Helium Micro Air Vehicle (MAV)

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Team 07

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1 Introduction

1.1 Introduction

Dr. Srinivas Kosaraju requested to design a Helium Micro Air Vehicle (MAV). The Helium MAV is a device that will attempt fly over fires and contaminated areas to take images. There are constraints that will be considered in the Helium MAV project. Such as; the budget should not be more $2000. Also the remote control guidance system is one of the constraints and last, we must reach an altitude of 30.5 m. The objectives of this project are to limit the weight or the payload capacity that the blimp could carry, optimizing the response time for the blimp, enclosure testing and minimizing the cost. The Helium MAV will be tested for multiple runs as well as the enclosure testing. This project will use “clean” energy which is not affect the environment that can help to reduce the Carbon Dioxide in the atmosphere. In addition, Helium MAV should be more durable than any commercial product in the market.

2 Objectives

This set of objectives have been deemed necessary for the Helium Micro Air Vehicle to succeed and function properly. The table below lists the objectives and the units that they will be measured in.

1. Weight/payload - This is important in carrying equipment and since it takes a lot of helium to lift a small amount of weight our team needs to reduce weight and increase the payload capacity, this will be measured in kg.

2. Optimize Response Time - The MAV needs to have optimal response time during flight. This means the helium MAV must be able reach a certain altitude in a reasonable amount of time to begin observations of fires and contaminated areas, this will be measured in sec.

3. Minimize Cost - The budget is important since there is only a limited amount of money, so minimizing the cost is essential.

4. Twice the distance and able to stay in the air longer - This product must be competitive to other commercial products such as quadcopters, the goal is to be able to go at least twice as far and last twice as longer in the air. The distance traveled will be in m.

5. Durable - Durability is important since in the atmosphere the MAV will be exposed to different temperatures, moisture, and winds so the product must be able to last.

6. Ease of storage - A person must be able to lift the MAV up and be able to store it in a compact area so volume matters, and will be measured.

Table 1: Measurement and requirements units

Objective	Measurement	Units
Limit Weight/Payload	Mass	kg
Optimize Response Time	Time	seconds
Minimize Cost	Currency	$
Double distance of standard quadcopters	Length	m
Durable	Time	seconds
Easy to Store	Volume	m^3

3 Designs

3.1 Quadrino

The quadrino nano is a flight controller with incorporated sensors. The quadrino contains a magnetometer, pressure, GPS, accelerometer, ATMega 2560 processor and a gyroscope. The gyroscope shows the orientation of the quadrino, which will be used to see the orientation of the blimp. The accelerometer show how fast the MAV is traveling. Magnetometer show the direction, the pressure sensor is configured to show altitude, and the ATMega is the processor and is programmable. The GPS only works under an open sky so inside any enclosure will interfere with the signal. The GPS must be mounted on the outside of the enclosure to be able to work effectively.

The quadrino came with its own firmware that is compatible with the program multiwii, which is a program used to control multirotor aircrafts. The firmware is used to calibrate the quadrino to function with the brushless motors and servos and also allow adjustments to the sensors. The quadrino has 2 serial ports and 3 i2c ports along with a motor, radio and many more ports that are displayed in Figure (1). The reason for choosing the quadrino nano is it has integrated sensors along with a compact light weight enclosure.

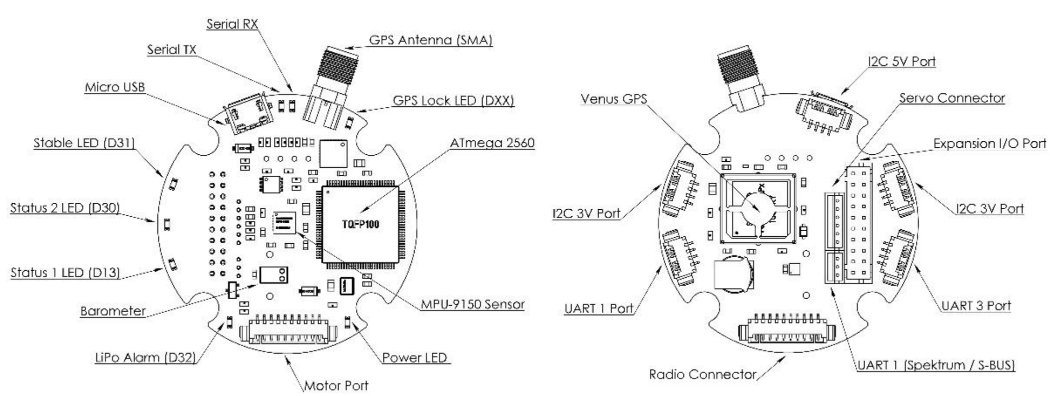


Figure 1: Quadrino

3.2 Camera Setup

The camera used is a lynx compatible ELP 2.1mm lens USB camera. Do to complex coding the camera could not be integrated with the quadrino to transmit images back. The setup is made of 1 USB camera, 1 raspberry pi 2, 1 mini SD card and 1 mini 64 gb USB. The raspberry pi has 4

USB ports, 2 of these ports are used for the USB and camera. The raspberry pi also has a built in micro USB port along with a mini SD card port. The reason our team went with this microcontroller is the coding is more user friendly and has more than enough power to operate the camera. There will also be a 5 volt portable battery connected to the raspberry pi's micro USB port to provide power to the system.

To first set up the raspberry pi the SD card must have Raspian downloaded on it. Raspian is a free program and will allow you to get the necessary video and image files for the camera to work. The directory fswebcam will have to be uploaded as well, which can be done directly from the raspberry pi. This is also a requirement for the USB camera to work. Then a file will be created using the configuration function to store the images. In the code you must reference the USB and tell the raspberry pi to dump the image within a file created in the USB drive.

To get the raspberry to automatically take photos, a code was created to take a certain amount of pictures every second until it reaches the required limit. Every picture the camera takes automatically sends the image to the USB drive. The USB drive then can be taken out and connected to a computer to download the images you want. Every time the raspberry pi runs it automatically overwrites the previous photos, this is done to save space. The USB is 64 gb which can store up to 36620 JPEG photos for a 5 Megapixel Camera and 3662 photos for raw uncompressed photos. When plugged in to a power supply the raspberry pi automatically runs the code, this is where the delay function is useful. The delay functions specifies when to start taking images. For example if you write delaySeconds(120) it will wait 120 seconds before beginning to take photos. The range function is used to specify how man images the camera will take. What I noticed from using the USB camera is the camera needs to be primed. To prime the camera the skip function is used to not store the first few frames, this will warm up the camera and allow the images to come out clearer. Time stamps and other functions can also be incorporated into the photos.The camera will be mounted onto the enclosure where the viewing is possible while the raspberry pi is setup inside to be protected by moister and the air that can damage the raspberry pi.

Figure 2: Camera Setup

3.3 Radio Transmitter

3DR 915 MHz radio transmitters are used for inflight communication and allow telemetry data to be sent back in real time. One transmitter connects directly to the quadrino's serial port and the other connects to a computer acting as the ground station. The transmitter can send data back up to 500 m this can be enhanced by changing the antenna. The antenna needs to be on the outside of the enclosure so that the signal isn't disrupted. This moment the radio transmitters are set up and can send gps, altitude, acceleration, receiver and magnetometer data back.

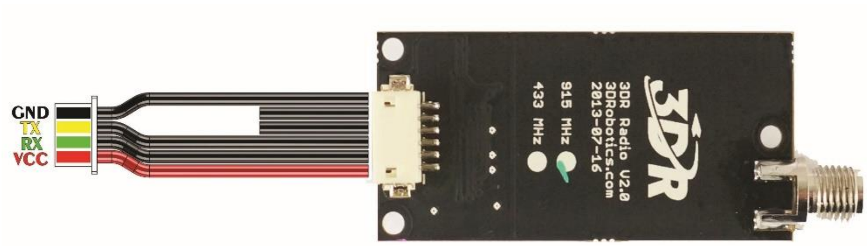


Figure 3: 3DR Radio Transmitter Wiring Setup

3.4 Receiver/ Controller

Currently using a Fly-sky 6 channel receiver that communicates with a CT6B controller. To communicate with the controller a binding process had to be done. To bind the receiver to the controller you had to attach the bind plug to one of the channels then power the receiver and then turn on the controller. To save the binding process you first take out the binging plug from the receiver, unplug the power source then turn off the controller if this is not done the binding processes won't be saved. To see if the process was saved power the receiver and turn on the controller the LED will light up when the controller is turned on.

The receiver will be connected to the radio port on the quadrino this will power the receiver and will be able to see what channels are functioning in the WinGui program. To test the function of the channels you pull up the WinGui program and turn on the controller. Move the controller sticks this should show a change in corresponding channel you are moving.

Figure 4: Receiver Controller

3.5 Electronic Speed Controller (ESC)

Electronic speed controllers are used to control the motors speed. A 40 amp ESC is recommended for the LD mk-4114 brushless motor. To connect the motors to the ESC bullet connects must be soldered on. The motor has a 3.5 mm male connector bullet so a 3.5 mm female connector bullet is needed to connect properly. The opposite end of the esc will be the connections to the battery. The Turnigy battery has 5 mm bullet at the discharge inlet so a 5mm bullet is needed to connect to the battery. There is a servo plug that connects to the receiver or quadrino to allow control over the motor.

3.6 Possible Electronic Setup

For prototyping to test out the motors a bread board, PCB board, bullet connectors, and wiring were used. This can be seen in Figure(6), this was used to test the different channels on the receiver as well as seeing how far the servo would turn. As of right now it can turn 90 degrees. Calibration of the controller may be needed to increase the functionality.

One possible electronic setup will be to use a PCB board to be the central power supply First will have to solder a 6-7.2 volt battery directly to the PCB board giving it a ground and positive output. Then attach the wires from the servos to the PCB board giving them power. The ground from the quadrino will also be soldered to the PCB board. All the signal wire on the motors will be attached to their specific channels on the receiver, the receiver will be powered by the quadrino itself. For the brushless motors the signal wires will also be attached to the receiver but the brushless motors have a bigger battery this is attached to the motors separately through the esc. The ground will still be attached to PCB board. BEC's will be soldered to the PCB board then attaches to the esc to power the 5 volt plug of the esc. In Figure(5) is a rough estimate of what the servo setup will look like.

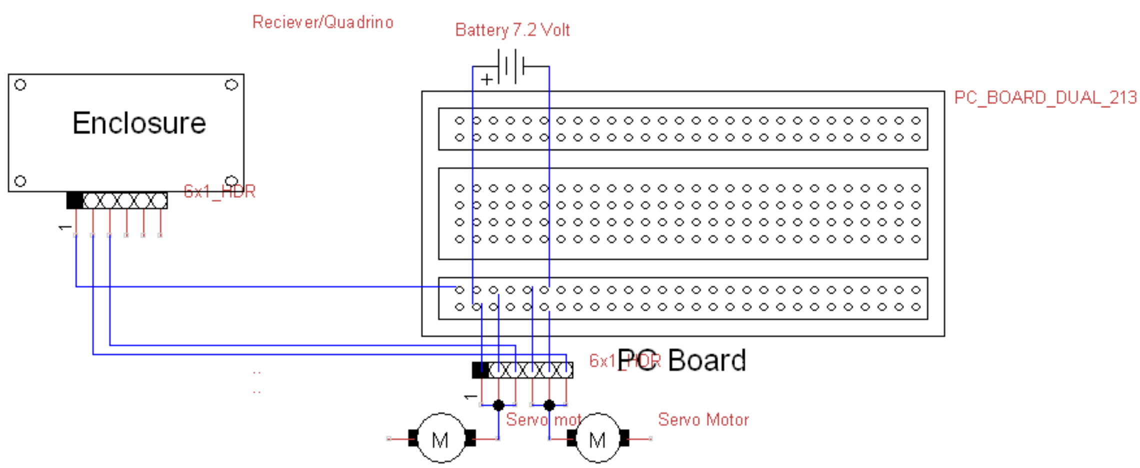


Figure 5: Possible Servo Setup

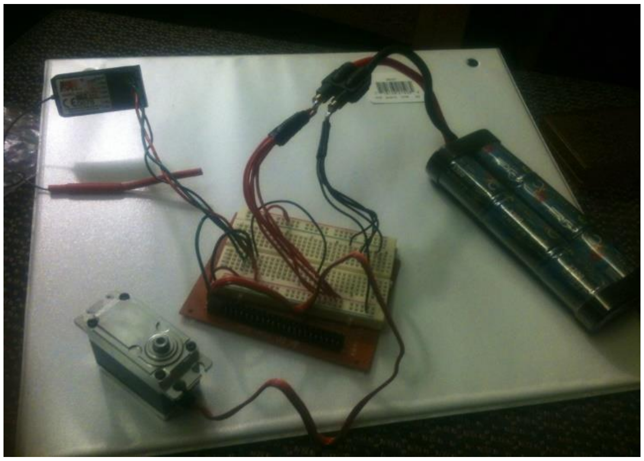


Figure 6: Testing Prototype

4 Enclosure Design

Initial stages referred to the need of the enclosure's ability to house all components, as well as provide support for the propulsion system.

1) The original design had overstated the area in which would be required for the components and elements of the system specified to client needs of operation. Based on the research we had done of these elements, we composed a list of products that would enable the H-MAV to function as required. For example, the GPS was researched as a stand-alone system and not part of the later realization that we could use one singular product, namely the Quadrino, to act as the GPS, magnetometer, accelerometer, gyroscope and control for the motor signals at once. Not only could the system weigh less, this consolidation was a huge step forward in conserving the area in which was required for the enclosure.

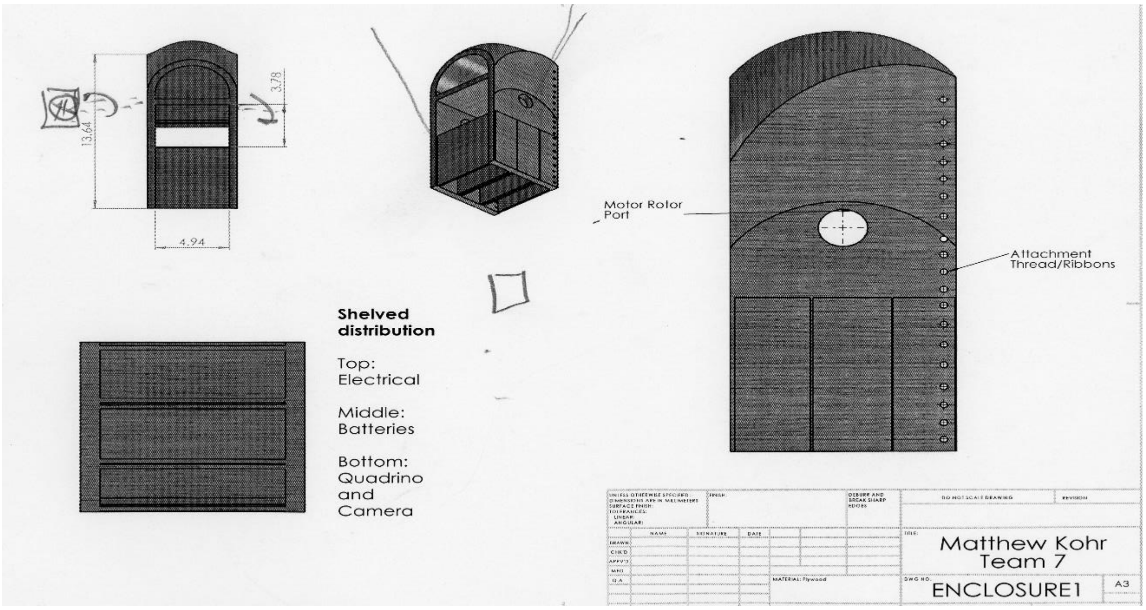


Figure 7: Enclosure one

The propulsion system idea for the original design specified the motor assembly on either side of the enclosure. However, the blades of the propeller were not accounted for in this design and presented a huge problem with the distance between the blimp itself and the action space of the props. We understood after we chose the motor and propeller assembly that this method would not be suitable.

2) The second enclosure was the prototype in which was manufactured using a fishing box for the partition of the elements and a PVC pipe assembly connecting the motors below the enclosure. However, accurate the design may have been, the materials we used were insufficient for providing a stable base for the motors and shafts.

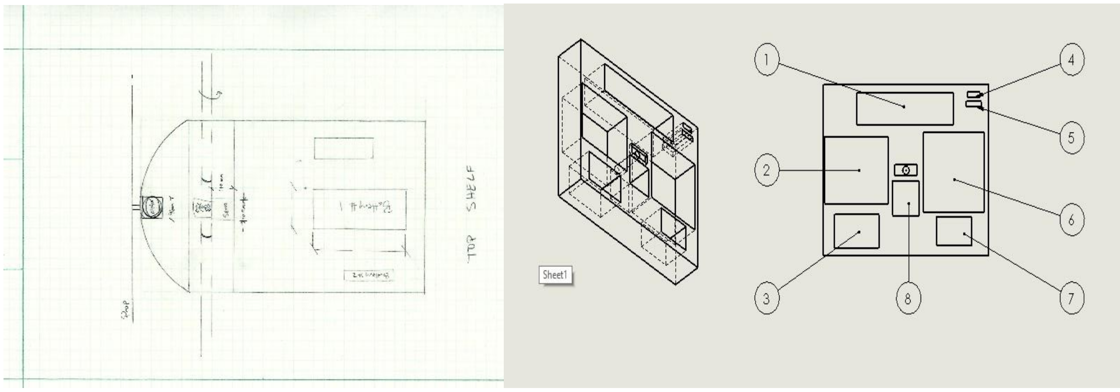


Figure 8: Enclosure prototype

3) The third enclosure design is the current method to house all components, operate the motor assembly, and ensure a factor of safety that is substantial and reliable. We have streamlined the enclosure to be long and slender and aerodynamic all the way around to minimize drag forces. We house all components on one level and organized in the attempt to specify our center of gravity. This optimizes our gyroscope readings and makes flight control more predictable.

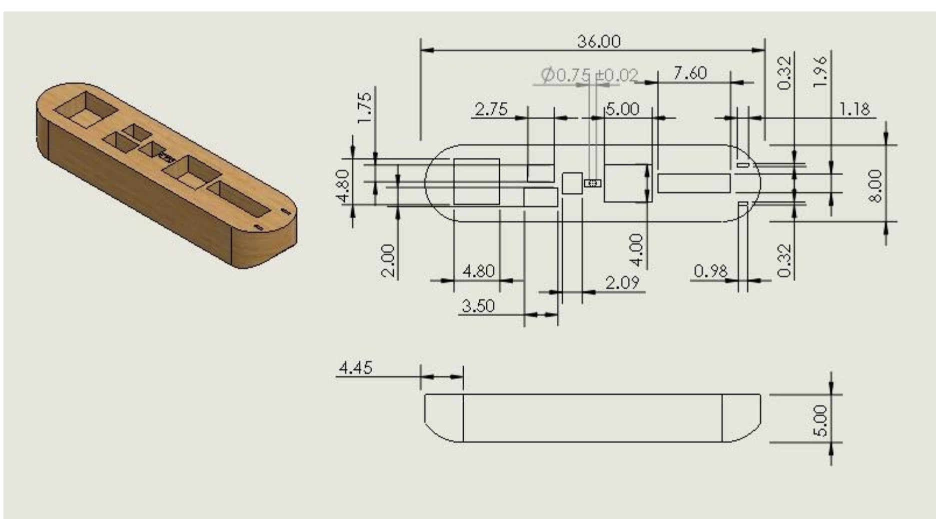


Figure 9: Final enclosure with measurements.

4.1 Shaft Design

Once the final enclosure is designed a hole will be drilled in the middle to allow a shaft system to connect to it. The shaft system will be designed to hold the motors, servos, and the propellers. The design is a T-shape hollowed pipe and will be connected to the bottom of the enclosure. The 2 sides will contain small cylindrical enclosures that will hold the servos in place. Smaller cubed enclosures will be attached to the servos which will contain the motors holding the propellers. The servos shafts can move freely which will rotate the cubed enclosures 90-180 degrees. The rotation of the motors and propellers will allow the blimp to go forward and descend. The motors will be strapped in place by attaching Velcro and safety straps to cubed enclosures. When the enclosures rotate the propellers will not touch the shafts because the pipes are longer than the propellers. The material for the T-shape shaft system will be made of carbon fiber or PVC because they are both lightweight which is crucial to keeping the weight under the project limit. The figure below, shows the T-shape system with small cylindrical enclosures where the servos will be placed and the connection to the bottom of the enclosure, which contains the electronics.

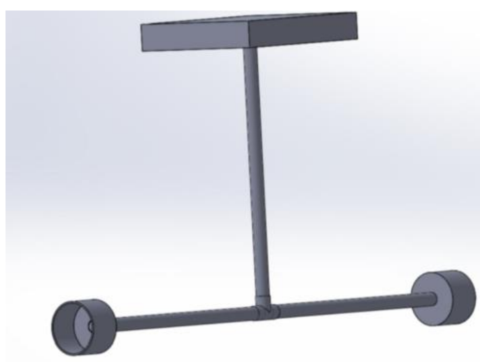


Figure 10: Preliminary Shaft Design.

4.2 Steering

As a result of the propellers only allowing the blimp to ascend, descend, and move forward a steering mechanism was designed in order for the team to steer the blimp left or right in case individual motor control is not possible. Understanding that our two motors now will only function as axial propulsion leads us to the problem of steering during flight. Ultimately, we needed to create a method to control our direction in 3 dimensions.

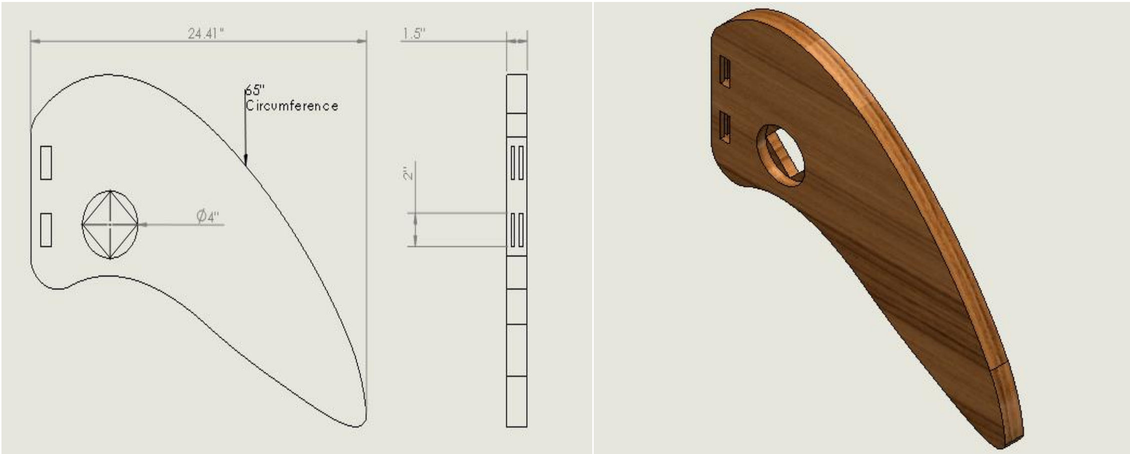


Figure 11: Directional Fin.

In order to solve this problem and keep current designs, we created a fin. Using biological inspiration from the dorsal fins of water animals, we have designed a tailing fin for rear of the blimp to streamline flight. This assembly is composed of a dorsal type shape with a hole at the center of inertia, which will contain a small motor and propeller that will control the lateral direction of the rear and thus control the direction of forward movement.

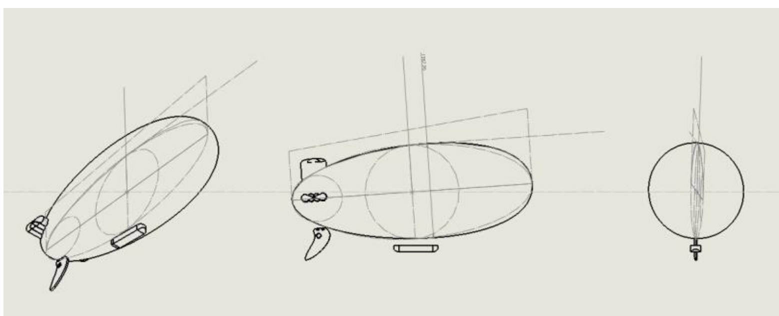


Figure 12: Total Dimensions of Blimp.

4.3 Attachment Methods

Our design will attach the blimp by means of ribbons. The ribbons will circumvent the blimp and run through guides in the enclosure and fin. This allows us to eliminate the strain and tear of the blimp from directly "gluing" Velcro to small areas of material in which have already posed problems and required patching.

We can use a couple methods, such as plug and bore, ratchet strap-hook and cleat and cam loops that will allow us to tighten the enclosure to the blimp once filled.

1) Plug and Bore

Using the plug and bore method, we can attach the ribbons to plugs at the end of one side. The will fit into a bore and fit snugly to the enclosure. This method would require us to either manufacture the enclosure with a 3D printer and have these bores already made or create them ourselves.

Figure 13: Plug and Bore

Source: gympart.com/

2) Ratchet straps and hooks

Cargo shipment methods that involve securing equipment in vehicles have used this method countless times. The enclosure would have holed slits in the perimeter of the enclosure and hook into the inner compartment. We would use ratchet straps to tighten the enclosure to the blimp once filled.

Figure 14: Ratchet Straps.

Source:.aliexpress.com

3) Cleat and Cam loop

The boating industry uses this method to tie ships to docks. We would again have slits cut into the perimeter of the enclosure, wrap the ribbon around the enclosure through the slits and secure the end to a cleat. This method would require securing the cleat on the inner part of the enclosure with four washers, nuts and bolts for each cleat. This is an advantageous method because we would not have to use knots that would come undone and utilize CAM loops.

Figure 15: Cleat and Cam.

Source:strapworks.com/

4.4 Propellers

The propeller selection is based upon the functionality needed; a low diameter, high pitch propeller is used for a speed system and a high diameter, low pitch propeller is for high thrust system. The blimp for this project requires a high amount of thrust to counter the lift force of the helium gas, therefore, high diameter, low pitch propellers are needed. As a result, the Dynam Carbon Fiber Propellers have been selected to perform the desired task because they can exert the required thrust.

4.5 Motors and Battries

The motors has been selected to have high thrust to be able to counter act the drag force and the buoyancy force. To achieve such a task a high power motor with a low KV $\left(\frac{Rpm}{Volt}\right)$ value can be used to maximize the thrust. Based on these specs the LDPOWER M4114-320KV Brushless Motor (CW) was chosen which has 320KV, 999W and can be powered by 14.8V-22.2V (4S-6S) battery.

The following equation is used to calculate the dynamic thrust based on each battery:

$$F = 4.392399 * 10^{-8} * RPM \frac{d^{3.5}}{\sqrt{Pitch}} (4.23333 * 10^{-4} * RPM * pitch - V_{air}) \quad \text{Eq. 1}$$

Where:

F = Thrust (N)

D = Diameter (in)

RPM = Propeller (rotation/min).

Pitch = Propeller pitch (in)

V_{air} = Propeller forward wind speed (m/s)

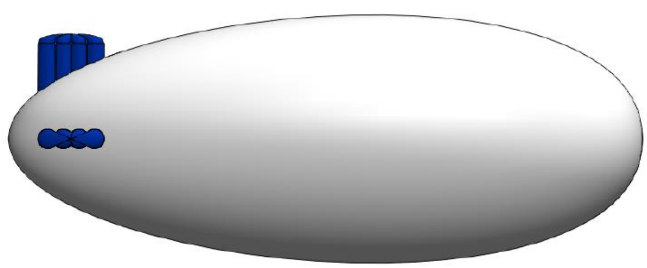
The force can be calculated as static thrust by setting the air speed equal to zero. By multiplying the volts of the 4s battery and the 6s battery, with the motor's KV the RPM can be determined for the two different cases. Once the RPM is calculated, the value is substituted into the equation above. The velocity of air for this particular case was estimated to be around 30 mph from a last year's weather report on a mid-April day. The thrust values calculated by the equation were found to be 3.19 kg for a 4S battery and 6.28 kg for a 6S battery. To conclude the 6S battery will be used to maximize the potential RPM, therefore, the thrust. The team found the Turnigy nano-tech 8000mAh 6S (22.2V) as the best battery for this system but do to weight constraints a lower voltage battery may need to be used.

4.6 Servos

The servos needed must be able to withstand the weight of the motor, the enclosure containing the motor, a propeller and be able to rotate 180 degrees. The servos' function is to be able to change the direction of the propellers which will allow the blimp to descend and go forward while in flight. Lightweight high torque servos, Turnigy™ TGY-20C, were chosen because they have a high torque of 40kg/cm and light weight of just 78g.

4.7 Testing Procedure

Prior to the day of testing Tom, a manager at the machine shop, installed the helium tank for the team in Building 77 Capital Assets. The regulator as well as the hose were also attached to the helium tank. Tom showed the team how to use the regulator, and how to release the helium at no pressure so the team would not tear the blimp during the filling process. Once everything was prepared and there was enough cleared space for the testing, the team expanded the blimp on the ground. Afterwards, the hose was attached to the back entrance sleeve of the blimp and then tied with a bungie cord and rubber bands so the helium could not escape. Upon opening the valve of the tank at no pressure, the blimp took approximately fifteen minutes to fill up. During the filling process, a prototype enclosure was made and attached to the bottom strings of the blimp. The blimp used all of the helium in the tank which was approximately 217ft^3, it was then noticed that the blimp would need more helium to be completely filled. However the blimp was still acceptable for testing. Once the blimp was full the team added small weight bags to the enclosure in order to determine how much weight the blimp could carry. The end results, that the team concluded, was that the blimp could carry 3.11Kg. The next step was to measure the dimensions of the blimp in order to create a SolidWorks design. Below, Figure(16) shows the SolidWorks design created with the measured dimensions including the approximate volume in units of mm.



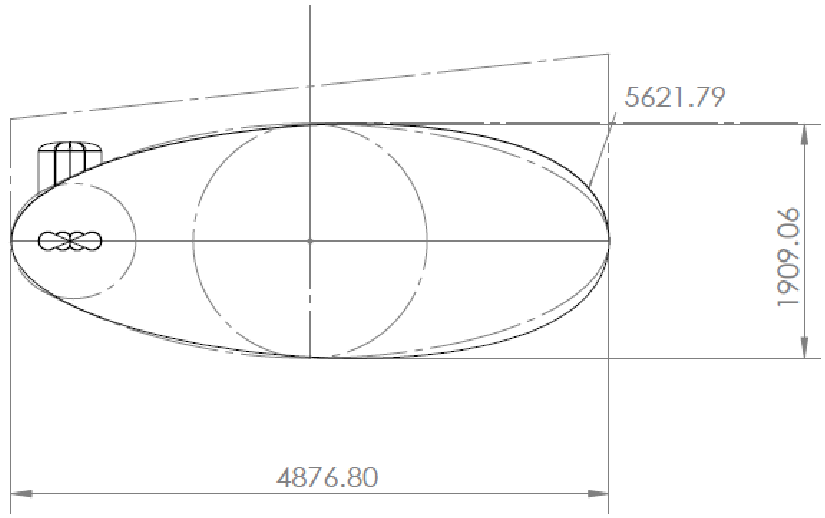


Figure 16: SolidWorks drawing of Blimp

The final results were that the blimp was 4.87 m in length, mid diameter of 1.9 m and an approximate volume of 5.62 m^3. When the testing was over, the team secured the blimp by attaching strings to table tops and connecting them to the blimp, so the blimp would not float to the ceiling. The next day the blimp was checked in order to see how much helium was lost in a 24 hour period and the team concluded that testing can only be done on that same day with one tank of helium. Below are figures that show the blimp during the testing.

Figure 17: Side view of the blimp.

Figure 18: Back view of the blimp.

For further testing, it has been requested that two more helium tanks are needed and Professor Kosaraju has approved. The current goal of the team is to not exceed 2.27Kg, to be on the safe side. Overall the testing went well and the next testing will be performed when the final enclosure design and all other components are attached.

5 Bill of Material (BOM)

The BOM is a detailed description of each component within the blimp. Table 2 portrays this. Each part has an assigned part name, a quantity of how many of each part are in the blimp. The dimensions of the components and how much it weighs (kg). By being thorough, eventually the components can be put together in the enclosure and placed in the right way to help the blimp lift it easily without any trouble.

The research process for this project requires investigation into different aspects of energy losses and movements within the blimp. There are areas of the blimp that experience greater energy and helium losses than others, and there are different variables that need to be considered. Construction method and construction material are some of the variables that need to be taken into account when determining where the losses are the greatest.

Cost increases can also occur depending on the type of equipment being used for better blimp materials. For instance, the bill of materials that we have chosen is making the blimp comparable to quadcopters in the market with more advantages and available at a cheaper cost.

Table2: Bill of Materials

Name	Cost ($)	Quantity (#)	Total Cost	Weight (g)	Total weight	Dimensions(mm)
lynxmotion quadrino nano	149.99	1	149.99	64.22	64.22	53*53*17
Flight receiver- Fly-Sky 2.4G 6-Channel Receiver (R6B) for CT6B 6-CH TX	11.24	1	11.24	25	25	30*25*8
Lynxmotion Quadrino Nano Advanced Wiring Kit	9.99	1	9.99	20	20	
3DR 915MHz Radio Set for UAV	100	1	100	20	20	26.7*55.5*13.3
Raspberry Pi 2	42	1	42	60	60	127*101.6*76.2
USB camera	45	1	45	15	15	121.92*121.92*71.12
micro SD card	8.05	1	8.05	1.5	1.5	
Portable Battery	14.99	1	14.99	30	30	88.9*50.8*6.35
mini USB Flash Drive 64 gb	15.99	1	15.99	22	22	
Brushless Motor	$56.90	2	$113.80	154	308	47*37.8
Turnigy Servo 180 degree	64.48	2	128.96	78	156	40.5*21*42
Repair	100		100			
Turnigy Battery	99.99	1	99.99	1105	1105	195*50*55
Blimp	221	1	221	NA	NA	230
Helium	150	1	150	NA	NA	217
Regulator	130	1	130	NA	NA	NA
Propellers	72	1	72	230	230	30 * 5.5
ESC	21.99	2	44	62	40	47*20*10
TOTAL	NA	20	1457	NA	2096.72	NA

6 What is Due Next

Currently as a group we have finished an aspect of the project. First Designs being implemented a reduce weight limit, researching several costs for items being bought. By using better quality material the blimp would be capable of carrying more weight. As project progresses the blimp design will have several improvements which will lead to our final design consisting of a power supply to both the servo and the motor on one single system. The quadrino will be connected to the signal receiver as well as make it connected to the full system. After all the connections are made the parts that are being placed in the enclosure will be secured inside the enclosure and is able to send the signal to the ground unit. The next step is to design and construct the final enclosure and final step is to test the blimp with the final enclosure and all the parts are placed in.

7 Conclusion

Upon analyzing all the data collected in the various figures and tables in researches for the quadcopters and blimps. The design of a blimp that can fly over contaminated areas and fires is possible and available to the public at a price lower than quadcopters also to help firemen see the area before engaging and make a plan to succeed without much fatality or injuries.

First was buying a blimp that can compete with expensive quadcopters that are not durable and cannot handle a force of any type. The second improvement would be adding extra support to the blimp by adding propellers that have a high thrust to counter the helium lift force and help move the blimp faster towards any direction. The third improvement is to install a lightweight servo with high torque that can have high torque that can turn shafts or motors enclosures. The fourth improvement is to have an in flight controller to make it easy to communicate with the user and be user friendly and also have a GPS telemetry data communication system to help the user view the location of the blimp.

The enclosures design is the current method to store all components, to operate the system of the blimp and give all the electric wiring as well as the full system that is being installed a safety aspect. The enclosure is going to be long and slender and aerodynamic all the way around to minimize drag forces. All the components will be on one level. The fin we created using biological inspiration from the dorsal fins of water animals. This assembly is composed of a dorsal type shape with a hole at the center of inertia, which will contain a small motor and propeller that will control the side direction of the rear and therefore control the direction of movement.

If this plan of adding the extra features to the blimp could come into action, it is firmly believed that these improvements would make this product far more proficient and customer-user friendly than the current models that are in the market.

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