AUVSI Design Competition

Interim Design Report

Team 8
Submitted: 10/31/14
Submitted to: Dr. Shih, Dr. Helzer, Dr. Gupta, Dr. Frank
Authors: David Hegg, Christopher Bergljung, Jermaine Dickey, William DiScipio, Gavarni Leonce, John Murnane, Tavarius Slaughter

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Group Members:

David Hegg (Group Leader):
David Hegg is a Mechanical Engineering student from Florida State University. His area of interest is in the aerospace industry where he is currently a research assistant at the Florida Center for Advanced Aero-Propulsion. David has also interned at Arthrex and at Gerdau over the past two summers.

Christopher Bergljung (ME Lead):
Christopher Bergljung is a Mechanical Engineering student from Florida State University. This fall Christopher took part in the FIPSE study abroad program at UNIFEI in Itajuba, Brazil. Christopher has also interned three summers in Sweden. His experience is in Marine Engineering with a focus on non-destructive testing and product safety.

Jermaine Dickey (Programming Lead):
Jermaine Dickey was born and raised in Tallahassee. His interests are in Mechatronic Controls. Jermaine is employed with the National High Magnetic Field Lab as a student researcher studying superconducting magnets. As a senior at the College of Engineering, he has almost reached his dream of becoming a Mechanical Engineer.

William DiScipio (Secretary):
William DiScipio is a fourth year Mechanical Engineering student. He has developed his passions and expertise for aerospace and dynamic systems. Furthermore, he has been involved in several organizations, such as SAE, AIAA, and FCAAP. He further ensures his professional development by working at a Fortune 500 company.

Gavarni Leonce (EE Lead):
Gavarni Leonce is an Electrical Engineering student from Florida State University. As one of two electrical engineers on Team 8, Gavarni has a large role in the project. Gavarni is also interested in software engineering. Upon graduation, he will study for another year to acquire a degree in computer engineering.

John Murnane (Web Designer):
John Murnane is a Mechanical Engineering student from Florida State University. He is currently taking part in the FIPSE study abroad program, studying at UNIFEI in Itajuba, Brazil. Over past summers, John has had five consecutive internships with a medical manufacturing company; gaining irreplaceable real-world experience.

Tavarius Slaughter (Treasurer):
Tavarius Slaughter is an Electrical Engineering student from Florida State University. He has interned for a Fortune 500 company, PPL Corporation, as a transmission design engineer. Tavarius also works two jobs, he is the Keeper of Finance of Omega Psi Phi Fraternity incorporated, and an active mentor in the community.

Acknowledgement:

Team 8 would like to thank Dr. Shih for funding this project and advising Team 8 throughout the process as well as Dr. Frank who has been helpful assisting with the electrical side of the project. Dr. Shih has provided Team 8 with the opportunity to test his personal quad-rotor vehicle in order for the team to acquire a better understanding about quad-copters. Moreover, Team 8 has chosen to design an unconventional aerial vehicle and Dr. Gupta has offered his opinion about what Team 8 should research for the successful completion of the design. Team 8 has been grateful to be able to have access to an extensive amount of knowledge that would not be accessible without the help of Dr. Shih, Dr. Frank, and Dr. Gupta and would like to thank them for their continuous support throughout the project.

Abstract:

Team 8 is multidisciplinary team of engineers whose main objective is to design a vertical takeoff and landing (VTOL) aerial vehicle for the AUVSI competition. Several members of Team 8 are involved in the FIPSE study abroad program. Even with this diverse team, Team 8 has successfully designed the vehicle for the competition and are moving forward to manufacturing the vehicle with goal of finishing the VTOL flight by May 2015.

I. Introduction

Team 8 has been given the task of competing in an international competition while also working with team members that are studying abroad in Itajuba, Brazil as part of the FIPSE program. The distance between teammates made the team seek various outlets to find effective communication. Among which are Facebook, Skype, and GroupeMe app. This challenge alone gives the team experience with communicating by means other than face-to-face when time and space does not allow. However, successful means of communication were achieved in the development of an Unmanned Aerial Vehicle (UAV).

The Association for Unmanned Vehicle Systems International (AUVSI), host a competition in which schools from around the world can test their engineering skills against each other by building the best UAV for an assigned task.[1] The 2015 AUVSI competition has the mission tasks of autonomous flight, object detection, and reconnaissance. These tasks are to be done as quickly and accurately as possible while maintaining fully autonomous flight. Each team is given 40 minutes to complete the mission and then return to its control station.[1] Last year's senior design team was unable to compete in the AUVSI competition, but competed in another competition and was able to achieve autonomous flight and data acquisition successfully. The biggest problem they had was the inability to take clear photos and to perform an autonomous landing.

Taking these factors into account, Team 8 wanted to design a new UAV that was better equipped to accomplish these problems. Originally, the plan was to design a multi-rotor vehicle so that the camera could have a stationary platform to take clear pictures from and also have an easier way to take off, land, and navigate. The only problem with this idea is that the average flight time for a multi-rotor is only fifteen to twenty minutes.[2] This time of flight would not be enough to complete the mission and is far under the allotted time of the mission. There is no required time of flight for the AUVSI competition so the multi-rotor could compete but would have the disadvantage of having to return to the command center during the mission to exchange the batteries if they were depleted.

While still in the research and development phase, Team 8 came across an UAV design by Latitude Engineering[3] which happened to be the ideal vehicle for the AUVSI competition. This UAV is shaped similar to an airplane but features four vertical facing propellers in addition to a horizontal facing prop. The four vertical facing propellers give the UAV the abilities of a multi-rotor by enabling Vertical Takeoff and Landing (VTOL) by generating lift, while the fifth rotor gave it the ability to achieve fixed wing flight, where lift is generated under its wings. A multi-rotor has limited flight time as compared to the fixed wing, due to its need to create lift by way of its propellers which continually draws current to the four motors, draining its batteries. The fixed wing uses a fraction of this energy by not working directly against gravity and only having to power one motor.

Though this is the ideal UAV, it is relatively new and has little data on the design. Latitude Engineering took an extensive amount of time to get their UAV running properly due to the challenges associated with balancing a nonsymmetrical vehicle with four evenly spaced props, which then can transition itself from multi-rotor flight to fixed wing flight.

Though this task may be difficult, Team 8 is enthusiastic about getting the task complete. The difficulty of the challenges are what fuel the motivation of Team 8, as well as designing a cutting edge UAV that similar models of have only recently been debuted. There are not many times in a person's life that they have the chance of working with a team to design and building something that is still a developing technology. Team 8 hopes to gain useful knowledge in this quest that can be used once in their careers.

Team 8 will not be competing in this competition but rather preparing the 2016 team with the competitive edge. This competitive edge will come in the form of a hybrid UAV capable of VTOL, fixed wing and rotor wing flight. With this design, the futures team will set up to be highly competitive in future competitions.

II. Design and Analysis

A. Frame Design

Team 8 decided that the existing fixed wing Senior Telemaster plane, outfitted with a quad-rotor aircraft attachment, would be the best possible aircraft for the 2015 AUVSI SUAS Competition. The frame of the quad-rotor would be attached to the plane, and would create a hybrid aircraft, with multiple flight capabilities. When designing the frame for the quad-rotor attachment, many constraints were taken into account. First, the frame needed to be lightweight in order to obtain vertical takeoff and landing, and to sustain the plane's horizontal flight capabilities. Second, the frame needed to be designed strong to firmly support the quad-rotor components and to avoid major damage if motor failure was to occur. The attachment needed to be relatively low cost due to the other components that needed to be purchased under the $1500.00 budget. The team therefore allotted a $300 budget for the frame. With quad-rotor, a common issue is vibration from the motors affecting flight. To avoid any vibration issues, the frame must provide vibration damping across the frame, as well as between the plane and the frame. It was decided to keep the design of the frame as simple as possible, to avoid any unforeseen complications. Finally, the team believed it would be an interesting possibility to make the attachment removable and interchangeable. This would open a new possibility for use on other aircraft. Team 8 was able to come up with three preliminary designs, each having their own advantages and disadvantages:

i. Design 1:

The first design of the attachment, seen in Figure 2, consists of two beams running parallel to the plane. They are attached to the front and back wings of the plane and provide a platform on which to mount the quad-rotor motors. To attach the beams to the plane, a rod would be inserted into both the front and back wings, to provide support and an attachment point along the balsa wood trussed wings. Vertical rods of two different lengths would go from the rods inside the wings to the parallel beams. They would offset the beams enough for clearance of the propellers. Two motors will be placed on each beam, creating a square of equal width and length. The symmetrical shape is important to keep the aircraft as stable as possible during vertical flight. This design requires little modification to the integrity of the plane. Also it is lightweight, aerodynamic, and has few parts. However, it will be difficult to insert and secure the rods in both wings. In addition, the design is very strong and hard to keep from moving and vibrating. The beams are vulnerable because they are not solidly attached.

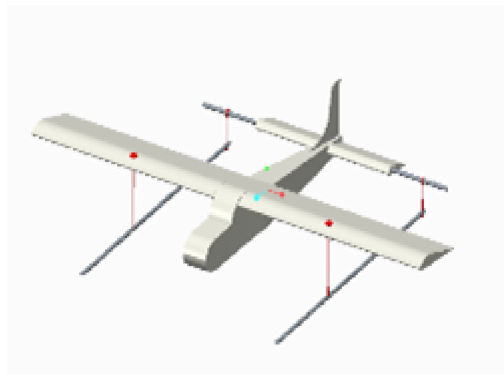

Figure 1: Design 1

ii. Design 2:

Design two of the quad-rotor attachment is significantly different than the first. In the second design, the frame is attached directly to the bottom of the plane. The shape of the frame is also modified into a pentagon, with two crossbeams for attachment and support, seen in Figure 3. The motors will again form a square, equidistant from left to right as well as front to back. The frame allows a large attachment area, while staying strong and lightweight. The frame also reduces the number of components.

The frame is thought to be as simple and structurally sound as possible, while keeping clearance for the propellers of both the quad-rotor and the front propeller of the plane.

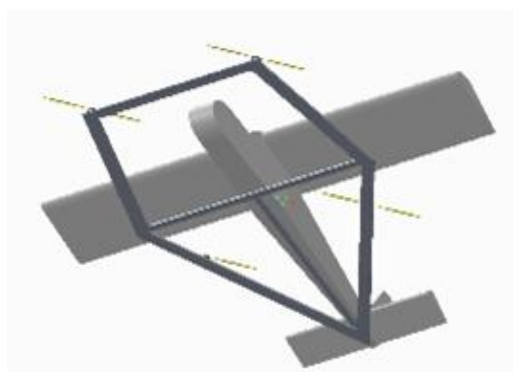

Figure 2: Design 2

These potential benefits are countered by its multiple disadvantages. The frame is relatively large, and therefore will be heavier than other options. Unfortunately the weight of the design can't be greatly reduced without suffering a loss in strength. Finally, the frame will needed to be hard mounted to the plane, using screws or similar attachments.

iii. *Design 3:*

The last design is somewhat of a compromise between all of the possibilities, seen in Figure 4. The frame is a modified "H" shape, with two cross beams supporting two beams parallel to the plane. The cross beams are attached to a lightweight base running across the width of the fuselage. The base is to be attached to the plane using high-strength Velcro. This is a simple solution that avoids major modification to the existing plane. The Velcro would also allow the attachment to be removable. Between the plane and the base, a sheet of rubber will be placed to reduce the transfer of vibration from the frame to the plane. The resulting frame would be lightweight, strong, removable, and vibration damping.

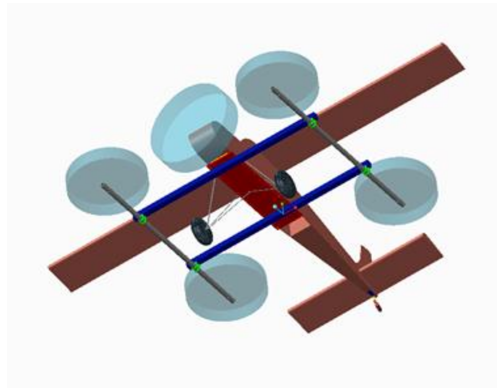

Figure 3: Design 3

The advantages of this design are directly related to the constraints of the frame attachment design. The design will not be as light as the first, but will still be lighter than the second design. Additionally, it is built to withstand the forces of the motors and the weight of the plane. The frame remains strong by selecting lightweight, but high strength materials. Vibration damping will be achieved using the rubber spacer. Finally, the attachment design's simplicity is another advantage. The design attaches to the plain via removable, high-strength Velcro. No modification to the original plane is necessary, making this an ideal design.

iv. *Selection*

When selecting the optimum design for the frame attachment, the original constraints of the design needed to be considered for each. Each design had its own advantages and disadvantages, and when compared, the decision was simple. The first design is too structurally weak, and would not provide a solid base for the motors of the quad-rotor. Also, the design would require modification to the original plane, a difficult task that Team 8 would like to avoid. The second design would be stronger, however it would be very heavy and also require modification to the fuselage of the plane. Again, this presents a major issue. The final design would not only be strong, but also would require no or minimal modification to the plane. Although it is not the lightest design, it is a strong design that would also allow for easy adjustment. Design three is the best option to create the best possible aircraft with VTOL capabilities.

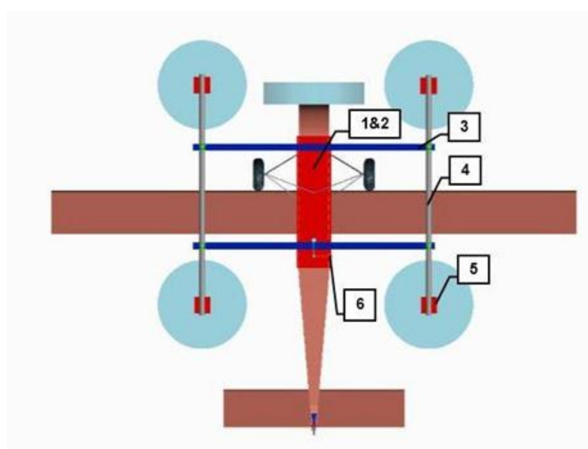

Figure 4: Design 3 Breakdown

After deciding on design three, Team 8 needed to finalize the design and select materials and components that complied with the design constraints. First, it was decided to make the base of the attachment and the mounts for the motors out of G-10 Garolite (#1 in Figure 5). The G-10 is extremely strong and tough, and Team 8 was able to get the material for free, saving on cost. To reduce damping, it was decided to use an adhesive backed polyurethane foam between the base and the plane (#2 in Figure 5). The blue beams (#3 in Figure 5), are made of 6061 Aluminum square tubing. The aluminum is lightweight, strong, and relatively inexpensive. To verify the strength of the aluminum tubing, a displacement analysis was used. By drawing the aluminum tubing in PTC Creo, and selecting Aluminum 6061 as the material, Team 8 was able to simulate the actual component. Next, the center of the beam was fixed in position, this is the section that will be secured to the base. After, a point force equal to that the motors will apply on the single beam (about 5kg or 49N calculated in section *B: Thrust Calculation/Motor Choice*) was applied 5 cm from either side, where the beams will connect. The aluminum beams only deflected 2.026 mm, as seen in Figure 6. High-strength rigid carbon fiber tubes are used as the parallel beams for the motors (#4 in Figure 5). These are extremely lightweight and strong, and avoid vibration. The frame will be attached to the plane using high-strength Velcro. The Velcro will provide a low cost way to attach the frame, while keeping the frame removable and distributing the load across the plane. The final design weighs a total of 2.67kg as seen below in Table 1. The total cost of the design is $277.40, as shown in the Budget section on Table 3. The result is a design that is lightweight, strong, cost effective, vibration damping, simple, and removable.

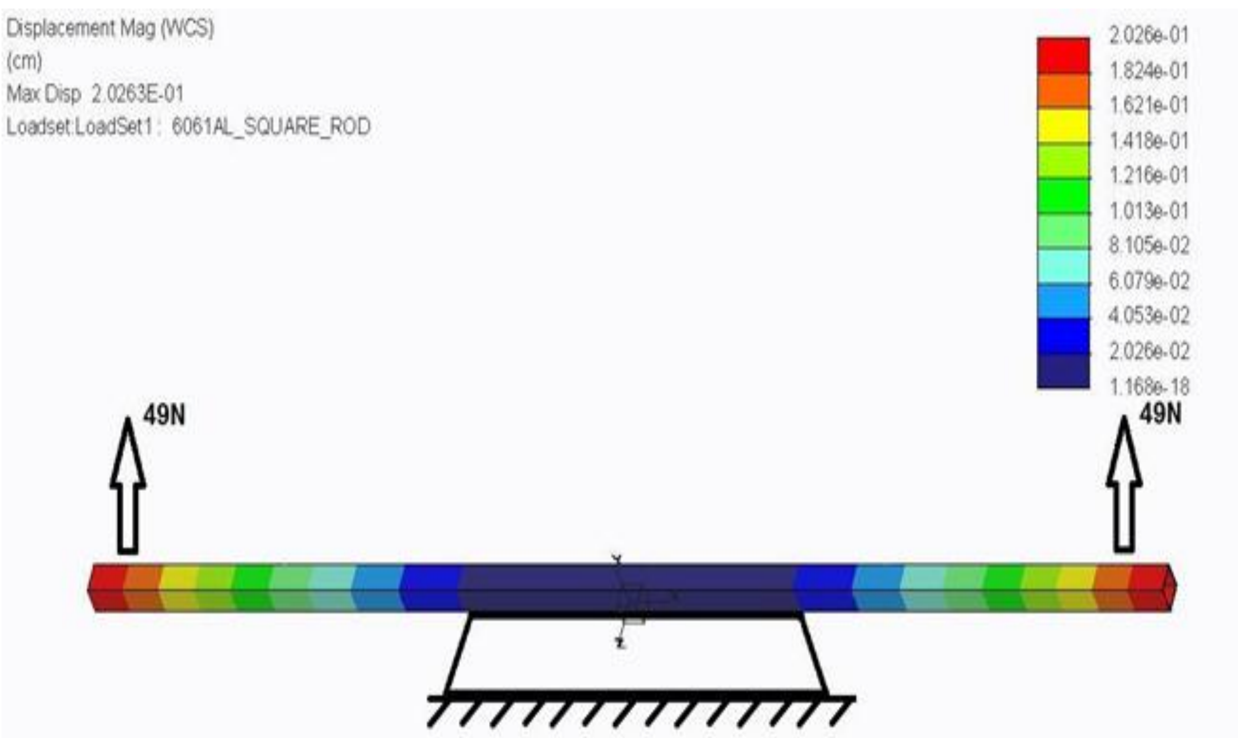

Figure 5: FEA Analysis

Table 1: Frame Material Breakdown

Component	Description	Dimensions	Volume	Density	Weight/ Part	Vendor	Qty.	Total Weight (lb)
G10	Base Excellent Tensile and Impact Strength	60x15.5x.4 cm 23x6.1x.1575"	22.097	0.063	1.392	n/a	1	1.392
Carbon Fiber Tubes	Parallel Arms for holding the motors Excellent Tensile Strength	0.5OD x 0.414ID x 48"	11.850	0.067	0.794	McMaster-Carr Part #:2153T41	2	1.588
6061 Al	Square Tubes Connecting Base to Motor Tubes	1 x 1 x 48" 0.0625" thick	11.250	0.1	1.125	McMaster-Carr Part #:6546K53 6ft.	2	2.250
Padding	Padding Between the Base and Plane, Protects Plane and Decreases Vibration	24 x 24 x .25"	35.075	0.012	0.406	McMaster-Carr Part #:86375K252	1	0.406
D.B. Orange	Epoxy for Attaching Motor Mounts to Carbon Fiber	n/a	n/a	n/a	0.000	theepoxysource.com	1	0.000
Velcro	Industrial Strength Double Sided Velcro to Attach the Frame to the Plane	n/a	n/a	n/a	0.250	n/a	1	0.250
Zip Ties	Zip ties to Secure the Carbon Fiber Tubes to the Center Bars	n/a	n/a	n/a	0.000	n/a	1	0.000
Hardware	Screws, Bolts, Etc.	n/a	n/a	n/a	0.000	n/a	1	0.000
						Total Weight (lb)		5.886
						Total Weight (kg)		2.670

B. Thrust Calculations/ Motor Choice

The calculation of thrust was of utmost importance to Team 8, as it could lead to rapid failure if miscalculated. There are many variations and variables that are present in these calculations. It is therefore that Team 8 has combined the use of both computer aided analysis with other basic calculations to ensure the best outcome. The first part in ensuring the most accurate calculations of the weight is to inventory all the necessary elements. After the inventory of existing items Team 8 created a list of all necessary items to create the new hybrid design. These included all the items listed in the base design as well as the components need for the quad copter: four motors, four ESCs, sufficient battery power and battery life and four propellers. With all the weights calculated it was determined that the weight of the hybrid design would be about 11.5 kg including all components. As a rule of thumb for thrust requirements for quad-rotors, it was determined that the standard thrust requirement for quad-rotor is[6]:

$$Required\ Thrust\ per\ motor = \frac{(Weight * 2)}{4} \qquad Eqn. 1$$

Using *Eqn.* 1, it was determined that the required thrust for each motor would be 5.65 kg. The team used this as a basis for originally determining which motor, propeller, ESC combination would be the best for this project. A comparative table was used to aid in the selection of the motor. This table shows the prices and weights of each motor. This method was chosen as all three motors had similar values for maximum thrust with a 16 inch prop and this would allow us to obtain the best motor for the best value.

Table 2: Motor Comparison

	Cobra	T-Motor	Tarrot
Motor Price	$299.96	$519.6	$239.6
Prop. price	$72.00	$135.00	$120.00
ESC price	$192.00	$180.00	$180.00
Motor Weight	844g	1012g	672g
Prop Weight	244g	100g	90g
ESC Weight	48g	240g	250g
Plane Weight	8238g	8238g	8238g
Misc. Weight	300.8g	300.8g	300.8g
Total Price	$563.96	$834.60	$539.60
Total Weight	9674.8g	9890.8g	9550.8g
Thrust*	3749g	3850g	3500g

*Max thrust with a 16 inch propeller with 5.5 pitch

Table 2 shows that the Cobra 4510 motor was the best option as it provided the best price/performance trade off. The team then turned to E-calc [4]and the Static Thrust Calculators[5] to provide the necessary data to make our decision. As stated earlier, the necessary thrust per motor value is 5.65kg. E-calc says that the thrust required to hover should be between 80 and 90 percent of the max thrust. This puts our required max thrust to be between 6.25[4] and 6.81[4].

E-calc and the Static thrust calculator were used to determine if our specific combination of motor, prop, battery and ESC would work. From the many values obtained with E-calc, the one that was most important was the throttle percentage, which was 84 percent, falling into the acceptable range.[4] The static thrust calculator was used with the specific propellers and yielded a value for max thrust which confirmed the values from E-calc. For comparison, the companies all supplied specifications for 16” propellers. However our model will use 18” propellers. The thrust calculator gave a value for max thrust as 6.62kg[5] with 18” X 5.5 pitch props running at the recommended 7000rpms.

With all the calculations done, the final selections were made. Starting in the top right corner of figure 7 and moving clockwise, the Cobra 4510 motor, the APC 18” X 5.5 props, the Venom Flight pack batteries, and the Cobra 60 amp multirotor ESC’s are shown.

Figure 6: Motor, Props, ESC, and Battery Selections

C. Electrical components

i. Autopilot Selection

Team 8 has elected to utilize the Ardupilot Mega 2.5 set from last year’s plane. Team 8 chose this system because it is already in Team 8 possession and the Ardupilot system has a multitude of programing options for performing different autonomous tasks. The Ardupilot module consist of a 3-axis gyroscope, 3-axis accelerometer, 3-axis magnetometer, and a 3-axis barometer. In addition, the Ardupilot supports 3DR radio telemetry and Mediatek MT3329 GPS unit. A picture of the Ardupilot system is shown in figure 8 with the system specification shown below as well.[7]

Figure 7: Ardupilot System

Ardupilot Mega 2.5 system features include: offers user the opportunity to choose between different programing options, arduino programming toolkit for adding and modifying programming options, autonomous takeoff and landing for multi rotor vehicle, failsafe functions for different circumstances, autonomous GPS waypoint navigation, and record and relay telemetric data back to ground system.

ii. Electronic Speed Controllers (ESC's)

The Cobra 60A Opto Multi Rotor ESCs were chosen to control the quad-rotor motors for this design. These ESCs are compatible with the Cobra multi-rotor motors and they have a higher current rating than the motor. Their current rating prevent them from overheating when the motor is operating at high currents. Furthermore, the ESCs utilize opto-isolators to transmit electrical signals between two circuits via light. As a result, high voltages will not interfere with the receiver signals. The ESC can be seen in Figure 8. Cobra ESC system features include: Automatic throttle range identification for smooth throttling, 500HZ refresh rate for connection with flight controller, prevents motor from running if the propeller cannot rotate, automatic power off option if ESC is operating above 230F, and prevents aircraft from flying away by switching to idle if the throttle signal is lost.[8]

Figure 8: Cobra 60A Opto Multi Rotor ESC

III. Risk and Reliability Assessment

When dealing with a project that involves installment of components, there will be a risk factors involved. For this design of a VTOL Aerial Vehicle, there are risk factors that can affect the performance of the overall end product. With different electrical components that make up the design, this also increases the chance of a component failure or a component not working to the potential that it was calculated for. The effect of a component failure could lead to flight problems as the different components such as the ESC's (Electronic Speed Controller), motors, autopilot system, and wirings are just some of the components that goes into producing flight of the Aerial Vehicle.

The lift of the aerial vehicle depends on thrust calculations that was completed so that the four motors can sufficiently provide the needed thrust based on the overall weight. If those calculation are inaccurate, this will cause the motors selected to be insufficient to providing the appropriate amount of lift. To counter act this problem, Team 8 has triple checked the thrust calculations with the manufacturer specs, E-calc, and a Static Thrust Calculator.

Overheating of certain electrical components based on inaccurate calculations or continuous usage is something that has to be accounted for as a risk factor possibility with dealing with components such as motors. Once again, Team 8 prepared for this by overcompensating on power usage and selecting larger capacity ESC so overheating will not be a problem. To go along with this, all the high current components will be mounted on the exterior of the plane to allow easy heat transfer between the components and the atmosphere.

On to the mechanical framework design, there will be risk factors as well. Vertical flight components are being added to a previous year's plane design that only was designed for forward takeoff and flight. The addition of the vertical design components can cause stabilization issues, which is why vertical test flight is important with the new components installed to correct any problems.

Once the vertical test flight is complete and working successfully, another risk is the transitioning of vertical flight to forward flight. This will be the biggest obstacle of the project, as the vehicle will transition between the two flight modes in mid-air based on slowing down and turning off the vertical motors while the forward front motor is on and working.

With an aerial vehicle there is a risk in just the flying aspect of the design. Crashing the design could cause mechanical and or electrical failures. The crashing of the aircraft could be caused by things such as loss communication between transmitter and receiver, component failure, battery failure, unsuitable weather conditions, or even an accidental error by the person manning the controls. Even though we chose parts that are cost efficient and can easily be replaced, a severe enough crash could cause serious problems to the aircraft and jeopardize the success of the overall project. These were taking into account for when selecting autopilot system and ESC. Both of these components have fail safe modes that significantly reduce the risk of a catastrophic crash.

IV. Procurement

With the finalization of calculations, the next part step in the project is the ordering of framework and electrical components for the aircraft. The necessary parts, costs of those parts, and number of that specific part that is needed has been mentioned previously in the report. The ordering of the parts that will be used to build the VTOL aerial vehicle will be completed as soon as the spring semester commences. The parts will be ordered through the Aero-Propulsion, Mechatronic, and Energy (AME) building procedures which consist of filling out a purchase requisition form and submitting it for approval. Once approved, all the parts will be ordered and shipped to the AME building and can be picked up by any member of the team. These parts are listed in Table 1 and Table 2.

V. Communication

Effective communications during this project was essential for making progress. It was important to reach out to experts on the feasibility of the project concept. Various professors were contacted and were held meetings with in order to gain knowledge on the limitations and feasibility of our design. With our sponsor, Dr. Shih, it was also important to maintain an active relationship so that he could tell us his concerns and recommendations and we as a team could address them. Since our team includes students from the electrical engineering department it was important to keep in contact with our advisor, Dr. Frank, on the electrical side. We made sure to keep him updated and invite him to relevant meetings and presentations.

One of the biggest aspects of our project was the communication with the international team members. As a part of the FIPSE program, we had multiple students in Brazil and it was necessary to maintain open communication with them. Some of the problems with this were the different time zones, different schedules, poor internet connection, and technological limitations. To overcome these issues, various mediums were used to communicate with the team members abroad. These included, text messaging, Facebook, email, FaceTime, Skype, Dropbox, and Google Docs. By using these tools we were able to verbally communicate with them as well as transfer files and documents that were necessary in progressing with our project. Doing so has given us the opportunity to experience international collaboration in preparation for a career in a global society.

VI. Environmental and Safety Issues and Ethics

When designing the autonomous vehicle there are various safety and ethical factors that must be considered. Since the aircraft is large and will be in flight it is important to ensure that it does not become a dangerous falling object. Careful attention must be made preflight to ensure that all parts and components of the plane are secure. Control segments and propulsion systems must be checked on the ground to ensure that they work properly. By doing so the risk of a mechanical malfunction in the air will be reduced. The five blades of the vehicle pose a hazard as well. Care must be taken with the vehicle so that any spinning blades do not strike a person or any objects.

The coding that will control the test must be tested in low risk conditions in order for any potentially dangerous bugs in the code to be fixed. Errors in the code could lead to an out of control plane and must be checked and tested adequately in order to prevent any mishaps. A kill switch must be implemented into the system so that in the event of a malfunction the aircraft can be powered down before it crashes in order to minimize damage. Further precautions such as not flying the vehicle directly over people should be taken so that in case of a catastrophic failure, no one gets hurt.

Another consideration is that an experienced remote controlled aircraft pilot should supervise or control the operation of the aircraft. Having an experienced pilot allows for potential disasters to be averted and, if in the case of an autonomous mode malfunction, allows for human control recovery of the aircraft and a safe landing. Team 8 has been in constant contact with an experience pilot who has agreed to run our test flights for us to ensure safe flight of the vehicle.

Some of the ethical considerations include following competition rules and operating on proper radio frequencies. It is important to follow the regulations of the competition so that safety and compliance is maintained. This will allow ethical competition and fairness in the competition. It is important that the radio frequency requirements are followed so that there is no interference with military, emergency, or civilian transmissions. This will also ensure that the transmissions do not affect other teams competing. Maintaining proper ethical standards ensure good sportsmanship and a safe competition.

VII. *Project Management*

i. Budget

Team 8 was given a budget of $1500 to complete the project assigned to them. The budget is supplied from the Aero-Propulsion, Mechatronic, and Energy building funds at Florida State University. With this budget at a set value, Team 8 had to determine which different components of the design were feasible and which ones were not.

ii. Budget Breakdown

The most expensive parts for Team 8 were the four Cobra 4510 DC motors. Individually, the motors cost $74.99 and the cost of all four is $299.96. Finding these motors was a complicated matter as many other options were presented but none of them were priced as reasonably as the cobra motors. Team

8 decided it was better to be budget conscious here, while still providing the required thrust, and the price of the cobra motors was a main reason why they were selected.

The second most expensive component was the material used to build the frame. The frame is composed of numerous different materials and Table 3 shows a breakdown of the different materials and the associated cost.

Table 3: Frame Cost Breakdown

Frame Design: Cost Analysis						
Component	**Dimensions**	**Weight (lb)**	**Price**	**Qty.**	**Subtotal**	**Extras**
G10-Base	23x6.1x.1575"	1.392	n/a	1	$0.00	
G10-Mount	2.36 x 2.36 x .1575"	0.055	n/a	4	$0.00	
Carbon Fiber Tubes	0.5ODx0.414 ID x 43.3"	0.716	$35.87	2	$71.74	$35.87
AL6061-Cross Beams	1 x 1 x 43.3" 0.0625" thick	0	$23.38	2	$46.76	$23.38
Foam Spacer	24 x 24 x .25"	0.25	$34.03	1	$34.03	
D.B. Orange-Epoxy	N/A	0	$16.00	1	$16.00	
Velcro	N/A	0	$20.00	1	$20.00	
Zip Ties	N/A	0.000	$10.00	1	$10.00	
Hardware	N/A	0.000	$20.00	1	$20.00	
				Subtotal	$218.53	$58.87
			Total		N/A	**$277.40**

The total cost of all the frame parts is $277.40. The combination of all the parts that compose the frame come in as the second most expensive part for Team 8.

The next two parts are the least expensive parts Team 8 plans on buying. These two parts are six APC Props that cost $12/prop and four electronic speed controllers (ESC's) that are $48/controller. This brings the total for the props and ESC's to be $72 and $192, respectively.

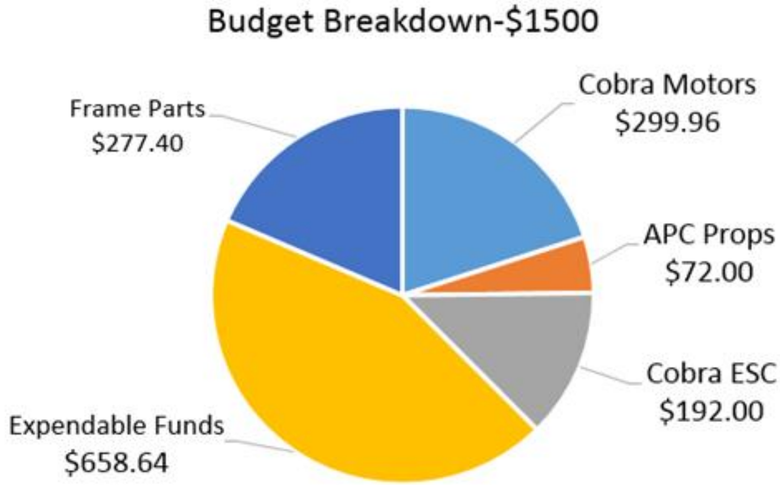

Figure 9: Budget Breakdown

With the cost of each part now defined, a total breakdown of Team 8 budget is shown in the pie chart shown in Figure 10. Referring to the pie chart, it can be seen that Team 8 has efficiently spent their available budget for the project. With left over funds being $658.64, it allows Team 8 to have financial flexibility to purchase any extra or new parts in the future if anything comes up.

VIII. Schedule/Gantt Chart

The plan for Team 8 is to complete this vertical takeoff and landing aspect of the hybrid plane by the May 2015. With this being the case, there is still the transitional flight aspect that still needs to be completed for the hybrid vehicle to be fully operational. With this being said, this project will be complete over a two year time frame and this is represented in the Gantt charts shown in appendix A.

IX. Conclusion

In summary, Team 8 has decided that the optimal design for the AUVSI competition will be a hybrid design of a quad-rotor vehicle and fixed wing vehicle. This will use the aluminum and carbon fiber frame along with the Cobra 4510 motors, the Cobra 60 ESCs, and the Venom flight packs. The team got together and came up with three design that could be used to build this design. After weighing all the advantages and disadvantages of each design, Team 8 came to the conclusion that design 3 would be the best fit for the time frame and budget established.

With the final design determined, the materials needed to complete this design were selected. For the frame, and extensive report of material size, cost, and quantity were laid out earlier in this report and have been agreed upon by the team. Also selected were the motors, props, ESC's, and batteries needed for the design. Once again the performance of all these were laid out and were selected on by the team using different criteria to rate each one.

With all the parts necessary to complete this design selected, Team 8 has moved into a part acquisition stage of the project. At this moment, purchase orders will be placed for all the necessary parts to have them order before the semester ends. With that in place, Team 8 will be in prime position to begin building the design when school resume in January 2015.

X. References

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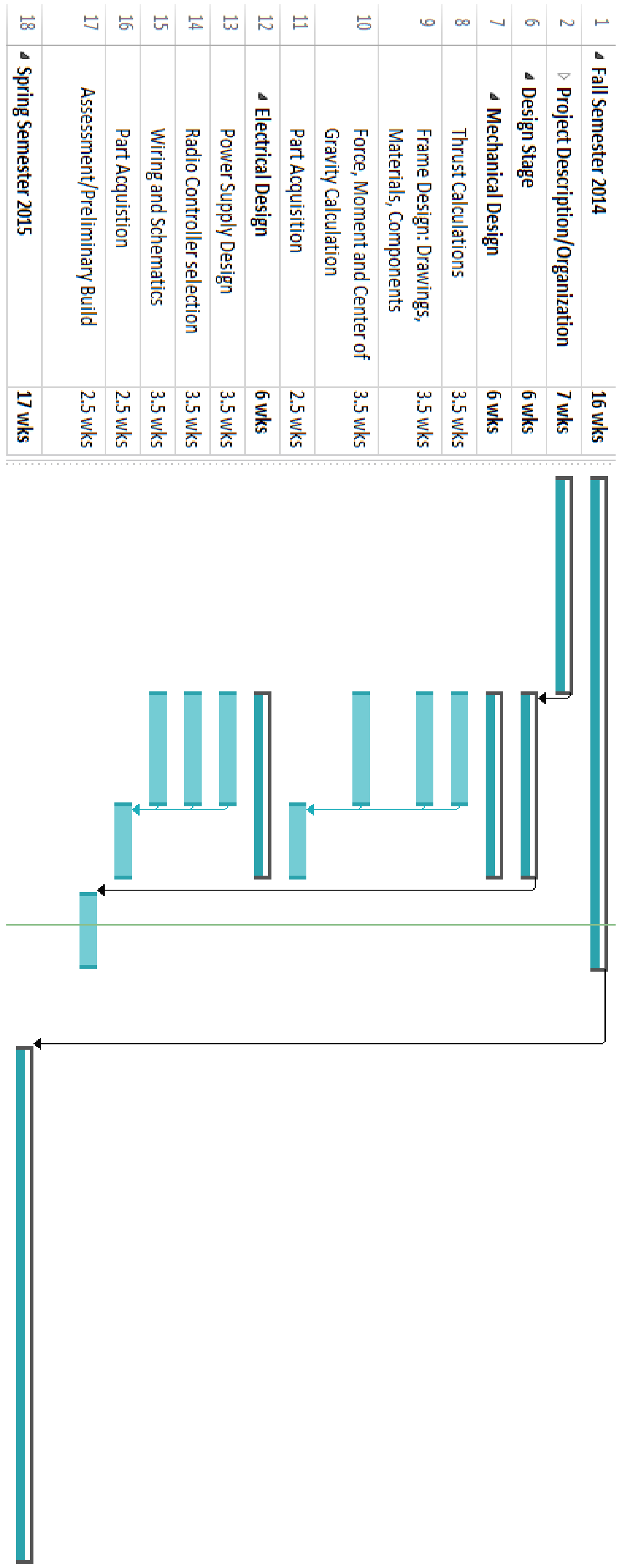
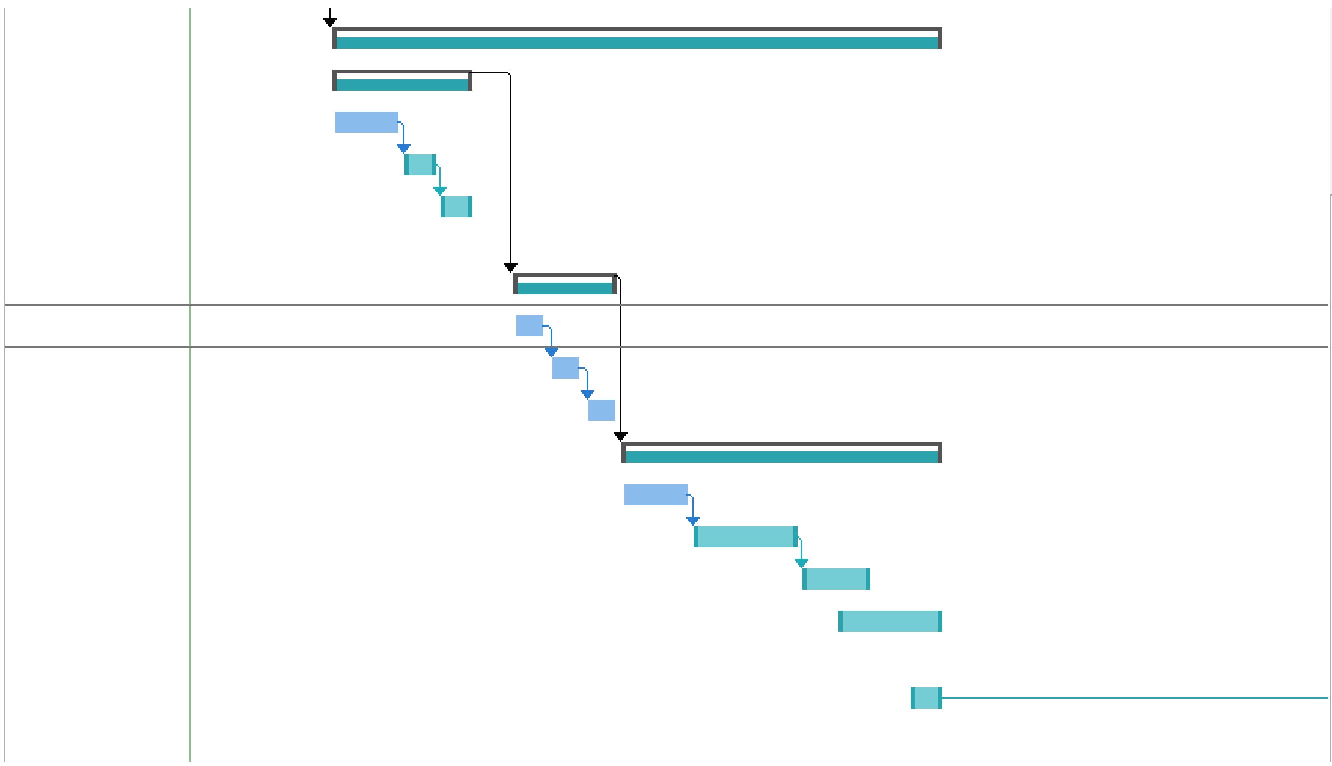
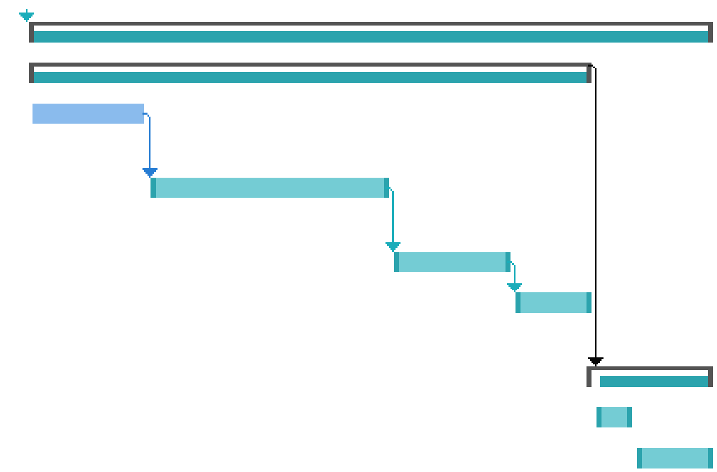
I. Appendix A


1 Fall Semester 2014 16 wks
2 Project Description/Organization 7 wks
6 Design Stage 6 wks
7 Mechanical Design 6 wks
8 Thrust Calculations 3.5 wks
9 Frame Design: Drawings, Materials, Components 3.5 wks
10 Force, Moment and Center of Gravity Calculation 3.5 wks
11 Part Acquisition 2.5 wks
12 Electrical Design 6 wks
13 Power Supply Design 3.5 wks
14 Radio Controller selection 3.5 wks
15 Wiring and Schematics 3.5 wks
16 Part Acquistion 2.5 wks
17 Assessment/Preliminary Build 2.5 wks
18 Spring Semester 2015 17 wks

18	**Spring Semester 2015**	**17 wks**
19	**Build Design**	**4 wks**
20	Complete design build	2 wks
21	Drawings of assembled design	1 wk
22	Troubleshoot and order supplementary parts	1 wk
23	**Forward Flight Test**	**3 wks**
24	Test forward flight	1 wk
25	Troubleshoot	1 wk
26	Supplemental test if necessary	1 wk
27	**VTOL Test**	**9 wks**
28	Mount Motor/Rotors to Frame	2 wks
29	Test VTOL/Stability	3 wks
30	Touble Shoot	2 wks
31	Supplemental Test for VTOL/Stability	3 wks
32	Assessment and Future Plans	1 wk
33	**Fall Semester 2015**	**17 wks**



3	**Fall Semester 2015**	**17 wks**
4	**Transitional Flight**	**14 wks**
5	Research Transitional Flight Options	3 wks
5	Implement the best option for transitional flight	6 wks
7	Test Transitional Flight	3 wks
3	Troubleshoot and supplemental test	2 wks
9	**Competition Secondary Task**	**3 wks**
0	Research and select secondary task	1 wk
1	Designs for secondary Task	2 wks



42	**Spring Semester 2016**	**17 wks**
43	**Autopilot**	**8 wks**
44	Optimize autopilot code	5 wks
45	Test Autonomous Flight	2 wks
46	Troubleshoot Autonomous Flight	1 wk
47	**Secondary Task**	**7 wks**
48	Build/Code Secondary Objectives	3 wks
49	Test Secondary objectives	2 wks
50	Troubleshoot/optimize design	2 wks