

Final Binder Report

Paramotor Flight Control Development Platform



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SUBJECT: Flight Platform Solution Final Report.

Professor Johnson:

As per your request, AIT is hereby submitting the final binder concerning the Paramotor Flight Platform Solution. This document reports the tests performed and the results of each test matrix and how it complies with our technical specifications. Any question and concerns regarding the project can be directly addressed to the Engineering Project Manager or alternatively to any of the AIT members.

We hope that you find this report satisfactory.

Sincerely,



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Enclosed: Final Binder

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List of Acronyms and Symbols with Units

DMM	Digital Multimeter
ESC	Electronic Speed Controller
d_1	Riser Distance (Front)
d_2	Riser Distance (Center)
d_3	Riser Distance (Back)
\bar{d}	Average Riser Distance
Mean Deviation	$\frac{ d_1 - \bar{d} + d_2 - \bar{d} + d_3 - \bar{d} }{3}$
Power	Voltage*Current

Abstract

To satisfy the research needs of Dr. Pranav Bhounsule our team created a device with the flight characteristics of similar paramotors while also increasing the capacity for instrumentation and improving the maximum flight time, and efficiency. In order to provide the extended flight time and increased instrument and control payload that were required, a large parafoil wing would be needed. Designing a parafoil was outside the scope of this project and as such a suitable sized wing with appropriate flight characteristics was sourced. The craft was designed around the restrictions of weight and geometry set by the chosen wing, an Opale Camo H2.6. In current configuration, the craft has an estimated flight time of one hour at optimum conditions. The device is well under the maximum weight for the wing, for extended flight time an extra battery can easily be added. It contains additional room for several more instruments or micro-controllers depending on the needs of Dr. Bhounsule as he develops control systems. The team has successfully developed a craft that meets the needs specified by the client Dr. Bhounsule namely a mid-sized remote controlled paramotor with a flight time of one hour. This device will be sent to Chicago where it will be used to further develop the first automated flight control system for a paramotor.

1.0 Introduction and Background

1.1 Introduction

The market is saturated with both quadcopter and fixed wing drones. These types of devices have severe draw backs in power consumption or photo quality. Paramotors for recreational use are common. They represent an untapped market for aerial photography and other remote-controlled applications. The team's project is to develop a paramotor device that improves on existing devices by consuming much less power than a comparable photography drone and achieving a slower airspeed and the ability to take pictures without motion blur. This device will be used by Dr. Bhounsule to develop a control system that can automate the craft and follow GPS waypoints. The objective of this project is to create flight solution that is capable of low power consumption, increased flight time, easy to operate and more affordable over a quadcopter. The project will comply with FAA regulations Title 14 CFR Section 21.185, 21.191, 21.193, Fly sUAS, FAA Form 8130-7, and Texas Government Code, Chapter 423. Finished product must be able to fly with 10 kg of total weight. Propeller must provide 8N of thrust and consume less than 1000W of power while cruising. Parafoil must be able to withstand maximum of 25km/h wind gusts from all directions.

1.2 Background

There are other types of similar craft available such as fixed wing airplanes and multi-copter drones. The widespread use of these types of crafts is partially due to the simplicity of controlling their flight behavior. Automated GPS guided systems can be bought easily and are often built into premade drones, and as of yet there is no such system available for a paramotor.

2.0 Purpose

2.1 Problem Statement

Dr. Bhounsule is interested in developing an automated flight system for a paramotor, and though remote controlled paramotors are available none of them have the features he needs to successfully implement the instruments and control systems he needs to perform his research. The project we were given was to develop a remote controlled paramotor with an extended flight time and a modular design that is able to easily integrate multiple sensors or microcontrollers.

3.0 Objective

3.1 Objective

The objective of this project is to create a mid-sized remote controlled paramotor that meets the research needs of Dr. Pranav Bhounsule, including

4.0 Specifications

4.1 Performance Requirements

Discuss key performance requirements (including flight time and instrumentation).

Together with our sponsor our team decided on several characteristics that would be critical to the device being able to perform the research needed by Dr. Bhounsule. These characteristics include a flight time of at least an hour, stable flight characteristics, an open design to accommodate additional instruments, and the ability to takeoff unassisted.

Several instruments are necessary for our device and are included in the design. The instruments included are utilized in the testing of the craft and consist of a battery monitor, a GPS module, and a telemetry radio. There are many other instruments and sensors that can be added if they are needed for automation such as an accelerometer, a digital compass, and a tachometer. These can easily be added and utilized by the control software that will be developed.

4.2 Physical Specifications

From the performance requirements a set of physical specifications was created that were used to guide the design of alternative concepts. Of those specifications six are the most critical. They are the takeoff weight, power consumption, flight speed, FAA compliance, noise level, and within a budget.

The takeoff weight is determined by the wing and the desired cruising speed. The chosen wing has a maximum loading of 10kg, and our design decisions needed to be based around that maximum. Along with the weight the flight speed is determined by the wing loading and sets a maximum of 20mph.

To achieve a nominal flight time of one hour we calculated a maximum power consumption such that a single 6S battery could power the entire flight. A single battery was chosen due to budget and weight constraints. The power consumption was determined to need to be below 1000W.

According to OSHA standards the decibel limit for hearing damage is 100dB. We used this value to ensure that the device would not damage hearing by flying to near to someone. We also researched relevant FAA requirements for drones and other similar craft and designed the paramotor to follow all relevant laws. And lastly our device was designed to be built with a budget of \$2000, which was given to us by our sponsor.

5.0 Concept Design

5.1 Alternative Solutions

Three concept designs were initially thought out for various ways of constructing paramotors platform. It had to be aerodynamic and capable of automation in future by Dr. Bhounsule. These three concepts were a three wheeled frame with no cover and a ducted fan motor, a four wheeled frame with a cover and an open propeller, and a three wheeled

design with an open propeller. Each design has positive and negative features and ultimately a three wheeled design with an open propeller was chosen.

5.1.1 Concept 1



Figure 1: Concept 1

The first concept is a standard paramotor design with no wheels, a simple frame, and a GoPro camera. The frame will be constructed from wood as it allows for a cheaper cost of manufacturing. The use of no wheels will allow for a lighter aircraft and cost reduction. A disadvantage of no wheels is that the aircraft will have to be assisted on take-off by the operator. The operator will also have to assist the aircraft in landing as no wheels will not allow the aircraft to land in a safe manner. The use of a standard GoPro allows for a simple and economically friendly camera system to be attached to the aircraft in various situations. The system can be programmed for the operator to live stream footage to a transmitter. The wing in use for the system will be a three-meter wing. The wing is constructed to handle the desired load of up to seven kilograms. The overall design of Concept 1 is low in cost and weight. The design allows for the simplest outcome. The breakdown of this concept can be found in Table 11 on the Appendix section.

5.1.2 Concept 2

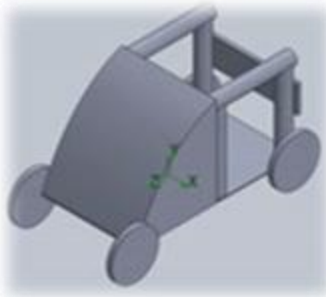


Figure 2: Concept 2

The second concept is a trike paramotor design with a four-meter wing. The aircraft will use a ducted fan for safety purposes and to help provide a greater thrust. The wing will be four meters in length to be able to lift the vehicle and maintain payload in flight. Aluminum tubes will be used to construct the frame of the housing unit. Aluminum is chosen for the low weight and higher strength than a 3D printed piece. The frame is economically friendly to the team but is not the cheapest concept available. The team will add a shell of either carbon fiber or fiberglass to the housing unit to improve aerodynamics. Three wheels will also be added to the bottom of the frame to improve stability in takeoff and landing. A common drone camera will be placed in the aircraft to capture footage. The overall design is a middle of the cost and somewhat competitive weight concept. The team is intrigued by this design as the most viable solution. Table 12 in the appendix section breaks down Concept 2.

5.1.3 Concept 3



Figure 3: Concept 3

Concept three is created to have the most high-end equipment. The design will be of a quad-frame paramotor design with a five-meter wing. The aircraft will be propelled by a ducted fan to improve safety as mentioned in concept 2. The housing frame will be constructed from steel to improve durability and toughness of the aircraft. The material will also increase overall weight which is why the five-meter wing will be used. The wing can carry up to twenty kilograms. A carbon fiber or fiberglass shell will be placed over the housing unit to increase aerodynamics and lessen drag. Four wheels will be placed on the frame to allow for stability on takeoff and landing throughout the aircraft. A custom camera made by DJI will be placed in the housing unit. The camera will have the ability to rotate in any direction and have moisture wicking capabilities in more dynamic weather. The design is the highest in cost and weight, but it is the most durable out of all the concepts. Table 13 in the Appendix section of the document shows this configuration.

5.2 Selection Criteria and Results

The three wheeled frames had more advantages over a four wheeled frame, most importantly it is lighter in weight due to needing one less wheel and axle. However, there would be less space to accommodate more instrumentation. Nonetheless, the design of the three wheeled frame allows for the user to place levels inside of the fuselage, allowing to mount other instruments like; sensors, cameras, or extra batteries.

6.0 Prototype Design

6.1 Analytical/experimental

The team used a few different techniques to determine the parameters for the paramotor. The main thing the team needed to know was the flight envelope that would correspond to the paramotor. The envelope can be seen below:

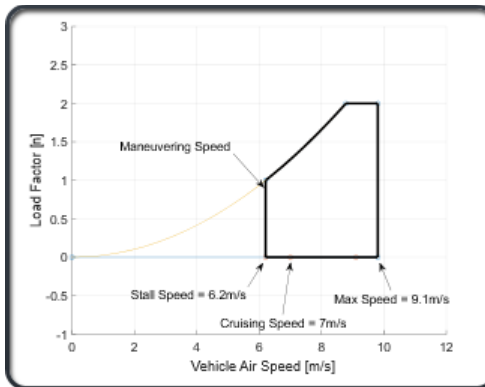


Figure 4: Flight Envelope

The flight envelope is important because it tells the team what the paramotor is able to operate. Traditionally a flight envelope would have both a positive and negative load but since the paramotor cannot operate upside down due to the wing deflating; it only has a positive load. The paramotor has a stall speed of 6.2 meters per second and a max speed of 9.1 meters per second. The max speed is needed to determine how fast the paramotor needs to be going on takeoff. The cruising speed is 7 meters per second which is what the paramotor will be operating at when it is in flight.

Another important analysis that had to be made was how the forces distributed across the fuselage. In order to do this the team created a free body diagram of the fuselage that can be seen below:

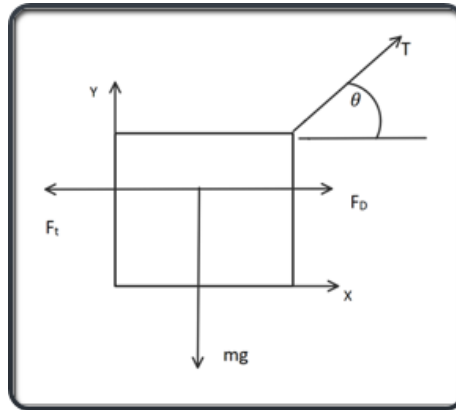


Figure 5: Free Body Diagram

The fuselage has four main forces acting on the body. The first main force is the gravitational force which acts straight down on the body. The propeller will provide a thrust force which will move the body in the positive x direction. The parachute will provide a sense of drag that will pull the paramotor in the negative x direction. The parachute also provides a tension to the fuselage since it is connecting to the frame. This tension can be determined by taking the cosine and sine of some angle multiplied by the amount of tension provided on the body. All these forces make up the acting forces on the fuselage. The team took this into consideration while designing.

6.2 Product safety/failure

During the designing phase the team had to consider various safety features and risk mitigation that can be associated with the paramotor. The main risk that the team and client were worried about was if the propeller had cutoff midflight and sent the paramotor into freefall. The fact that the paramotor was attached to a parafoil helped provide drag on freefall. Thus, slowing down the objects velocity and providing for a softer impact. The axle on the wheels were also designed to take any impact that came with a drop. At worst case scenario the axle would absorb the shock and brake at the weld. This led This led to the main fuselage not being damaged.

In the event of longer flight with the chance of the battery dying out the paramotor has the option to add another battery to act as a backup battery. This will also be beneficial if the paramotor is not fully charged but needs to take flight.

The last main feature is the addition of a shroud to the fuselage to help minimize debris from entering the electronics. The shroud is made of polycarbonate and covers all sides of the fuselage except for the floor and back plate. The floor is not covered because the electronics are attached to an aluminum plate that acts as the floor. The back plate is left open for airflow to reach the propeller and allow for the motor wires to reach the inside of the fuselage.

6.3 Design refinements/optimization

The team needed seven ECO's after the completion of the fabrication package. All seven were to change nut and bolt placements that were located on both the mounting plate and the base plate. The team had made a mistake when calculating original hole placement and ended up being off by an eighth of an inch. The team then recalculated the plates and hole placement. The changes were approved and completed with no issues.

6.4 Diagrams

The electronics of the craft are designed such that they are controlled by a single receiver while being powered by two separate batteries as seen in figure 3. This is done so a large powerful battery can be used to power the propeller while a smaller battery powers the telemetry and servos. This design enables the craft to continue flight in the event of the main battery failing or running out of charge. If the main battery fails, the back-up will be able to control the craft and it can be landed safely.

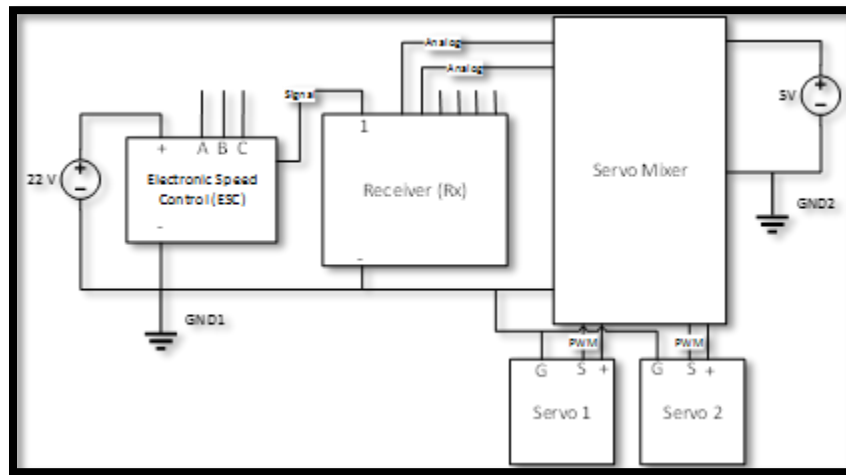


Figure 6: Electronics Schematic

Figure 4 shows the system flow chart. It shows the process that the user will go through to fly the craft and details the transposition that is done by the servo mixer and how its controls differ from standard aircraft. As seen on the right side the servo mixer reads a neutral control stick and brings both servos to the upright position and only brings them down as the control is moved. This is different to aircraft in that there is no upward deflection available as there is on a wing. The pitch can only be controlled by means of changing the thrust.

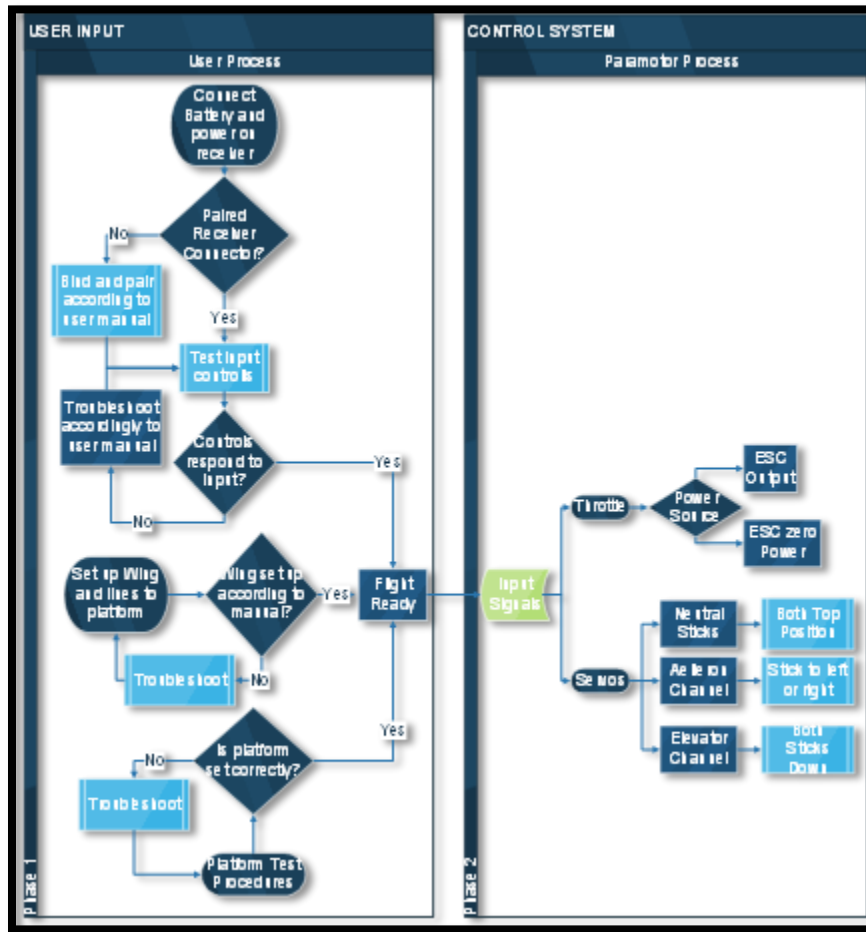


Figure 7: Controls Schematic

6.5 Key drawings

Figures 5 and 6 show the assembly drawings of the entire craft. The first shows an assembled version which gives a good idea of the shape of the final craft, while the exploded view helps to demonstrate how all the individual pieces fit together. Figure 7 shows an exploded view of the frame, this drawing is of all the frame parts that were welded together. The last drawing figure 8 is the wheel assembly which is designed to be easily manufactured and replaced in case of damage.

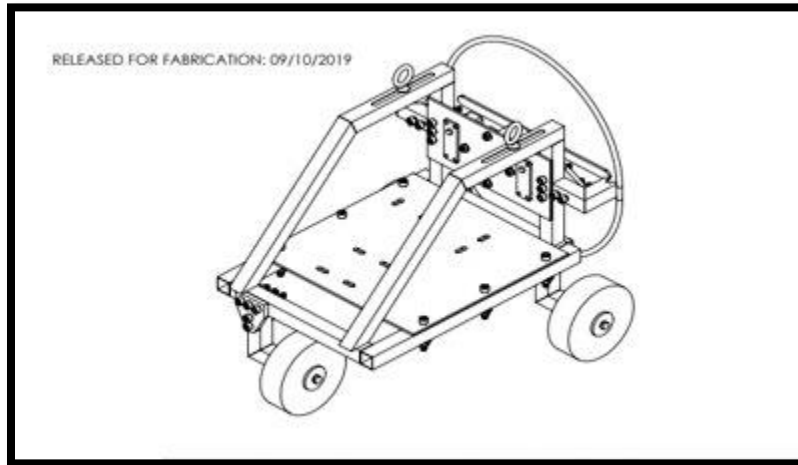


Figure 8: Full Assembly Drawing

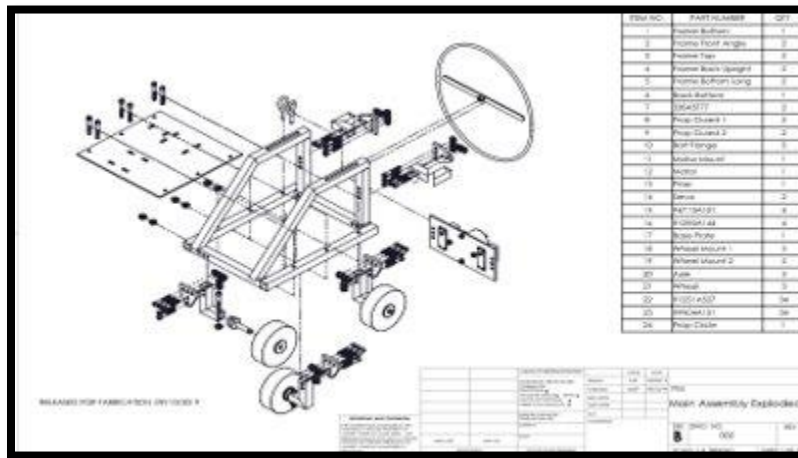


Figure 9: Exploded View of the Paramotor

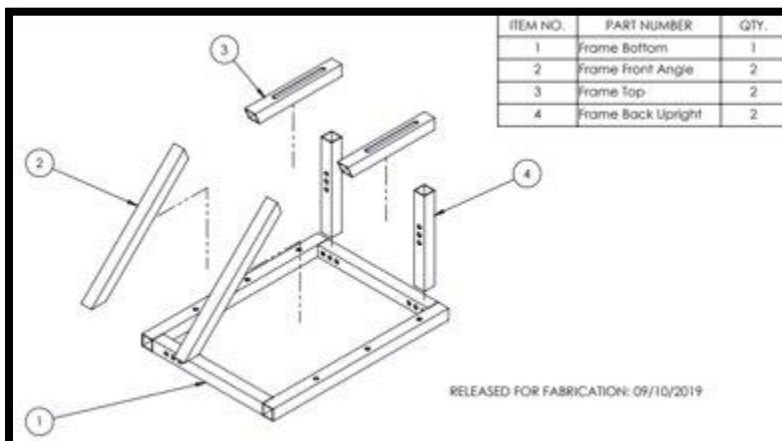


Figure 10: Fuselage Subassembly

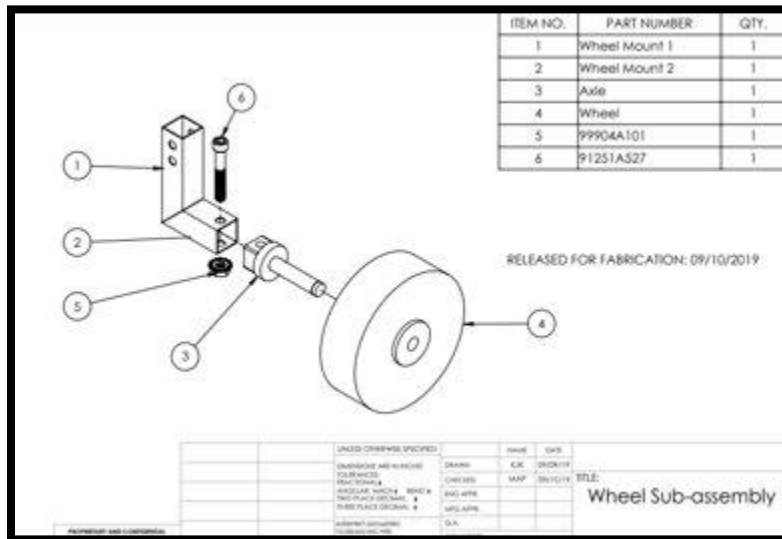


Figure 11: Wheel Subassembly

7.0 Prototype Fabrication

7.1 Fabrication Method

The fabrication consisted for the most part of cutting aluminum stock to the correct shape and welding it into the fuselage of the craft. Figure 9 shows the bottom weldment of the frame it was the first piece to be welded and served as a proof of concept for the team. The fabrication was worrisome initially due to a lack of welding experience on the team.



Figure 12: Weldment of the Bottom of the Fuselage

Figure 10 and 11 show some of the wheel mount subassembly. This assembly attaches the wheels to the frame and provides the ground clearance. The wheel assembly also serves as a primary point of failure in the event of a crash, it is designed to be easily replaceable while also absorbing the impact. The final version of the paramotor also included a wire mesh that is spread across the propeller guard and keeps the riser lines from tangling in the propeller.



Figure 13: Axle for the Wheel



Figure 14: Wheel attached to the Axle.



Figure 15: Full Fuselage Assembly not including Parafoil

7.2 Drawings

The team followed the fabrication drawings to help complete the fabrication process. The general assembly and subassemblies can be seen in section 6.4 of this report. The rest of the drawings can be seen in the fabrication package tab at the conclusion of this report. The frame was attached using an arc welder. The plates were attached using hex nuts. The electronics were attached by Velcro. For full fabrication detail please refer to section 7.1.

7.3 Bill of Materials

In order to complete the project, the team had to make a bill of materials on parts that were needed. All the materials were ordered online and shipped to the sponsor and then handed over to the team. The team had a total of twenty-three different parts that were bought. The parts purpose can be separated into two different uses which is frame or electronics. The aluminum, nuts, bolts, and screws were all bought to makeup the frame. The motor, servos, propellers, ESCS, receivers, and transmitter were bought to help makeup the electronic schematic that can be seen in the electronic section of this report. The team had a cost budget of approximately \$2000. The full list can be seen in the table below:

Table 1: Bill of Materials

ITEM NO.	PART NAME	MANUFACTURER	PART NO/ASIN	QTY
1	Rubber wheel	McMaster-Carr	2337T35	3
2	Brushless motor	Esprit	MARE10-510	1
3	Propeller 12x8 Pusher	Esprit	AER7227/37	1
4	Propeller 13x9 Pusher	Esprit	AER7227/44	1
5	Socket hex screw	McMaster-Carr	91290a144	100
6	Socket hex screw	McMaster-Carr	91251a527	25
7	Tig welding electrodes	TIG Welding Equipment	102-WT016	1
8	Servo Motor	DSSERVO	DS3218MG	4
9	2200 mAh Battery	Gens Ace	B50C-2200-2S1 TRX	1
10	Retaining Ring	Hvazi	CXZYDQ290P	1
11	Main Battery	Hoovo	B07MQT98D7	1
12	Paraglider wing	Esprit	OPL12131	1
13	GPS module	Pixhawk	B07NRMFTXL	1
14	Flange locknut	McMaster-Carr	99904A101	100
15	Battery Charger	Eyesky	ECB6	1
16	Eyebolt	McMaster-Carr	33045T77	2
17	ESC	Esprit	JETIELITEE80S B	1
18	ESC programmer	Esprit	JETISPINBOX	1

19	Aluminum sheet 1/8	McMaster-Carr	89015K18	1
20	Aluminum sheet 1/4	McMaster-Carr	8975K142	1
21	Aluminum tube	McMaster-Carr	6546K52	1
22	Flange locknut	McMaster-Carr	94710A101	25
23	Bullet connector	Hobbypower	B00EZKW1T4	20

8.0 Prototype Testing

8.1 Test Plan Summary

The purpose of the test plan is to make sure the project meets client standards. The client gave the team an initial amount set of specifications that the paramotor must be able to operate at. The team then devised seven test that would test all the main functions of the client specifications. The test that were conducted are as follows: critical dimension test, electronics bench test, range and noise test, corrosion and UV test, drop test, weight and strength test, and lastly a flight test. The details of each test are laid out in the section 8.2 in this report. The results of the test are in section 8.3 in this report.

8.2 Test Setup or Apparatus

The overall test plan consists of seven main tests. The first test is the critical dimensions test. Using calipers measure the distance between the riser slots on the frame at three points. The frontmost point before the radius begins, the rearmost and the center. All measurements should be between 14 and 18 cm and within 5mm of each other. With device on a flat surface measure the distance from the surface to the bottom of the frame. Secure the back of the frame to a flat reference surface and measure the deviation along the axles to verify alignment. They need not be aligned with the reference surface just aligned together.

The second test is the weight and strength test which works by attaching a mass of 25 kg which is tied with bridling rope and attached to the hanging scale. If the rope doesn't collapse it pass the test otherwise it fails, the test. Weight of wing also be tested with scale to assure it doesn't weigh no more than 40 gr/m². After fabrication the final product must not exceed 8 kg.

The third test is the electronics bench test which works by setting up all electronics on device in final configuration, do not attach propeller. Disconnect all connections from receiver except for the power. Pair with transmitter and use DMM to check signal received matches the one transmitted. Reconnect all cables. Check servo behavior matches expectations with various transmitter conditions. Using transmitter set throttle to 50%. Use DMM to measure current through motor power cables. Run at 50% throttle for 1 hour, to

simulate flight a fair will be directed across the device. Measure temperature of ESC at 15-minute intervals. Disconnect batteries and check voltage.

The fourth test is the drop test which a Welded frame (unibody frame) will be subjected to a drop test from 20-foot height and will be tested for weld cracks with dye penetrants with provided instructions from the manufacturer.

The fifth test is covering the wing material which works by using the small patches included with the wing. One of these samples will be placed in a 3.5% saltwater solution for 1 hour and then removed. After a day the material will be inspected for holes and manually manipulated to check for brittleness. Another sample will be placed in a sunny location protected from the weather for a week and inspected the same way.

The sixth test is the range noise. In this test one of the team members will be attached with a receiver and a GPS module. The other members will stand with the transmitter. The receiver will be attached with an LED to show that it is still receiving signal from the transmitter. The team member with the GPS module and receiver will begin to run to at least two miles away from the transmitter and see if signal could still be reached. The team will also see if the GPS module can still be traced by the telemetry system.

The last main test that is being conducted is the flight test. Here the finished paramotor will be given 30 m to take off, and once it up in the air servos will be tested for maneuverability. This test will cover how paramotor behaves turning left, right and during braking.

8.3 Test Results Summary

The results for the seven tests are described in this section. For the dimensions test the distances between the risers was measured at three points. The mean deviation of the riser distances was calculated to give a value for the parallelism of the slots. Acceptable criteria were determined to be a mean deviation of below 5 mm and the device was significantly under the required value. As well ground clearance was specified to be a minimum of 50mm and was measured to be 113mm which is well above the required value. The parallelism of the wheels was measured by aligning the side of the frame to a common reference and measuring the distance from that reference to the front and back of each wheel. The alignment is the difference between those two measurements with a zero being perfectly aligned. Each wheel was within 4mm of being aligned and the mean deviation of these measurements was 3.3mm which is within the acceptable criteria of 5mm.

Table 2: Riser Slot and Ground Clearance Results

T-01 Critical Dimensions			
Test	Acceptance Criteria	Measured Value	Pass/Fail
Riser Distance (Front)	14cm<d ₁ <18cm	17.3cm	P
Riser Distance (Center)	14cm<d ₂ <18cm	17.4cm	P
Riser Distance (Back)	14cm<d ₃ <18cm	17.5cm	P
Parallelism	Mean Deviation < 5mm	0.67mm	P
Ground Clearance	>50mm	113mm	P

Table 3: Axle Alignment Results

T-01 Critical Dimensions			
Test	Acceptance Criteria	Measured Value	Pass/Fail
Back Left Axle Deviation	N/A	2mm	N/A
Back Right Axle Deviation	N/A	2mm	N/A
Front Axle Deviation	N/A	4mm	N/A
Parallelism	Mean Deviation < 5mm	3.3mm	P

The weight and strength test results were tricky but to ensure the safety of the device bridle lines were tested to ensure a breaking strength above 25kg. This value was decided upon because of the maximum weight of the craft as well as the maximum loading in the flight envelope. The lines were tested by suspending 25kg from a single line. The lines tested did not fail at that weight. The fabric weight was tested to match the weight listed in the manual for the wing. This weight is listed as 32 gr/m² and a value of 40 gr/m² was deemed as acceptable. The fabric tested to be accurate to the specification of 32 gr/m². The maximum weight possible for the wing is listed as 10kg and the listed specifications state the craft should weigh no more than 8kg to ensure flight stability. The weight of the craft in its current configuration was 5kg which is within acceptable weight for the wing and will provide a more efficient flight.

Table 4: Weight and Strength Results

T-02 Weight and Strength Data			
Test	Acceptance Criteria	Component condition	Pass/Fail
Bridling rope	Hold 25 kg without failure	N/A	P
Wing fabric	Weight < 40gr/m ²	32gr/m ²	P
Overall product	Weight < 8 Kg	5kg	P

The electronics bench test is one of the most crucial components for the proper function and behavior of the paramotor. It is why adequate testing procedures were set for these components and why it is important to be able to monitor the behaviors in temperature and power consumption of the functioning set. The transmitter signal responded to the manipulation and activation of the transmitter. Also, the servo motors responded in a positive way towards the corresponding desired behavior, yielding an optimal control for the paramotor. Additionally, the behavior in terms of temperature and power consumption of the electronics yielded temperatures well below our acceptance criteria dictated by our specifications. Yielding in that regard a safer performance when operating the paramotor.

Table 5: Receiver Signal Results

T-03: Receiver Signal Matrix		
Test	Acceptance Criteria	Pass/Fail
Receiver signal channel 1	Signal changes as transmitter is manipulated	P
Receiver signal channel 2	Signal changes as transmitter is manipulated	P
Receiver signal channel 3	Signal changes as transmitter is manipulated	P

Table 6: Servo Behavior Results

T-03: Servo Behavior Matrix		
Test	Acceptance Criteria	Pass/Fail
Servo behavior (no input)	Both servos are in upright position	P

Servo behavior (right turn)	When control stick is moved to the right only the right servo moves downward	P
Servo behavior (left turn)	When control stick is moved to the left only the left servo moves downward	P
Servo behavior (slowing)	When control stick is moved downward both servos move downward in unison	P

Table 7: Current, Power and Temperature Results

T-03: Current, Power and Temperature Matrix			
Test	Acceptance Criteria	Measured Value	Pass/Fail
Motor Current	<50A	6A	P
Motor power consumption	1000W	133W	P
ESC Temperature (Initial)	<60°C	21.2°C	P
ESC Temperature (15 min)	<60°C	22.5°C	P
ESC Temperature (30 min)	<60°C	23.1°C	P
ESC Temperature (45 min)	<60°C	23.3°C	P
ESC Temperature (60 min)	<60°C	24.1°C	P

The test that had the most risk was the drop test as it could end in the total loss of the paramotor. The paramotor was flown to a height of approximately twenty-five feet and reached a stable position. Once stability was reached the throttle to the propeller was cut off allowing no thrust to be provided. This action caused no lift to be provided to the parafoil thus causing it to fall to the ground. The paramotor hit the ground and took a couple of bounces before coming to rest. The team first visually inspected the welds for any main cracks visible to the naked eye. None were visible so the team poured dye penetrant into the frame to check for minor cracks. No penetrant was leaking, and all the welds held as expected. The front axle was bent slightly but the team was able to bend it back in place with no problems to the frame or electronics.

Table 8: Weld Strength Results

T-04 Weld Strength		
Test	Broken welds or large cracks (yes/no)	Pass/Fail
Dye penetrant	None found	P

The wing material was tested next to see how it withstood to weathering. The parafoil came with a couple of spare patches just in case repair had to be made to the parachute. One of the patches was taken and placed in saltwater solution for one hour. Once the hour was complete, the patch was taken out and left to sit overnight. The team came back the next day and evaluated the patch. No noticeable corrosion was observed. The team also placed another patch outside for one week to check for weathering and UV resistance. At the conclusion of the one week the team noticed no change in color or material strength.

Table 9: Wing Material Corrosion Resistance Results

T-05 Wing Material		
Test	Acceptance Criteria	Pass/Fail
Corrosion	No noticeable difference between new material and tested sample.	P
UV	No noticeable difference between new material and tested sample.	P

The test that gave the team the most problems was the range and noise test. The range goal for the transmitter and telemetry was to be at least 2 miles. The device did not pass this test and signal was lost at a significantly shorter distance around 2000ft. If the client is dissatisfied with the current range, then stronger transmission methods are available and can be added to the device. These include larger antennas and more powerful telemetry systems. The maximum noise level was determined to be the level that OSHA lists as causing damage during extended exposure. Our tests were to be performed outdoors to better simulate real world conditions but during testing indoors the value was measured much closer than specified and was still much below the specified value. Therefore, it can be assumed that at any range the device will not be loud enough to cause hearing damage.

Table 10: Range/Noise Results

T-06 Range and Noise Data			
Test	Acceptance Criteria	Measured Value	Pass/Fail
Transmitter/Receiver	≥ 2 miles	N/A	F
GPS Module	≥ 2 miles	N/A	F
Noise level	>100 dB	76.7	P

The last test that was important to complete was the flight test. This was the culmination of all the test and would determine if the overall project was a success. The paramotor was taken to the Kitty Hawk Field in New Braunfels, Texas to test flight. The airfield is equipped with various runways. The team used the end of the runways to test takeoff. The paramotor was able to take off on its own with thirty feet. The vehicle quickly ascended into the sky. Once in the sky, the team tested to see how the paramotor will operate with turning. With the controller the paramotor was turned to the left and did a couple of circles. The vehicle was then straightened back out and then turned to the right for a couple of circles. The vehicle had no problem turning in either direction. The vehicle was once again straightened back out and flown near the runway. The team then initiated the brakes to test how the vehicle will land. The parafoil deflated the back of the parachute as expected to allow the vehicle to return to the ground. The test flights were a success.

Table 11: Launch and Flight Behavior Results

T-07 Launch and Flight Matrix	
Test	Pass/Fail
Turning Right	P
Turning Left	P
Slowing	P
Self-Launch	P

9.0 Project Management

9.1 Personnel

The following is a brief summary of the key personnel. Additional details are contained in the Communications section of the report.

Kyle Kinsey – Engineering Project Manager

Mr. Kyle Kinsey was the team leader for this project and as such delegated the responsibilities among the other teammates. He was also the primary fabricator and with Matthew Pantoja created the design and fabrication drawings for the device. He has demonstrated the ability to implement the knowledge gained through his education to successfully develop a product from an initial idea into a functioning prototype.

Matthew Pantoja – Mechanical Design Engineer

Mr. Matthew Pantoja has contributed excellent problem-solving abilities and process-thinking skills and embraces creativity and innovation. Through his studies, he has gained extensive knowledge of thermodynamics and product design, among many other components of mechanical engineering. He was a part of the Baja SAE team which taught him project design early in his college career. He has demonstrated strong technical and methodical aptitude with an innate ability to analyze problems and devise creative solutions that enhance the quality of the project. Matthew has been an effective communicator who builds positive, cohesive relationships with all personnel associated with the project. Collaborated with the design analysis fabrication and testing throughout the project.

Tarunjeet Singh (TJ) – Systems and Control Engineer

Tarunjeet Singh has contributed to majority of hands on part of the The Paramotor. It includes the sorting out all the electronic that were needed, fabrication and testing of the project. Fabrication included milling the plates, making shafts on the lathe, and cutting and drilling the materials according to design parameters. TJ has also used his collective knowledge from all engineering courses to make this project meet its functional requirement and design parameters. TJ also worked on testing all the electronic connectivity, orientation and response timings of throttle and servos. TJ has been an effective asset for completion of this project.

J. Ramon Vazquez C. - Engineering Finance Manager

Mr. Ramon Vazquez has contributed to multiphase programs throughout his career. These include; being design and test lead of the NASA NCAS Mars competition, Secretary and interim president for Aeronautics and Rocket Club at UTSA, Mechanical Engineering Intern for various projects involving sustainability, mechatronics, and aerospace engineering. He has acted as the team's communications director, project management in earned value analysis, scheduling and personnel, as well as being the scribe and record holder of the project. Collaborated in producing the technical solution, fabrication, and testing procedures.

9.2 Overall Schedule

A Gantt chart, or harmonogram, is a type of bar chart that illustrates a project schedule. This chart lists the tasks to be performed on the vertical axis, and time intervals

on the horizontal axis. The width of the horizontal bars in the graph shows the duration of each activity.

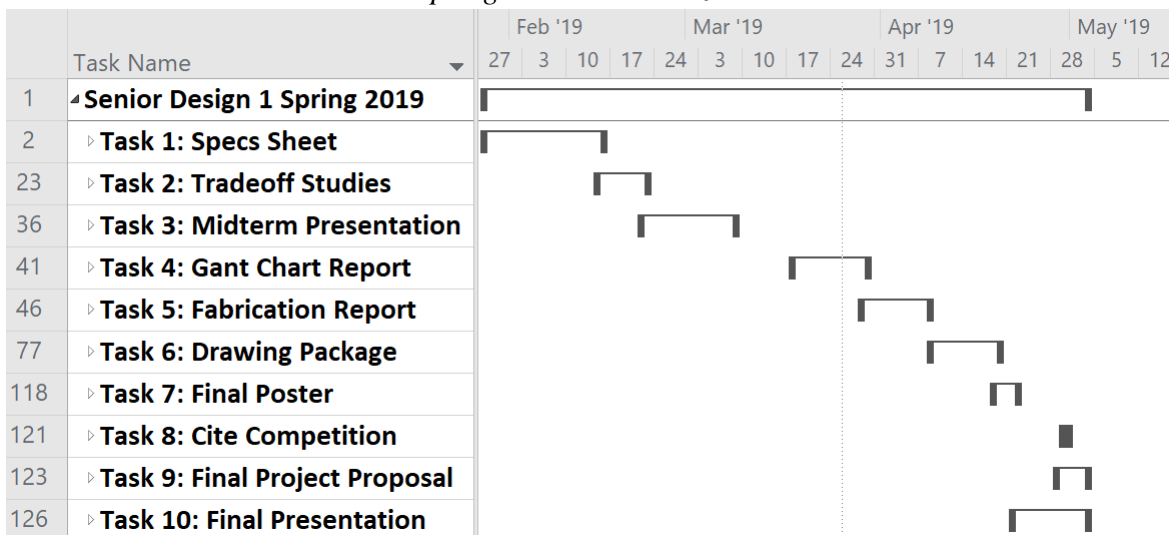
This tool was utilized to show the work performed in detail with the time it took place keeping compliance throughout the deliverables and project development. This tool was crucial to keep track of hours spent by team members and utilized to determine the earned value in the financial performance.

The following sections show the summarized Developed Gantt chart for Senior Design I in the Spring 2019 Semester, Summer of 2019, and Senior Design II in the Fall 2019 Semester in chronological order. The criteria for this arrangement of time was to separate the whole project, into the scholastic semesters, and then into the deliverables for each semester period. Since summer is not stipulated as a scholastic semester, the period in between the two semesters was assigned to Summer 2019. Each section and deliverables are explained in detail in the following sections

9.2.1 Senior Design I Spring 2019

In Senior Design 1, the project began as planned on January 28, 2019. The whole section was set to encompass 70 days. The semester was broken up into 10 main tasks and deliverables including specification sheet, tradeoff studies, fabrication report, drawing package, and presentations. Each task consisting of numerous sub tasks needed to be completed for the main task to be completed. The week of March 8 was left empty due to spring break. The week was used as a vacation period for the team to relax and reenergize for the remaining of the Senior Design 1 course. All items in this section were 100% completed. The following table shows some of the main task needed to be completed in Senior Design 1:

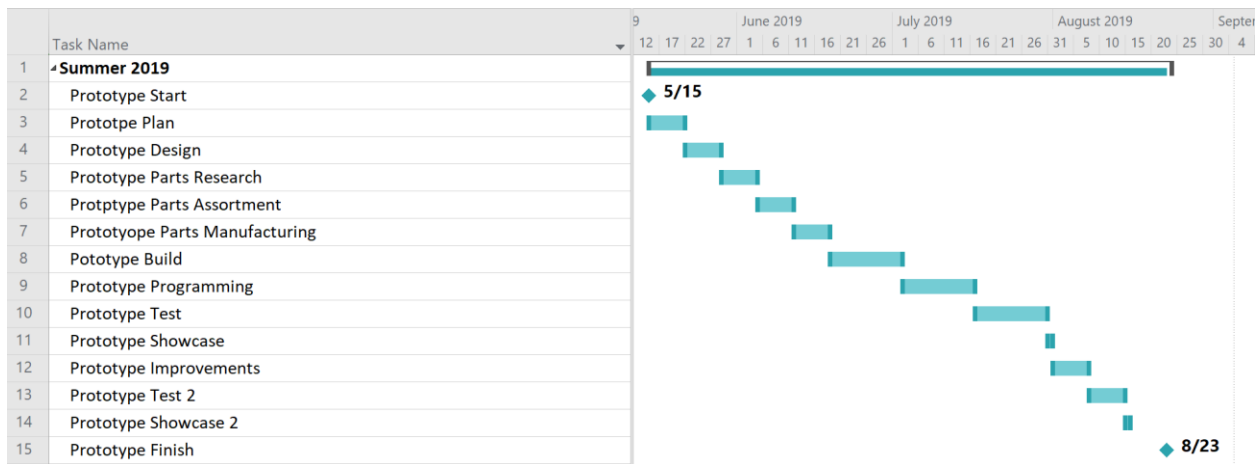
Table 12: Spring 2019 Summarized Gantt Chart



9.2.2 Summer 2019

One of the client’s prerogatives and objectives was that an early prototype of the final product must be showcased before Senior Design II. Summer 2019 was the period utilized by the team to Fabricate and test this early prototype. This whole section consisted of 54 days and 14 tasks including the plan, design, manufacturing, assembly, programming, and preliminary testing. A vacation period of approximately one month was assigned to allow the team to rest from the strenuous Spring Semester and generate creativity and energy for the next tasks at hand. All items in this section allotted to a total of 100% completion. The following table shows the rollout of the Gantt Chart for Summer 2019.

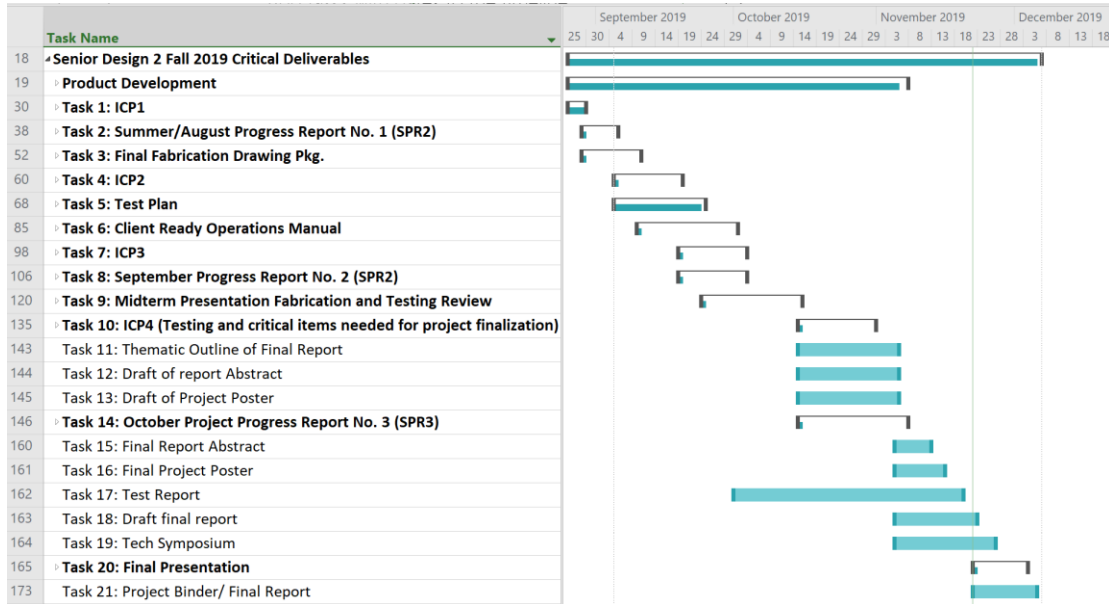
Table 13: Summer 2019 Summarized Gantt Chart



9.2.3 Senior Design II Fall 2019

The final product development phase started in the Fall 2019 Semester. This section was built in accordance with the Senior Design II Fall 2019 Syllabus. It was determined that the Semester had 75 days in total for the team to accomplish all the milestones and deliverables required. Referring on the rolled-up Gantt Chart of this section, all items excluding Task 19-Task 20 are at 100% complete. This yields a total of 90.90% completion overall.

Table 14: Fall 2019 Summarized Gantt Chart



9.3 Financial Performance

The following sections discuss AIT’s EVA (Earned Value Analysis). Contrasting planned financial resources vs actual values.

Earned Value Management (EVM) is a project management technique that Objectively tracks physical accomplishment of work. This is used to track the progress and status of a project & forecast the likely future performance of the project. The total Budgeted Cost of Work Scheduled (BCWS) came out to be ≈\$ \$223,800.00. However, for the current week (Week 28) this yields a total of \$ \$195,500.00 Budgeted Cost of Work Performed (BCWP) also sometimes called Earned Value (EV) yields a result of \$216,329.51. While Actual Cost of Work Performed (ACWP) also sometimes called Actual Cost (AC) yields a value of \$210,100.00. When performing Schedule Variance, a value of \$20,829.5 which indicates we finished ahead of schedule. While a result of \$6229.51 for Cost Variance shows that we finished under budget. Table 1 shows the Earned Analysis performed for these 28 weeks of labor.

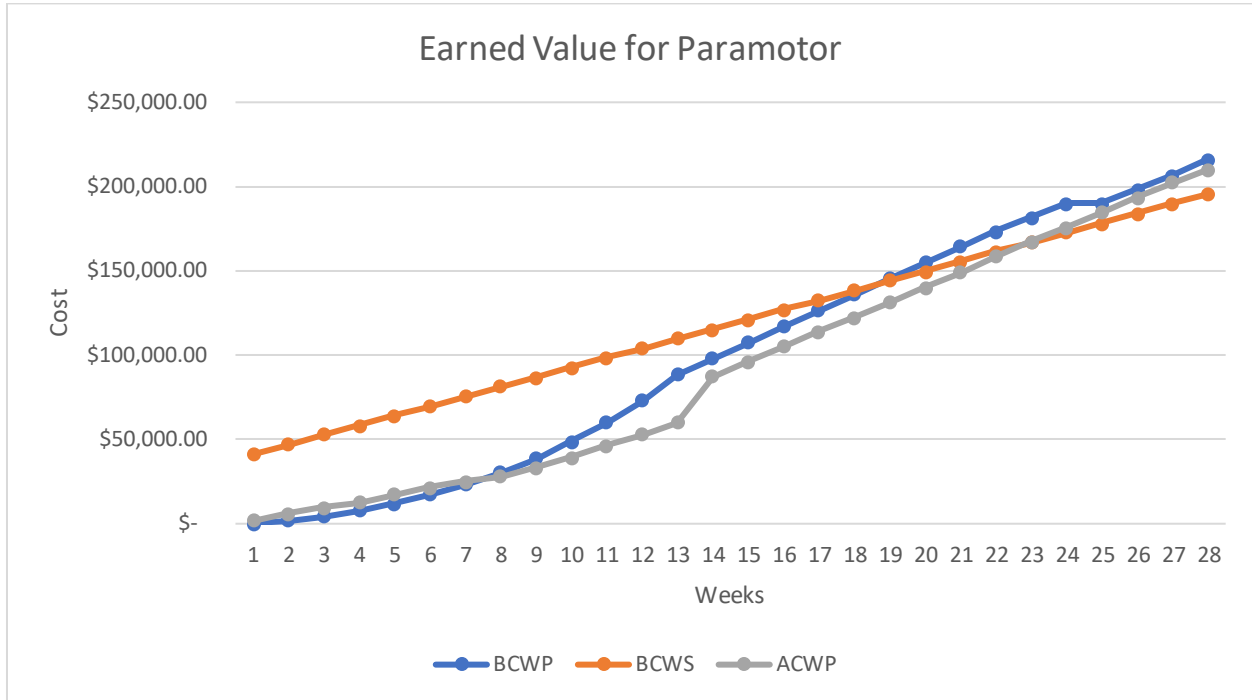


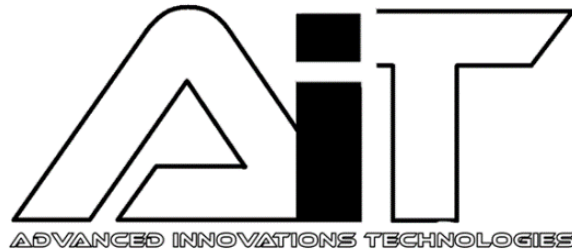
Figure 16: Earned Value chart

10.0 Conclusion

In accordance with the technical specifications in Appendix A, and the test plan outlined in this document and submitted previously, Advanced Innovations Technologies developed a functioning Paramotor Flight Development Platform. The device passed all tests except the transmission range. All other aspects including power consumption and flight behavior were successful and performed above specifications. The device has been deemed acceptable as-is by the client without the need for modification to bring the transmission range into compliance.

8.0 Communications

To ensure the fabrication as planned, Advanced Innovation Technologies will be meeting with the Senior Project Manager, Professor James Johnson bi-weekly Thursday meetings at 8:40 AM. Additionally, the design team members meet at minimum of three times a week and keep mentor/sponsor Dr. Pranav Bhounsule up to date by email when needed. Contact Information of all team members:



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Appendix A: