VeganEgg Scrambler

Frisky Whiskers

Neil Desai, Levi Downing, Siddharth Kurwa,
Evan McCall, Claire Puccini, Mallory Sico

30 April 2018

Agenda

- Introduction
  - VeganEgg
- Prototyping
  - Scrambling Assembly
  - Blender Assembly
  - Temperature Monitoring
  - Consistency Monitoring
  - User Interface
  - User Safety
- Simulation
  - Finite Element Analysis (FEA)
- Design of Experiment (DOE)
- Engineering Specifications

Primer on VeganEgg Scrambling

Add 2 tbsp VeganEgg powder to ½ cup cold water

Mix thoroughly

"Pancake batter" consistency

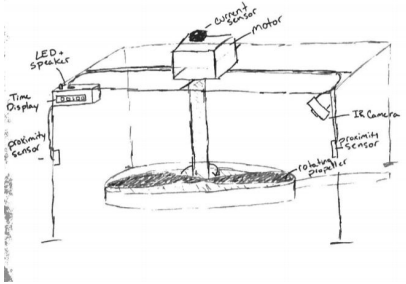
Scramble mixture like regular eggs

~ 6-7 minutes

Scrambled VeganEggs are ready to eat

Prototyping the Scrambler: Primary Task

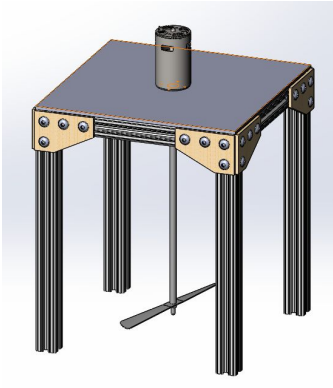
Original Concept



Insights:

- Need top plate to support/ insulate motor
- Use frame brackets to secure frame structure

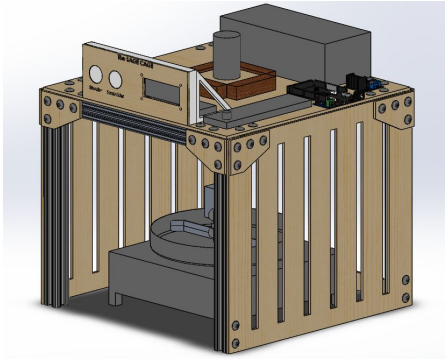
Embodiment of Concept



Insights:

- Need safety plates on sides
- Make more space on top plate for electrical hardware

Final Concept



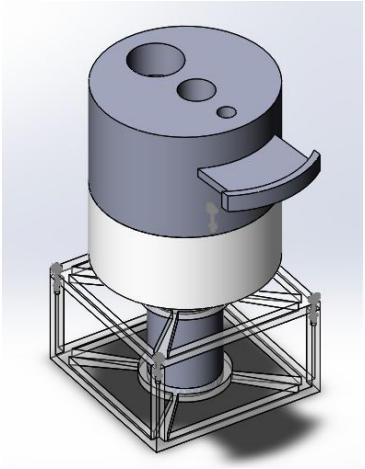
Insights:

- Provide safety from delinquent user actions
- Improved UI interface
- Secure electrical components

Prototype

Prototyping the Blender: Secondary task

Original Concept



Insights:

- Problematic vibration
- Difficult pouring
- Difficult cleaning
- Top heavy

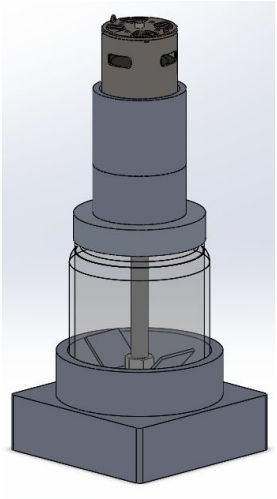
Simplification of Concept

http://www.instructables.com/id/Powerful-Homemade-Blendereasy-to-Make/

Insights:

- Provides ease of manufacturing
- Improve stability

Final Concept



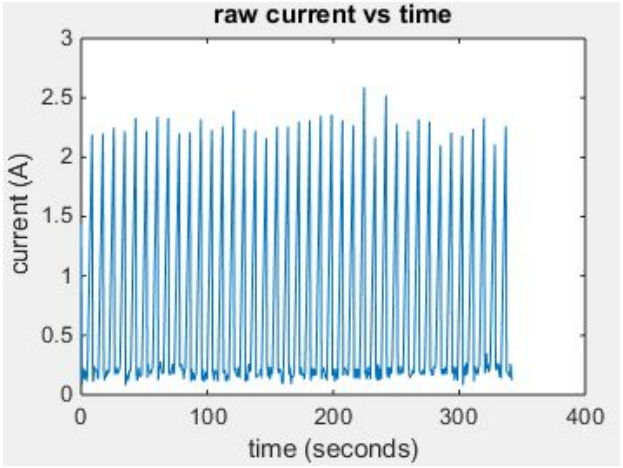
Insights:

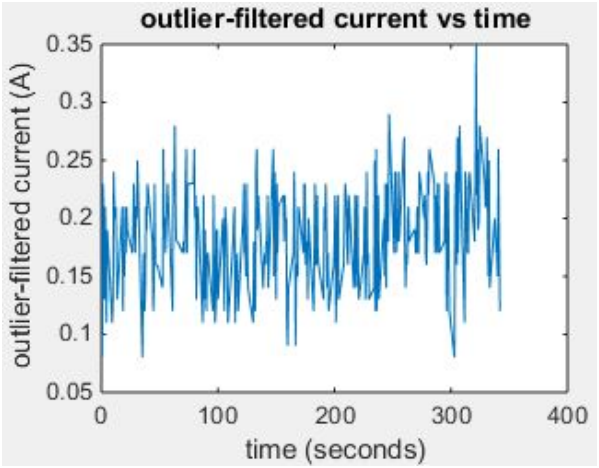
- Reinforce the base
- Solder motor connections

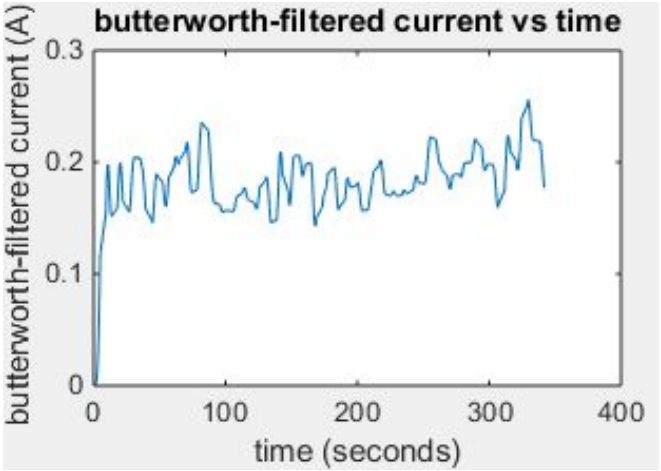
Prototype

Prototyping: Consistency Monitoring

- Hypothesize that egg consistency correlates to motor torque/current draw
- Correlation between consistency and current is difficult to detect in real-time even with signal processing







Prototyping: Consistency Model

- Recognized need for another factor to strengthen consistency model
  - Selected time because it has a positive correlation to egg consistency
- Made an expression for consistency with current and time-dependence
- Consistency must exceed threshold for 3 cycles to finish scramble

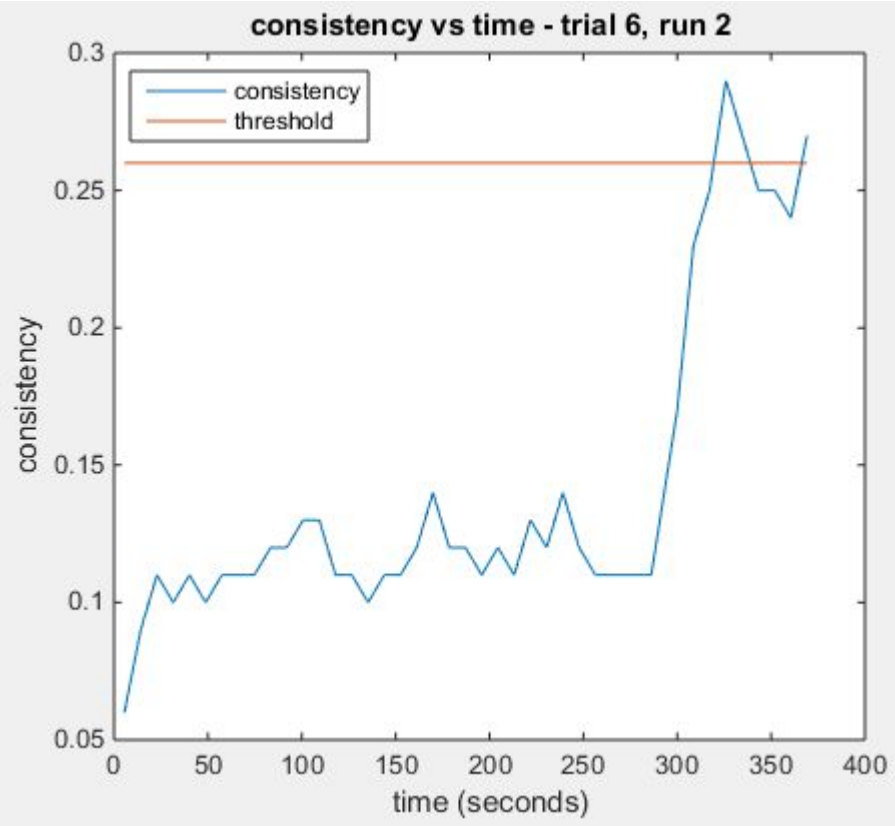
$$con_i = con_{i-1}(1 - W) + [min(\overrightarrow{cur_i})(1 - \frac{t_i - t_0}{300}) + max(\overrightarrow{cur_i})(\frac{t_i - t_0}{300})]W$$

$con = consistency$
$W = filter\ weight$
$cur = current$
$t_0 = initial\ time$

Time-weighted current

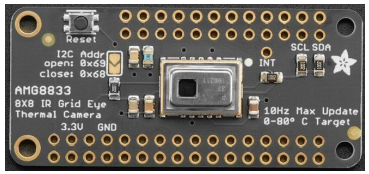
Recursive filtering

Prototyping: Consistency Monitoring Results

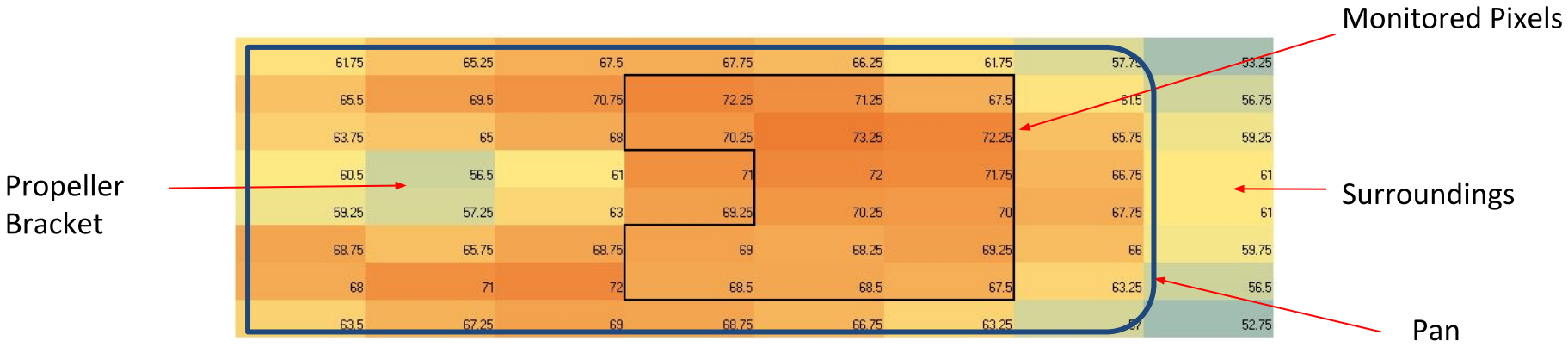


Prototyping: Temperature Monitoring

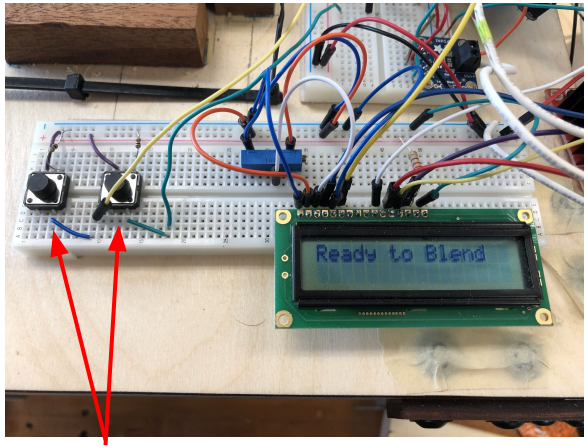
- Mean pixels that reach 66℃ (steady-state temperature): 12 pixels
  - Standard deviation: 5 pixels
- 7 pixels must hit steady-state temperature to complete scramble



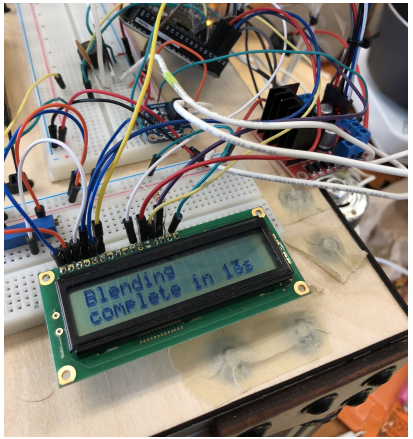
IR Camera
Sampling at 1.67 Hz



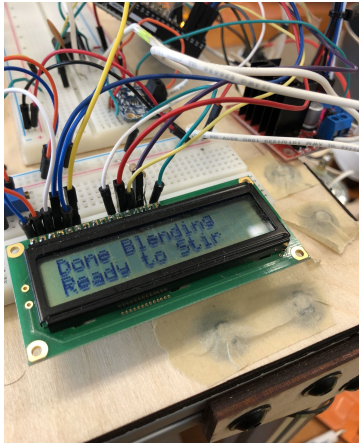
Prototyping: User Interface

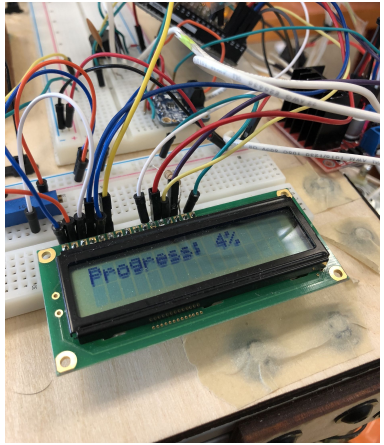


Control buttons for easy navigation between steps



Procedure updates throughout egg cooking progress

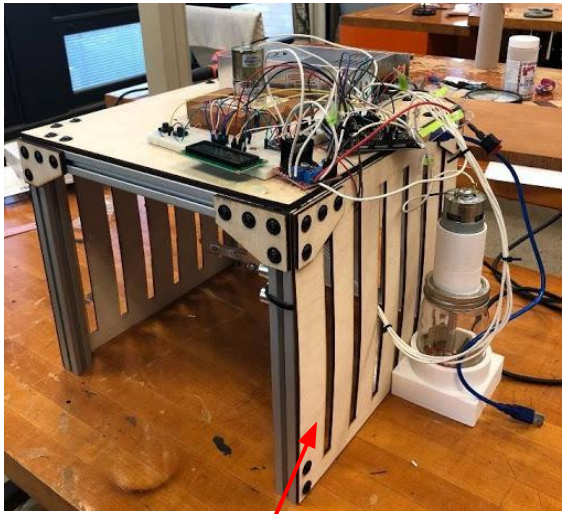




Percent progress updates

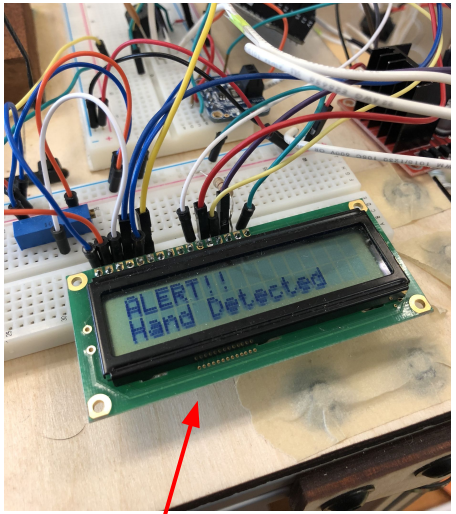
The final prototype will incorporate a front panel

Prototyping: User Safety



4-sided enclosure reduces risk of user interference; slots allow for ventilation

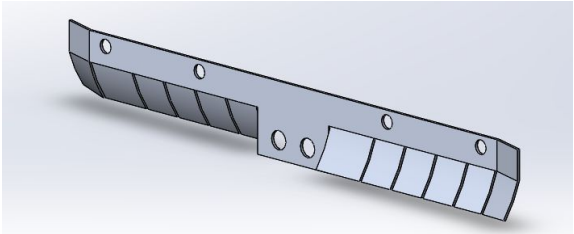
Proximity sensor for hand detection; sends signal to stop motor



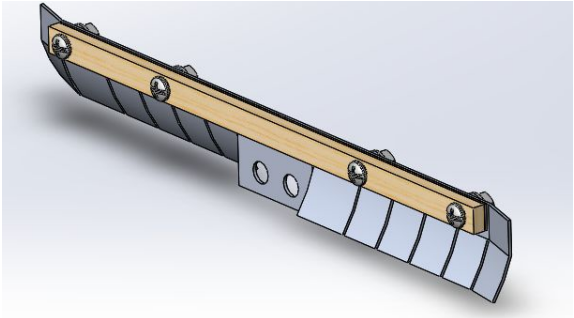
"ALERT!! Hand Detected"

Computational Modeling: Simulation

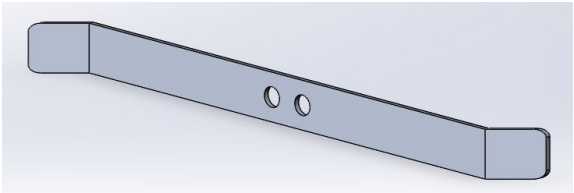
- Boundary Conditions
  - Fixed at center
  - Free at ends
- 3 Propellers
  - 20 Gauge
  - 20 Gauge - Reinforced
  - 16 Gauge
- 2 Loading Cases
  - Egg loading along propeller
  - Pan collision (off-nominal case)



20 Gauge

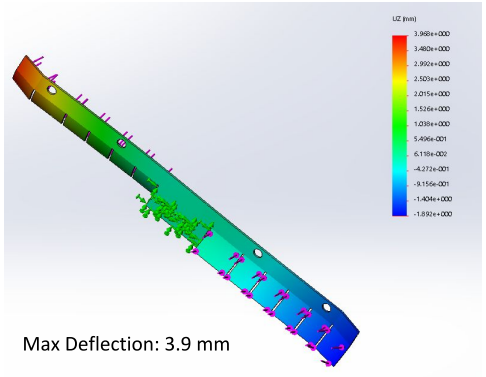
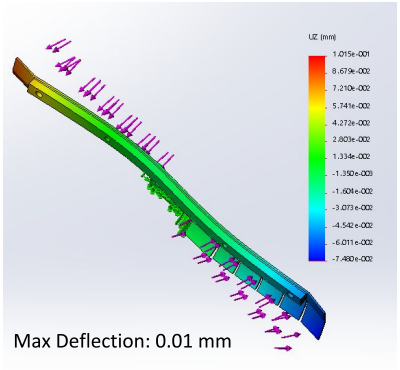
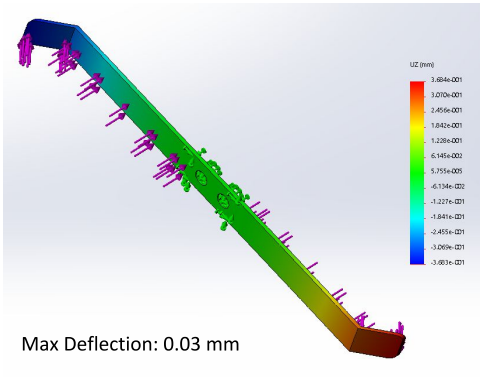
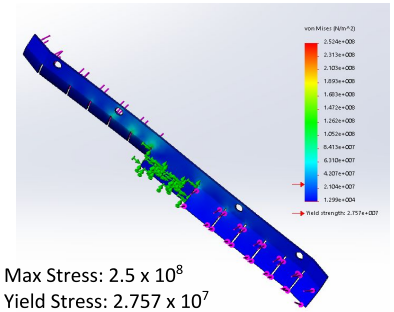
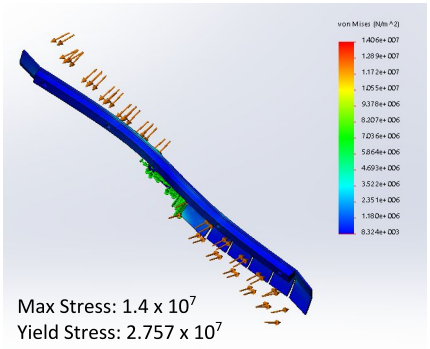
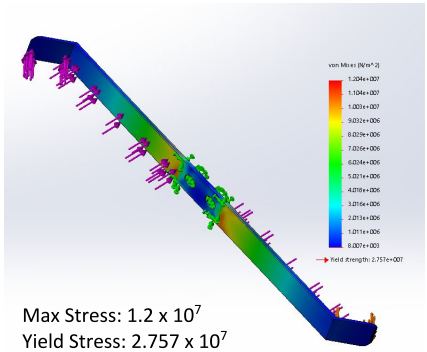


20 Gauge - Reinforced

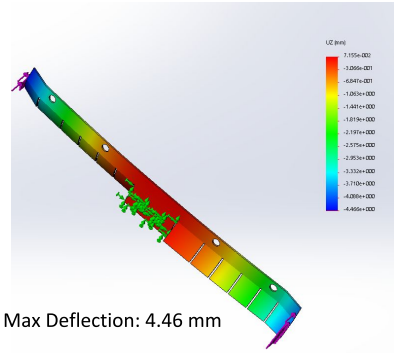
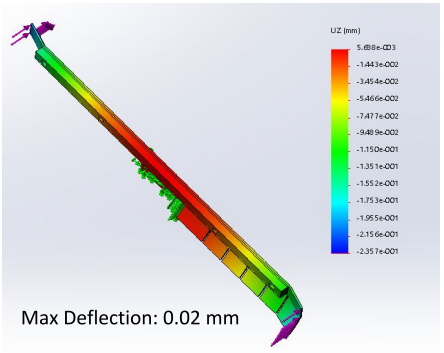
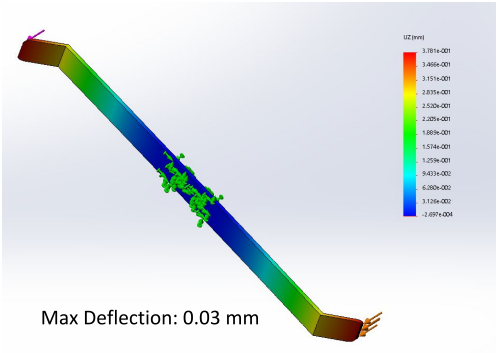
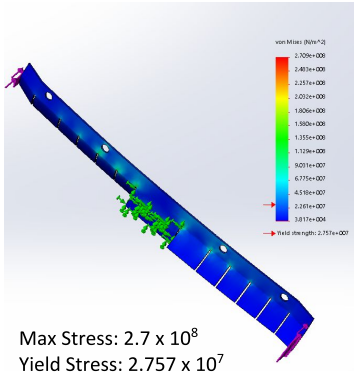
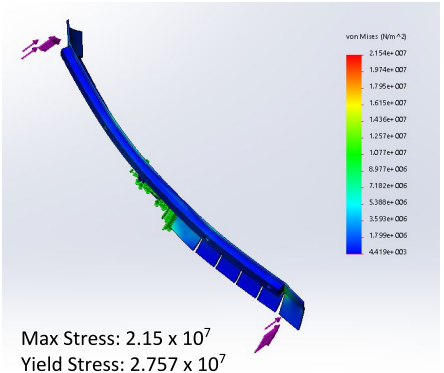
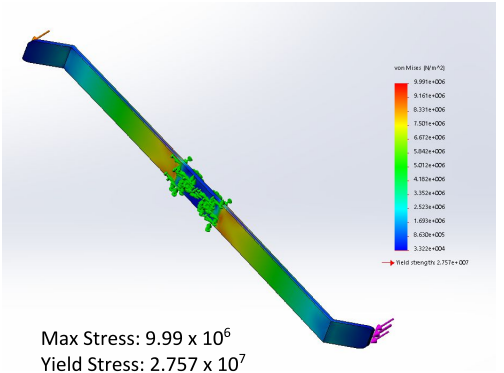


16 Gauge

Simulation: Egg Loading Along Propeller

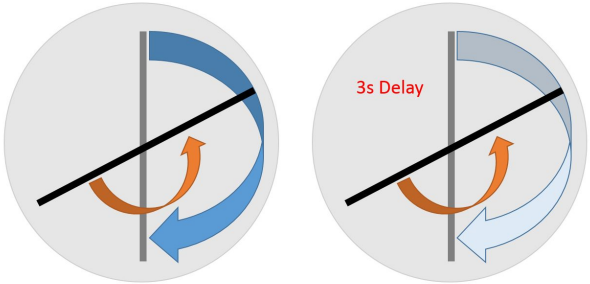
	20 Gauge Propeller	20 Gauge Propeller - Reinforced	16 Gauge Propeller
Displacement	 Max Deflection: 3.9 mm	 Max Deflection: 0.01 mm	 Max Deflection: 0.03 mm
Stress	 Max Stress: 2.5×10^8 Yield Stress: 2.757×10^7	 Max Stress: 1.4×10^7 Yield Stress: 2.757×10^7	 Max Stress: 1.2×10^7 Yield Stress: 2.757×10^7

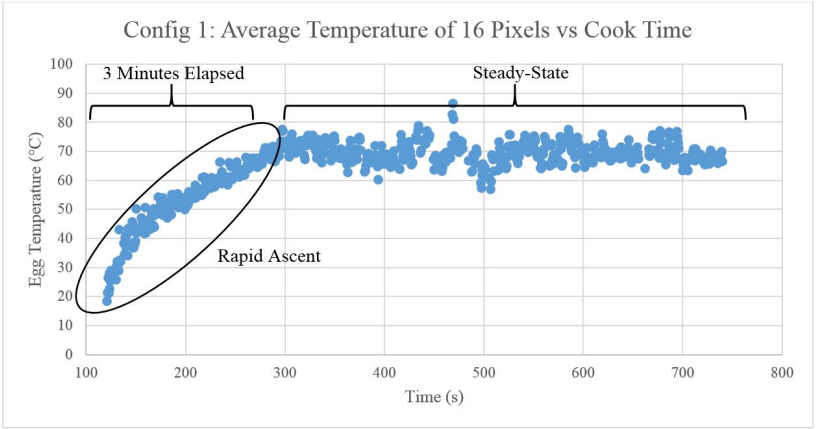
Simulation: Propeller Pan Collision

	20 Gauge Propeller	20 Gauge Propeller - Reinforced	16 Gauge Propeller
Displacement	 Max Deflection: 4.46 mm	 Max Deflection: 0.02 mm	 Max Deflection: 0.03 mm
Stress	 Max Stress: 2.7×10^8 Yield Stress: 2.757×10^7	 Max Stress: 2.15×10^7 Yield Stress: 2.757×10^7	 Max Stress: 9.99×10^6 Yield Stress: 2.757×10^7

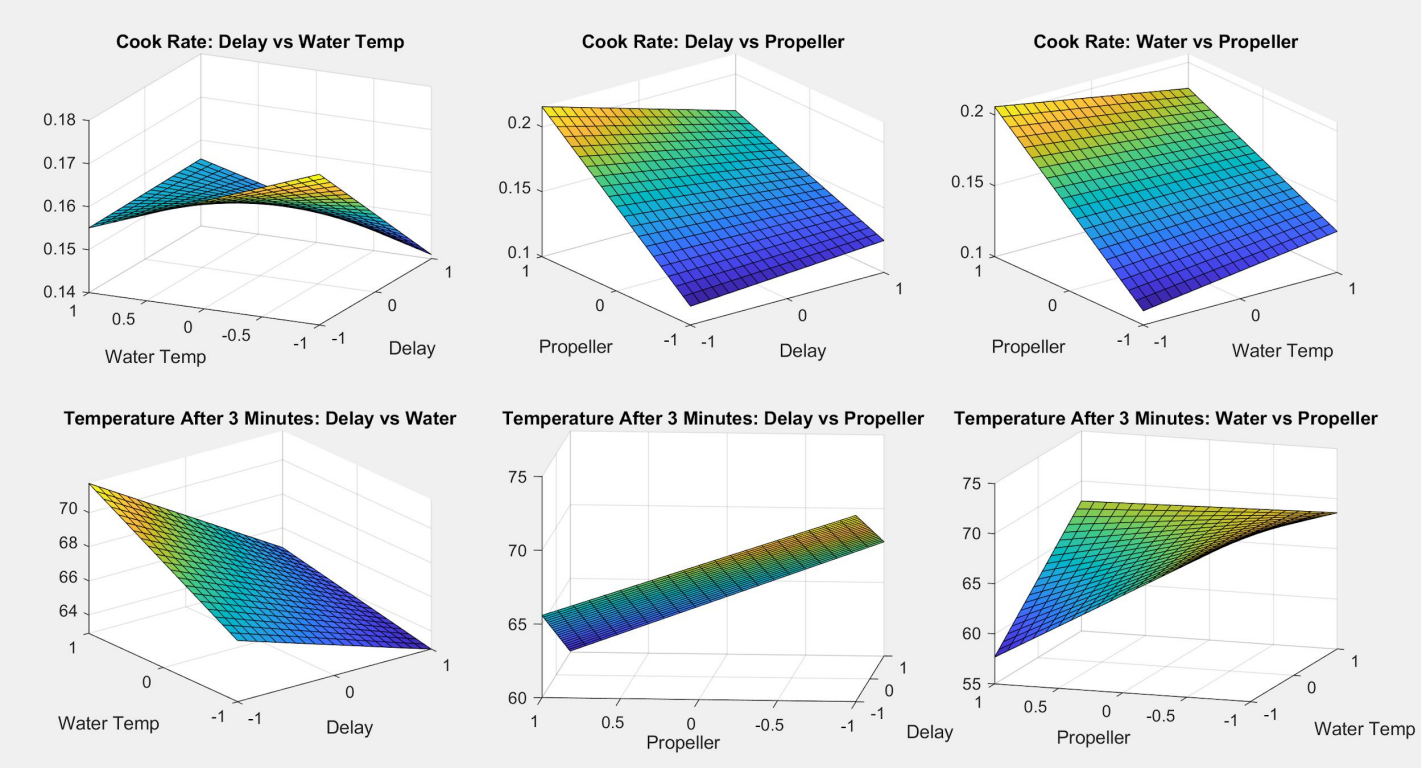
Physical Experimentation: DOE Factors and Responses

- Factors:
  - Propeller Shape
  - Propeller Motion
  - Initial Water Temperature
- Responses:
  - Cook rate (g/s)
  - Temperature after 3 minutes (°C)





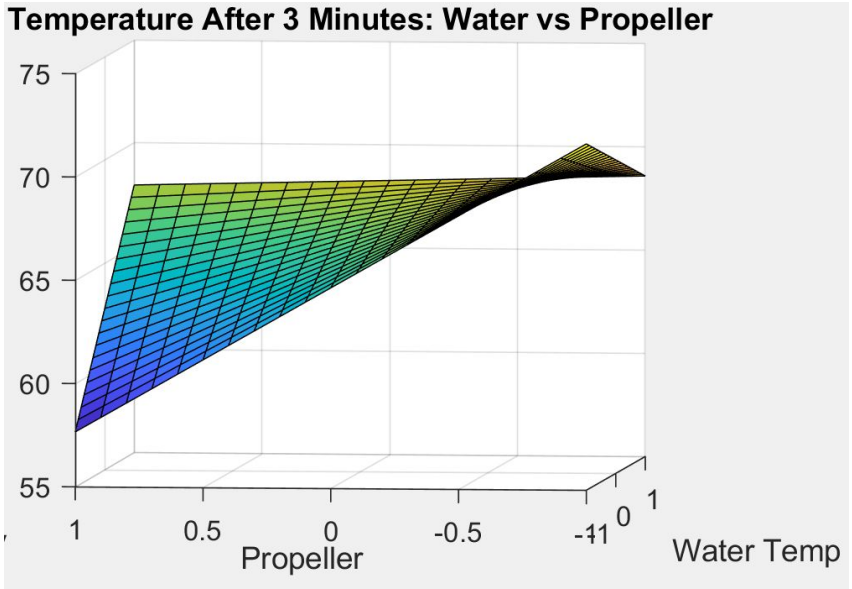
Physical Experimentation: DOE Statistical Analysis



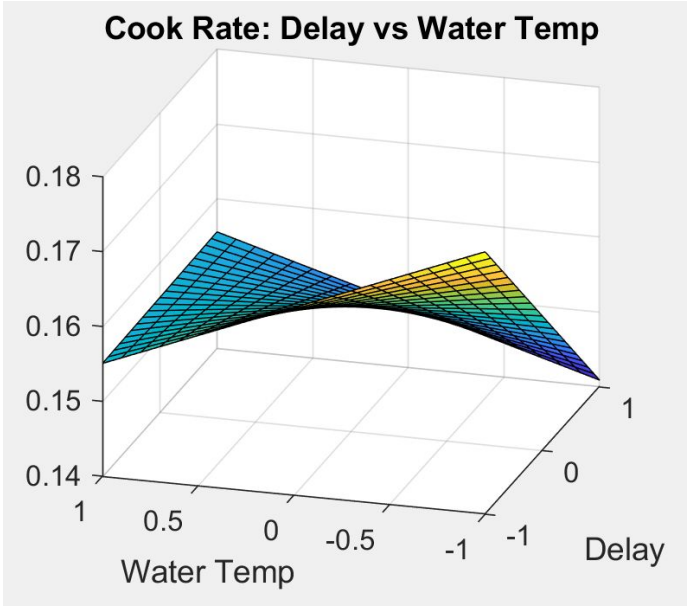
Physical Experimentation: DOE Insights

- Prioritize Temperature After 3 Minutes to make Propeller decision
- Prioritize Cook Rate to make Delay and Water Temperature decision

Flat Propeller



No Delay & Cold Water



Engineering Specifications

	Specification	Met Specification?		Nominal Performance
1	Preparation time < 100 seconds		✓	• 75 seconds (30 seconds mix + 45 seconds egg transfer)
2	Scrambling time < 500 seconds		✓	• 300 - 500 seconds
3	Total time < 600 seconds		✓	• 375 - 575 seconds
4	Total time of user intervention < 300 seconds		✓	• 45 seconds
5	Number of user intervention steps <= 5		✓	• 5 steps (measure ingredients, push mix button, oil pan, egg transfer, push scramble button)

Engineering Specifications

Specification		Met Specification?		Nominal Performance
6	Number of safety features > 2		✓	• 3 features (enclosure, proximity sensor, E-stop)
7	Response Percentage = 90%		✓	• Visual and auditory stimulus
8	Minimum design safety factor to yield > 2		✓	• 2.3
9	Sodium intake < 400 mg		✓	• 150 mg
10	Stirring power input < 5 Watts		✓	• 1.2 - 4.8 Watts

Engineering Specifications

	Specification	Met Specification?		Nominal Performance
11	Cooked egg temperature=~70 °C		✓	• 66 °C
12	Pan coverage area = ~85%		✓	• 96.69% (7.375 propeller diameter, 7.5 pan diameter)
13	Weight < 5 lbs	✗		• 13.5 lbs (prototype weight)
14	Cost < $300		✓	• $288.78
15	System height < 18 inches		✓	• 16 inches

Questions?

Presenters:

- Neil Desai
- Levi Downing
- Siddharth Kurwa
- Evan McCall
- Claire Puccini
- Mallory Sico

Appendix

- Validating Factor Choices for DOE
- DOE Statistical Confidence
- Adjustable Motor Height
- Electronics
- Propeller Design
- Demonstrating Time and Current Dependence
- Simulation Propeller Fixed-End Boundary Conditions

Physical Experimentation: Validating Factor Choices

Drag Applied to Propeller

- Working assumption: Submerged body
- Curved blades = 0.16 N
- Flat blades = 0.33 N

$$\mathcal{D}_f = \tfrac{1}{2}\rho U^2 b \ell C_{Df}$$

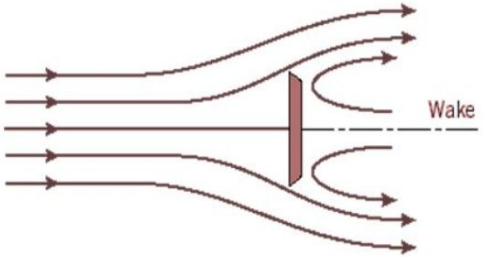
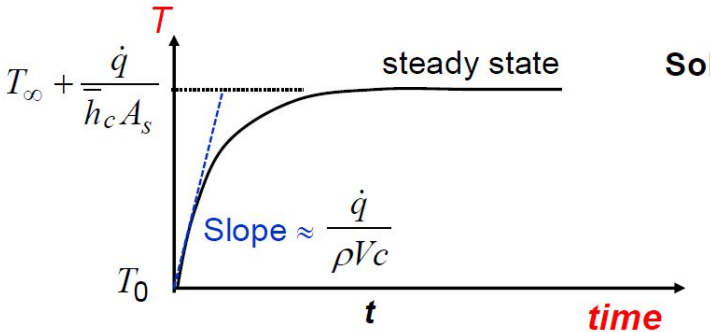


Fig. 9.9 Flow over a flat plate normal to the flow.

Temperature at 3 minutes

- Working assumption: Lumped capacitance
- 4℃ reaches 86.4℃
- 29.4℃ reaches 112.2℃



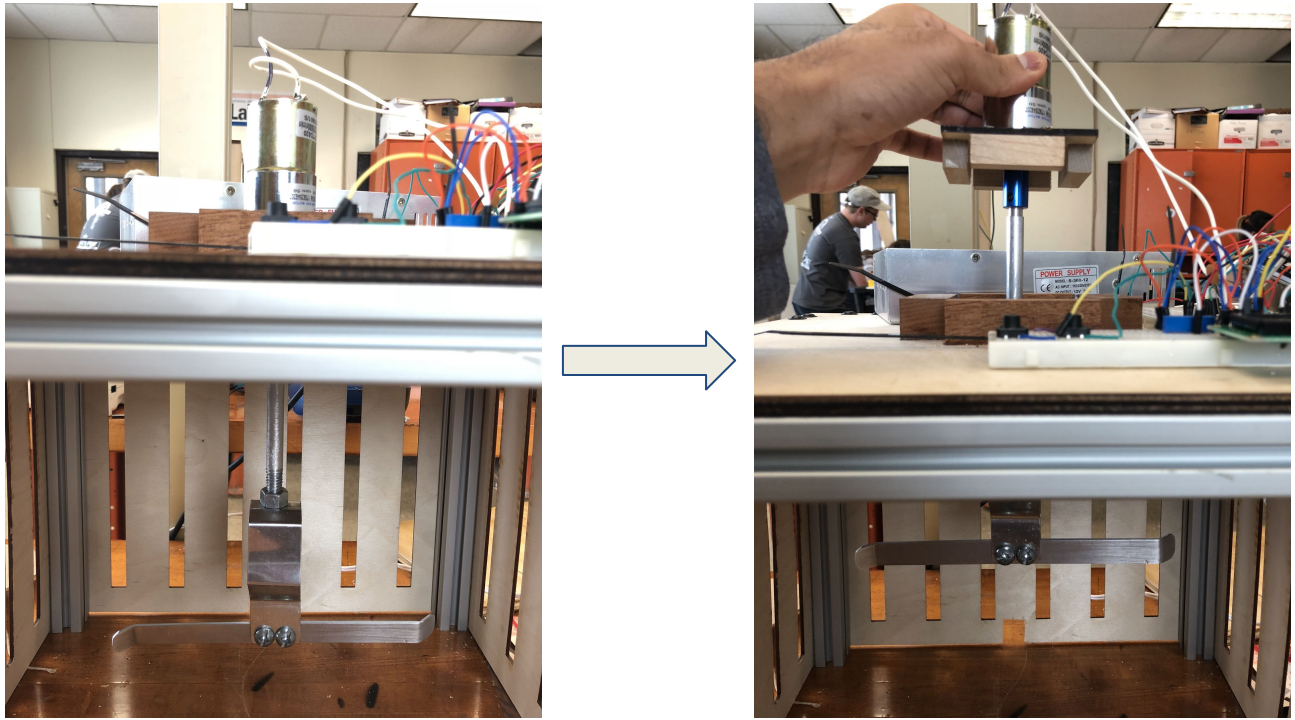
Solution:

$$T(t) \approx T_0 + \frac{\dot{q}}{\rho V c} t$$

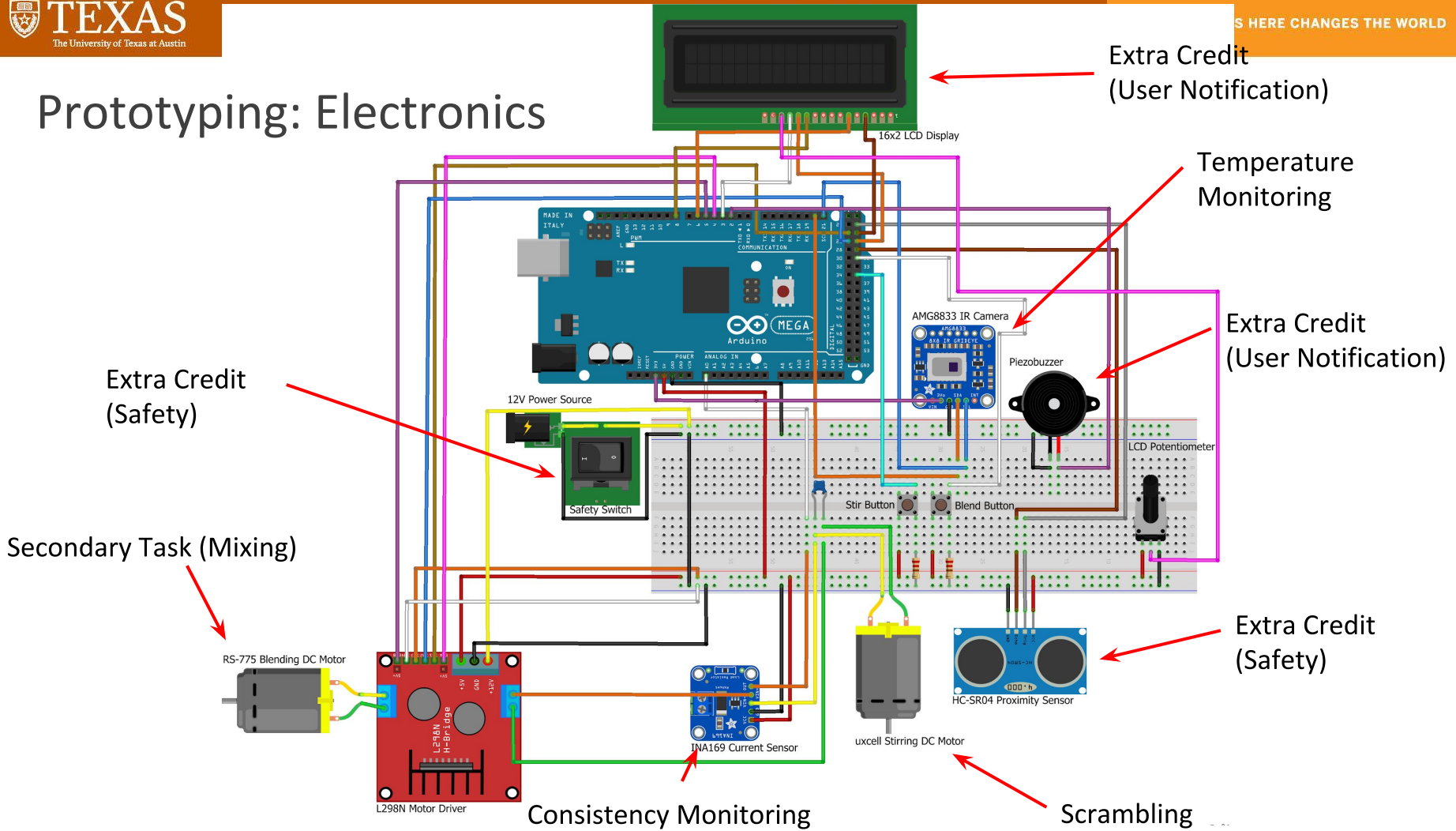
Physical Experimentation: Confidence

- Cook rate (g/s)
  - S.E. = 0.005
  - Delay v Water: $0.157 - 0.008x_1 - 0.001x_2 + 0.009x_1x_2$
  - Delay v Propeller: $0.157 - 0.008x_1 + 0.037x_3 - 0.013x_1x_3$
  - Water v Propeller: $0.157 - 0.001x_2 + 0.037x_3 - 0.011x_2x_3$
- Temperature at 3 minutes
  - S.E. = 1.462
  - Delay v Water: $66.505 - 2.608x_1 + 1.780x_2 - 0.814x_1x_2$
  - Delay v Propeller: $66.505 - 2.608x_1 - 3.689x_3 - 0.158x_1x_3$
  - Water v Propeller: $66.505 + 1.778x_2 - 3.689x_3 + 3.376x_2x_3$

Adjustable Motor Height

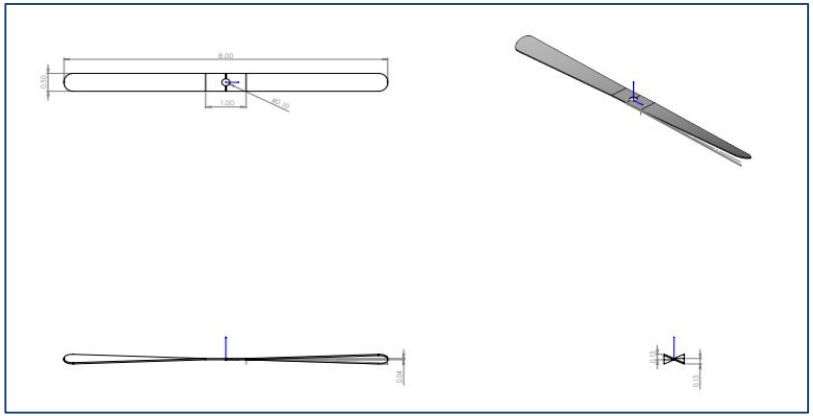


Prototyping: Electronics



Propeller Design

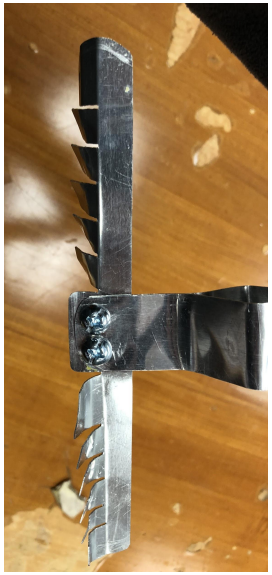
Original Concept



Insights:

- Middle of Pan Untouched

Prototype 1

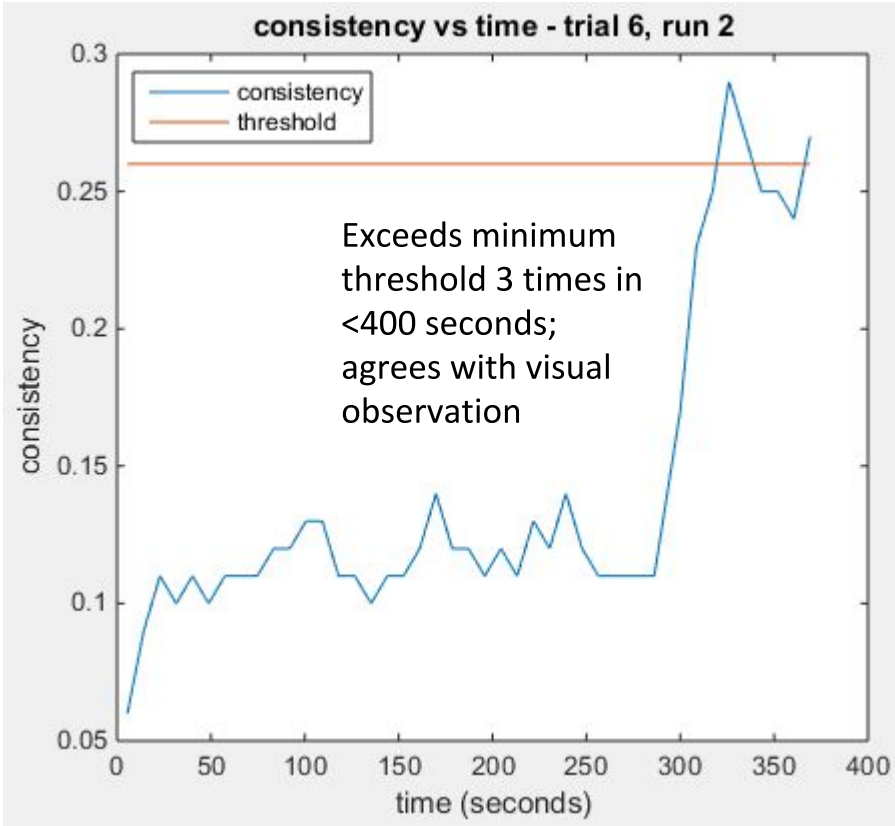


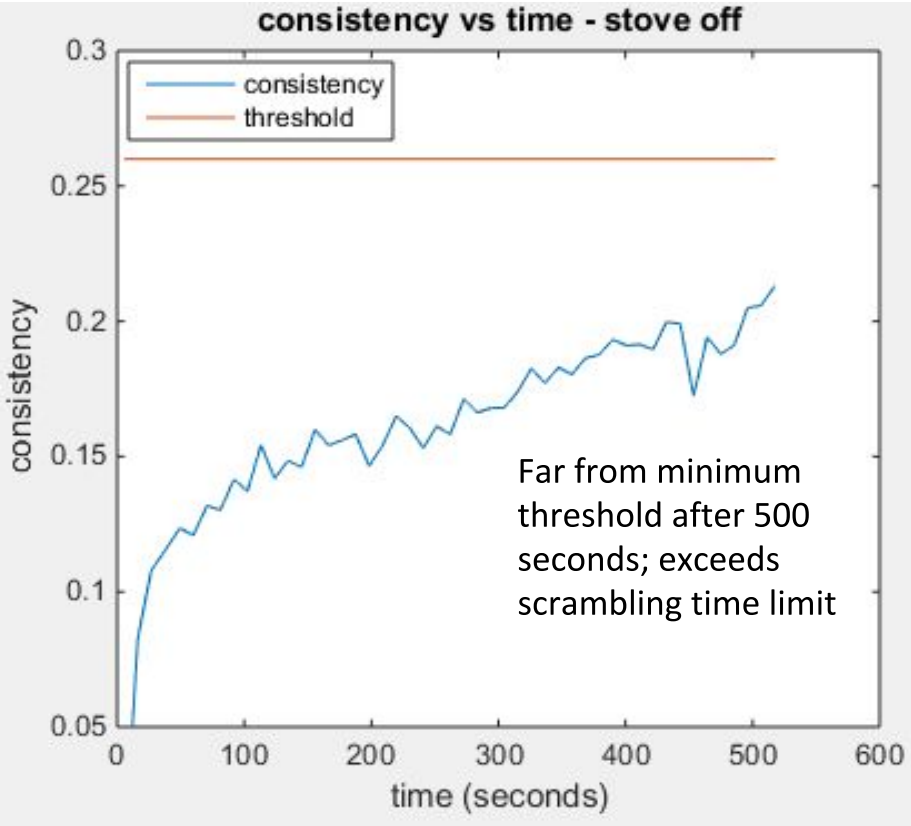
Insights:

- Difficulty Cleaning
- Difficult to Manufacture
- Eggs Pushed to Outer Wall
- Plastic Deformation of Propeller

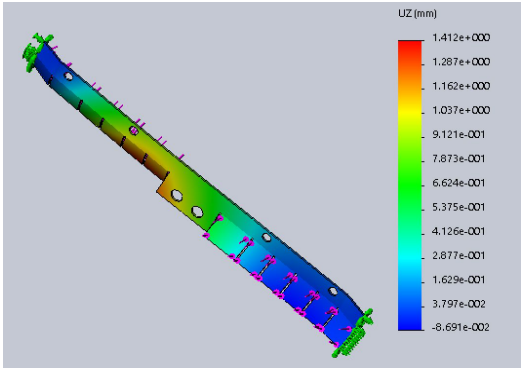
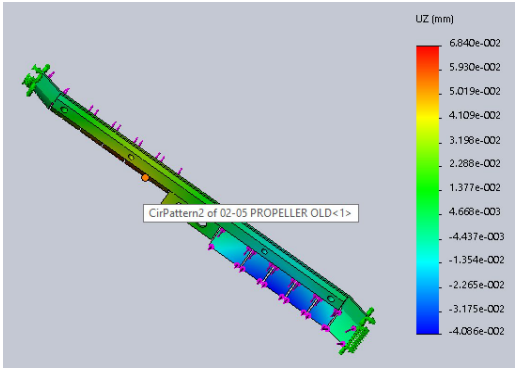
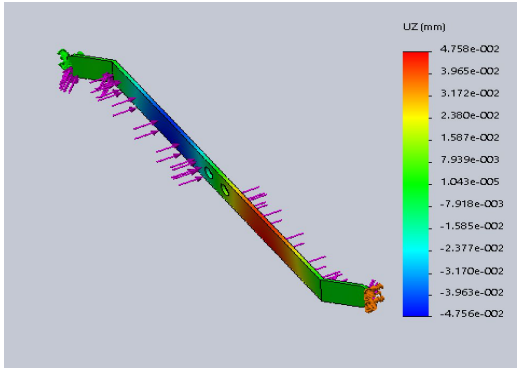
Prototype 2

Prototyping: Demonstrating Time and Current Dependence





Simulation: Fixed Ends Boundary Condition

	20 Gauge Propeller	20 Gauge Propeller - Reinforced	16 Gauge Propeller
Displacement			
Stress