

EML4552 – Team 15 – 03/15/16

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Portable Wind Turbine

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Overview

- Project Scope and Objectives
- Wind Turbine Base
 - Modeling
 - Analysis
- Base-Nacelle Connection
- Nacelle Design
- Electrical Components
- Turbine Blades and Mounting
- Portable Turbine Packaging
- Budget Overview
- Moving Forward
 - Schedule
 - Remaining Work



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 (~9 mph) at an approximate height of 2m
 2. Lightweight (80 lb max)
 3. Easy to assemble and disassemble
 4. Prototype (Budget of \$2,000)
 5. Power output of 5W

Turbine Body- Design

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

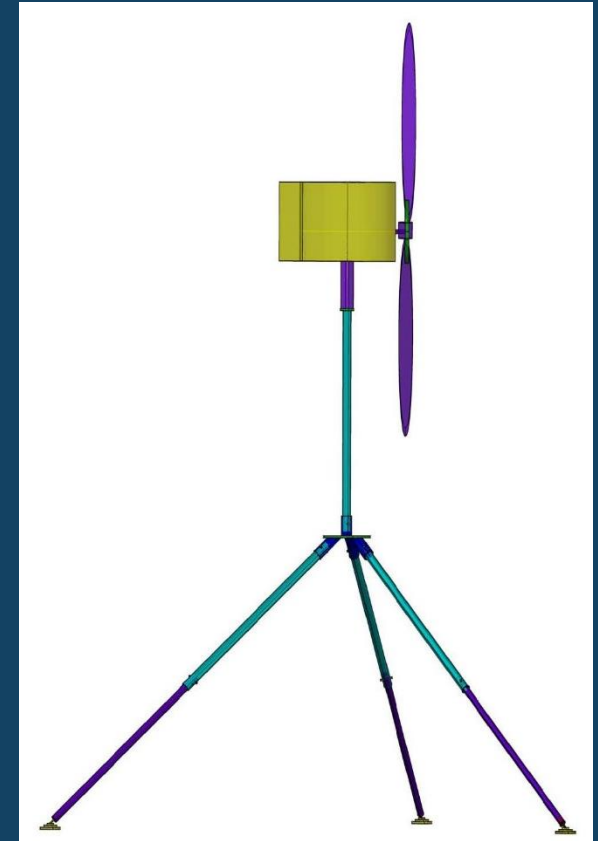


Figure 1. Turbine Base Design

Turbine Body- Parts

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

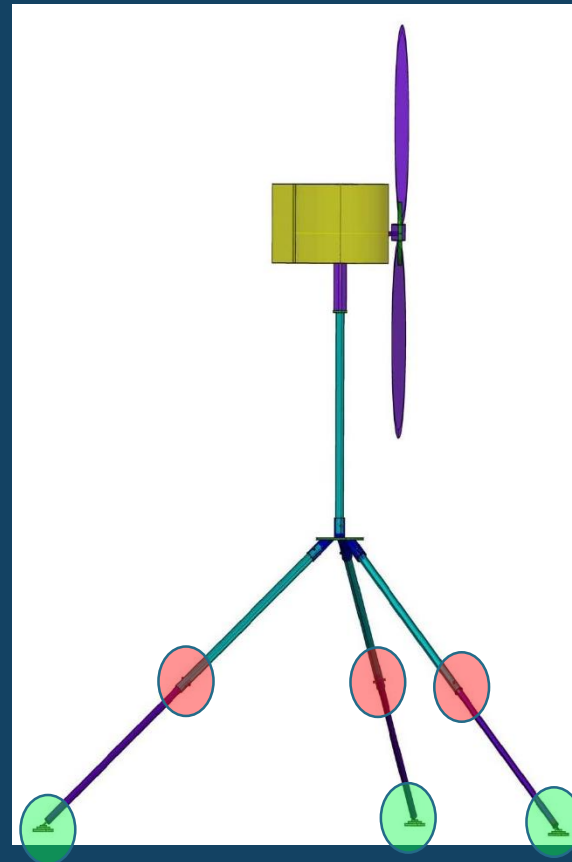


Figure 2. Part location



Figure 3. Tube Clamp



Figure 4. Base Feet

Plate Connecting Legs and Neck

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

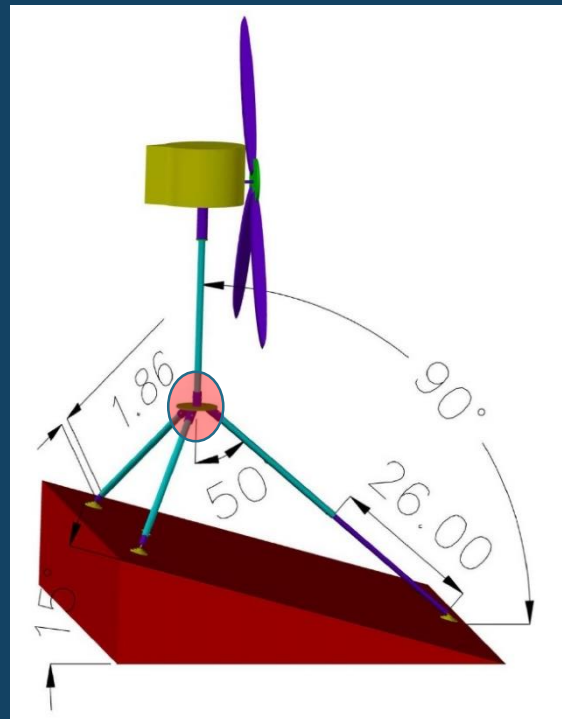


Figure 5. Angle of Legs

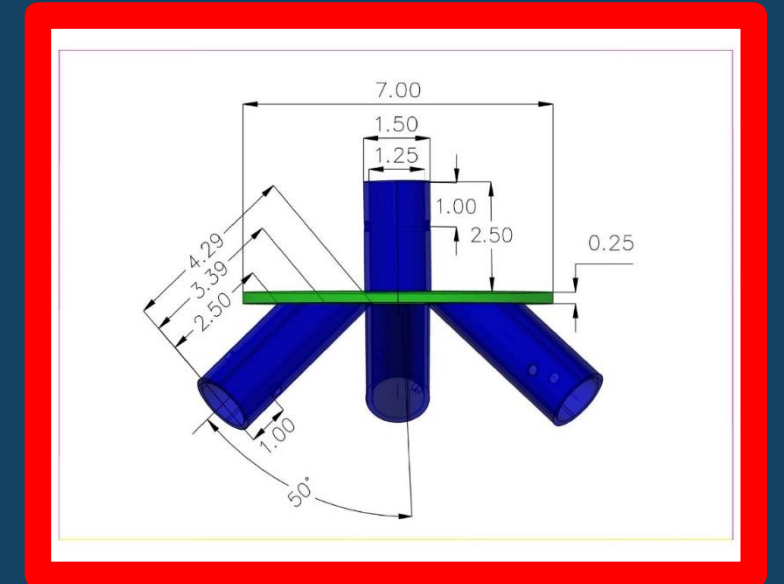


Figure 6. Leg and Neck Connection

Turbine Body- Calculations

- Bending and Axial Stress

- RISA: Case 1: 9.71 ksi

- Case 2: 4.79 ksi

- Hand: Case 1: 6.98 ksi

- Case 2: 2.86 ksi

- Buckling

- Negligible

- Shear

- Negligible

RISA 3D Images

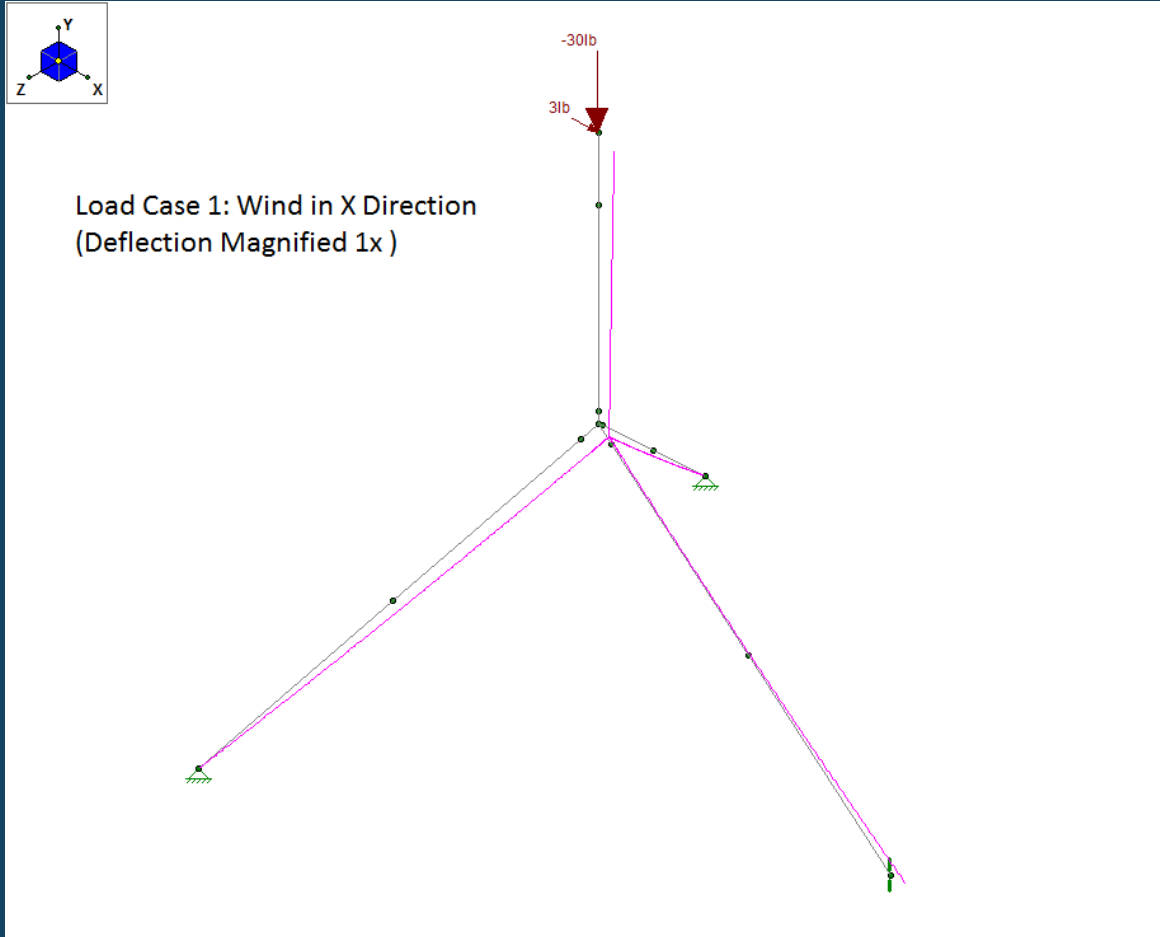


Figure 7. Load case 1

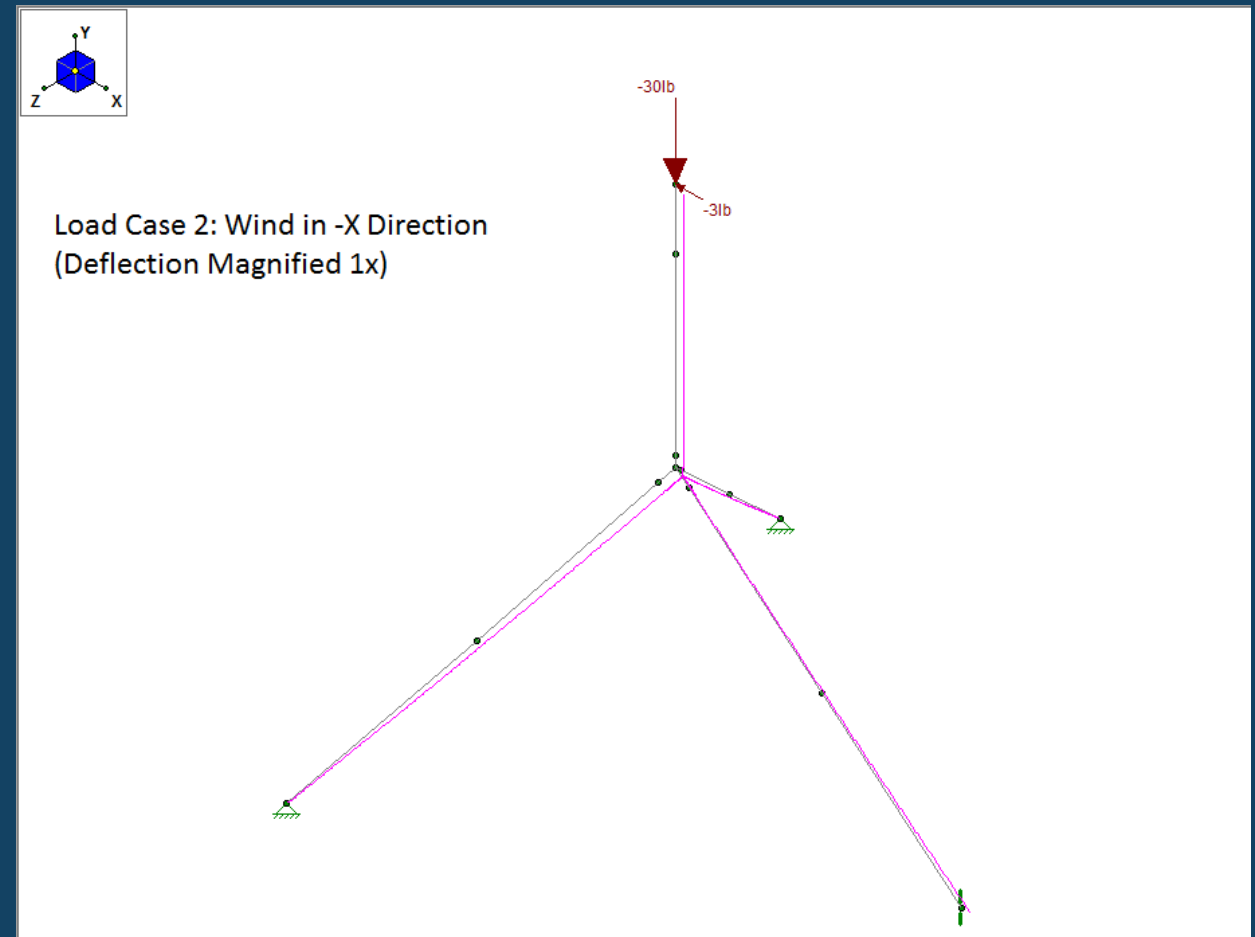


Figure 8. Load case 2

Turbine Body- Overturning

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

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

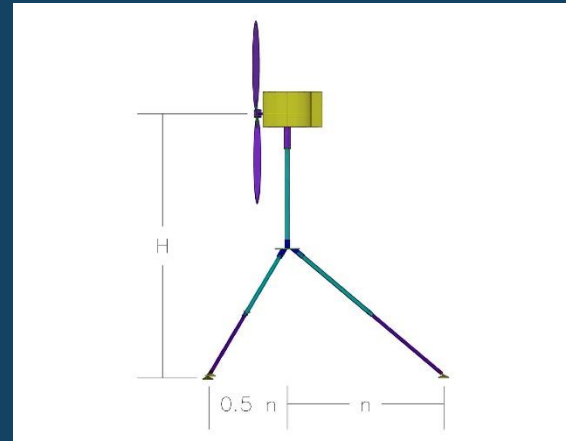


Figure 9. Overturning Case 1

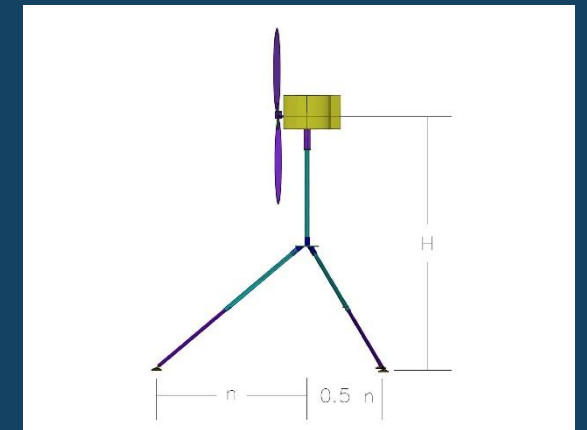


Figure 10. Overturning Case 2

Turbine Body- Bump Displacement

- Failure: 15.5 inches
 - (Angle of 9 degrees)
- Assumed: 8 inch max
 - (Angle of 5.86 degrees)

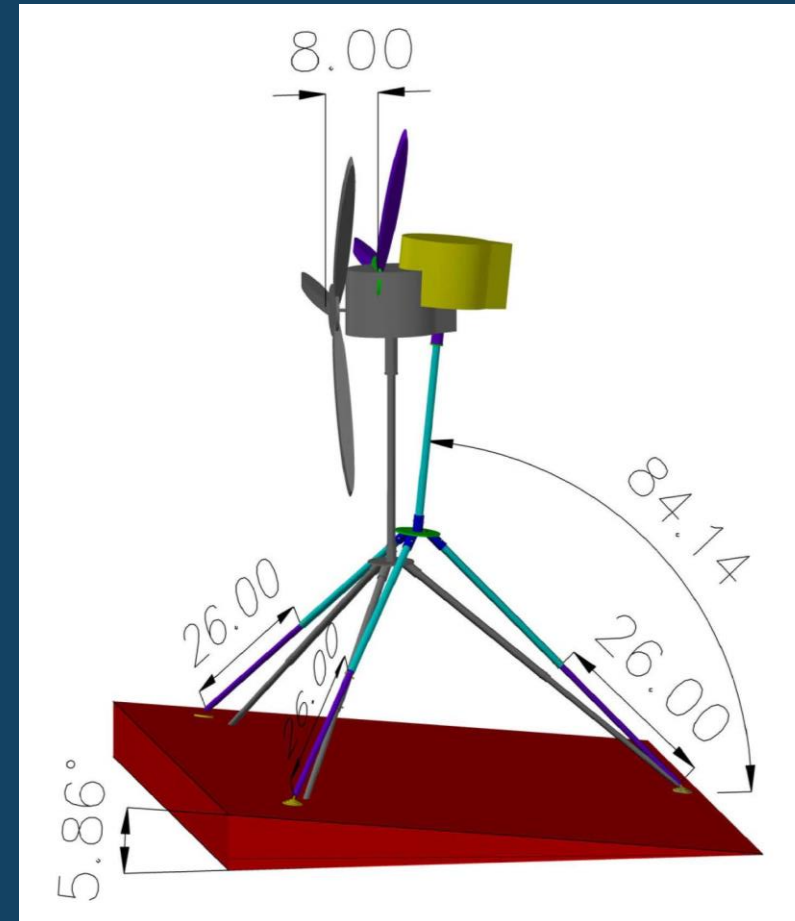


Figure 11. Bump Displacement

Nacelle Mounting

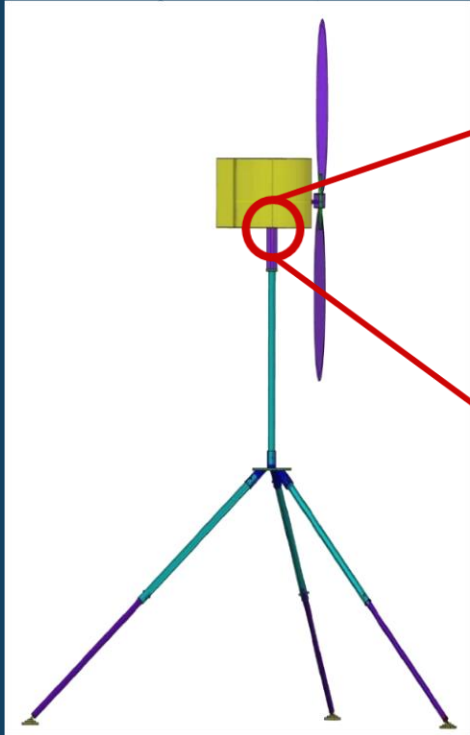


Figure 12. Location on Turbine



Figure 13. Quick Release

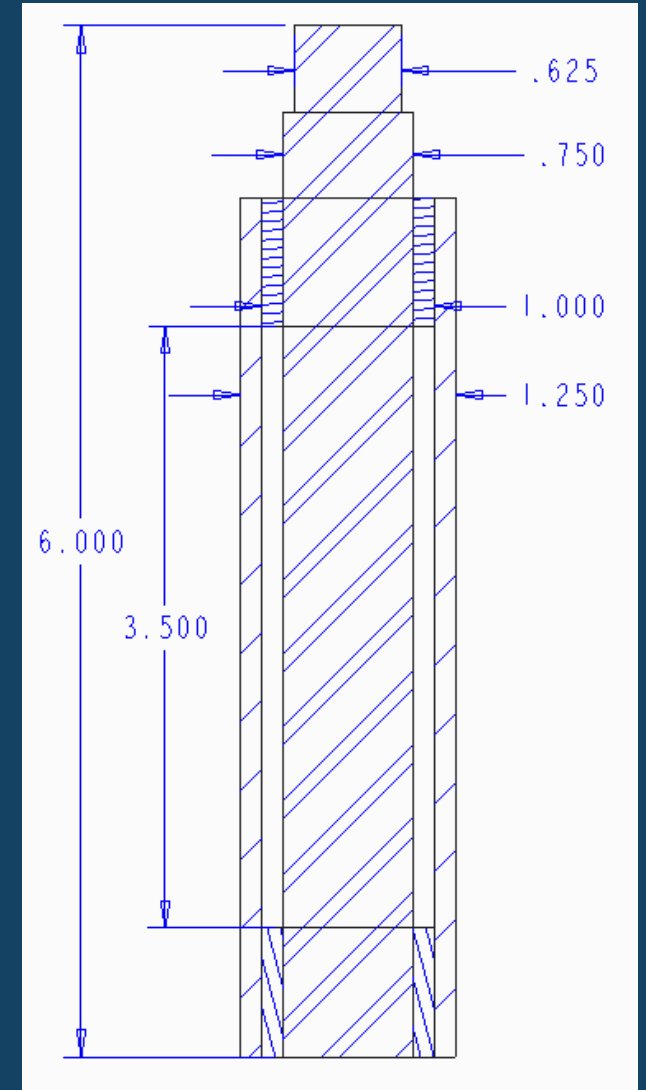


Figure 14. Section View (dimensions in inches)

Nacelle

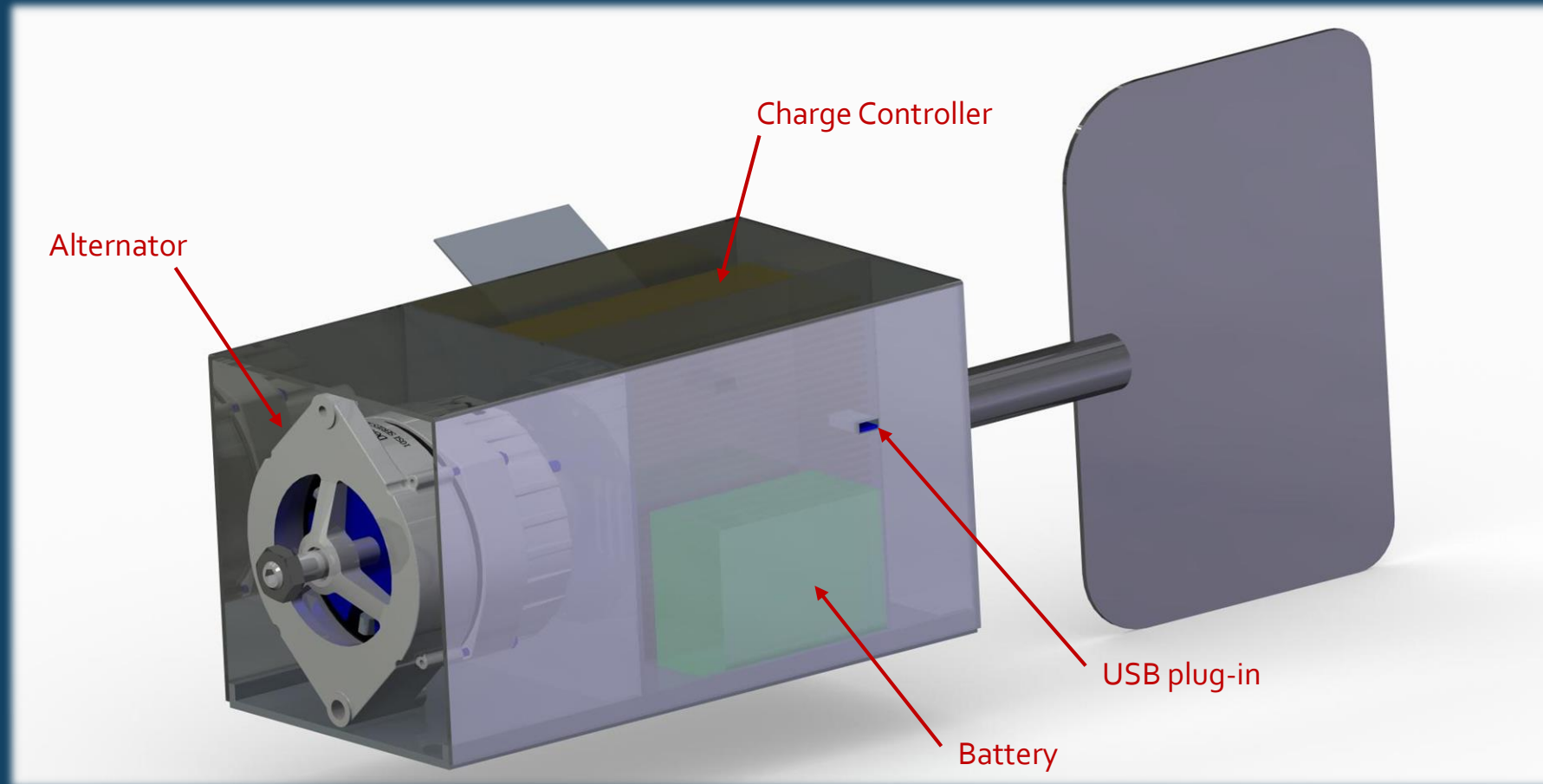


Figure 15. View of the left side of the nacelle with the major electrical components labeled

Nacelle

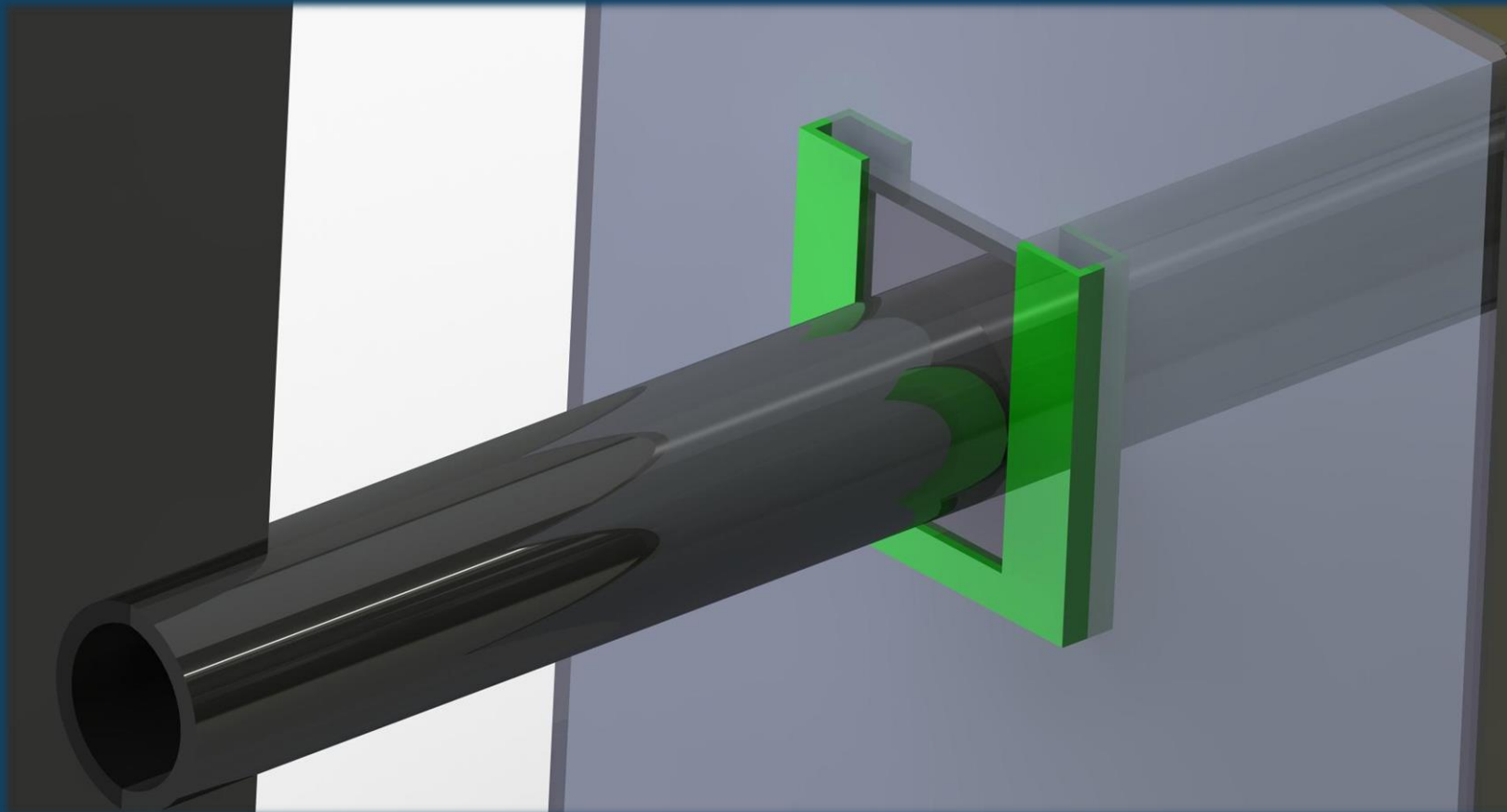


Figure 16. View of the rear of the nacelle showing the mounting slot for the tail vane

Nacelle

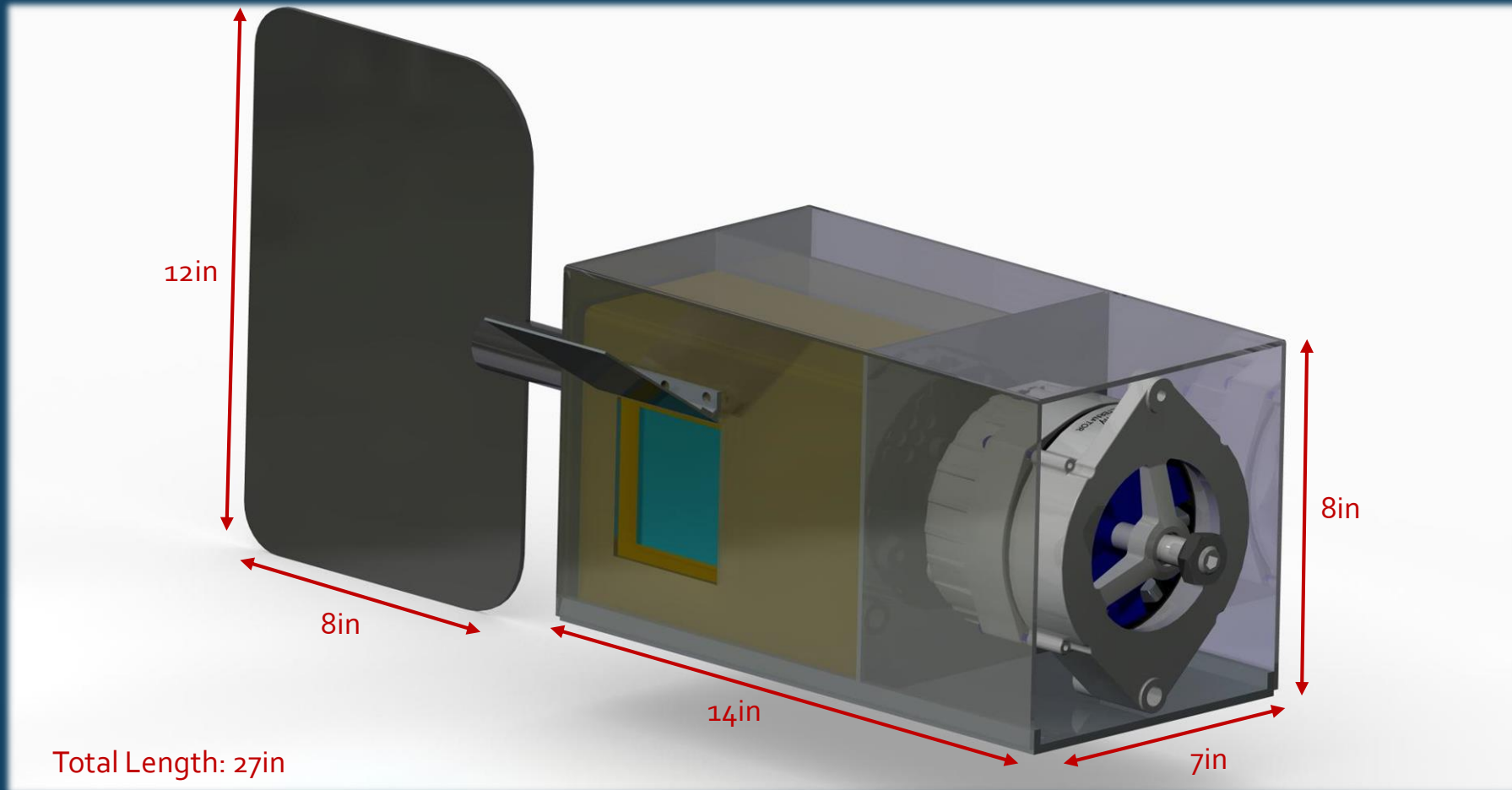
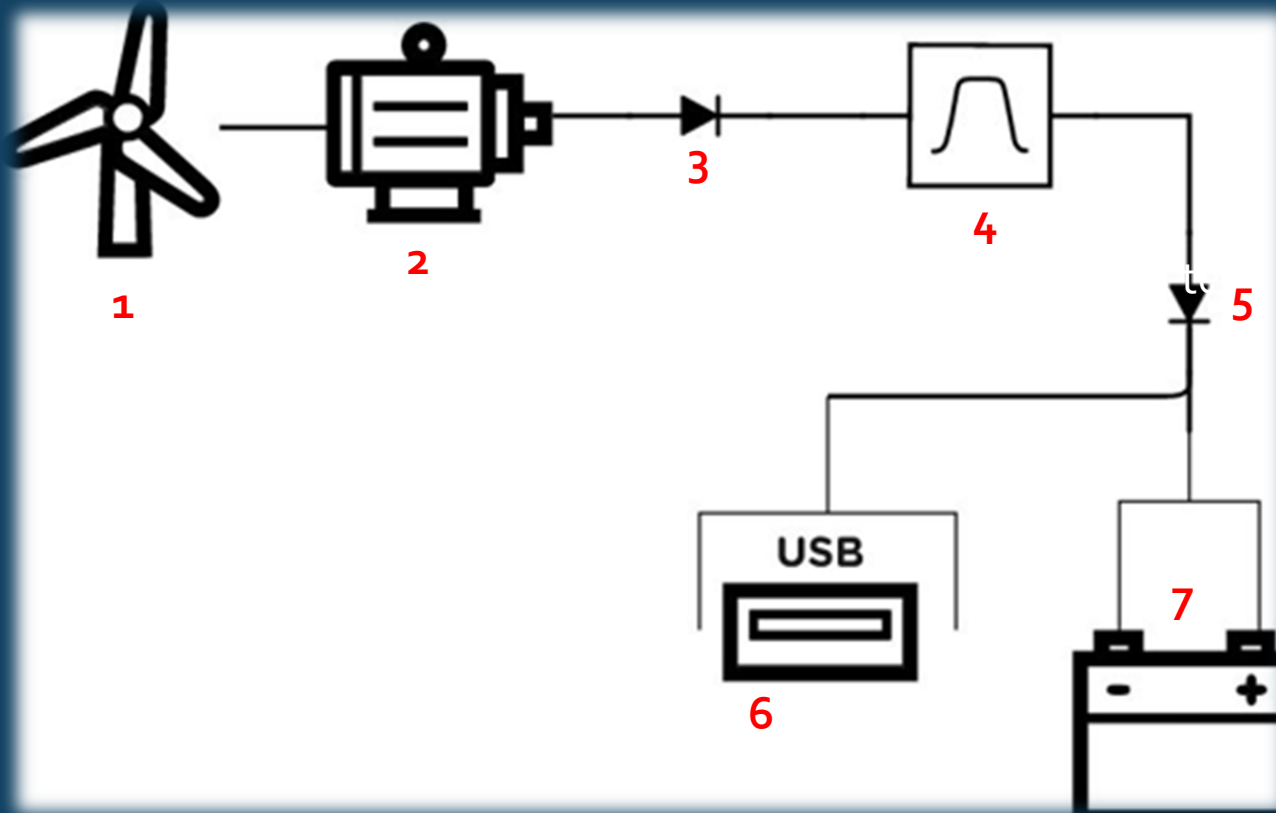


Figure 17. View of right side of the nacelle with major dimensions denoted

Electrical Diagram



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

Figure 18. Diagram of the major electrical components of the turbine.

Electrical Components

- Charge Controller
 - WindyNation TrakMax 30L 12V Charge Controller Regulator
 - Maximum Power Point Transfer
 - LCD Screen
 - User Friendly
- Battery
 - Battery Tender- 12V Lithium Iron Phosphate



Figure 19. Charge Controller



Figure 20. Battery

Blade Mounting

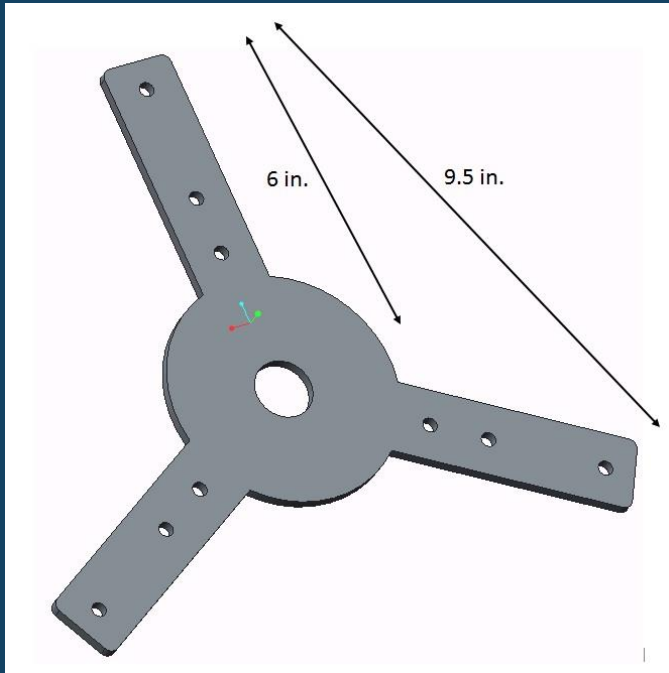


Figure 21. Blade mounting hub

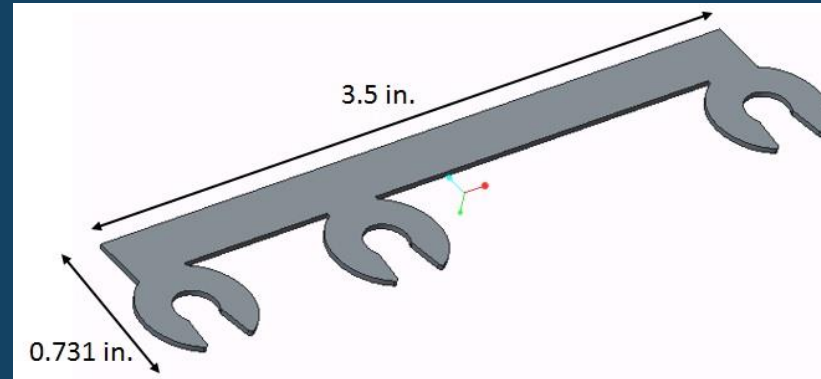


Figure 22. Clip to secure blades

- Hub plate will be made using water jet
 - Pegs/shafts will be welded into holes on hub, Hardened Steel 8620
 - E-clip for shafts requires further modification
- Handle
Openings on face

Blade Mounting

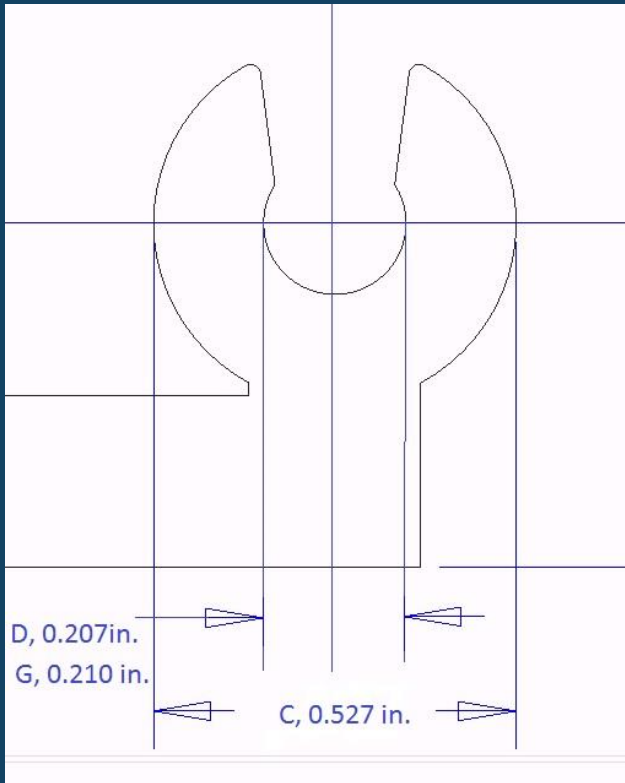


Figure 23. Clip dimensions

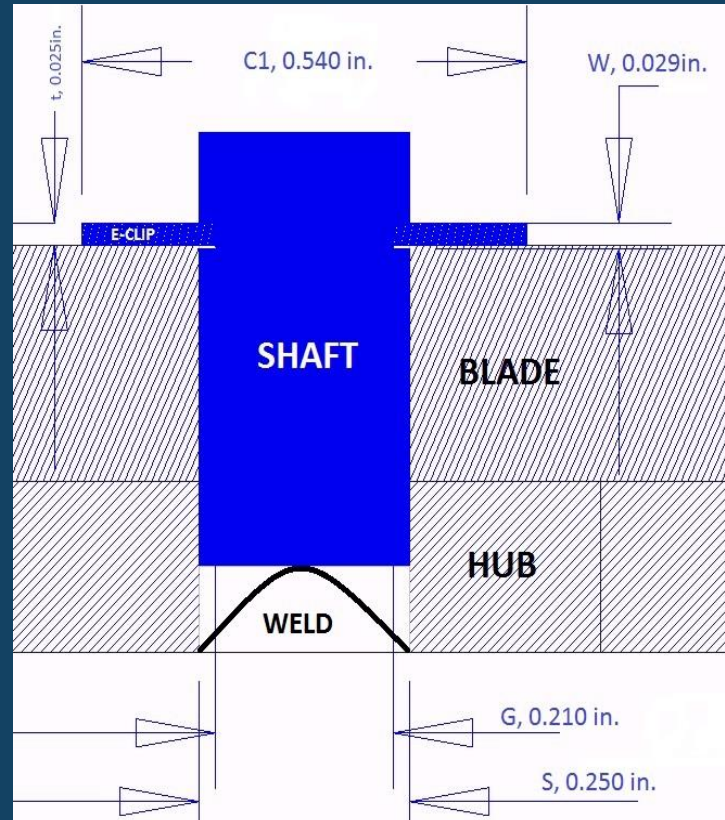


Figure 24. Hub section view

- Retaining clip, is e-clip style
- Designed based on engineering specifications for a 0.250 in. mounting shaft.
- Load Capacities
 - P_r , max ring thrust load
 - P_g , max groove thrust load
- Rotational
- Impact
- Edge Margin Calculation
- Installation Stress

Turbine Blades

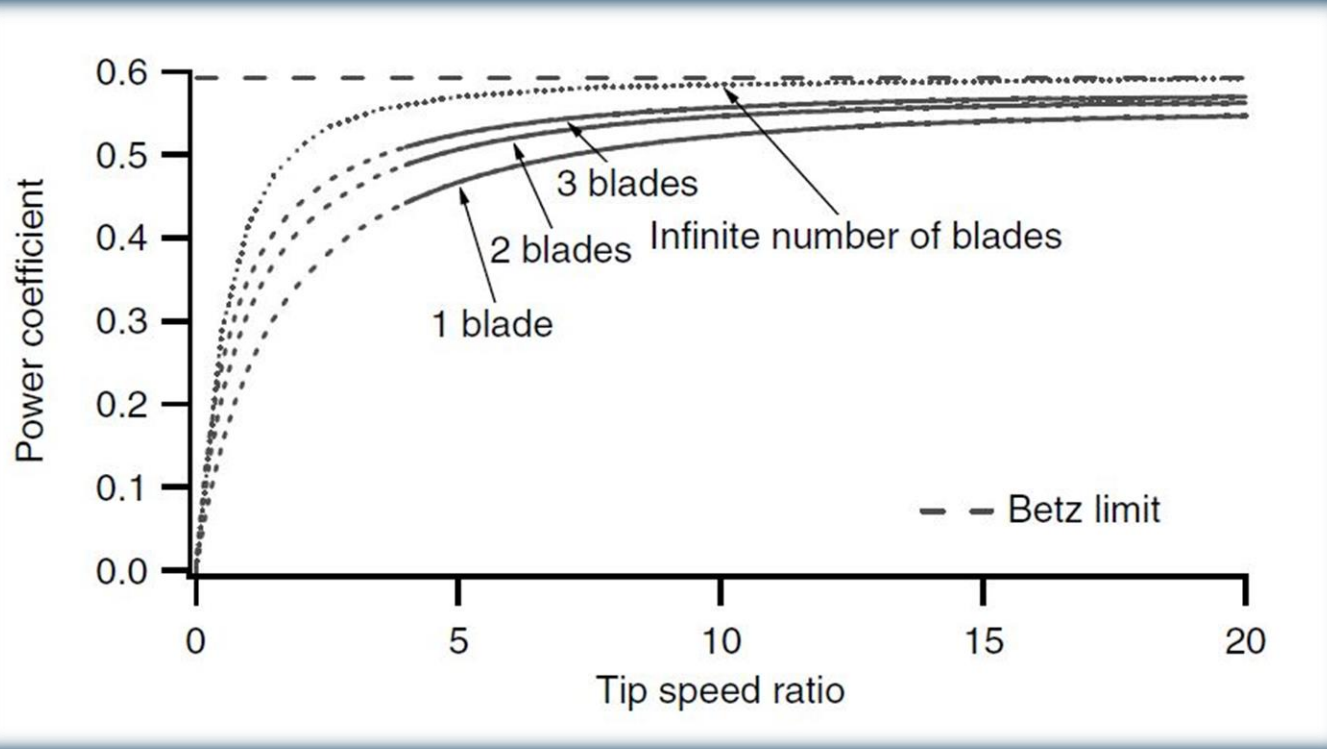


Figure 25. Power coefficient vs. TSR

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

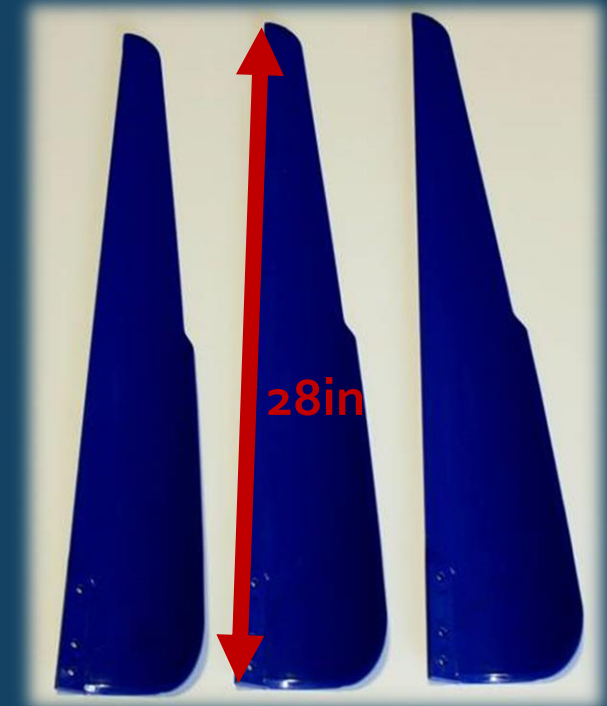


Figure 26. Selected blades.

Packaging



Figure 27. Packaging concept

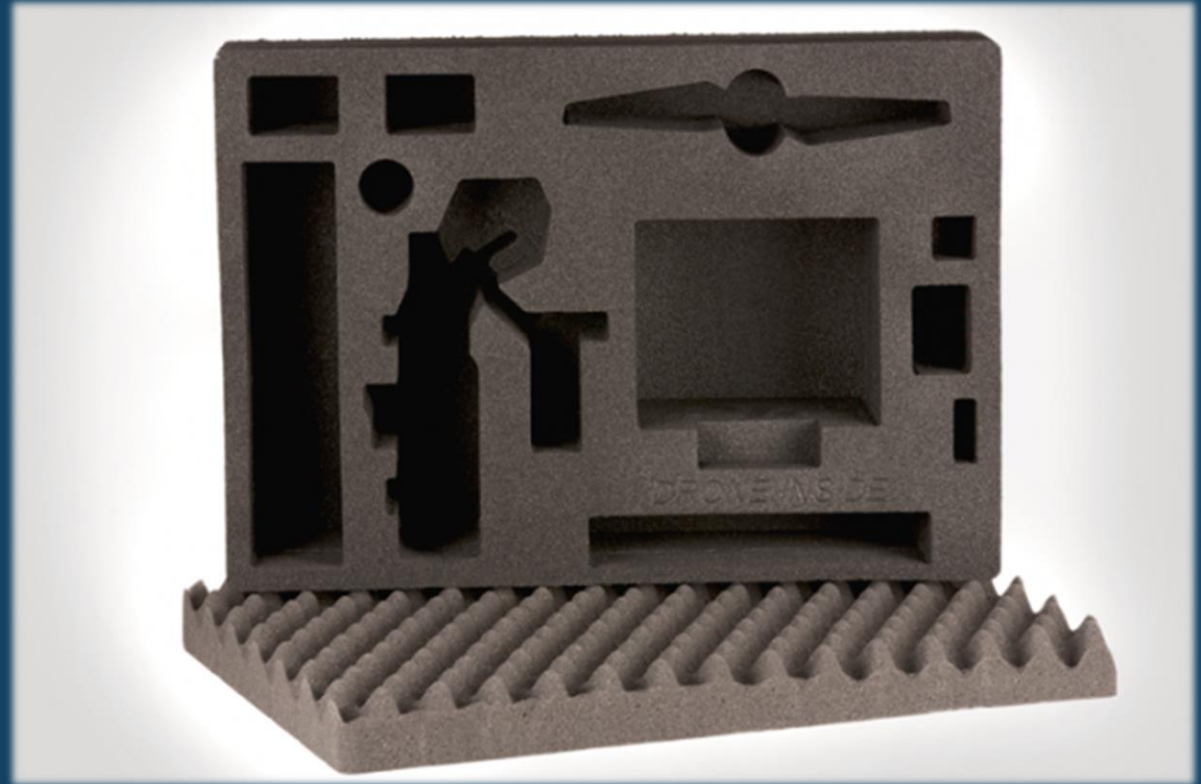
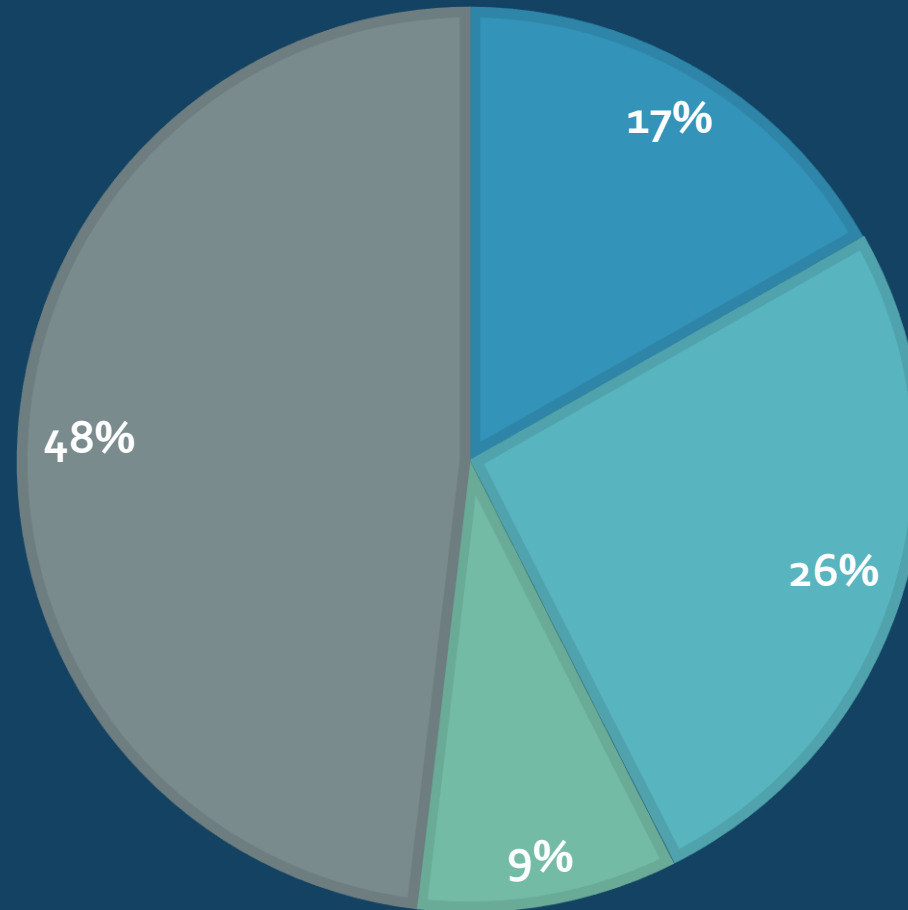


Figure 28. Packaging concept interior

Budget

PORTABLE WIND TURBINE BUDGET

■ Body ■ Electrical ■ Nacelle ■ Remaining



Moving Forward

- Finalize nacelle design
- Complete packaging design
- Submit final work orders to machine shop
- Receive parts from machine shop
- Complete assembly
- Test turbine



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Questions?

Appendix

Calculations

Overturning Equations

- $W_{Min} = \frac{2F_W H}{L \sin \phi}$

- $F_W = \frac{W_T L \sin \phi}{2H}$

- If $W_T = 30lb$ and the over turning axis is the minimum distance,
 - $F_W = 6.55 \frac{m}{s}$ (14.7 mph)
- If $W_T = 30lb$ and the over turning axis is over the extended foot,
 - $F_W = 9.26 \frac{m}{s}$ (20.8 mph)

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*

- $\sigma = \sigma_{Axial} + \sigma_{Bending}$

- $\sigma_{Axial} = \frac{F}{A}$

- $\sigma_{Bending} = \frac{Mc}{I}$

- *Due to Buckling*

- $P_{cr} = \frac{\pi^2 EI}{k^2 L^2}$

- *Variables*

- $E_{alum} = 10,000 \text{ ksi}$ $\sigma_{y_{alum}} = 35 \text{ ksi}$

- $k_{neck} = 2.0$ $k_{leg} = 0.7$ $c = \frac{d_0}{2}$

- $L_{leg} = 26 \text{ inches}$ $L_{neck} = 26 \text{ inches}$

$$I_{pipe} = \left(\frac{\pi(d_0^4 - d_i^4)}{64} \right)$$

Failure of Legs Equations

- Stress:

- $$\sigma_{legsroller} = \left(\frac{\left(W_T + 2FW \frac{H}{L \sin \phi} \right) L \sin \phi \frac{d_0}{2} \frac{64}{\pi(d_0^4 - d_i^4)}}{3} \right) + \left(\frac{4 \left(W_T + 2FW \frac{H}{L \sin \phi} \right) \cos \phi}{3\pi(d_0^2 - d_i^2)} \right)$$

- $$\sigma_{legspin} = \left(\frac{\left(F_W \cos \phi - \left(W_T + 2FW \frac{H}{L \sin \phi} \right) \sin \phi \right) L \frac{d_0}{2} \frac{64}{\pi(d_0^4 - d_i^4)}}{3} \right) + \left(\frac{4 \left(W_T + 2FW \frac{H}{L \sin \phi} \right) \cos \phi}{3\pi(d_0^2 - d_i^2)} \right)$$

- Buckling:

- $$W_{Max} = \frac{\left(\frac{\pi^2 EI}{k^2 L_{leg\ seg.}^2} \right) - \left(\frac{2FW}{3 \sin \phi} \right)}{3 \cos \phi}$$

Failure of Neck Equations

- Bending

- $$\sigma_{Neck} = \left(\frac{(H-L \cos \phi) F_W \frac{d_0}{2}}{\left(\frac{\pi(d_0^4 - d_i^4)}{64} \right)} \right) + \left(\frac{4W_N}{\pi(d_0^2 - d_i^2)} \right)$$

- 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

$$• W_{Min} = \frac{F_W \left(H \cos \theta + \frac{L}{2} \sin \phi \sin \theta \right)}{\left(\frac{L}{2} \sin \phi \cos \theta - H \sin \theta \right)}$$

$$• F_{W_{Max}} = \frac{W_T \left(\frac{L}{2} \sin \phi \cos \theta - H \sin \theta \right)}{\left(H \cos \theta + \frac{L}{2} \sin \phi \sin \theta \right)}$$

$$• \theta = \sin^{-1} \left(\frac{\text{Offset Distance}}{H + \frac{L}{2} \sin \phi} \right)$$

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.
 - $\tau_{pin} = \frac{V}{\left(\frac{\pi(d_0^2 - d_i^2)}{4}\right)}$