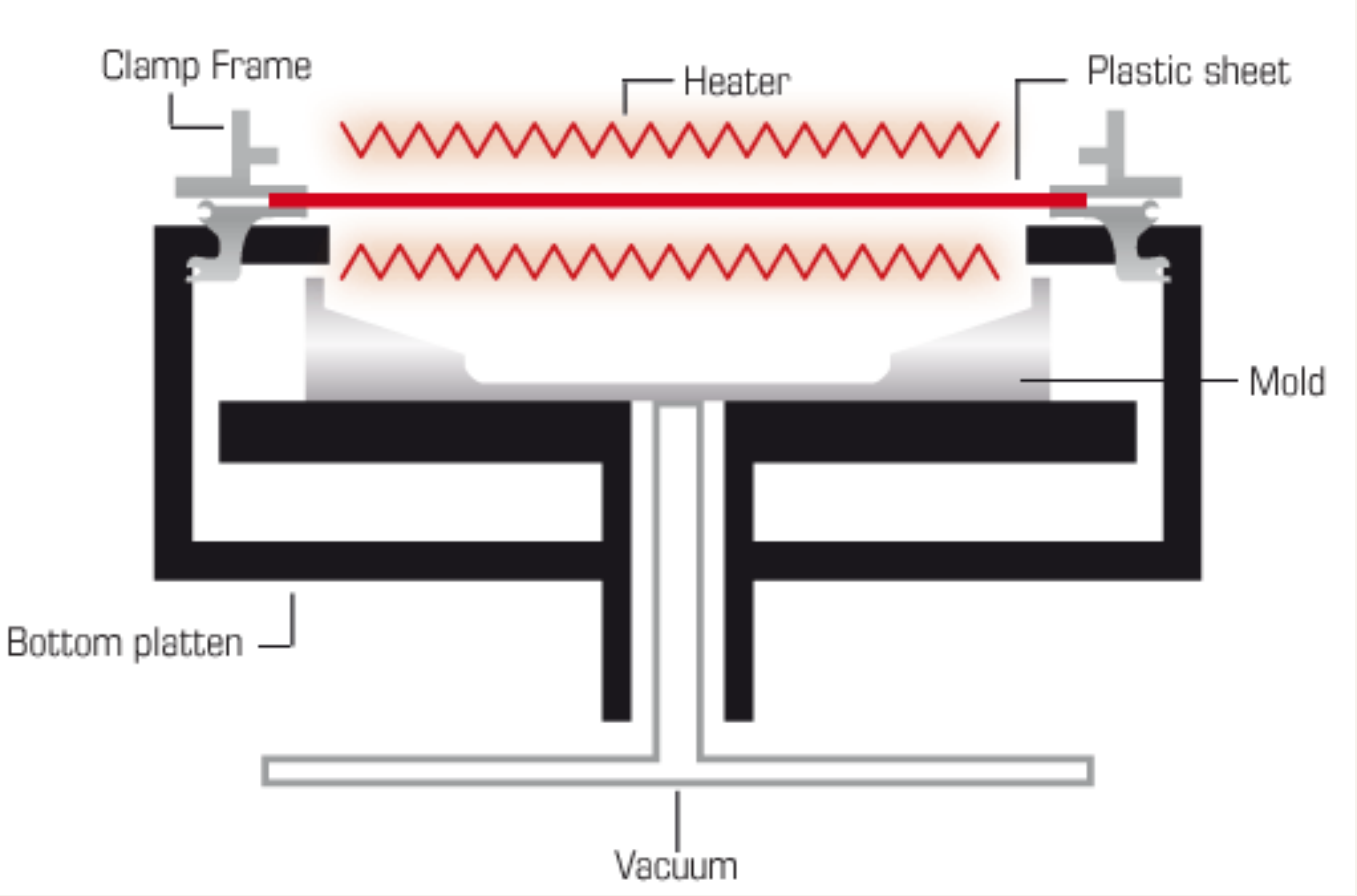
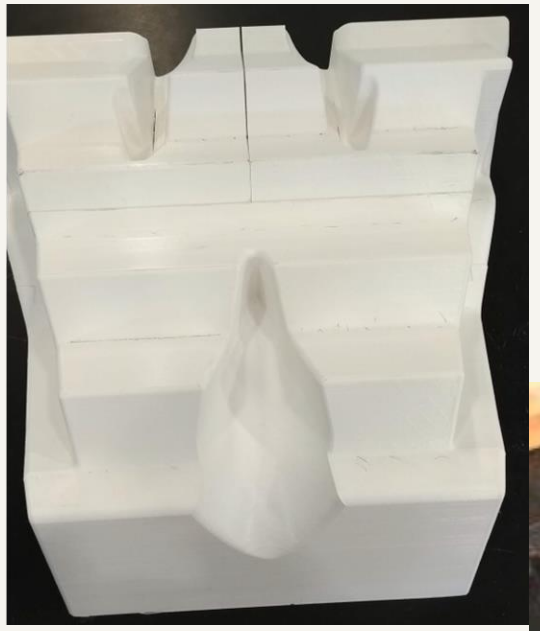
Cost Efficient 3D Printed Thermoforming Mold

Team Members: Julianna Buck, Chris Frego, ZeRajha Smith
Advisors: Jay Shoemaker, Michael Green

What is Thermoforming?



Project Inspiration



- Mold design from a Society of Plastics Engineers (SPE) project in 2019
- The original mold:
  - A multi-tiered spice rack
  - Material of parts is polylactic acid (PLA)
  - Beyond equipment capabilities

Background Information

- Procuring aluminum molds are expensive
  - $2,000 - $10,000
  - Time consuming
  - High volume production

Project Objective

- **Goal**
  - To create a cost-effective mold using 3D printing

- **Criteria**
  - Mold created entirely from 3D printing using PLA
  - Cost effective, functional mold

Project Objective

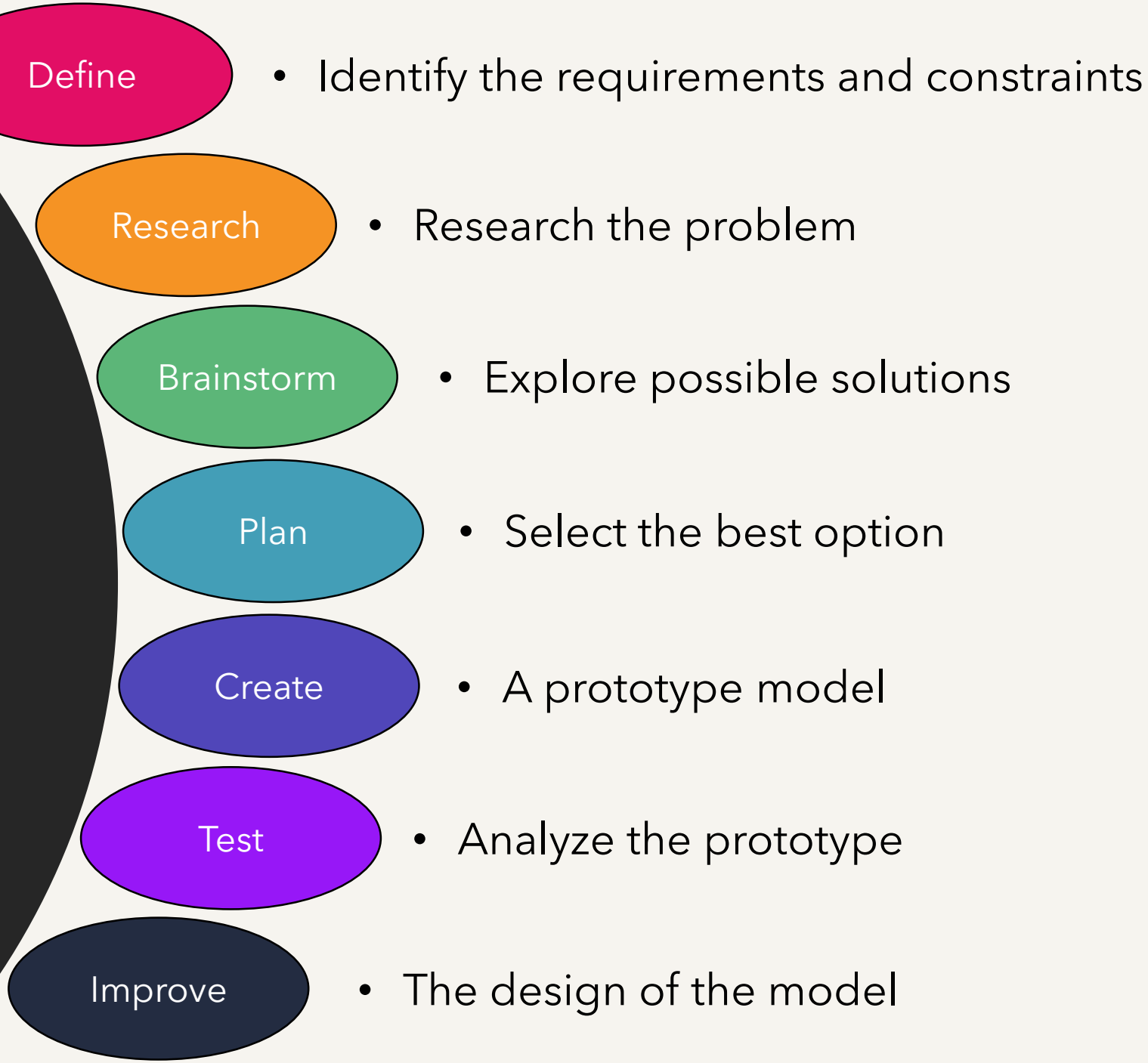
- **Deliverables**
  - Provide documentation on process
  - Calculate time and cost comparisons for the mold vs. alternatives
- **Constraints**
  - Size of 3D printer
  - Budget/Cost
  - Functionality of thermoforming machine
  - Availability of materials

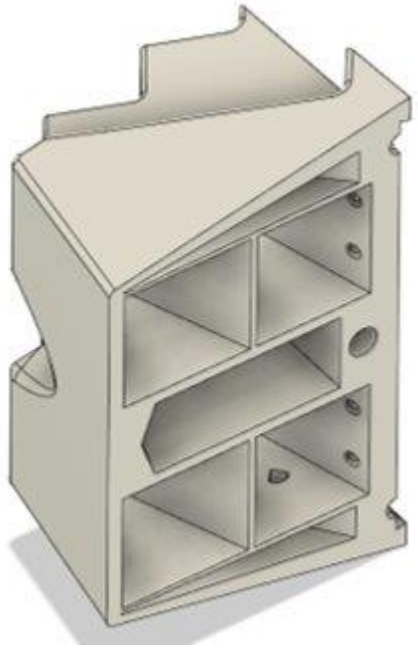
Project Objective

- **Objective**
  - Prepare and test prototype mold
  - Identify points of failure for new designs
  - Print new designs for comparisons
  - Test and analyze mold deterioration

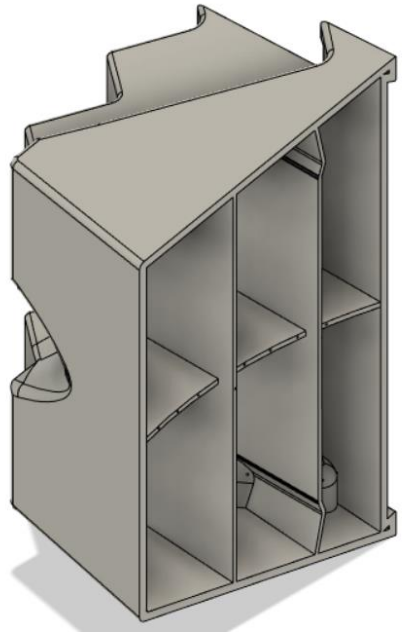
Project Plan

Engineering Design Process





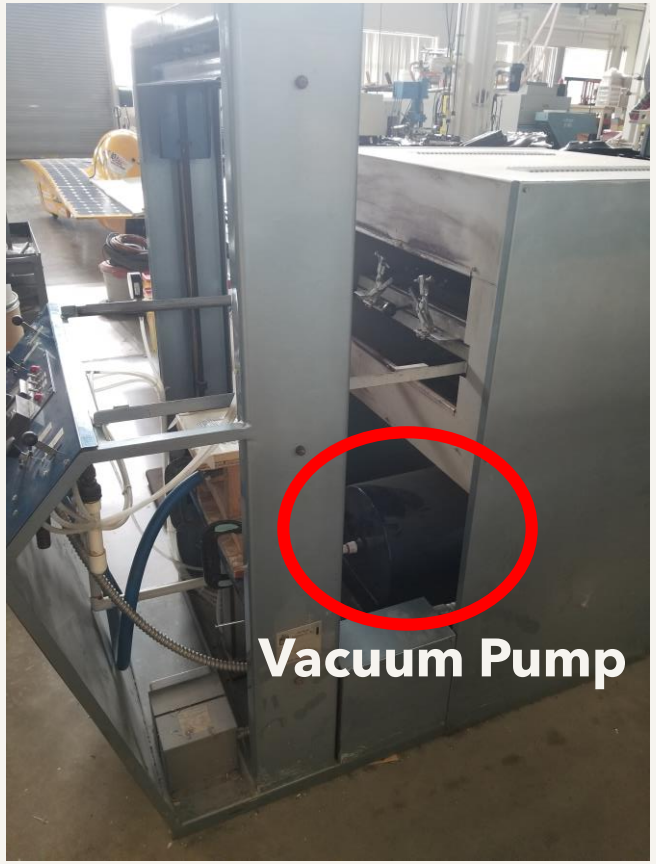
Original Vacuum Channel Design to New Vacuum Channel Design



Original Mold – CAD

- Drilled through the holes on the prototype
- Updated the model to simplify the vacuum channels

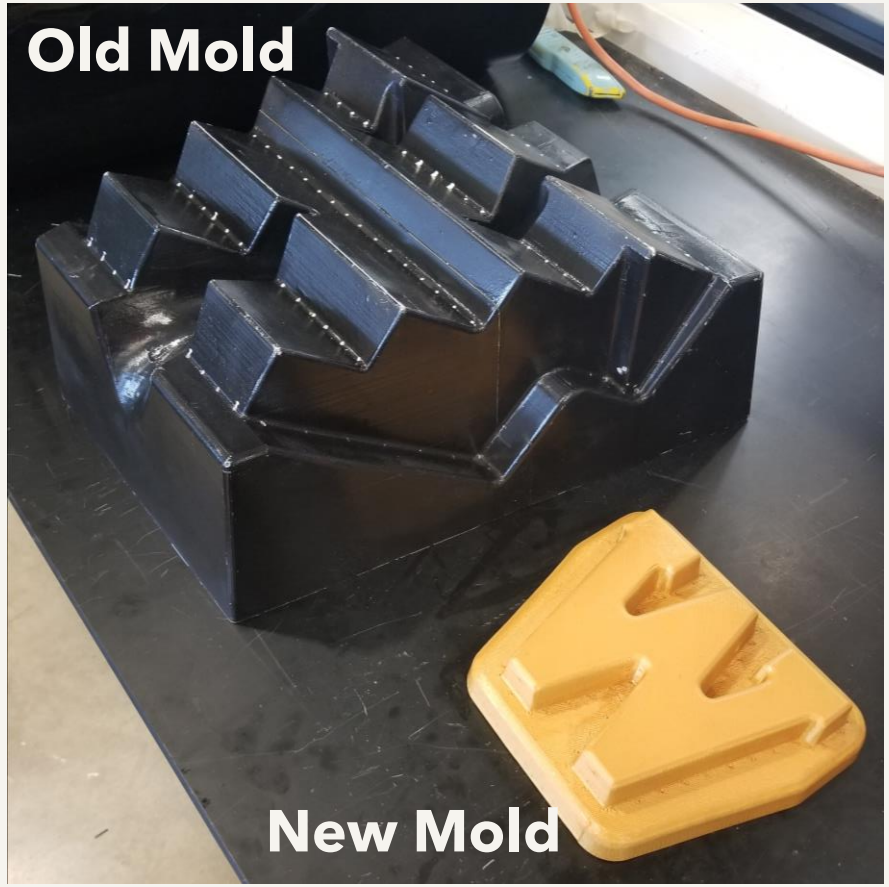
Vacuum Table



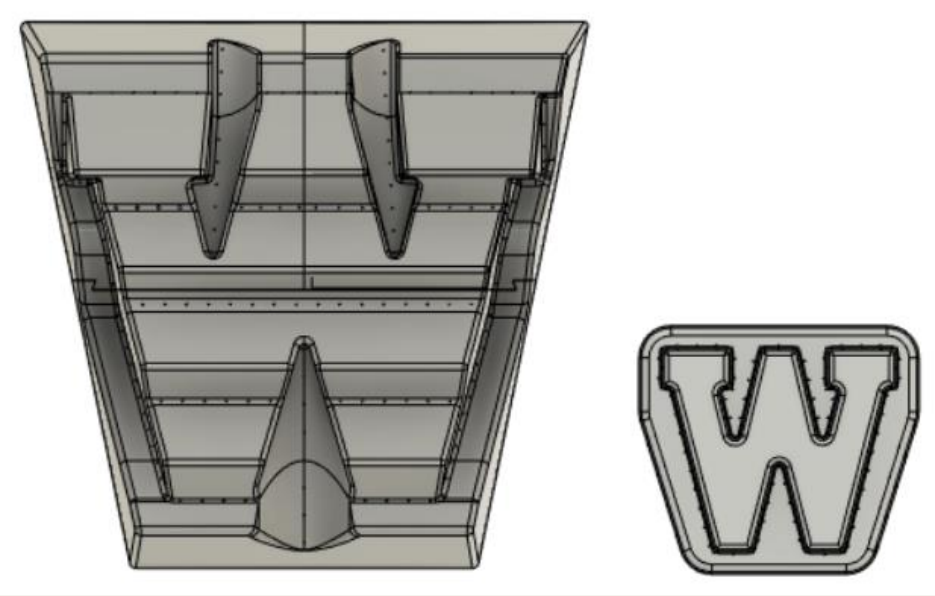
Equipment Issues

- Set up thermoforming machine to start test the prototype mold
  - Attached new pump
  - Fabricated new vacuum table
  - Replaced part of vacuum pump system

New Mold Design



- Smaller mold
- Requires less vacuum force



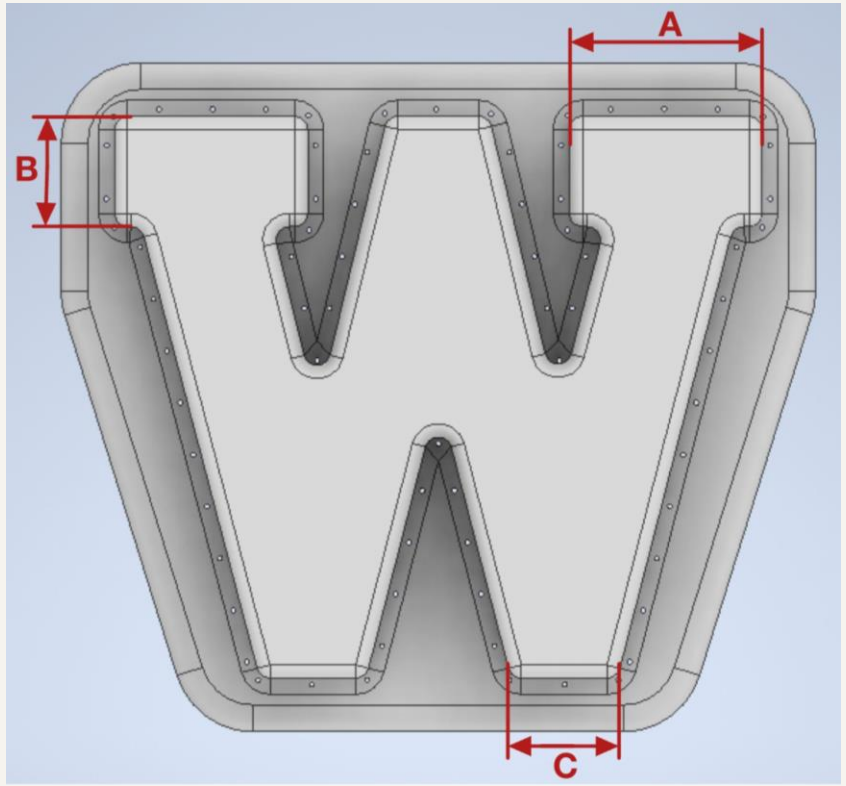
New Mold Design - CAD

1st Model – Too Large

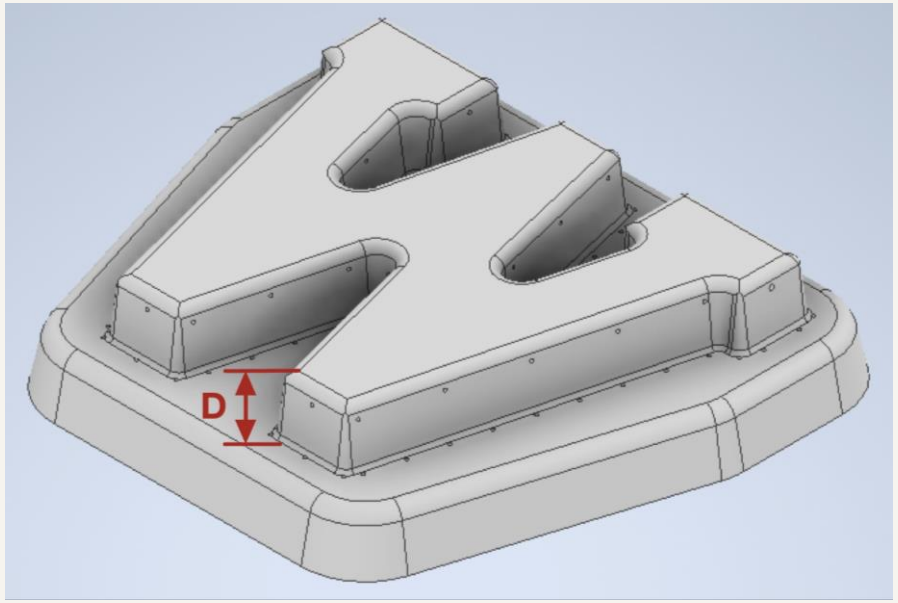
2nd Model – Not Enough Supports

Final Model

New Mold Design – Critical Dimensions



- Established the critical dimensions for the mold

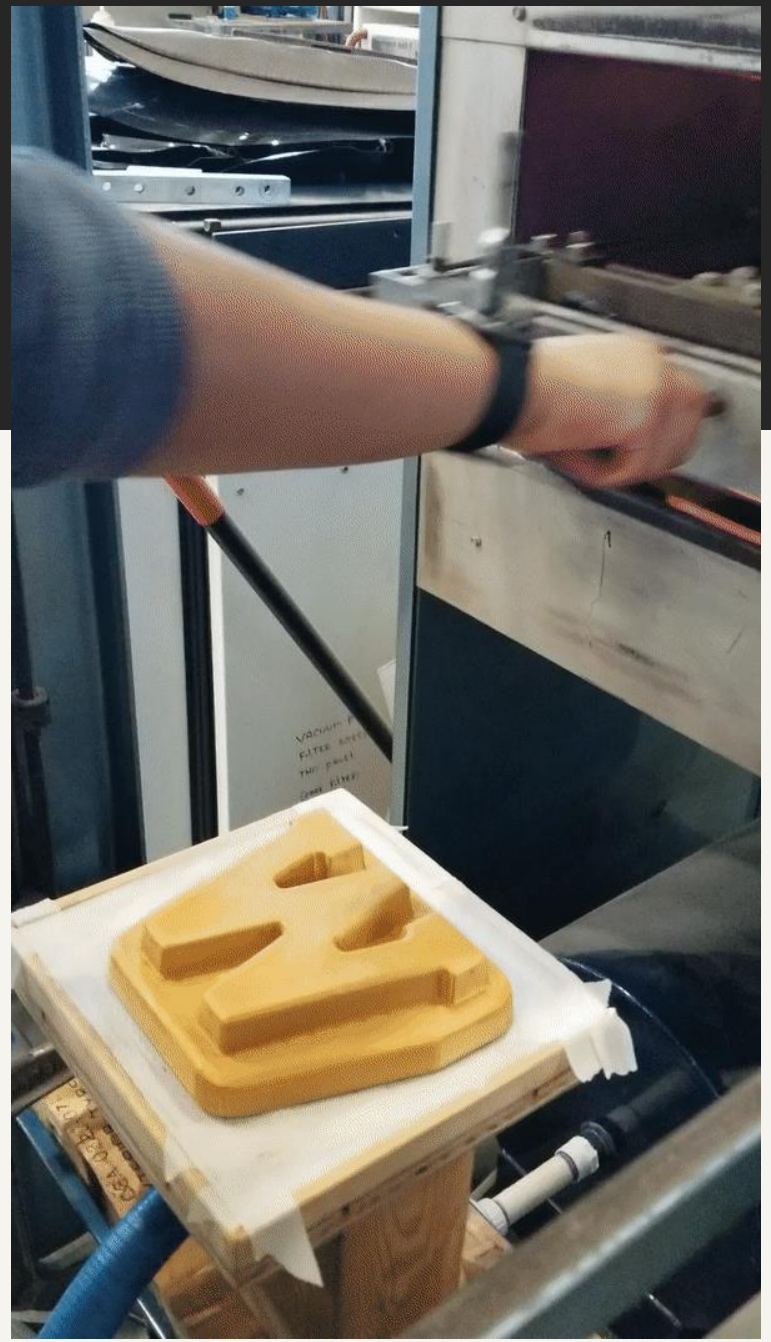


Critical Dimensions	
Level	Distance (in)
A	1.733
B	0.984
C	0.991
D	0.744

Testing

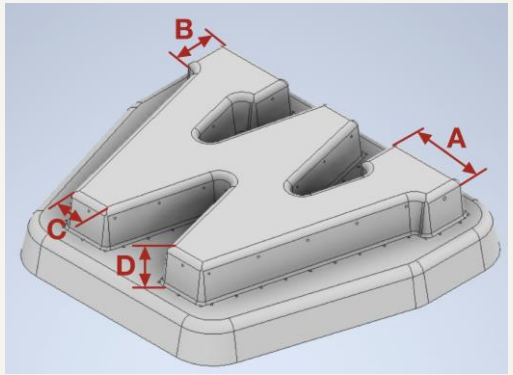
- Made 100 parts
- Cycle time for one part:
  - 5 minutes total
  - Including 2 minutes for cool time

Final Part



Data

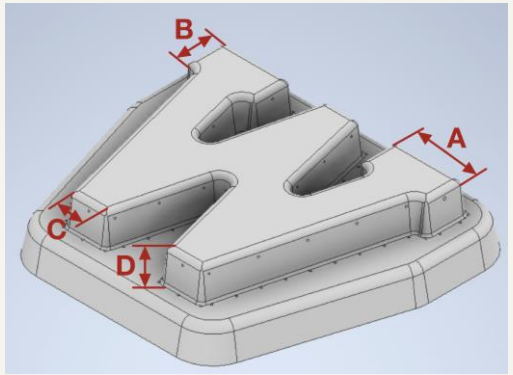
- Decline measured every 5 parts
- Baseline of 10% deterioration as mold failure
- Highest calculated deterioration is 4.45%

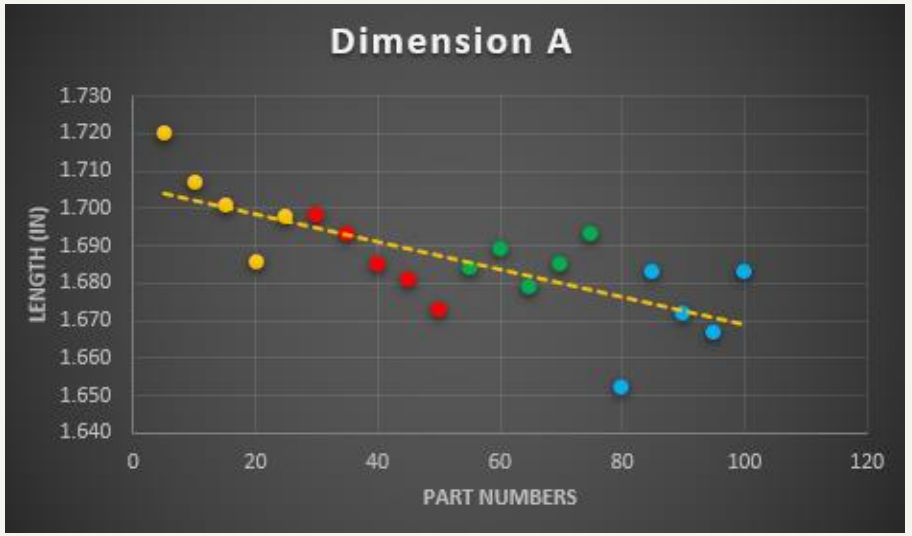


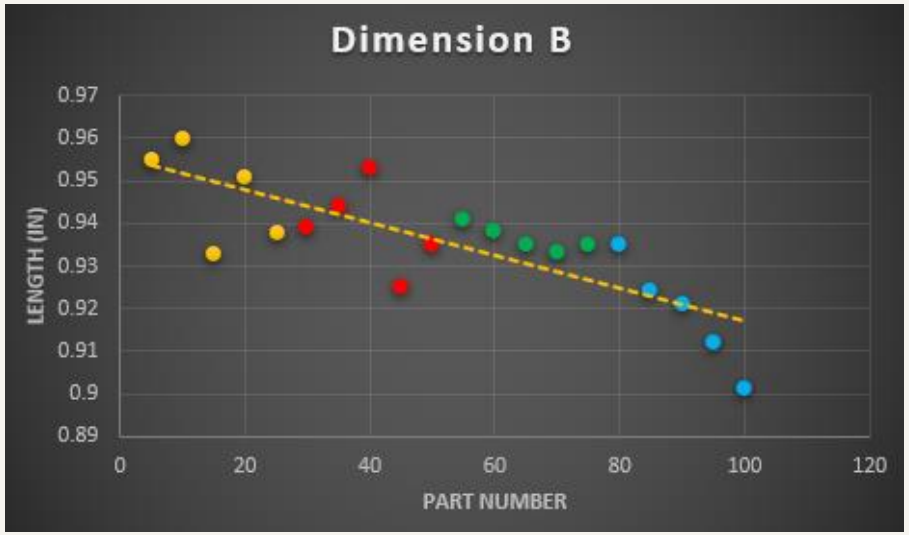
Part #	Heat %	Time (s)	Cool Time (m)	A (in)	B (in)	C (in)	D(in)
5	80	13	2	1.720	0.955	0.988	0.740
20	80	13	2	1.686	0.951	0.982	0.745
30	80	13	2	1.698	0.939	0.997	0.740
40	80	13	2	1.685	0.953	0.945	0.737
50	80	13	2	1.673	0.935	0.982	0.735
60	80	13	2	1.689	0.938	0.955	0.731
70	80	13	2	1.685	0.933	0.964	0.736
80	80	13	2	1.652	0.935	0.927	0.761
90	80	13	2	1.672	0.921	0.951	0.738
100	80	13	2	1.683	0.901	0.944	0.738
Total Deterioration:				3.95%	3.56%	4.45%	0.27%

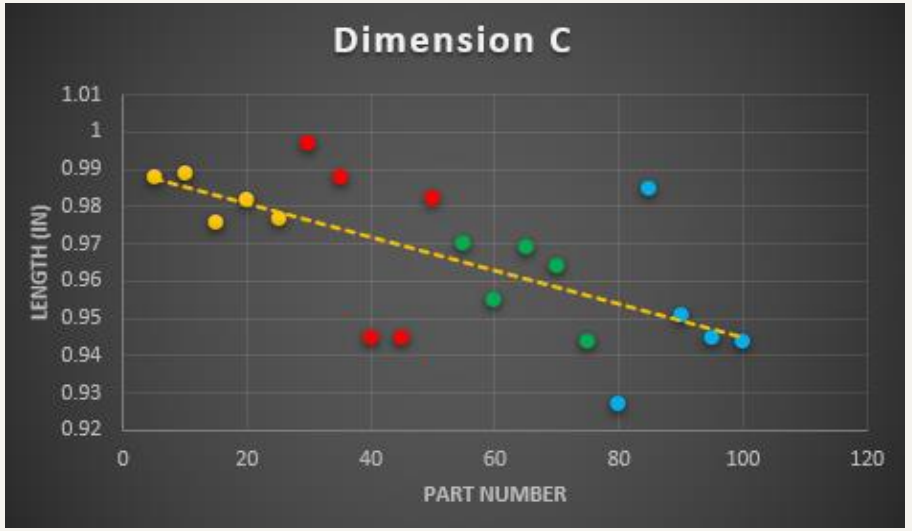
Data Trends

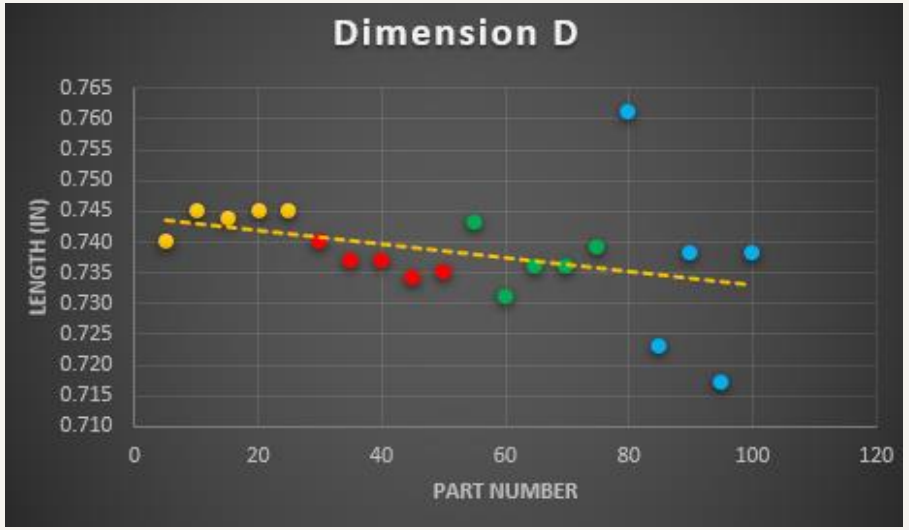
- General decline over the course of making parts











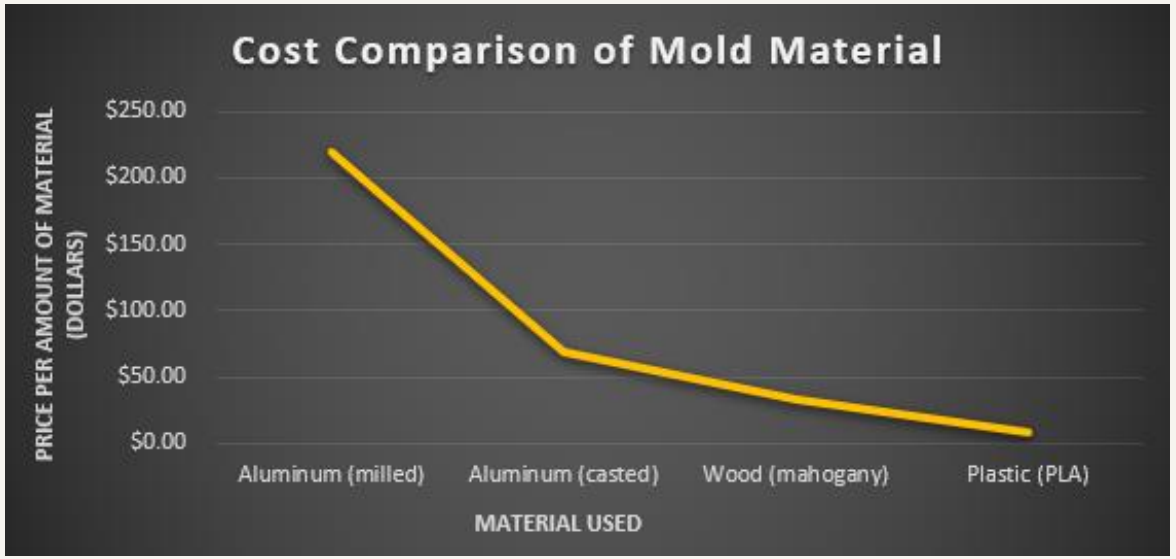
Mold Design – Time and Cost

- New Mold:
  - 2 days to 3D print
  - Used 312 grams of filament
  - Mold cost $7.80
  - Cost to manufacture = 13 cents

Mold Design – Time and Cost

Costs of Materials

- Aluminum
  - Cast = $69.64
  - Billet = $219.89
- Wood (Mahogany) = $32.99
- PLA = $7.80



%Decrease in Cost (Milled Al)	%Decrease in Cost (Casted Al)	% Decrease in Cost (Wood)
96.45%	88.80%	51.97%

Mold Design – Time and Cost

Mold Creation & Turnaround

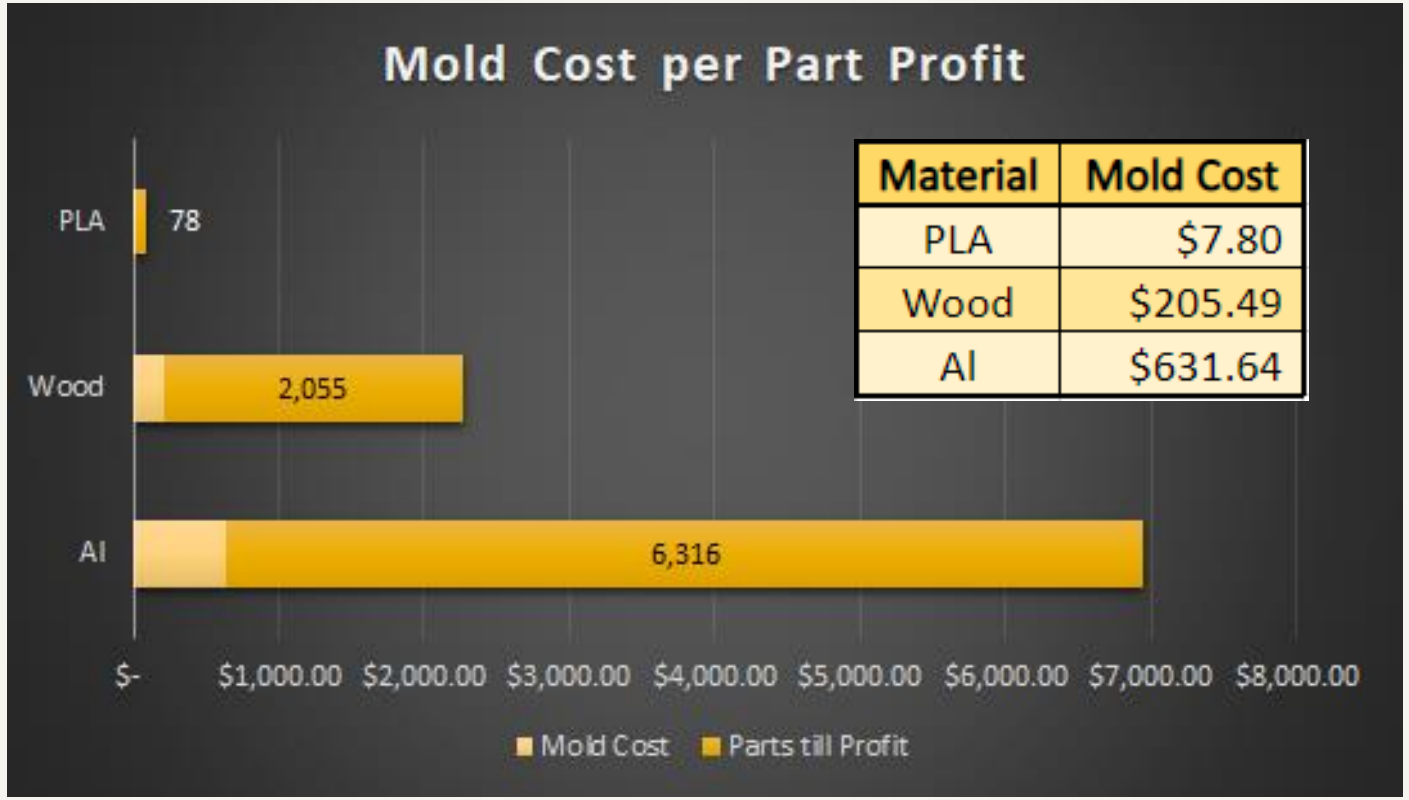
- Aluminum = 6 weeks (total)
  - Machine time = 2.81 hrs
  - Lead time = 1006 hrs
- Wood = 4 weeks (total)
  - Machine time = 2.3 hrs
  - Lead time= 670 hrs
- PLA = 43 hrs (total)

% Increase in Time (Al)	% Increase in Time (Wood)
93.47%	94.65%

Mold Design – Cost to Part Profit

Cost to Make Mold & Parts to Make Profit

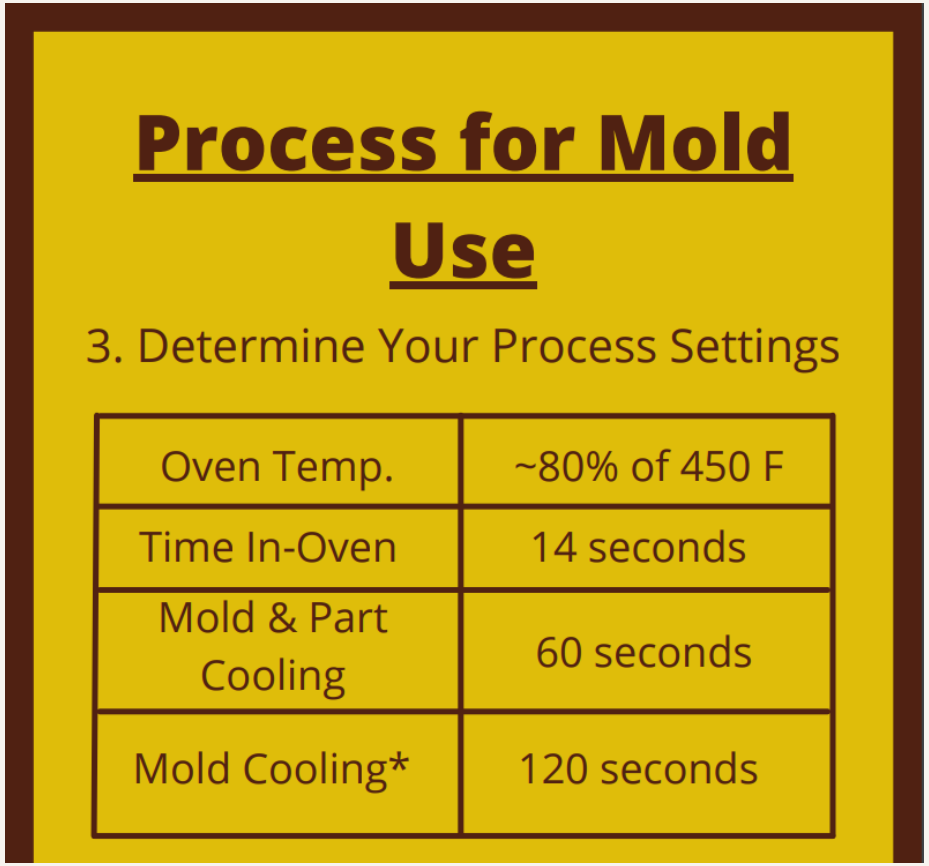
- Determined by machine time cost plus materials
- Follows known trends in industry



Material	Mold Cost
PLA	$7.80
Wood	$205.49
Al	$631.64

Process Documentation

- Describes process considerations
  - Tools & equipment used
  - Safety considerations
  - Process settings



Process for Mold Use

3. Determine Your Process Settings

Oven Temp.	~80% of 450 F
Time In-Oven	14 seconds
Mold & Part Cooling	60 seconds
Mold Cooling*	120 seconds

(Example section from book)

Project Conclusion

- Effective for runs of ≈200 parts
- Cost efficient for small runs of parts
- Use mold release for ease of separation
- Ensure proper mold design (effective supports, draft, etc.)

Mold Without Supports

Mold With Supports

Q & A