# Windmill

Utah Valley University Capstone 2
4/22/22

Presented by the Airbenders:

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# Overview

- The goal of the 2021-2022 Windmill Capstone is to do a mock run of the Collegiate Windmill Competition (CWC).
- The purpose of this competition is to build a functioning model wind turbine that adheres to competition standards.

# Problem Definition

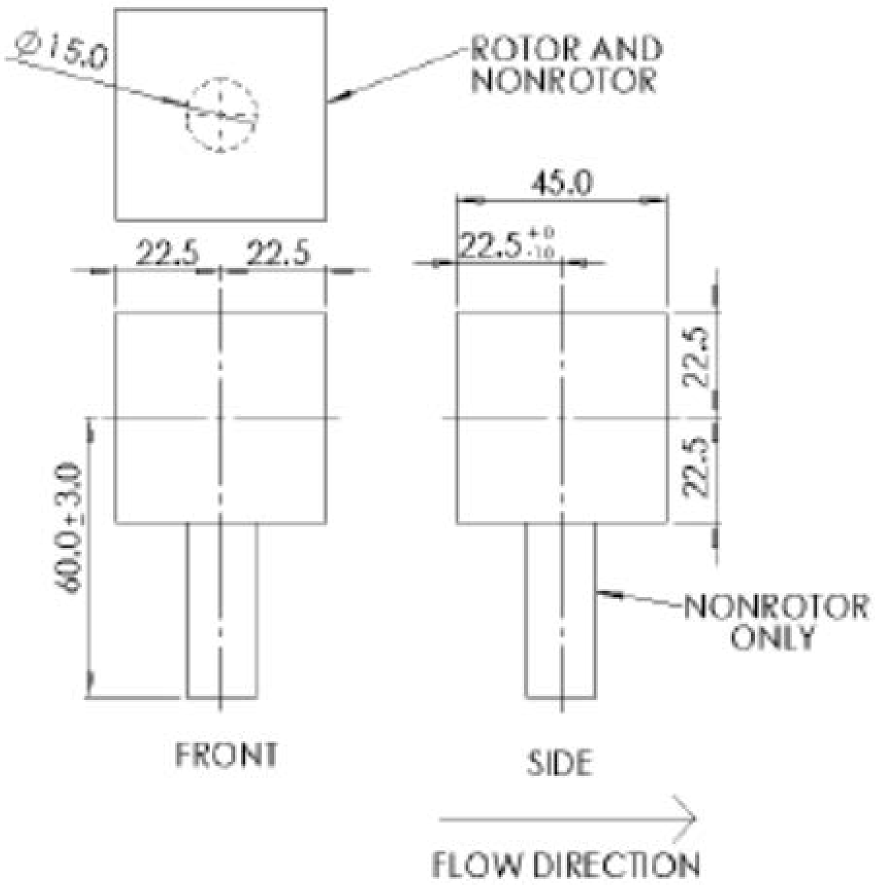
- Identify customer needs
- Derive design requirements
- Research existing documentation

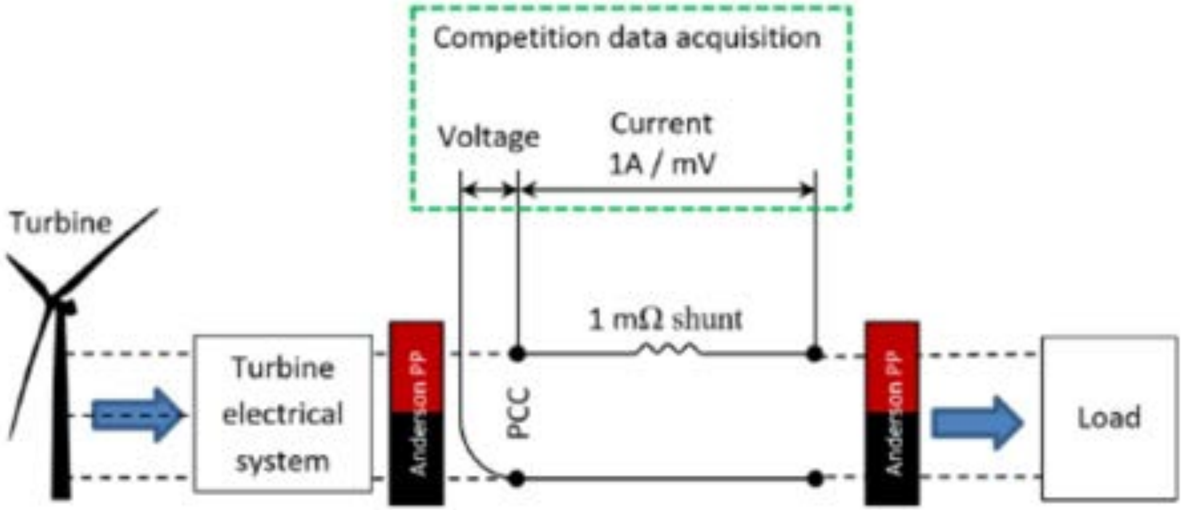
# Customer Needs/Design Requirements

| 3.1 | Built to withstand air speed of 22 m/s(no testing will be done above 13 m/s) |
|---|---|
| 3.1.1.1 | Rotor and non-rotor parts must be contained in a 45cm cube. This cube may be shifted as much as 10cm aft of the yaw table centerline when the turbine is aligned with the flow |
| 3.1.1.2 | A 15cm diameter cylinder centered on the mounting flange extending from the tunnel floor to the bottom of the cube can contain only non-rotor turbine parts. For this purpose, non-rotor turbine parts will be defined as anything that does not capture energy from the moving air, including the mounting flange. |
| 3.1.1.3 | All turbines must fit through the turbine door (61cm by 122cm) in one assembly with no additional assembly occurring inside the tunnel other than attachment to the base flange and connection to external electrical components. Electrical connections should not be made in the nacelle during installation. |

| Rotor and non-rotor parts must be contained in a 45cm cube. This cube may be shifted as much as 10cm aft of the yaw table centerline when the turbine is aligned with the flow | The turbine is small and fits in a 45 x 45 x 45 cm cube. |
|---|---|
| Voltage must be DC at the PCC and is required to be at, or below 48V at all times. | The output voltage of the Windmill at the testing station is less than or equal to 48V and is DC. |
| No batteries of any type or caps. Or combinations of caps.<br>With nameplate voltage and capacitance ratings corresponding to over 10 J of energy will be permitted. | The Windmill has batteries, capacitors, or combinations of them not exceeding 10J of energy. |

# Defining Specifications



# Research

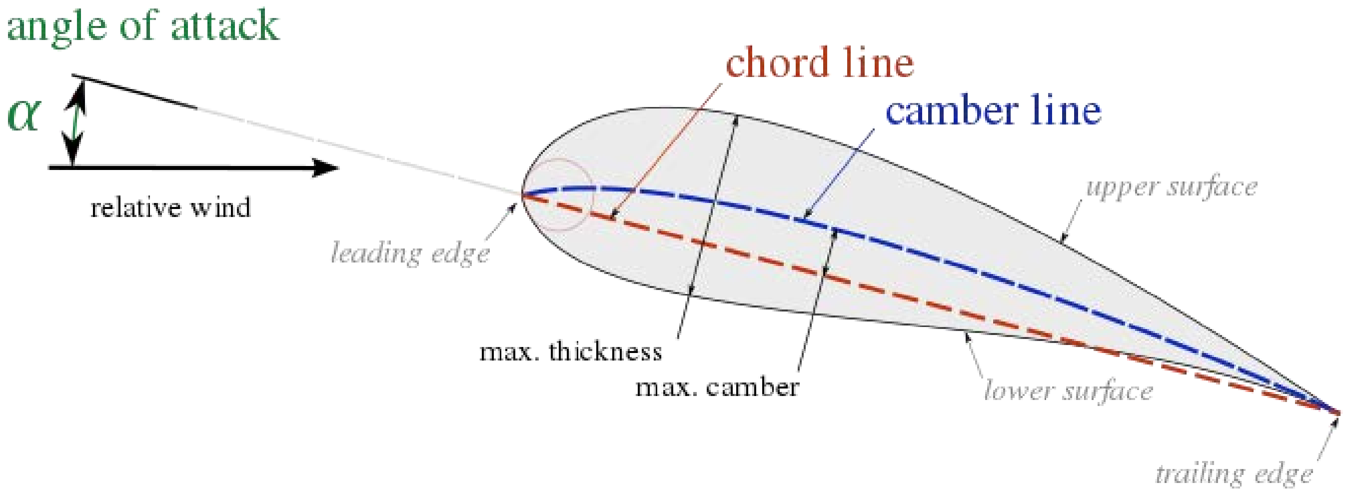
The team read from several scholarly articles.

Reviewed competition winning designs from past years.

Worked **with** BYU's team and some industry professionals

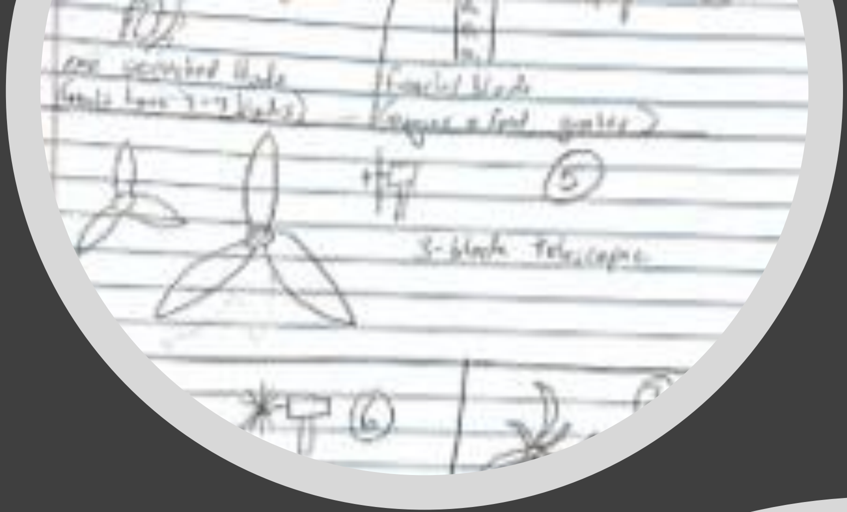
# Completed Research

- Articles were considered from organizations like NACA, NASA, and universities like Stanford.
- Points of interest:
  - Airfoil
  - Angle of attack
  - Ideal number of blades
  - Lift vs. Drag




- Lift style turbines are more commonly used in large scale industrial wind farms and utilize long, narrow blades

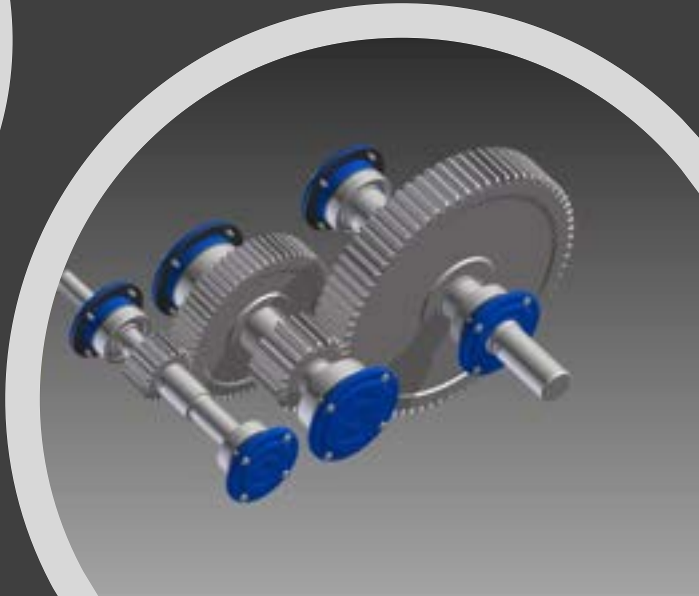
- Drag style turbines feature wider blades and are mainly used for small scale energy production



# Concept generation and selection

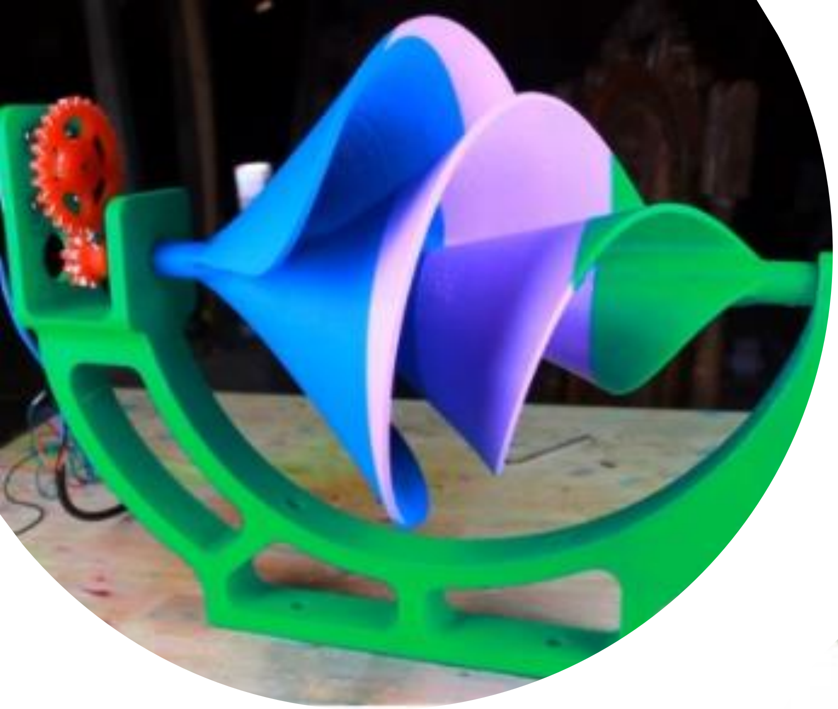
# Concept Generation: Nacelle

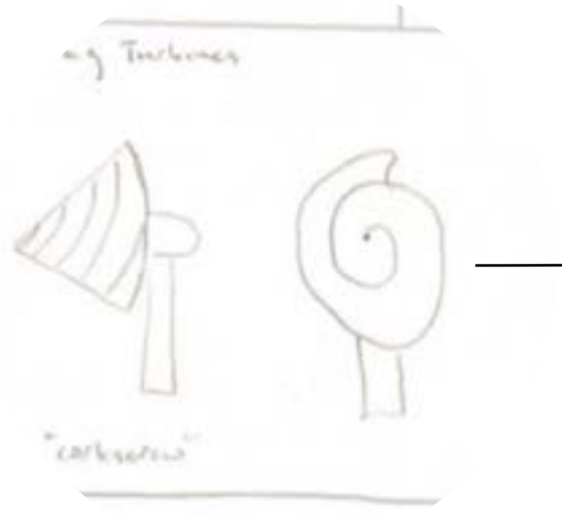
- CVT (Continuous Variable Transmission)
- CVP (Continuous Variable Planetary)
- Making a gearbox

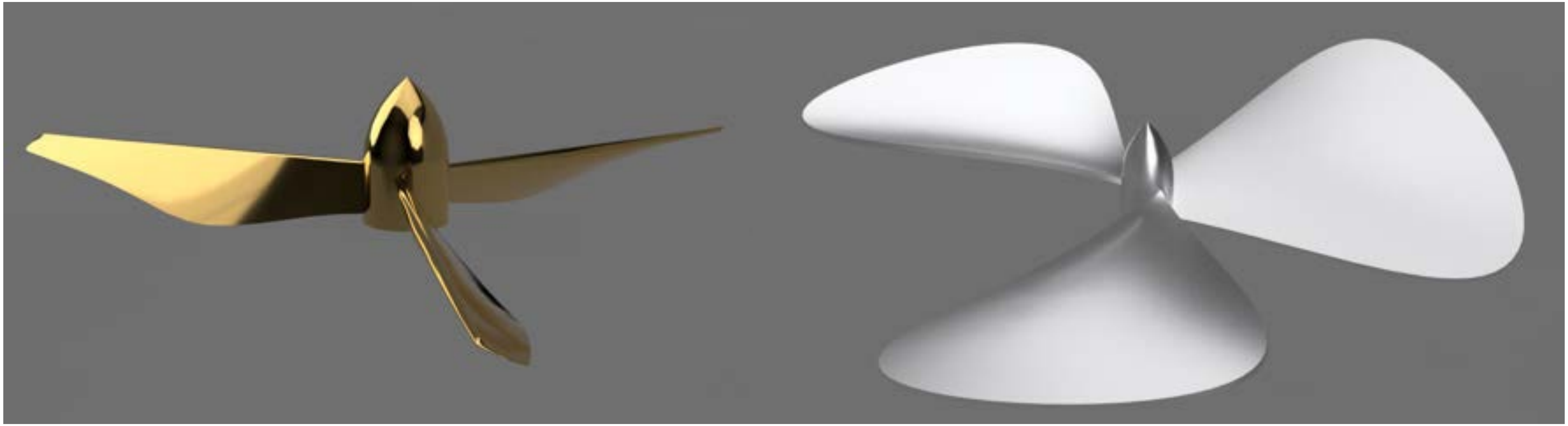
# Concept Generation | Blades

- Over 70 different concepts were explored
- Many proposed concepts had similar features such as number of blades, shape, blade size etc.
- Used morph charts to consolidate the designs for testing
- Each design represented a certain morph

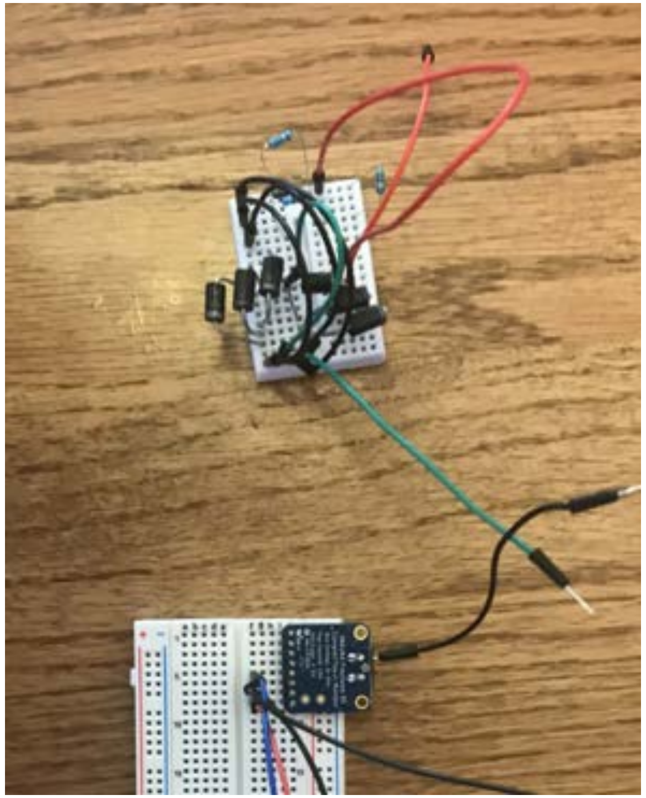




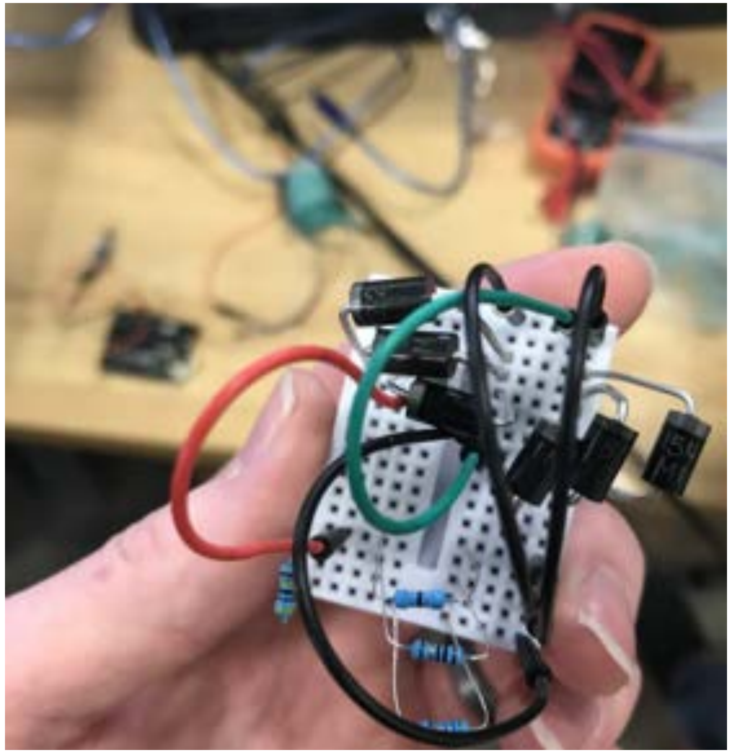
# Final Contenders: Averages



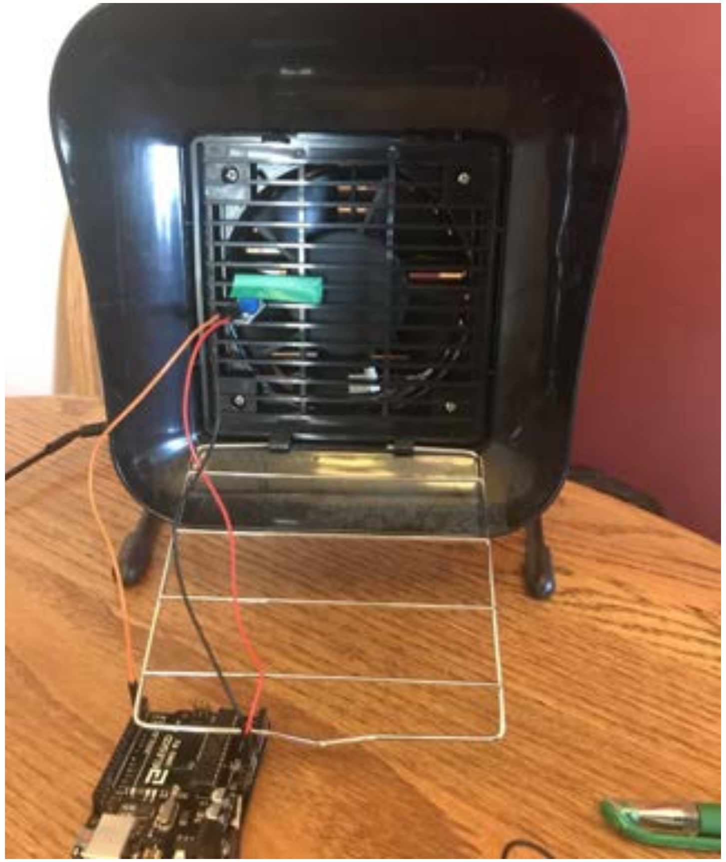
| Blade | Tunnel Speed (m/s) @ 5 V | Tunnel Speed (m/s) @ 10 V | Cut in speed | Max volt (V) | Max tunnel speed (m/s) |
|---|---|---|---|---|---|
| Lift 30° Twisted | 10.7833333 | - | 6.406666667 | 6.873333333 | 14.15333333 |
| Drag (55° twist) | 3.57666666 | 5.753333333 | 3.626666667 | 10.21 | 5.93 |



Power Sensor



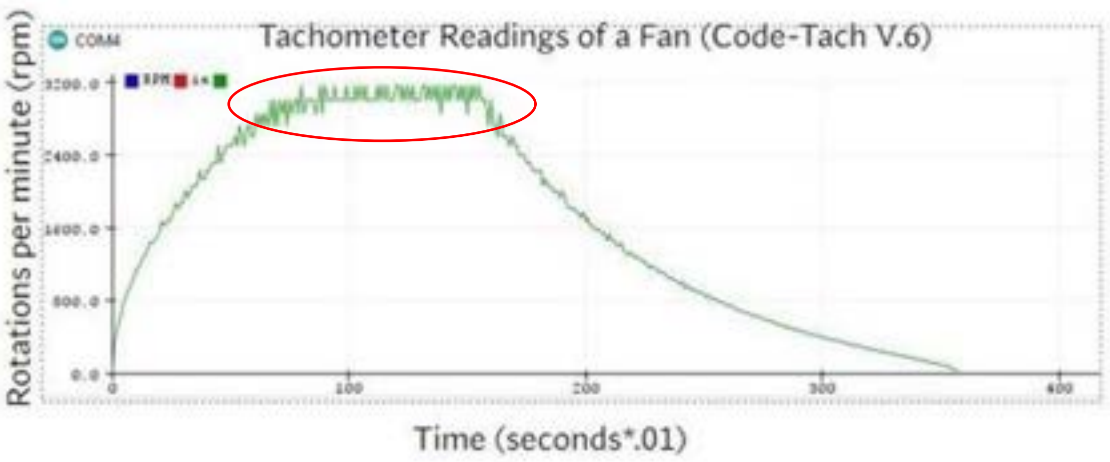
Load



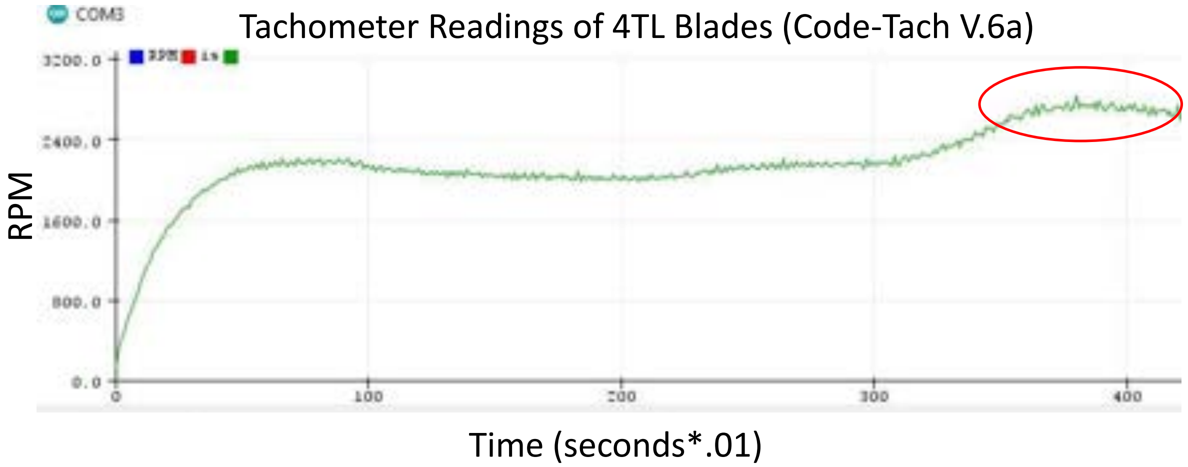
Tachometer (rpm)

# Electronics

# Rotations per minute (rpm)




- 10% Error
(at 3200 RPM)




- 3% Error
(even at 4000 RPMs)

# Load, Power, and Control

## Two 100 watt power load paths

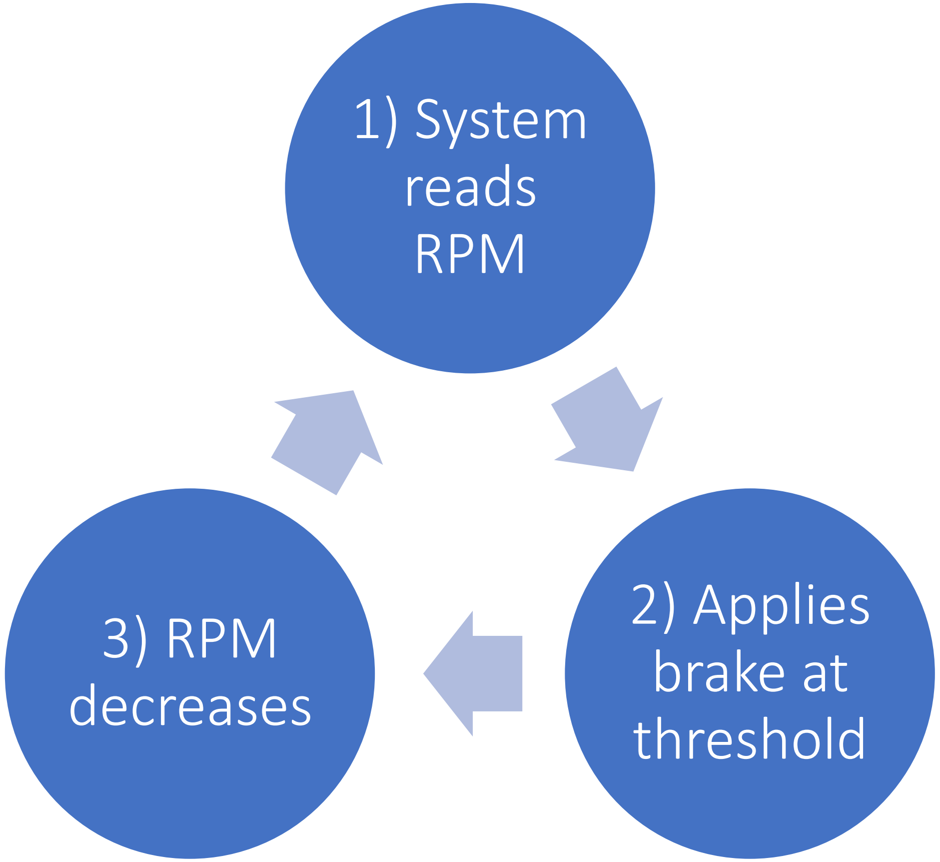
- High and low resistance values for different cases

## Power Sensor

- Detects voltage, current, and power

## Safety

- System monitors RPM, and applies the brake when it gets too high
- An emergency stop button also engages the brake as well as a dump load



# Schematic and final circuit! TM pending

## Our circuit includes:

- Electronics had to meet the NEMA 1 classification (i.e. people are protected from touching the electronics)
- A three-phase rectifier
- Capacitors to smooth output
- Power sensor and Arduino to display power information
- 2 Potentiometers to adjust our high and low load values

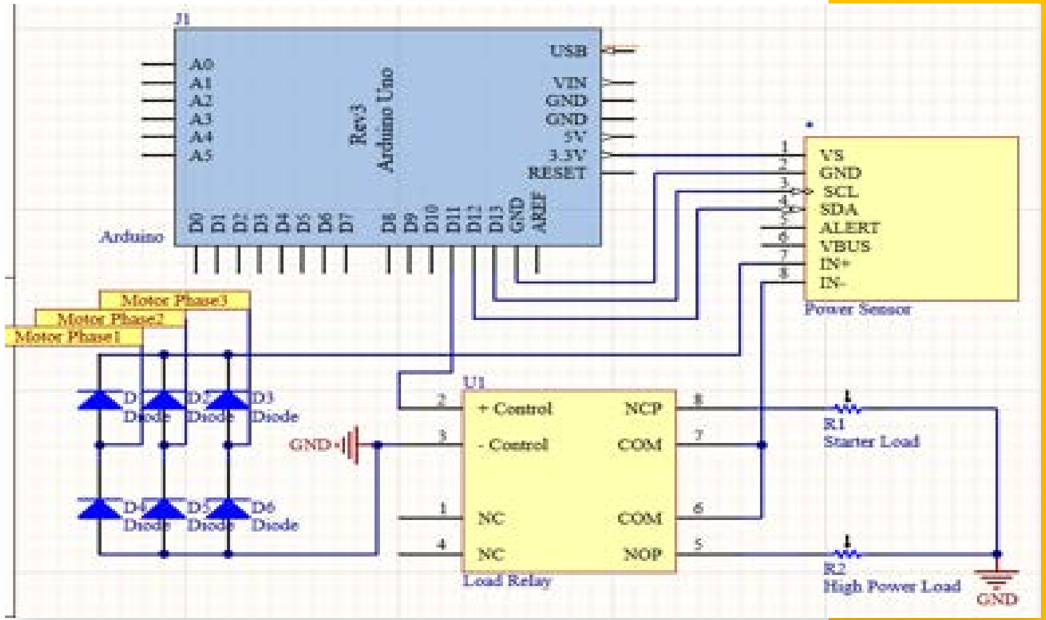



Figure 16.1 Placeholder for beautiful schematic of our horrendous circuit

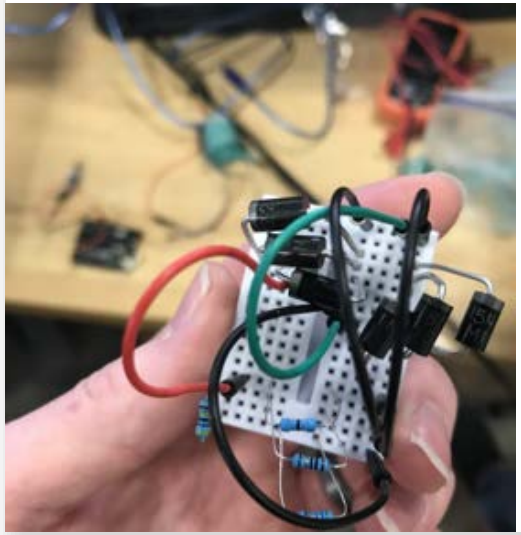
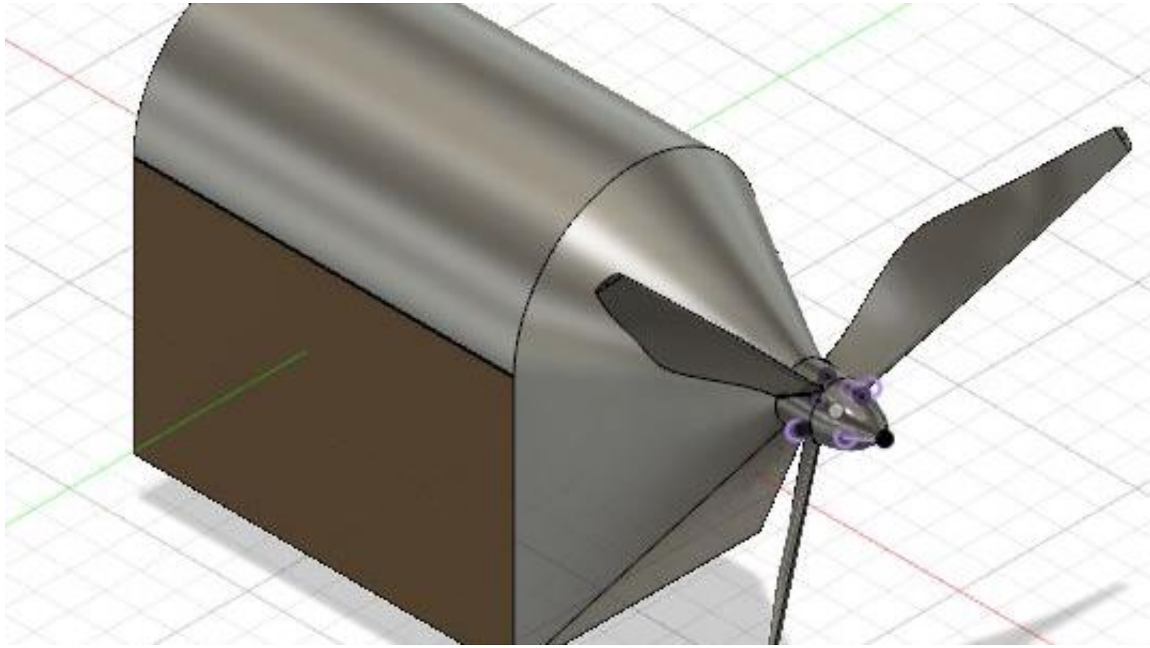
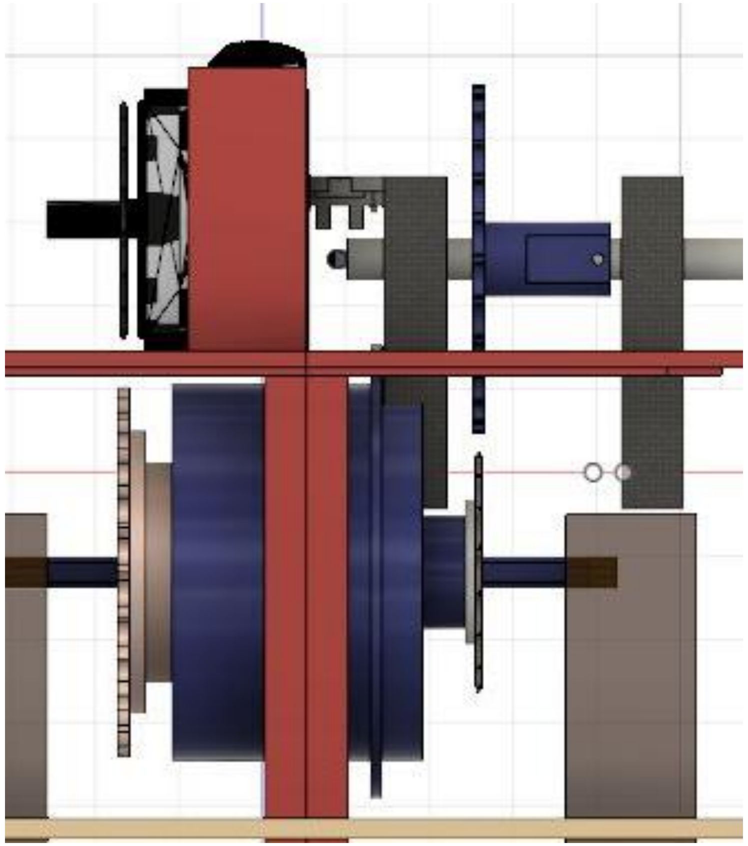


Figure 16.2 Placeholder for final circuit

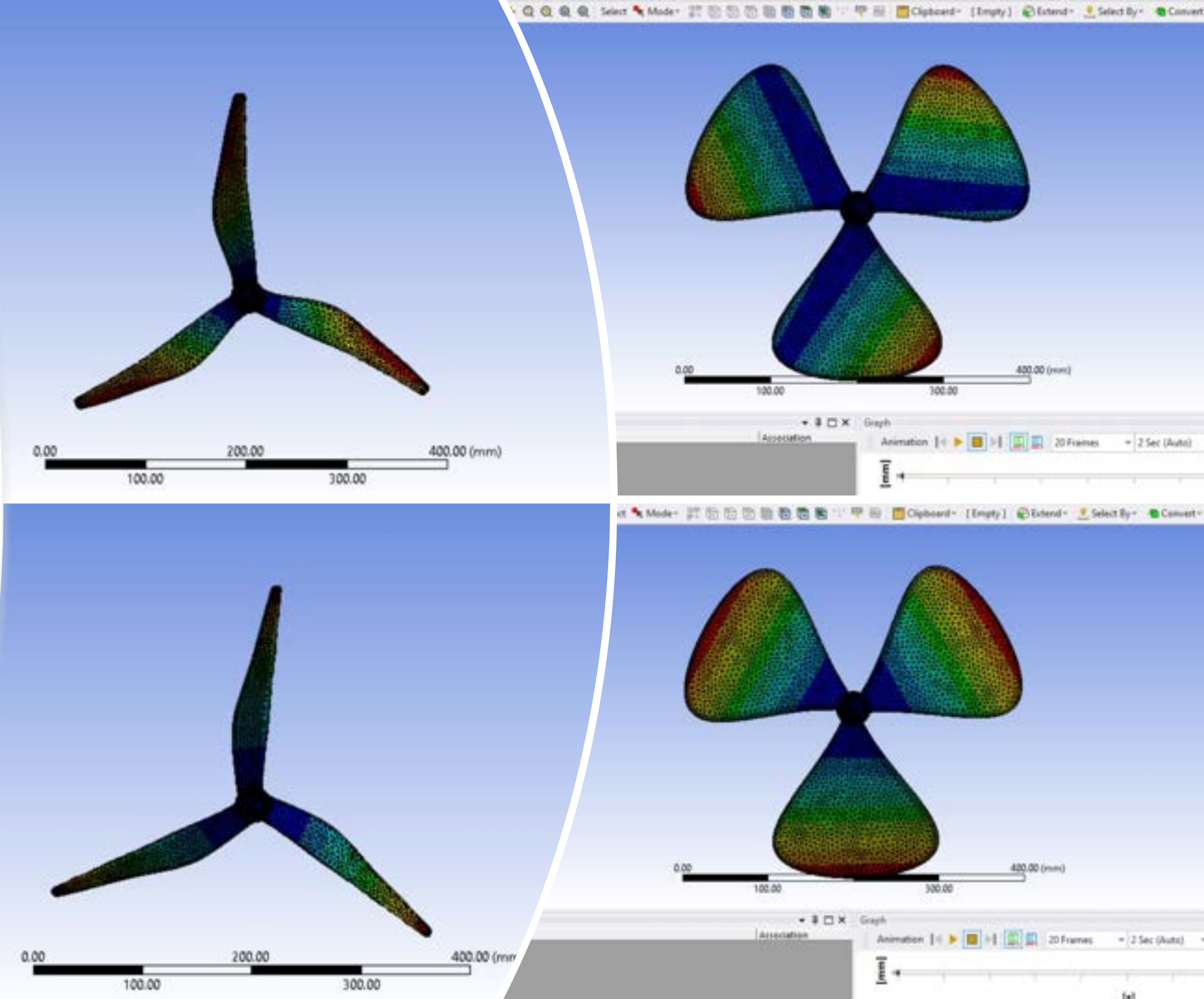
# Modeling, Testing, and Analysis





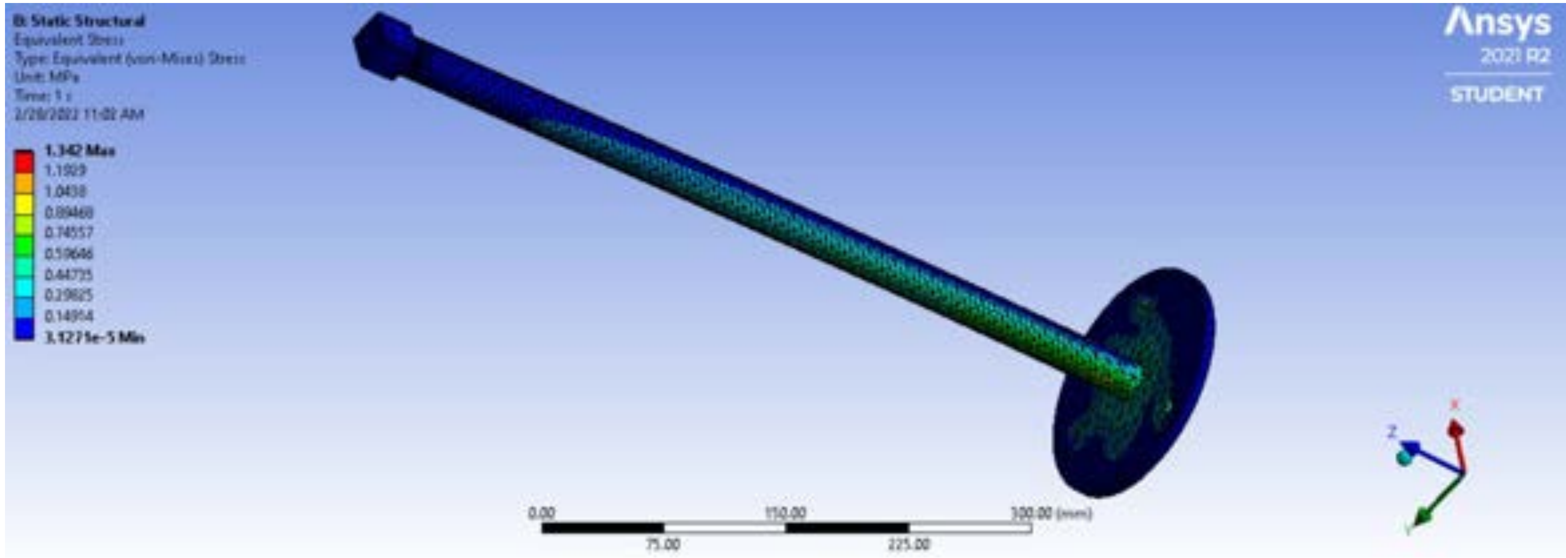
# Analysis: Blades

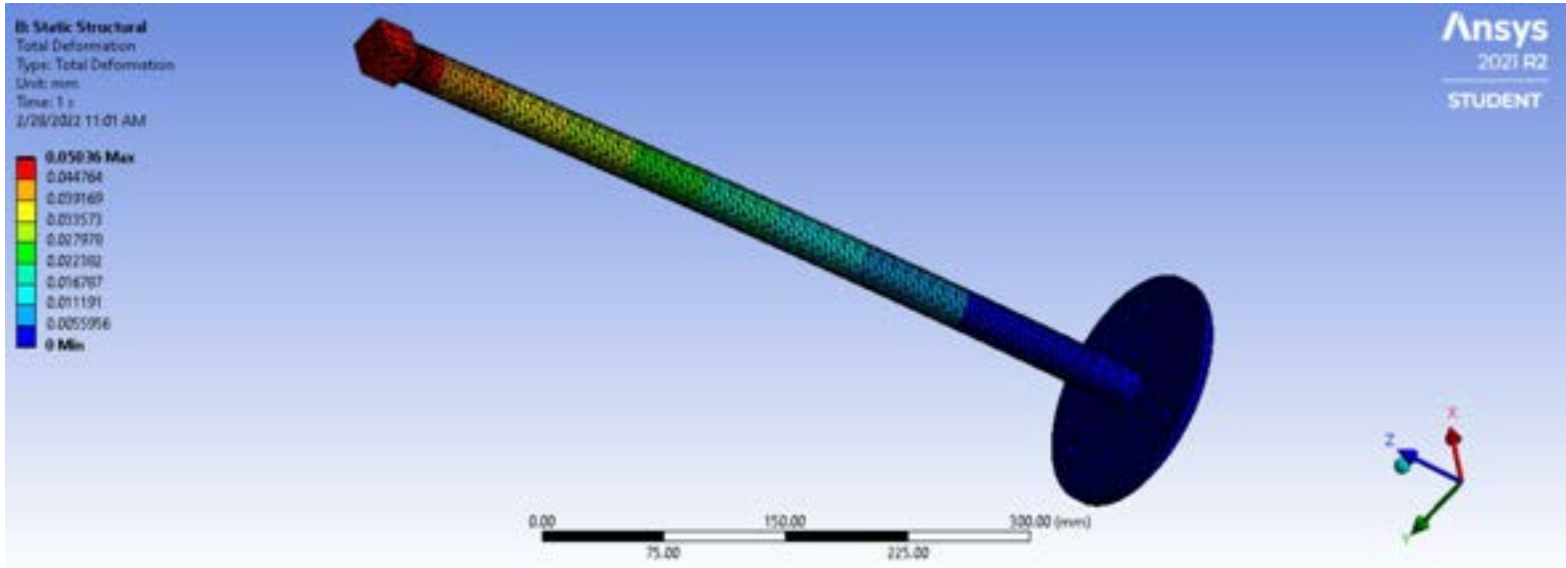
- Using ANSYS Workbench
- Scale models at 200 mm and 400 mm diameter
- Performed Static Structural Analysis
  - Total deformation with and without rotation
  - Equivalent (von Mises) Stress with and without rotation



# Analysis: Nacelle

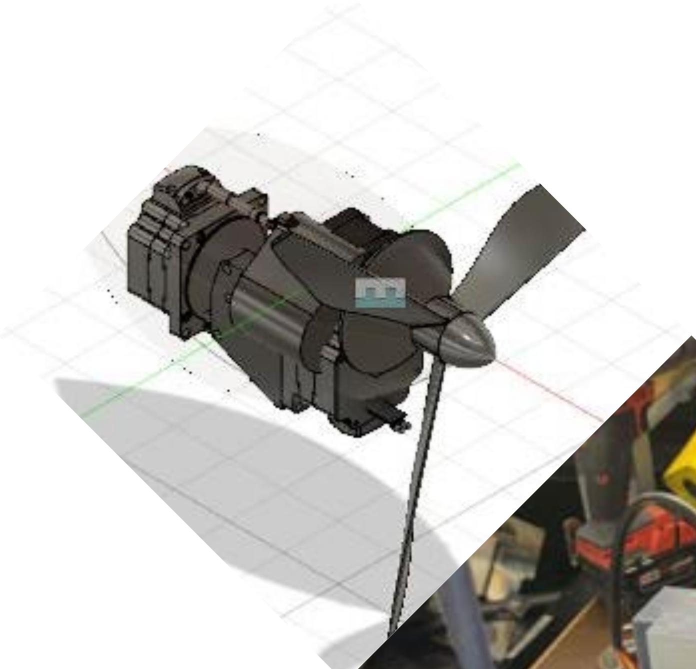
- **Verified the base and tower joint won't fail.**
- **The plate is fixed through the bolt holes (BC)**
- **Force was applied to the cube at the top (BC)**
- **Max equivalent stress: 1.3Mpa**
- **Max deformation: 0.05mm**



# Final Assembly

- CVP up to 1.7 Gearing
  - Reduced gears to reduce torque required up to 1:4
  - Reduced gearing further up to 1:3
- Changed to Gearbox
  - 1:2 Ratio
- Final design displayed no gearing



# Final Design Testing

# Results | Design Requirements

- 25/30 Design requirements met
- 5 pending test and approval

# Lessons Learned

- Prototype, Prototype, Prototype
  - Plan builds thoroughly
  - Test every aspect of a design
  - Find the errors quickly and document them
- Commit to a final design and build it early
  - Assembly *always* takes longer than expected
  - There are *still* going to be errors in the final design, plan on several
- A key benefit of a team is verifying each other's designs
  - Save on material and time if every design is double-checked by multiple people

# Questions