CWC '19

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Project Description

- U.S. Department of Energy is our sponsor
- Collegiate Wind Competition- U.S. Department of Energy
  - Competition held in Boulder, Co May 13th-14th
  - Fifth team representing NAU at the Competition
  - Working with Electrical Engineering group

Faisal

Black Box Model

- Main purpose of the turbine is to produce power
  - Result of harnessing the wind's kinetic energy and converting it to electrical power

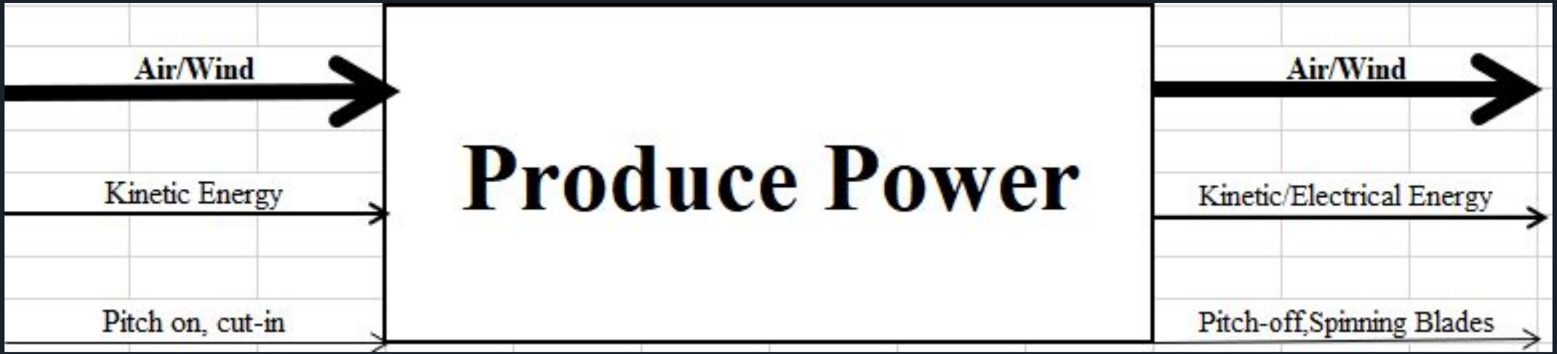

Figure 1: Black Box Model

Riley

Hypothesized Functional Model

- Conversion from Kinetic Energy to Electrical Energy
- Complete Certain Tasks for Competition
- No human interaction during testing

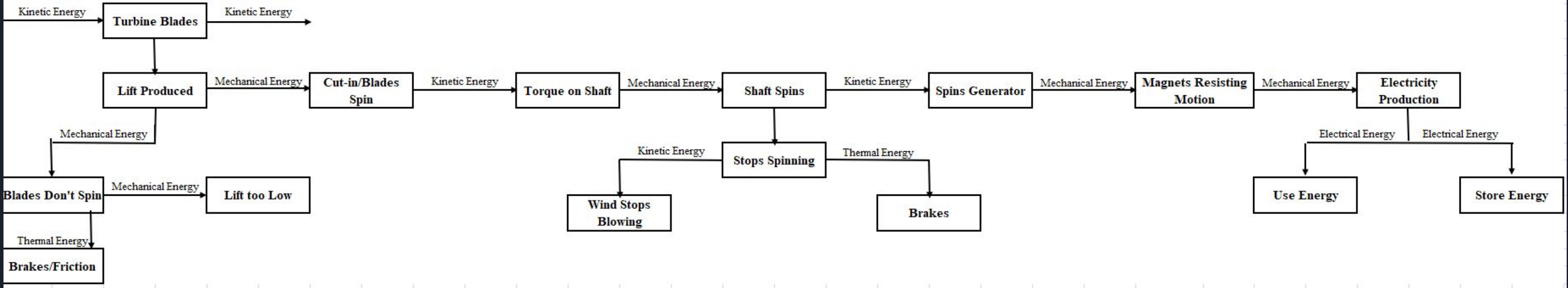

Figure 2: Hypothesized Functional Model

Riley

Concept Generation

- 5-4-5 method sketching (includes a few bio-inspired designs)
- Sketches done individually in own time

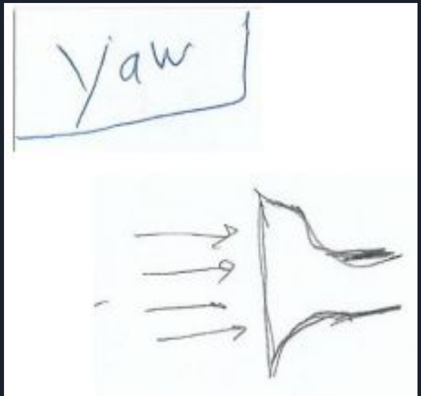

Figure 3: Yaw Concept Generation

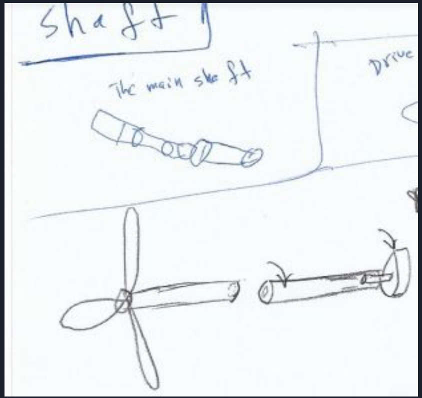

Figure 4: Shaft Concept Generation

Riley

Blade Design Concepts

- Small blade:
  - Pros: Smaller amount of material, therefore easier to move
  - Cons: Not an optimum swept area
- Wide base:
  - Pros: Higher swept area, easier cut-in due to wide base
  - Cons: More material, will need more thrust to be propelled

Figure 5: Small Blade Design

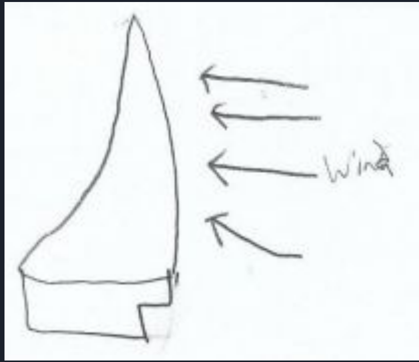

Figure 6: Wide Base Blade Design

Riley

Nacelle Designs

- Side panels
  - Pros: Potential for yawing from nacelle
  - Cons: Less strong
- Hole design
  - Pros: Options for wire organization for electrical team
  - Cons: Crowded nacelle because of wires being directed towards front of design

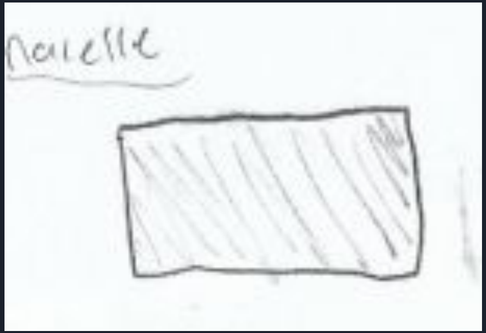

Figure 7: Side Panel Nacelle Design

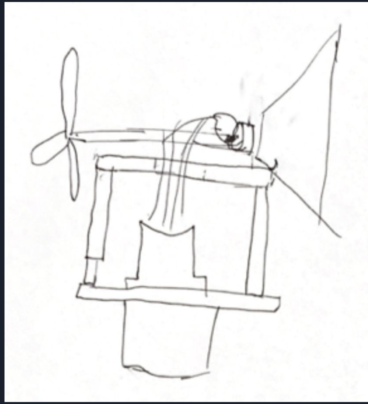

Figure 8: Hole Nacelle Design

Riley

Tower Design Concepts

- Rolly Chair
  - Pros: Lighter than a baseplate
  - Cons: Not stable or fastenable to comp. mount
- CWC '18
  - Pros: Sturdy design, can be fastened to mount
  - Cons: Strength over-designed, could be cheaper

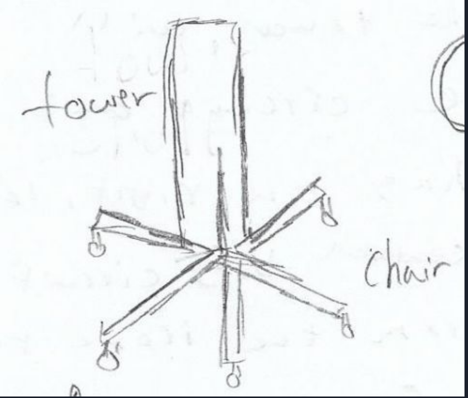

Figure 9: Rolling Chair Tower Concept

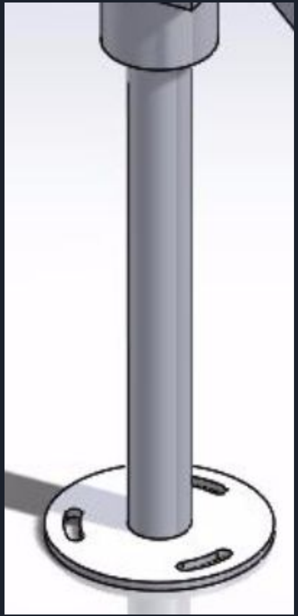

Figure 10: Round Tower Concept(CWC '18)

Abdulaziz

Yaw Design Concepts

- Tower Yaw
  - Pros: Compact and durable
  - Cons: Inefficient yawing power, too little surface area
- Angled Pyramid Scheme
  - Pros: Compact, strong and high efficiency
  - Cons: Heavier than other potential yaws

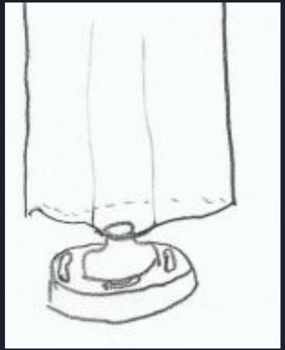

Figure 11: Tower Yaw Concept

Figure 12: Pyramid Concept

Abdulaziz

Brake Design Concept

- Linear Actuator (CWC ‘18)
  - Pros: Compact, high stopping power
  - Cons: Poorly designed, high cost

- Stepper
  - Pros: Strong stopping power and accurate
  - Cons: Less compact

Figure 13: Linear Actuator(CWC ‘18)

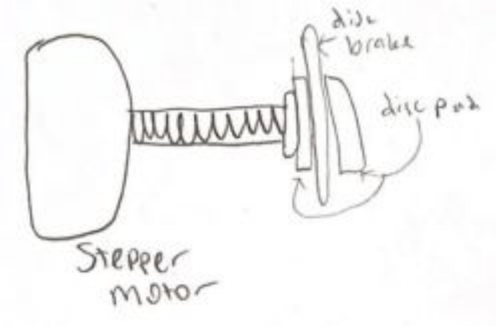

Figure 14: Stepper Motor Concept

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Shaft Design Concept

- Hollow Shaft Design
  - Pros: Weight reduction, easier to rotate
  - Cons: Smaller cross-sectional area (less durable)
- Thick Diameter Ends
  - Pros: Durable at concentrated stress points (Larger cross-section)
  - Cons: Heavier than necessary, higher stress concentration at diameter changes

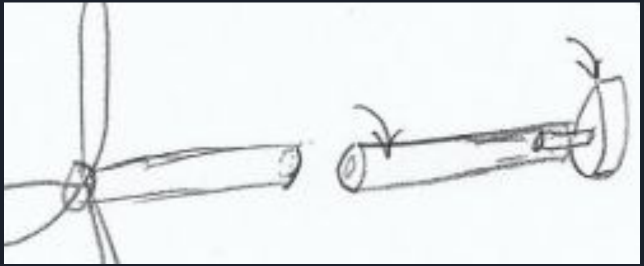

Figure 15: Hollow Shaft Concept

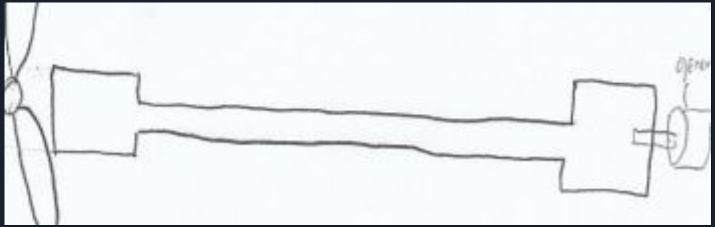

Figure 16: Thick Diameter Ends Concept

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Pugh Chart - Blade

- Top 3 choices are Wide Base, Small Blade, and Betz Blade

		Blade(s)				
		Feather Blade	Small Blade	Wide Base	Heavy Blade	Betz Blade
	Concept	1	2	3	4	DATUM
Criteria						
Cost Effective		-	+		-	
Optimize efficiency			-	+	+	
Compact			+			
Low Cut-in		-		+	-	
Strong		-		+	+	
Durable		-	-		+	
Lightweight		+	+	-	-	
Portable/ease of assembly						
# of +'s		**1**	**3**	**3**	**3**	
# of -'s		**4**	**2**	**1**	**3**	
Sum		**-3**	**1**	**2**	**0**	

Table 1: Blade Concept Pugh Chart

Pugh Chart - Yaw

- Top 3 choices are Pyramid(tip), Pyramid(separate), and Rough

		Yaw					
		Active	Pyramid(tip)	Pyramid(separate)	Rough Surface	Tower Yaw	CWC '18
	Concept	1	2	3	4	5	DATUM
Criteria							
Cost Effective		-			+	-	
Optimize efficiency		+	+	+	+	-	
Compact		+	+	+	+	+	
Low Cut-in							
Strong			+	+		+	
Durable		-					
Lightweight		-	+	+	+	-	
Portable/ease of assembly		-	+	+	+	+	
# of +'s		**2**	**5**	**5**	**5**	**3**	
# of -'s		**4**	**0**	**0**	**0**	**3**	
Sum		**-2**	**5**	**5**	**5**	**0**	

Table 2: Yaw Concept Pugh Chart

Tanner

Pugh Chart - Nacelle

- Top 3 choices are open front/back, hole, and side panels

			Nacelle						
		CWC'18	Cubic	Hexagon	Pyramid	Oval	Open Front/Back	Side Panels	Hole
	Concept	DATUM	2	3	4	5	6	7	8
Criteria									
Cost Effective			-	-	-	-	-		
Cooling			-	-	-	-			
Yaw			+	+			+	+	
Compact			-	-	-	-	-		+
Low Cut-in									
Strong			-	-	+	+	-	-	
Durable									
Lightweight			-	-	-	-	-	-	+
Portable/ease of assembly			-	-	-	-	-		
# of +'s			1	1	1	1	1	1	2
# of -'s			6	6	5	5	5	2	0
Sum			-5	-5	-4	-4	-4	-1	2

Table 3: Nacelle Concept Pugh Chart

Tanner

Pugh Chart - Shaft

- Top 3 choices are hollow, polymer, CWC ‘18

		Shafts				
		Hollow	Thick Ends	Polymer	Plain	CWC 18
	Concept	1	2	3	4	DATUM
Criteria						
Cost Effective		-		+	-	
Optimize efficiency		+	-	-	-	
Compact						
Low Cut-in		-	-		-	
Strong			+	-	+	
Durable		-		-	+	
Lightweight		+	-	+	-	
Portable/ease of assembly						
# of +'s		**2**	**1**	**2**	**2**	
# of -'s		**3**	**3**	**3**	**4**	
Sum		-1	-2	-1	-2	

Table 4: Shaft Concept Pugh Chart

Pugh Chart - Brakes

- Top 3 choices are CWC ‘18, dynamic, and stepper motor

				Brake Design			
		CWC '18	Dynamic	Hydraulic	Stepper Motor	Brushless	Yaw Brake
Criteria	Concept	DATUM	1	2	3	4	5
Cost Effective				-	+	-	+
Optimize efficiency			-	-		-	-
Compact			+	-	-	-	
Low Cut-in							
Strong			-	+	+		+
Durable				+		-	
Lightweight			+	-	-	-	+
Portable/ease of assembly			+	-	+	-	-
# of +'s			**3**	**2**	**3**	**0**	**3**
# of -'s			**2**	**5**	**2**	**6**	**2**
Sum			**1**	**-3**	**1**	**-6**	**1**

Table 5: Brake Concept Pugh Chart

Tanner

Pugh Chart - Tower

- Top choice was CWC ‘18 tower design

		Tower					
		Triangle	CWC '18	Rolly Chair	Tower Yaw	Wide Base	Mesh
	Concept	1	DATUM	3	4	5	6
Criteria							
Cost Effective		-		-	-	-	-
Optimize efficiency				-	+		+
Compact		-		-	-	-	
Low Cut-in					+		
Strong		+		-	-	+	-
Durable		+		-	-	+	-
Lightweight				+	-	-	+
Portable/ease of assembly		-		-	-	-	
# of +'s		**2**		**1**	**2**	**2**	**2**
# of -'s		**3**		**6**	**6**	**4**	**3**
Sum		**-1**		**-5**	**-4**	**-2**	**-1**

Table 6: Tower Concept Pugh Chart

Design Matrix - Blades

- The best design will have a wider base

		Blade Design Concept(s)					
		Small Blade		Betz Blade		Wide Base	
Criteria	Weight(%)	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Cost Effective	12.87%	65	8.3655	60	7.722	60	7.722
Optimize efficiency	7.63%	20	1.526	50	3.815	70	5.341
Compact	13.77%	60	8.262	50	6.885	50	6.885
Low Cut-in	13.32%	40	5.328	60	7.992	80	10.656
Strong	11.68%	50	5.84	60	7.008	70	8.176
Durable	11.80%	50	5.9	60	7.08	70	8.26
Lightweight	9.43%	70	6.601	50	4.715	45	4.2435
Portable/ease of assembly	10.70%	50	5.35	50	5.35	50	5.35
		SUM=	47.1725	SUM=	50.567	SUM=	56.6335

Table 7: Blade Decision Matrix

Tanner

Decision Matrix - Yaw

- The best design will be the pyramid(separated tip)

		Yaw Concept(s)					
		Pyramid(Tip connection)		Pyramid(Separated tip)		Rough Surface	
Criteria	Weight(%)	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Cost Effective	12.87%	50	6.435	50	6.435	65	8.3655
Optimize efficiency	7.63%	70	5.341	70	5.341	65	4.9595
Surface Area normal to flow	13.77%	65	8.9505	65	8.9505	50	6.885
Yaw Rate (Torque)	13.32%	70	9.324	70	9.324	60	7.992
Strong	11.68%	70	8.176	70	8.176	60	7.008
Durable	11.80%	70	8.26	70	8.26	60	7.08
Lightweight	9.43%	40	3.772	40	3.772	70	6.601
Portable/ease of assembly	10.70%	45	4.815	50	5.35	50	5.35
		SUM=	55.0735	SUM=	55.6085	SUM=	54.241

Table 8: Yaw Decision Matrix

Decision Matrix - Nacelle

- The best design will be the open nacelle with a hole in the bottom

		Nacelle					
		CWC'18 (Open)		Open w/ access hole		Side Panels	
Criteria	Weight(%)	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Cost Effective	12.87%	65	8.3655	65	8.3655	50	6.435
Optimize efficiency	7.63%	40	3.052	55	4.1965	60	4.578
Compact	13.77%	70	9.639	85	11.7045	65	8.9505
Low Cut-in	13.32%	1	0.1332	1	0.1332	1	0.1332
Strong	11.68%	75	8.76	75	8.76	75	8.76
Durable	11.80%	75	8.85	75	8.85	75	8.85
Lightweight	9.43%	55	5.1865	60	5.658	45	4.2435
Portable/ease of assembly	10.70%	35	3.745	40	4.28	50	5.35
	91.2%	SUM=	47.7312	SUM=	51.9477	SUM=	47.3002

Table 9: Nacelle Decision Matrix

Tanner

Decision Matrix - Shaft

- The best design will be similar to CWC’18 design

		Shaft Design					
		Hollow		CWC'18		Polymer	
Criteria	Weight(%)	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Cost Effective	12.87%	40	5.148	60	7.722	50	6.435
Optimize efficiency	7.63%	60	4.578	65	4.9595	45	3.4335
Compact	13.77%	50	6.885	50	6.885	65	8.9505
Low Cut-in	13.32%	65	8.658	60	7.992	70	9.324
Strong	11.68%	50	5.84	60	7.008	40	4.672
Durable	11.80%	50	5.9	60	7.08	40	4.72
Lightweight	9.43%	65	6.1295	55	5.1865	70	6.601
Portable/ease of assembly	10.70%	50	5.35	50	5.35	50	5.35
		SUM=	48.4885	SUM=	52.183	SUM=	49.486

Table 10: Shaft Decision Matrix

Decision Matrix - Brakes

- The best design will be using a stepper motor to initiate braking

		Brake					
		CWC'18		Dynamic		Stepper Motor	
Criteria	Weight(%)	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Cost Effective	12.87%	35	4.5045	80	10.296	75	9.6525
Optimize stopping power	7.63%	75	5.7225	40	3.052	80	6.104
Compact	13.77%	40	5.508	65	8.9505	50	6.885
Releasing Power	13.32%	15	1.998	60	7.992	70	9.324
Strong	11.68%	65	7.592	60	7.008	75	8.76
Durable	11.80%	50	5.9	50	5.9	75	8.85
Control	9.43%	60	5.658	50	4.715	70	6.601
Portable/ease of assembly	10.70%	5	0.535	60	6.42	45	4.815
	91.2%	SUM=	37.418	SUM=	54.3335	SUM=	60.9915

Table 11: Brake Design Decision Matrix

Tanner

Decision Selection

- Based on Pugh Chart and Decision Matrix the best designs are:

Blade	Yaw	Nacelle	Shaft	Brake	Tower
Wide Base	Pyramid (Separated Tip)	Open with access hole	CWC '18 (Similar Design)	Stepper Motor	CWC '18 (Similar Design)

- All designs fit into criteria given by Department of Energy

Tanner

Schedule

- Used Gantt project template in Excel
- Current position - catching up to original schedule still, but further caught up than before

TitleRegion..BO60	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	Person Responsible	PERCENT COMPLETE
Website Setup	11	3	24	3	Abdulaziz	100%
Website Update(s)	15	70			Abdulaziz	5%
House of Quality	15	4	16	2	Riley	100%
Benchmarking	10	5	15	2	Team	100%
Research Design(s)	10	10	16	10	Team	95%
Concept Generation	20	6	25	10	Team	95%
Ind. Analytical Report	42	30	42		Each person	15%
Designing	40	20	51		Riley&Tanner	20%
Blade Design	55	12			Riley	10%
Brake Design	55	10			Tanner	10%
Tail Design	55	[illegible]			Faisal	10%
Nacelle	55	[illegible]			Naser	5%
Tower/Baseplate	55	5			Abdulaziz	10%
EE systems collaboration	55	20			Riley	0%
EE systems incorporation	[illegible]	20			Riley&Tanner	0%
Solidworks Modeling	[illegible]	12			Tanner	0%
Blade Modeling	65	10			Riley	0%
Tail Modeling	65	10			Faisal	0%
Nacelle Modeling	65	10			Naser	0%
Tower/Baseplate Modeling	65	5			Abdulaziz	0%
3D printing for prototype	[illegible]	10			Tanner	0%
Preliminary Report	5	40	[illegible]		Riley	20%
Final Report	45	5			Naser	0%

Table 12: Gantt Chart Project Schedule

Budget

- Summary of costs and anticipated costs throughout the project

	Budget		
	Part	Cost	Reference
Bought:	Blade 2B4:C630s Blade Swashplate	$ 10.88	https://www.amazon.com/gp/product/B013V5HFXU/ref=oh_aui_detailpage_o00_s00?ie=UTF8&psc=1
	4x8x3mm Rubber Shielded Ball Bearings	$ 10.88	https://www.amazon.com/4x8x3mm-Rubber-Shielded-Bearings-MR84-2RS/dp/B019I2WVCA/ref=sr_1_1_sspa?s=toys-and-gar
	EL-Kit-003 UNO Project Super Starter Kit	$ 38.12	https://www.amazon.com/EL-KIT-003-Project-Starter-Tutorial-Arduino/dp/B01D8KOZF4/ref=sr_1_2_sspa?s=electronics&ie=
Future Costs:	3D Carbon Fiber Filament by iFun	$ 35.93	https://www.amazon.com/Ifun-Filament-Compatible-Dimensional-Requirements/dp/B0747P98Q9/ref=asc_df_B0747P98Q9/
	2' of 1" OD 4130 Chromoly Steel	$ 18.29	https://www.onlinemetals.com/merchant.cfm?pid=7337&step=4&id=250&CAWELAID=120293320000038245&CATARGETID=1
	2' of 1" Aluminum Square Tubing	$ 4.67	https://www.onlinemetals.com/merchant.cfm?pid=20737&step=4&showunits=inches&id=1270&top_cat=60
	8" x 8" (0.5" thick) 6061-T6 Aluminum Plate	$ 24.93	https://www.onlinemetals.com/merchant.cfm?pid=1250&step=4&showunits=inches&id=76&top_cat=60
	.125" 4130 Steel Sheet (12"x12")	$ 31.67	https://www.onlinemetals.com/merchant.cfm?pid=20902&step=4&id=949
	(12"x24") 6061-T6 Aluminum Sheet	$ 26.40	https://www.onlinemetals.com/merchant.cfm?pid=1244&step=4&showunits=inches&id=76&top_cat=60
	SunnySky X41085-17 KV380 Motor	$ 33.98	https://www.buddyrc.com/sunnysky-x4108s-17-380kv.html
	Z9504B 3/4" Bearing	$ 7.77	https://www.amazon.com/Z9504B-Bearing-inch-Sealed-Z9504RST/dp/B0028BM3EW/ref=sr_1_5?s=industrial&ie=UTF8&qid=
	PLA Filament	$ 42.00	https://www.matterhackers.com/store/3d-printer-filament/pla
	Linear Actuator	$ 65.00	https://www.actuonix.com/Actuonix-PQ-12-P-Linear-Actuator-p/pq12-p.htm
	1/4" 6061-T6 aluminum round	$ 3.64	https://www.metalsdepot.com/aluminum-products/aluminum-round-bar?gclid=EAIaIQobChMI1Z76pLWH3gIVTbjACh2FGw1v
	Pillow Block Bearing	$ 16.50	https://www.amazon.com/UCP204-12-Pillow-Block-Mounted-Bearings/dp/B01LXU87L9/ref=sr_1_2_sspa?ie=UTF8&qid=1539
	Assortment of nuts and bolts	$ 35.00	
Travel and Costs:	Travel and Competition costs	N/A	Department of Energy is covering the cost (within reasonable cost)
	Total:	$ 405.66	

Table 13: Project Budget sheet

Naser

Questions ?

References

[1]Ace Energy. (2018). *Us Department Of Energy Logo - Ace Energy*. [online] Available at: http://en.stonkcash.com/us-department-of-energy-logo/ [Accessed 15 Oct. 2018].

[2]Northern Arizona University, "NAU Collegiate Wind Competition 2017-2018," U.S. Department of Energy, Flagstaff, 2018.