Homework 5

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1 Motor Analysis

I used both the RCBenchmark test stand and the manual tools to do the measurement since I was the first to set up and do the tests. I used the multimeter to measure the resistance, voltage, and current, and a laser tachometer to measure the RPM. It is possible that since I included the wires in the resistance measurement, the measured resistance was higher than the manufacturer data (HobbyKing.com). I verified K_v and I_0 with the test stand, but not R_0. It is possible that the manufacturer calculates K_v based on builing parameters as opposed to testing.

	Measured	Manufacturer
K_v (RPM/volt)	2760	2850
R_0 (ohms)	.65	.475
I_0 (amps)	.67	.70

Table 1: The manual measurement matched RCBenchmark test stand data, but deviated slightly from manufacturer data.

2 Motor Propeller Plots

Using the above values determined from the motor analysis, I graphed the motor and propeller efficiency. I set a range of values for omega. I then used a for loop and called the motor and propeller efficiency functions I created for each omega value. The motor efficiency function uses the equations provided in the class slides to calculate motor efficiency. The propulsion efficiency function was more complicated. The J value was calculated from the inputted omega, velocity, and propeller diameter. I then used the propeller data and interpolation to find the propeller efficiency. First, I examined the change velocity had on the efficiency. The below graphs show the efficiency plots for various flight speeds. (Note: the sudden drop off in propeller efficiency is due to a J value that was not captured in the data and thus an unknown efficiency but based on the ending slope the general trend can be assumed.)

A flight speed of 8 m/s was also analyzed but the performance decreased from that of the 9 m/s flight speed. From the motor and propeller efficiency standpoint, the optimal flight speed that maximizes the efficiency appears to be around 9 m/s. This speed has the largest shared area below the curves which signifies a larger range of acceptable operating values. It also has the highest efficiency.

The above graphs were for a voltage of 6 volts. Below, the battery voltage was changed to examine the effect voltage had on the efficiency. Increasing the voltage allowed for a larger range of acceptable omega values for motor efficiency. A voltage of 8 volts would be ideal, again due to the larger shared area below the curves signifying a larger operating range.

3 Propulsive Efficiency

Using the flight speed as the parameter that determines the operation condition (lift and drag over the main wing), the performance of the propulsion system was determined and is shown in

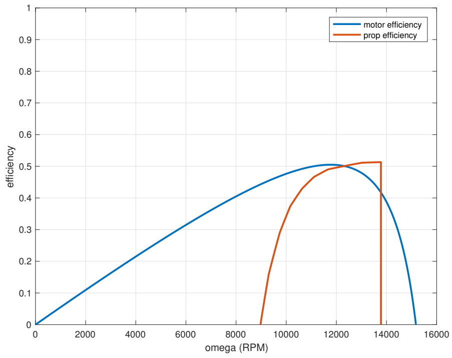


Figure 1: The motor and efficiency plot for a flight speed of 9 m/s.

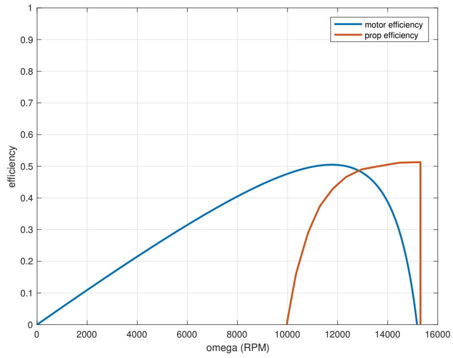


Figure 2: The motor and efficiency plot for a flight speed of 10 m/s.

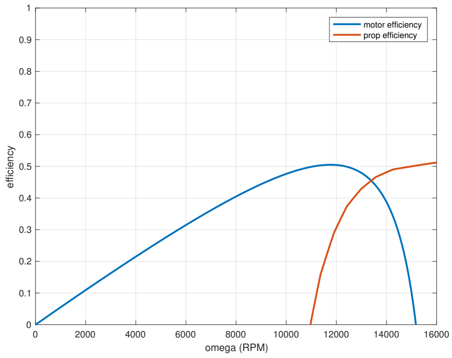


Figure 3: The motor and efficiency plot for a flight speed of 11 m/s.

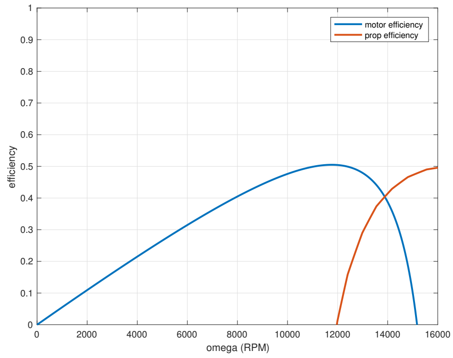


Figure 4: The motor and efficiency plot for a flight speed of 12 m/s.

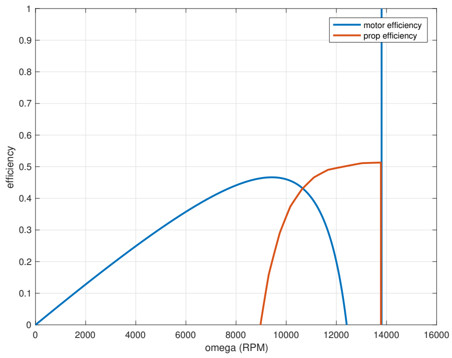


Figure 5: The motor and efficiency plot for a battery voltage of 5 volts.

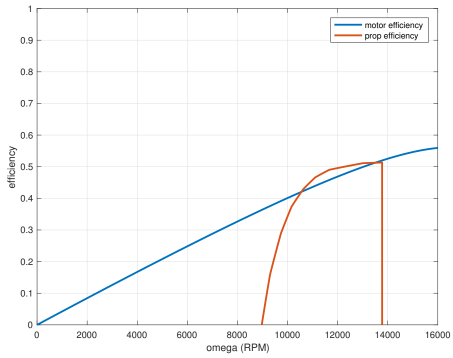
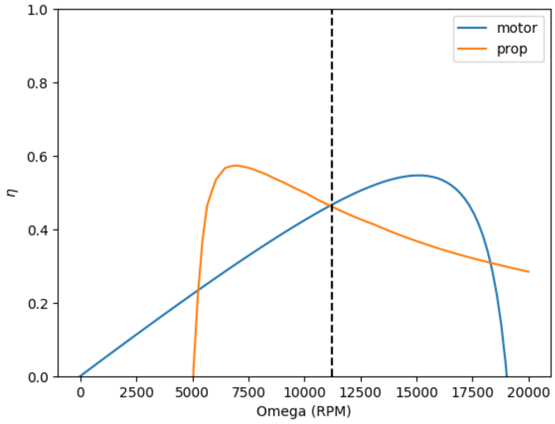
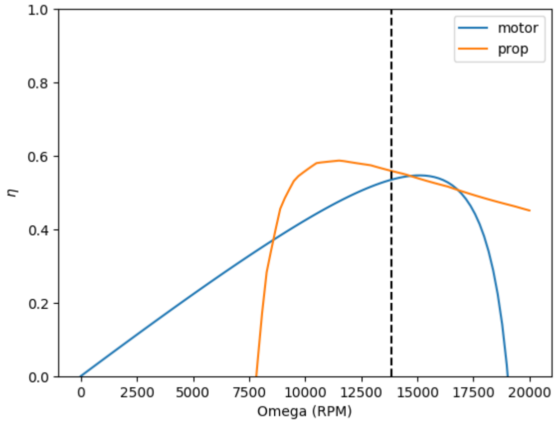


Figure 6: The motor and efficiency plot for a battery voltage of 8 volts.

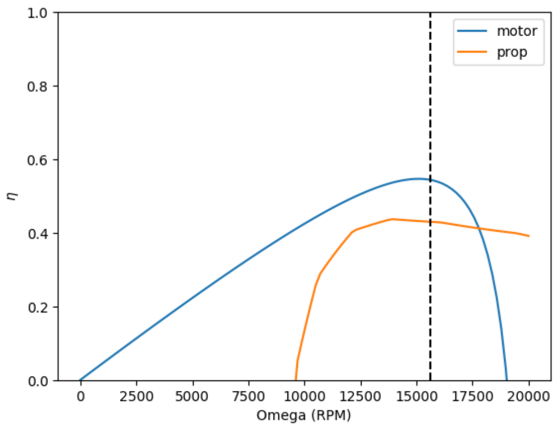
Fig. 7. From Figs. 7a and 7e it can be seen that the flight speed of optimum performance for this combination of motor and propeller is at 6 m/s, however, our current design flight speed is 9.8 m/s, which means that our airplane will have a lower endurance than if flying at 6 m/s. We are predicting a drag of 0.37 N for our current design at a cruise speed of 9.8 m/s, and Fig. 7c shows that at such speed each motor will generate about 0.19 N of thrust, adding up to 0.38 N between both motors, allowing our design to perform correctly. From Fig. 7d it can be seen that our overall propulsive efficiency at 9.8 m/s is 0.2.



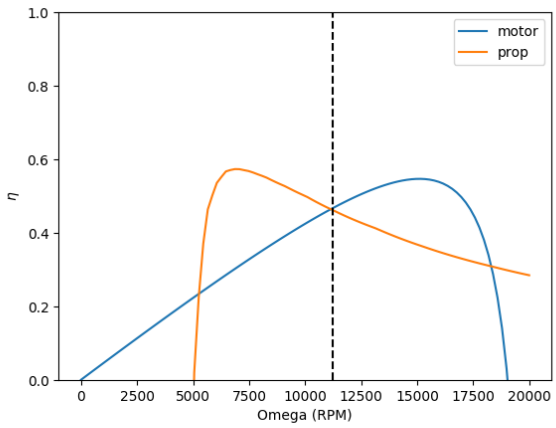
(a)



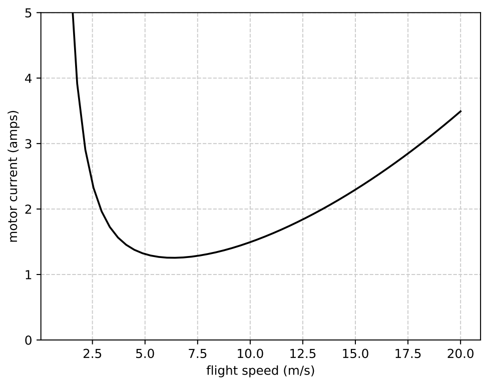
(b)



(c)

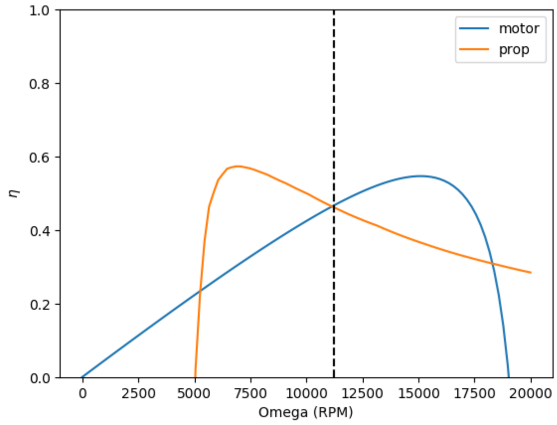


(d)

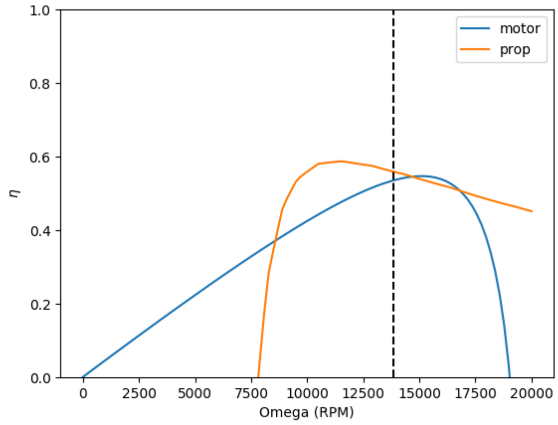


(e)

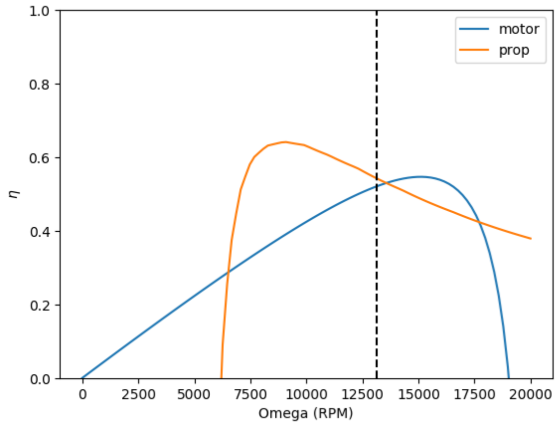
Figure 7: Performance of propulsion system at multiple flight speeds during steady level flight.



(a) APC 4.2x4 Prop Efficiency Matching Analysis



(b) GWS 4.5x3 Prop Efficiency Matching Analysis



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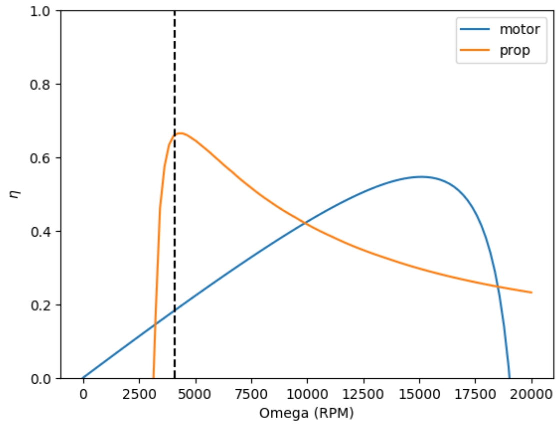
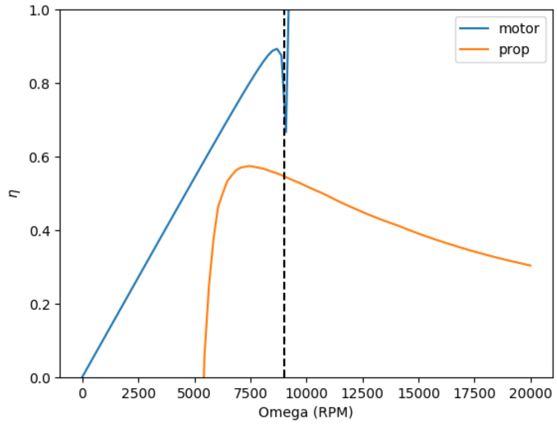


(d) DA 4022 9x6.75 Prop Efficiency Matching Analysis

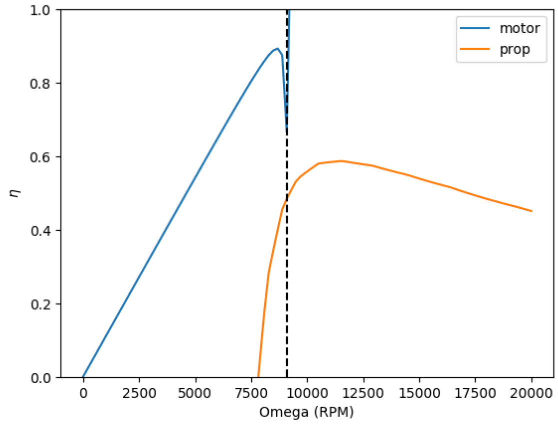
4 Motor and Prop Combination Selection

With there being an almost infinite number of possible propeller-motor-battery combinations, we decided to first fix the motor and battery to the ones that are provided and only change the propeller in our analysis. This fixed our motor Kv,idle current, and resistance, as well as our battery voltage (7.4V). We set the flight speed to be our optimal flight speed calculated from previous homeworks (9.8m/s). We figured that this would also be the cheapest component if we decide to upgrade it.
The propeller that we are given is the APC 4x3.3. Since we were unable to find data on this propeller online, we used the APC 4.2x4 propeller as an approximation. We then used Dr. Ning's Juliabox code to calculate graph the performance measurements of this propeller and found a Total Efficiency of 22.7% and a thrust of 0.671 N, see Figure 8a. Then using this propeller a baseline, we began looking through other propellers to try and find one that increased the total efficiency and thrust and that better matched the motor efficiency curve. Figures 8a,8b,8c, and 8d show a few of the propellers that we tried. For the propellers with a diameter in the 4-5" range, we used the data for a Re 6000. For the 9" prop we used a Re 4000. It is clear that the 9" diameter propeller are more efficient at lower rotation speeds, but for our current motor the smaller propellers match the motor efficiency better.As seen in Figure 8b the GWS 4.5x3 propeller was a much better match and it increased the total efficiency to 29.9% and a thrust of 0.718 N.

We then decided that we should look at slightly more efficient motor. In the Turnigy Aerodrive SK3 line, there are more efficient motors. We selected the 1280 Kv model to test with our old and new propeller. Using their motor data we generated Figures 9a and 9b. As expected, the lower kv shifts the plot to the right, but the change in resistance and no load current also affected the plot. While this motor is more efficiency, it does not match well with our given or our newly selected propeller.



(a) APC 4x3.3 Prop Efficiency Matching Analysis with a more efficient motor



(b) GWS 4.5x3 Prop Efficiency Matching Analysis with a more efficient motor

5 Building the Unstallable

5.1 New Canard: Austin and Jenna

We used the foam cutter to cut a new canard wing that was thicker and more durable. We ran into some challenges with the foam cutter not working and with it leaving ridges in the wing. To fix this we ended up cutting it slightly larger than needed and then sanding it down. We also cut the fuselage parts from poster board. From our multiple iterations on the canard we learned it is best to consider and draw out the dimensions of the parts ahead of time instead of realizing after a part is cut that the dimensions are too small. This would have saved time and resources if we knew how small the canard was going to be ahead of time.

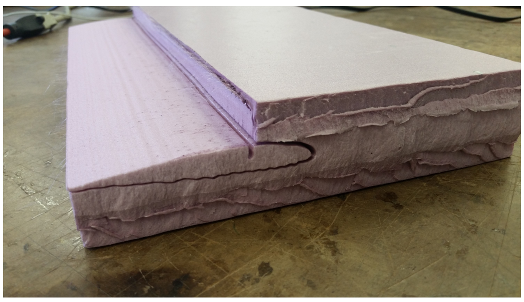


Figure 10: Some good looking picture.

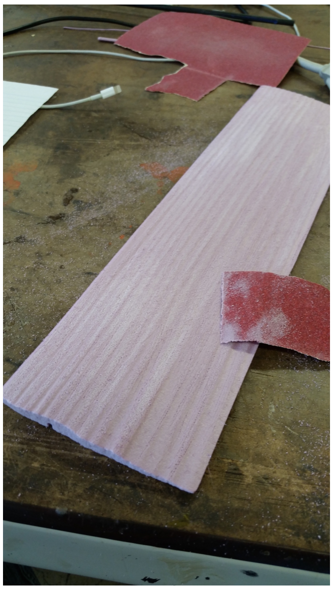


Figure 11: Another beautiful picture.

5.2 Plane Assembly: Kevin and Eduardo

We assembled the fuselage, canard, and main wing. Spar slots had been previously cut into the wing sections, however the connection was tricky due to the dihedral and sweep. To account for this, we used a built-up section of plywood, epoxy, and carbon fiber arrow shafts that had both the 5 degree dihedral and 30 degree sweep. In hind sight, it would have been much simpler to design the aircraft with only dihedral. To get the spar assembly to fit into the wing, we cut out extra

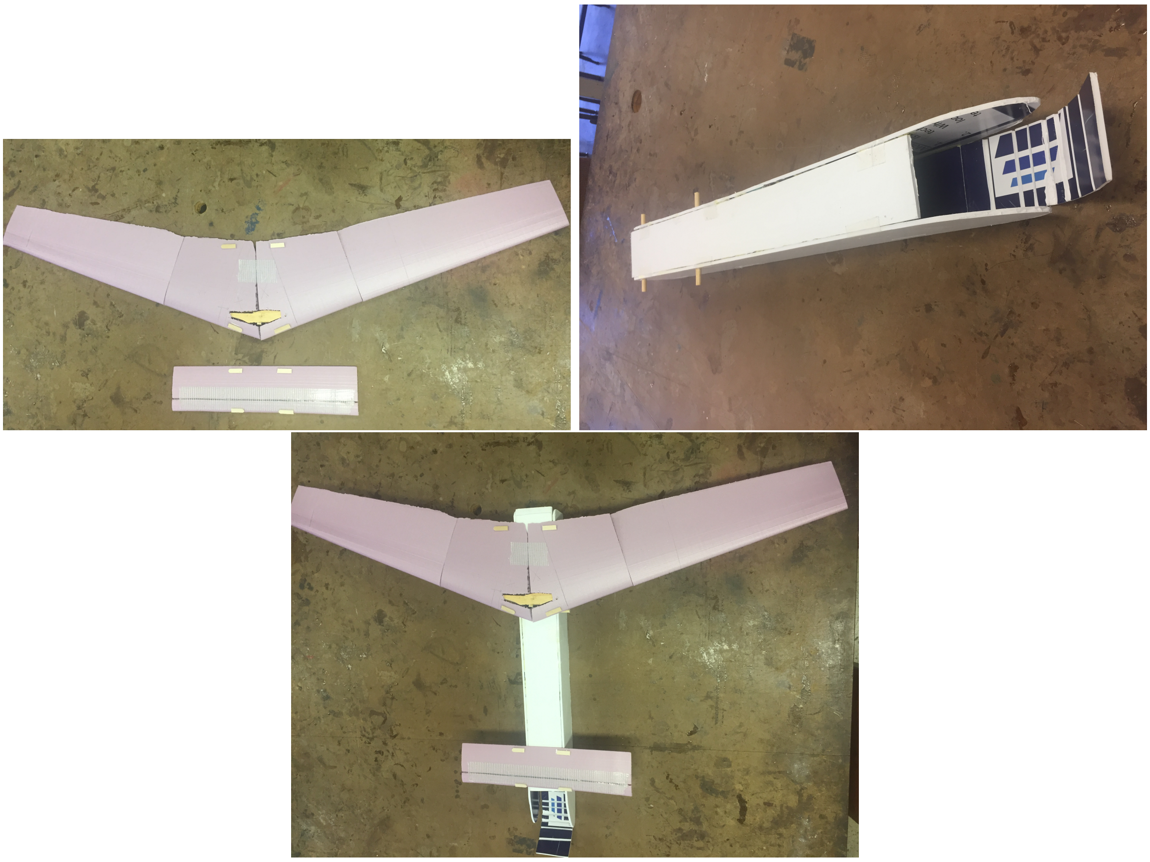


Figure 12: Wing and fuselage assemblage.

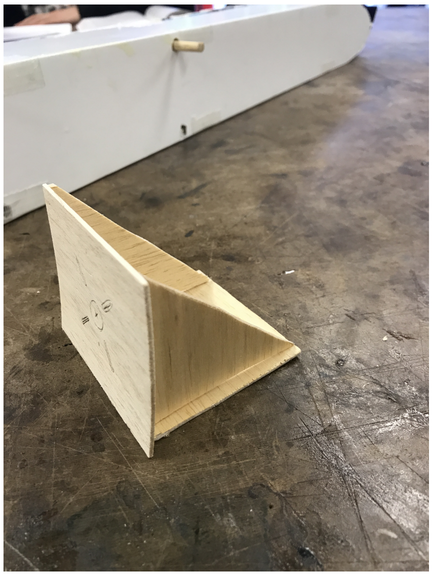
sections which we plan to cover with packing tape. The canard was much simpler and required only a carbon rib and some tape. We plan to try to keep most of the structural components accessible if we decide to build another wing and scrap this one.

The fuselage was assembled by gluing together sections of cardboard as shown in Fig. 12, and holes we placed for a spar to go through where the wing will be mounted.

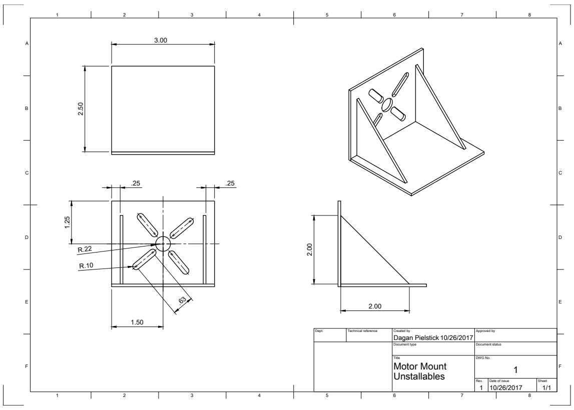
5.3 Motor Mount: Dagan

I was tasked to design and build the motor mount. We have paid the EE Shop for the parts, but have not yet been able to collect the parts from the TA's. This limited the construction as we did not want to drill holes without first validating their position. The size and locations of holes was created from the motor data sheet, see Figure 13c. These holes were sketched onto the actual material to provide a visual cue about motor placement, see Figures 13a and 13b. This was cut from Balsa wood. The balsa wood seems a bit flimsy for this task, but this can be modified by locating the struts closer to the center (where the force of the motor will be applied). It is anticipated that a small hole be made for the motor wirings to pass into the fuselage. To aid in the construction process, small groves will be helpful when gluing the assembly together.

(a) Assembly Mounted in Fuselage



(b) Motor Mount Assembly Profile



(c) Engineering Drawing of Motor Mount

Figure 13: Motor Mount Drawing and Assembly