UAV Semester 1 Final Report

Propeller Sizing

Propeller sizing cannot be above 4 inches otherwise the propellers will not fit inside the required 250mm spherical max sizing. The propellers also should not overlap otherwise the motors will interfere which each other's airflow resulting in a reduction in performance. The dimension sizing is in millimetres.

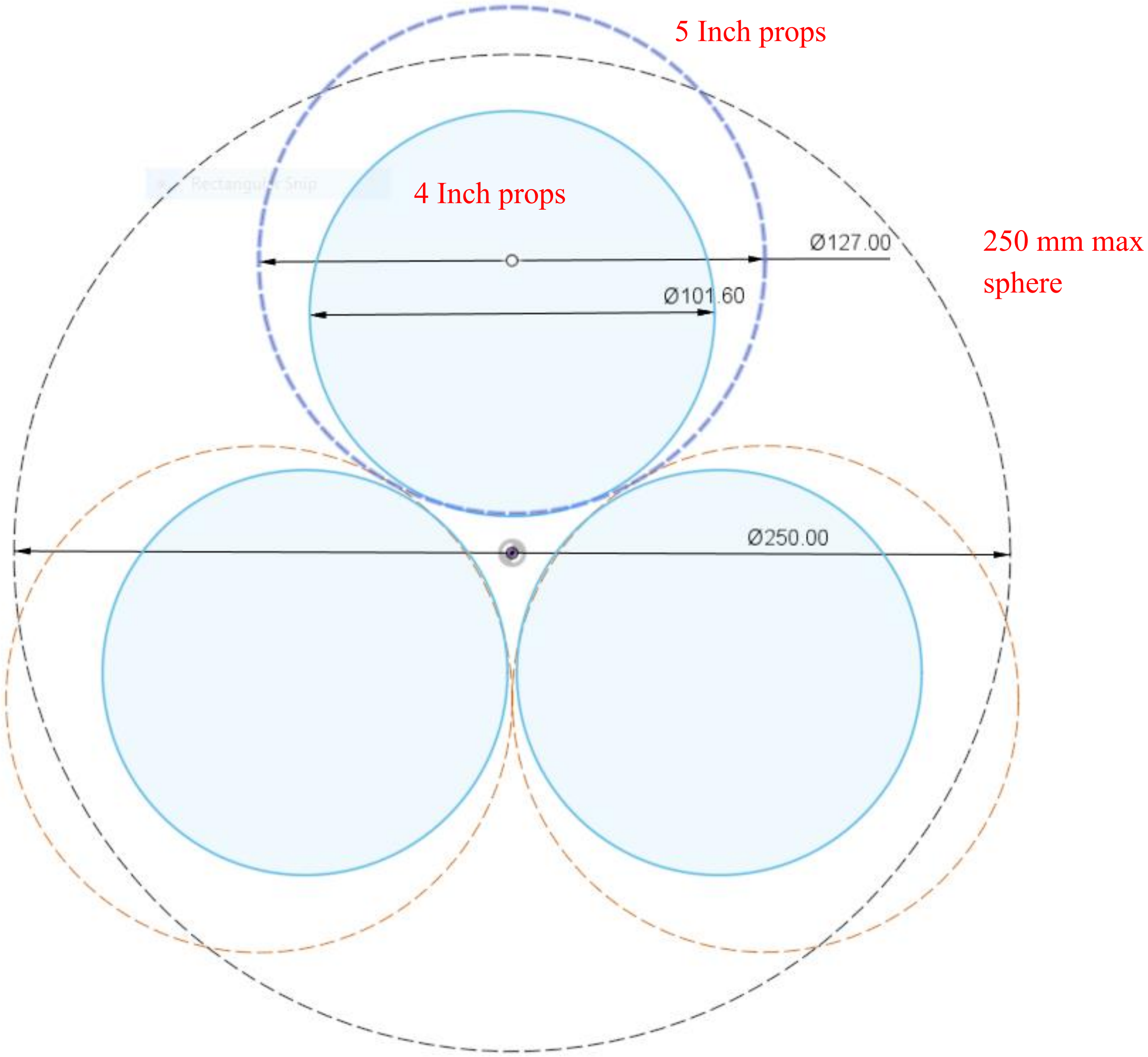


Figure X.X: Propeller Sizing

Propulsion and Electrical Power

Motor Name	KV Rating	Prop Name	ESC	Max Thrust	T/W Ratio
Emax Eco 1407	2800	HQ 4*4.3*3	Formula 45A	350	4.2
Emax Eco 1407	3300	HQ 4*4.3*3	Formula 45A	437	5.244
Emax Eco 1407	4100	HQ 4*4.3*3	Formula 45A	569	6.828
Emax Eco 1106	6000	Avan mini 3"	Formula 45A	214	2.568
Emax Eco 2 2207	2400	HQ 5*4.8*3	N/A	1580	18.96
XING X1507 FPV NextGen	2800	3*4*3	N/A	689	8.268
XING X1507 FPV NextGen	2800	3*5.2*3	N/A	812	9.744
XING 1303 5000KV FPV Micro	5000	2*2*4	N/A	180	2.16

Table 1.1: Motor T/W Ratio

The Thrust to Weight ratio should be enough that 1 motor can lift the drone if the others fail. This will not allow for a successful continuation of the planned flight, instead it will allow for a controlled crash landing. This should result in the minimum amount of damage being done to the drone on impact.

The max weight allowed is 250 grams, therefore the motor must provide at least 750 grams worth of thrust. This results in a T/W ratio of 3. Given this requirement both the Emax Eco 2 2207 and the XING 1303 should be removed from contention as their T/W ratio is less than three.

Motor Stator Sizing

In electric motors the larger the internal stator the more power that motor is capable of producing, this is because the larger the stator is the more air it is capable of displacing. The motor naming scheme dictates the size of its stator. The first two digits give the stator diameter in mm and the last two digits give the stator vertical length in mm. for example the Emax Eco 2 2207 has a stator diameter of 22 mm and a stator length of 7 mm.

Using this information, the possible power output of a motor can be found by comparing stator volumes which can be calculated using the following equation.

$$Volume = \pi r^2 * l \qquad \text{Equation 1.1}$$

This equation shows that an increase in the diameter of the stator is more influential on its power output than an increase in the stator vertical length. In fact, doubling the stator diameter will quadruple the volume, while double the stator length will only double the volume.

```
d = 01 : 01 : 30;          % d = stator diameter (mm)
r = d/2;                   % r = stator radius (mm)

% Stator Lengths
L1 = 01; L2 = 02; L3 = 03; L4 = 04; L5 = 05;
L6 = 06; L7 = 07; L8 = 08; L9 = 09; L10 = 10;

% Stator Volumes
V1 = pi .* r .* r .* L1; V2 = pi .* r .* r .* L2; V3 = pi .* r .* r .* L3;
V4 = pi .* r .* r .* L4; V5 = pi .* r .* r .* L5; V6 = pi .* r .* r .* L6;
V7 = pi .* r .* r .* L7; V8 = pi .* r .* r .* L8; V9 = pi .* r .* r .* L9;
V10 = pi .* r .* r .* L10;

figure (1)
hold on
plot (d,V1); plot (d,V2); plot (d,V3); plot (d,V4); plot (d,V5);
plot (d,V6); plot (d,V7); plot (d,V8); plot (d,V9); plot (d,V10);
grid on
grid minor
legend('1 mm Stator Length','2 mm Stator Length', '3 mm Stator Length', ...
       '4 mm Stator Length','5 mm Stator Length','6 mm Stator Length', ...
       '7 mm Stator Length','8 mm Stator Length','9 mm Stator Length', ...
       '10 mm Stator Length', ...
       'location','NorthWest');
ylabel('Volume (cubic mm)');
xlabel('Stator Diameter (mm)');
title('Stator Volume based on a Stator Length');
ax.FontSize = 18;
hold off
```

Figure 1.1: Stator Volume MATLAB code

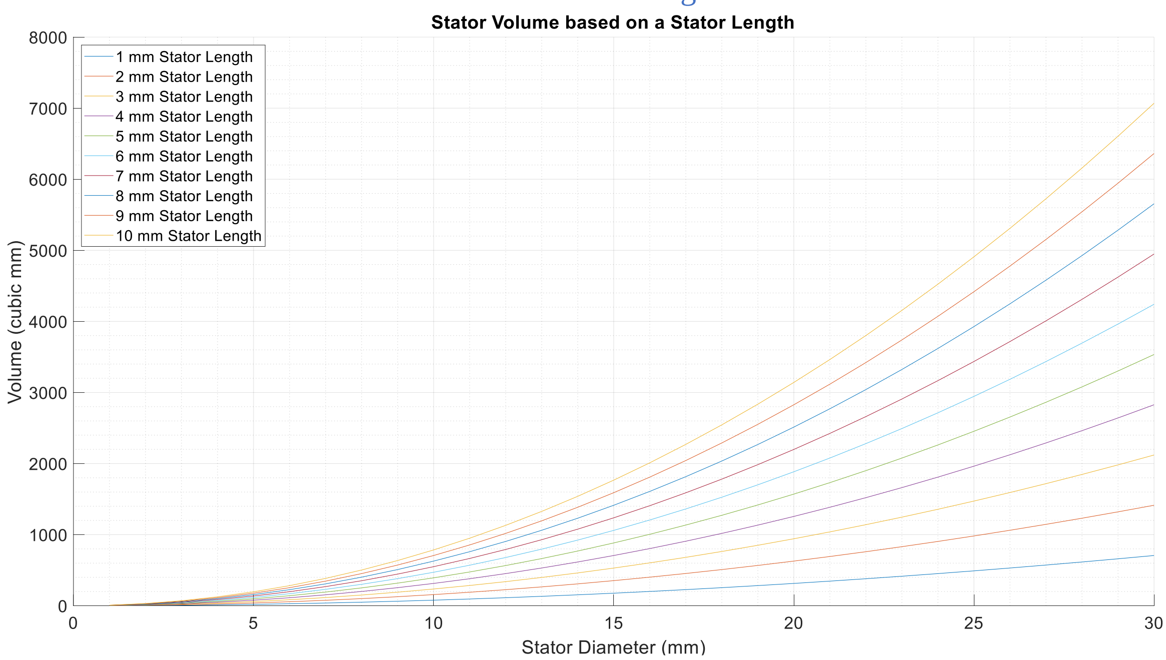


Figure 1.2: Stator Volume Graph

An increased stator length results in an increase in the permanent magnet size which will result in the motor producing more power at a higher RPM. Increase the stator diameter on the other hand will increase the electromagnet coil size and result in more torque being producible at a lower RPM. Either way a larger stator volume and thus a higher motor torque will allow for the use of a propeller with a larger diameter.

Battery Research

The battery that will be supplying power for the drone is a LiPo, a Lithium Polymer battery. LiPo is a new technology that improves on the design of Lithium-Ion batteries, it allows for a high continuous current.

They like all batteries are a DC supply, and as such require no AC to DC conversion. As they are high current supplies they can be split in parallel without serious current loss. This makes them great choices for drone motor supplies as then can require constant high current draw.

Final Motor Selection

Given the max weight of 250 grams, each motor should be able to produce this lift in the event that the other two motors fail. As the drone should be able to run at a low current draw a low KV rating is preferable. This is because the motor KV rating is its RPM per Volt value, so a lower KV value should relate to a higher Torque output.

Motor Type	The voltage (V)	propeller type	current (A)	thrust (G)	power (W)	efficiency (G/W)	speed (RPM)	Remote control throttle
Eco 1407-2800KV	12	HQ 4*4.3*3	1.2	75	14.4	5.21	11000	40%
	12		2.8	153	33.6	4.55	15500	60%
ESC: Formula 45A	12	propeller	5.3	245	63.6	3.85	19700	80%
	12		9.3	350	111.6	3.14	MAX	MAX

Table 1.2: Chosen Motor Data Table

Motor store page: HobbyRC. 2020. *Emax ECO 1407 2800KV Motor*. [online] Available at: <https://www.hobbyrc.co.uk/emax-eco-1407-2800kv-motor> [Accessed 10 December 2020].

Final Battery Selection

Once the motors were selected, we could then use the total current draw and the standard voltage of a LiPo battery to find the required capacity to power our drone for the required 5-minute flight time.

To find this out we simulated the possible flight times for a range of battery capacities in mAh. A C-rate of 100C was used due to its mid-range specification and a Discharge Rule of 80% was assumed to allow for a 1/5 increase in current draw without failing to meet the required flight time.

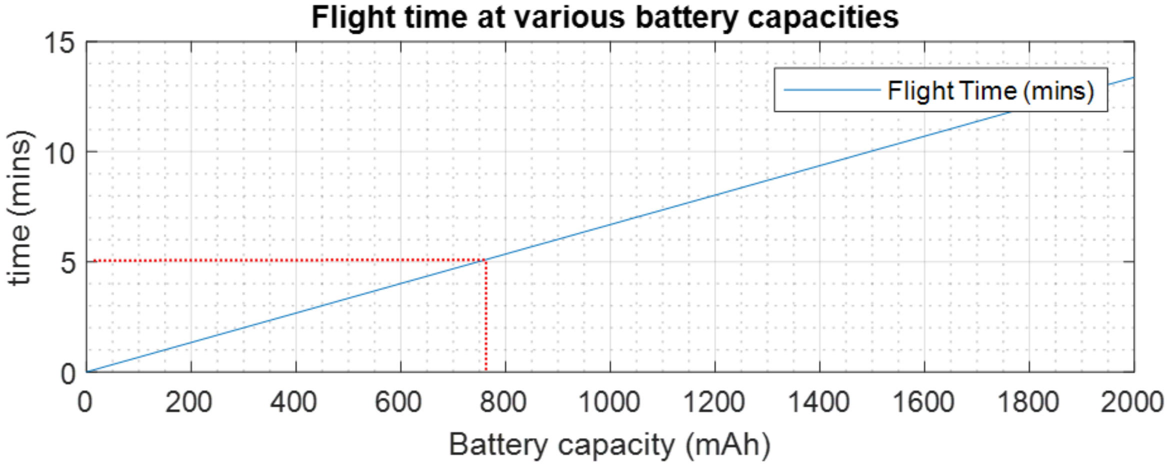
```
% Input data
Nm = 3; % Number of Motors
ImM = 9.3; % Max Motor Current in Amps
Io = 2; % Estimated TotalOther Current in Amps
Nseries = 3; % Number of Battery Cells in Series
Vbatnom = Nseries * 3.7; % Total Nnominal Battery Voltage
```

```
Qcap = 0 : 50 : 2000; % Battery Capacity in mAh
DR = .80; % Battery Discharge Rule
Lfly = .30; % Standard Flying Load

% Battery C-rate
C1 = 10; C2 = 20; C3 = 30; C4 = 40; C5 = 50;
C6 = 60; C7 = 70; C8 = 80; C9 = 90; C10 = 100;

% Max Current, Flight Current, Max Power
ImaxFL = Io + ImM * Nm
Ifly = ImaxFL * Lfly
Wmax = ImaxFL * Vbatnom

% expected flight time
Tflight = ((Qcap./1000)/(Ifly))*60;
TflightDR = (((Qcap./1000)/(Ifly))*60)*DR;

% number of batteries needed
NbatReqC1 = (ImaxFL)./((Qcap.*C1)./1000); NbatReqC2 = (ImaxFL)./((Qcap.*C2)./1000);
NbatReqC3 = (ImaxFL)./((Qcap.*C3)./1000); NbatReqC4 = (ImaxFL)./((Qcap.*C4)./1000);
NbatReqC5 = (ImaxFL)./((Qcap.*C5)./1000); NbatReqC6 = (ImaxFL)./((Qcap.*C6)./1000);
NbatReqC7 = (ImaxFL)./((Qcap.*C7)./1000); NbatReqC8 = (ImaxFL)./((Qcap.*C8)./1000);
NbatReqC9 = (ImaxFL)./((Qcap.*C9)./1000);
NbatReqC10 = (ImaxFL)./((Qcap.*C10)./1000);

figure(1)
tiledlayout(2,1) % Requires R2019b or later

nexttile
plot (Qcap,Tflight);
legend('Flight Time (mins)', 'location','NorthEast');
grid on
grid minor
xlabel('Battery capacity (mAh)');
ylabel('time (mins)');
title('Flight time at various battery capacities');

nexttile
plot (Qcap,TflightDR);
legend('Discharge Rule Flight Time (mins)', 'location','NorthEast');
grid on
grid minor
xlabel('Battery capacity (mAh)');
ylabel('time (mins)');
title('Flight time at various battery capacities');

figure(2)
hold on
plot (Qcap,NbatReqC1); plot (Qcap,NbatReqC2); plot (Qcap,NbatReqC3);
plot (Qcap,NbatReqC4); plot (Qcap,NbatReqC5); plot (Qcap,NbatReqC6);
```

```
plot (Qcap,NbatReqC7); plot (Qcap,NbatReqC8); plot (Qcap,NbatReqC9);
plot (Qcap,NbatReqC10);
grid on
grid minor
legend('10C','20C', '30C', '40C','50C','60C', '70C', '80C', '90C', '100C', ...
    'location','NorthEast');
ylim([0 4]);
ylabel('Number of batteries required');
xlabel('Battery capacity (mAh)');
title('Number of batteries required for various battery capacities');
ax.FontSize = 18;
hold off
```

Figure 1.3: Battery Capacity MATLAB code

Translatorscafe.com. 2020. *Drone Lipo Battery Calculator • Electrical, RF And Electronics Calculators • Online Unit Converters*. [online] Available at: <https://www.translatorscafe.com/unit-converter/en-US/calculator/multicopter-lipo-battery/> [Accessed 10 December 2020].



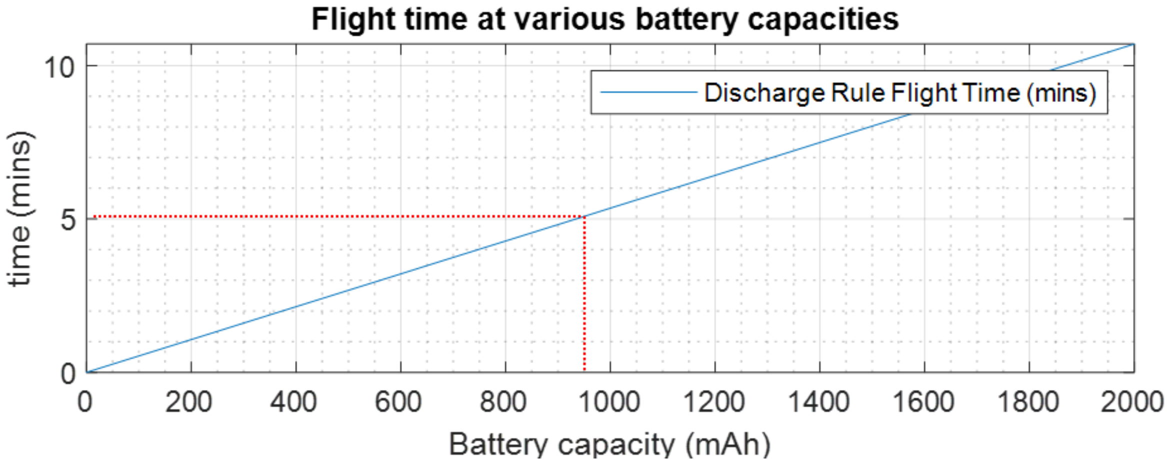


Figure 1.4: Battery Capacity Graph

Based on this setup we will require at least 760mAh, however this is an absolute minimum of battery capacity and does not allow for any safety excess capacity. Using an 80% discharge rule provides a 20% battery capacity safety overhead for unforeseen consumption requirements. This is then shown in the second graph which shows the minimum with this discharge rule is 975mAh.

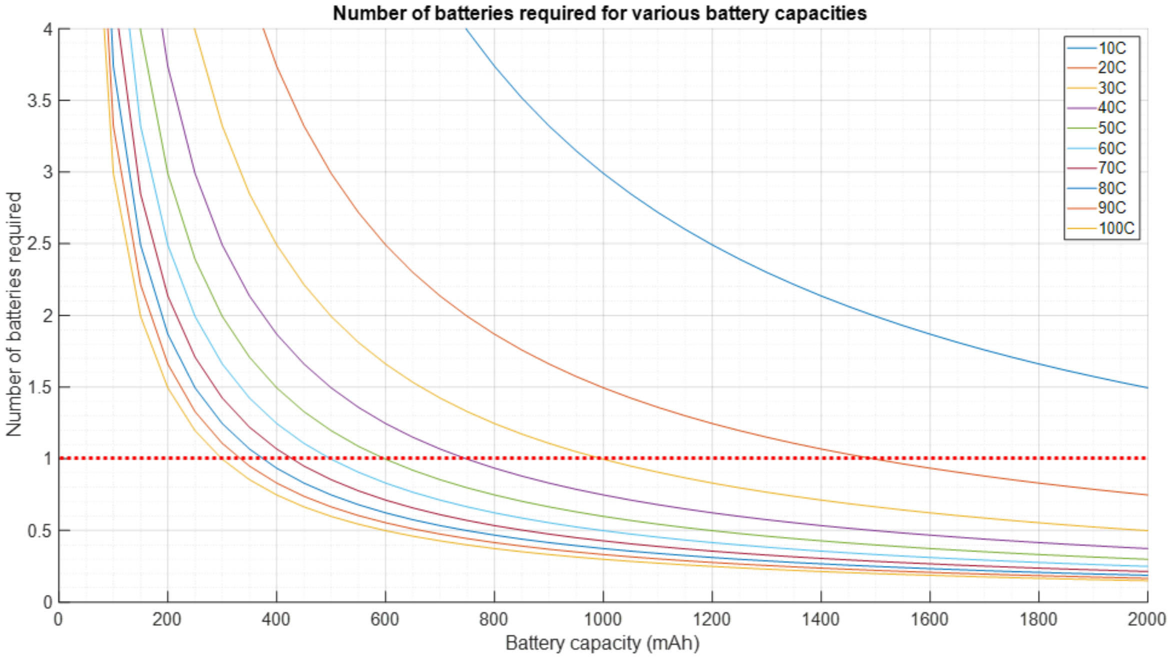


Figure 1.5: Batteries Required Graph

The MATLAB simulation suggests that the minimum required battery capacity is 975mAh and with a C-rate of at least 40C only 1 battery is required, reducing the weight load. If the battery capacity is 1000 mAh or higher the C-rate can be lowered down to 30C.

ESC Selection

ImaxFL (A)	Ifly (A)	Wmax (W)
29.9000	8.9700	331.8900

Table 1.3: Drone Current and Power Values

The Calculated max current draw while flying means that we will need to select an ECS that can manage at least 30A per motor. Given the max burst current requirements for 3 of the chosen motors this ESC has been selected.

Spedix IS25 25A 4in1 ESC (2-5S) (20mm)

- Firmware: BLHeli_S
- Input: 2-5s LiPo battery
- Constant current: 25A
- BEC: NO
- Burst current: 35A for 10 seconds
- Size: 29×32x5mm
- Mounting hole distance: 20×20mm, M3 Mounting

HobbyRC. 2020. Spedix IS25 25A 4In1 ESC (2-5S) (20Mm). [online] Available at: <https://www.hobbyrc.co.uk/spedix-is25-25a-4in1-esc-2-5s> [Accessed 10 December 2020].

Both its constant and burst current are higher than required and its use of the BLheli_S software allows for hardware PWM providing smoother motor speed control.