EML4552 – Team 15 – 04/14/16

Sponsor: Dr. Sungmoon Jung – Advisors: Dr. Jung, Dr. Shangchao Lin, Mr. Sean Martin – Instructor: Dr. Nikhil Gupta

Portable Wind Turbine

Katelyn Bamundo-Stephen Freeman-Matthew Hutchisson-Stephanie McLellan-Garrett Rosenthal-Rishad Walker

Overview

- Project Scope and Objectives
- Overview of Portable Wind Turbine
- Design Process
  - Base
  - Nacelle
  - Electrical

Project Scope and Objectives

- Objective: create lightweight, portable wind turbine that is easy to assemble and disassemble so that inexperienced operators may use the device.
- Revised Objectives/Constraints
  1. Operate in wind speeds of 4 m/s (~10 mph) at an approximate height of 2m
  2. Lightweight (80 lb max)
  3. One person should be able to assemble and disassemble
  4. Prototype (Budget of $2,000)
  5. Power output of 5W

Portable Wind Turbine

Turbine Base- Design

- Creo Parametric
- Modeled in AutoCad 3D
- Stress and Deflection Analysis in RISA 3D

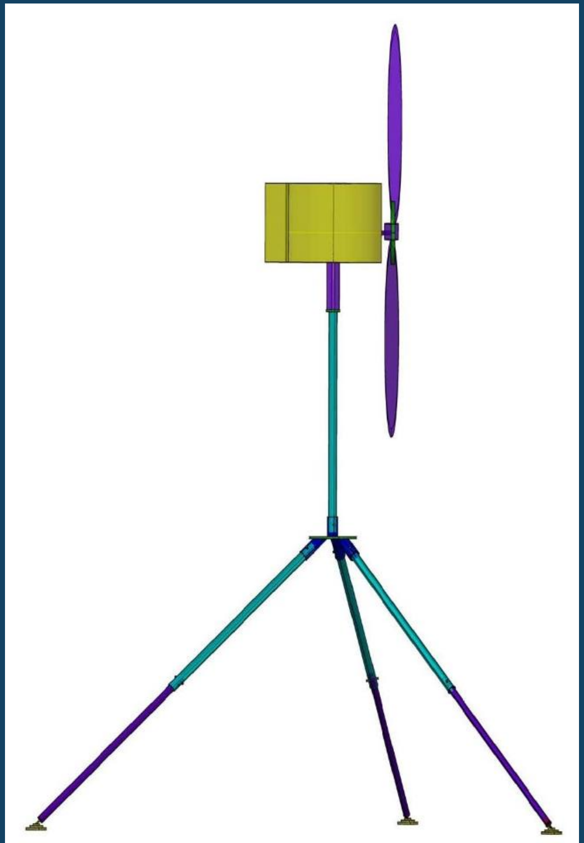


Figure 1. Turbine Base Design

Base Alternatives

Body

Figure 2. Bodiless

Figure 3. Cylinder

Figure 4. Cross

Base

Figure 5. Tripod

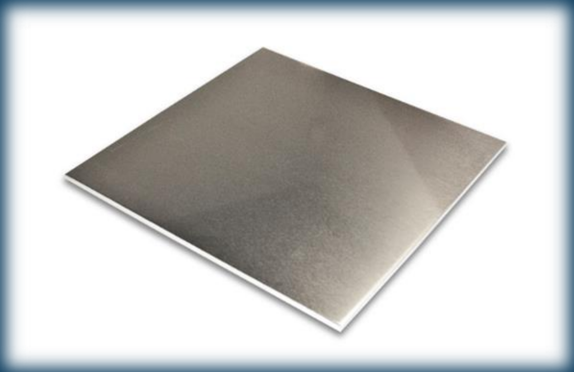


Figure 6. Solid

Turbine Base - Parts

- Telescoping Legs
  - Clamps
- All Terrain Feet
  - Screwed into bottom of legs
- Images
  - Part Locations
  - Tube Clamps (Red)
  - Base Feet (Green)

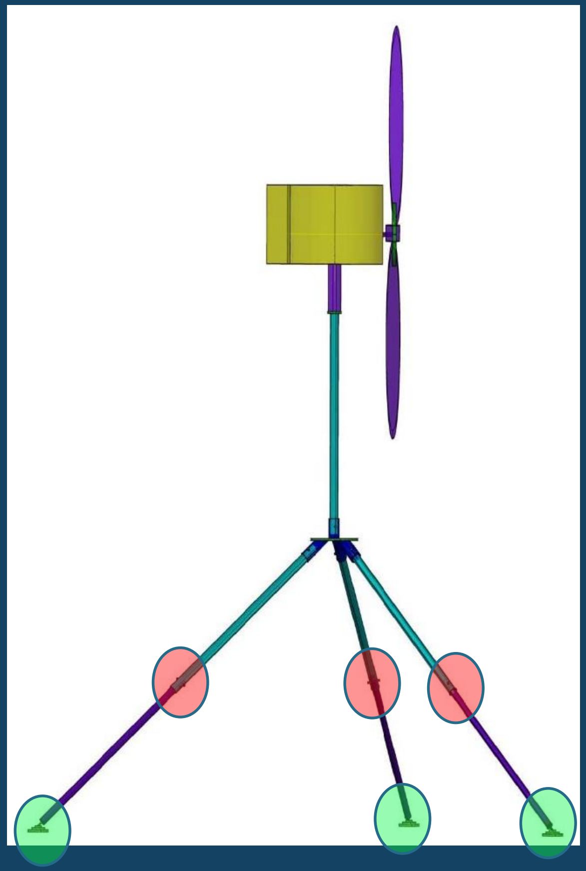


Figure 7. Part location

Figure 8. Tube Clamp

Figure 9. Base Feet

Turbine Base - Design

- Stability Against Overturning
  - Rayleigh Wind Distribution
- Accidental Bump
  - Assume 8 inch offset
- Sloped Surface
  - Assume 15°

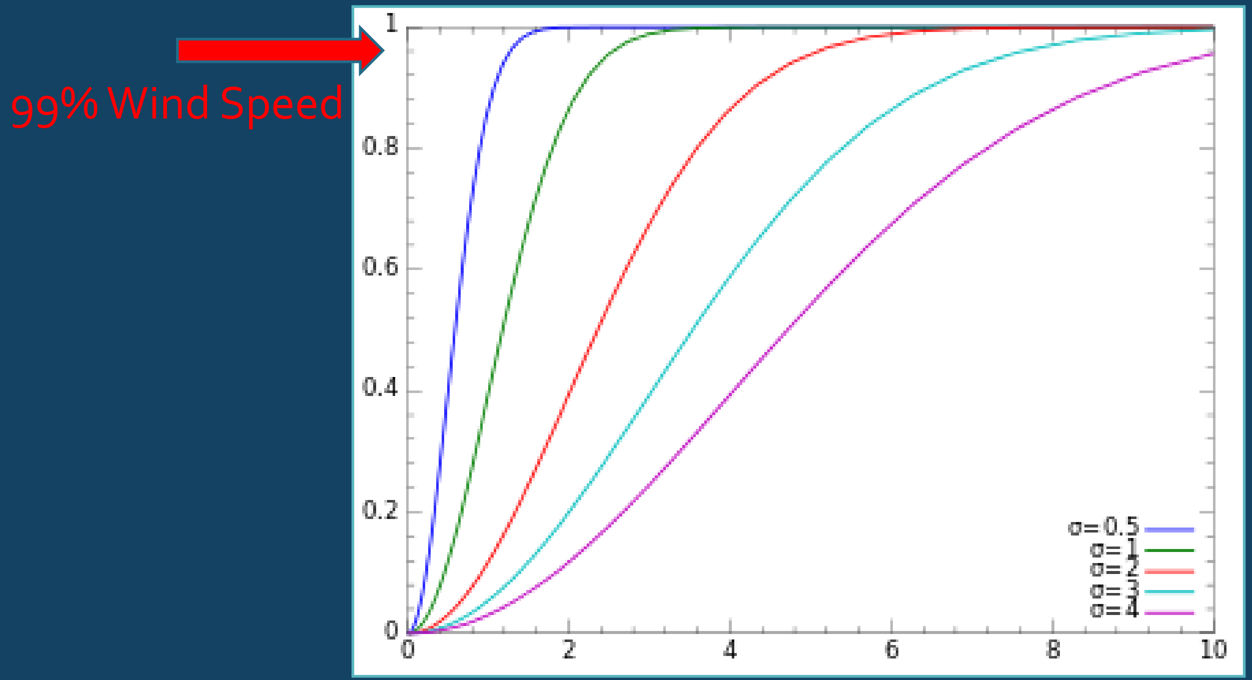


Figure 10. Rayleigh Distribution

Plate Connecting Legs and Neck

- Angle of legs
  - 55.44 degrees is maximum
  - Chose 50 degrees
- Pin Connection

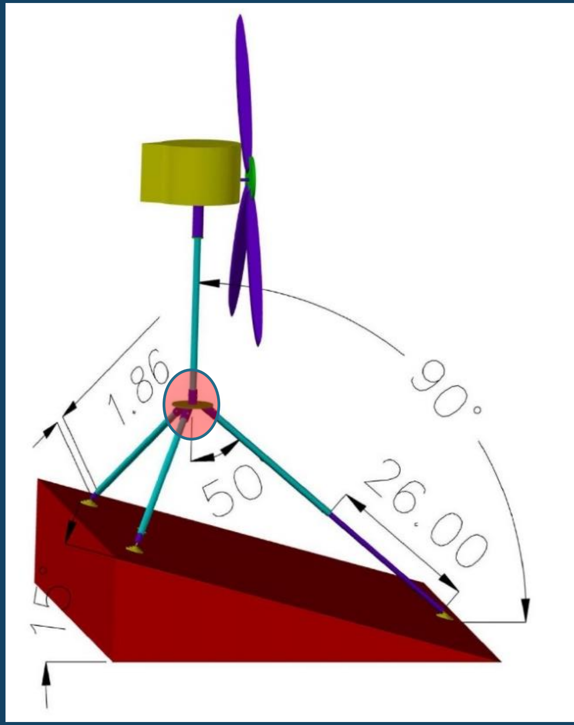


Figure 11. Angle of Legs

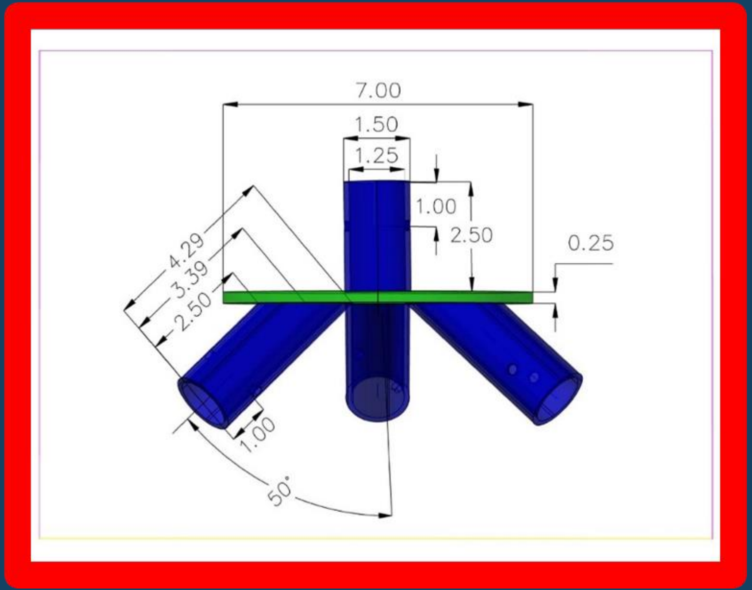


Figure 12. Leg and Neck Connection

Turbine Base - Overturning

- Case 1: 9.26 m/s (20.8 mph)
- Case 2: 6.55 m/s (14.7 mph)

- Wind speed for overturning
  - $F_w = (W_T)(n)/H$

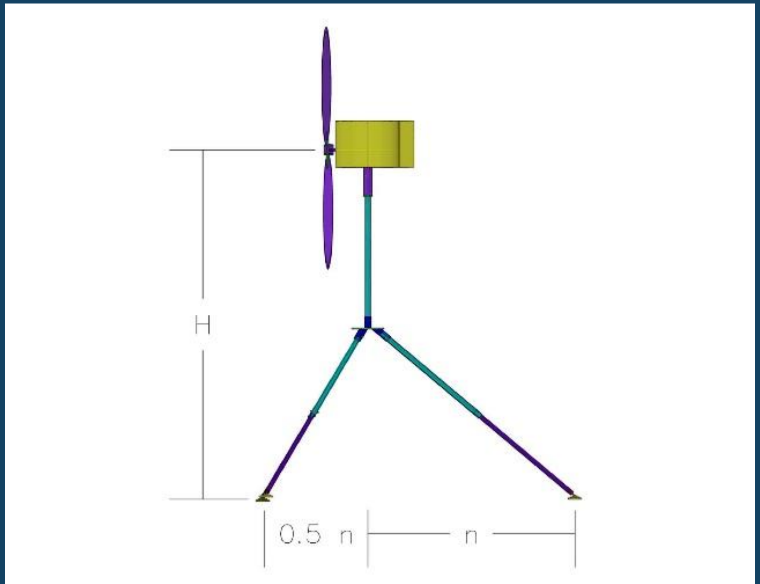


Figure 13. Overturning Case 1

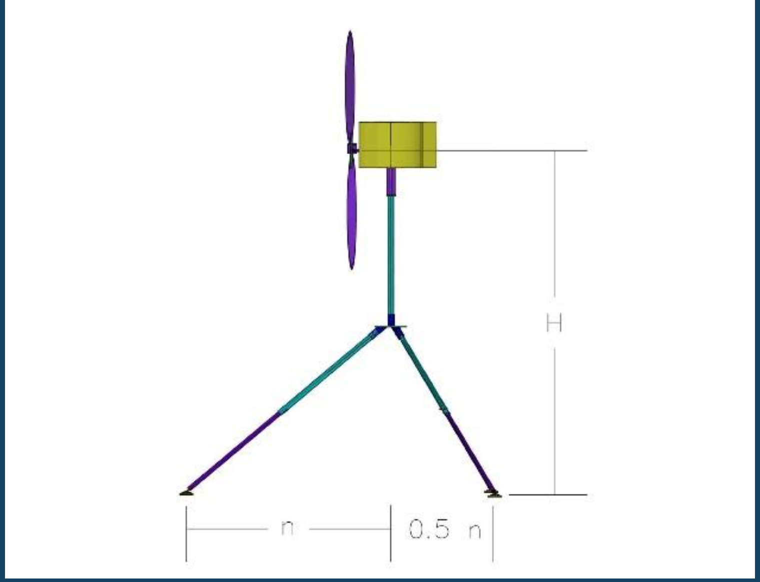


Figure 14. Overturning Case 2

Turbine Base- Calculations

- Bending and Axial Stress
  - RISA: 6.65 ksi
  - Hand: 6.98 ksi
- Buckling
  - Negligible
- Shear
  - Negligible

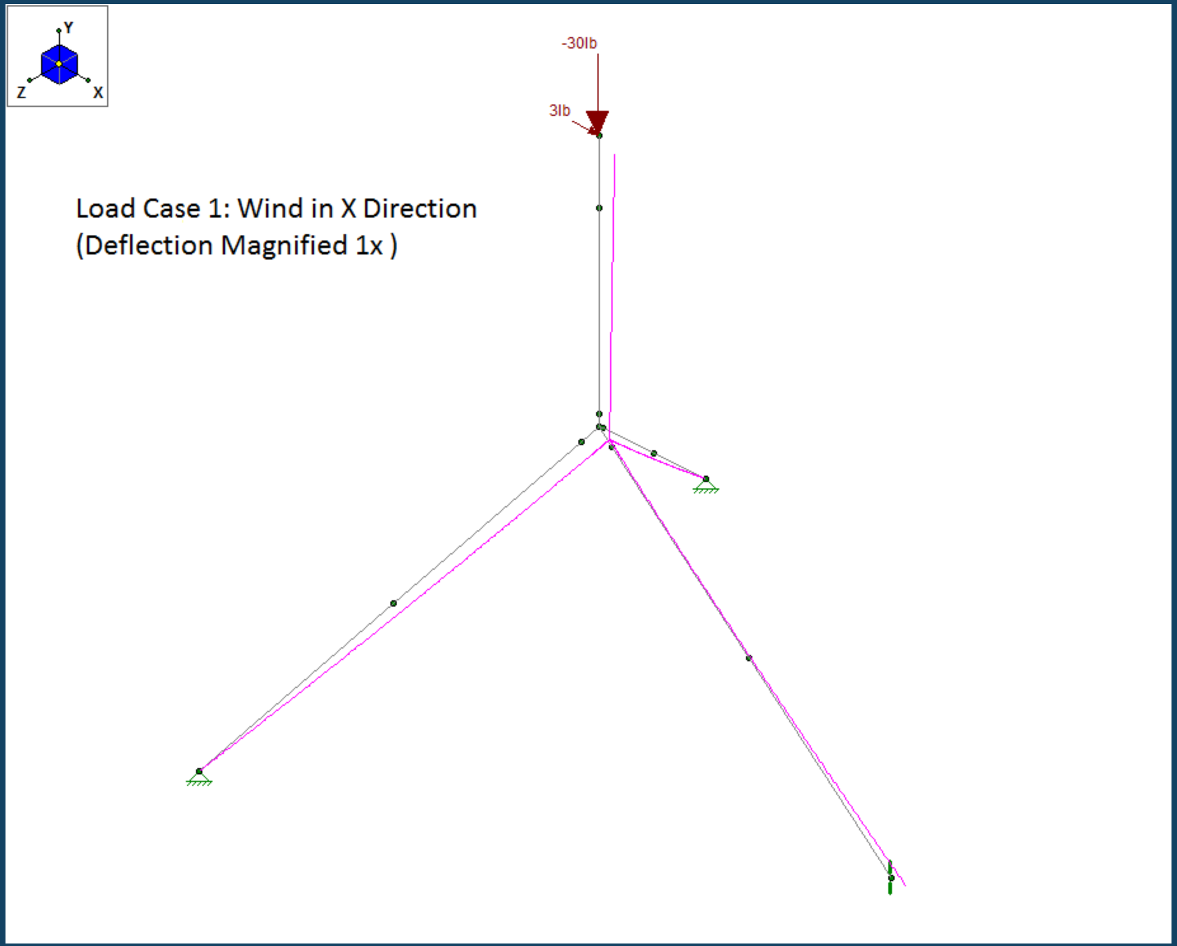


Figure 15. Loading of base

Turbine Base - Bump Displacement

- Failure: 15.5 inches
  - (Angle of 9 degrees)

- Assumed: 8 inch max
  - (Angle of 5.86 degrees)

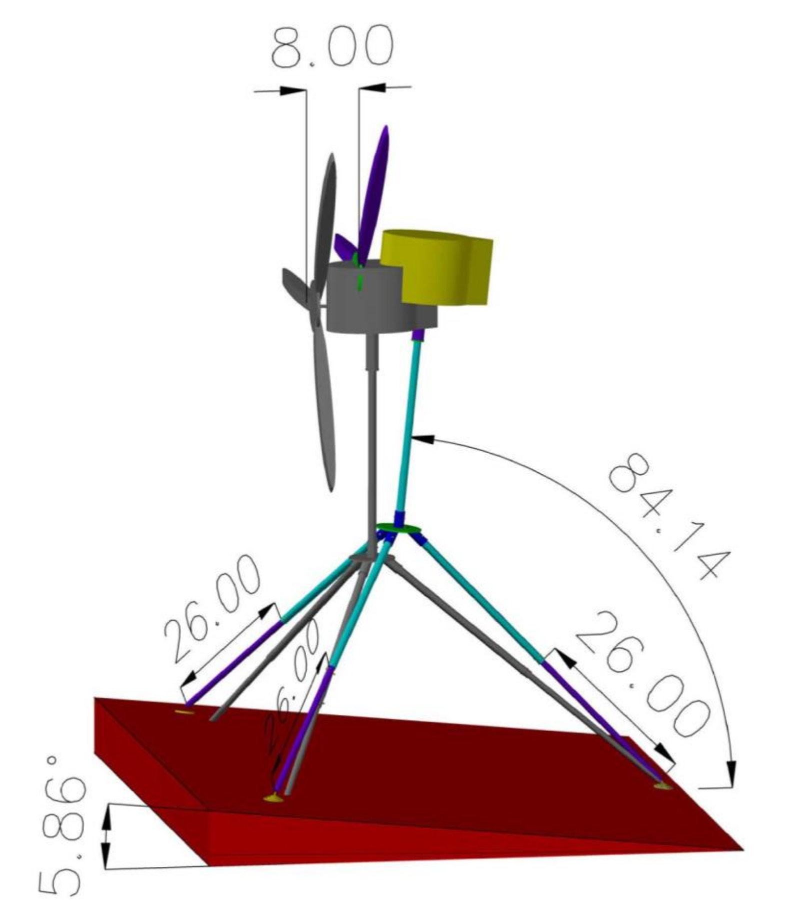


Figure 16. Bump Displacement

Nacelle Mounting

Figure 17. Location on Turbine

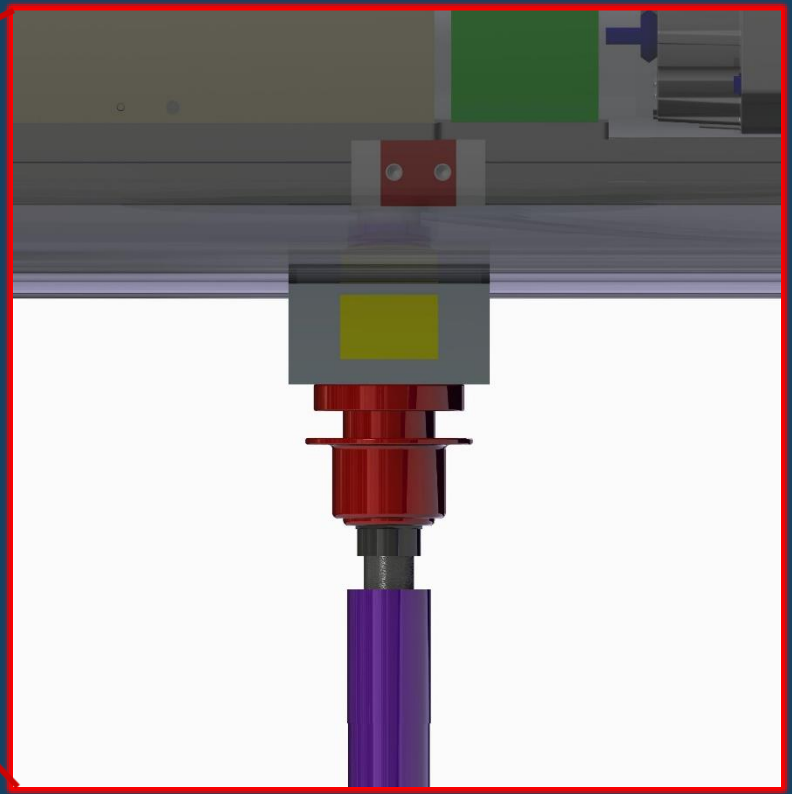


Figure 18. Quick Release

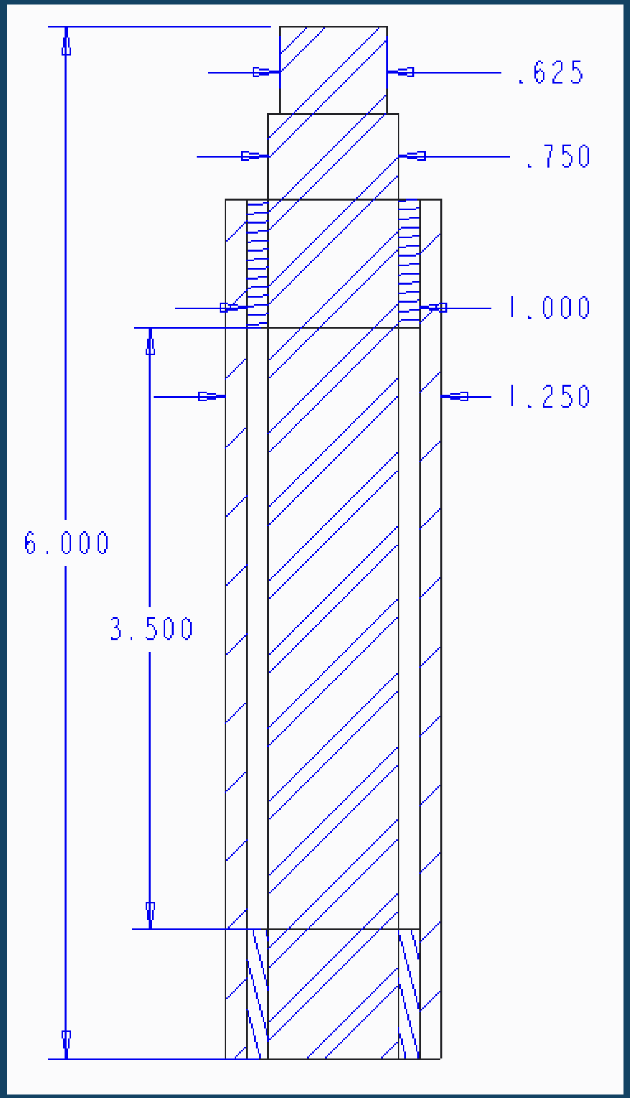


Figure 19. Section View (dimensions in inches)

Nacelle Design

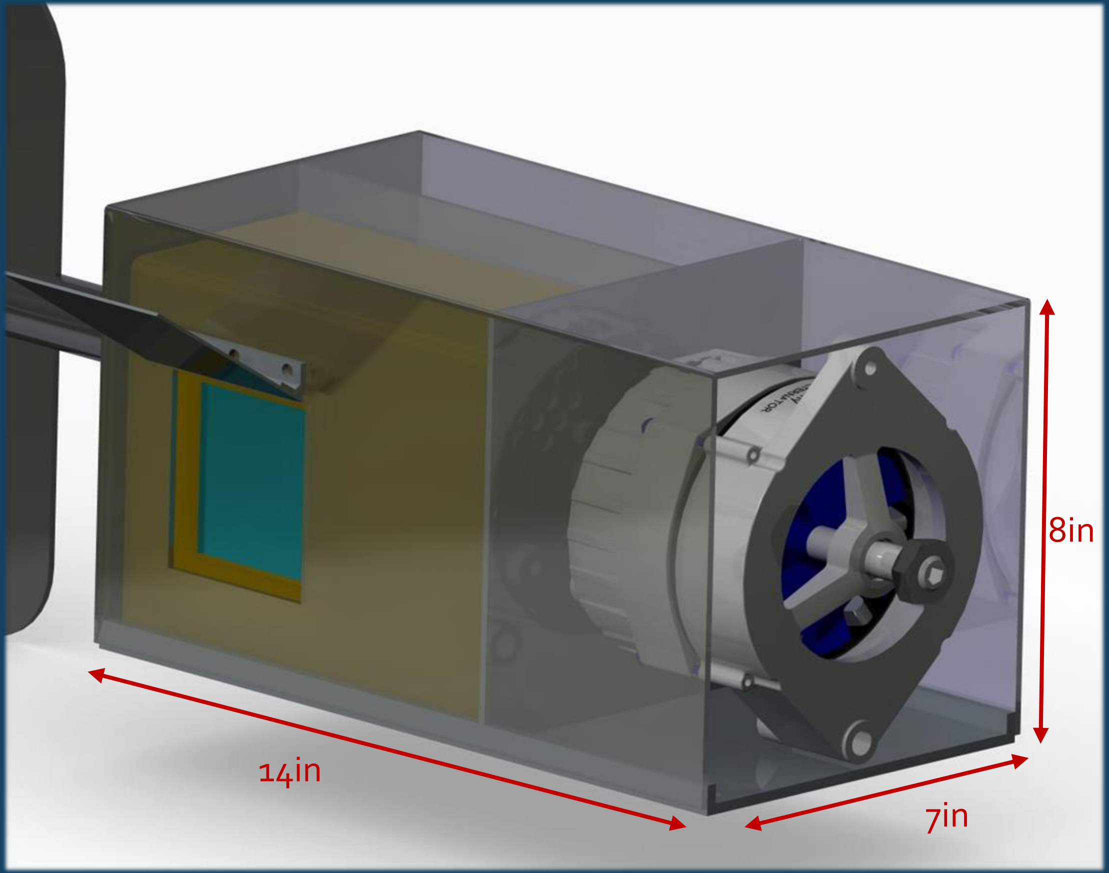


Figure 20. Box nacelle concept

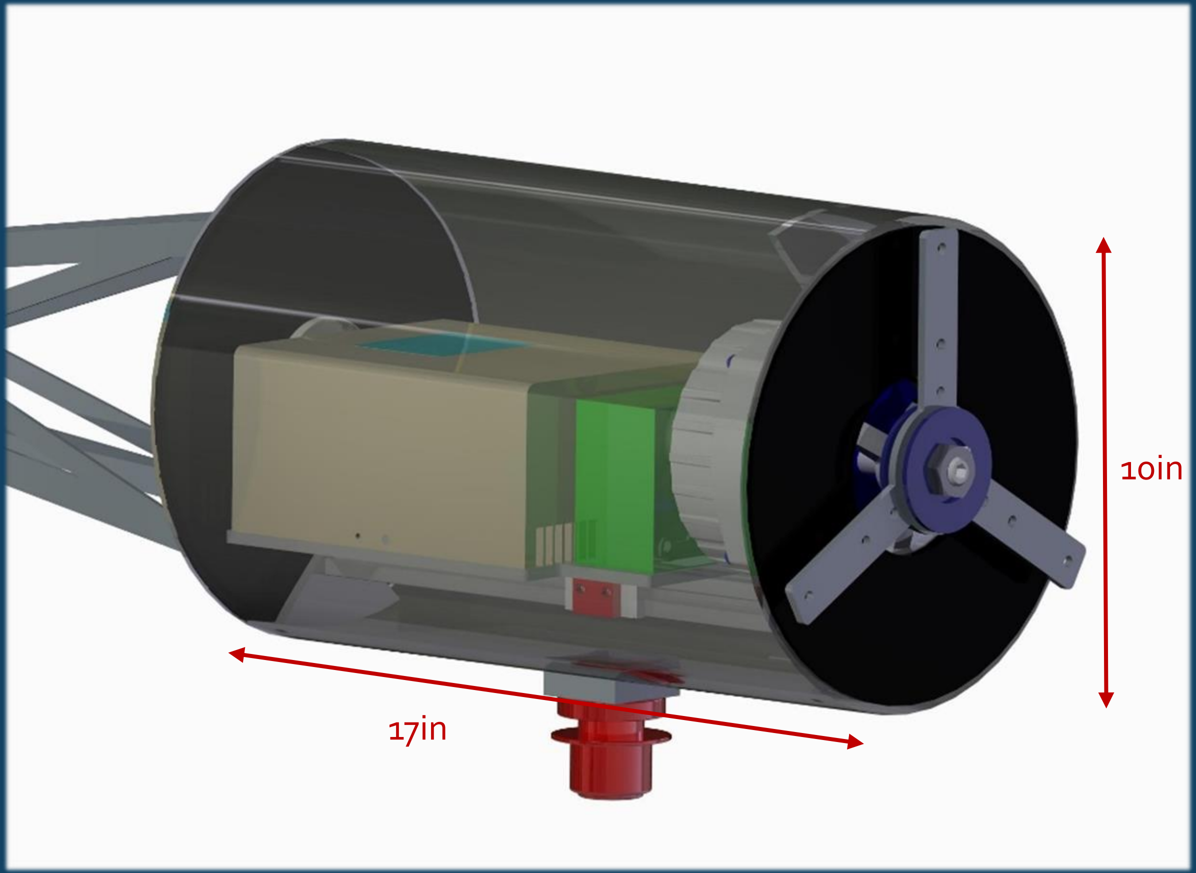


Figure 21. Selected nacelle concept

Nacelle

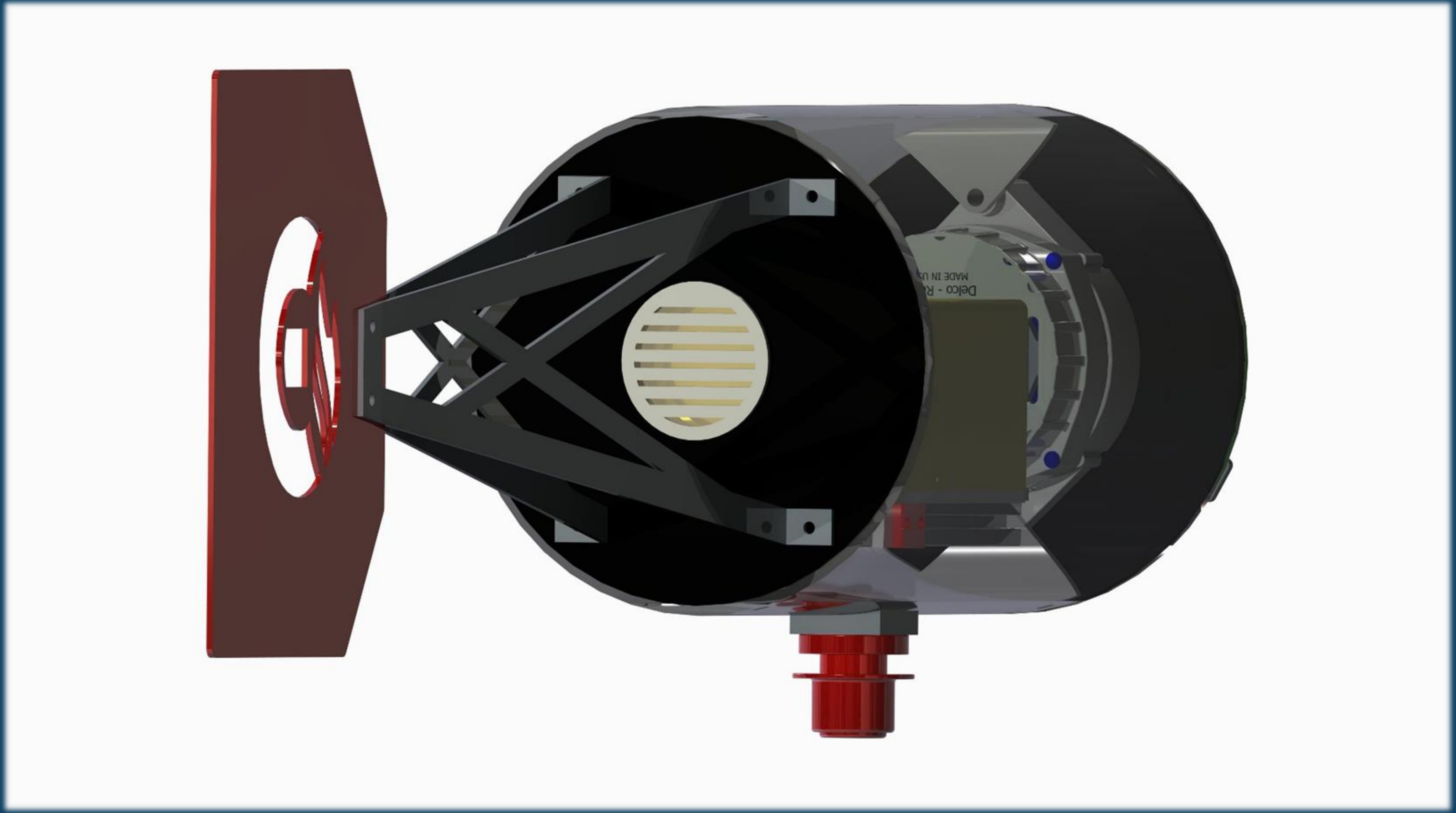


Figure 22. Rear of nacelle with louver vent

Nacelle

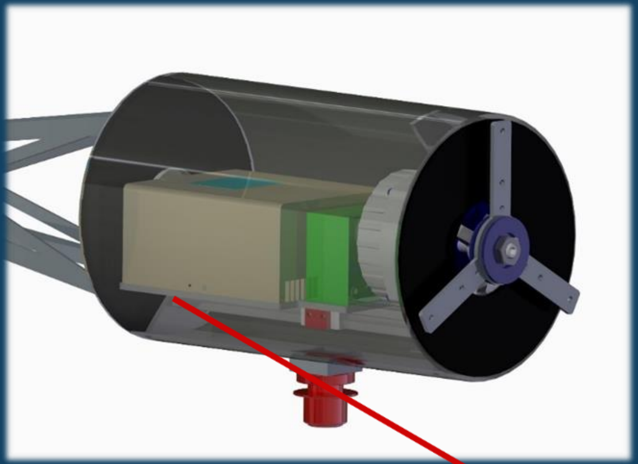


Figure 23. Tray location

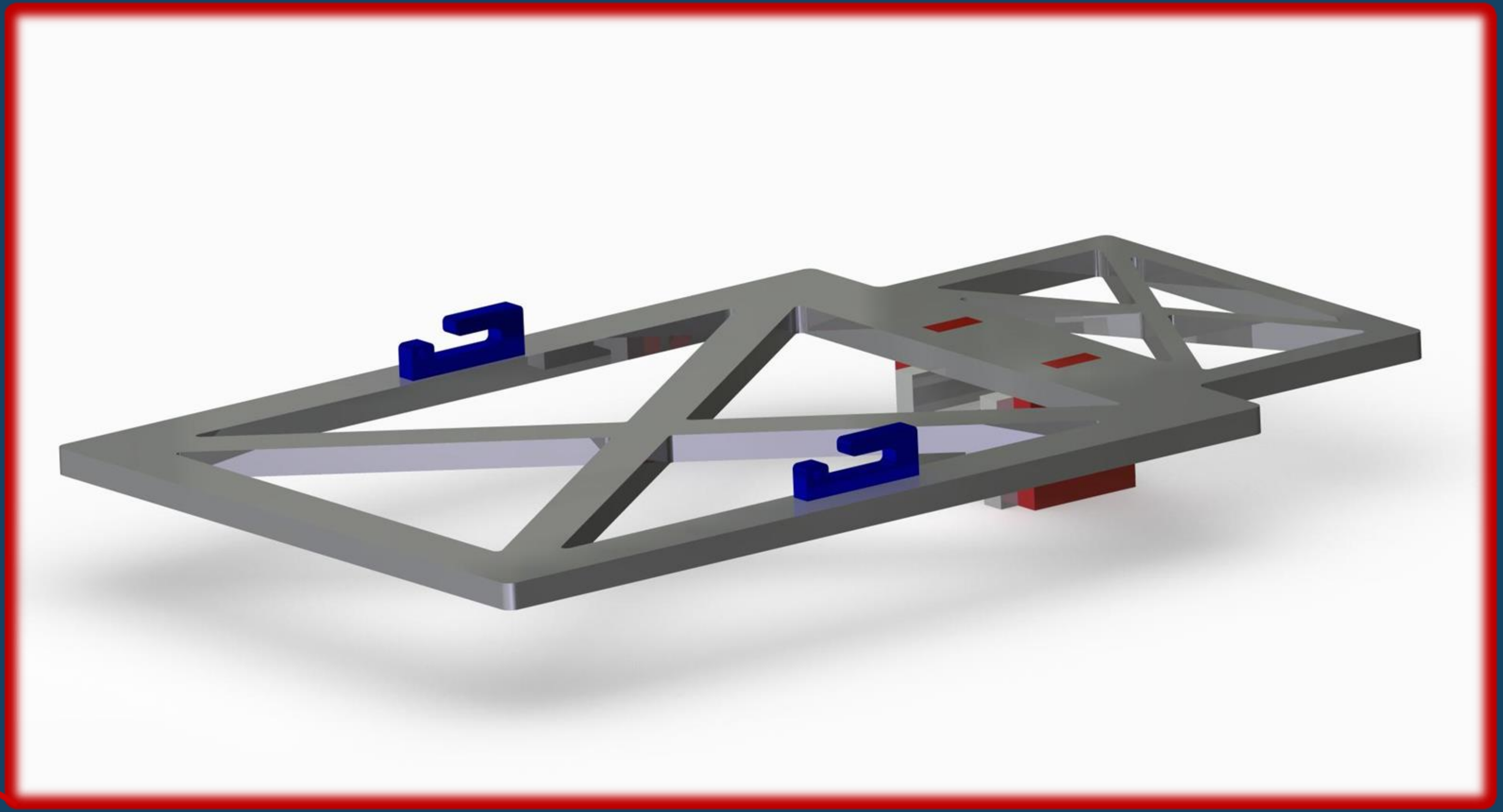


Figure 24. Sliding plate for charge controller and battery

Nacelle

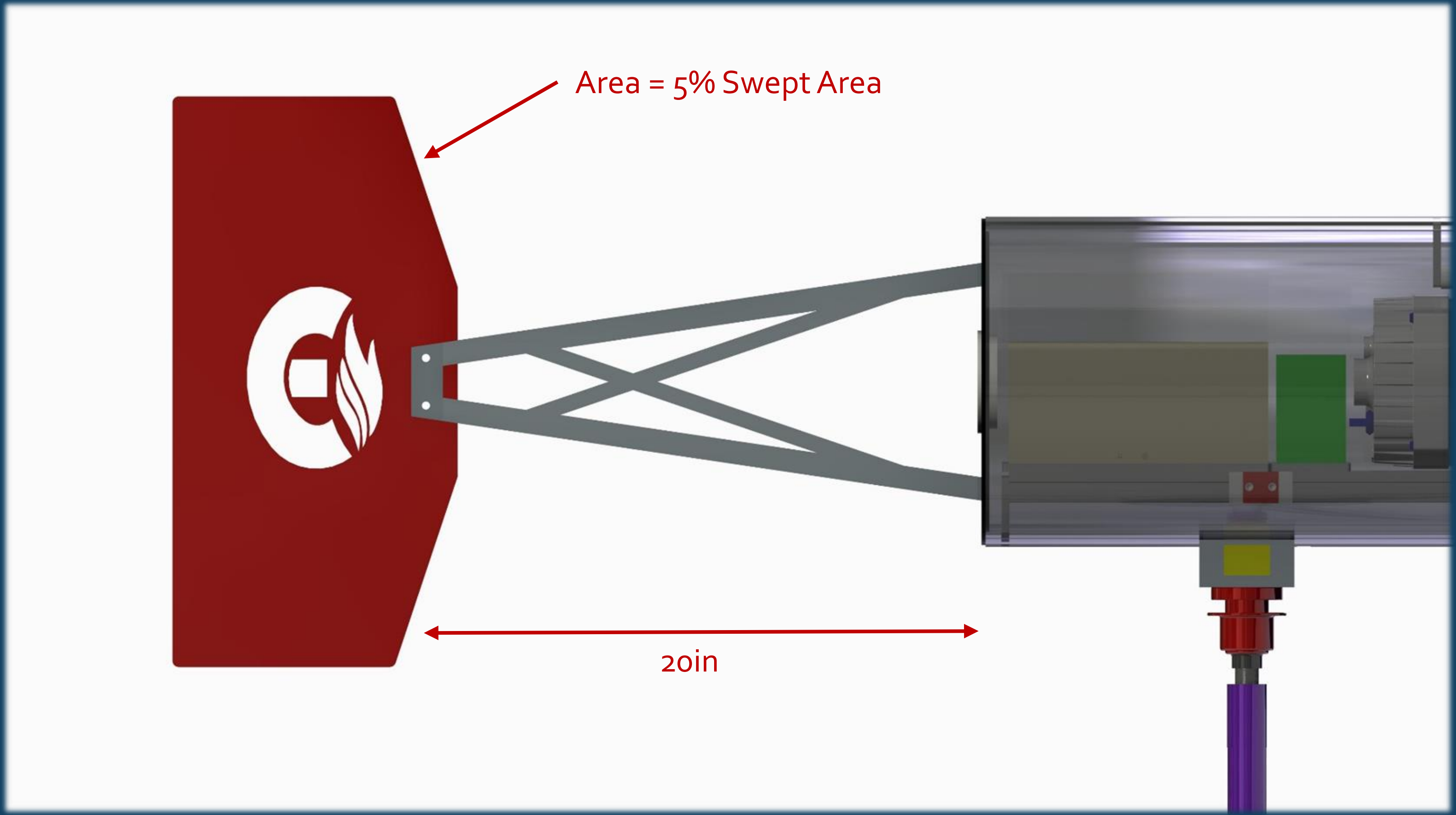


Figure 25. Tail vane information

Blade Mounting

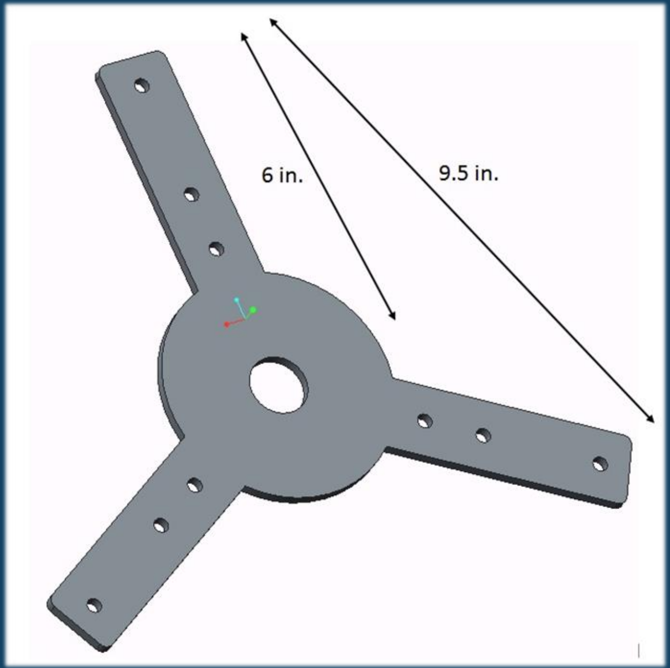


Figure 26. Blade mounting hub

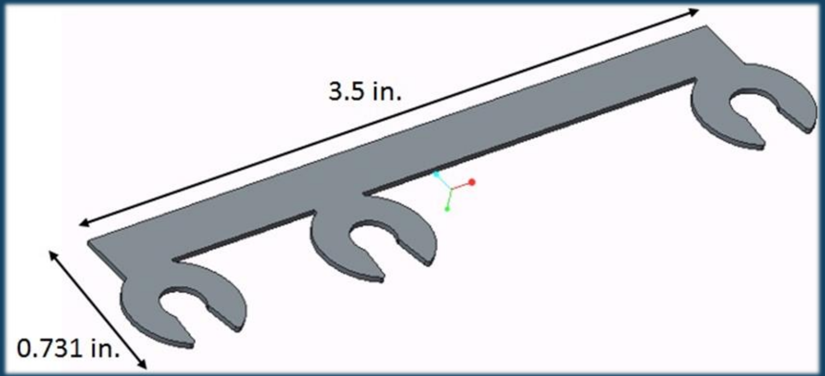


Figure 27. Clip to secure blades

Figure 28. 1/4 – 20 Wing nut

- Hub plate made using water jet
- Concerns of vibrations using clip concept
- Final selection of wing nuts

Turbine Blades

Figure 29. Vertical axis blades

Figure 30. Selected horizontal axis blades

Turbine Blades

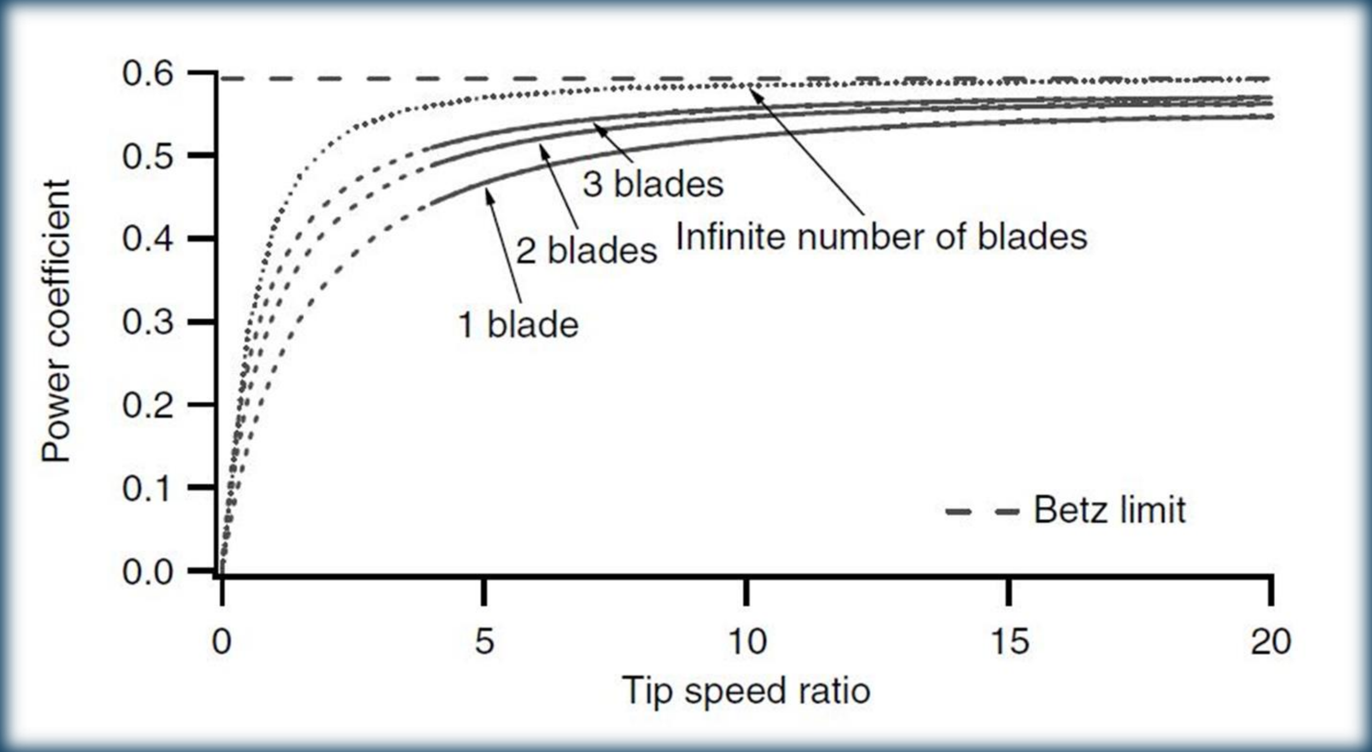


Figure 31. Power coefficient vs. TSR

$$Tip\ Speed\ Ratio\ (TSR) = \frac{\omega * R}{V_w}$$

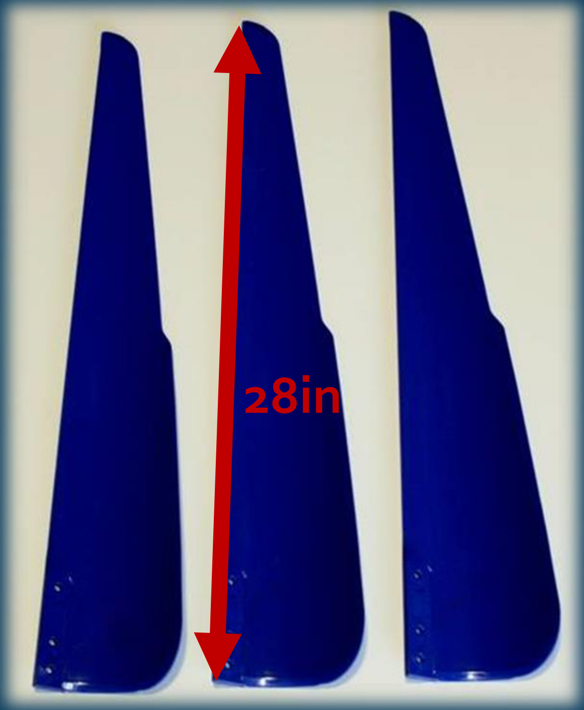


Figure 32. Selected blades.

Electrical Diagram

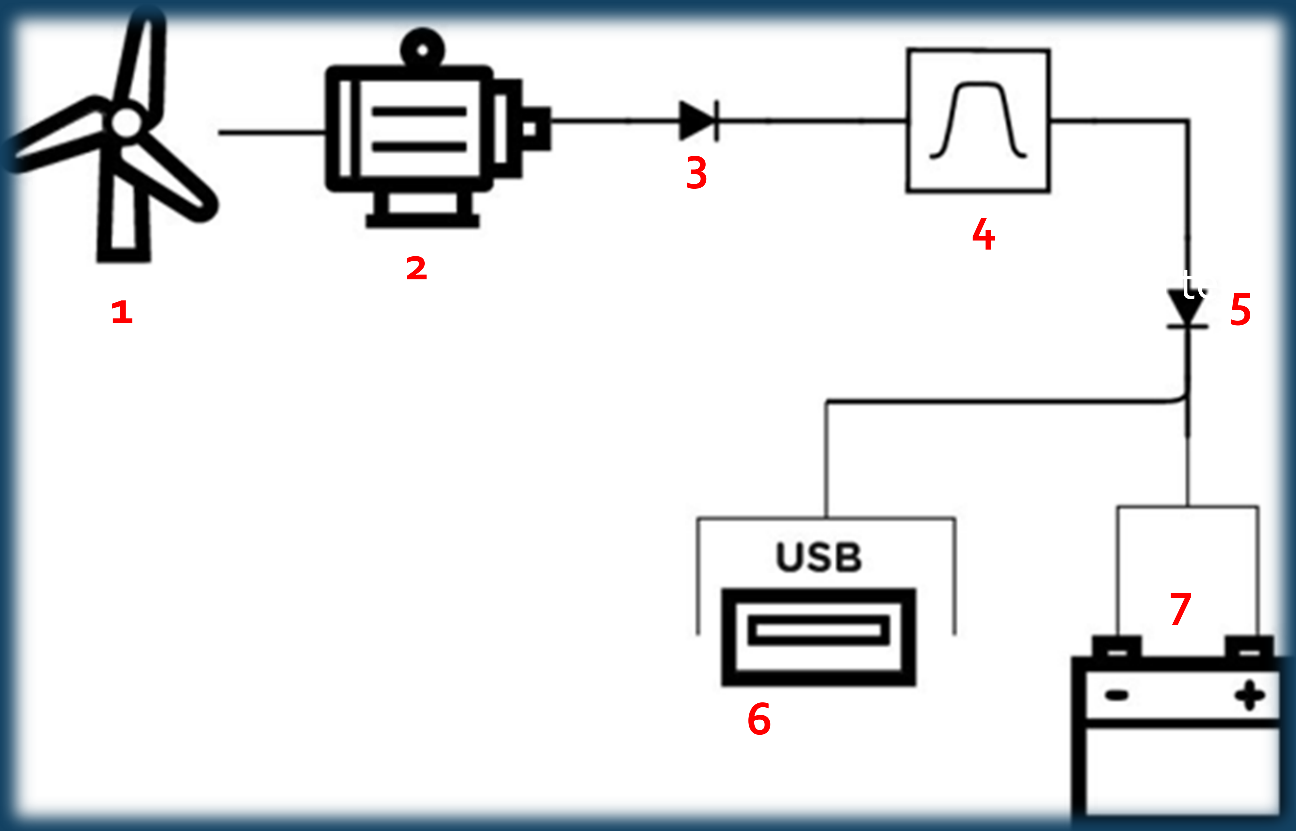


Figure 33. Diagram of the major electrical components of the turbine.

1. Blades
2. Alternator
3. Diode
4. Charge Controller
5. Diode
6. USB Plug
7. Battery

Alternator

$239.99
~15 lb
~100 watts @ 250 rpm

$239.00
~10 lb
~90 watts @ 250 rpm

Figure 34. HuricaneWinds Low wind PMA for Wind Generator

Figure 35. WindBlue DC-540 Low Wind Alternator

Charge Controller

Figure 36. Genasun GV-5 Charge Regulator

Figure 37. WindyNation TrakMax 30L 12V Charge Controller Regulator

Charge Controller

Table 1. Charge Controller Comparison

Genasun GV-5	WindyNation TrakMax 30L
• 10A 12 V MPPT controller • 140 Watts • High Speed MPPT • 5 Year Warranty • $159.00	• 30A MPPT controller • Adjustable battery charging voltages: 12, 24, or 48 Volts • LED Screen • Built in diodes • Auto-detects battery system

Selected: **WindyNation TrakMax 30L**

Battery

Table 2. Battery Decision Matrix

	Life Cycle	Cost	Safety	Environmental Safety
Lead Acid	-	-	-	-
Lithium Ion	+2	+1	+3	+3
Gel Batteries	+3	-3	+2	+1

Battery

Selected: LiFePo4

- Safer than standard Li+
- Longer Life Cycle
- Environmentally Safer

Figure 38. Battery

Packaging

Figure 39. Pelican Storm iM3075

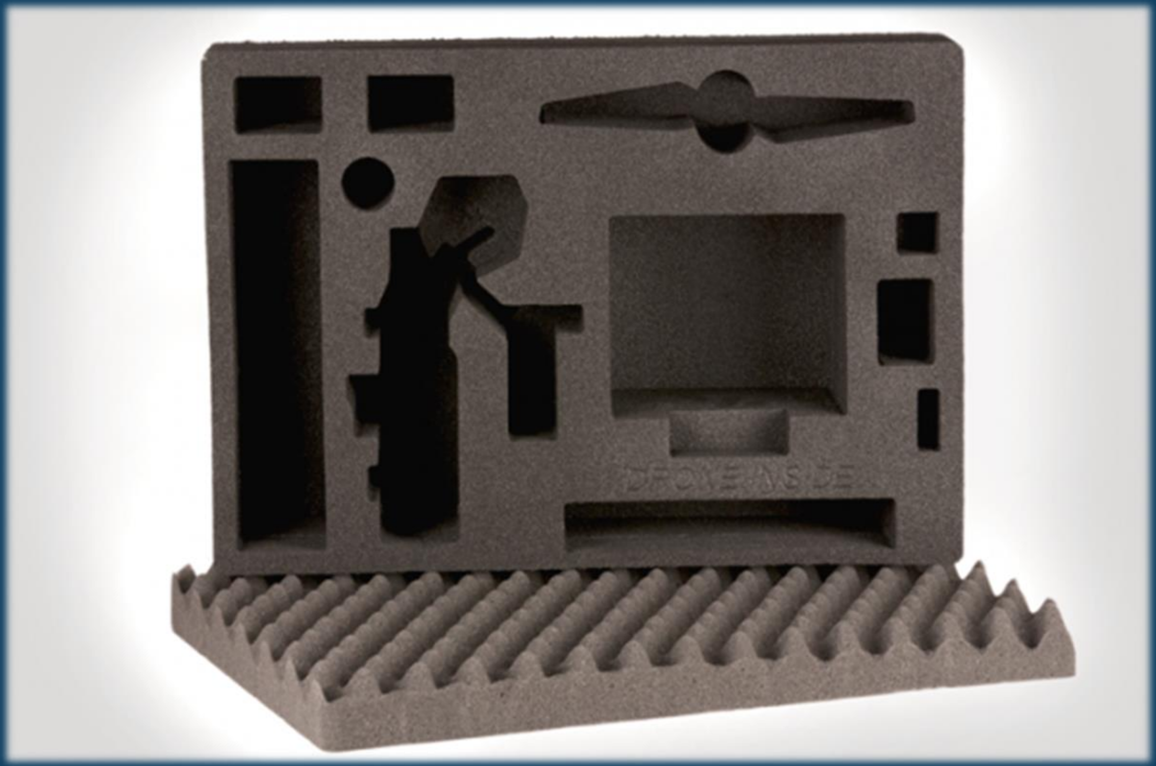
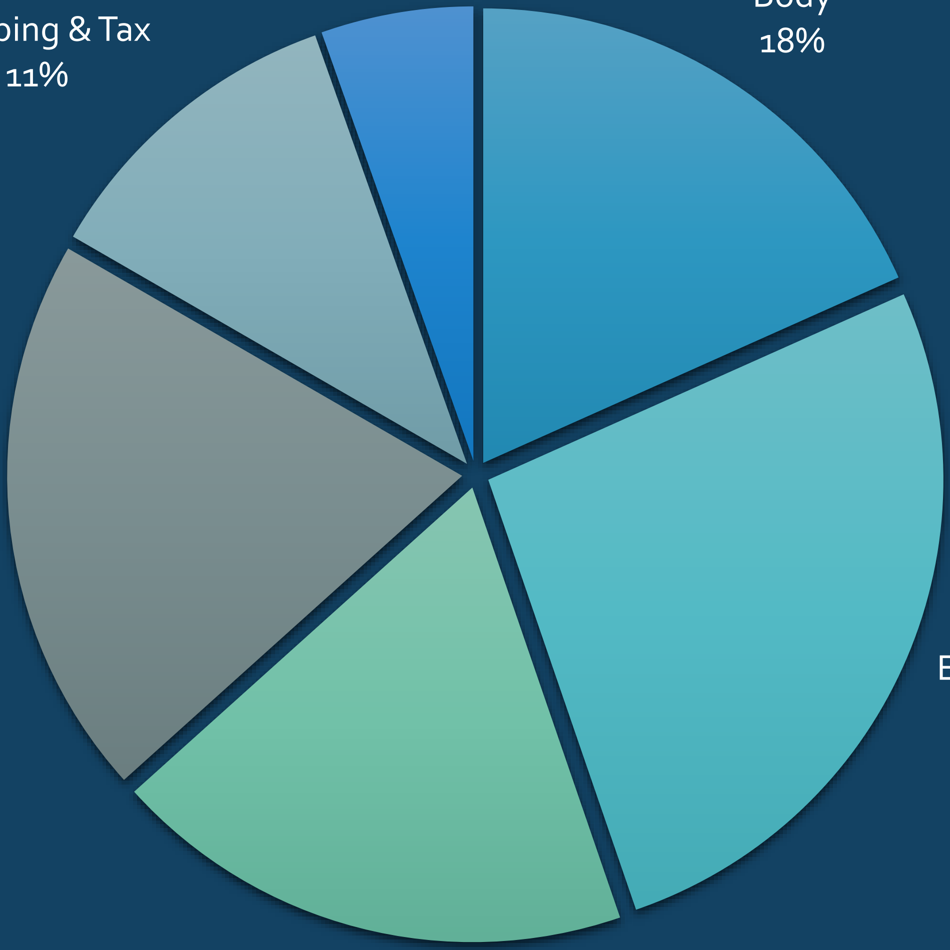


Figure 40. Interior fitted foam (Example)

Budget

Total: $2000.00



Conclusion

- Prototype completed within budget
- Simple, tool-free assembly
- Assembled and disassembled by one person
- Below target weight (45lbs total)
- Successfully generates power

Recommendations

- Add braking system for turbine blades
- On/off switch for battery output
- Reduce size
  - Charge Controller
  - Alternator
- Reduce Weight
  - Nacelle material

References

1. Claremont. Stick Figure Drawing Checklist, Image, Web, Accessed Nov. 16, 2015. http://claremont.sd63.bc.ca/pluginfile.php/20101/mod_page/content/9/stick_figure_drawing_checklist_800_2328%20(1).jpg
2. Rayleigh Distribution, Web, Accessed Dec. 3, 2015. https://upload.wikimedia.org/wikipedia/commons/thumb/a/a9/Rayleigh_distributionCDF.svg/325px-Rayleigh_distributionCDF.svg.png
3. WindyBlue Power, DC-540 Motor, Image, Web, Accessed Nov. 18, 2015. http://www.windbluepower.com/Permanent_Magnet_Alternator_Wind_Blue_Low_Wind_p/dc-540.htm
4. Clamp, Image, Web, Accessed February 10, 2016. https://www.rockwestcomposites.com/accessories/locking-mechanisms/telescoping-clamps/1403
5. Tripod Feet, Image, Web, Accessed Febuary 10, 2016. http://www.bhphotovideo.com/c/product/326244-REG/Gitzo_G1410_130B3_G1410_130B3_All_Terrain_Shoes.html/prm/alsVwDtl
6. Explora. Tips on Upgrading to a Professional Video Tripod System, Image, Web, Accessed Oct. 21, 2015. http://www.bhphotovideo.com/explora/video/tips-and-solutions/tips-upgrading-professional-video-tripod-system
7. Stainless Supply. 6061-T651 Aluminum Plate, Image, Web, Accessed Oct. 21, 2015. https://www.stainlesssupply.com/order-metal-online/docs/g3c1067s58ss0p0/6061-T651-Aluminum-Plate.htm
8. Manwell, McGowan and A.L. Rogers. *Wind Energy Explained: Theory, Design and Application, 2nd Ed.* West Sussex, UK: John Wiley & Sons Ltd., 2009. PDF, pg 140.
9. WindyNation. 28in HyperSpin Aluminum Wind Turbine Generator Blades, Image, Web, Accessed Oct. 21, 2015. http://www.windynation.com/Blade-Sets/28-inch-HyperSpin-Aluminum-Wind-Turbine-Generator-Blades-Set-of-5/-/651?p=YzE9NQ
10. Peerless Wind Systems Corporation. The Art of Wind, Image, Web, Accessed Oct. 21, 2015. http://www.peerlesswindsystems.com/
11. PresenterMedia. Running Up Arrow Stairs, Image, Web, Accessed Oct. 21, 2015. http://www.presentermedia.com/index.php?target=closeup&maincat=clipart&id=5692
12. http://www.hurricanewindpower.com/permanent-magnet-alternator-low-wind-pma-rpm/
13. https://genasun.com/all-products/solar-charge-controllers/for-lithium/gv-5-li-lithium-5a-solar-charge-controller/

Questions?

Appendix

Calculations

Overturning Equations

- If and the over turning axis is the minimum distance,
  -
- If and the over turning axis is over the extended foot,
  -

Maximum Angle of Legs (Phi)

To still account for a 15 degree slope and have 28 inch leg segments

- 2 axis that could require slop adjustment
  - A. 2 legs parallel on slope with one extended away
    - Maximum angle: 55.44 degrees
  - B. 1 leg on slope with other 2 legs extended away
    - Maximum angle: 60.45 degrees
- Neither calculation accounted for the additional leg length caused by:
  - Need for welded piece to exceed 2”
    - Right now accounting for complete overlap. Will not be.
  - Feet adding to the 56 inch leg length
- Additional leg length causes slightly lower maximum angles of legs
  - Since the adjustable part remains constant at 26 inches.
- Max angle if actual leg length increases 2 inches to 56 inches:
  - A. 53.80 degrees
  - B. 59.13 degrees
- Conservatively, choose 50 degrees
  - Tripods on the market use 30 degrees as their angle.

Maximum Angle of Legs (Phi) Equations

- A. $$\frac{3 \times L \times \sin\left(\tan^{-1}\left(\frac{\tan \phi}{2}\right)\right) \times \tan \theta \times \sin(90-\theta)}{\sin\left(90+\theta-\tan^{-1}\left(\frac{\tan \phi}{2}\right)\right)} = \Delta L$$

- B. $$\frac{3 \times L \times \sin(\phi) \times \tan \theta \times \sin(90-\theta)}{\sin(90+\theta-\phi)} = \Delta L$$

Failure of Members

- *Due to Stress*

- Due to Buckling

- Variables
    -
    -
    -

Failure of Legs Equations

- Stress:
- Buckling:

Failure of Neck Equations

- Bending
  - $\sigma_{Neck} = \left(\frac{(H - L \cos \phi) F_W \frac{d_0}{2}}{\left(\frac{\pi \left(d_0^4 - d_i^4 \right)}{64} \right)} \right) + \left(\frac{4 W_N}{\pi \left(d_0^2 - d_i^2 \right)} \right)$
- Buckling
  - $W_{Max} = \frac{\pi^2 EI}{k^2 {L_{neck}}^2}$

‘Bump’ Displacement

- Where the Nacelle is ‘bumped’ and is offset a distance.
  - Checked against overturning

- Maximum offset ‘bump’ distance under normal conditions:
  - 15.55 inches (at center of nacelle)
    - 8 inches was goal
    - Equivalent to having the turbine on a 9 degree sloped surface (max slope under normal conditions)

Shear Calculations

- $\tau = \frac{V}{A}$
- Due to Pins on Tube
  - Negligible
  - $\tau_{tube} = \frac{V}{d_0 L_{leg\ seg.}}$
- Due to Tube on Pins
  - Still Negligible, though significantly larger, depending on selected pin size.
  - $\tau_{pin} = \frac{V}{\left(\frac{\pi\left(d_0^2 - d_i^2\right)}{4}\right)}$