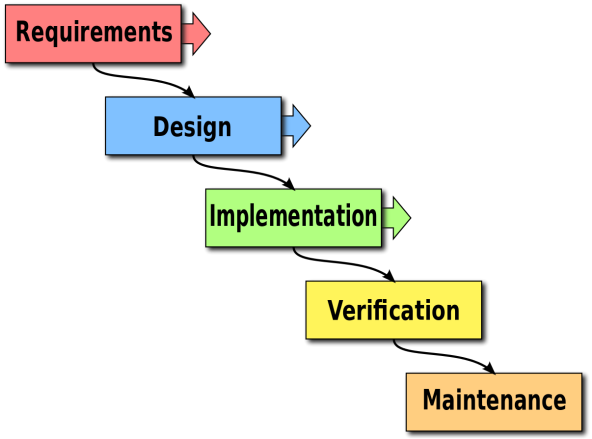
  - Typically for Consumer Product

- Waterfall
  - Focused on risk evaluation

  - More quantitative
  - Classically associated with Engineering
  - **KNOW** what to build

  - Typically for defense/B2B products





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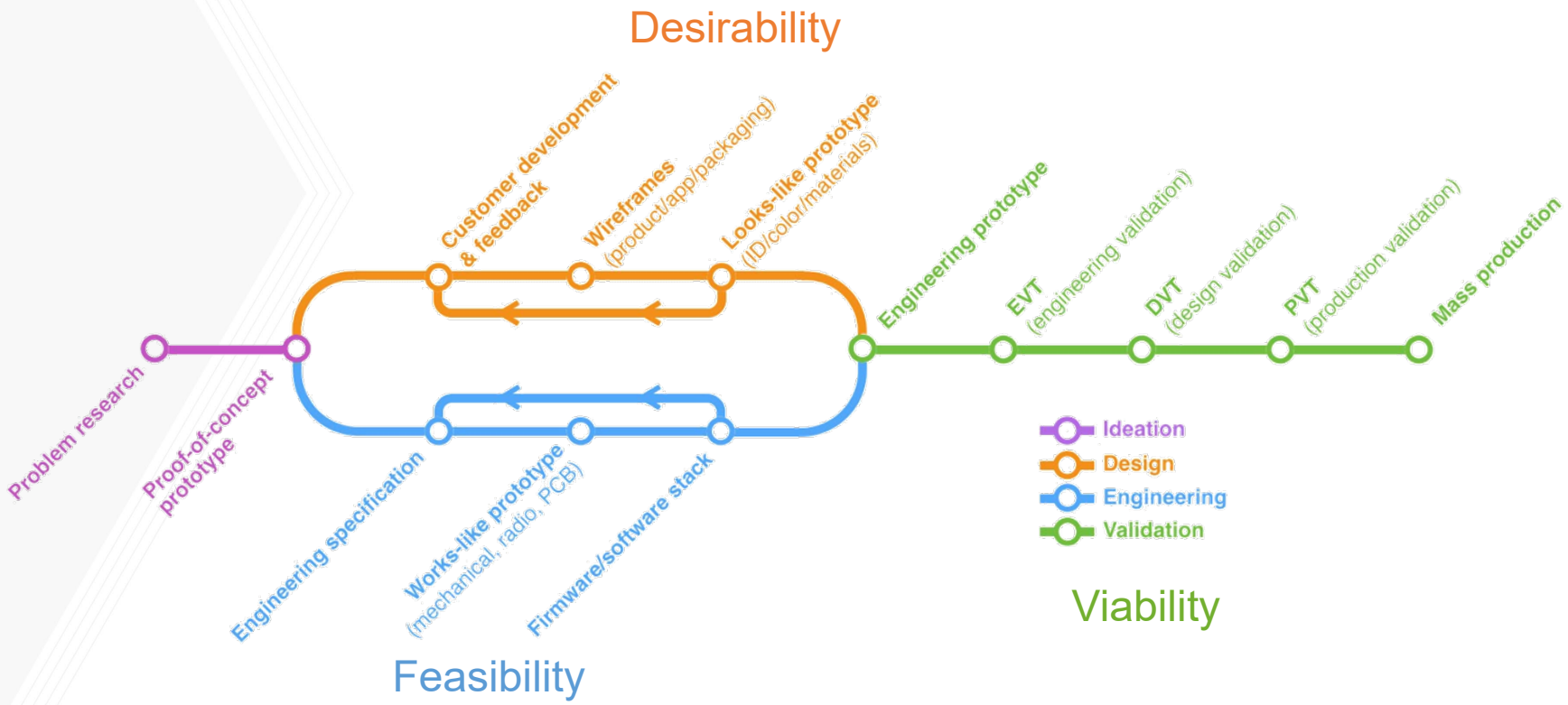
Typical hardware product design process

- Combination of several iterations within a waterfall framework



https://blog.bolt.io/ideation/

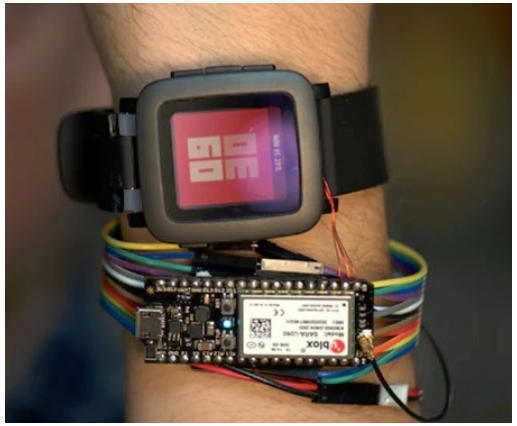
Functional types of Prototype - Example

- ***Looks-like*** *(Desirability)*

  Focuses on the look, feel, form, and aesthetics of the product.

- ***Works-like*** *(Feasibility)*

  Demonstrates functionality and ensures technical challenges are resolved



Courtesy: Scott Miller

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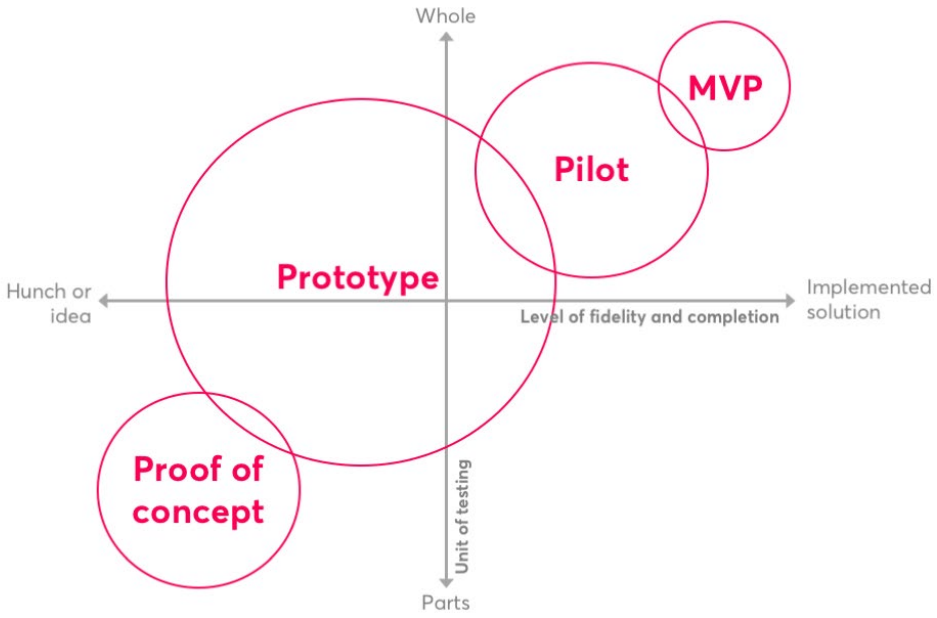
Demystifying Terms (*from Wikipedia*)

- **P**roof **O**f **C**oncept – A realization of a certain method or idea in order to demonstrate its feasibility or a demonstration in principle with the aim of verifying that some concept or theory has practical potential
- **P**rototype - An early sample, model, or release of a product built to test a concept or process
- **M**inimum **V**iable **P**roduct – A product with just enough features to satisfy early customers and to provide feedback for future product development



https://www.nesta.org.uk/blog/proof-of-concept-prototype-pilot-mvp-whats-in-a-name/

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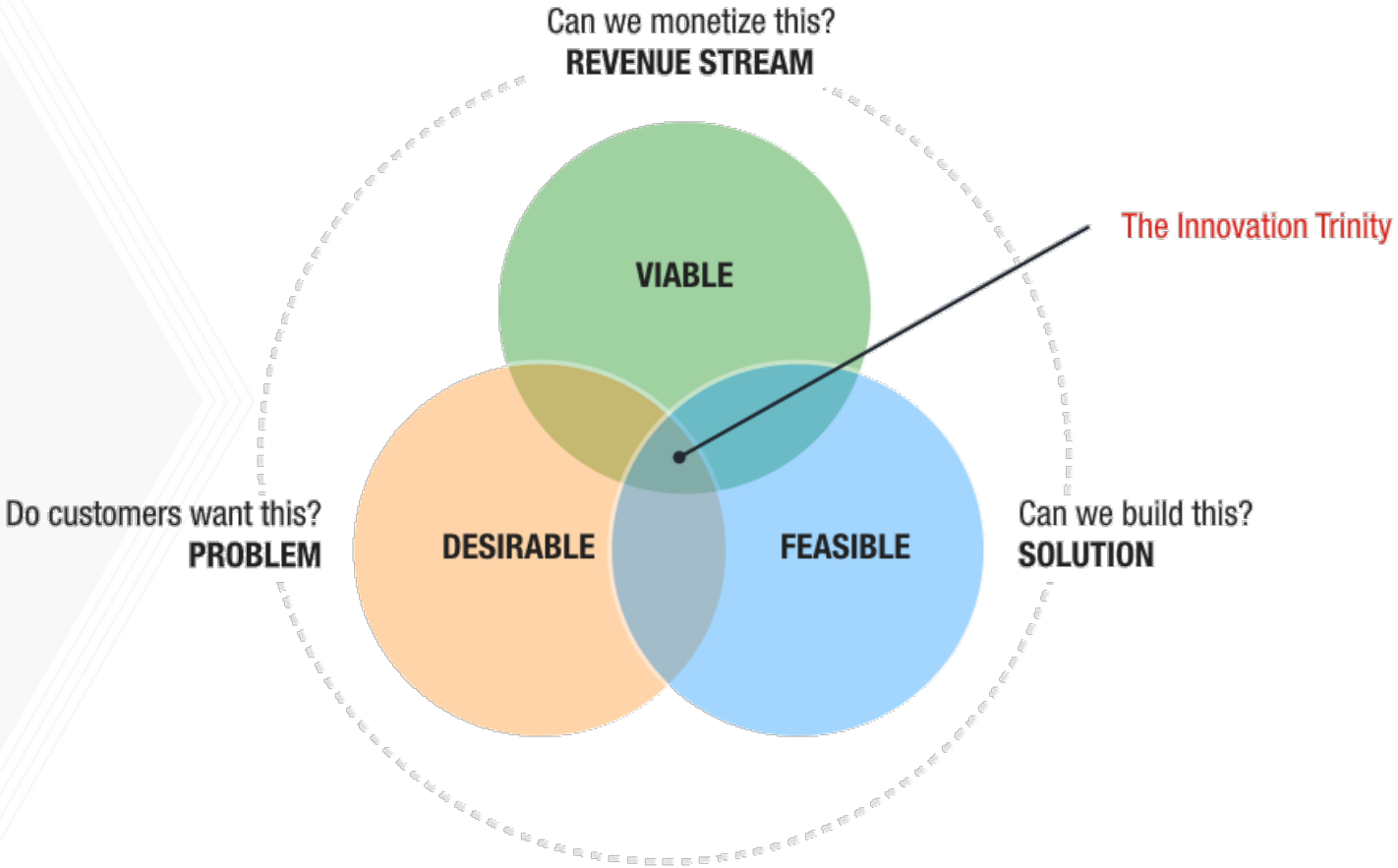
Reminder about Innovation Triad



Modification from IDEO's Innovation Framework

https://blog.leanstack.com/lean-startup-or-business-model-design-or-design-thinking-is-the-wrong-question-f84216fad869

Prototyping through Innovation Framework

Context: ACME Tool company has a product family of 18V cordless drills, saws and sanders that have been very successful in the consumer market. Their marketing department recommends expanding the product line to include cordless handheld vacuum.

Desirability	Feasibility	Viability
Need: Design and build a prototype of a handheld vacuum. ***Your prototype should focus on solving a customer need and you should work to create a positive customer experience.***	**Need:** Design and build a prototype of a handheld vacuum. ***Your prototype should focus on solving a key issue in functionality or technical feasibility.***	**Need:** Design and build a prototype of a handheld vacuum. ***Your prototype should focus on creating an economically viable solution that is ready for mass manufacture.***
Goal: A jury consisting of corporate executives, typical customers and investors will judge your design based on ***its aesthetics, ergonomics, and general appeal to consumers.***	**Goal:** A jury consisting of corporate executives, typical customers and investors will judge your design based on ***its performance, functions, and features.***	**Goal:** A jury consisting of corporate executives, typical customers and investors will judge your design based on economic potential, predicted assembly cost, and ***its ability to be successfully mass manufactured.***

Menold, Jessica, Kathryn Jablokow, and Timothy Simpson. "Prototype for X (PFX): A holistic framework for structuring prototyping methods to support engineering design." *Design Studies* 50 (2017): 70-112.

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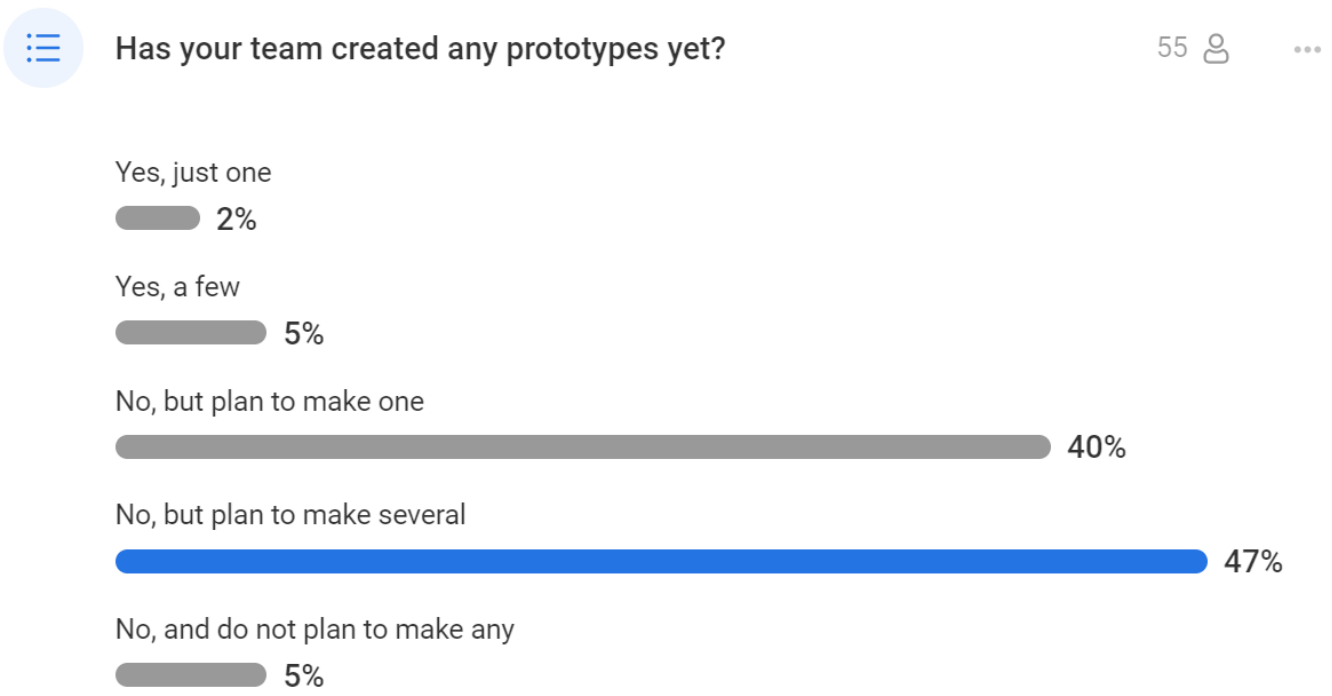
Has your team created any prototypes yet?



ⓘ Start presenting to displa

Why Prototype? Prototyping Outcomes

1. Refine ideas
   - Clarify requirements
   - Identify potential performance increases
   - Identify mistakes and failure modes
   - Reduce risks early

2. Communicate
   - Observe or experience use and user needs
   - Discuss with stakeholders

3. Explore ideas
   - Test multiple concepts
   - Gather information about the design space
   - Ideation tool

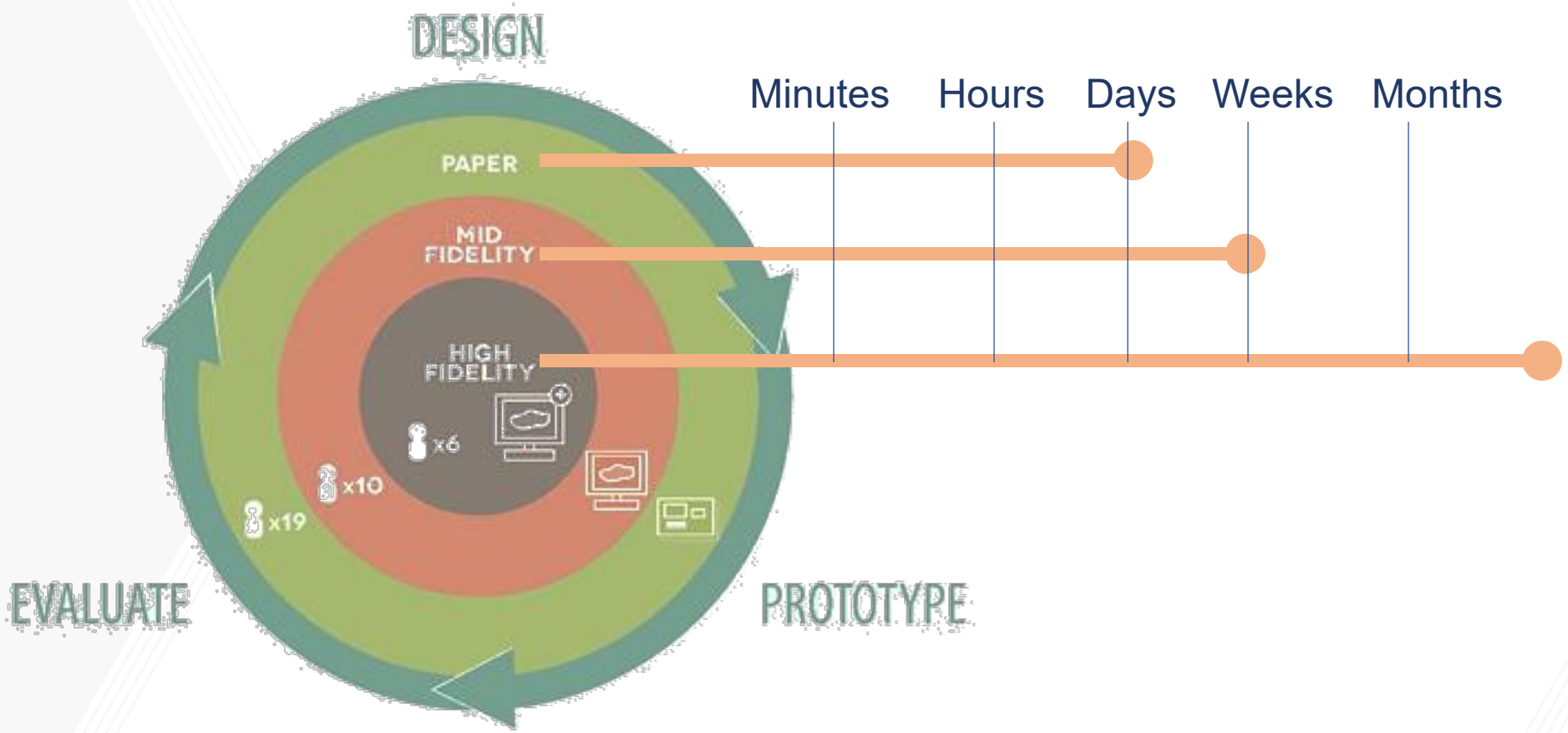
4. Learn
   - Test phenomena
   - Verify mental or computational models
   - Increase confidence

There is ALWAYS a specific purpose for prototyping…

how to decide the correct purpose?

Camburn, B. A., 2015, "Design Prototyping Methods," Dissertation, The University of Texas at Austin.

Evaluation is a necessary task after each Prototype



http://cargocollective.com/ivytsai/Data-Visualization

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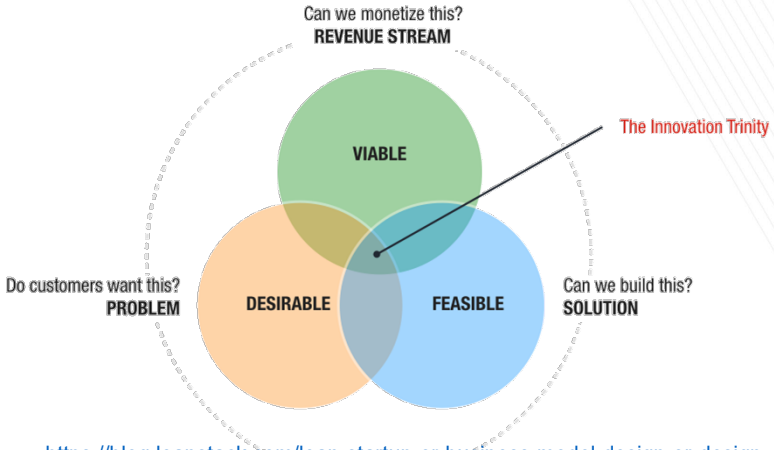
Quick recap



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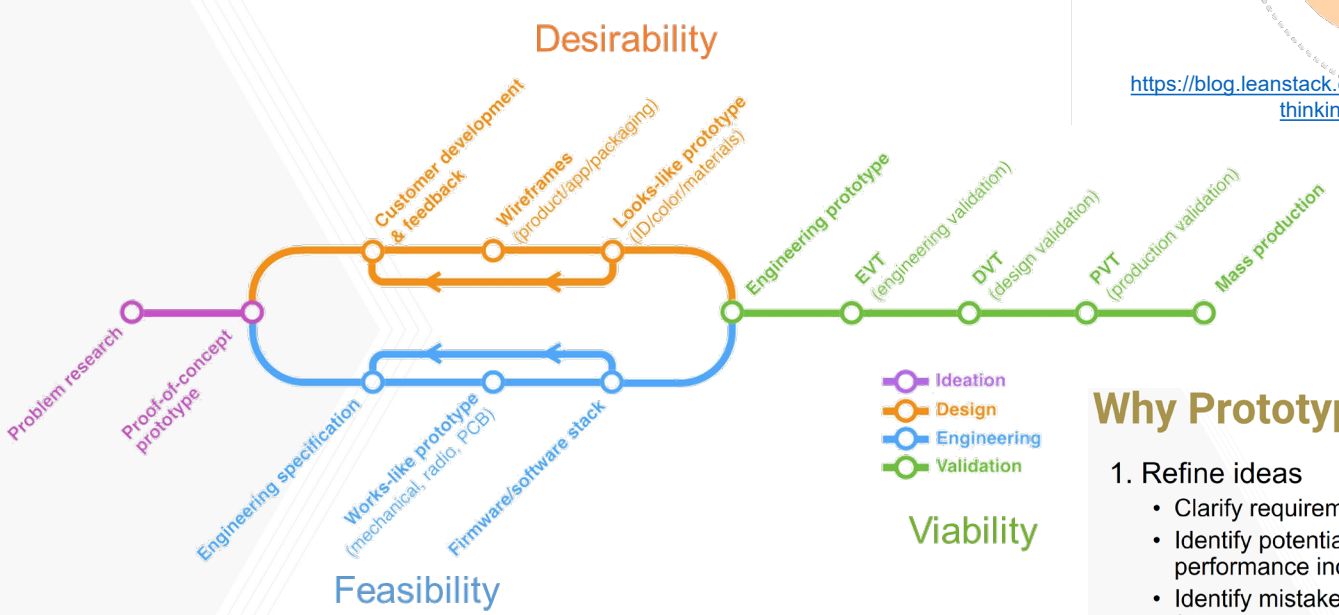

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Past Team Spotlight - Tennibot

https://tennibotxcapstone.wordpress.com/

Tennibot X
Robotic Tennis Assistant

Georgia Tech
Stefanos Charalambous, Tamir Gonen Cohen, Ira Soltis,
Muhammad Anmbus Iqbal, Nicholas Jozwiak, Iason Vratimos
Advisor: **Dr. Amit Jariwala;** ***Sponsor:*** **Tennibot**

Introduction

The **International Tennis Federation** expressed the need to reduce the number of people on tennis courts

➔ **The problem:** 6 ball persons are required to collect tennis balls during competitive matches

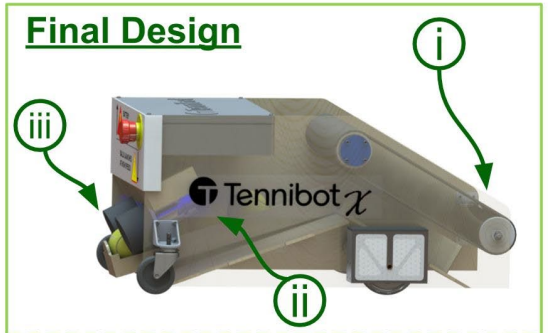
➔ **The solution:** a robotic system to replace the ballpersons

Operation

Value Proposition

- **40%** less people on court
- **5 hours** continuous operation
- **25%** more balls stored
- **Reduced** health risk during Covid-19

Final Design



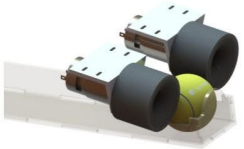
i Collection

Conveyor belt **intake** mechanism

ii Storage

Actuated ramp to **store** 5 tennis balls

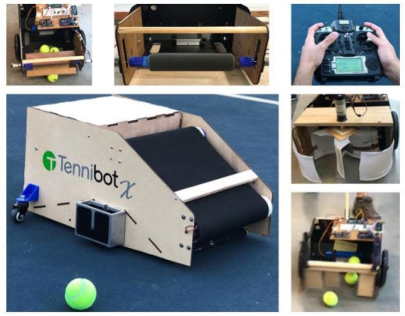
iii Dispensing



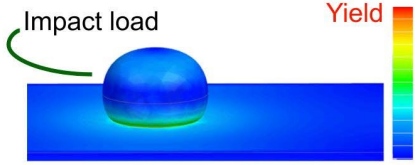
Rollers to **dispense** tennis balls

Analysis & Testing

- **40+** design concepts generated
- **15+** physical prototypes



Finite Element Analysis (FEA)



Modeling & Control of Motors

Future Work

- Design for manufacturability
- Add disinfection mechanism
- Autonomous operation

Questions to consider when prototyping

1. How many concepts to test in parallel?
2. How many iterations of each concept?
3. Virtual or physical?
4. Breakdown into isolated subsystems?
5. Scale down the size?
6. Relax design requirements?

What is the best use of your **time**, **money** and access to **resources** (like fabrication tools) to validate your hypothesis that your conceptual solution is indeed **feasible**?

T. Gurjar, D. Jensen, R. Crawford, "Effects of a Structured Prototyping Strategy on Capstone Design Projects", 122nd ASEE Annual Conference Proceedings

Prototyping Strategies – *Number of Concepts*

- Prototype several concepts in parallel if…
  - Evaluation ranks of multiple concepts are close enough
  - Sufficient time and materials are available

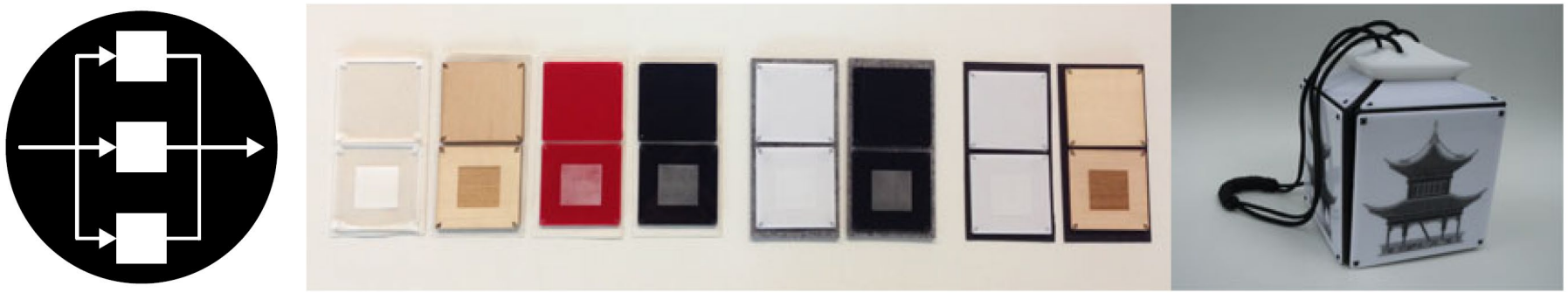
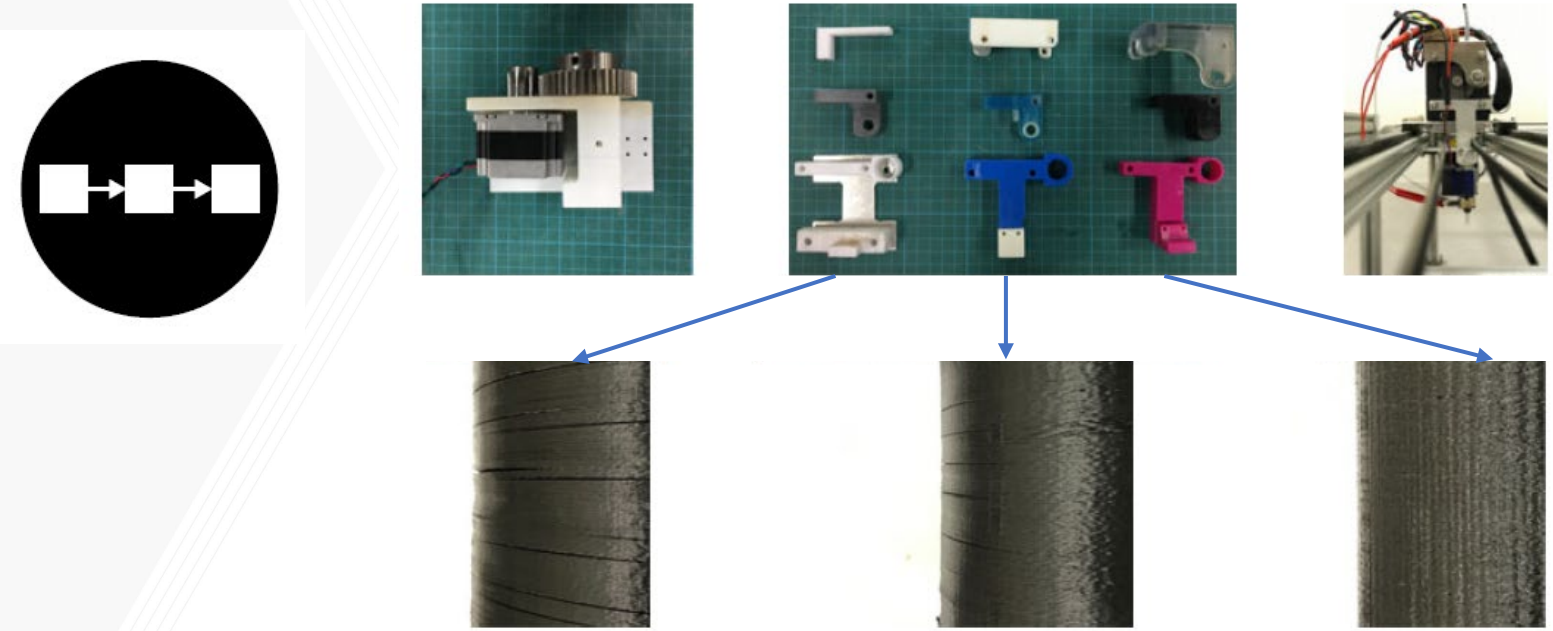


Figure 8. An example of parallel prototyping. (Left) Eight alternative textile prototypes for the casing of a collapsible carrier; (right) prototype of the selected materials in the final concept (right).

Camburn et. al "*Design prototyping methods: state of the art in strategies, techniques, and guidelines*", Design Science vol. 3, e13

Prototyping Strategies – *Number of Iterations*

- Prototype numerous iterations if …
  - Difficult to meet the requirements with lesser iterations
  - Team has less experience with prototyping



An example of iterative design. (Left) Initial design; (centre) a series of three iterative refinements; (right) the final design for a large-scale 3D printer extrusion head. The reliability of the print process gradually increased with each iteration (test prints shown below each design). The final design required nearly 40 iterations to achieve reliable printing. Courtesy of Gilmour Space Technologies.

Camburn et. al "*Design prototyping methods: state of the art in strategies, techniques, and guidelines*", Design Science vol. 3, e13

Prototyping Strategies – *Virtual* or *Physical*?

- If virtual models are sufficiently accurate
- If CAD models necessary for advanced engineering analysis like FEA, CFD, etc.
- If virtual prototyping will take less time

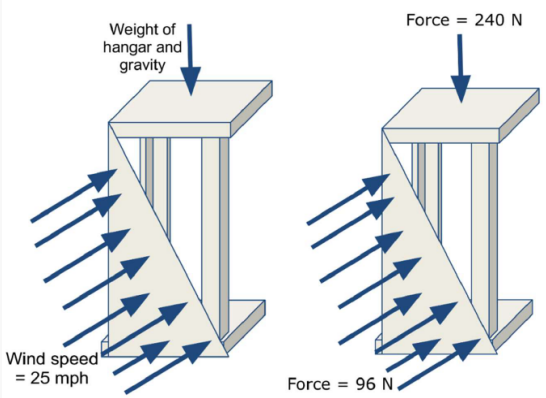


Figure 28: FEA Load conditions on the Base

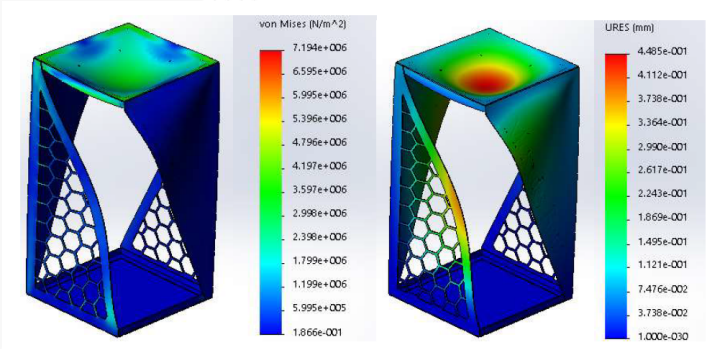


Figure 29: FEA results for von Mises stress (left) and displacement (right)

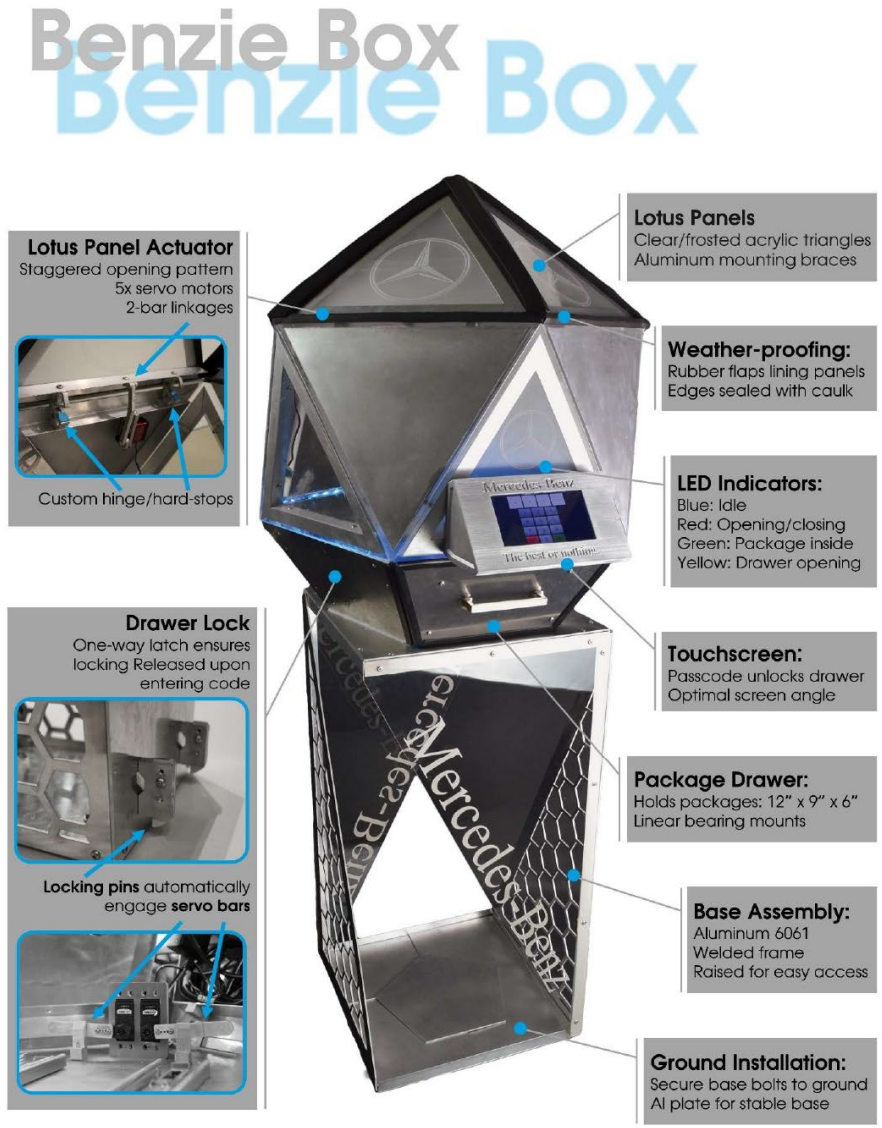


Figure 36: Final Working Model

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Prototyping Strategies – *Subsystem Isolation*

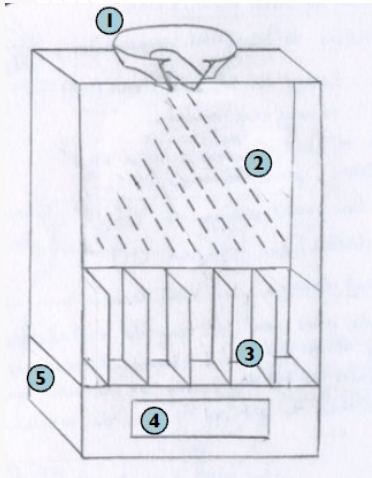
- If interfaces between subsystems are predictable
- An isolated subsystem can be properly tested
- Few subsystems embody critical design requirements

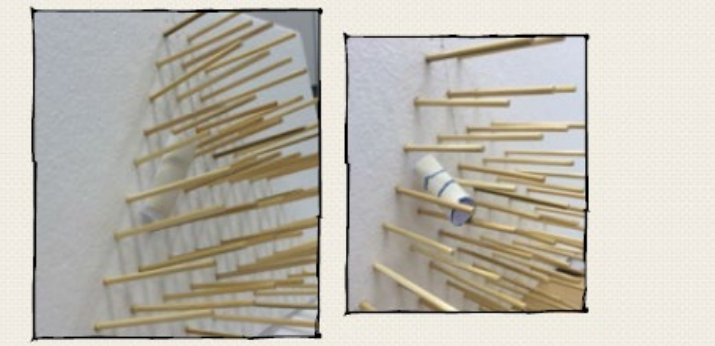
Figure 16. (Left) Isolated subsystem prototype of an electric vehicle drive train; (center) integrated functional design of the same vehicle; (right) final model of the market product, rendering. Courtesy of Gilmour Space Technologies.

Camburn et. al "*Design prototyping methods: state of the art in strategies, techniques, and guidelines*", Design Science vol. 3, e13

Prototyping Strategies – *Scaling*

- If known scaling law will permit accurate knowledge gain
- If scaling will simplify the prototype





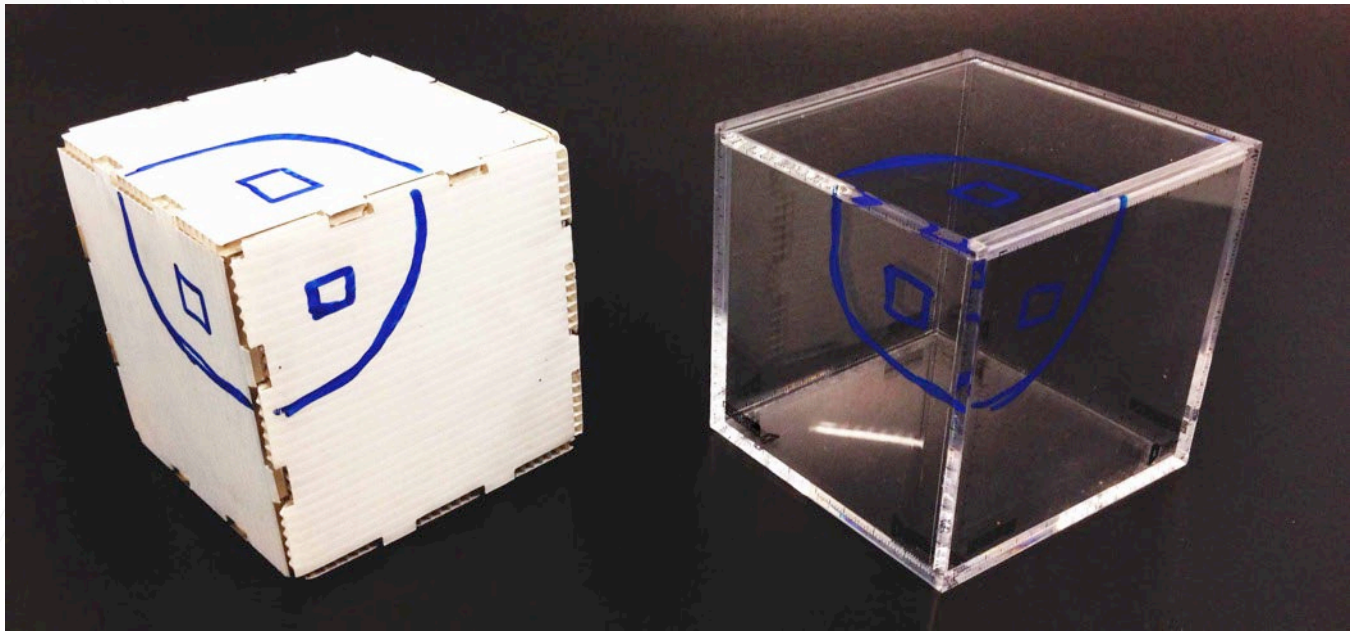
1st prototype using styrofoam for base board, skewers for pins

Quick prototype made from cardboard and push-pins

Courtesy: Students in SUTD 3.007 Fall 2013

Prototyping Strategies – *Relaxing Requirements*

- If design requirements are flexible to allow meaningful results despite relaxing requirements
- If prototype can be simplified



(*left*) Relaxed prototype made from posterboard; (*right)* fully functional prototype for a 3D whiteboard.

Camburn, B. A., 2015, "Design Prototyping Methods," Dissertation, The University of Texas at Austin.

Prototyping occurs in stages

Low Fidelity → High Fidelity

Sketches

Experiments
- Lab testing
- Partial systems

Alpha Prototypes
- Limited user testing
- May have partial systems

Beta Prototypes
- More general user testing
- Tweaks

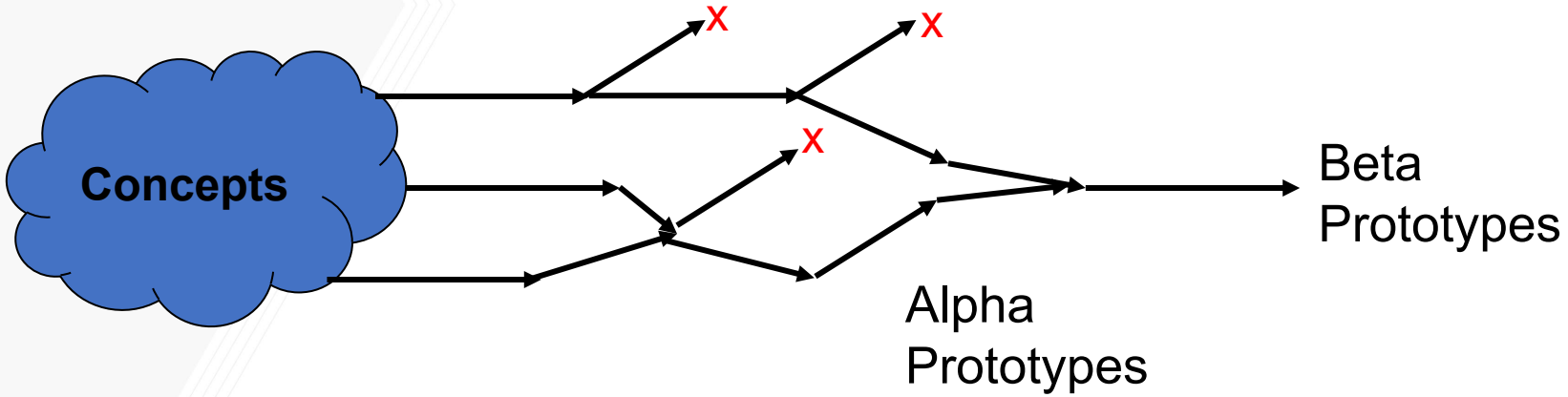
Pre-production Prototypes

But the stages are not a single trail of ideas

Low Fidelity → High Fidelity

Sketches | Experiments | Alpha Prototypes | Beta Prototypes | Pre-production Prototypes

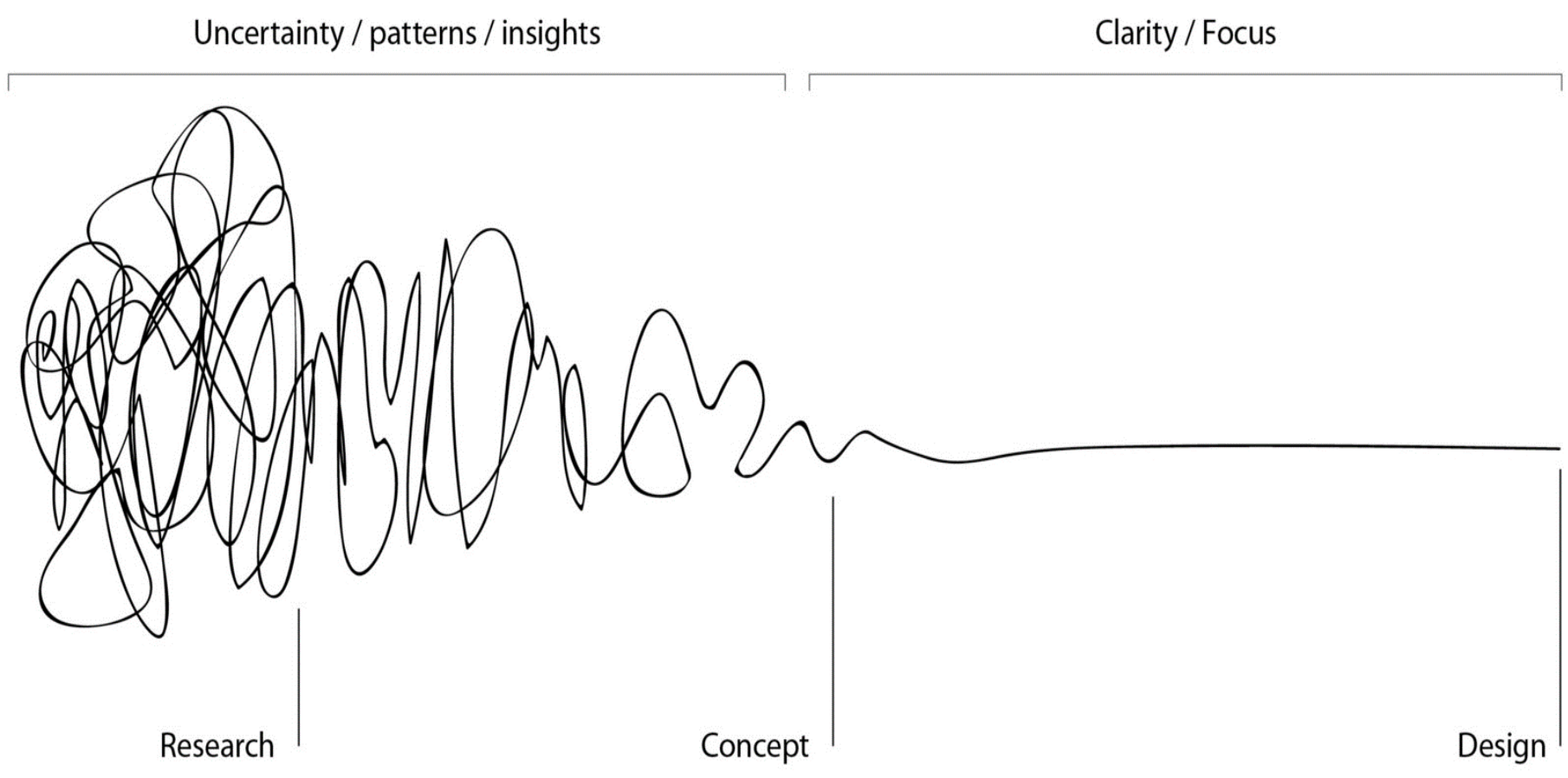
What really happens



Be wary of fixating

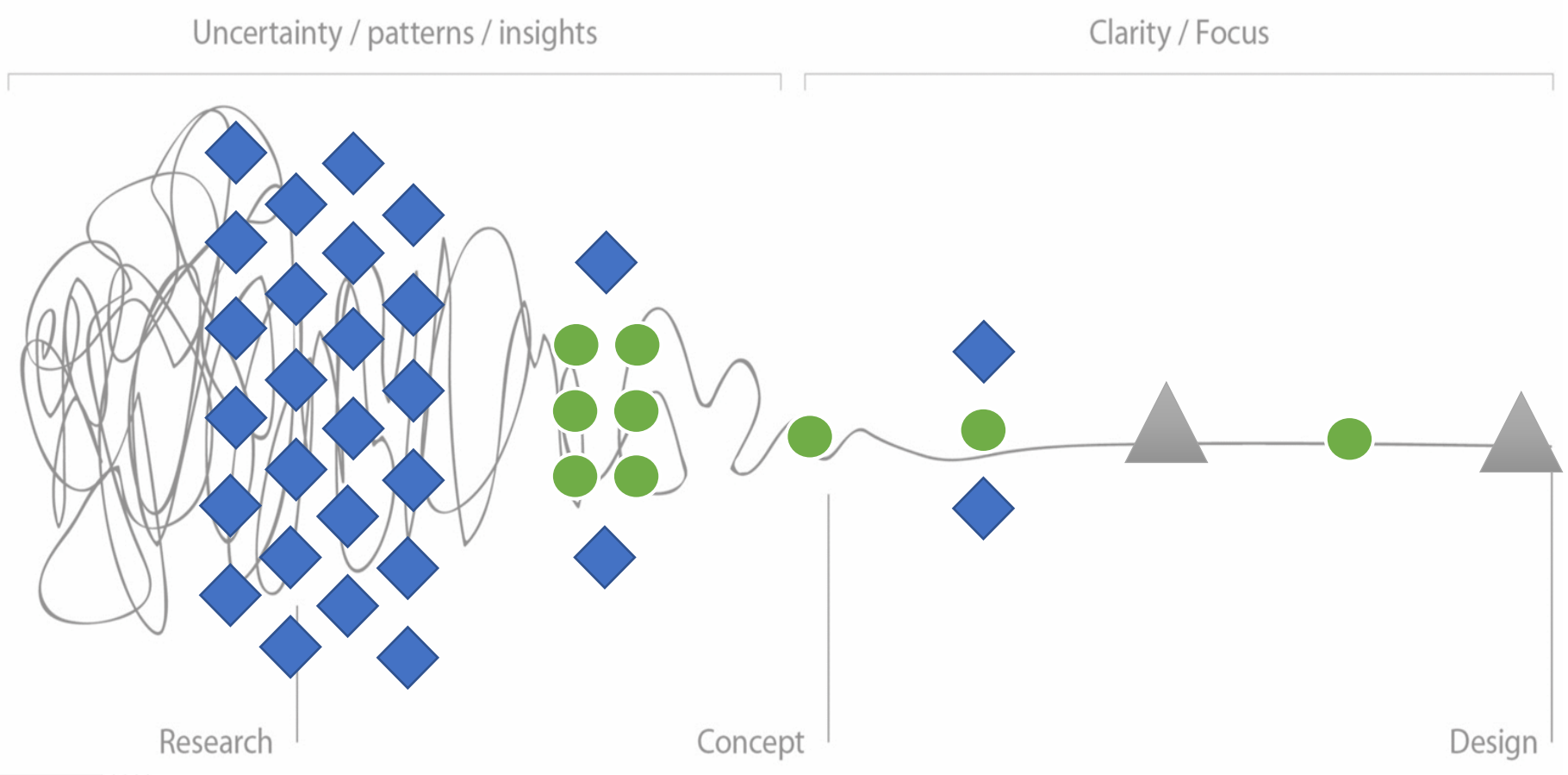
Know when to abandon an idea

Capstone Design Process



Design thinking squiggle from IDEO

Capstone Design Process



KEY

- Low Fidelity Prototype
- Medium Fidelity Prototype
- High Fidelity Prototype

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What is this prototype and what is it testing?

“We wouldn't know how it felt unless we could actually hold it, but since we didn't have one, the only thing to do was make one”

http://www.gamasutra.com/view/news/181321/Sometimes_paper_is_your_best_prototyping_tool__even_if_youre_Nintendo.php

Cardboard is your friend

Military tank seat prototype.
Credit image: Courtesy of PageOne for DailyMail

Cardboard iPhone Scanner made by designer Kyle A Koch. Credit Image: Kyle A Koch

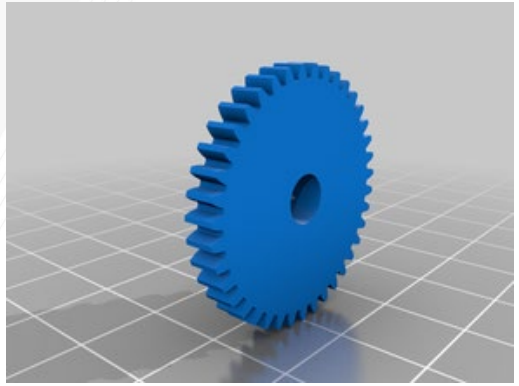
http://makingsociety.com/2014/11/how-to-cut-cardboard-prototyping/

Discussion

Q. Imagine that your final design involves a gear. Which of the following option would you pick?

- Option A:

1. Design gear in CAD
2. Build a 3D printed prototype in a makerspace
3. Test the prototype gears with the rest of the prototype
4. Build the gears for the final prototype in a machine shop



- Option B:

1. Select gears from McMaster Carr based on requirements.
2. Download CAD for your simulation.
3. Order the gears for your final product.

Plastic Gear - 14-1/2 Degree Pressure Angle

Press-Fit Mount, 48 Pitch, 12 Teeth

1 Each

ADD TO ORDER

In stock
$7.06 Each
57655K11

Pressure Angle	14 1/2°
Pitch	48
Number of Teeth	12
Pitch Diameter	0.25"
OD	0.29"
Face Width	1/8"
Overall Width	0.313"
Fabrication	Molded
Color	White
Material	Nylon
Bore Type	Plain
Mount Type	Press Fit
For Shaft Diameter	3/32"
Hub	
Diameter	0.188"
Width	0.188"

Discussion Prompt Follow-up

- Option A:

1. Design gear in CAD
2. Build a 3D printed prototype in the Invention Studio.
3. Test the prototype gears with the rest of the prototype
4. Build the gears for the final prototype in a machine shop

Cost: 3 weeks of design time, ~$500 of in-house machine time.

- Option B:

1. Select gears from McMaster Carr based on requirements.
2. Download CAD for your simulation.
3. Order the gears for your final product.

Cost: 0.5 weeks of design time, ~$60-150 of ordering cost

When NOT to prototype?

Antikythera Mechanism, 37 gear astronomical calculator - 87 BC

Do Not: Reinvent the Wheel!

Discussion Prompt #1 Follow-up

!=

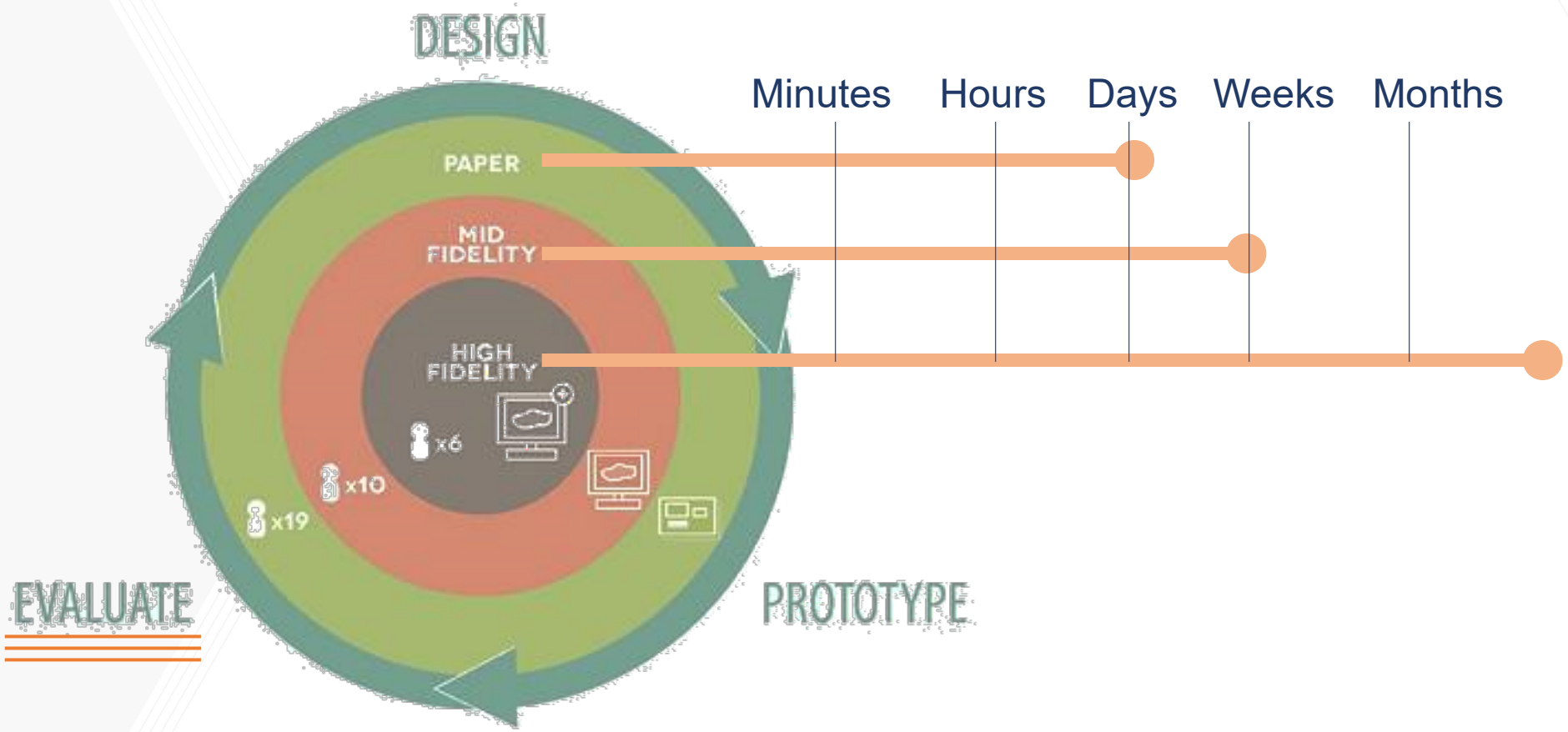
DO NOT: Mistake Your Prototype for Your Final Product

Risks with Prototyping

1. Novice designers may self-impose additional constraints
   - Assume only a certain material or manufacturing process is available
   - Unreasonable/excessive use technology as a driving factor to make design decisions
2. Fixation with “ONE” final prototype
3. Changing prioritization of design constrains during prototyping

Prototype with a clear hypothesis!
Else you are building an art exhibit.

Evaluation is a concurrent task during product development



Your prototype should help evaluate a hypothesis

ONLY BUILD with a clear purpose

http://cargocollective.com/ivytsai/Data-Visualization

Are you designing a prototype or prototyping your design?

All The Best!

- Acknowledgements to
  - Scott Miller (CEO, Dragon Innovation)
  - Veronica Spencer (BSME, MSID 2019)

Common Errors

- “BoM should be less than $800”
- “How Validated” column of Specification Sheet says “measure”
- Past team struggles
  - Waiting for too long to make a decision of building a prototype or conduct basic analysis
  - Team dynamics. Say it out loud before it is too late

slido

How could you earn an A in this class?

ⓘ Start presenting to display the poll results on this slide.

Alumni Feedback

- What do you think you did right when taking capstone design?
- What did you do wrong when taking the course?
- What would you do differently now if you took the course again?

https://mecapstone.gatech.edu/resources/reimbursement-guidelines/

Project Prototyping Support

About | Sponsors | Students | Expo | News | Contact | September 19, 2022

- Schedule – Fall 2022
- Syllabus
- Resources
  - FAQ
  - Library Resources
  - Reimbursement Guidelines
  - Drafting Guide
  - Student Manual

Reimbursement Guidelines

The following guidelines only apply to teams totyping needs with their respective faculty instructor. DO NOT ASSUME that reimbursement for your project prototyping n eck with your faculty instructor prior to incurring any expenses.

Towards the end of the semester, **one** member of your team will be reimbursed for a portion of your project's prototyping expenses, if your team's prototyping activity was approved by your faculty instructor. Prototyping should be done for a specific purpose

Who is reimbursed?

1. **Please click** here to check your project reimbursement limits.
2. As a general rule, the following teams are reimbursed by the School of ME
   1. Current students enrolled in the ME Capstone Design Course
   2. Current students enrolled in the Interdisciplinary Capstone which has ME faculty as their team's primary advisor
3. NOT for student-teams sponsored directly by faculty or entrepreneurs

Georgia Tech
CREATING THE NEXT

Project Intro Video Assignment

- 1-Minute Project INTRO Video Assignment on CANVAS by **5:00pm on Monday, October 10**. You can reuse this video for the final expo video
  - Talk **ONLY** about the **problem** you are trying to solve. You can make a longer (4-6 minute) video for the final expo
  - Please upload the video on CANVAS under assignments (only one member per team needs to upload)