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EE 416: Electrical Engineering Design
Dr. Jacob Murray

Artemis Project
Midterm Progress Report of Beta Prototype
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Contents

I. Executive Summary

This report contains the Artemis Project's progress towards the beta prototype of the wind turbine for the Everett Wind Energy Team (EWET). The report covers the broader challenges of developing an offshore wind farm, including manufacturing and environmental costs. Expenditures for the project have almost been completed, with no major purchases remaining. The iterative design of the turbine is underway, with some changes to the yaw control required. The blade pitch control is soon to be completed. Tests have been conducted to estimate the potential power output at various wind speeds. The addition of the wireless system will remove the need for a USB cable between the onboard computer and a montioring laptop. MakerPlot software will be used to monitor and manually control the turbine. Final integration and testing of the prototype will be completed in the near future.

II. Summary of Business Analysis

For the alpha prototype development, Artemis Project spent $1343.05. So far, the team has spent an additional $1437.28. The cost breakdowns are shown in Appendix B. The team estimates that less than $100 remains to be spent, including the ESP32 wireless computer and project boxes to contain the electronics.

III. Broader Impacts and Contemporary Issues

The general goal of wind energy production is to diversify energy sources away from fossil fuels, such as coal, oil, and natural gas and to reduce emissions. However, wind turbines are not without their critics and issues. Issues relating to noise pollution and obnoxious shadows aremitigated by moving the turbines to an offshore location. However, offshore turbines impact acquatic wildlife and fishing operations, as well as shipping and other ocean travel.

The production of the turbines themselves and their installation is also energy- and resource-hungry, particularly for those components which would be manufactured in China or other overseas locations. Ensuring that as many components as possible are made in the United States would benefit the corporate image.

The offshore installation would be in the Gulf of Mexico off the coast of Texas near Houston and Galveston. This is prime real estate for the offshore oil and gas market as well. Recently, a federal judge vacated the leases of 80 million acres that had been auctioned last year, saying that the government did not properly account for the climate change effects of oil production on that much offshore property[1].

Texas is heavily dependent on oil and gas for energy and economically. Wind turbines are seen by some as an almost existential threat. During the winter storm of 2021, some politicians blamed the existence of wind turbines for the power outages despite making dup only a small percentage of Texas' energy production[2]. An offshore wind installation in Texas needs to prove itself to the people that it is durable and reliable and not a threat to oil and gas jobs.

IV. Results to Date

Since the demonstration of the alpha prototype, Artemis Project has consolidated the wiring from the test bench setup. The wind vane, which will be the input for the yaw control system, was installed on the top of the nacelle. Three buck converters were installed on one side of the nacelle, and the Arduino control unit was placed on the other side. The 5 V power for the Arduino and the ground control were installed on the nacelle's underside. Two Anderson power pole connectors for the generated power were connected to the outputs from the buck converter. These are shown in Figure 1.

Two of the buck converters were damaged from increased voltage during a high-speed rotor test and were replaced. However, this test confirmed that the remainder of the system withstood speeds of over 2000 RPM.

The computer functionality for the yaw control has been completed and tested. The turbine blades must be perpendicular to the wind direction to generate the maximum power. The

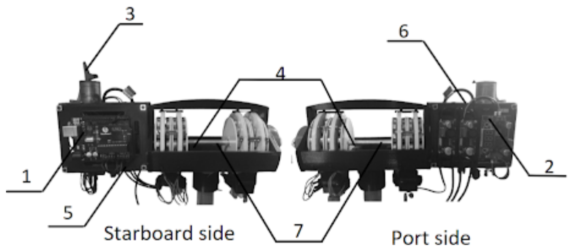

Fig. 1: Beta wind turbine prototype. (1) Arduino, (2) port-side buck converters, (3) wind vane, (4) power pole connectors, (5) ground busses, (6) starboard-side buck converters, and (7) rotor axle.

wind tunnel blows in a single direction, but winds from different directions can be simulated by rotating the turbine. If the wind is not blowing directly in front of the turbine, it will rotate itself using a continuous servo to face the wind. A digital threshold creates a hysteresis effect to avoid constant adjustments.

In high winds, the yaw control will rotate the turbine to be parallel with the wind to avoid damage to the turbine blades and potentially harmful excess power generation, which can cause overheating and fire damage.

V. Analysis, Modeling, and Simulation Results

The power coefficient (C_p) is the ratio of the power generated by the turbine to the power in the wind. For the estimated power coefficient of 0.3, the power output generated increases from 5 to 11 m/s and then holds steady at 38 W. This is shown in Figure 2.

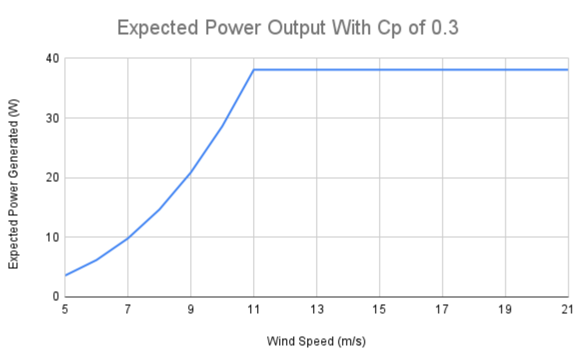

Fig. 2: Expected power output with C_p = 0.3.

Another important factor in determining the efficiency of the generator is the Kv rating, the ratio of the unloaded RPM to the peak voltage on the coil wires. In Figure 3, the Kv rating is the inverse of the slope, or 1/0.0411 = 24.33. Using this line, we can estimate the no load voltage at a given rotational speed.

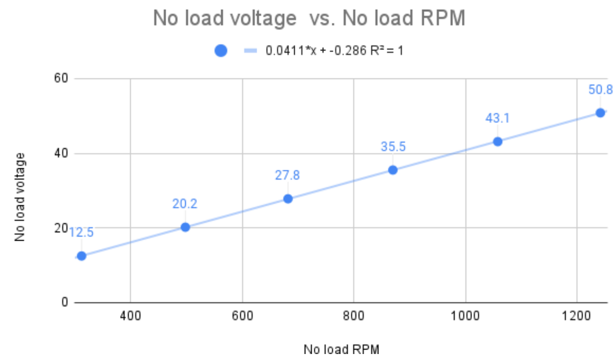

Fig. 3: Kv rating

VI. Beta Prototype Test Results

A. Yaw Control

For the alpha prototype, the yaw control utilized a 360-degree servo motor to adjust the turbine's direction based on the wind vane. The servo was not continuous. Once it reached its maximum rotation, it had to rotate in the opposite direction. This limitation caused issues if the wind came from near the servo's maximum or minimum rotational ability. Also, this servo required a 1:1 gear ratio to the nacelle and required a great deal of torque to turn. The servo utilized was also large and drew excessive power, making it unsuitable for lower wind speeds.

The new replacement yaw control servo is continuous and draws much less power. Unfortunately, even with 3D-printed gearing and lubrication, the new servo is still unsuitable because it produces less torque and cannot overcome the static friction on the support. One possible solution is to add bearings to reduce the friction between the nacelle and the support. Another solution is to use two of the smaller servos.

With the yaw control functioning, the rotation limit is based on the physical wire connection. Presently, a slip ring mechanism is not used because of the limited requirements of the Collegiate Wind Competition tests but may be implemented if the twisting of the wire connections becomes an issue.

B. Load Control

The load control simulation setup consists of a manually-adjustable 200 Ω rheostat, shown in Figure 4; a Festo four quadrant dynamometer, with a 2:1 belt transmission pulley ratio coupling mechanism, shown in Figure 5; and the beta prototype shown in Figure 1.

The beta prototype rotor axle is coupled to the dynamometer transmission axle using a coupling adapter with slip and vibration compensation capability. The dynamometer is controlled by LabVolt Data Acquisition and Control Interface software installed on a Windows 10 laptop. The power output of the system is assessed using the current measuring functionality of an onboard Precision Digital Current and Power Monitor - INA 260, positioned at the number 5 callout in Figure 1.

The accuracy of the measured current data is verified using a stand-alone Fluke multimeter. The voltage is measured separately by another independent multimeter.

Fig. 4: 200 Ω 0.7 A rheostat

During the preparation stage of the analysis, the team determined that the most useful input parameter would be the torque that the prototype's rotor axle (shown in Figure 1, callout 7) experienced at various wind speeds. Other input parameters are expressed in terms of this torque. The mechanical engineering subteam of the Everett Wind Energy Team (EWET) estimated the torque values, utiliz-

Fig. 5: Dynamometer with 2:1 coupling belt transmission ratio mechanism

ing the fundamental relationships described in Equation (1):

$$\tau_R = \frac{P_w \times c_p}{\omega_{\text{rotor}}} = \frac{c_p(\lambda, \theta) \times \rho \pi R^3 V_w^2}{2\lambda}, \qquad (1)$$

where $\tau(R)$ is the torque experienced by the prototype rotor axle, $P(w)$ is the power available in the wind, $C(p)$ is the power-degrading coefficient expressed as a function of the tip speed ratio and pitch angle, and ω(rotor) is the rotational speed of the prototype axle in (rad/sec). For the purpose of the analysis, $C(p)$ was taken to be 0.3, which indicates that only 30 % of the power available in the wind would be extractable. The torque values were assumed to be between 0.1 N·m and 0.3 N·m. This assumption was based on previous experiments which demonstrated the approximate range of the available rotor axle speeds relative to the wind speeds.

Thus torque is used as the input parameter, and generated power is the output parameter. The load control constants were determined by observing the Arduino controller operational threshold as one limiting factor and maximum available power as the other limiting factor. It was determined experimentally that no more than ~0.3 W of power was available at 0.1 N·m constant torque while the Arduino controller was operating.

This result indicates that there is 60 mA of reserve current available at this torque level for pitch control and data analysis, assuming a 5 V Arduino supply. At 0.3 N·m torque power output was measured to be ~50 W. In this experiment, the rotor's speed was not captured because it was not a function of the pitch control and tip speed ratio, which are not available in the dynamometer simulation setup as controlled parameters.

C. Pitch Control

During the alpha prototype development, the turbine was tested in the wind tunnel by manually adjusting the pitch angle of the blades. The pitch control was designed to control the torque and rotational speed of the rotor to extract the maximum power from the wind. The team discovered that a steep angle of attack produced high torque and low rotational speed. Conversely, a shallow angle of attack produced low torque and higher rotational speed.

The angle of attack will be adjusted by the pitch control mechanism using a rod that traverses the main shaft of the rotor. The rod will move linearly to adjust the pitch to a steeper or shallower angle of attack. The particulars of the mechanism are still being designed. However, the team has decided to utilize a 180-degree servo to control the pitch angle. Mathematically, the rotational motion of the servo and the linear motion of the shaft are related by Equation (2):

$$\cos\theta = \text{shaft travel} = \frac{Y}{\tan\theta}, \qquad (2)$$

where the distance Y is the fixed distance of the servo center of rotation to the shaft and θ is the angle of the servo. Figure 6 illustrates the relationship of the servo arm to the linear shaft motion.

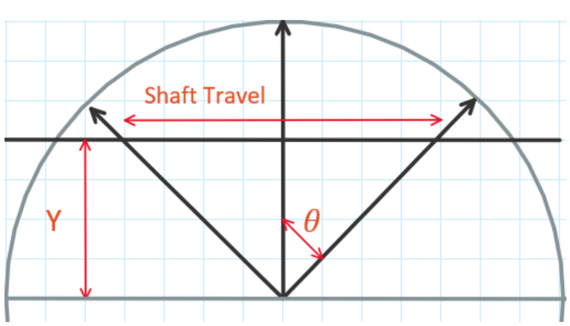

Fig. 6: Pitch control shaft diagram

An alternative pitch control mechanism is to use a continuous servo with a rack and pinion to move the shaft. However, the angle of a continuous servo cannot be determined, only the speed and direction, which would create an open control loop. Without the angle as a known input, this would require that other inputs, such as wind and rotor speeds, would be measured after the pitch adjustment to decide if additional adjustments are required. Reading these additional values will increase the response time. Therefore, the team decided to use a traditional non-continuous 180-degree servo.

D. MakerPlot

MakerPlot is a low-cost Supervisory Control and Data Acquisition (SCADA) software package[3]. It retreives data and transmits commands over the serial connection between the Arduino and a laptop computer. EWET has purchased MakerPlot licenses to be the primary monitoring and manual control system for the turbine. However, creation of a custom interface is pending on the completion of the automatic control system and system interface on the existing Arduinos.

E. Wireless communication

One limitation of monitoring and controlling the turbine through the Arduino systems is that wires must run from a laptop into the wind tunnel. To physically disconnect the system, the addition of a wireless interface utlizing an ESP32 chip is being explored. The ESP32 has built-in WiFi and Bluetooth Low Energy, of which Bluetooth is more suitable for the project due to WiFi access control restrictions that may also be different at the competition venue.

The ESP32 package being utilized is an M5Stack M5StickC Plus. It contains two buttons, a 1.14 inch OLED display, and both standard female pin connectors and a Seeed Grove connector. The M5StickC is powered using a USB-C connector with 5 V and 500 mA. The unit also contains a built-in 120 mAh battery.

It is possible for the ESP32 to replace one or both of the Arduinos. However, that would require the purchase of additional external components, such as motor controllers. It's current task will be limited to being a bridge between wired serial communications and wireless Bluetooth communications. It will also be necessary to find a way to read Bluetooth data in at the laptop and have it appear as though it is coming over the serial port and, conversely, transmit apparent serial data over Bluetooth instead because MakerPlot only supports serial communication. A fallback would be to use a second device connected by USB to the laptop.

VII. Beta Prototype Validation Results

A. Power Verification Analysis

Verifying the system's power output is a complex process that depends on the functionality of the system's controls. The current progress towards verification as described in Section VI-B: "Load Control." In summary, the current prototype solution has demonstrated that it will sustain the predicted power output of the system.

The system has been verified to produce $0.3\,\mathrm{W}$ of power at $0.1\,\mathrm{N \cdot m}$ of torque and $50\,\mathrm{W}$ at $0.3\,\mathrm{N \cdot m}$.

B. Power Quality Analysis

The Collegiate Wind Competition (CWC) will judge the turbine's power output quality based on its stability over five seconds. The electrical noise produced by power electronics switching to manage the system's output is a factor that must be minimized.

A Digilent Analog Discovery Studio board and associated WaveForms software was used as an oscilloscope to measure the prototype's power output quality. The results are shown in Figure 8 and 9 in Appendix A. These figures demonstrate that the voltage fluctuation is within 10 % of the measured mean voltage magnitude, and the ripple is 2 % of the same relative magnitude. These findings, however, are not indicative of the pass-fail status of the measured power output, and further clarification is needed of the terms in which power quality judgments will be passed.

VIII. Summary of Work Remaining

A. Mechanical

As discussed in Section VI-A, the yaw control is currently being revised by the mechanical engineering subteam at EWET. Artemis Project determined during alpha prototype testing that the existing mechanism was insufficient to allow the current continuous servo motor to turn the nacelle. As discussed, a bearing mechanism will be implemented to determine if that will be sufficient to reduce friction. If not, a second servo motor will be installed.

The pitch control design is nearing completion. The next stage is to replace the existing setup with an improved design. Tests will be conducted to determine the effectiveness of the new pitch control mechanism. The final stage is to create packaging for the load components to ensure that they are implemented according to the CWC requirements.

B. Control

The control subsystem consists of the two Arduino computers (and potential ESP32), the solid-state relays which control the load, the buck converters which stabilize and regulate the power output. The Arduinos are connected to the wind vane to determine wind direction, and Hall sensor on the shaft to determine the rotational speed. These inputs are used to determine how the yaw and blade pitch should be adjusted to either maximize power generation during normal operation or to minimize power and speed in high-wind situations.

The work remaining on the control systems largely depends on the implementation of the mechanical design. The general algorithms have been developed, although experimental data is needed with final mechanical design to determine the magnitude of the adjustments that the computer needs to make.

Although the system is designed to operate autonomously, manual control is also implemented through the MakerPlot software and an emergency stop button.

C. Programing

Developing the pitch control software will primarily require the completion and testing of the physical mechanism to determine the details of what is needed. Because the 180-degree, non-continuous servo motor was chosen to control the linear motion of the shaft, preliminary software development can be completed. The geometry and mechanics of the shaft relative to the servo are known. However, we do not know how the connections on the other end of the shaft will affect the rate of change of the pitch. Once the pitch control mechanism has been implemented, the relationship between the motor and the shaft motion can be determined experimentally.

The system needs a power pitch control algorithm to improve power generation stability over a fixed blade design. For the "power curve performance" task of the competition, stable power must be generated at wind speeds from 5 to 11 m/s. The buck converters limit the voltage, and the load controls the current, so producing stable power should not be difficult. Tip speed ratios for each wind speed have been calculated that would theoretically produce the most power possible.

The control system must also determine if the tip speed ratio is too high for a particular load and wind speed in order to avoid stalling. Turbine blades have a similar shape to an airplane wing, called an airfoil. As with an airplane, a turbine can suffer a stall. If the angle of attack is too steep, the airflow can separate from the blade and cause turbulence, pushing the air in the boundary layer back towards the front of the wing or blade. For an airplane, this destroys lift, causing the airplane to fall. For a turbine, the rotational speed will slow significantly. This phenomenon is illustrated in Figure 7.

It may be wise for the software to position the turbine blade angle for a more conservative tip speed ratio than calculated to improve stability at the cost of some output power. This way, the program can have predetermined pitch angles for each wind speed that can be set and left alone unless prompted otherwise.

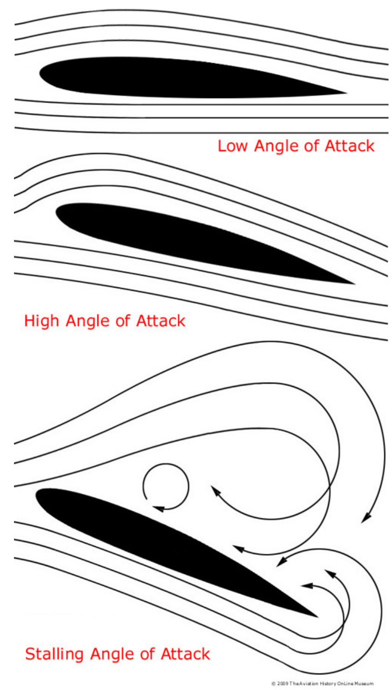

Fig. 7: Airfoil at low angle of attack, high angle of attack, and stall[4].

Once the desired rotational speed is met, the load will be increased to the next step.

The durability aspect of the competition requires that the turbine operates at variable winds speeds from 6 to 22 m/s for five minutes. The turbine must be able to produce power across this range.

Artemis Project's primary concern, and the concern in producing an offshore wind farm in hurricane territory is to keep the turbine's blades from being damaged or even torn off in a high wind situation. The pitch control system can adjust the blade's angle of attack to reduce speed and avoid damage in such cases, in addition to maximizing power output in normal conditions.

However, even when trying to reduce blade rotational speed to protect the integrity of the turbine, the system must still be able to maintain consistent power output. With the current KV rating of the turbine, this is about 1400 ± 300 RPM, which will likely be maintained if we can achieve low enough tip speed ratios. If low tip speed ratios cannot be achieved at high wind speeds due to mechanical limitations, blade or pitch mechanism redesign will be required.

D. Power

A second Arduino connected to the load will receive commands from the turbine's Arduino controller and pass them to a bank of solid-state relays. The Arduino will switch between load resistance values using the onboard controller. The optimal values will be determined experimentally. Implementing the software control system will need to wait until the mechanical subteam has implemented the relay system.

IX. Conclusion

Over the past two months since the demonstration of the alpha prototype, Artemis Project and EWET have continued to make progress on the wind turbine prototype for the Collegiate Wind Competition. A wind farm off the coast, in the Gulf of Mexico, presents many challenges. However, it will diversify Texas' energy production which is currently heavily dependent upon oil and gas. This would also create jobs and avoid job loss from fewer oil platforms being built.

The mechanical aspects of the beta prototype are still being developed, such as the yaw and pitch control. The yaw system is being redesigned to reduce the torque required by the servo motor. The blade pitch control is ready to be installed. The computer algorithms to control the yaw system is completed and work will begin shortly on the pitch control algorithm. The pitch must be adjusted to maximize power production under normal conditions and protect the turbine in high-wind situations.

The team has calculated the theoretical power the turbine can produce at various wind speeds, and tests have measured the generator output at various rotational speeds.

The addition of load control will be completed after the pitch control mechanism and the wireless communication have been installed. The MakerPlot software will be used to measure the turbine sensors to maximize the power output.

As forward progress continues, more testing will need to be done in the wind tunnel to prepare for the scenarios that will be faced at the CWC.

References

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[2] E. Douglas and R. Ramsey, "No, frozen wind turbines aren't the main culprit for texas' power outages," *The Texas Tribune*, Feb. 17, 2021. [Online]. Available: https://www.texastribune.org/2021/02/16/texas-wind-turbines-frozen/.

[3] "Makerplot," [Online]. Available: http://www.makerplot.com/.

[4] "Angle of attack," *The Aviation Online History Museum*, Jun. 1, 2015. [Online]. Available: http://www.aviation-history.com/theory/angle_of_attack.htm.

Appendix A
Images

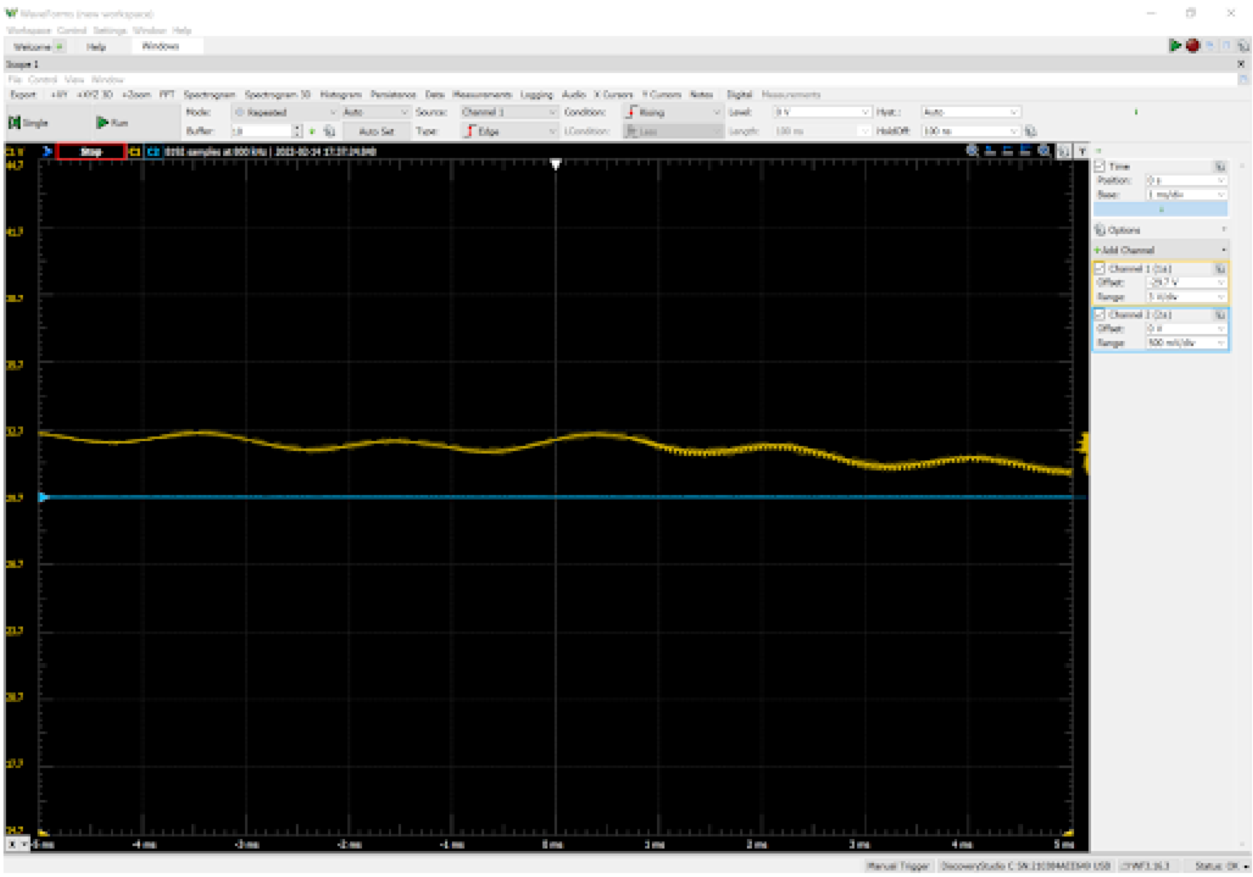


Fig. 8: Voltage fluctuation

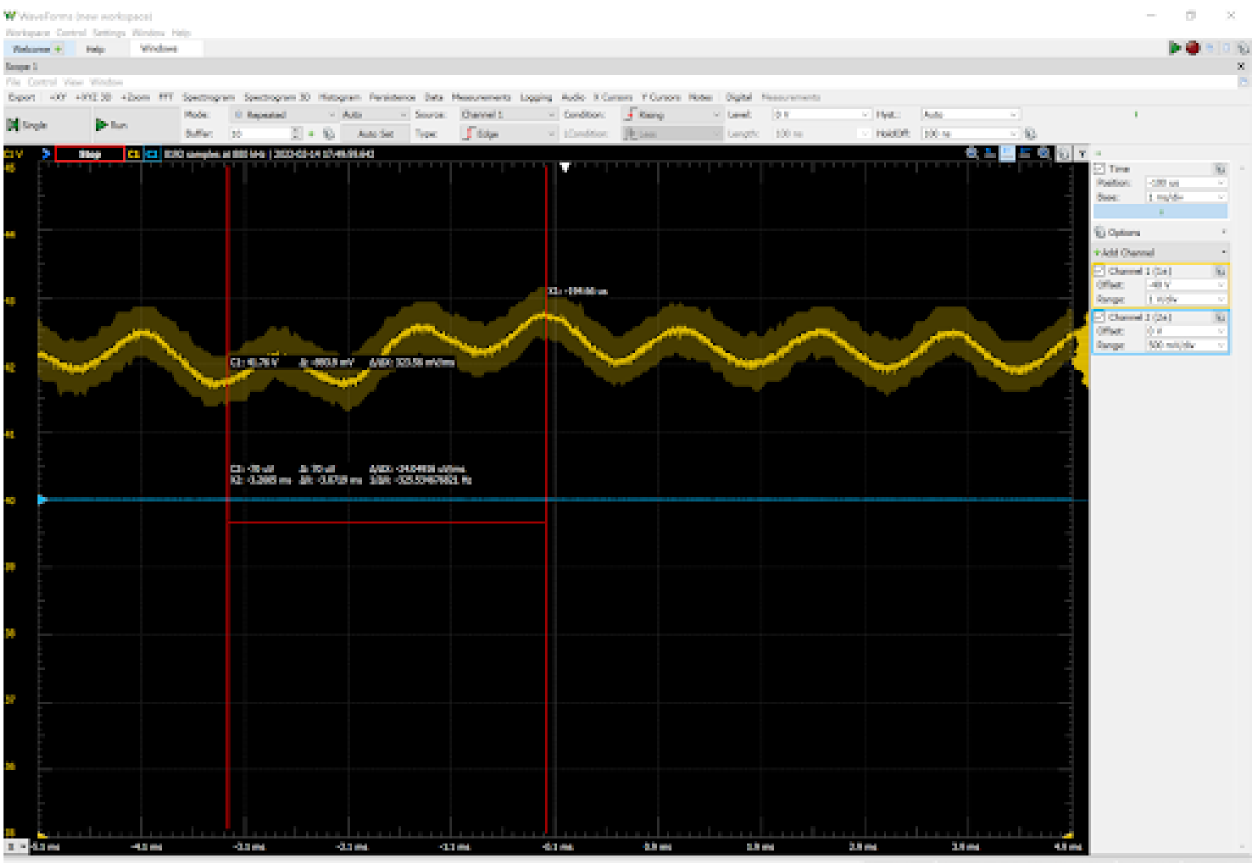


Fig. 9: Ripple

Appendix B
Material Costs

Product	Price (USD)	Comment
35 W Mini Disc Generator Coreless Generator Three-Phase Permanent	$319.60	
Rheostat 100 W 100 Ω 1000 V Std Shaft	$94.28	
Rheostat 100 W 200 Ω 1000 V Std Shaft	$114.71	
ALITOVE DC 12 V 5 A Power Supply Adapter Converter Transformer AC	$11.89	Unused
MakerPlot licenses	$236	
Adafruit 4226 INA260 High or Low Side Voltage, Current, Power Sensor	$39.80	Unused (3/4)
Round Tube, 304/304L Stainless Steel, 0.065” Wall Thickness, 5/16” OD	$13.94	Research Material
Zener Diodes: 30 V 5 W	$1.44	Research Material
Resistors, 25 Ω, 35 W, 5%	$6.72	Research Material
Thick Film Resistors: Through Hole 75 Ω 35 W 5% TOL	$6.86	Research Material
Schottkey Diodes, BOJACK 1N5822, 3 A 40 V DO-201AD	$5.99	Replenish WSU stock
MOSFET SMOS Low RON Nch Io: 0.4 A Vdss: 60 V Vgss	$3.08	Unused
Potentiometer, Max power 400 W Max R-200 Ω	$25.50	
Mini Electric Linear Actuator Stroke 2	$29.99	Research Material
FEETECH 35KG Continuous Rotation Servo Motor 360° High Torque	$27.99	Research Material
DC-DC Buck Boost Converter Module 5.5 to 30 V 12 V to 0.5 to 30 V	$25.98	Research Material
DC12 to 24 V miniature electromagnetic clutch	$10.25	Unused
Modern Device Wind Sensor Rev. P	$24.00	
DC Buck Converter, DROK DC to DC Step Down Power Supply Module	$59.98	
SainSmart 8-Channel 5 V Solid State Relay Module Board for Arduino	$19.99	
Misc (connectors, heatshrink tuning, epoxy, PLA str.)	$89.89	Manufacturing expense
Total	$1167.87	
Est. Tax + Shipping (15%)	$175.18	
Grand Total	$1343.05	
Total Unused	$25.21	
Total Research	$112.92	

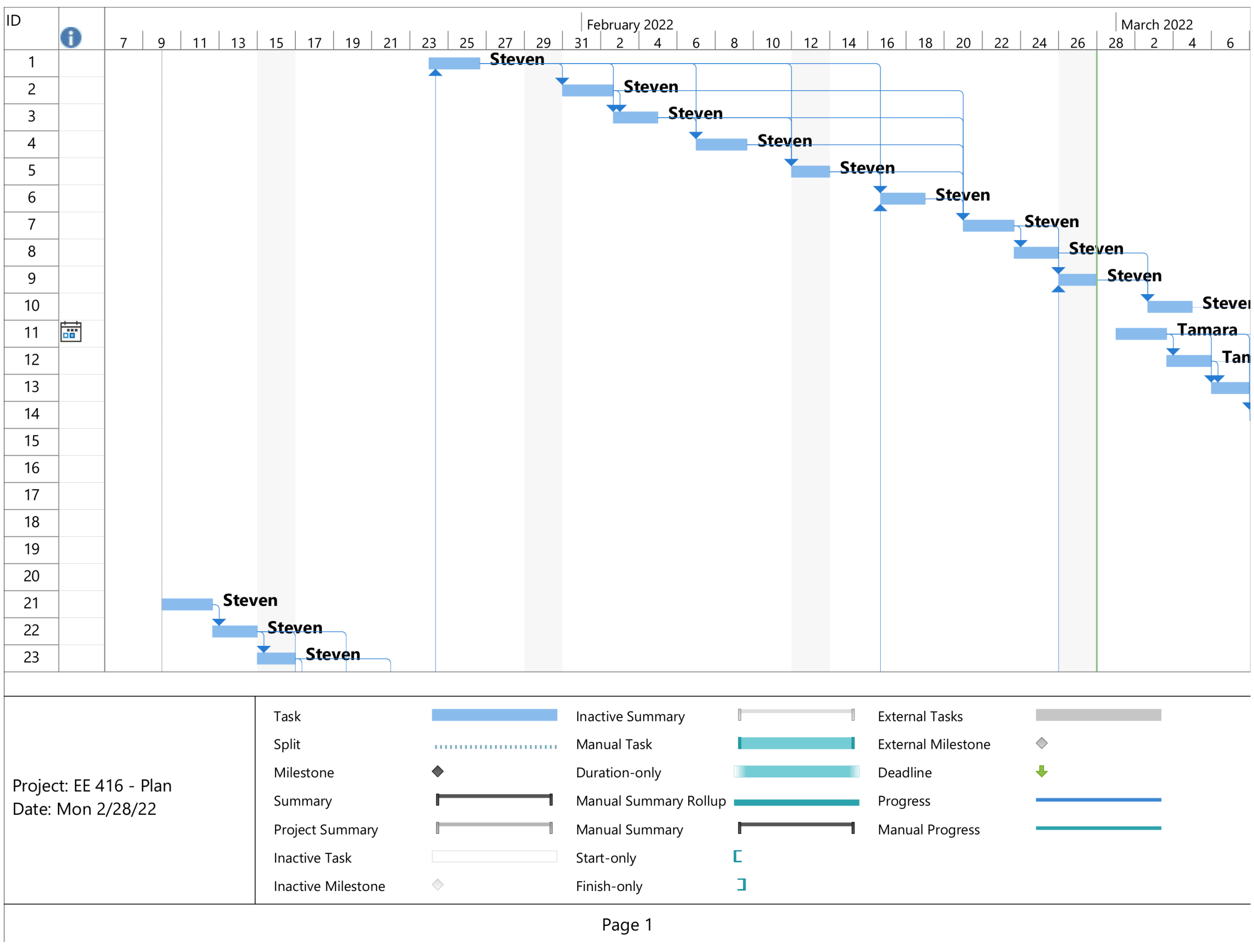
Beta Prototype Costs:

Product	Price (USD)	Comment
Modern Device Wind Sensor Rev. C	$17.00	
Power Pole Extension Cable	$27.98	
LM2596HVS DC-DC Down x 10	$21.98	Replacements
FEETECH FS90R x 2	$14.98	
Total	$81.94	
Est. Tax + Shipping (15%)	$12.29	
Grand Total	$94.23	
Total for Alpha and Beta	$1437.28	

Appendix C
Gantt Chart

ID		Task Mode	Task Code	Subsystem	Task Name	Duration	Start	Finish	Predecessors	Resource Names
1			BS-RR	Braking System	Research Report	7 days	Mon 1/24/22	Wed 1/26/22	26	Steven
2			BS-PC	Braking System	Blade Pitch Controller	7 days	Mon 1/31/22	Wed 2/2/22	1	Steven
3			BS-MD	Braking System	Motor Driver	7 days	Wed 2/2/22	Sat 2/5/22	1,2	Steven
4			BS-SRV	Braking System	Servo	7 days	Mon 2/7/22	Wed 2/9/22	1,3	Steven
5			BS-MC	Braking System	Motor Controller	7 days	Sat 2/12/22	Mon 2/14/22	1,4,3	Steven
6			BS-PD	Braking System	Power Disconnection	7 days	Wed 2/16/22	Sat 2/19/22	1,51,5	Steven
7			BS-MT	Braking System	Mechanical Test	7 days	Mon 2/21/22	Wed 2/23/22	2,3,4,5,6	Steven
8			BS-HW	Braking System	High Wind Detector	7 days	Wed 2/23/22	Sat 2/26/22	7	Steven
9			BS-ES	Braking System	Emergency Stop Butt	7 days	Sat 2/26/22	Mon 2/28/22	7,49	Steven
10			BS-ST	Braking System	Subsystem Test	7 days	Wed 3/2/22	Sat 3/5/22	8,9	Steven
11			MP-RR	MakerPlot	Research Report	7 days	Tue 3/1/22	Thu 3/3/22		Tamara
12			MP-BPP	MakerPlot	Blade Pitch Plotter	7 days	Thu 3/3/22	Sun 3/6/22	11	Tamara
13			MP-PP	MakerPlot	Power Plotter	7 days	Sun 3/6/22	Tue 3/8/22	11,12	Tamara
14			MP-RSP	MakerPlot	Rotor Speed Plotter	7 days	Tue 3/8/22	Thu 3/10/22	11,13	Tamara
15			MP-WSP	MakerPlot	Wind Speed Plotter	7 days	Thu 3/10/22	Sun 3/13/22	11,14	Tamara
16			MP-YP	MakerPlot	Yaw Plotter	7 days	Sun 3/13/22	Tue 3/15/22	11,15	Tamara
17			MP-BPC	MakerPlot	Blade Pitch Control	7 days	Thu 3/17/22	Sun 3/20/22	12,16	Tamara
18			MP-LC	MakerPlot	Load Control	7 days	Tue 3/22/22	Thu 3/24/22	13,17	Tamara
19			MP-YC	MakerPlot	Yaw Control	7 days	Sun 3/27/22	Tue 3/29/22	16,18	Tamara
20			MP-ST	MakerPlot	Subsystem Test	7 days	Thu 3/31/22	Sun 4/3/22	14,15,17,18,19	Tamara
21			PC-RR	Pitch Control	Research Report	7 days	Mon 1/10/22	Wed 1/12/22		Steven
22			PC-ME	Pitch Control	Design from Mech. E.	7 days	Wed 1/12/22	Sat 1/15/22	21	Steven
23			PC-MD	Pitch Control	Motor Driver	7 days	Sat 1/15/22	Mon 1/17/22	22	Steven
24			PC-MC	Pitch Control	Motor Controller	7 days	Mon 1/17/22	Wed 1/19/22	22,23	Steven
25			PC-SRV	Pitch Control	Servo	7 days	Wed 1/19/22	Sat 1/22/22	22,24	Steven
26			PC-MT	Pitch Control	Mechanical Test	7 days	Sat 1/22/22	Mon 1/24/22	23,24,25	Steven
27			PC-AH	Pitch Control	Algorithm: High Spee	7 days	Mon 2/28/22	Wed 3/2/22	26	Steven
28			PC-AL	Pitch Control	Algorithm: Low Speed	7 days	Sat 3/5/22	Mon 3/7/22	26,27	Steven
29			PC-AVL	Pitch Control	Algorithm: Very Low Speed	7 days	Mon 3/7/22	Wed 3/9/22	26,28	Steven
30			PC-AT	Pitch Control	Automation Test	7 days	Wed 3/9/22	Sat 3/12/22	28,29,27	Steven

ID		Task Mode	Task Code	Subsystem	Task Name	Duration	Start	Finish	Predecessors	Resource Names
31			WC-RR	Wireless	Research Report	7 days	Tue 3/15/22	Thu 3/17/22		Tamara
32			WC-HW	Wireless	Hardware Integration	7 days	Sun 3/20/22	Tue 3/22/22	31	Tamara
33			WC-SW	Wireless	Software	7 days	Thu 3/24/22	Sun 3/27/22	32	Tamara
34			WC-ST	Wireless	Subsystem Test	7 days	Tue 3/29/22	Thu 3/31/22	33	Tamara
35			YC-RR	Yaw Control	Research Report	7 days	Wed 1/26/22	Sat 1/29/22		Steven
36			YC-WSS	Yaw Control	Wind Speed Sensor	7 days	Sat 1/29/22	Mon 1/31/22	35	Boris
37			YC-ALG	Yaw Control	Algorithm	7 days	Sat 2/5/22	Mon 2/7/22	36	Steven
38			YC-MC	Yaw Control	Motor Controller	7 days	Wed 2/9/22	Sat 2/12/22	37	Steven
39			YC-MD	Yaw Control	Motor Driver	7 days	Mon 2/14/22	Wed 2/16/22	37,38	Steven
40			YC-SRV	Yaw Control	Servo	7 days	Sat 2/19/22	Mon 2/21/22	37,39	Steven
41			YC-MT	Yaw Control	Mechanical Test	7 days	Mon 2/21/22	Wed 2/23/22	38,39,40	Boris
42			YC-BS	Yaw Control	Bearing Connection to Shaft	7 days	Wed 2/23/22	Sat 2/26/22	41	Boris
43			YC-BH	Yaw Control	Bearing System Housi	7 days	Sat 2/26/22	Mon 2/28/22	41,42	Boris
44			YC-BN	Yaw Control	Bearing Connection to Nacelle	7 days	Mon 2/28/22	Wed 3/2/22	41,43	Boris
45			YC-ST	Yaw Control	Subsystem Test	7 days	Wed 3/2/22	Sat 3/5/22	42,43,44	Boris
46			PW-BC	Power	Buck Converter Assembly	7 days	Mon 1/10/22	Wed 1/12/22		Boris
47			PW-AM	Power	Ammeter	7 days	Sat 1/29/22	Mon 1/31/22	46	Steven
48			PW-KV	Power	KV Rating Test	7 days	Wed 1/12/22	Sat 1/15/22	46	Boris
49			PW-APP	Power	Anderson Power Pole Connectors	7 days	Mon 1/31/22	Wed 2/2/22	47,48	Boris
50			PW-LS	Power	Load System	7 days	Wed 2/2/22	Sat 2/5/22	49	Boris
51			PW-LA	Power	Load Algorithm	7 days	Sat 2/5/22	Mon 2/7/22	50	Boris
52			PW-ST	Power	Subsystem Test	7 days	Mon 2/7/22	Wed 2/9/22	51	Boris
53			IT-MON	Integration Test	Montoring Systems	7 days	Tue 4/5/22	Thu 4/7/22	20,34	Tamara
54			IT-CTL	Integration Test	Control Systems	7 days	Sun 4/3/22	Tue 4/5/22	20,10,51	Tamara
55			IT-PW	Integration Test	Power Generation	7 days	Mon 4/4/22	Wed 4/6/22	52	Boris
56			IT-END	Integration Test	Test Finished Prototype	7 days	Wed 4/20/22	Fri 4/22/22	53,54,55	Tamara
57					Buffer	35 days	Fri 4/22/22	Wed 5/4/22	56	
58			POST	Poster	Poster Presentation	7 days	Wed 5/4/22	Fri 5/6/22	56,57	Tamara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March 2022
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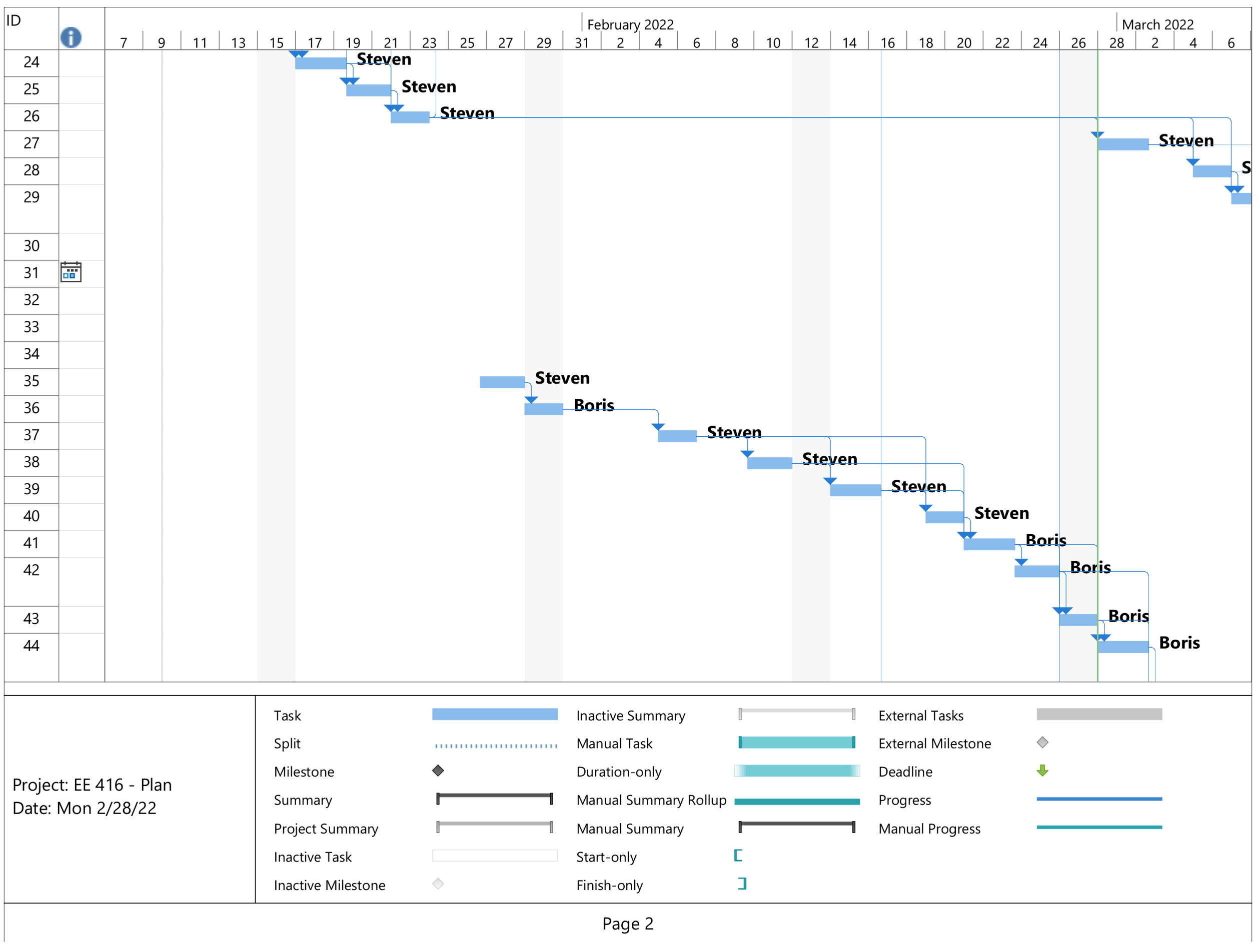
Steven
Tamara
Project: EE 416 - Plan
Date: Mon 2/28/22
Task
Split
Milestone
Summary
Project Summary
Inactive Task
Inactive Milestone
Inactive Summary
Manual Task
Duration-only
Manual Summary Rollup
Manual Summary
Start-only
Finish-only
External Tasks
External Milestone
Deadline
Progress
Manual Progress
Page 1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External Tasks
External Milestone
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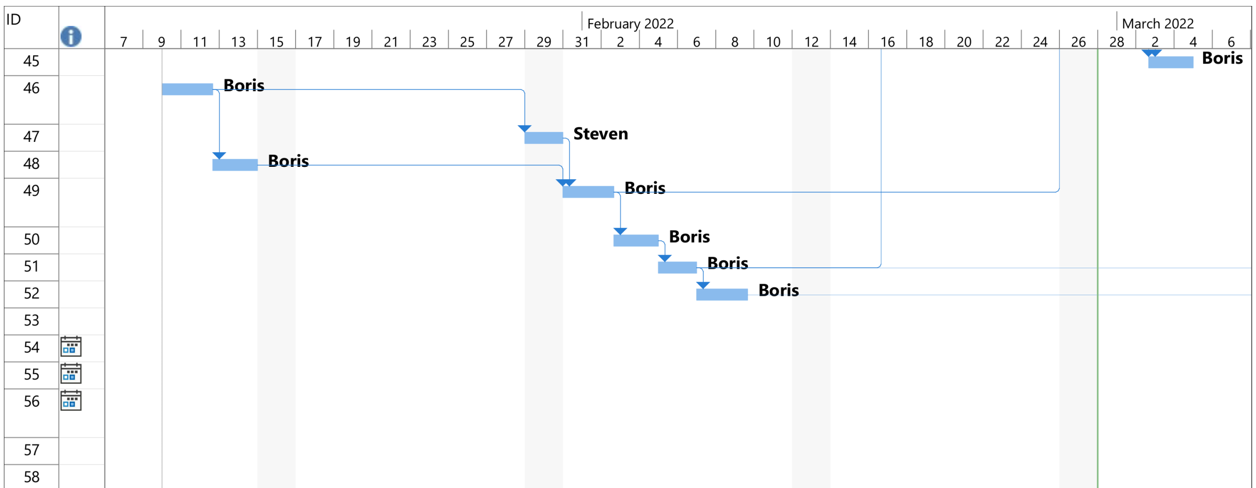
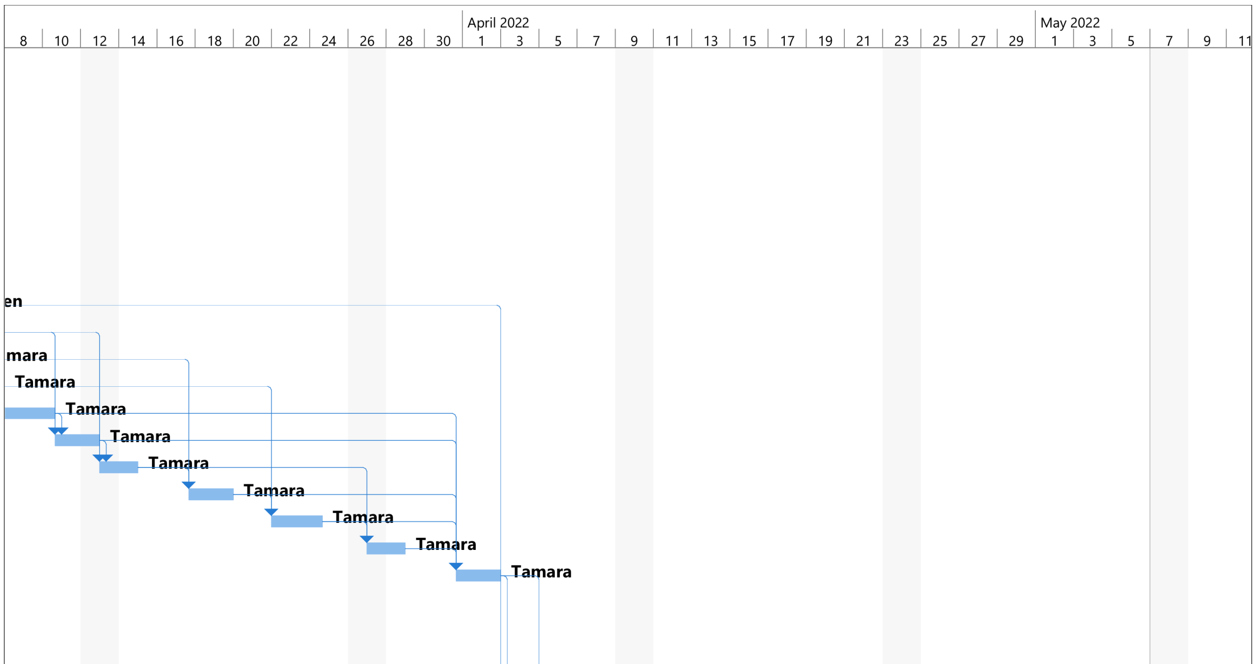
Manual Progress
Page 2



Project: EE 416 - Plan
Date: Mon 2/28/22

Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	



Task		Inactive Summary		External Tasks	
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Milestone		Duration-only		Deadline	
Summary		Manual Summary Rollup		Progress	
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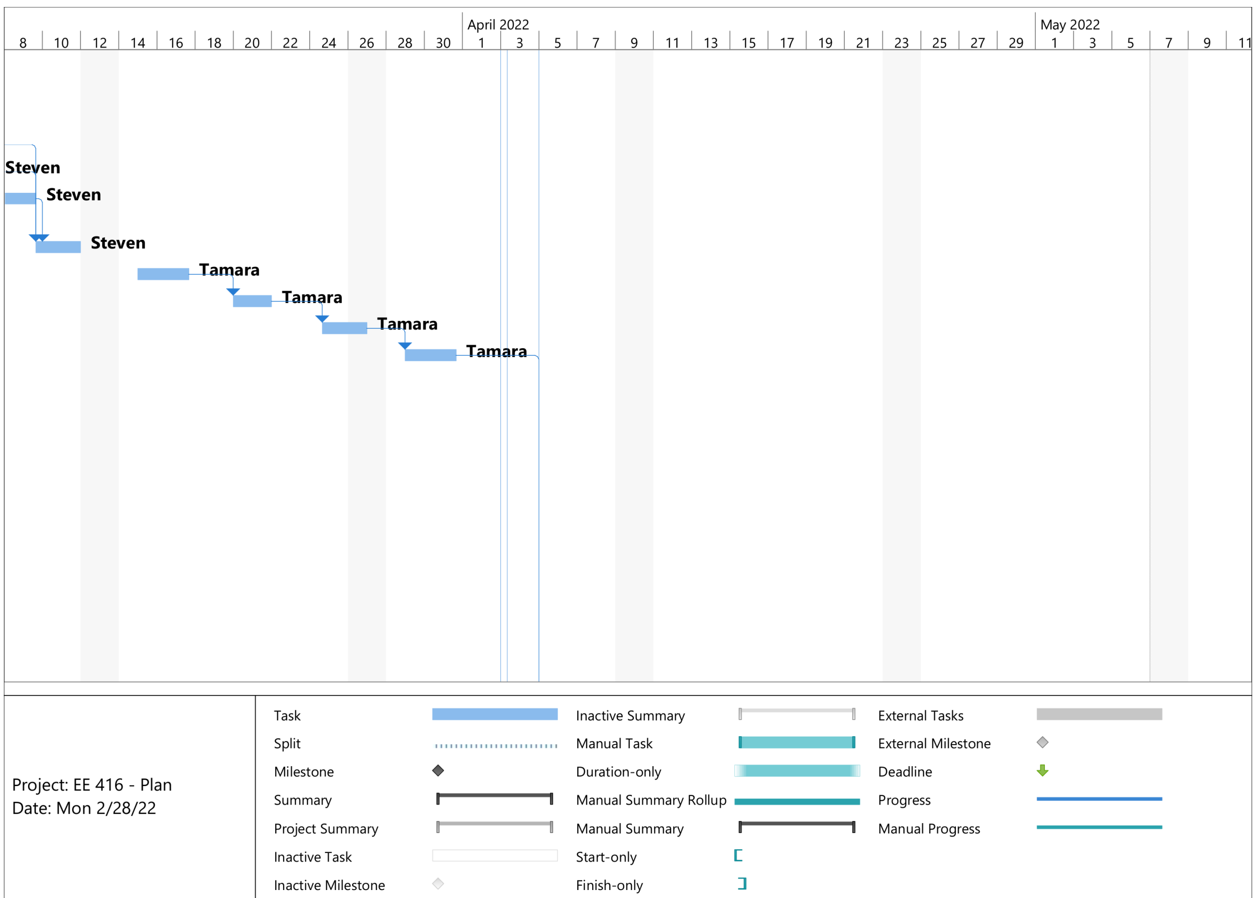
Inactive Task		Start-only			
Inactive Milestone		Finish-only			

Project: EE 416 - Plan
Date: Mon 2/28/22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May 2022
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Steven
Steven
Steven
Tamara
Tamara
Tamara
Tamara
Project: EE 416 - Plan
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Task
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Project Summary
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External Milestone
Deadline
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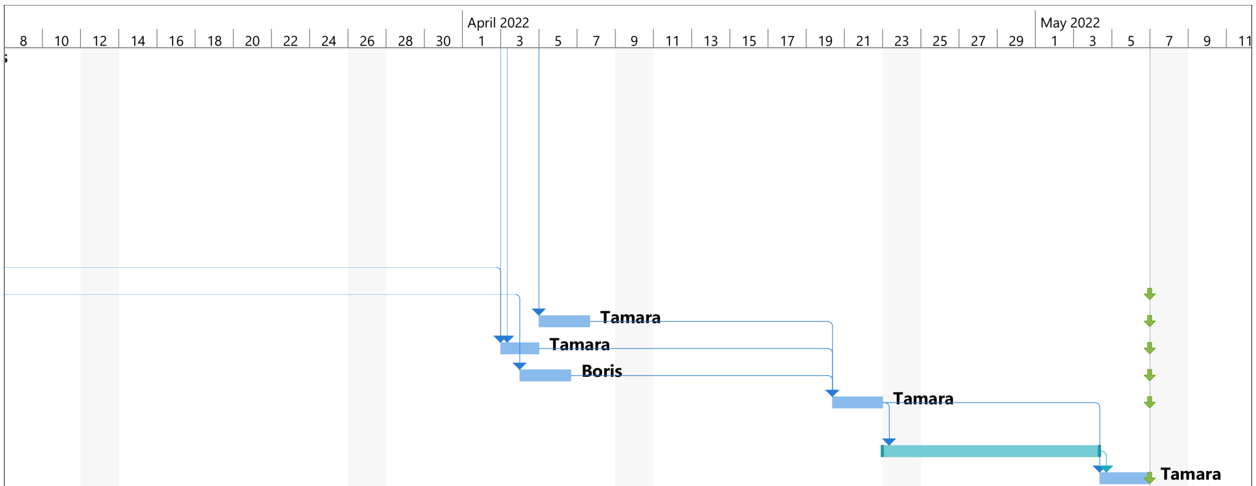
Manual Progress



Project: EE 416 - Plan
Date: Mon 2/28/22

Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	

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