Final Report: Interim Design

Team 15

Portable Wind Turbine

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Abstract

This report outlines Team 15's progress in the development of a portable wind turbine for use in situations such as disaster relief, military applications, research and recreational activities. The project sponsor is Dr. Sungmoon Jung, who is also the group's primary advisor. The goal of this project is to focus on the portability aspects of the turbine design, with a lesser focus on the power generation abilities of the turbine. With this in mind, the team has the objective of generating enough power to charge a small electronic device, such as a phone, but is not necessarily focused on the efficiency of the power generation. Other constraints outlined by the project sponsor are that the rotational axis of the wind turbine blades must be no higher than 2m (6.56ft) off the ground when fully assembled and that the turbine should be able to operate using wind speeds of 4m/s (8.95mph). The budget for the project is $2,000 which will be used for construction of a prototype in the spring semester.

1. Introduction

Wind energy is defined as the process in which wind is harnessed to generate mechanical power which is then turned into electricity. The first wind turbine company in the United States was established in 1850. The first windmill was the Halladay Windmill, which was designed for the landscape of the American West. In 1890 more than six million windmills had been erected throughout the countryside of the United States. Wind power made it possible for farmers and ranchers to pump water for irrigation and provide electricity for homes and businesses. Fast-forwarding, the National Wind Technology Center was established in 1993, becoming the nation's premier wind energy technology facility. By 2012 the United States installed wind turbines had a power generation capacity of 60 gigawatts, enough to power approximately 15 million homes.[1]

As time progresses, the need for alternative energy sources becomes more imperative as the amount of nonrenewable energy resources, such as fossil fuels and natural gases, continue to decrease. These nonrenewable energy resources are not only limited but also contribute greatly to global carbon emissions. There are various forms of alternative energy including wind, solar, and biomass, which are often referred to as renewable energy resources. Wind energy has been the world's fastest growing source of electricity generation since the 1990s, according to the U.S. Department of Energy. Wind energy is beneficial since it produces no emissions, it does not deplete over time, and it has energy price stability. The focus of this report is on wind energy that will be collected and converted for power generation through use of a portable wind turbine.

A wind turbine functions in the same manner that a steam turbine would, with rotation being the essential factor. Generally a wind turbine will have blades that are attached to an input shaft and once wind blows past the blades, it will cause rotation of the turbine which is connected a generator. A generator produces power through utilization of a magnet and copper coil. Once the magnet rotates in the coil magnetic induction occurs and power can be produced. Average wind turbines output power ranging from 1-3.5 MW, with blade lengths up to 164 ft. (50m), and average tower heights of 200 ft. (60m).

The task has been given to design a portable wind turbine in order to further investigate the application of wind turbines and their practical use. As previously mentioned wind energy is a growing source of electricity, by making wind energy portable there emerges an alternative method of electricity generation in large scale mobile machinery, such as automobiles and aircrafts. In order to accomplish the given task students from both the Mechanical and Civil Engineering disciplines will work in conjunction to design the portable wind turbine. This report entails past and current and future project objectives.

The objective of this project is to create a lightweight, portable wind turbine capable of supplying power in remote, rural areas. The main focus of the design is that it must be highly portable and easy to assemble and disassemble so that inexperienced operators may use the device. In addition the assembly and disassembly of the design must be safe for the operator. Because of these restraints, the design must be able to generate power using 4m/s winds at a maximum height of only 2m. The sponsor of the project has allotted $2,000 for the turbine design and construction

2. Project Definition

2.1 Background Research

There are many ways to harness wind energy and take advantage of this natural resource. A portable wind turbine would be a convenience to people who are camping outdoors in places without outlets. The portable wind turbine can also be used for military applications. The most important aspect of the portable wind turbine is to create a convenience to the consumer with a green way of producing energy. The portable wind turbine will be able to generate enough power to charge small devices. Only one current development example exists. The Trinity wind turbine, is a small portable wind turbine that generates about 15 watts in 10 m/hr winds and weighs only 1.4lbs. Not only is the Trinity a one of a kind portable wind turbine but it is also easy to assemble and cheap to buy. This is a good example of the goal for the new portable wind turbine that will be designed by Team 15.[2]

Although portability is harder to find, Team 15's background research has shown that a variety of small wind turbines already exist and can provide relatively substantial amounts of power. Targeting their research towards existing turbines that are priced closest to their $2,000 budget constraint, Team 15 found useful information on four miniature wind turbines. Three of these turbines are developed by Southwest Windpower, while a fourth is by AeroVironment. Comparisons of relevant information for each of the turbines are given in Table 1.

Table 1. Comparison of existing, miniature wind turbines.[3,4,5,6]

Model	***Weight***	***Price***	***Spin Up Wind Speed***	***Power Output (~4$\frac{m}{s}$ Wind)***
Southwest Windpower Skystream 3.7	70kg	$5,399	3.5$\frac{m}{s}$	200W
Southwest Windpower Air X	6kg	$1163	3.13$\frac{m}{s}$	250W
Southwest Windpower Whisper 500	70kg	$7,095	3.4$\frac{m}{s}$	500W
AeroVironment Architectural Wind	59kg (Each)	$134,400 (Incl Install)	2.2$\frac{m}{s}$	25W (Each)

Southwest Windpower's "Xzeres" Skystream 3.7 is a three-bladed, downwind turbine designed and built for grid-connected residential use. The Skystream 3.7 has a blade diameter of 3.72m (12ft) and sweeps an area of 10.7m^2 (115.7ft^2). The rotor speed is maintained at 50-325rpm during operation using electronic stall regulation with a redundant switch control braking system. Using built in controls and inverters, a gearless alternator and a slotless, brushless permanent magnet, this wind turbine produces energy at an advertised average cost of $0.99/kWh. The Skystream 3.7 is rated for 2.1kW with 11$\frac{m}{s}$ winds and has a maximum power of 2.6kW. The manufacturer includes a five year warranty for the Skystream 3.7.[3]

Much smaller than the Skystream 3.7, Southwest Windpower's Air X is the world's best-selling small wind turbine and includes a three year warranty from the manufacturer. This 3-blade turbine uses a neodymium alternator and with a diameter of 1.14m (46in) sweeps an area of only 1.64m^2 (17.6ft^2). Using an electronic torque control braking system, the Air X keeps the rotor under 900rpm during operation. This turbine has both a rated and peak power output of 400W at wind speeds of 12.5$\frac{m}{s}$.[4]

The Southwest Windpower Whisper 500 is a somewhat atypical turbine design in that it uses only two blades. With a diameter of 4.5m (15ft) these blades sweep over an area of 16.4m^2 (175ft^2). The Whisper 500 has a rated power of 3kW at 10.5$\frac{m}{s}$ and a peak power output of 3.2kW at 12$\frac{m}{s}$.[5] This system is designed for off-grid use and regulates its speed using a combination of mechanical over speed protection and side-furling. Southwest Windpower offers a five year warranty for the system and recommends professional installation.[7]

Designed to take advantage of the wind profiles created by building walls in urban settings, the AeroVironment Architectural Wind uses a five bladed design. These blades create a diameter of approximately 1m (3ft) and each turbine has a rated power of 1kW. One distinguishing feature of the AeroVironment design is that its systems are sold in arrays of 12 turbines and includes installation. Aesthetic turbine hoods can be added for an additional price.

The location of where a wind turbine is placed is crucial to generate enough power to operate efficiently. Different areas around the world experience different wind speeds at different heights due to vegetation, construction, and local wind patterns. Team 15's portable wind turbine is designed to operate at wind speeds of around 4m/s (8.95 mph). Because of the portability factor, this wind turbine is to have a height of 2 meters. Team 15 researched areas around the world where this product can be marketed and used efficiently to generate enough power to charge small devices. Figure 1 displays the average wind speeds around the globe at 80 meters from the ground surface.

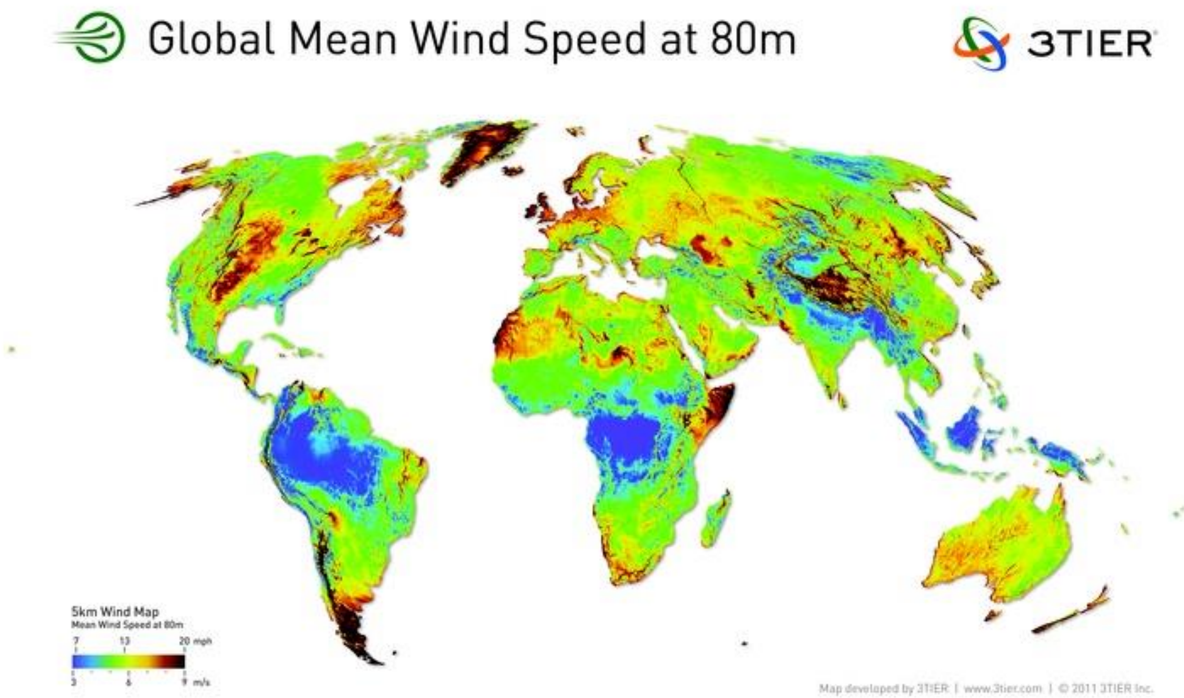

Figure 1. Global wind speeds.[8]

Wind speed increases with height in a logarithmic fashion. Because of this, the wind at 2 meters off the ground is much less than the speeds at 80 meters. Equation 1 below is the log wind profile ratio and represents what the velocity at height 1 would be based on the velocity at height 2.

$$\boldsymbol{V_1 = V_2 \frac{\ln\left(\frac{Z_1}{Z_0}\right)}{\ln\left(\frac{Z_2}{Z_0}\right)}} \tag{1}$$

In the above equation, Z_2 is the elevation of the unknown wind speed. V_2 correlates with Z_2 and is the wind speed at that elevation. Z_1 is the elevation of the known wind speed. V_1 correlates with Z_1 and is the wind speed at that elevation. For this project, Z_1 is taken as 2 m, Z_2 as 80 m, V_1 as 4 m/s and V_2 will be the wind speed at 80 m off the ground. The last variable, Z_o, is the surface roughness length and is chosen based on the desired environment. Z_o was chosen based on a wind flow and landscape description of "rough", stating there are natural crops and obstacles such as buildings or mountains. Looking at these conditions, Z_o is considered 0.25 m. Since there is not an exact way to calculate the speeds around the globe at such a low altitude, the team decided to use the known average of 4 m/s at 2 meters off the ground to solve for what wind speeds to look for at 80 meters high. Using Equation 1, a wind speed of 11.1 m/s (24.8 mph) at 80 meters off the ground will correlate to a wind speed of 4 m/s at 2 meters off the ground. The yellow on the map shows areas where the average wind speed is 13 mph and the dark red shows areas of 26 mph. The red and orange coloring on Figure 1 displays areas around the world where Team 15's Portable Wind Turbine can be marketed and used efficiently. The yellow areas on the map display areas around the globe where the Portable Wind Turbine can sometimes be used if the wind speed is above the average for that area. However, if the terrain in the chosen area is more open, such as a desert or a beach, it is more susceptible to having higher wind speeds at a lower elevation due to minimal obstructions. Z_o for this type of open landscape is 0.03 m. Using the log wind profile ratio equation, the wind speed at 80 m off the ground correlating to a wind speed of 4 m/s at 2 m off the ground would be 7.5 m/s (16.8 mph). So for these landscapes and terrains, areas on the map designated by a green or yellow color would also have an optimal wind speed for Team 15's wind turbine to operate efficiently.

Team 15 took a closer look at where the wind turbine could operate efficiently in the United States. Figure 2. Average wind speeds in the United States at 80m shows the wind speeds in the U.S. at 80 m off the ground. Again, using the log wind profile ratio, the correlating wind speeds at this elevation were calculated against the 4 m/s wind speed at 2m off the ground. The regions in Figure 2. Average wind speeds in the United States at 80m designated by the purple coloring are areas with optimal average wind speeds. It was determined that the mountainous region in the center of the United States was the best location for wind speed for Team 15's wind turbine to operate efficiently.

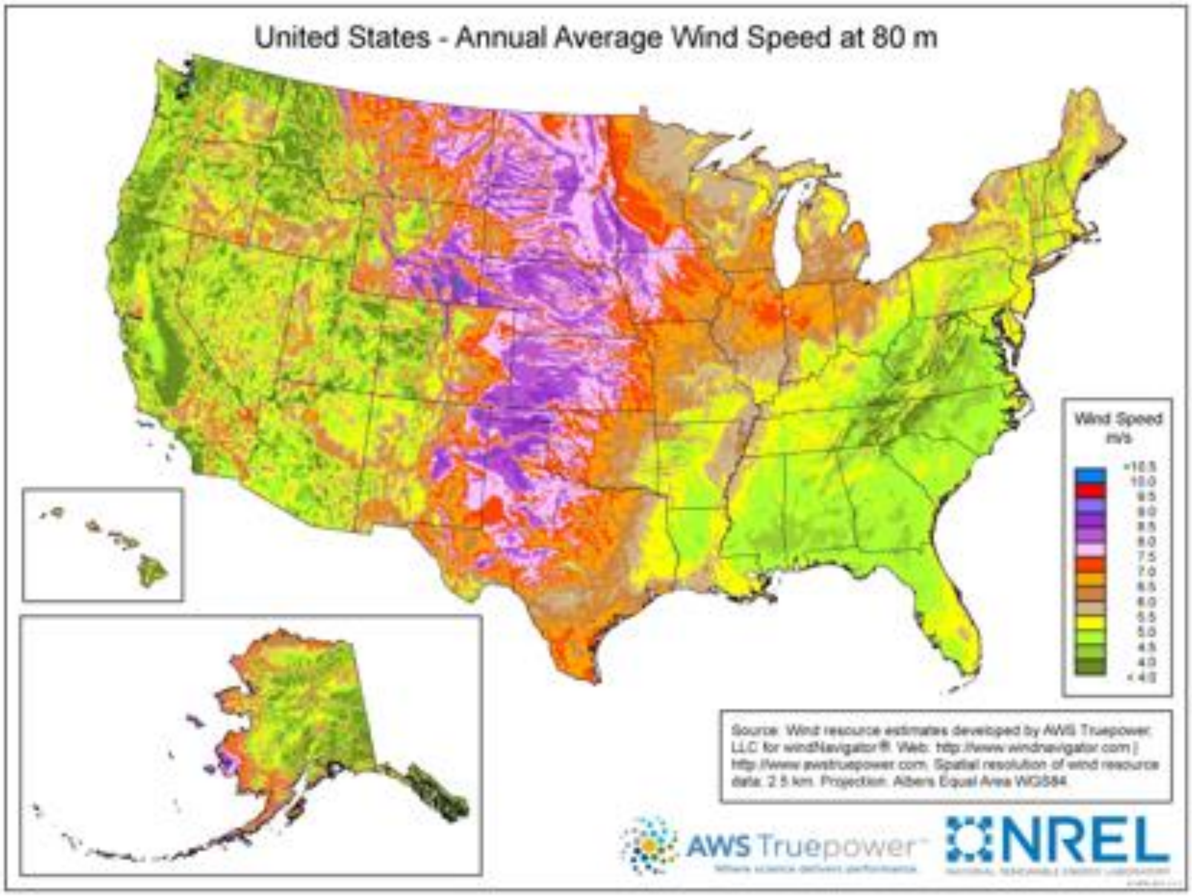

Figure 2. Average wind speeds in the United States at 80m[8]

2.2 Need Statement

Team 15 is designing a portable wind turbine for the sponsor, Dr. Sungmoon Jung. Dr. Jung desires that the team create a small turbine that can produce enough power to charge a small device, while being easy to transport. The turbine must operate in $4\frac{m}{s}$ winds, be lightweight, easy to assemble and disassemble, cost under $2000, and be able to handle a variation of wind and climate conditions at the height of two meters. There is a need for portable, renewable energy. Current small wind turbines cannot produce energy efficiently from $4\frac{m}{s}$ winds or be relocated easily.

2.3 Goal Statement & Objectives

Due to the fact that wind speeds are lower at ground level, the two meter, portable turbine will have to utilize energy from only four meter per second winds.

"Design a lightweight and portable wind turbine that may be easily assembled and produce enough energy at low wind speeds to charge a small device."

The objectives of this project are to design a wind turbine that meets the following criteria:

- Produce enough energy to charge a small device.
- Operate at lower wind speeds than current models.
- Assemble more easily than current models.
- Structurally stable on various surfaces and in various situations
- Light enough to allow easy transport.

2.4 Constraints

The following are the constraints for the project as defined by the sponsor. Team 15 will be utilizing skills gained in the courses taken in the College of Engineering to come up with the proper performance and design for the portable wind turbine.

- Must be easy to assemble and disassemble
- Structural stability in various locations with different terrains
- Lightweight for portability
- Operational in low wind speeds (4 m/s)
- Height of turbine will be no more than 2m

2.4.1 Design Specifications

The following are the design specifications for the portable wind turbine:

1. The turbine must operate in an average wind speed of 4 m/s at a maximum height of 2 m.
2. The design must be lightweight. Team 15 desires to keep the total weight under 80lbs
3. The design must be easy to assemble and disassemble.
4. The design has a maximum budget of $2,000.

2.4.2 Performance Specifications

The following are the performance specifications for the portable wind turbine:

1. The power output of the wind turbine will be a minimum of 5 watts.
2. The turbine will be able to handle a variation of wind and climate conditions.
3. The turbine will not break or overturn due to anticipated, reasonable conditions.
4. The turbine will generate enough power to charge a small device such as a cell phone.

3. Design and Analysis

3.1 House of Quality

For the design of this project, the team was given specific consumer requirements to abide by. Using these requirements the team developed engineering characteristics that strongly related to the requirements. As shown in the Appendix, Team 15's House of Quality shows a representation of how those engineering characteristics were quantified and related to the consumer requirements, which were also quantified and ranked. Team 15 felt cost to be the most important since the budget is at a strict $2,000. The engineering characteristics varied from size, to material type of different parts, to weight and weather resistivity. The House of Quality was a useful tool for the team to decide which characteristics were most important to focus on during design and analysis of the rest of the project. It is important to note that the house of quality was more utilized as a live document for most of the semester, being that most of the team started the semester off with little experience with wind turbines. As research was compiled and analysis of parts began to start, characteristics were updated and added as needed. The team has since finished the HOQ and is no longer a live document, but rather guidelines to follow throughout the rest of this project. The team found that based on the seven consumer characteristics determined, the three most important engineering characteristics to consider are weight, size, and the material type of the blades. Since the most important consumer characteristics to consider are portability, cost, and maintaining a power output of at least 5 watts, it makes sense that the three engineering characteristics to consider are the size, weight, and blade type.

3.2 Functional Analysis

The function of the portable wind turbine will be essentially the same as that of a full scale wind turbine. The force of the wind on the turbine blades will spin an input shaft, which will cause rotation of a shaft in a generator, producing power to charge small devices. However, the key difference between this project and typical wind turbine projects is that Team 15 is much more concerned with the portability and ease of use characteristics of the turbine as opposed to power output and power generation efficiency. This defining focus of the project was highly emphasized by the project sponsor. In order to improve the portability aspects of the design, Team 15 will be designing methods to allow the turbine to be quickly assembled and disassembled, as well as to allow the turbine to fit in as small a space as possible. The team is currently conducting research into the electrical components required for power generation, with the aid of several faculty advisors. The electrical component research will be discussed in more detail later in this report. Team 15 is also looking into the input RPM requirements of small scale generators in order to determine if power can be effectively generated without the use of a gearbox between the input shaft (connected to the turbine blades) and the generator shaft. Elimination of the gearbox would be ideal for this project since this would reduce the overall weight of the design and the main focus of the project is portability.

3.3 Design Concepts

In order to facilitate concept generation, Team 15 broke the brainstorming process for the portable wind turbine into three main categories: Blades, Body and Base. For each of these categories the team developed three concepts to consider. Although turbine blades are to be purchased “off the shelf”, the team needed to decide what type of blades to look for. The generator and nacelle of the turbine were not included in the brainstorming process. The generator was not included because, like the blades, it will be purchased as an “off the shelf” component. Team 15 is currently conducting research on generator types, sizes and efficiencies in order to select the best product for the project. The nacelle of the turbine was not included in the project because it is simply a housing for the generator and other electrical components as well as a mounting point for the blades of the turbine and thus is dependent on the final design of the other features of the turbine.

3.3.1 Turbine Blades

The first subsystem of the portable wind turbine considered by Team 15 was the blades of the turbine. For all of the concepts proposed, the team would need to develop their own method of mounting the blades to the input shaft of the turbine so that they could be easily and safely detached for transportation of the turbine. Standard wind turbine blades were the first and perhaps most obvious choice proposed by members of the team. Similar in shape to the blades seen on a full scale turbine, the standard turbine blade has one distinct advantage in that it is very commonly produced and easy to source. An example of this type of blade can be seen in Figure 3. An example of a standard turbine blade design.[7]

Figure 3. An example of a standard turbine blade design.[7]

Although the example shown above shows a hub with five blades, background research has shown small scale wind turbines using anywhere from two to eight blades. These other combinations are also options for Team 15.

The second concept proposed was a hybrid blade design. Similar in arrangement to the standard blade design, the individual hybrid blades twist in a helical fashion as they extend away from the rotational access of the turbine input shaft. Although images of this design were difficult for the team to acquire, Figure 4. An example of the helix like twist of the hybrid blade concept.[8] gives an example of the helical twist of the blade. One major drawback to this concept is that this design is still in the research and development phase. Therefore, should Team 15 choose to move forward with using this blade design for the portable wind turbine, they would face serious challenges in sourcing the blades.

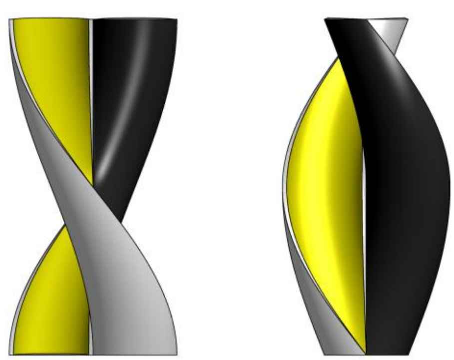

Figure 4. An example of the helix like twist of the hybrid blade concept.[8]

The final blade concept suggest by the members of Team 15 was a vertical access turbine. This type of turbine uses wave-like blades to rotate about a vertical access as opposed to a horizontal access like a typical turbine. An example of these blades is shown in Figure 5. An example of vertical axis turbine blades.[9]

Figure 5. An example of vertical axis turbine blades.[9]

As well as being more difficult to source than the standard turbine blade shape, this blade type has the added disadvantage of being much more difficult to disassemble as there must be supporting rings at both the top and bottom of the blades. These rings would most likely also detract from the overall portability of the design.

3.3.2 Turbine Body

After developing three potential concepts for the blades of the turbine, Team 15 moved on to brainstorming body types for the turbine. Similarly to the blades, the team will also need to develop a method of joining the selected body of the turbine to the nacelle. This attachment must allow the nacelle to safely and easily detach as well as turn freely to align to the wind while attached. The first of the concepts for the body of the turbine actually completely eliminates the body in a "bodiless" wind turbine.

Figure 6. Bodiless wind turbine concept.

Shown in Figure 6. Bodiless wind turbine concept. using a four-legged base, the bodiless design concept sits the nacelle of the turbine directly onto the base of the turbine. The elimination of the body of the turbine has several potential advantages such as greatly increasing the portability of the design by reducing both the weight and the total number of parts that are needed.

Secondly, Team 15 developed a cylindrical body concept for the wind turbine. Similar to the bodies of full scale turbines, the cylindrical shape would give strength and rigidity to the turbine body. Team 15's concept is constructed of several cylinders with decreasing diameter. This design would allow the body to collapse into itself for added portability, while being able to expand to the maximum height of 2m. A basic CAD model of this design is shown in Figure 7. Cylindrical turbine body concept.

Figure 7. Cylindrical turbine body concept.

The final design for the body proposed by members of Team 15 was a cross style body, shown in Figure 8. Cross turbine body concept.This design would be able to fold onto itself, becoming flat, for easier transportation. The design also includes cut-outs from all sides in order to reduce the weight and thus the portability of the design. In order to avoid interference between the blades of the turbine (should the standard or hybrid blade concepts be selected) and the body of the turbine, the cross design is tapered as it extends upwards from the ground. Although this design would provide a sturdy midsection for the portable wind turbine, the long, flat, triangular shape that is formed when the design is folded onto itself would be very awkward to transport.

Figure 8. Cross turbine body concept.

3.3.3 Turbine Base

Finally, Team 15 developed design concepts for the base of the turbine. The first concept proposed was a tripod based design. An example of a professional grade video camera tripod is shown in Figure 9. A professional grade video camera tripod.[10]

Figure 9. A professional grade video camera tripod.[10]

Clearly, designing a tripod base would rely on Team 15 being able to design a portable wind turbine with a nacelle light enough to be supported by the tripods. The design concept of telescoping legs for the tripod base would aid in the ease of assembly for Team 15's wind turbine. This concept has several advantages in that tripods are designed to be extremely compact and portable.

The next, and arguably simplest, concept proposed by members of Team 15 was a solid plate for the base of the turbine. An example of this simple concept can be seen in Figure 10. A plate similar to what would be used as a solid base.[11]

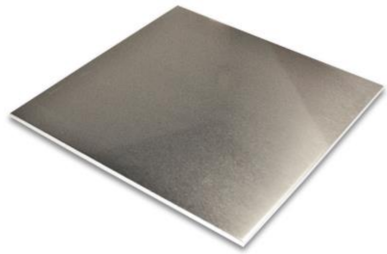

Figure 10. A plate similar to what would be used as a solid base.[11]

This concept would rely on the size and weight of the base plate in order to stabilize the portable wind turbine. Obviously the major disadvantage of this design concept is that, since it relies on large size and high weight to function, it would significantly detract from the portability of the turbine.

The final concept proposed for the base of the turbine was that of ground anchors, similar to that shown in Figure 11. A ground anchor.[12]These ground anchors are used in the same manner as tent stakes, but offer more stability as they screw into the ground. This concept could either be used on its own, securing lines to the body of the turbine then anchoring them to the ground, or in combination with either of the other turbine base concepts.

Figure 11. A ground anchor.[12]

3.3.4 Turbine Base Calculations

In designing the base for the portable wind turbine there are many issues to consider. The failures of the parts are very important. For the aluminum tubing the bending and buckling of the material need to be evaluated. This means that the tubing of the base needs to be strong enough to hold the nacelle and blades of the turbine as well as accounting for the wind loads on the base. The bolts in the tubing also need to be evaluated for shearing. Another concern with the design of the base includes stability against overturning. To do this the Rayleigh wind distribution and a sloped surface will be assumed. The Rayleigh Chart shows the distribution of wind speeds that can be anticipated from several average wind speeds. Since the speed of wind fluctuates at any given location, the actual wind speed at a location which has the design speed of four m/s can be predicted based on the lowest of the five lines in Figure 12. Rayleigh Distribution Chart Though the average wind speed is four m/s, there is a one percent chance that the wind fluctuates up to 10 m/s. In this case, the additional wind could cause a failure of the turbine due to overturning or failure of the individual parts. Therefore, some of the calculations for the base and the body will include accounting for ten m/s winds. An accidental bump on the turbine base also needs to be evaluated in case the consumer bumps into it. For this an 8 inch offset will be assumed. Finally, a foundation capacity for the anchor will need to be evaluated. This will include an extra factor of safety against tipping which varies based on soil type so many soil types will be considered.

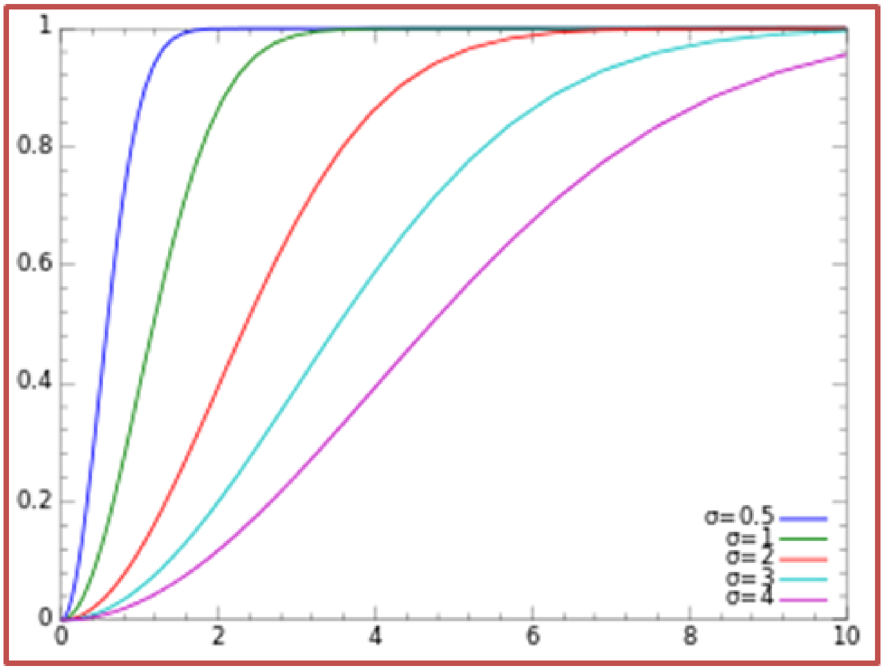

Figure 12. Rayleigh Distribution Chart

3.4 Evaluation and Selection of Design

After developing a selection of design concepts, Team 15 constructed a Pugh Matrix in order to evaluate the concepts. Since there is currently no portable wind turbine on the market, Team 15 decided to rank the design concepts relative to one another. The matrix can be seen in

Table 2. Pugh Matrix used by Team 15 for concept evaluation and selection. In this matrix, Team 15 used “0” to denote the design used as a reference. The use of “-1” indicates that the attribute of that design was rated as worse than the datum and “1” indicates that the attribute is considered better than the datum.

Table 2. Pugh Matrix used by Team 15 for concept evaluation and selection.

		Blades			***Body***			***Base***		
Criteria	***Rank***	***Standard***	***Hybrid***	***Vertical***	***Bodiless***	***Cylindrical***	***Cross***	***Tripod***	***Solid***	***Anchors***
Cost	1	0	-1	-1	1	0	-1	0	-1	1
Feasibility	2	0	-1	-1	0	0	-1	0	0	0
Stability	3	0	0	0	0	0	0	0	-1	0
Assembly	4	0	0	1	1	0	0	0	1	-1
Portability	5	0	0	-1	1	0	-1	0	-1	1
	Score	0	-2	-2	3	0	-3	0	-2	1

The items in the “Criteria” column were the considerations used to rate each design concept. These criteria were developed directly from the project constraints and need given by the project sponsor. Cost was ranked as the most important of the criteria for selection since the project sponsor dictated that the portable wind turbine prototype must not exceed $2,000. Team 15 decided that, because of their limited fabrication experience, feasibility should be the second most important criteria for design concept selection. This would insure that the team would not face excessive machining and fabrication tasks when moving into the embodiment design phase of the project. The stability and assembly criteria were very difficult to rank for Team 15, because both are critical components for a wind turbine and a design that must be able to be repeatedly disassembled and reassembled. In the end, however, Team 15 decided that the stability related directly the safety of the design and therefore should take precedence over the easy of assembly. The lowest ranking of the criteria used in the Pugh Matrix is the portability. Although this may seem like a contradiction with the project goal, it is important to realize that a ranking of five only means that portability is less important than the other four criteria, and still very important to consider when moving forward. Team 15 decided that portability should be ranked fifth because the portability of any of the concepts can easily be altered simply by changing the dimensions of the concept. For example, if the standard blade design when using four blades is not portable enough, the team could reevaluate using only three blades. Numerous similar examples were presented by team members during the development of the Pugh Matrix and therefore the portability criteria was ranked lower than the other, more rigid criteria listed in the matrix.

3.5 Detailed Design

3.5.1 Blade Selection

One of the constraints of the project was that Team 15 should use off-the-shelf wind turbine blades in their portable wind turbine design. After evaluating concepts and deciding to move forward with the standard blade shape, Team 15 considered a myriad of wind turbine blade suppliers. Ultimately, Team 15 selected a company called Windy Nation to source the blades from. Windy Nation provided much more information about their products than many other suppliers. The company is also based in the United States, lowering the lead time for receiving the blades and facilitating communication between the supplier and Team 15.

Windy Nation offers two options in each of three categories for their wind turbine blades. These options can be seen in Table 3. Blade options offered by Windy Nation. These blade options offered by Windy Nation can be selected in any combination, offering a wide variety of blade kits to Team 15.

Table 3. Blade options offered by Windy Nation.

Category	***Option 1***	***Option 2***
Blade Material	Aluminum	UV-stabilized Polycarbonate
Blade Length	28in	35in
Number of Blades	3	5

In order to narrow down the selection of blades offered by Windy Nation, Team 15 first considered the material of the blades. Although aluminum is often marketed for its light weight, the UV-stabilized polycarbonate blades were 1-3lbs lighter in every case. Combining this fact with the fact that aluminum can easily be bent and permanently deformed, Team 15 decided that the UV-stabilized polycarbonate blades were a better option for their application. These blades would hold up to abuse better than the aluminum blades, as well as reduce the overall weight of the final design.

Next, Team 15 contacted Windy Nation in order to find out the Tip Speed Ratio (TSR) for the blade sets offered. The Tip Speed Ratio is a parameter defined in the design process of turbine blades and relates wind velocity (V_w) to the tangential velocity of the blade tips (V_t) through the equation:

$$V_t = V_w * TSR \tag{2}$$

Windy Nation informed Team 15 that the three bladed sets were designed with a TSR of 4.8, while the five bladed sets were designed with a TSR of only 2.5. This information led Team 15 to believe that the three bladed set would be a better choice for the portable wind turbine. A higher TSR would mean a higher tangential velocity, and therefore more rotations per minute of the input shaft, for the same wind velocity. Since Team 15 desired to eliminate the need for a gear box in the portable wind turbine, a higher rotation speed of the input shaft directly from the turbine blades would be optimal.

Before making a final decision, Team 15 turned to their advisor for additional confirmation that the three bladed design was the better choice. Dr. Jung provided Team 15 with the graph shown in Figure 13. Power coefficient (efficiency) versus Tip Speed Ratio of wind turbine blades. The Betz limit is the theoretical maximum efficiency.This graph shows the power coefficient, or efficiency of the turbine blades at capturing the kinetic energy of the wind, as compared to the Tip Speed Ratio for a variety of blade numbers. The Betz limit is the theoretical maximum efficiency of any wind turbine blade set.

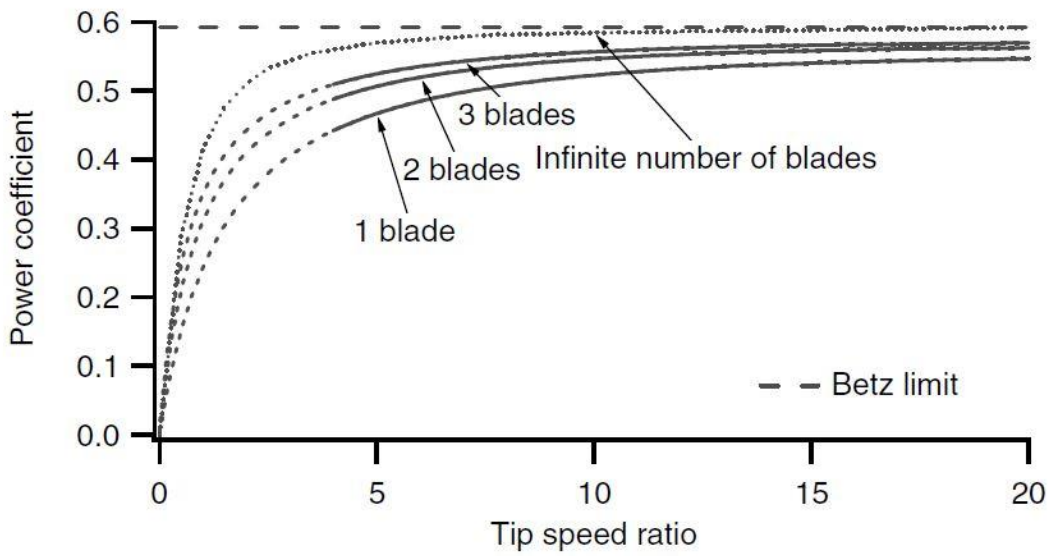

Figure 13. Power coefficient (efficiency) versus Tip Speed Ratio of wind turbine blades. The Betz limit is the theoretical maximum efficiency.

As seen in the graph, there is not much increase in power coefficient from a three bladed design to a design using an infinite number of blades. Clearly, this means that a desig using five blades would have minimal increase in power coefficient over a design with three blades. Combining this with the previously discussed higher TSR of the three blade design and the reduced number of parts and therefore lower weight of the three blade set, it was clear that the three blade set was the best option for Team 15.

The final parameter to be considered in blade selection was the length of the blades. Using the shorter, 28in blade would reduce the overall size and weight of the portable wind turbine package. The shorter blade length would also yield a higher rotational speed for the same wind speed, since Windy Nation's three bladed sets are all designed with a 4.8 TSR. This information led Team 15 to finalize their blade selection as the Windy Nation 28in, 3-blade, UV-stabilized polycarbonate turbine blades. A picture of the selected blades can be seen in Figure 14. Final blade selection made by Team 15.

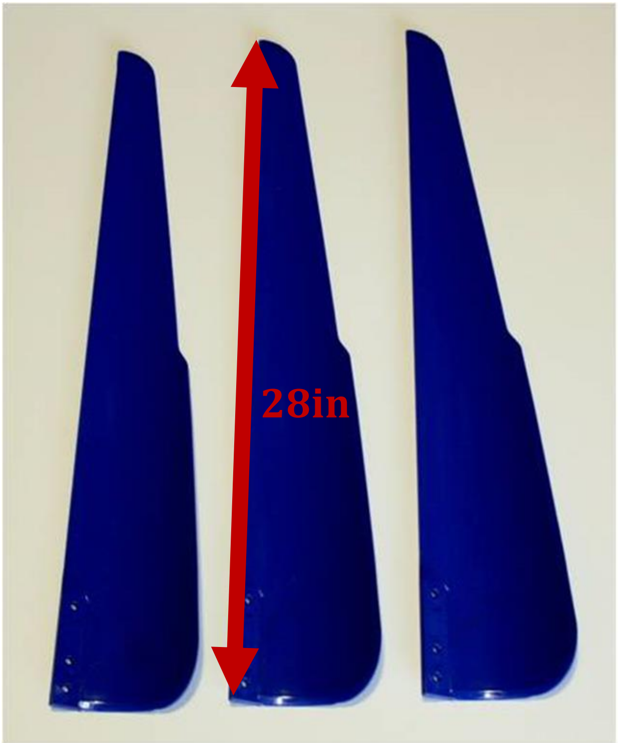

Figure 14. Final blade selection made by Team 15.

3.5.2 Body and Base Design

The alternative that was selected for the body of the turbine was a long, aluminum tube as shown in Figure 15. This concept was selected since it provides more space for the blades to spin, without hitting the base and it aids in a minimization of size and number of parts. This helps both in decreasing the weight and improving portability.

Figure 15. Final body selection for the portable turbine.

The alternative that was selected for the base was the telescoping tripod design, as shown in Figure 16. Tripod base selection.The three legs, each with two telescoping sections, will provide for a sturdy base while still minimizing number and size of parts. The telescoping design will aid in the ease of assembly and disassembly. Team 15 decided to minimize the height of the base and maximize the body length. Again, all of this included will allow free spinning of the blades, increase portability, decrease weight, and allow assembly for any user.

Figure 16. Tripod base selection.

The telescoping tripod base legs will lock in place with a simple locking with retainer pin as shown in Figure 17. Pin (with locking retainer) The pin selection for the base is very important considering it will be one of the most vulnerable places for failure. Using a pin made out of steel will be the most efficient way to account for these failures because of the strength of the material. Choosing a pin like this also gives flexibility in the length of the tripod legs on sloped or flat surfaces. The aluminum tubing on the tripod will have several holes for different leg lengths. This will account for slope stability and can be seen in Figure 18 below.

Figure 17. Pin (with locking retainer)

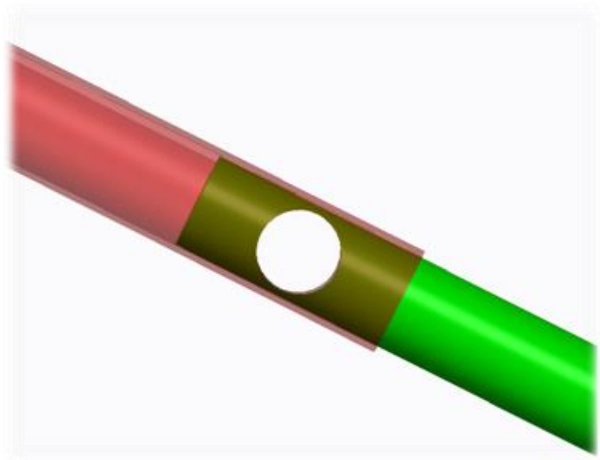

Figure 18. CAD model of where pin (with locking retainer) will be placed to hold telescoping parts in place.

An anchor will be used in the design of the turbine base in order to provide more resistance to overturning. The screw anchor in Figure 19 shows a representation of this design choice. The screw anchor is suitable for most of the soil situations in the locations that this turbine will be implemented. Also, this design will only require one anchor for the whole turbine as opposed to one for each leg of the base, as some other anchors would require.

Figure 19. Tripod Anchor Selection

3.5.3 Nacelle Mounting System Design

The main focus of the Team 15's project was to maximize the portability of the wind turbine design. In order to do this it was critical that the design be able to easily and quickly come apart and go back together. At the same time, the total number of parts in the design must be reduced. This presented a challenge for Team 15 as to how to mount the nacelle of the turbine to the rest of the system. The nacelle must be securely mounted to the base, with no risk of coming detached from the force of the wind. It must also be able to rotate freely about a vertical axis in order to keep the rotational axis of the blades facing into the wind.

To accomplish this task Team 15 considered a number of methods that could be used to secure the nacelle to the base of the turbine while still allowing quick and easy removal. Initially, Team 15 evaluated concepts involving a pinch style release system or a simple pin, but both of these ideas were quickly rejected due to the perceived difficulty of accessing the release underneath the nacelle once it is mounted to the base.

Figure 20 shows a simple CAD model of the design that has been selected by Team 15 to use to secure the nacelle to the base of the turbine. This system uses an off-the-shelf steering wheel quick release. A quick release such as this is normally used in competitive driving situations to allow for quick and easy steering wheel removal. This gives the driver of the vehicle more room to enter or exit the vehicle. Team 15 will adapt this design to their application by bolting the top of the quick release to the bottom of the nacelle instead of to a steering wheel.

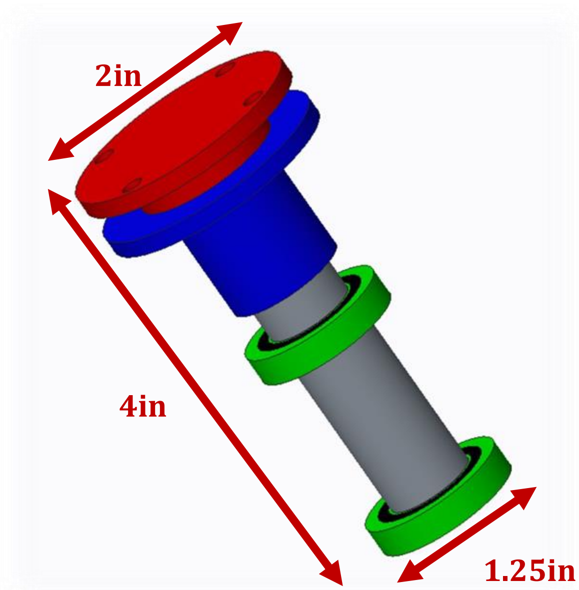

Figure 20. Steering wheel quick release system developed by Team 15 for nacelle mounting.

Mounted to the bottom of the nacelle, the quick release will mate to a shaft that will be fit into a set of bearings, fit into the base of the turbine. Two bearings will be used in order to provide stability for the mounting shaft. These bearings will allow the nacelle of the turbine to rotate freely when changing wind direction exerts a force on the tail vane of the turbine. Figure 21 shows views of the mating ends of the shaft and the quick release.

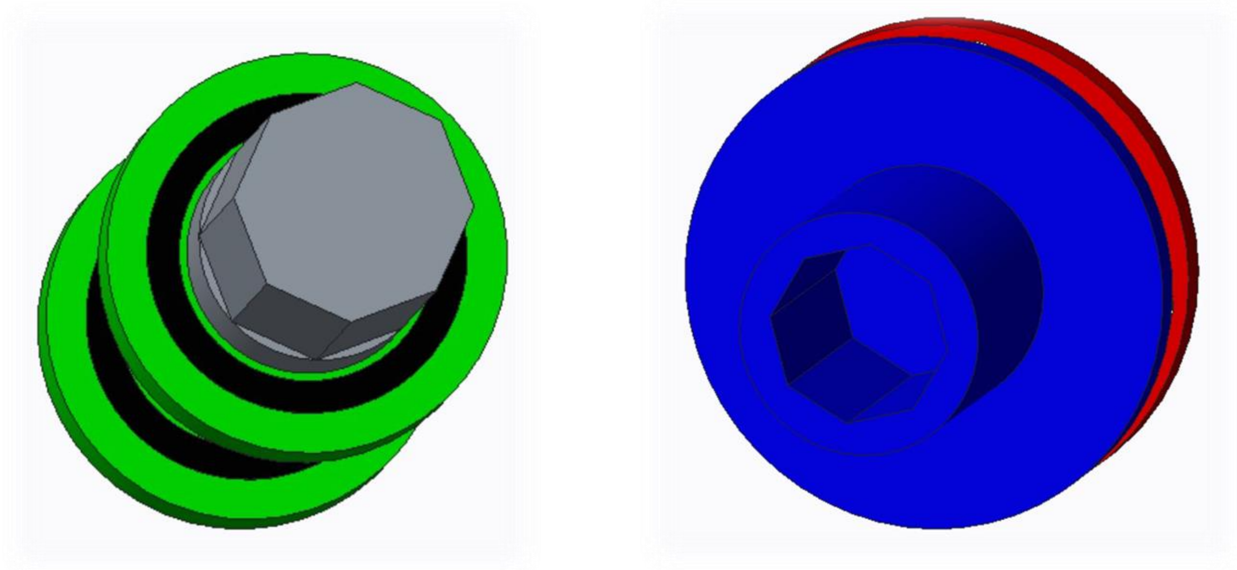

Figure 21. Views of the female end of the quick release and the male end of the shaft fit into bearings in the base of the turbine.

Team 15 is currently working on sourcing parts for this quick release system. The constraints for these parts include that the bearings must fit into the base which is being designed and that the surface area of the mounting plate of the quick release must be sufficient to provide stability to the nacelle. The nacelle, however, cannot be created until electrical components are selected. As discussed in the appropriate section of this report, the required electrical components are still being researched by Team 15.

3.5.4 Blade Mounting System Design

An essential component of the wind turbine design is the blade mounting. An innovative way to attach and remove the blades from the assembly is needed to increase the portability of the wind turbine. In order to design a blade mounting system that would be easy to assemble and increase portability, current blade mounting systems were researched and inspected. It was discovered that many smaller wind turbines use a standard wind turbine hub which is blade dependent, such as the ones shown in Figure 22. Standard wind turbine hubs used for A) three blade turbines and B) five blade turbines.These hubs are standard and may be ordered from multiple companies. The ones shown in the figure are provided by Windy Nation, where the hubs overall diameter, thickness, and material type depends on the blades selected for the application, however the central hole comes in two standard alternator shaft sizes, those diameters being 1 in. or 17mm.

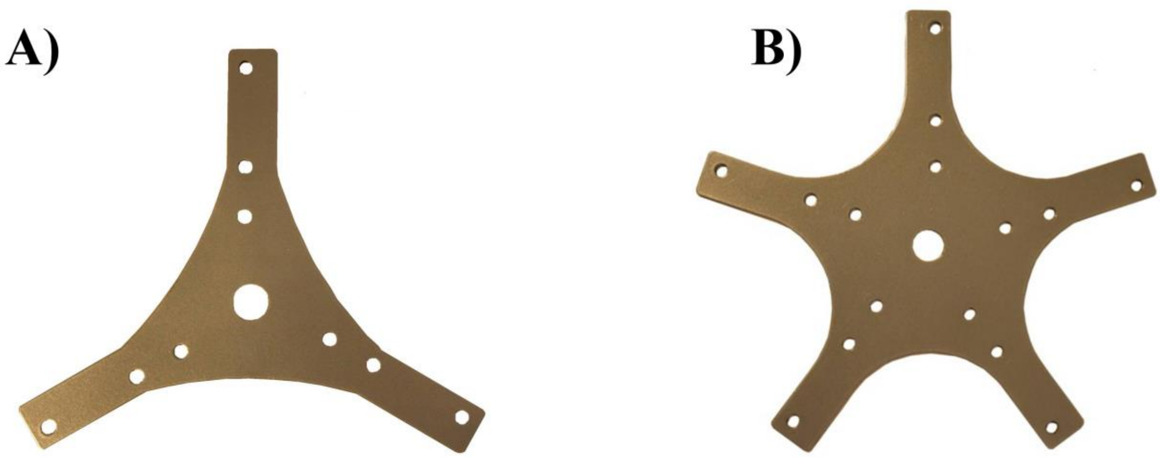

Figure 22. Standard wind turbine hubs used for A) three blade turbines and B) five blade turbines.

In the early stages of the portable wind turbines design, it was assumed that a standard 3-blade wind turbine hub would be used as this would be the easiest option, since it required no further manufacturing or fabrication. In this design instead of using conventional bolts and screws to attach the blades, plastic fasteners or "snap screws" would be used in order to provide easy and quick assembly. However after analyzing this design, the strength of the fasteners was deemed questionable, also there is essentially no way to secure the hub to the shaft in this design.

Considering this information a new design was implied where a standard 3-blade wind turbine hub could be used, however a hexagonal sleeve could be welded to the front of the hub. This cylindrical sleeve will have a bored internal diameter that will allow just enough tolerance for the shaft to enter without rubbing the sleeve. Additionally the sleeve will have a 2-3 places for tapped screw holes. The screws will generally act as pins that will secure the hub into place once the bottom of the screw makes contact with the shaft. Both the original and updated designs are pictured in Figure 23. The A) original and B) updated hub designs for blade mounting.

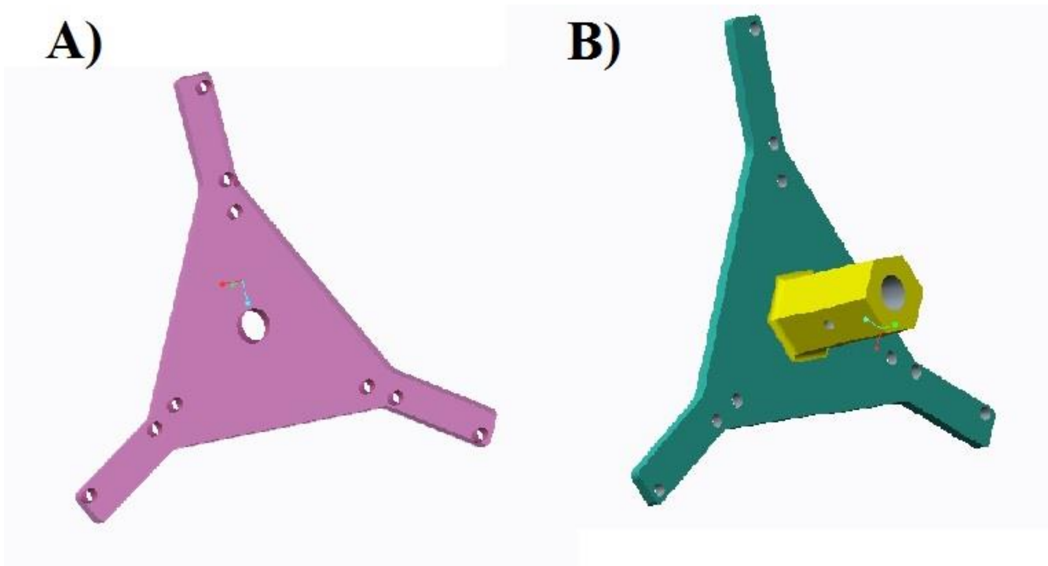

Figure 23. The A) original and B) updated hub designs for blade mounting.

Other additional design schemes are being considered to increase the portability of the blades, such as the addition of hinges at each of the blade mounting positions to allow the blades to fold back for easy storage.

3.5.5 Power Generation System Design

As far as meeting the criteria that the system must output at least 5 watts of power, the power generation might be most important aspect. Team 15 has been doing extensive research on different generator/alternators. Currently, the team is looking at a DC motor to convert the mechanical energy of the blades to electrical energy to charge the battery. The advantage to using a DC motor instead of an AC motor is to alleviate having to change the current back to direct from the alternating current. The two major motor characteristics being kept in mind during generator selection are the volts-to-rpm ratio and the amperage rating. Any motor has a set voltage-to-rpm ratio, and the significance of having one is that the created voltage can be determined by applying some constant rpm to the motor. This voltage quantity is important because if the outputted voltage is not as large as the battery requires, the battery will not charge or be able to output any power. A good volts-to-rpm ratio is anything above 0.035. Similarly, the minimum amperage rating wanted is as low as 5.

As far as the conversion of electrical power from the generator to a battery goes, research is still being done. With complications such as current flowing in the right direction always, or the voltage peaking as the wind speeds up or slows down, combined with the lack of electrical engineering knowledge, Team 15 has had to overcome some obstacles and really put an effort into learning this somewhat foreign language. Team 15 has learned that a diode can be used to main a constant current direction. This is useful to keep the battery from charging the motor to turn the blades when the wind slows down or is not apparent. A charge controller is being researched as well, to act as a prevention to overcharging. The charge controller works by regulating the voltage when the battery reaches a specific voltage. Once the voltage drops due to less wind speeds or an increase in electrical usage, the controller allows the maximum possible charge[18].

4. Methodology

The idea behind Team 15's strategy to success is delegation and everyone holding everyone accountable. There is no way to be successful in a project of this scale if the workload is not distributed equally. The delegation of each task to the person who can best handle that portion of project is equally important, and ultimately left to the team leader to decide. As a way of holding everyone accountable on their individual tasks, the team will meet at least once a week. In addition, biweekly meetings are held with the team sponsor and advisor for updated progress reports and troubleshooting throughout the project.

4.1 Schedule

As a way to establish a timeline for task breakdowns, the team used the Gantt chart that is shown in the Appendix. As a baseline for the project, the team did preliminary research on wind turbines and what exactly is out there on the market currently. Since this was the first time a small-scale turbine was being tested, the research was initially done on large scale turbines and the data was extrapolated down to determine what kind of energy and power we were dealing with. Following large scale turbine research, the team found the little bit of research on small scale turbines that exist, and pricing of those small scale turbines. After the team had an idea of what made up a turbine, different parts of the turbine and project were delegated to team members for research. Those parts consisted of blades, alternators (DC motors), material selection, potential applied forces, and cost analysis. More in depth research of each of those will be expanded on throughout the rest of the semester, specifically alternators and applied potential forces.

Having done sufficient background work, the team selected several designs of different parts of the turbine for analysis and selection. The mechanical students created three designs for wind turbine blades. The civil students created three designs for the tower structure as well as three designs for the base. Each of the 9 total designs were constructed in Creo PTC to have an idea what they would look like.

The team is currently applying a force analysis on the parts to see where major stresses occur. Using Creo PTC as the main software to design and analyze the different designs, the team will be able to make the right selection of designed parts. This will ultimately help the team continue to keep on track with the project timeline as well as well keep things under budget, which is a major challenge with the project being limited to $2,000.

By the end of fall semester the team should have selected a complete design and be in the position to order parts so that come spring semester, building and troubleshooting will have sufficient time.

4.2 Resource Allocation and Budget

To really start the project off right, at the beginning of the semester each team member had a responsibility to perform background research of wind turbines to bring to the table. Additional research was later assigned on a more individual manner. While the beginning of the semester was meant for general wind turbine research, after a little less than a month initial designs were created as a team. The mechanical engineering students had a focus on the blade design, connection to nacelle, and size. The mechanical students also focused on the nacelle size, housing, and type. The civil engineering students studied up on external forces to be considered, body type, and base type. Currently both sets of students are working on their assigned sections, with a couple different designs to be selected for analysis by November 2.

Once the team has the selected designs built in Creo PTC and a proper force analysis has been applied, the team as a whole will participate in a complete design selection. The design selection will be based on a decision matrix and the House of Quality. Table 4. Allocation of Resources shows the main tasks that each team member is expected to focus on throughout the project. This task assignment list is subject to change.

Due to the scheduling of the project and the ongoing research of the electrical components a detailed budget has not been developed. The team is well aware of the $2,000 maximum budget constraint, but must complete their research involving the power generation components before a more precise budget can be presented.

Table 4. Allocation of Resources

Task	**Team Member(s) Responsible**
• Background Research - Wind Power	• Stephanie McLellan
• Background Research - Suitable Locations for Wind Speed Constraint	• Katelyn Bamundo
• Background Research - Existing small scale wind turbines	• Stephen Freeman • Rishad Walker
• Background Research - Structural design and Material (Body and Nacelle)	• Katelyn Bamundo • Stephanie McLellan
• Background Research - Blade Material	• Stephen Freeman • Matthew Hutchisson
• Background Research - Alternators	• Garrett Rosenthal • Stephen Freeman
• Preliminary Structure Design	• Katelyn Bamundo • Matthew Hutchisson • Stephanie McLellan
• Blade Selection	• Matthew Hutchisson • Stephen Freeman
• Alternator Selection	• Stephen Freeman • Garrett Rosenthal • Rishad Walker
• Structure CAD Drawings	• Stephen Freeman
• Gear Box CAD Drawings (if needed)	• Garrett Rosenthal
• Structural Force Analysis	• Katelyn Bamundo • Matthew Hutchisson • Stephanie McLellan
• Cost Analysis	• Garrett Rosenthal • Stephanie McLellan
• Design Selection	• All Team Members

5. Safety

The design must include safety features in order to prevent injury to the operator during assembly and disassembly. Since the turbine must be able to be taken apart for transport, the individual parts must be assembled in a way that guarantees restriction of motion for all parts other than the rotor blade, the internal shaft and possibly the nacelle of the turbine. Also, the turbine as a whole must be secured to the ground in a way that prevents it from falling, even in situations where the ground is not level or there is severe weather. Finally, a visual instruction manual must be included so that people not familiar with the turbine will be able to set it up correctly, easily and safely.

5.1 Risk Assessment

As per university policy, Team 15 has completed the Risk Assessment form provided by the Mechanical Engineering department. The team brainstormed potential risks of the project and what could be done in order to mitigate these risks. The Risk Assessment was reviewed, signed and dated by all members of Team 15 as well as the project sponsor, Dr. Sungmoon Jung. This document has been scanned and inserted into the appendix of this report. In addition to the standardized Risk Assessment form, Team 15 has discussed using particular caution when testing the turbine blades. The rest of the project is, by design, safe for both the team to be testing as well as the consumer to use.

5.2 Environmental Concerns and Ethics

The purpose for the portable wind turbine is to generate power in an un-harmful, ecofriendly way. The turbine will be converting the mechanical energy of the wind to electrical energy, so a DC generator will be used. The generator will charge a lithium ion battery, which will then be able to charge a small device. The lithium ion battery comes with its own environmental concerns. This includes resource depletion, global warming and ecological toxicity, which is an effect of using lithium ion batteries made out of nickel and cobalt. To lessen the environmental effects of using this battery it will be better if there was a cathode material substitution, proper recycling of the battery when needed and solvent-less electrode processing.[16]

The nacelle of the portable wind turbine will be made of plastic. This comes with its own environmental concern as well. The most important aspect of using plastics is the proper recycling method once the plastic material has been used. The type of plastic will also be evaluated for the use of the wind turbine. Some plastics are toxic such as PVC and vinyl. Other plastics contain BPA (Bisphenol-A), which can be harmful to hormone growth in humans. The proper selection of plastic types is important in the turbine so that the environment and consumer have the least amount of risk using the product.[17]

6. Conclusion

Since the last report, Team 15 has begun the detailed design of the selected concepts. Team 15 is focusing on the portability and ease of assembly of the wind turbine design, prioritizing this over the power generation of the design as emphasized by the project sponsor. The team has finalized the selection of turbine blades to use in the design. Work is progressing on the development of the base of the portable wind turbine. A concept has been developed for mounting the nacelle to the base, and the detailed design will be finalized upon completion of the base design and formulation of the size and weight of the nacelle. Research is ongoing to determine the components needed in the nacelle in order for the turbine to be able to produce power and charge a small device. The team will complete this research over the interim between the fall and spring semesters and be ready to begin ordering components for turbine assembly upon their return in January.

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Appendix A

Engineering Characteristics

Consumer Requirements (CR)	C.I.	Size	Material Type: Body/Legs	Material Type: Blades	Weight	Corrosion Resistance	Weather Resistant Strength	Thermal Resistance
Portable	4	9	2	2	7	2	2	2
Easy to Assemble	3	6	4	4	7	2	2	2
Safety of Assembly	2	5	5	4	6	3	5	5
Cost	4	7	8	8	7	6	5	3
Durable	2	3	9	8	5	8	7	5
Energy Efficient	3	5	4	8	5	7	5	7
Power Output of 5 W	4	3	3	7	3	5	5	5
		125	104	128	126	101	93	87
	Rank	2	4	3	1	5	6	7

Figure 24. The House of Quality developed by Team 15 (roof not shown).

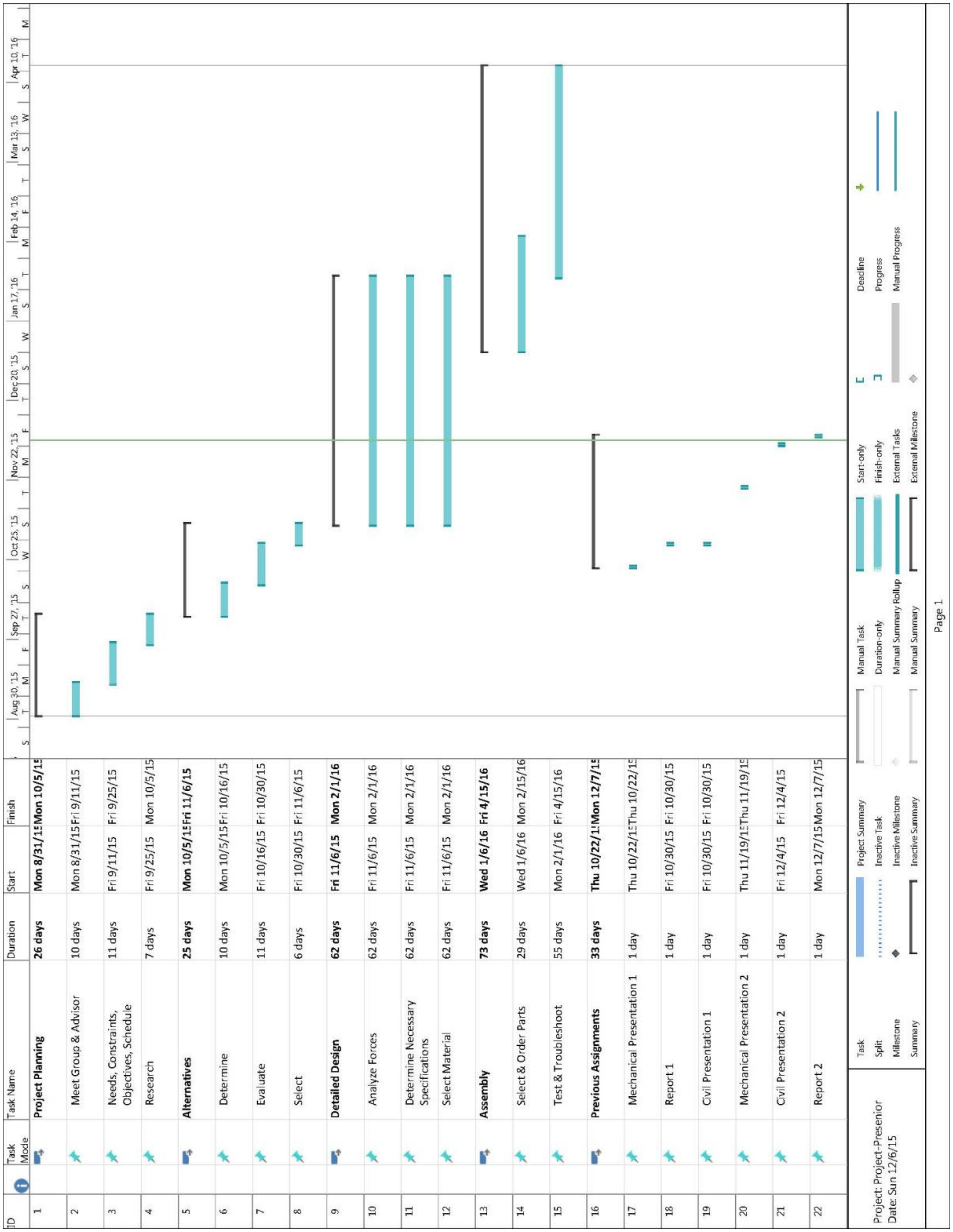

Figure 25. Gantt Chart developed by Team 15.

Risk Assessment
Safety Plan

Project information:

Portable Wind Turbine		10/30/2015
Name of Project		Date of submission

Team Member	Phone Number	e-mail
Katelyn Bamundo	407-456-2261	kmb12j@my.fsu.edu
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Faculty mentor	Phone Number	e-mail
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Dr. Shangchao Lin	850-410-6624	slin3@fsu.edu
Dr. Patrick Hollis	850-410-6319	hollis@eng.fsu.edu

I. Project description:

The goal of the project is to create a lightweight, portable, easily assembled and disassembled wind turbine. This turbine will be able to be operated by any untrained individual and will provide enough power to charge/power small, electronic devices. The portable wind turbine must stand no higher than 6ft and must be capable of generating power from 4m/s winds. The team must provide information on where these wind conditions exist and where the device could be marketed.

II. Describe the steps for your project:

During the fall semester the team must conduct research on power generation, wind turbine operation and construction, innovative methods of assembly that would make the turbine user friendly and safe to assemble and disassemble, materials that would provide the required strength, durability and weather resistance while reducing the weight and increasing portability, and areas where the required wind speeds exist and that the design could be marketed. The team must also develop and analyze design concepts.

During the spring semester the team will finalize part selection, order parts and construct, test and trouble shoot the design.

III. Given that many accidents result from an unexpected reaction or event, go back through the steps of the project and imagine what could go wrong to make what seems to be a safe and well-regulated process turn into one that could result in an accident. (See examples)

During the construction of the prototype, parts may need to be machined from raw materials. Machining always involves risks due to the involvement of sharp edges, rotating parts, etc.

During testing of the prototype there will be risk of electrocution since the prototype is designed to generate power. There will also be safety risks involving the rotating blades of the turbine and the possibility of the turbine falling over onto one of the team members.

During assembly and disassembly of the turbine there will be risks that parts will be dropped and cause injury.

IV. Perform online research to identify any accidents that have occurred using your materials, equipment or process. State how you could avoid having this hazardous situation arise in your project.

There are numerous examples of injuries resulting from the use of essentially every piece of equipment available in the CoE machine shop. Team 15 will help avoid these situations by following all machine shop protocols and not using any of the machines or tools available before receiving proper training.

There are numerous examples of injuries resulting from working with electricity where the worker did not insure that the project focus was disconnected from the power source before beginning work. Team 15 will avoid the risk of electrocution by working in pairs to ensure that any power source is completely disconnected before performing any electrical work.

Accidents have occurred where an object has fallen on someone and they have been trapped and unable to go for help. Team 15 will work in pairs so that even if one student is injured the other can contact emergency personnel

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Figure 26. Page 1 of Team 15's Risk Assessment.

V. For each identified hazard or "what if" situation noted above, describe one or more measures that will be taken to mitigate the hazard. (See examples of engineering controls, administrative controls, special work practices and PPE).

In order to avoid injuries in the machine shop the team will follow all machine shop protocols and wear all PPE that is required in the CoE machine shop (such as long parts, closed toed shoes, eye protection, etc.)
In order to eliminate the risk of electrocution during turbine testing, the team will disconnect the generator whenever any team member will be working with any of the electrical components of the prototype.
In order to avoid injury from the blades of the turbine, a "no-go" area will be marked off around the turbine during testing.
In order to avoid injury from the turbine falling over, a minimum of two team members will set up the turbine. This will allow one team member to stabilize the turbine while the other secures it.

VI. Rewrite the project steps to include all safety measures taken for each step or combination of steps. Be specific (don't just state "be careful").

During the fall semester the team must conduct research on power generation, wind turbine operation and construction, innovative methods of assembly that would make the turbine user friendly and safe to assemble and disassemble, materials that would provide the required strength, durability and weather resistance while reducing the weight and increasing portability, and areas where the required wind speeds exist and that the design could be marketed. The team must also develop and analyze design concepts and insure that the design is safe to operate by an untrained individual.
During the spring semester the team will finalize part selection, order parts and construct, test and trouble shoot the design. The will follow all safety protocols during prototype construction and always work in pairs to minimize risks.

VII. Thinking about the accidents that have occurred or that you have identified as a risk, describe emergency response procedures to use.

If a minor injury is sustained, the secondary team member must insure that the area is safe before attempting to help the injured team member. The secondary team member is responsible for contacting the team's advisor and the department emergency contacts.
In the event of a serious injury, the secondary team members must insure that the area is safe before attempting to help the injured team members. The secondary team member must immediately contact 911 as well as the team's advisor and department emergency contacts. The injured team member's emergency contact should also be contacted.

VIII. List emergency response contact information:

- Call 911 for injuries, fires or other emergency situations
- Call your department representative to report a facility concern

Name	Phone Number	Faculty or other COE emergency contact	Phone Number
Environmental Health & Safety	850-644-6895	Dr. Nikhil Gupta	850-410-6201
Emergency Services	911	Dr. Chiang Shih	850-645-0102
		Dr. Emmanuel Collins	850-410-6373

IX. Safety review signatures

- Faculty Review update (required for project changes and as specified by faculty mentor)
- Updated safety reviews should occur for the following reasons:
  1. Faculty requires second review by this date:
  2. Faculty requires discussion and possibly a new safety review BEFORE proceeding with step(s)
  3. An accident or unexpected event has occurred (these must be reported to the faculty, who will decide if a new safety review should be performed.
  4. Changes have been made to the project.

Team Member	Date	Faculty mentor	Date
[illegible]	10/29/15	[illegible]	10/29/2015
[illegible]	10/29/15		
[illegible]	10/29/15		
[illegible]	10/29/15		
[illegible]	10/29/15		
[illegible]	10/29/15		

Report all accidents and near misses to faculty mentor.

Figure 27. Page 2 of Team 15's Risk Assessment.

Biography

- Katelyn Bamundo is a senior in the Department of Civil Engineering at Florida State University. Katelyn is the Head Civil Engineer of Team 15. During her time at Florida State University, she has worked as an engineering intern at Universal Orlando.
- Stephen Freeman is the Vice President of the FAMU-FSU Society of Automotive Engineers and has worked at ASC-NHMFL and interned at Toyota Motor Sales in Torrance, CA. Currently working as an Undergraduate Research Assistant at AME, he has accepted a full-time offer from Toyota and will relocate to California after graduation.
- Matthew Hutchisson is a senior in Civil Engineering, focusing in structures. He has worked as an intern at Reynolds Smith and Hills and plans on attending graduate school before starting career.
- Stephanie McLellan is a senior in the Department of Civil Engineering. Stephanie was an intern at Turner Construction Company in Miami, FL and worked on building the American Express Headquarters in Sunrise, Florida. Stephanie has accepted a full time offer with Turner Construction Company and will relocate to Miami, FL after graduation.
- Garrett Rosenthal is a sixth year senior studying Mechanical Engineering at Florida State University. When not studying for classes, he enjoys participating in the university's intramural sports program and networking with his peers.
- Rishad Walker worked as a Project Engineer for Exp. Energy Services this past summer, gaining experience in Interstate Natural Gas and Crude Oil Transmission Pipeline Routing. Rishad plans to complete the Fundamentals of Engineering exam prior to his graduation, with later plans of receiving a Professional Engineering License.