Summer 2021

JME 4110: Drag Line Wind Energy Generator

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Joint Engineering Program

University of Missouri–St. Louis ▪ Washington University in St. Louis

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The purpose of this project is to develop a mechanical system, capable of harnessing energy from wind using a string attached to a kite. The mechanical system also must be able to pull the kite back to the starting position. The system must use less energy to bring the kite back to the starting position then it gains from the wind.

JME 4110
Mechanical Engineering
Design Project

Drag Line Energy Generation - Wind

Brian Bakula
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1 INTRODUCTION

1.1 VALUE PROPOSITION / PROJECT SUGGESTION

Energy in its electric form constitutes an essential part of our daily lives. We use energy for everything, whether it is to power as simple as our refrigerator in our houses or as complex as the industrial sector. Generating that energy remains difficult and not accessible to everyone and the sources are sometimes limited. To produce renewable energy for small voltage use, such as house light bulbs, we have designed a drag line energy generation system powered by a parachute kite. This will help reduce the use of polluting products and make electricity more accessible and affordable.

1.2 LIST OF TEAM MEMBERS

Brian Bakula

David Gengenbacher

Mouhamadou Bamba Kane

2 BACKGROUND INFORMATION STUDY

2.1 DESIGN BRIEF

The purpose of this project is to develop a mechanical system capable of harnessing energy from wind using a string attached to a kite which unwinds a string reel powering a generator. The mechanical system also must be able to pull the kite back to the starting position. The system must use less energy to bring the kite back to the starting position than it gains from the unwinding process, giving a net surplus of energy that can be stored. The system should not let out the kite higher than 150ft due to FAA regulations, and should be designed for a wide range of wind conditions but not all, since high wind can be notoriously catastrophic for systems like these and therefore the kite will be brought down on such occasions.

The revisions made to the project description were to minimize the risk of failure or destruction of the drag line system, and also to comply with federal regulations for kite flying. The addition of describing the need for a battery was added because of how variable the power generation will be in this type of system; it is important to have storage for the electrical power in order to actually use it in any practical manner.

2.2 BACKGROUND SUMMARY

We have done background research for some similar existing design that could give us an idea about how we should proceed further.

- http://www.kitepower.eu/technology.html

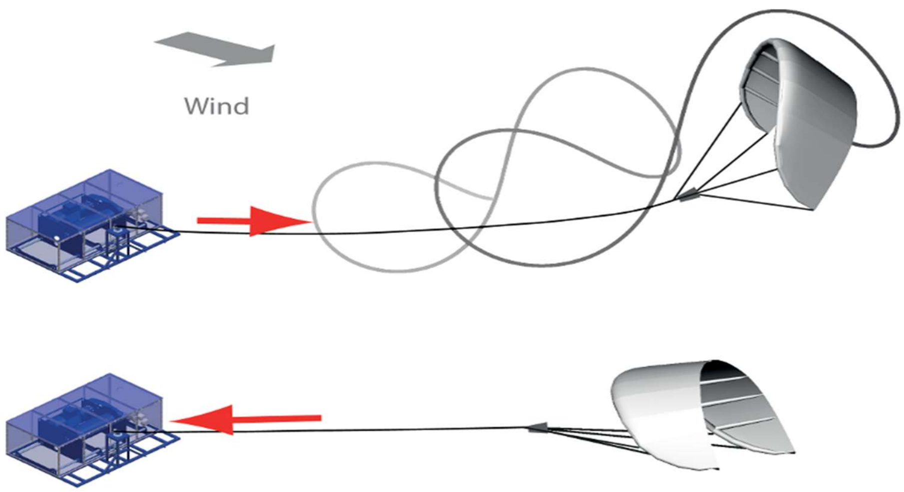


Figure 1: Similar Design

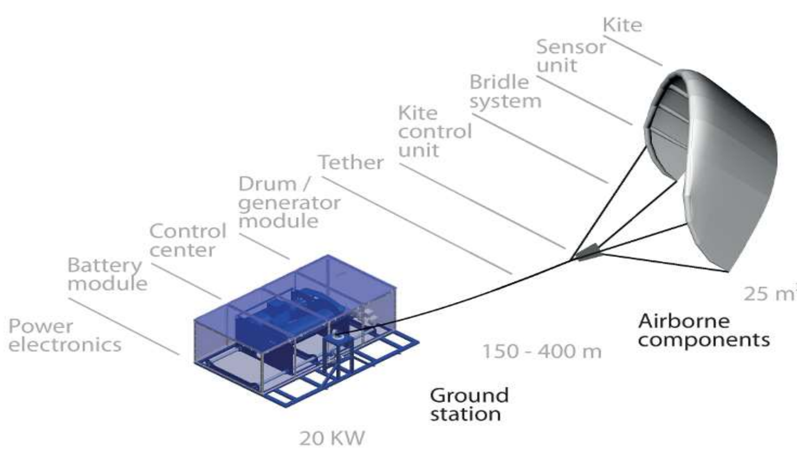


Figure 2: Similar Design continued

This design is nearly identical to ours in concept, with a kite that creates energy by unwinding a reel that drives a generator, and a reel-in strategy that utilizes a surface area reduction technique much like ours. The way they achieve surface area reduction is a little different from ours however, since we will be pulling the kite shut instead of altering the angle of attack.

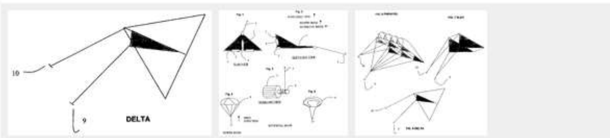
- **Patent #:** US20050046197A1

Wind energy production using kites and ground mounted power generators

Abstract

Systems and methods are described for creating low cost energy using kites connected to ground mounted equipment. In power mode the kites generate maximum energy by positioning the kite at a high angle of attack relative to wind direction. The kite is allowed to travel a distance limited only by the length of line attached. The opposite end of the line is attached to a reel capable of turning a shaft to create mechanical or electrical energy. Upon reaching a controlled length, the kite is repositioned to a minimum angle of attack relative to the wind to minimize energy required to retrieve the kite. The shaft rotation is then reversed thereby winding the line on the reel. Energy is expended in retrieval mode. The difference in energy during power and retrieval mode is the net energy gain available for useful work.

Images (3)



Classifications

F03D5/00 Other wind motors

View 3 more classifications

US20050046197A1
United States

Download PDF | Find Prior Art | Similar

Inventor: Gordon Kingsley

Worldwide applications

2003 · US

Application US10/656,004 events

2003-09-03 • Application filed by Kingsley Gordon Bruce

2003-09-03 • Priority to US10/656,004

2005-03-03 • Publication of US20050046197A1

Status • Abandoned

Info: Patent citations (7), Cited by (31), Legal events, Similar documents, Priority and Related Applications

External links: USPTO, USPTO Assignment, Espacenet, Global Dossier, Discuss

Description | Claims (3) | Hide Dependent

Figure 3: Google Patent Design

This design is similar to our own. It involves a rotating shaft where the rotation is created from the kite line.

- https://physicsworld.com/a/the-promise-and-challenges-of-airborne-wind-energy/

Turbulence ahead

All these advantages come at a price, and Ruiterkamp of Ampyx Power sums it up well. "The threshold for getting a first series to work is way higher than in other areas of wind energy," he told his colleagues in Glasgow. "We are working on intrinsically unstable systems. If something goes wrong, we are immediately in a situation that needs to be handled."

With a device as complex as an energy kite, the list of things that can go wrong is extensive. In another talk at the Glasgow meeting, Kitemill technical manager Lode Carnel rattled off a litany of problems that his Norway-based team had overcome on their current, rigid-wing prototype. Weak links breaking. Electrical connectors not up to industrial standards. Tether and wing materials that proved too flimsy or heavy. Though minor in themselves, Carnel explained that these issues contribute to

Advertisement

Figure 4: Wind Energy Harvestng Article

This article talks a lot about the wind harvesting process and different types of manufacturers for large kite energy generators. The relevancy of this article comes from the Turbulence Ahead section where it talks about all the problems, we could face whether it is in the building process or in the environmental issues.

- https://www.ecfr.gov/cgi-bin/text-idx?rgn=div5&node=14:2.0.1.3.15#se14.2.101_111

This URL goes over some of the government regulations to keep in mind when flying a kite. One of the important ones is that the kite cannot be flown 150 feet above the surface of the earth without notifying the FAA. These codes will be important to keep in mind when determining the max elevation of the kite used in our design.

Subpart B—Moored Balloons and Kites

Source: Docket No. 1580, 28 FR 6722, June 29, 1963, unless otherwise noted.

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§101.11 Applicability.

This subpart applies to the operation of moored balloons and kites. However, a person operating a moored balloon or kite within a restricted area must comply only with §101.19 and with additional limitations imposed by the using or controlling agency, as appropriate.

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§101.13 Operating limitations.

(a) Except as provided in paragraph (b) of this section, no person may operate a moored balloon or kite—

(1) Less than 500 feet from the base of any cloud;

(2) More than 500 feet above the surface of the earth;

(3) From an area where the ground visibility is less than three miles; or

(4) Within five miles of the boundary of any airport.

(b) Paragraph (a) of this section does not apply to the operation of a balloon or kite below the top of any structure and within 250 feet of it, if that shielded operation does not obscure any lighting on the structure.

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§101.15 Notice requirements.

No person may operate an unshielded moored balloon or kite more than 150 feet above the surface of the earth unless, at least 24 hours before beginning the operation, he gives the following information to the FAA ATC facility that is nearest to the place of intended operation:

(a) The names and addresses of the owners and operators.

(b) The size of the balloon or the size and weight of the kite.

(c) The location of the operation.

(d) The height above the surface of the earth at which the balloon or kite is to be operated.

(e) The date, time, and duration of the operation.

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Figure 5: Kite Regulations

3 CONCEPT DESIGN AND SPECIFICATION

3.1 USER NEEDS AND METRICS

3.1.1 Record of the user needs interview

Table 1: User Needs Interview

Project/Product Name: Drag Line Energy Generator (Wind)			
Customers: Jakiela, Giesman		Interviewer(s): David, Brian, Bamba	
Address:		Date: 6/28/2021	
Willing to do follow-up?		Currently uses:	
Type of user:			
Question	Customer Statement	Interpreted Need	Importance
How important is it for the kite to automatically launch and retract?	Make a different implementation. More manageable for class purposes. (Not too difficult to implement)	Needs to be easy to manufacture.	5
Does it need to meet a certain efficiency requirement? Or is net positive sufficient?	At least 50 % efficient. Not a huge deal.	Needs to have a net gain of energy at a minimum	5
How large does the system need to be? What type of device are we trying to power?	Ex: Adds charge to a phone battery	Needs to be able to power something more on a small scale	5
Should making the kite "snag resistant" for when it falls to the ground be a priority?	Yes. Cannot be able to get snagged on grass or trees, branches, etc..	Kite needs to be snag resistant.	4
How important is it for the kite to be resistant to weather change?	Vaguely should be able to be used most days. Can ignore extreme weather conditions(Tornado, Hurricane, thunderstorm,etc..)	Needs to be usable on a decent day weather wise.	4

Table 2: Needs Table

Need Number	Need	Importance
1	Needs to be easy to manufacture	5
2	Needs to have a net gain of energy at a minimum	5
3	Needs to be large enough to power something on a small scale	5
4	Kite needs to be able to return to the start point without encountering much resistance.	4
5	Needs to be usable in most weather conditions(low wind speeds, higher wind speeds), the exceptions being extreme/dangerous weather(thunderstorms, hurricanes, hail, blizzards, etc..).	4
6	Needs to be light enough for two people to carry.	2
7	Needs to be small enough to be stored in a section of a garage or shed.	3

3.1.2 List of identified metrics

Table 3: Metrics Table

Metric Number	Associated Needs	Metric	Units	Min. Value	Max Value
1	1,3,6,7	Number of parts	Integer	5	15
2	2,3	Energy gain during Energy Addition Phase	Joules	218	655
3	3,7	Launch Pad Surface Area	ft^2	6	12
4	2,4	Energy loss during the Descent of the Kite	Joules	217	570
5	2,5	Maximum operating wind speed	mph	3	25
6	3,6,7	Weight	lbf	10	70
7	2,4,5	Line length	ft	80	300
8	2,4,5	Kite surface area	ft^2	4	20
9	1	Cost	$	40	200

3.1.3 Table/list of quantified needs equations

Table 4: Quantified Needs Table

Drag Line Energy Generator Concept 1		Metric															
		Number of Parts	Energy Gain during Energy Addition Phase	Launch Pad Surface Area	Energy Loss during the Descent of the Kite	Maximum Operating Wind Speed	Weight	Line Length	Kite Surface Area	Cost	Metric 10	Metric 11	Metric 12	Metric 13	Need Happiness	Importance Weight (all entries should add up to 1)	Total Happiness Value
Need#	Need	1	2	3	4	5	6	7	8	9	10	11	12	13			
1	Manufacturability	0.6								0.4					0.655	0.178571	0.116964286
2	Net Gain of Energy		0.3		0.3	0.15		0.15	0.1						0.626068	0.178571	0.111797837
3	Large enough to power something on a small scale	0.3	0.3	0.3			0.1								0.623276	0.178571	0.111299308
4	Kite needs to be able to return to the start position without encountering much resistance				0.5			0.3	0.2						0.702443	0.142857	0.100349049
5	Needs to be useable in most weather conditions					0.6		0.2	0.2						0.726136	0.142857	0.103733766
6	Needs to be light enough for two people to carry	0.3					0.7								0.648333	0.071429	0.046309524
7	Small enough to be stored in a section of a garage or shed	0.3		0.6			0.1								0.698333	0.107143	0.074821429
8	Need 8														0	0	0
9	Need 9														0	0	0
10	Need 10														0	0	0
11	Need 11														0	0	0
12	Need 12														0	0	0
13	Need 13														0	0	0
Units		Integer	Joules	ft^2	Joules	mph	lbf	ft	ft^2	$	Unit 10	Unit 11	Unit 12	Unit 13	Total Happiness		0.665275199
Best Value		5	655	6	217	25	10	300	4	40							
Worst Value		15	218	12	570	3	70	80	20	200							
Actual Value		7	400	8	330	20	35	300	15	130							
Normalized Metric Happiness		0.8	0.416476	0.666667	0.679887	0.772727	0.583333	1	0.3125	0.4375							

3.2 CONCEPT DRAWINGS

- Concept 1

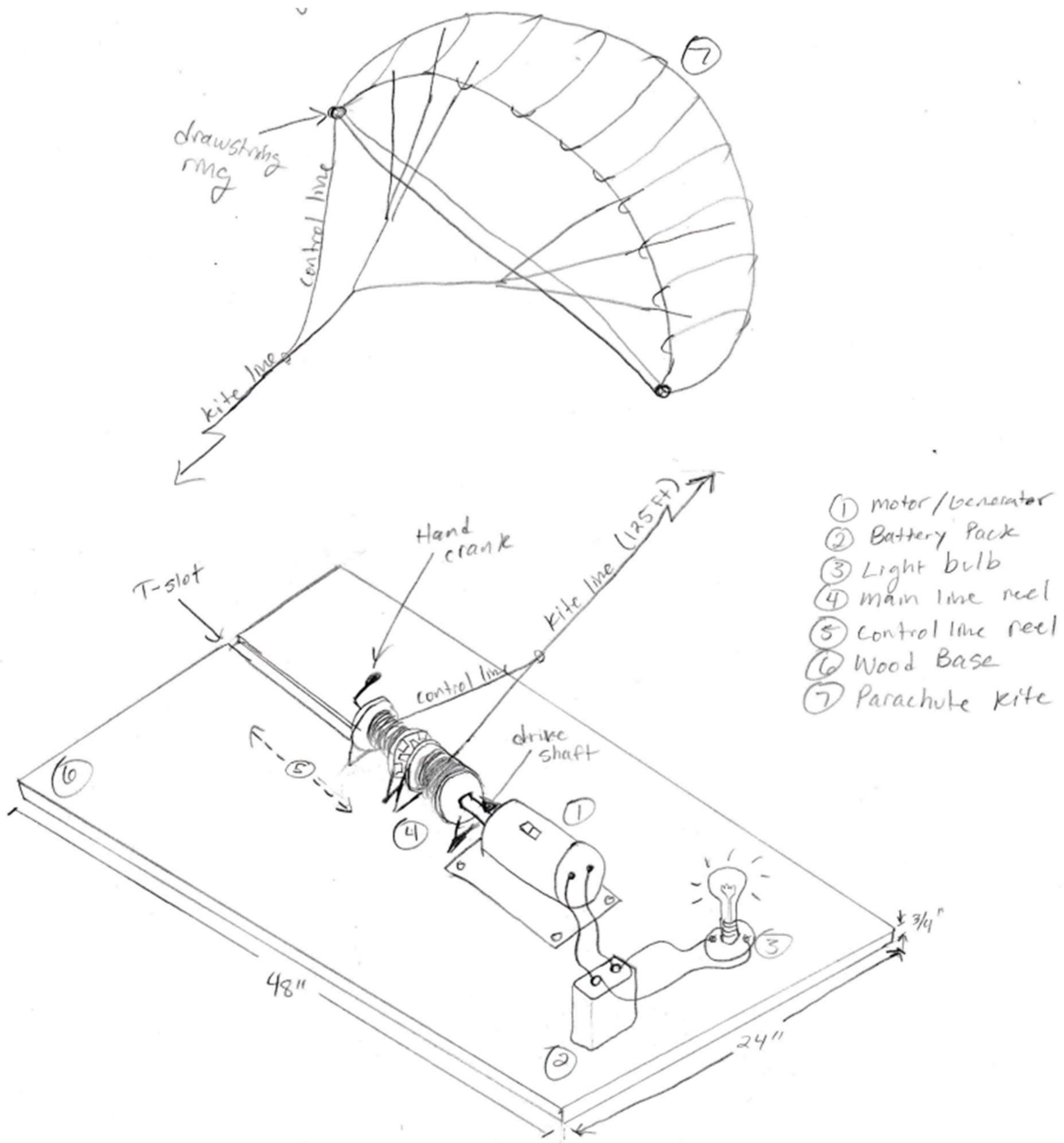


Figure 6: Concept 1

- Concept 2

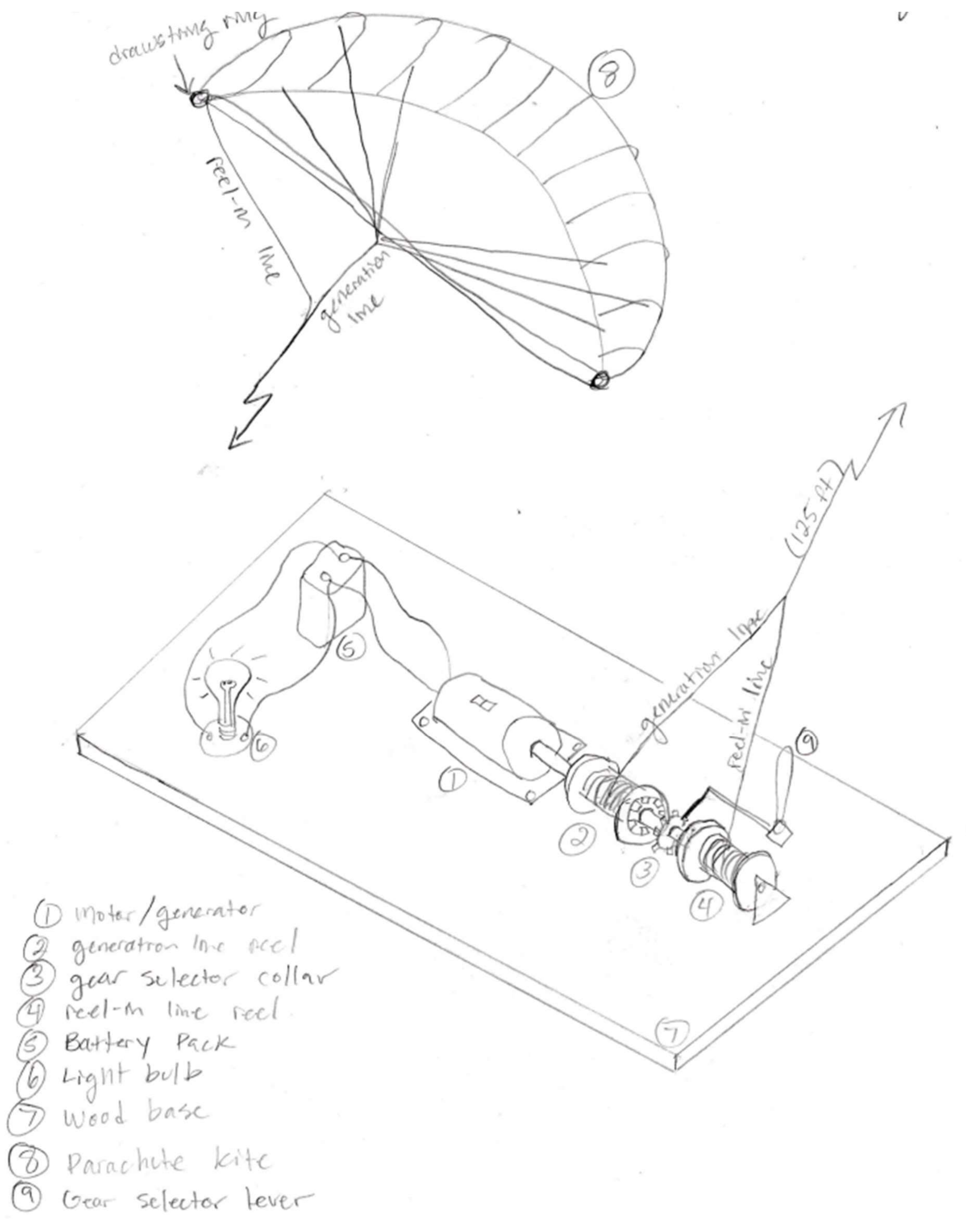


Figure 7: Concept 2

- Concept 3

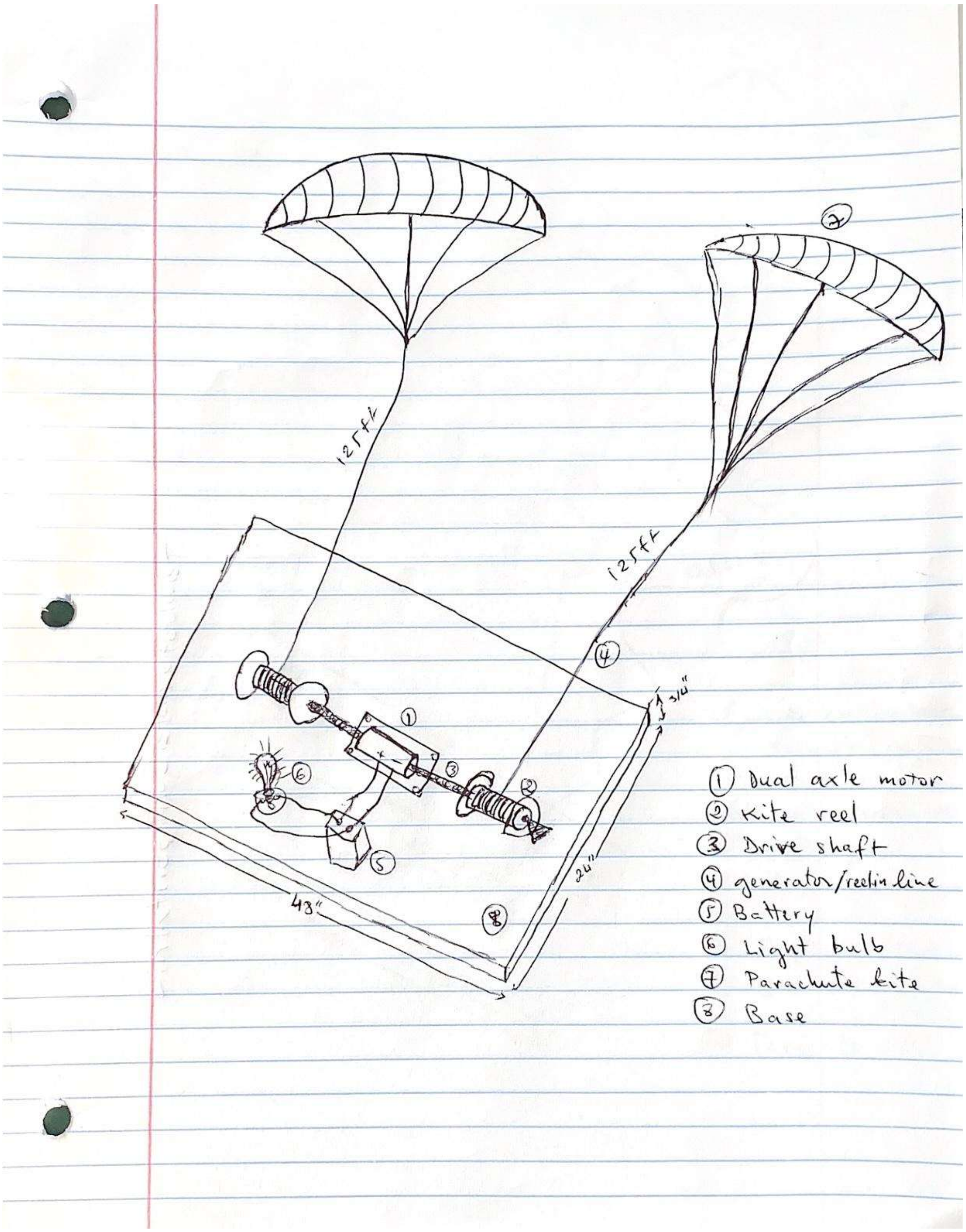


Figure 8: Concept 3

- Concept 4

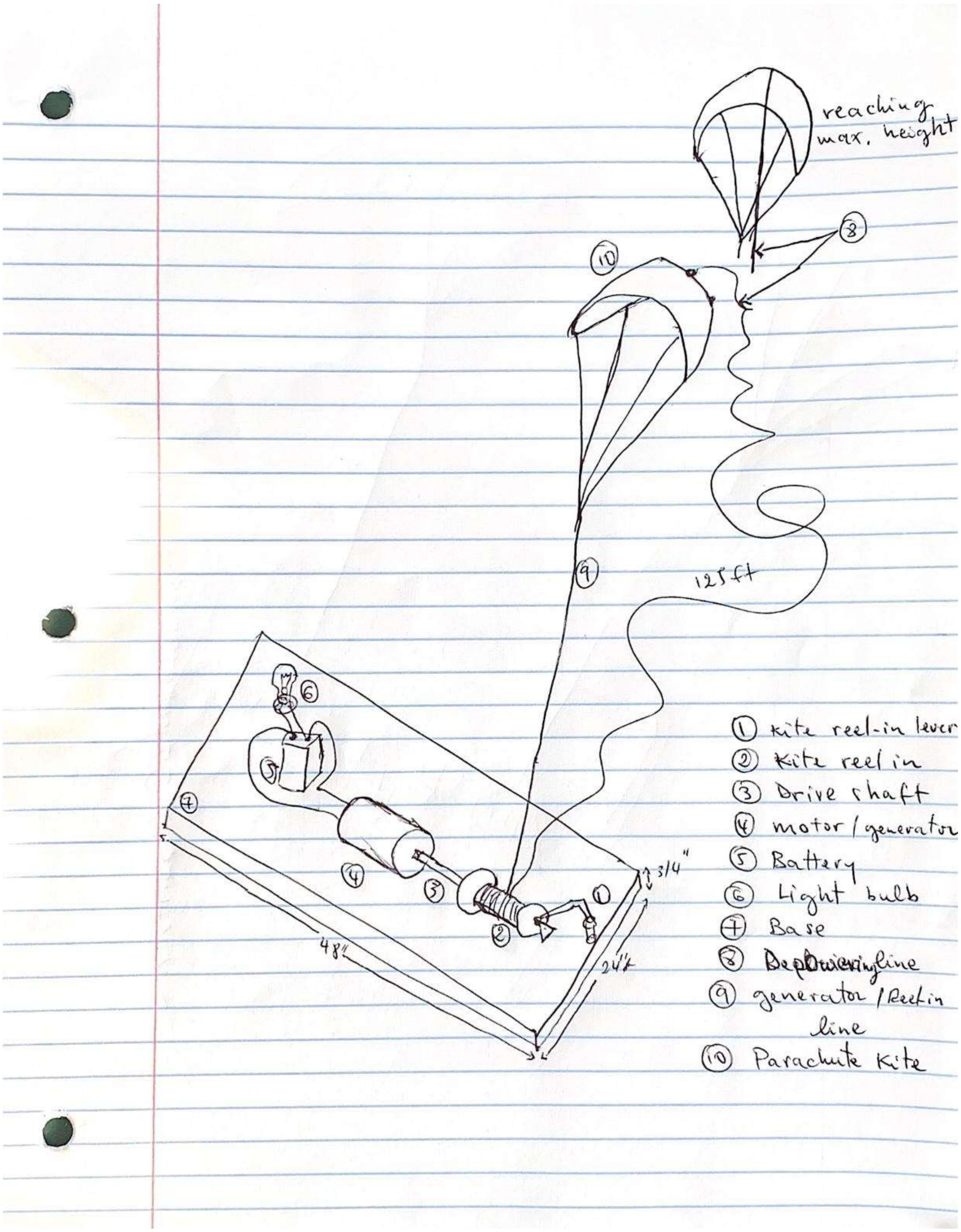


Figure 9: Concept 4

3.3 A CONCEPT SELECTION PROCESS.

3.3.1 Concept scoring (not screening)

- Concept 1

Table 5: Quantified Needs Table for Concept 1

Drag Line Energy Generator Concept 1		Metric															
		Number of Parts	Energy Gain during Energy Addition Phase	Launch Pad Surface Area	Energy Loss during the Descent of the Kite	Maximum Operating Wind Speed	Weight	Line Length	Kite Surface Area	Cost	Metric 10	Metric 11	Metric 12	Metric 13	Need Happiness	Importance Weight (all entries should add up to 1)	Total Happiness Value
Need#	Need	1	2	3	4	5	6	7	8	9	10	11	12	13			
1	Manufacturability	0.6								0.4					0.655	0.178571	0.116964286
2	Net Gain of Energy		0.3		0.3	0.15		0.15	0.1						0.626068	0.178571	0.111797837
3	Large enough to power something on a small scale	0.3	0.3	0.3			0.1								0.623276	0.178571	0.111299308
4	Kite needs to be able to return to the start position without encountering much resistance				0.5			0.3	0.2						0.702443	0.142857	0.100349049
5	Needs to be useable in most weather conditions					0.6		0.2	0.2						0.726136	0.142857	0.103733766
6	Needs to be light enough for two people to carry	0.3					0.7								0.648333	0.071429	0.046309524
7	Small enough to be stored in a section of a garage or shed	0.3		0.6			0.1								0.698333	0.107143	0.074821429
8	Need 8														0	0	0
9	Need 9														0	0	0
10	Need 10														0	0	0
11	Need 11														0	0	0
12	Need 12														0	0	0
13	Need 13														0	0	0
Units		Integer	Joules	ft^2	Joules	mph	lbf	ft	ft^2	$	Unit 10	Unit 11	Unit 12	Unit 13	Total Happiness		0.665275199
Best Value		5	655	6	217	25	10	300	4	40							
Worst Value		15	218	12	570	3	70	80	20	200							
Actual Value		7	400	8	330	20	35	300	15	130							
Normalized Metric Happiness		0.8	0.416476	0.666667	0.679887	0.772727	0.583333	1	0.3125	0.4375							

- Concept 2

Table 6: Quantified Needs Table for Concept 2

Drag Line Energy Generator Concept 2		Metric															
		Number of Parts	Energy Gain during Energy Addition Phase	Launch Pad Surface Area	Energy Loss during the Descent of the Kite	Maximum Operating Wind Speed	Weight	Line Length	Kite Surface Area	Cost	Metric 10	Metric 11	Metric 12	Metric 13	Need Happiness	Importance Weight (all entries should add up to 1)	Total Happiness Value
Need#	Need	1	2	3	4	5	6	7	8	9	10	11	12	13			
1	Manufacturability	0.6								0.4					0.56	0.1785714	0.1
2	Net Gain of Energy		0.3		0.3	0.15		0.15	0.1						0.617569	0.1785714	0.110280233
3	Large enough to power something on a small scale	0.3	0.3	0.3			0.1								0.563276	0.1785714	0.100585022
4	Kite needs to be able to return to the start position without encountering much resistance				0.5			0.3	0.2						0.688279	0.1428571	0.098325577
5	Needs to be useable in most weather conditions					0.6		0.2	0.2						0.726136	0.1428571	0.103733766
6	Needs to be light enough for two people to carry	0.3					0.7								0.588333	0.0714286	0.04202381
7	Small enough to be stored in a section of a garage or shed	0.3		0.6			0.1								0.638333	0.1071429	0.068392857
8	Need 8														0	0	0
9	Need 9														0	0	0
10	Need 10														0	0	0
11	Need 11														0	0	0
12	Need 12														0	0	0
13	Need 13														0	0	0
Units		Integer	Joules	ft^2	Joules	mph	lbf	ft	ft^2	$	Unit 10	Unit 11	Unit 12	Unit 13	Total Happiness		0.623341265
Best Value		5	655	6	217	25	10	300	4	40							
Worst Value		15	218	12	570	3	70	80	20	200							
Actual Value		9	400	8	340	20	35	300	15	120							
Normalized Metric Happiness		0.6	0.416476	0.666667	0.651558	0.772727	0.583333	1	0.3125	0.5							

- Concept 3

Table 7: Quantified Needs Table for Concept 3

Drag Line Energy Generator Concept 3		Metric: Number of Parts	Energy Gain during Energy Addition Phase	Launch Pad Surface Area	Energy Loss during the Descent of the Kite	Maximum Operating Wind Speed	Weight	Line Length	Kite Surface Area	Cost	Metric 10	Metric 11	Metric 12	Metric 13	Need Happiness	Importance Weight (all entries should add up to 1)	Total Happiness Value
Need#	Need	1	2	3	4	5	6	7	8	9	10	11	12	13			
1	Manufacturability	0.6								0.4					0.57	0.1785714	0.101785714
2	Net Gain of Energy		0.3		0.3	0.15		0.15	0.1						0.598819	0.1785714	0.106932019
3	Large enough to power something on a small scale	0.3	0.3	0.3			0.1								0.593276	0.1785714	0.105942165
4	Kite needs to be able to return to the start position without encountering much resistance				0.5			0.3	0.2						0.650779	0.1428571	0.092968434
5	Needs to be useable in most weather conditions					0.6		0.2	0.2						0.688636	0.1428571	0.098376623
6	Needs to be light enough for two people to carry	0.3					0.7								0.618333	0.0714286	0.044166667
7	Small enough to be stored in a section of a garage or shed	0.3		0.6			0.1								0.668333	0.1071429	0.071607143
8	Need 8														0	0	0
9	Need 9														0	0	0
10	Need 10														0	0	0
11	Need 11														0	0	0
12	Need 12														0	0	0
13	Need 13														0	0	0
Units		Integer	Joules	ft^2	Joules	mph	lbf	ft	ft^2	$	Unit 10	Unit 11	Unit 12	Unit 13	Total Happiness		0.621778765
Best Value		5	655	6	217	25	10	300	4	40							
Worst Value		15	218	12	570	3	70	80	20	200							
Actual Value		8	400	8	340	20	35	300	18	140							
Normalized Metric Happiness		0.7	0.416476	0.666667	0.651558	0.772727	0.583333	1	0.125	0.375							

- Concept 4

Table 8: Quantified Needs Table for Concept 4

Drag Line Energy Generator Concept 4		Metric: Number of Parts	Energy Gain during Energy Addition Phase	Launch Pad Surface Area	Energy Loss during the Descent of the Kite	Maximum Operating Wind Speed	Weight	Line Length	Kite Surface Area	Cost	Metric 10	Metric 11	Metric 12	Metric 13	Need Happiness	Importance Weight (all entries should add up to 1)	Total Happiness Value
Need#	Need	1	2	3	4	5	6	7	8	9	10	11	12	13			
1	Manufacturability	0.6								0.4					0.55	0.1785714	0.098214286
2	Net Gain of Energy		0.3		0.3	0.15		0.15	0.1						0.478365	0.1785714	0.085422278
3	Large enough to power something on a small scale	0.3	0.3	0.3			0.1								0.533276	0.1785714	0.095227879
4	Kite needs to be able to return to the start position without encountering much resistance				0.5			0.3	0.2						0.478052	0.1428571	0.068293109
5	Needs to be useable in most weather conditions					0.6		0.2	0.2						0.470455	0.1428571	0.067207792
6	Needs to be light enough for two people to carry	0.3					0.7								0.558333	0.0714286	0.039880952
7	Small enough to be stored in a section of a garage or shed	0.3		0.6			0.1								0.608333	0.1071429	0.065178571
8	Need 8														0	0	0
9	Need 9														0	0	0
10	Need 10														0	0	0
11	Need 11														0	0	0
12	Need 12														0	0	0
13	Need 13														0	0	0
Units		Integer	Joules	ft^2	Joules	mph	lbf	ft	ft^2	$	Unit 10	Unit 11	Unit 12	Unit 13	Total Happiness		0.519424869
Best Value		5	655	6	217	25	10	300	4	40							
Worst Value		15	218	12	570	3	70	80	20	200							
Actual Value		10	400	8	340	15	35	100	10	100							
Normalized Metric Happiness		0.5	0.416476	0.666667	0.651558	0.545455	0.583333	0.090909	0.625	0.625							

3.3.2 Preliminary analysis of each concept's physical feasibility

- **Concept 1**

It is difficult to say whether the drawstring will be able to keep the parachute closed as it's reeled back in, because tension on the main line might be enough to open the chute back up and cause it to no longer be energy efficient. This is because both reels are coupled in this design so when you reel one line in, both have to reel in. A high efficiency motor and low friction bearings would definitely be helpful in this design, but not necessary.

- **Concept 2**

Similarly to concept 1, this design was created to address the difficulty in keeping the parachute shut while it is being reeled back in, by creating a clutch to determine which reel the motor is turning, we can reel the kite back in using ONLY the control line, which will ensure the kite doesn't open back up, but the main line may get tangled up while the control line is reeling in. The clutch assembly is also relatively complicated and will be difficult to manufacture without some specialized tools. A high efficiency motor and low friction bearings would also be helpful in this design, but not necessary.

- **Concept 3**

In this concept we try to add a second kite and a dual axle generator. Both kites are connected and dependently reel in and out in opposite directions. This way we have a constant energy generation that will compensate for the energy loss. The difficulties that could occur are that the two control/main lines might tangle up or that the parachutes open back while being reeled in. The parachutes will be opened/closed and maintained in that position manually.

- **Concept 4**

To address the issue we had to keep the parachute closed for Concept 1 and avoid the clutch which could be complex for this design, we used a kite that will be powered at its normal position and depowered when the maximum height is reached. To do this we will need a depowering line that we act on the parachute. The issue we might face in this concept is that while reeling in the main line the depowering needs to constantly stay tied and reel in with the main line. Then it needs to be released without reeling out. That will need to be done manually.

3.3.3 Final summary statement

We decided to go with Concept 1 for our design for a couple of reasons. This design was relatively simpler than the other design (Concept 2) that involved coupling and decoupling the reels from each other. Concept 1 also utilizes the "drawstring" method of reducing the drag force on the kite as we reel it back in to start another generation cycle. We believe the drawstring method will be less prone to error and specifically to catastrophic nose-dives than the angle of attack approach (Concept 4).

There is a few more reasons we did not choose any of the other designs. For starters, the clutch in concept 2 is a little more complicated than we are comfortable assembling for a first time. This design would also require some high quality bearings to ensure the reel not coupled with the gear selector collar does not spin. In regards to Concept 3, we like the idea of having one kite generating while the other is being pulled back in, however we had difficulty in figuring out a way for the kites to reduce their surface area to be reeled back in without over-complicating the design with more reels and lines and another motor.

4 EMBODIMENT AND FABRICATION PLAN

4.1 EMBODIMENT/ASSEMBLY DRAWING

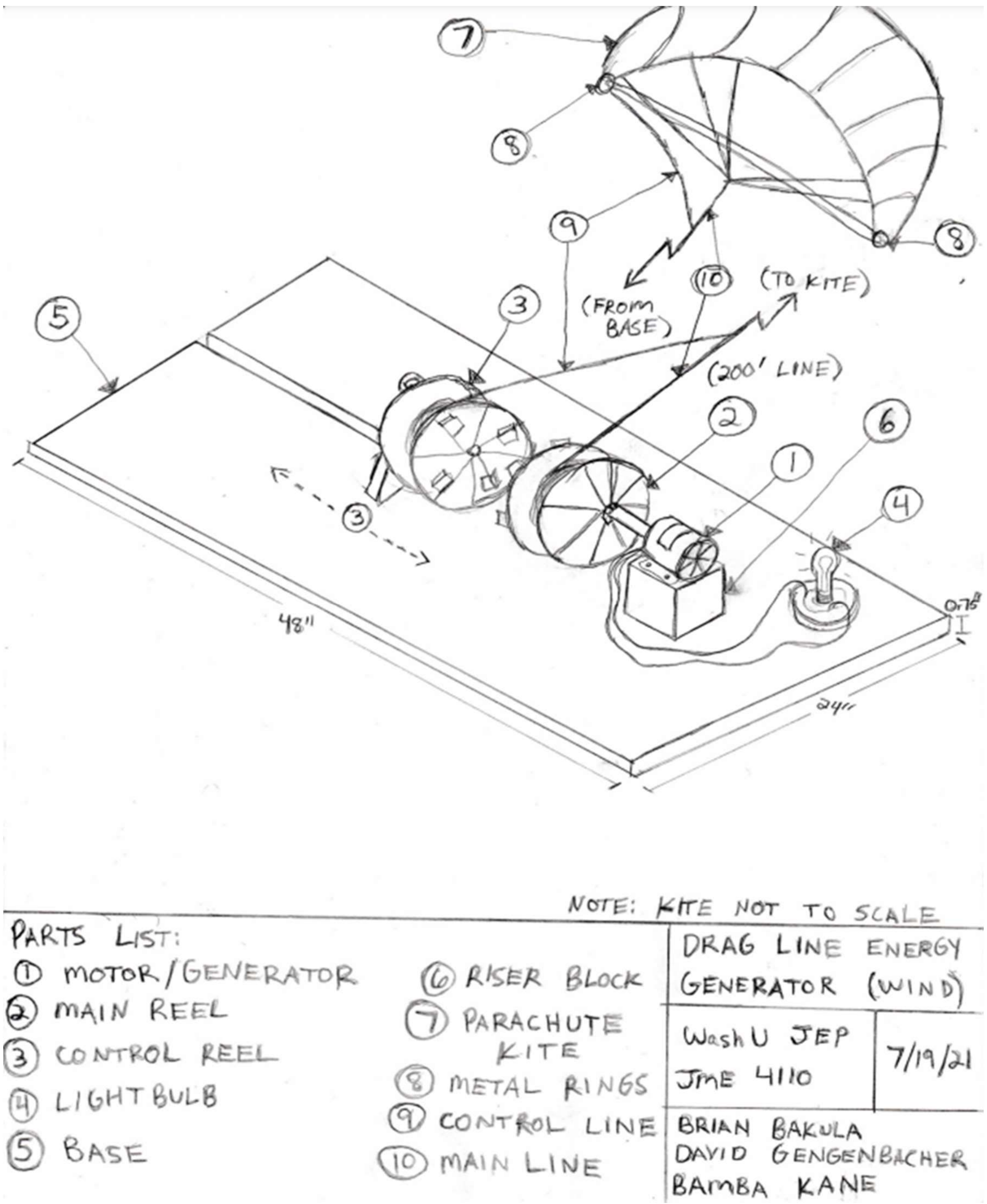


Figure 10: Embodiment Assembly Drawing

4.2 PARTS LIST

Table 9: Parts List

No.	Item Description	Unit	Unit Cost	Qty.	Material	Labor	Total
1	Motor/Generator	1	$43.99	1	Iron	$0.00	$43.99
2	Kite Line Reel	1	$29.87	2	Plastic/Steel	$0.00	$59.74
3	Light Bulb	1	$11.95	1	Glass/Aluminum	$0.00	$11.95
4	Base	1	$17.38	1	Pine Plywood	$0.00	$17.38
5	Riser Block	1	$0.00	1	Wood	$0.00	$0.00
6	Parachute Kite	1	$19.99	1	Polyester	$0.00	$19.99
7	Loose-Leaf Rings	12	$3.59	1	Iron	$0.00	$3.59
8	Kite Line	1	$15.99	1	Polyester	$0.00	$15.99
9	Wire	25ft	$6.03	1	Copper/Rubber	$0.00	$6.03
	Total Direct costs						$178.66
	Indirect Overhead Costs						$0.00
	Total before contingency						$178.66
	Contingency (15%)						$26.80
	Engineers estimate					**Subtotal:**	**$205.46**

4.3 DRAFT DETAIL DRAWINGS FOR EACH MANUFACTURED PART

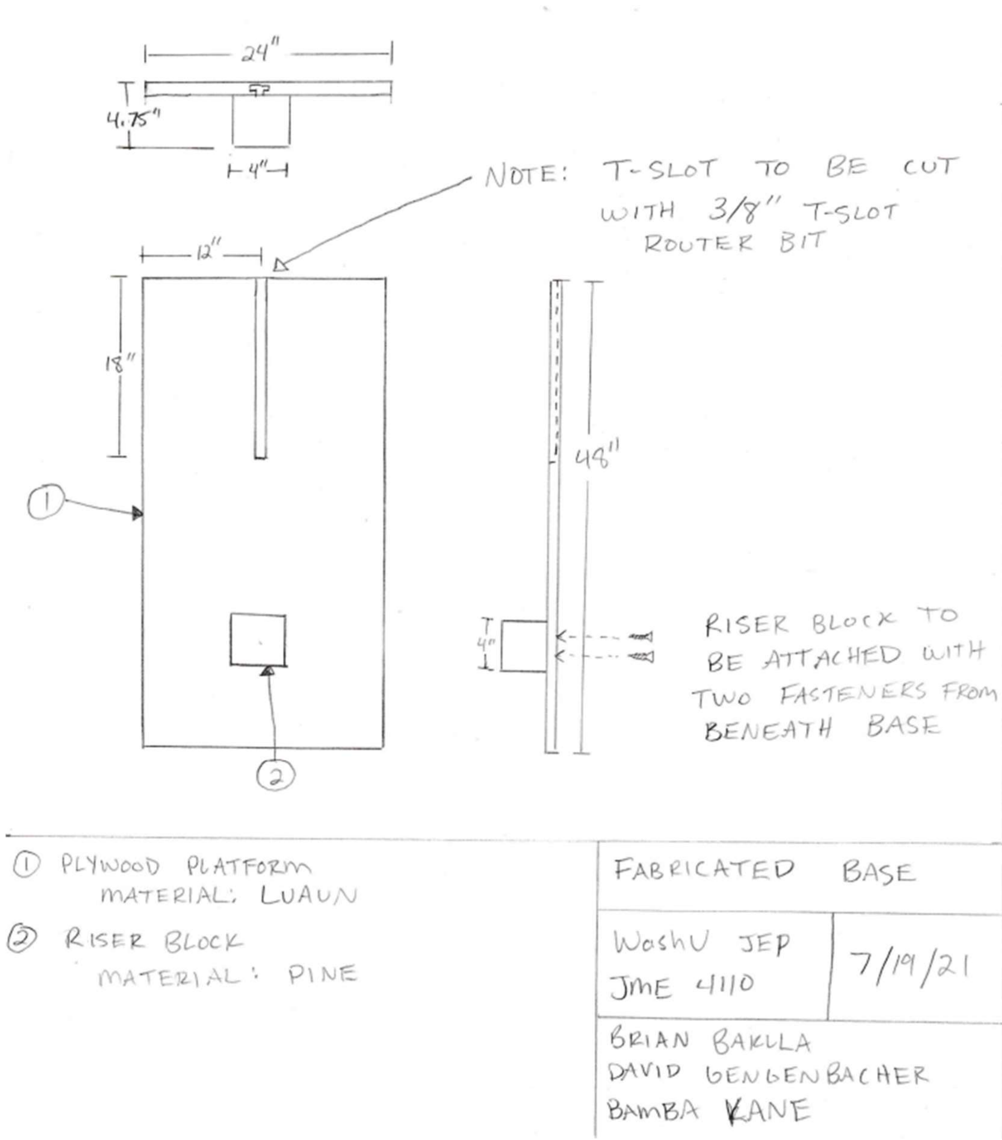


Figure 11: Fabricated Base Drawing

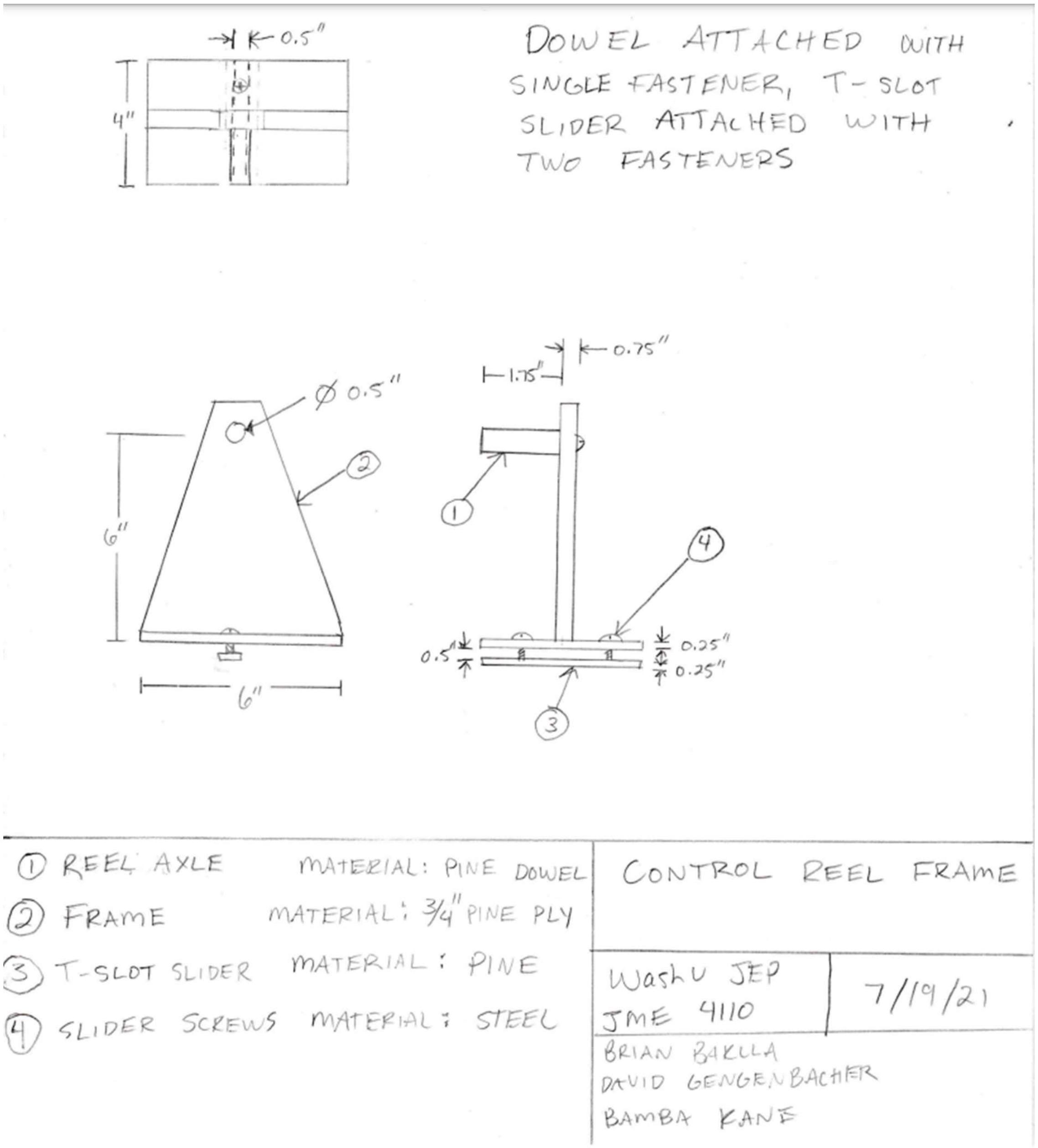


Figure 12: Control Reel Frame Drawing

4.4 DESCRIPTION OF THE DESIGN RATIONALE

Motor/Generator: We feel that our motor, at 350 W and 24V, provides sufficient power to show the concept of a wind energy generator. The motor is also within our allocated price range. The motor is designed for a wind turbine, so it can be easily connected to a spinning shaft and also has a bottom section which we can bolt to our launch platform.

EzeReel(Main reel and control reel): We had the most trouble deciding on which reel we wanted to use as the spool in our design. Most of the reels we found either didn't rotate or would be difficult to attach to our motor shaft. We ended up settling on the EzeReel since we feel it will operate well as a spool, and we believe there are ways to attach it to the motor. The main concern with the reel is how large it is. It is almost a foot in diameter. We will have to modify other parts of our assembly to make sure the motor lines up with the spool, but that shouldn't be too difficult. While the part will be larger than expected it will also generate more torque, so it should still create enough power.

Light Bulb: We feel that our light bulb, at 10 W and 12 V, will be relatively easy to power, while also showing our design concept of wind energy.

Base: We plan on making a 4 ft by 2 ft launch platform to allow for sufficient space for all of the other parts of our assembly. We also are considering the necessary weight of the base, as it needs to be heavy enough so that it remains stationary while the kite is in the air. This will be further elaborated on in the engineering analysis assignment.

Riser Block: The purpose of this part is to make sure the motor lines up with the main reel. Both of our reels are very large, so we will need to make modifications to make sure the assembly connects properly. The motor will be bolted to the top of the riser block

Parachute Kite: We chose a kite that we felt would give us decent torque on our main reel. We did some engineering analysis to ensure what minimum surface area we would need to generate a decent amount of torque on the reel. We did this by calculating the pressure of the wind on the kite and finding the force of the wind, then finding the torque.

$$V_{wind} = 10\,mph$$

$$P_{wind} = 0.00256 \cdot (V_{wind})^2$$

$$P_{wind} = 0.00256 \cdot (10\,mph)^2, \quad P_{wind} = 0.256\,\frac{lbf}{ft^2}$$

$$F_{wind} = P_{wind} \cdot A_{kite} \cdot C_D, \quad A_{kite} = 4ft \cdot 1ft, \; A_{kite} = 4ft^2$$

$$C_D = 1 \text{ (Assumption)}$$

$$F_{wind} = 0.256\,\frac{lbf}{ft^2} \cdot 4ft^2 \cdot 1, \quad F_{wind} = 1.024\,lbf$$

$$T_{spool} = D_{spool} \cdot F_{wind}, \quad T_{spool} = 5.75\,in \cdot 1.024\,lb$$

$$T_{spool} = 5.888\,lb \cdot in$$

Figure 13: Minimum Torque Calculations

These are just some basic calculations assuming a wind speed of 10 mph. The kite area was approximated as 12.4 ft.^2 but could very well be larger than that, which would mean a larger torque. The drag coefficient was also assumed to be 1, since this is impossible to know without testing the kite.

Metal Rings: The rings just need to be large enough for our kite line to easily fit through. They didn't require very much analysis.

Kite Line: We chose the Dacron line kite line for its durability, strength, and simplicity. We didn't do much analysis for the line. We chose something that was popular with most kite flyers, since the flight of our kite is very much the same as any other kite. With a tensile strength of 200 lbf, the line should be more than strong enough to endure any force than wind puts on the kite.

5 ENGINEERING ANALYSIS

5.1 ENGINEERING ANALYSIS PROPOSAL

5.1.1 Signed engineering analysis contract

ANALYSIS TASKS AGREEMENT

PROJECT: Drag-Line Energy Generation (Wind)

NAMES: Brian Bakula
David Gengenbacher
Bamba Kane

INSTRUCTOR: Jakiela/Giesmann

The following engineering analysis tasks will be performed:

1. Calculation of necessary wind speed to power light bulb

2. Percent difference calculation comparing real generator voltage values to catalog generator voltage values.

3. Testing of generator spool assembly to see how much rpm from spool is needed to power the light bulb.

The work will be divided among the group members in the following way:

1. David (DG)
2. Brian (BB)
3. Bamba (MBK)

Instructor signature: ____________; Print instructor name: Craig J. Giesmann__
Instructor signature: ____________; Print instructor name: Mark J. Jakiela

(Group members should initial near their name above.)

5.2 ENGINEERING ANALYSIS RESULTS

5.2.1 Motivation

1. Calculating the necessary wind speed is critical because it allows us to see if our prototype is plausible. For instance, if we calculate a very high necessary wind speed, this means the spool of our prototype is rotating at a slow speed. We could then look into how to improve the spool speed, maybe by decreasing the mass of the spool or increasing the torque.

2. Calculating the necessary wind speed is critical because it allows us to see if our prototype is plausible. For instance, if we calculate a very high necessary wind speed, this means the spool of our prototype is rotating at a slow speed. We could then look into how to improve the spool speed, maybe by decreasing the mass of the spool or increasing the torque.

3. We wanted to find the RPM because it gives a realistic goal to reach. Up until now, the calculations have involved many assumptions. Doing testing with the prototype gives us the numbers we really need to target, and we can adjust our prototype to meet those conditions.

5.2.2 Summary statement of analysis done

1.

$$P = T \cdot W, \quad W = 2700\ rpm, \quad P = 350W$$

$$T = \frac{P}{W}, \quad T = \frac{350W}{2700 \frac{rev}{min} \cdot \frac{2\pi}{60}}, \quad T = 1.24\ N \cdot m$$

$$T = 10.97\ in \cdot lb$$

$$T = r \cdot F_T \sin(\theta), \quad r = 5.5\ in, \quad \theta = 45°$$

$$F_T = \frac{T}{r\sin(\theta)}, \quad F_T = \frac{10.97\ in \cdot lb}{5.5\ in\ \sin(45)}, \quad F_T = 2.34\ lbf$$

$$F_T = P \cdot A \cdot C_D, \quad C_D = 1, \quad A = 6.2ft \cdot 2ft, \quad A = 12.4ft^2$$

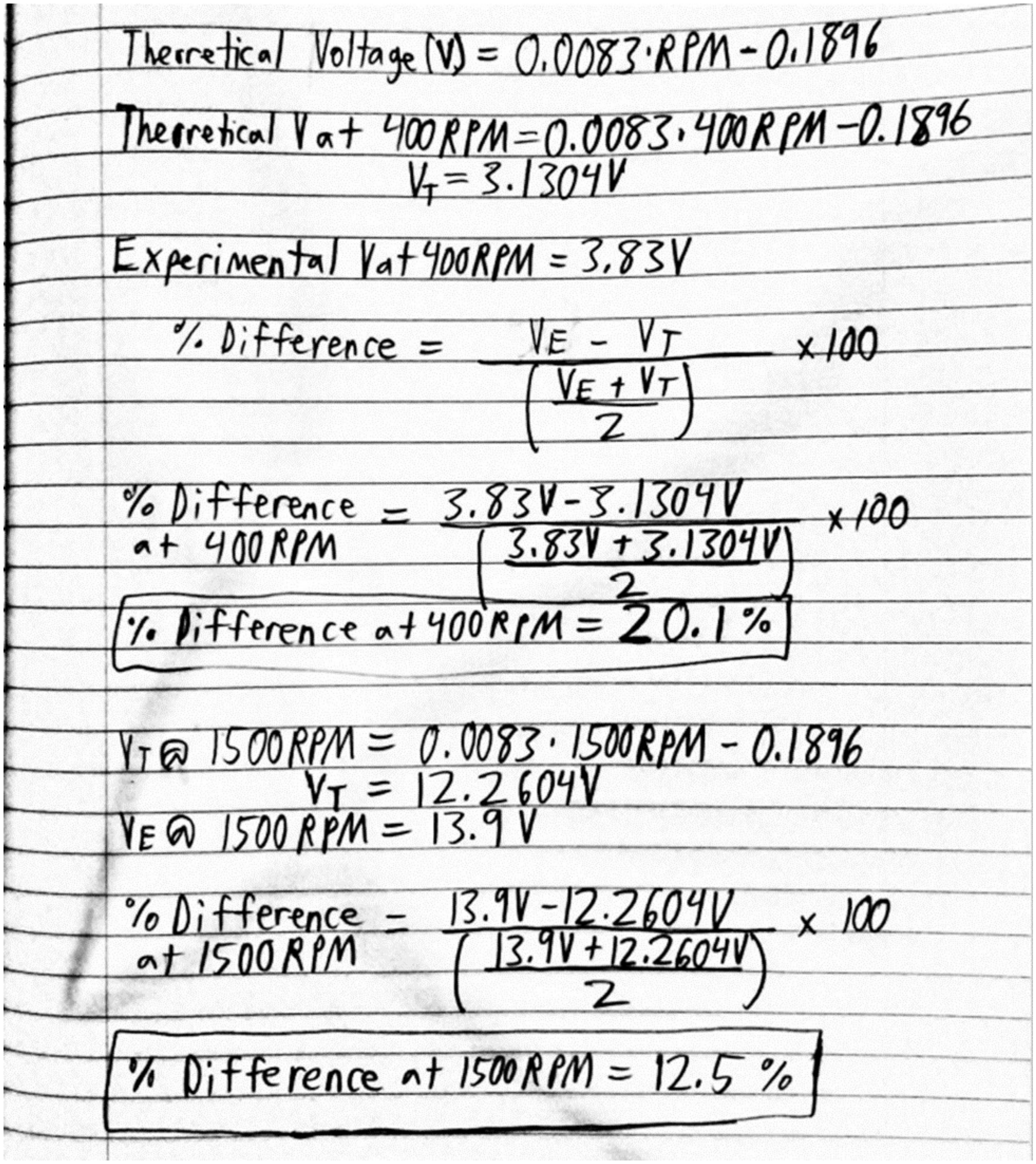
$$P = \frac{F_T}{A \cdot C_D}, \quad P = \frac{2.34\ lbf}{12.4ft^2 \cdot 1}, \quad P = 0.18871 \frac{lbf}{ft^2}$$

$$P = 0.00256(V_{wind})^2, \quad V_{wind} = \sqrt{\frac{P}{0.00256}}$$

$$V_{wind} = \sqrt{\frac{0.18871 \frac{lbf}{ft^2}}{0.00256}}, \quad \boxed{V_{wind} = 8.6\ mph}$$

Figure 14: Minimum Wind Speed Calculations

2.



Theoretical Voltage (V) = 0.0083·RPM − 0.1896

Theoretical V at 400 RPM = 0.0083·400 RPM − 0.1896

$V_T = 3.1304V$

Experimental V at 400 RPM = 3.83V

$$\% \text{ Difference} = \frac{V_E - V_T}{\left(\frac{V_E + V_T}{2}\right)} \times 100$$

$$\% \text{ Difference at } 400\text{RPM} = \frac{3.83V - 3.1304V}{\left(\frac{3.83V + 3.1304V}{2}\right)} \times 100$$

% Difference at 400 RPM = 20.1 %

V_T @ 1500 RPM = 0.0083·1500 RPM − 0.1896

$V_T = 12.2604V$

V_E @ 1500 RPM = 13.9 V

$$\% \text{ Difference at } 1500\text{RPM} = \frac{13.9V - 12.2604V}{\left(\frac{13.9V + 12.2604V}{2}\right)} \times 100$$

% Difference at 1500 RPM = 12.5 %

Figure 15: Generator Testing Results

3.

Table 10: Target Conditions to Power Light Bulb

Voltage(V)	Time(s)	Motor shaft RPM	Angular Acceleration, α(rad/s^2)	Torque(N*m)	Ft(N)	P(Pa)	V(m/s)	V(mph)
1.92	2.37	254.17	11.23	0.14	1.07	1.55	1.55	3.47
2.02	2.56	266.22	10.89	0.14	1.04	1.51	1.53	3.41
2.01	1.98	265.01	14.02	0.17	1.34	1.94	1.73	3.87
V = 0.0083*RPM -0.1896								
I(kg*m^2) =	0.0124		α =(RPM*(2π/60))/Time	T = I*α	Ft = T/(rspool*sin(45))	P = Ft/A	V = (P/(0.00064645*1000))$^{(1/2)}$	
A(m^2) =	0.691199							
rspool =	6 inches							

5.2.3 Methodology

1. This analysis was entirely theoretical. We had to make assumptions about some of the variables, such as kite surface area and mass moment of inertia. This was because we did not have the parts with us when the analysis was done.

2. The analysis involved a bit of testing. The testing was done by using a drill to spin the generator at two different RPM values, 400 RPM and 1500 RPM. The generator was connected to a multimeter to measure the voltage from the generator at each RPM. These voltage values were then compared to the catalog values. Only three catalog values were known. The three being 7.2 Volts at 900 RPM, 18.6 Volts at 2500 RPM, and 24 Volts at 2700 RPM. A linear trendline was constructed from these three values in excel. The linear trendline equation was used to find the catalog voltage values at each experimental RPM value to compare with the experimental voltage values. The comparison was done using percent difference to try to get an idea how much the values differed from one another.

3. This analysis involved testing and computation. First, test values were acquired for voltage and time. The way the test was performed involved one person pulling on the kite line while the other two people observed the lightbulb connected in series with a multimeter. Once the lightbulb was sufficiently lit up, we would stop pulling the kite line and observe the voltage at the moment the light bulb lit up. We took a video of the light bulb and the multimeter to see the exact voltage when the light bulb was lit. We also recorded the time to get to the required voltage. The voltage values were plugged into the theoretical RPM trendline equation from part 3 to get an approximate value for the required RPM of the motor shaft to light the light bulb. Dividing the RPM value by the experimental time value gave us the angular acceleration which allowed us to find the needed torque on the spool. The torque was used to find the needed force from the kite line which in turn was used to find the needed wind pressure. From the wind pressure, we were able to find the needed wind speed in mph. The wind pressure equation we used is for the wind pressure on a flat wall face, so it is probably not 100 % accurate, though we feel it is a good approximation. The computations were done in Microsoft excel.

5.2.4 Results

1. The results were that a minimum wind speed of 8.6 mph is required to power our generator. Our results are somewhat off. This is because the P = T*w equation is more focused on the necessary torque needed to stay at a specific angular velocity w. We are more focused on the torque needed to light the light bulb up.

2. The results indicate that the generator can generate more voltage in reality at the specified RPMs than is specified on the Amazon page. This is true for both the RPMs we compared. The percent difference at 400 RPM is 20.1% while at 1500 RPM it is 12.5%. It's difficult to consider these accurate since we didn't test enough RPM values, but it's probably reasonable to assume a percent difference between 10 and 20 percent.

3. The results indicate that we need around a 3.5 mph wind to produce the necessary torque to power the light bulb. This is good since we feel this wind speed is easily achievable. Even though these results are the most accurate we've acquired thus far, the actual wind speed needed is most likely greater than 3.5 mph because of friction and energy loss of the assembly. The good thing is that 3.5 mph gives us a good amount of room for error for those energy losses since it is such a small wind speed.

5.2.5 Significance

1. This analysis caused us to purchase a kite with a larger surface area, so the kite could capture more wind energy. We had previously done the analysis with a smaller kite and found that the wind speed was a little too high.

2. This analysis was done to give us a better idea of the capabilities of the motor. The motor seems to be even better at producing power than the Amazon page indicated, so the rest of the prototype was not changed. If the motor had produced significantly less power than was listed, we would have had to find a way to decrease the mass of the spool, so we could rotate at a low torque value.

3. Since this analysis gave us a low wind speed, we do not think our prototype needs to be modified as a result of it. The low wind speed indicates that our assembly is capable of producing the required voltage to light the light bulb.

6 RISK ASSESSMENT

6.1 RISK IDENTIFICATION

The following potential risks were identified. These are risks we feel as a group could have a negative impact on the project. These negative impacts being failure to complete the project, failure of the prototype to function, damage to wild life, and destruction of the prototype itself. A risk matrix was created to understand the severity of each risk. The following risks are as follows.

1. A bird contacting the kite while the kite is in the air

2. An excessively strong wind gust causes damage to the kite or prototype
3. The team falls behind on the project such as missing deadlines
4. Incorrect calculations during theoretical analysis
5. Insufficient wind for the prototype to work properly

6.2 RISK ANALYSIS

Table blank shows a risk assessment matrix for the project.

Table 11: Risk Assessment Matrix

Probability \ Impact	1	2	3	4	5
5					
4					5
3					3
2					1,4
1				2	

Severe Risk
Moderate Risk
Low Risk

1. Our prototype involves flying a kite in the air. We will have to be aware of birds as the kite could harm the bird and also potentially damage our kite.
2. Our prototype is only designed to power a light bulb. Our spool only needs around 200 – 250 RPM to generate enough power. A very strong gust of wind could rotate the spool at a much higher RPM than we anticipated and could potentially destroy our prototype or damage our kite.
3. This project involves a significant work load and some work must be completed before either work is started. For instance, some engineering analysis must be done before the construction of the prototype is begun. Some members of our team have other job commitments, so it can be easy to fall behind if we do not stay on task.
4. Incorrect calculations are a possibility to happen since we are human and humans make mistakes. This can obviously have a big impact on the performance of our prototype as the calculations are what tells us what target conditions to look for. For example, what RPM we need in our spool.
5. Missouri isn't a very windy state, and our design brief is all about wind energy. Obviously not having enough wind to power our light bulb would defeat the purpose of our assignment. We also need enough wind to get the kite in the air.

6.3 RISK PRIORITIZATION

1. Our strategy to prevent contact with any birds is to keep our kite stable while flying. We will do this by trying to keep the kite at lower elevations.
2. We will deal with excessive wind gusts by only using the prototype on days where the wind speed is less than 30 mph. This should be easy since Missouri is not a very windy state.

3. To prevent falling behind on the project, we will meet at least twice a week, every week until the project is completed. During these meetings we will work on the project while also assigning each other tasks to complete before the next meeting.
4. We will try to prevent incorrect calculations from being missed by triple checking our analysis and also relying on our engineering intuition. For example, if we notice that we calculated a 1500 RPM to light our 10-watt light bulb, we trust ourselves to realize that 1500 is significantly more RPM than we actually need.
5. There are two potential strategies we plan on employing to deal with insufficient wind. The first involves using the prototype on windy days. If we can get a day with winds of around 15 mph, that should be more than enough for our prototype to work. If we cannot get any windy days, our second strategy involves using a leaf blower to fly the kite. This will involve some skill on our part when using the leaf blower, but we feel it is possible.

7 CODES AND STANDARDS

7.1 IDENTIFICATION

Here is a list with bibliographic information of the codes and standards that are related to our design project.

i. National Fire Protection Agency - NFPA 70: National Electrical Code - Article 310.5 - 2008 Edition
ii. National Fire Protection Agency - NFPA 70: National Electrical Code - Article 445 2008 Edition
iii. Federal Aviation Administration - FAA 7210.3 19.5.2 - Part 101 Subpart B 101.13 a2 – 2021
iv. Federal Aviation Administration - FAA 7210.3 19.5.2 - Part 101 Subpart B 101.13 a3 – 2021
v. Federal Aviation Administration - FAA 7210.3 19.5.2 - Part 101 Subpart B 101.15 - 2021

7.2 JUSTIFICATION

i. This code deals with minimum size conductors for usage in general wiring scenarios. It was chosen because our design utilizes wiring in the generator and between the generator and the light bulb.

ii. This code handles all the regulations for generators. It was chosen because it contains a lot of relevant information such as proper labeling, overcurrent protection, conductor specifications, and other safety concerns like disconnecting means and GFCI protection.

iii. This regulation describes the max altitude a kite or balloon can fly, which is 500 feet. This is relevant as it describes the highest altitude we can fly our kite at.

iv. This regulation states the minimum ground visibility necessary when operating a kite. This is relevant as it describes the conditions needed to use our prototype.

v. This is not an exact code, but the paragraph referenced explains how unless the FAA is notified 24 hours prior, a kite cannot fly 150 feet above the surface. This is important information since it lets us know how high we can fly our kite without notifying the FAA.

7.3 DESIGN CONSTRAINTS

i. For 0-2000V applications, the minimum conductor size (AWG) for copper is 14.

ii. 1. Generators must be marked with the manufacturer's name, rated frequency, power factor, etc. (See code for entire list)
2. Generators operating at 65 volts or less and driven by individual motors shall be considered as protected by the overcurrent device protecting the motor if these devices will operate when the generators are delivering not more than 150 percent of their full-load rated current.
3. Where wires pass through an opening in an enclosure a bushing shall be used to protect the conductors. The bushing shall have smooth, well-rounded surfaces where it may be in contact with the conductors.
4. Generators shall be equipped with disconnect(s), lockable in the open position. The driving means for the generator must be able to be readily shut down. The generator cannot be arranged to operate in parallel with another generator or other source of voltage.

iii. Max vertical kite altitude of 500 feet if the FAA is notified before use of prototype.

iv. When using the prototype, the ground visibility must be greater than 3 miles.

v. Max vertical kite altitude of 150 feet if the FAA is not notified before use of prototype.

7.4 SIGNIFICANCE

i. Due to this code, the final model will need to use size 14 AWG copper wire, as opposed to the 16 we had previously used. Alternatively, we could use Aluminum or Copper-clad Aluminum as dictated by Table 310.5 from the code, shown below.

Table 12: Minimum Size of Conductors Regulations

Table 310.5 Minimum Size of Conductors

Conductor Voltage Rating (Volts)	Minimum Conductor Size (AWG)	
	Copper	Aluminum or Copper-Clad Aluminum
0–2000	14	12
2001–8000	8	8
8001–15,000	2	2
15,001–28,000	1	1
28,001–35,000	1/0	1/0

ii. We will need to add some additional information about the generator to the nameplate in order for it to meet the code requirements. Thankfully, our generator/motor meets the criteria for constraint number 2 already, so we do not need to add any kind of overcurrent protection. We will need to add some kind of bushing to the motor housing where the wires exit the housing in order to protect them from damage and be in compliance with the third constraint. This bushing can just be made of a soft rubber of any kind since chemical corrosion and significant heat are not risks for our design. Lastly, there are a few ways we could be in compliance with the fourth constraint, the easiest being just having a scissors to cut the kite string, but if this design were to be scaled up and used to create a more dangerous voltage a more sophisticated disengage mechanism would be required.

iii. This constraint can influence two aspects of the prototype, the angle of the kite line, and the length of the kite line. The amount of influence on each particular aspect depends on the other aspect. For instance, a higher angle of the kite line will mean the length of the line must be decreased, while a larger kite line length will mean the angle of the kite line must be decreased.

iv. This is an operating constraint. Since we should not be flying the kite in low visibility conditions anyway, we do not have to worry about flying the kite through fog or other possible poor weather conditions.

v. This constraint influences the same aspects as part 3, but obviously the max altitude targeted will be lower at 150 feet

8 WORKING PROTOTYPE

8.1 PROTOTYPE PHOTOS

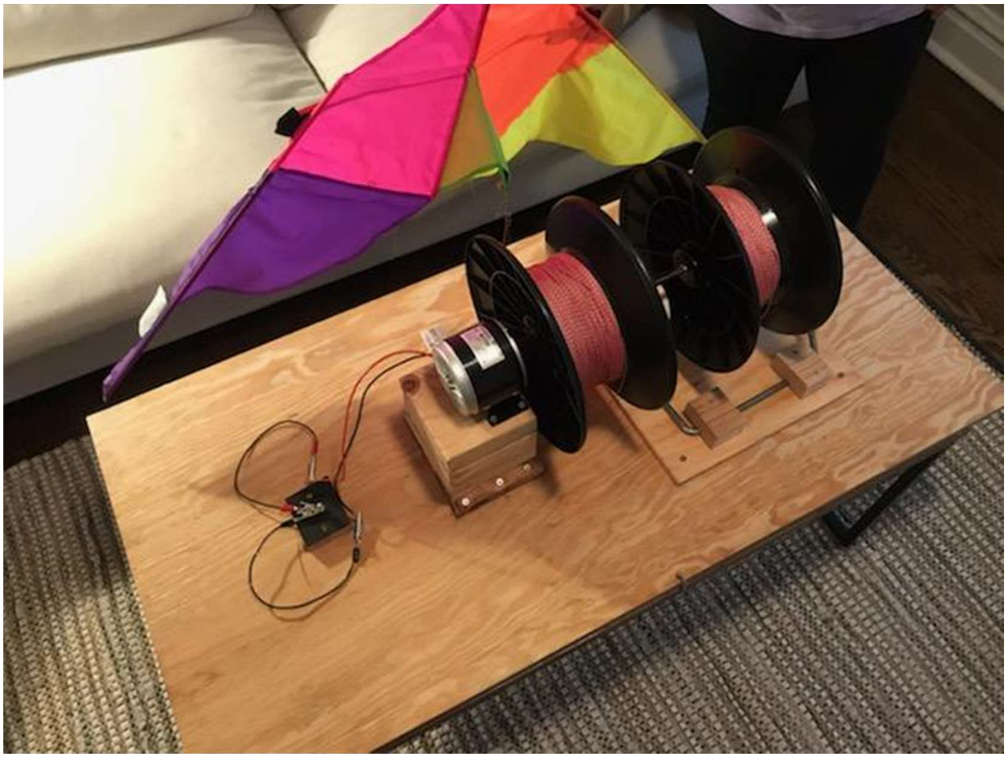


Figure 16: Final Prototype Photo 1

This photograph shows almost every part of our drag line wind energy generator. The rainbow kite is a delta kite, which is known for being easy to fly. The kite line connected to the delta kite traces back to the leftmost reel, which is what is used to spin the generator on the left, mounted on the wood blocks. The generator connects back to a light bulb using low voltage wire and alligator clips. The light bulb is resting on the black wood block which is screwed into the launch pad, the black coating makes it easier to see the light bulb in bright conditions. The whole system is secured to the base using screws and wood blocks to adjust the heights of the various components.

Figure 17: Final Prototype Photo 2

This photo does a better job showing our coupling mechanism between our main reel on the left and our control reel on the right. The control reel (right) is used to reel the kite back in after the line is fully extended, and the control reel is detached from the main reel (left). The reels have knobs extending towards each other (originally intended for cranking) that were covered in velcro to serve as means of coupling the two reels rotationally. We cut a piece of PVC pipe that fit snugly around the two knobs as an added precaution against undesired de-coupling. The PVC resists a lot of the shear forces that would normally tear the velcro apart. The reels and generator shaft are all aligned by sharing a common axle, which extends from the metal stand supporting the control reel (right). This axle needed an extension welded onto it to make it long enough to accommodate both reels. The main reel is coupled to the generator shaft via its rotating axle that we welded a hex socket impact bit onto the end of, which mates with the hex nut on the generator shaft.

8.2 WORKING PROTOTYPE VIDEO

A video of our working prototype can be found using the YouTube link below:

(4) JME 4110 Drag Line Wind Energy Generator - YouTube

The overall performance measure for our design was whether or not we were able to visibly power the light bulb using only wind force on the kite. At roughly the 35 second mark of the video, we were able to get the kite flying and for a few moments it took the reel for a spin, fast enough to power our lightbulb and produce visible light (pausing at the 0:37 mark of the video, you can see the light). Immediately after lighting the bulb, we quickly got some footage of the kite flying around to show that it was indeed the only thing pulling on the line.

8.3 PROTOTYPE COMPONENTS

Figure 18: Attachment Mechanism Between Main Reel and Generator Shaft

A close-up look at the attachment mechanism between the main reel and the generator shaft is shown above. The piece welded onto the axle of the reel is a ½" hex drive socket, which mates around the ½" hex nut that came already installed on the end of the motor shaft

Figure 19: Hex Drive Socket Adaptor

For clarity, we have included the above picture of a hex-drive socket adaptor for our reel axle. Please note that this is not the socket bit that we ended up welding to the final prototype, but it gives a better idea of how the attachment works.

Figure 20: Final Prototype Wiring Setup

This picture shows the basic wiring setup, a simple DC connection between the positive and negative terminals of the generator and the two leads of our lightbulb that we are attempting to power.

Figure 21: Final Prototype Kite

Above is a detailed image of the kite we used to accomplish our goal. It is much smaller than the original parachute kite we had intended to use, and it is a delta-style kite as well. The kite consists of a lightweight web material and rigid plastic bars that give it structure, as well as a fin beneath the kite where the line is attached.

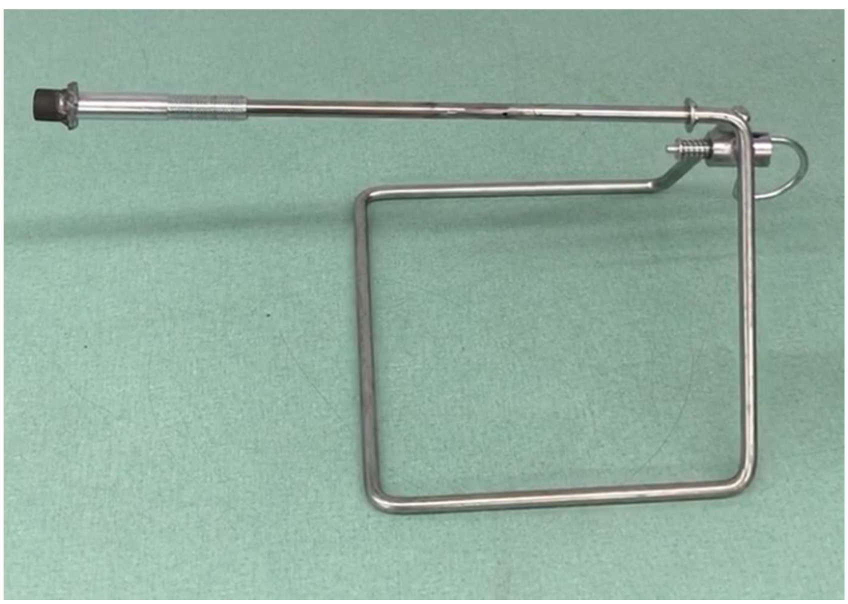


Figure 22: Axle Support

Finally, a more detailed look at the axle and support assembly. The main piece is all one solid metal bar, with an extension welded to the protruding axle to make it long enough for both reels to spin on. Situated freely on the end of the aforementioned axle is the rotating axle that would normally be hidden and secured inside the main reel. This part rotates freely around the stationary main axle, and is coupled with the generator via the hex socket bit welded to it.

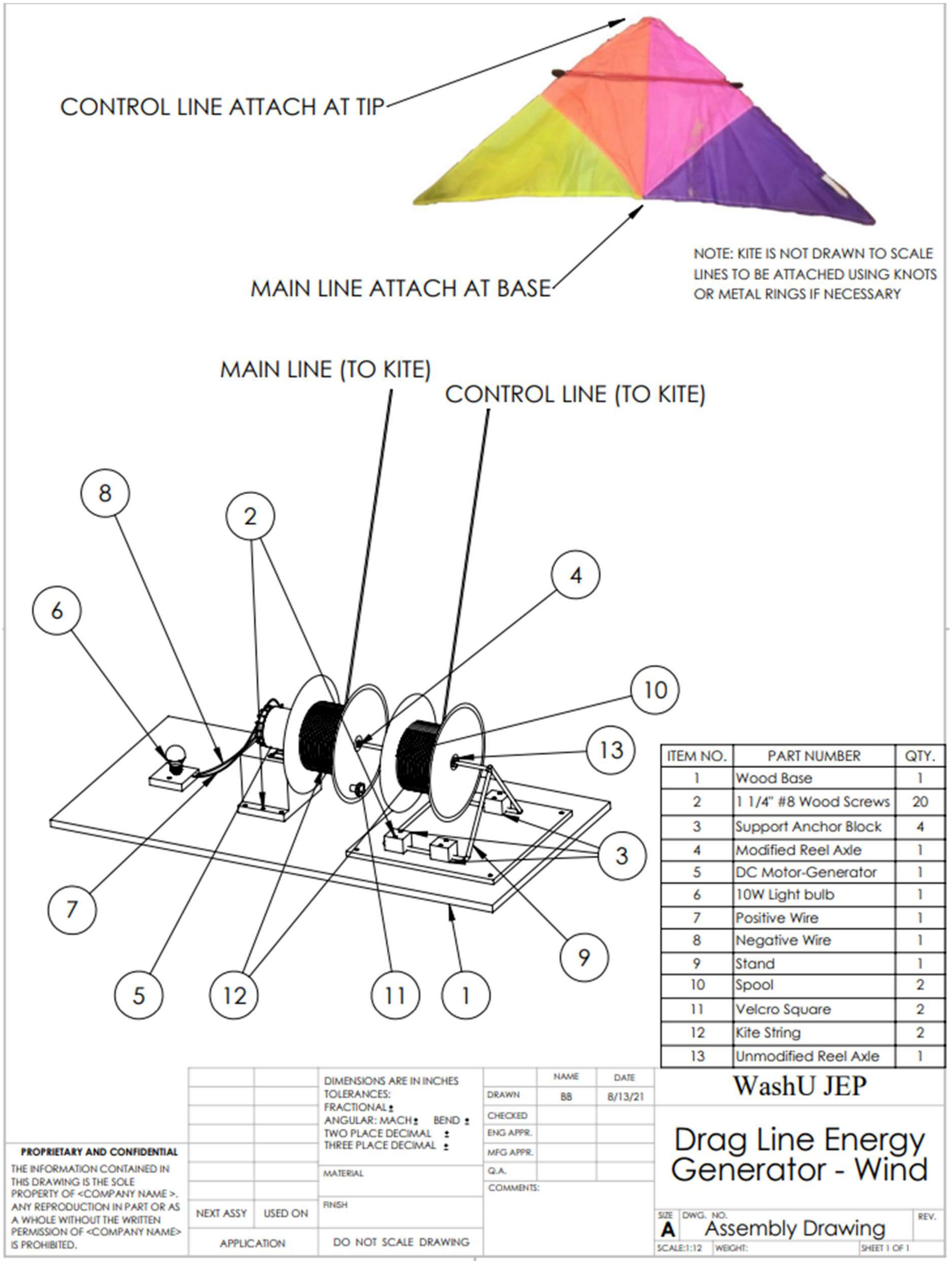
9 DESIGN DOCUMENTATION

9.1 FINAL DRAWINGS AND DOCUMENTATION

9.1.1 Engineering Drawings

See Appendix C for the individual CAD models.

After we have built our prototype and completed some testing before and after the prototype, we have come up with a final design that is represented in the following CAD drawing.



ITEM NO.	PART NUMBER	QTY.
1	Wood Base	1
2	1 1/4" #8 Wood Screws	20
3	Support Anchor Block	4
4	Modified Reel Axle	1
5	DC Motor-Generator	1
6	10W Light bulb	1
7	Positive Wire	1
8	Negative Wire	1
9	Stand	1
10	Spool	2
11	Velcro Square	2
12	Kite String	2
13	Unmodified Reel Axle	1

Figure 23: Final Assembly Solidworks Drawing

9.1.2 Sourcing instructions

A table summarizing all the information about each used part is attached below:

Table 13: Sourcing Instructions

PART NUMBER	PART NAME	DESCRIPTION	CATALOG SOURCE	PRICE
1	Wood Base	The pine plywood base, approximately 24”x48” that the whole assembly is attached to. This includes riser blocks that ensure everything is sitting at the correct height for axial alignment, as well as pre-drilled holes for attaching everything. Only height dimensions are critical, and spacing of the pre-drilled holes for the motor. Scrap wood is used for building up the structures on this part.	https://www.lowes.com/pd/23-32-in-Common-Pine-Sanded-Plywood-Application-as-2-x-4/1000068981	$19.34
2	1 ¼” #8 Wood Screws	Common construction wood screws for attaching parts to the wooden base.	https://www.lowes.com/pd/Grip-Rite-8-x-1-1-4-in-Gold-Yellow-Zinc-Bugle-Interior-Wood-Screws-1-lb/1000075735	$8.78
3	Support Anchor Block	Pine blocks fabricated to hold down the legs of the support stand that the reels rotate upon. Four of these blocks hold down the stand, and can be fabricated from almost any scrap wood thick enough to fit the cutout for the support bars as well as the two pre-drilled holes for screws. (See drawing for details)	N/A	N/A
4	Modified Reel Axle	The unmodified part comes with the EzeReel assembly that we ordered, the modification is welding a ½” hex socket impact bit onto the end of the axle to allow it to couple with the ½” nut on the motor output shaft. The main reel uses this axle to rotate around the support axle.	https://www.lowes.com/pd/Bosch-Impact-Tough-2-9-16-in-1-2-in-Nutsetter-Alloy-Steel-Hex-Shank-Screwdriver-Bit/1001045224	$5.99 for hex bit Axle included with Reel

5	DC Motor-Generator	The main component of the design, the 24V DC Motor/Generator is rotated by the spool (which is coupled using the modified reel axle) and converts rotational energy into electrical potential energy.	https://www.amazon.com/YaeTek-Permanent-Electric-Generator-Turbine/dp/B07K3VQYTZ/	$43.99
6	10W Light Bulb	This low voltage bulb is used to indicate whether or not any voltage is being generated by the DC motor/generator, by being hooked up with the motor in series.	https://www.amazon.com/Vstar-Watt-Hours-Light-Landscape/dp/B01JZ3SLVC/	$6.83
7	Positive Wire	This wire is connected to the positive terminal of the DC Motor/Generator and one of the terminals of the light bulb, it carries electrical current. Any low voltage primary wire will work.	https://www.lowes.com/pd/Southwire-25-ft-16-AWG-Stranded-White-GPT-Primary-Wire/3369902	$6.03
8	Negative Wire	This wire is connected to the negative terminal of the DC Motor/Generator and one of the terminals of the light bulb, it carries electrical current. Any low voltage primary wire will work.	https://www.lowes.com/pd/Southwire-25-ft-16-AWG-Stranded-White-GPT-Primary-Wire/3369902	$6.03 *don't need to purchase twice
9	Stand	The stand serves as the support structure for the main axle that both spools rotate about. The stand sits on one of the raised platforms of the base, and is secured down using the Support Anchor blocks (part 3). The stand was modified by welding an additional segment of steel bar onto the axle to allow both spools to fit on one axle.	https://www.premier1supplies.com/p/ezereel-wind-up-reel?gclid=Cj0KCQjwxdSHBhCdARIsAG6zhlVZQUX2Or2wWWUT_dBHFuhO7HKSUf8OAFX8Bpf28xxW82CO6Rk88KkaArB9EALw_wcB	$16.25 separate $34.75 as set w/ Spool (Need 2)

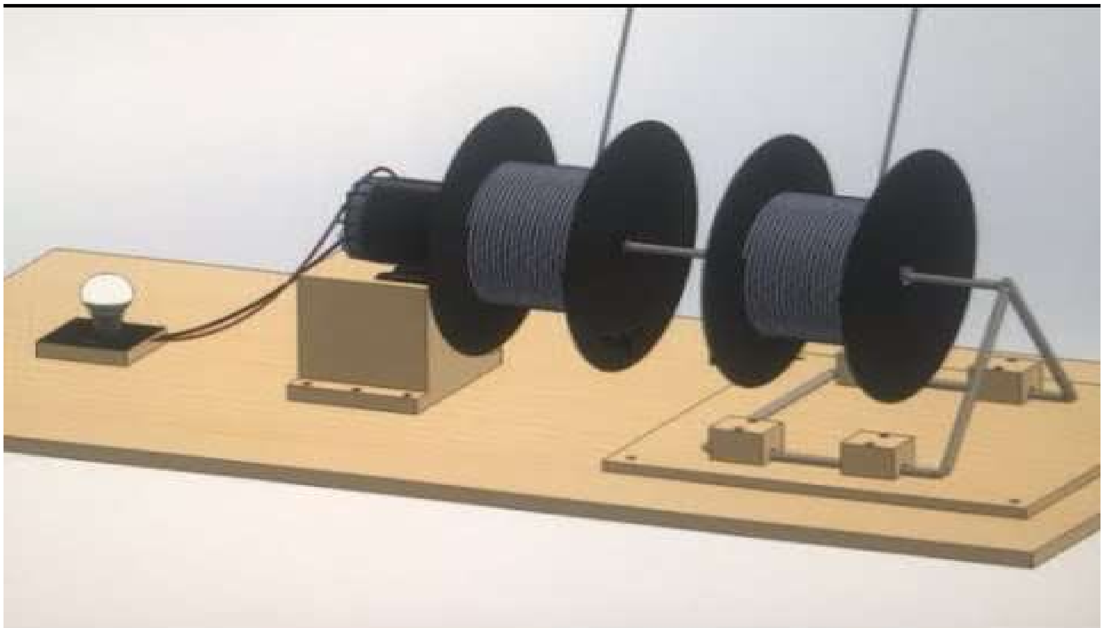
10	Spool	The spools are what the kite line is wound around, and they are rotated by the force of the kite line unwinding the spool. The main spool is coupled with the DC Motor/Generator at all times, and the control spool can be attached/unattached from the main spool using the velcro that is attached to their knobs.	https://www.premier1supplies.com/p/ezereel-wind-up-reel?gclid=Cj0KCQjwxdSHBhCdARIsAG6zhlVZQUX2Or2wWWUT_dBHFuhO7HKSUf8OAFX8Bpf28xxW82CO6Rk88KkaArB9EALw_wcB	$18.50 separate $34.75 as set w/ Stand (Need 2)
11	Velcro Square	The velcro squares attach to the knobs of the main and control reels, and allow them to rotate in unison with one another. They can be pulled apart to rotate only the control reel, in order to manipulate the kite and make it easier to reel back in. They're cut into 1"x1" squares to fit on the knobs.	https://www.lowes.com/pd/VELCRO-2-Pack-3-in-Black-Fastener/3033924	$3.28
12	Kite String	The polyester kite string is strong enough to stand up to the forces required to rotate the reel and produce electricity with the generator. We used 500ft in total, 250ft on each reel.	https://www.amazon.com/emma-kites-Polyester-Tactical-Resistant/dp/B01BDMGPOI/	$15.99
13	Unmodified Reel Axle	This is the axle that allows the control reel to rotate about the main axle on the stand. This axle is not modified in any way from its factory condition and comes with the reel assembly.	https://www.premier1supplies.com/p/ezereel-wind-up-reel?gclid=Cj0KCQjwxdSHBhCdARIsAG6zhlVZQUX2Or2wWWUT_dBHFuhO7HKSUf8OAFX8Bpf28xxW82CO6Rk88KkaArB9EALw_wcB	Axle included with Reel
14	Kite	The kite provides the drag force and pulls on the kite line to rotate the reel, which rotates the DC Motor/Generator's output shaft, which creates the electrical energy that powers the lightbulb. The kite we ended up using in our final prototype is a delta-style kite,	Scrounged from home, can be any kite with sufficient surface area and stability	N/A

		roughly 4 feet wide along it's longest edge.		

9.2 FINAL PRESENTATION

Follow the attached link for our final presentation.

JME4110 Drag Line Energy Generator Wind



10 TEARDOWN

Teardown was performed as directed by the instructor and necessary items were returned for future use.

11 APPENDIX A - PARTS LIST

This is an initial list of parts for the cost of raw materials, components, assemblies etc.

Table 14: Initial Parts List

No.	Item Description	Unit	Unit Cost	Qty.	Material	Labor	Total
1	Motor/Generator	1	$43.99	1	Iron	$0.00	$43.99
2	Kite Line Reel	1	$29.87	2	Plastic/Steel	$0.00	$59.74
3	Light Bulb	1	$11.95	1	Glass/Aluminum	$0.00	$11.95
4	Base	1	$17.38	1	Pine Plywood	$0.00	$17.38
5	Riser Block	1	$0.00	1	Wood	$0.00	$0.00
6	Parachute Kite	1	$19.99	1	Polyester	$0.00	$19.99
7	Loose-Leaf Rings	12	$3.59	1	Iron	$0.00	$3.59
8	Kite Line	1	$15.99	1	Polyester	$0.00	$15.99
9	Wire	25ft	$6.03	1	Copper/Rubber	$0.00	$6.03
	Total Direct costs						$178.66
	Indirect Overhead Costs						$0.00
	Total before contingency						$178.66
	Contingency (15%)						$26.80
	Engineers estimate					**Subtotal:**	**$205.46**

12 APPENDIX B - BILL OF MATERIALS

This is the final list of parts for the cost of raw materials, components, assemblies etc. which states the actual bill of your final project.

Table 15: Final Parts List

No.	Item Description	Unit	Unit Cost	Qty.	Material	Labor	Total
1	Motor/Generator	1	$43.99	1	Iron	$0.00	$43.99
2	Kite Line Reel	1	$29.87	2	Plastic/Steel	$0.00	$59.74
3	Light Bulb	1	$11.95	1	Glass/Aluminum	$0.00	$11.95
4	Base	1	$17.38	1	Pine Plywood	$0.00	$17.38
5	Riser Block	1	$0.00	1	Wood	$0.00	$0.00
6	Delta Kite	1	$19.99	1	Polyester	$0.00	$19.99
7	Loose-Leaf Rings	12	$3.59	1	Iron	$0.00	$3.59
8	Kite Line	1	$15.99	1	Polyester	$0.00	$15.99
9	Wire	25ft	$6.03	1	Copper/Rubber	$0.00	$6.03
	Total Direct costs						$178.66
	Indirect Overhead Costs						$0.00
	Total before contingency						$178.66
	Contingency (15%)						$26.80
	Engineers Final Cost					**Subtotal:**	**$205.46**

13 APPENDIX C – COMPLETE LIST OF ENGINEERING DRAWINGS

Drawings of different parts and a link to all the SolidWorks files are attached.

https://drive.google.com/drive/folders/1ohnVHY9DIcPzuAm-708yZVrVCJXFZgSk?usp=sharing

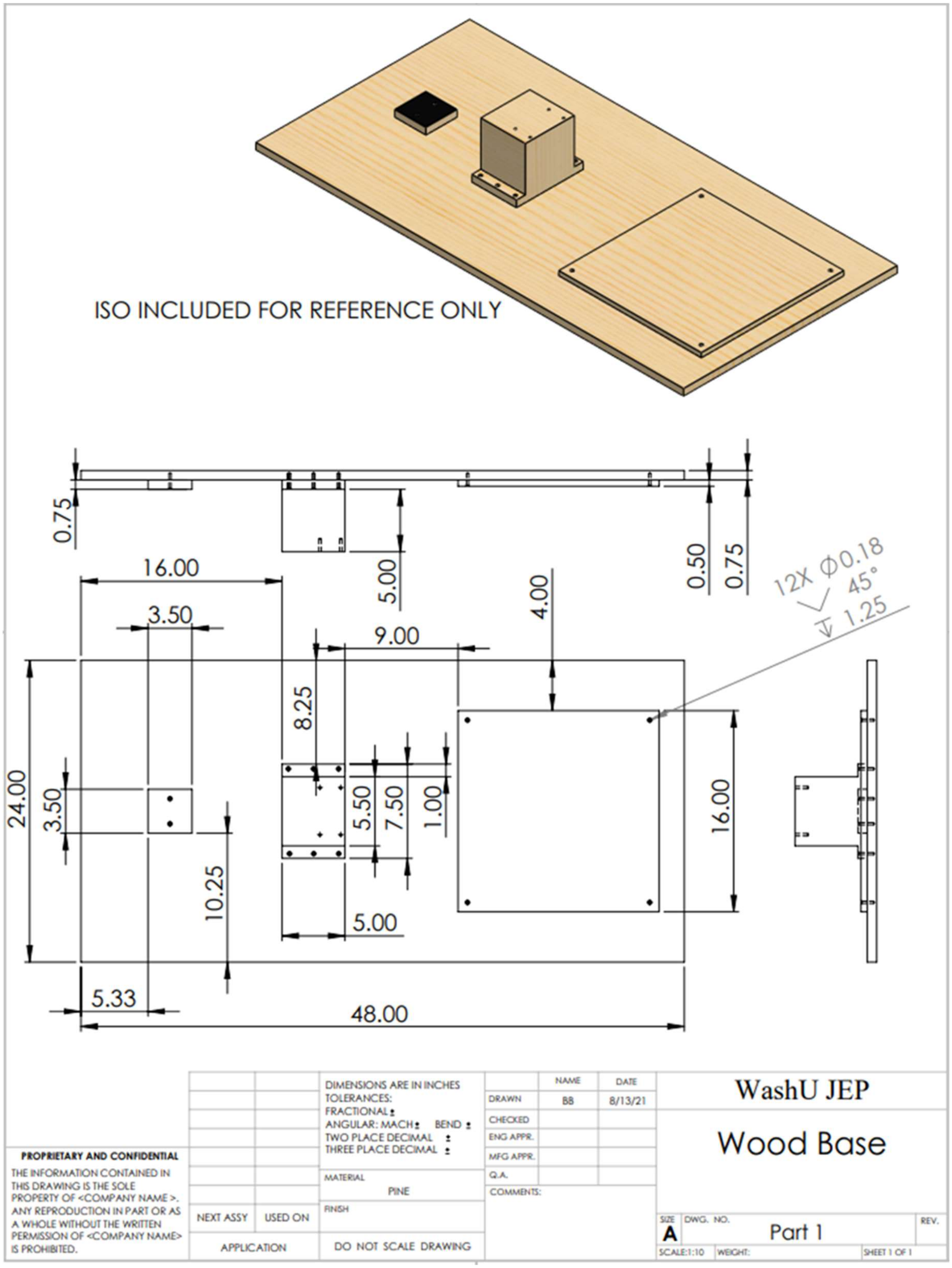


Figure 24: Wood Base SolidWorks Drawings

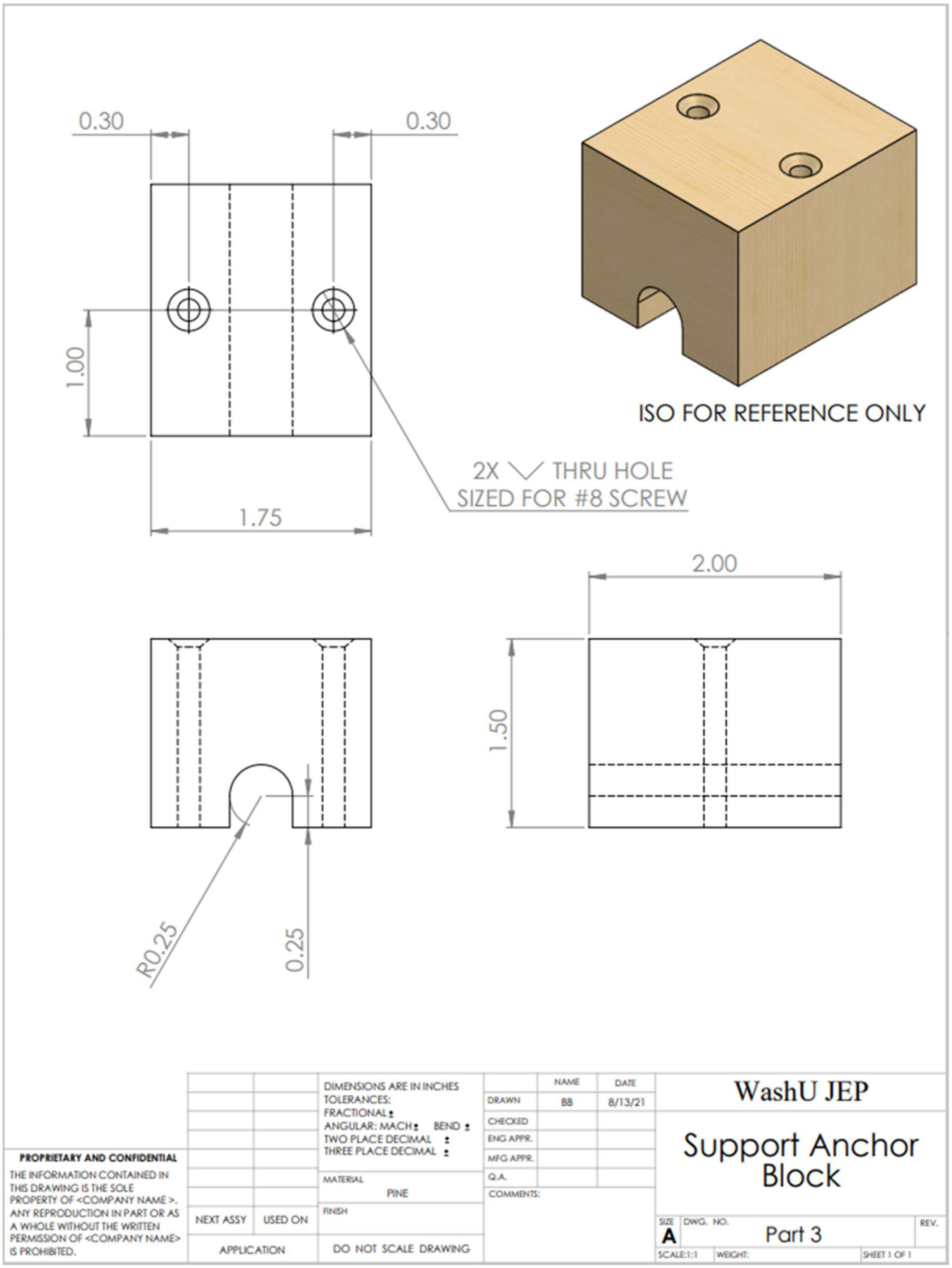


Figure 25: Support Anchor Block SolidWorks Drawings

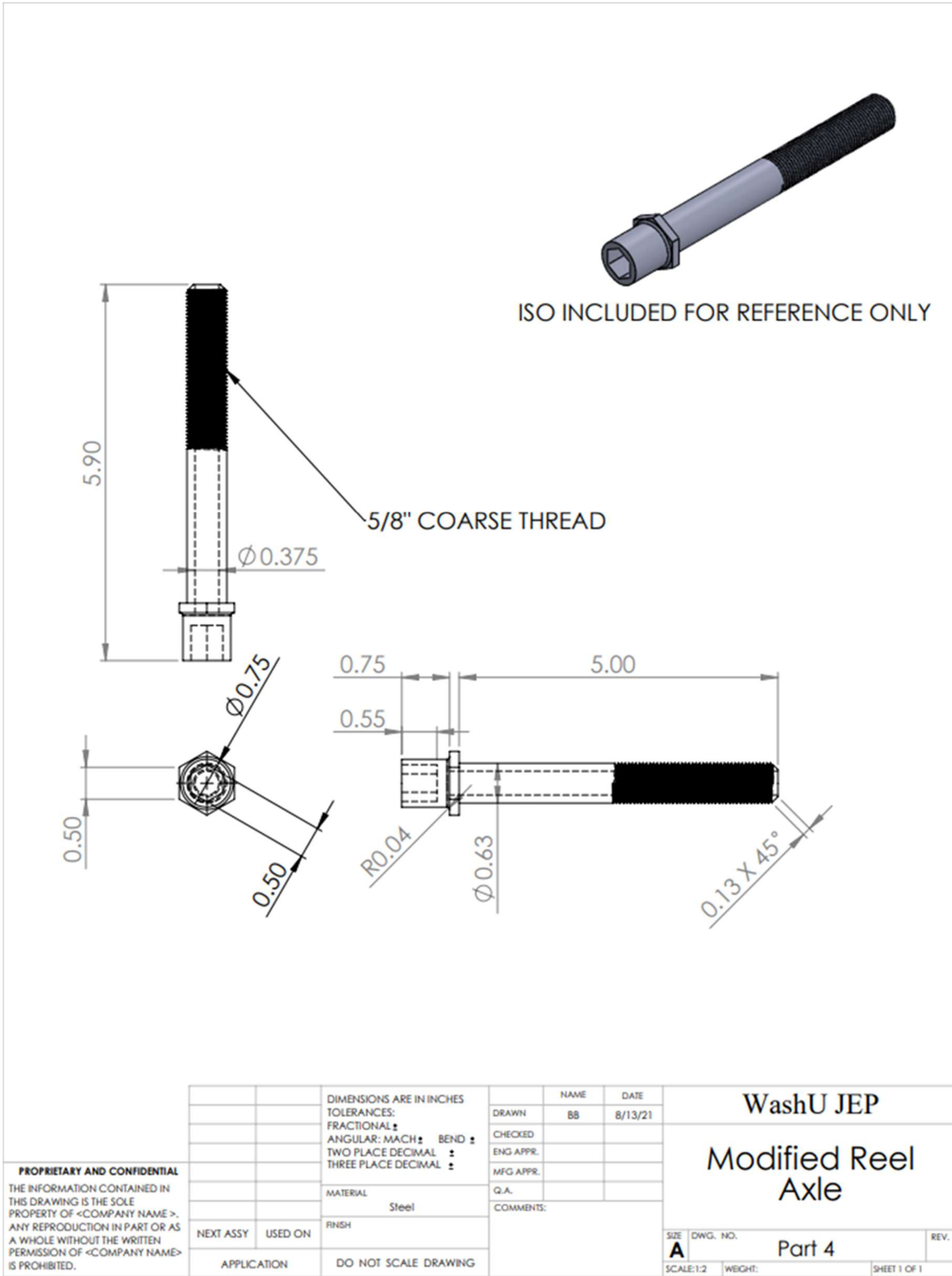


Figure 26: Modified Reel Axle Drawing

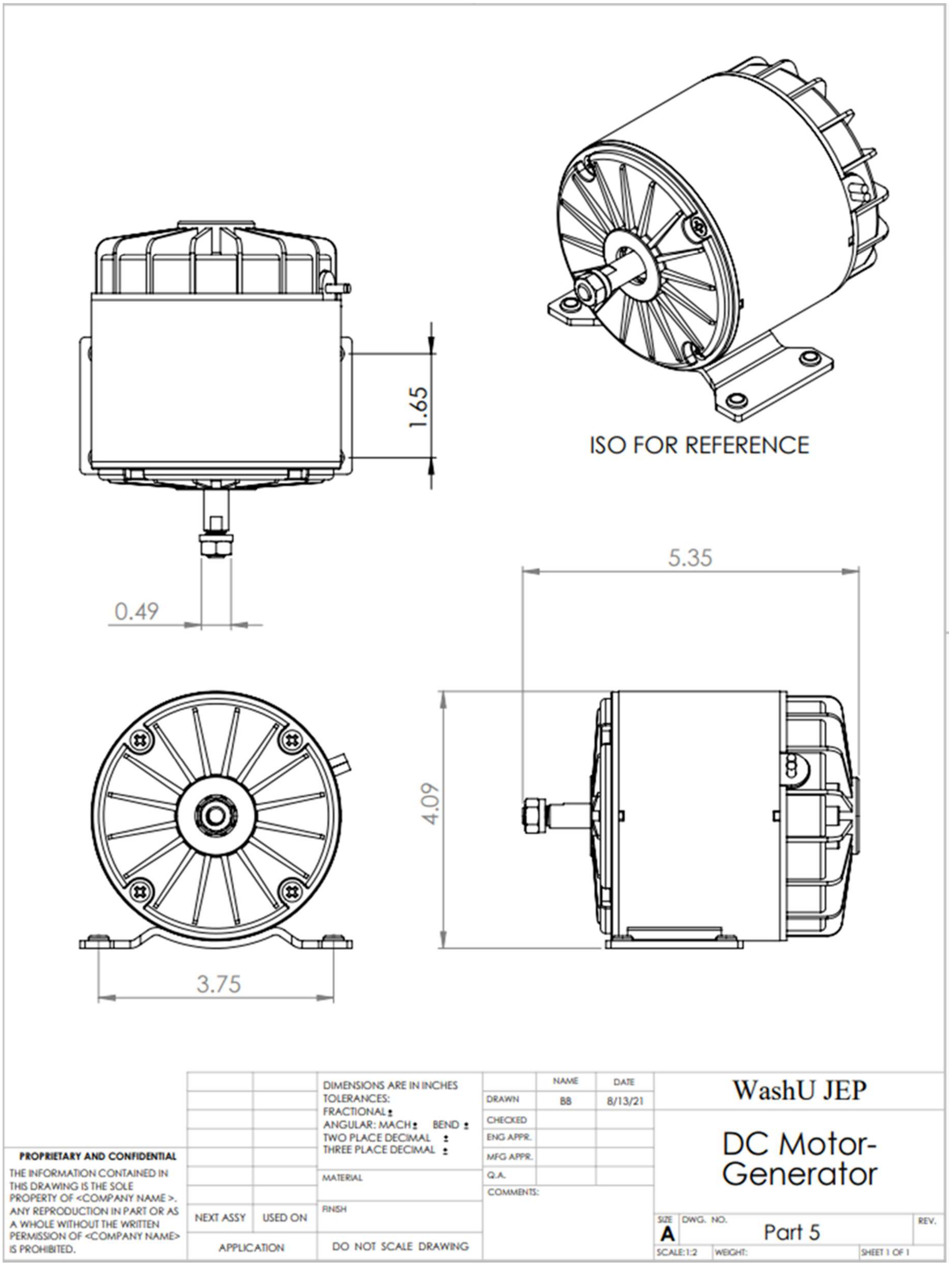


Figure 27: Generator SolidWorks Drawings

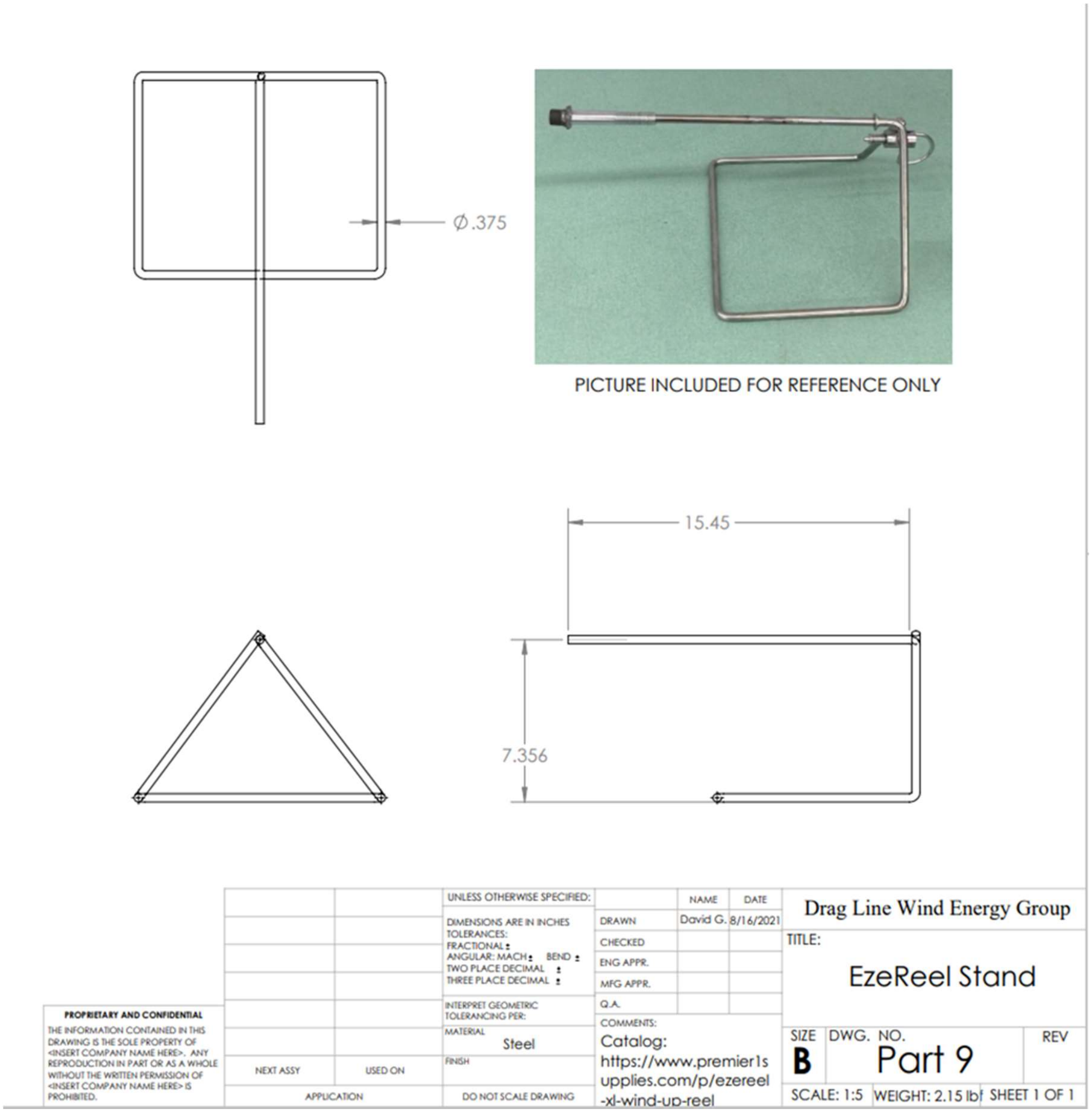


Figure 28: Spool Support Solidworks Drawings

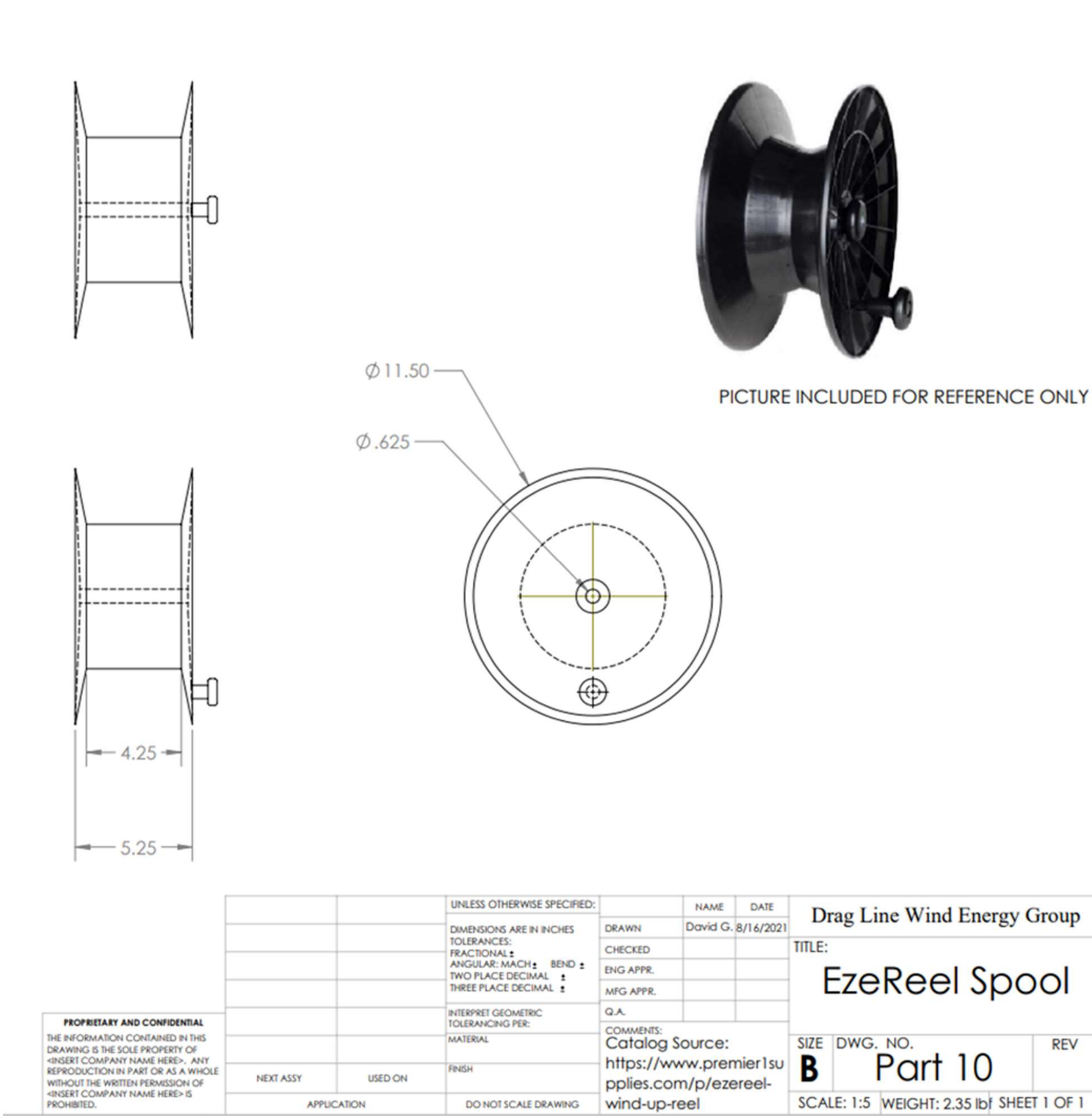


Figure 29: Spool SolidWorks Drawings

14 ANNOTATED BIBLIOGRAPHY

[1] "Electronic Code of Federal Regulations," *Electronic Code of Federal Regulations (eCFR) PART 101*. [Online]. Available: https://www.ecfr.gov/cgi-bin/text-idx?rgn=div5&node=14:2.0.1.3.15#se14.2.101_111. [Accessed: 15-Aug-2021].

This is a code of the United States federal regulations. This specific part talks about regulations concerning MOORED BALLOONS, KITES, AMATEUR ROCKETS, AND UNMANNED FREE BALLOONS.

[2] *Federal Aviation Administration - FAA 7210.3 19.5.2*. 2021.

This code and standard publication is the regulation published by the United States Federal Aviation Administration. It gives detailed rules about flying, in our case, fly a kite.

[3] *National Fire Protection Agency - NFPA 70: National Electrical Code*. 2008.

This publication is a code of protection that regularizes the electrical field in the United States. It gives different security perspectives about how electrical systems should be handled.

[4] "Technology," *KitePower*. [Online]. Available: http://www.kitepower.eu/technology.html. [Accessed: 15-Aug-2021].

This article was used to generate our initial concepts. It gives a perspective of what a kite-generated energy system could look like.

[5] "The promise and challenges of airborne wind energy," *Physics World*, 09-Dec-2019. [Online]. Available: https://physicsworld.com/a/the-promise-and-challenges-of-airborne-wind-energy/. [Accessed: 15-Aug-2021].

This article talks about the advantages and challenges that come with airborne wind energy. It is relevant to our subject because it creates a comparison and contrast about why this is a good proposal.

[6] "Wind energy production using kites and ground mounted power generators," 03-Mar-2005.

This patent is also about wind harnessing to produce energy using kites. It shows how different kites can be used to generate different ranges of energy.