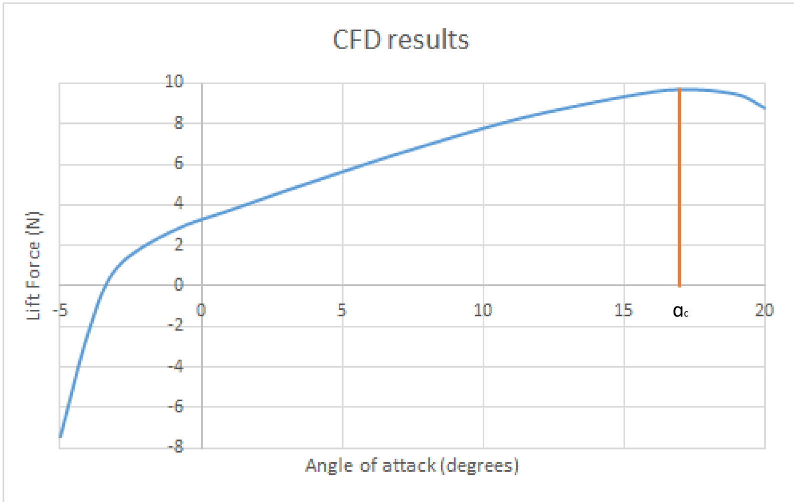
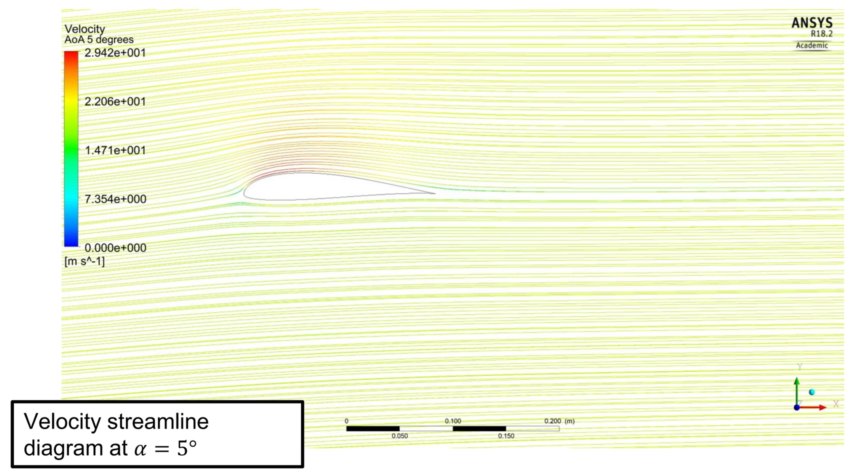
Fluids

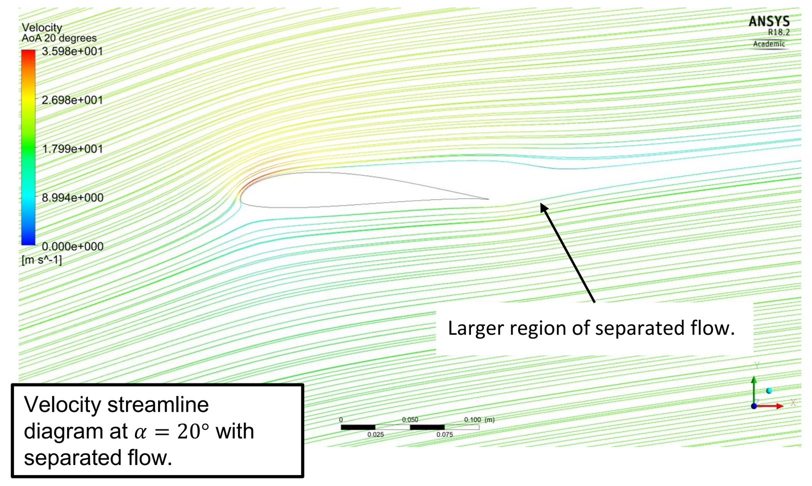
Above the critical angle of attack of 17° flow separation resulting in stall becomes an issue. The velocity magnitude streamlines show this increase area of separated flow for the 20° when compared to the 5° case.

The critical angle of attack of 17° was predicted using both Ansys Fluent and Javafoil analysis. The CFD approach gave a lift coefficient of 0.2171, which gives a maximum lift force of 19.4N from the full wingspan.



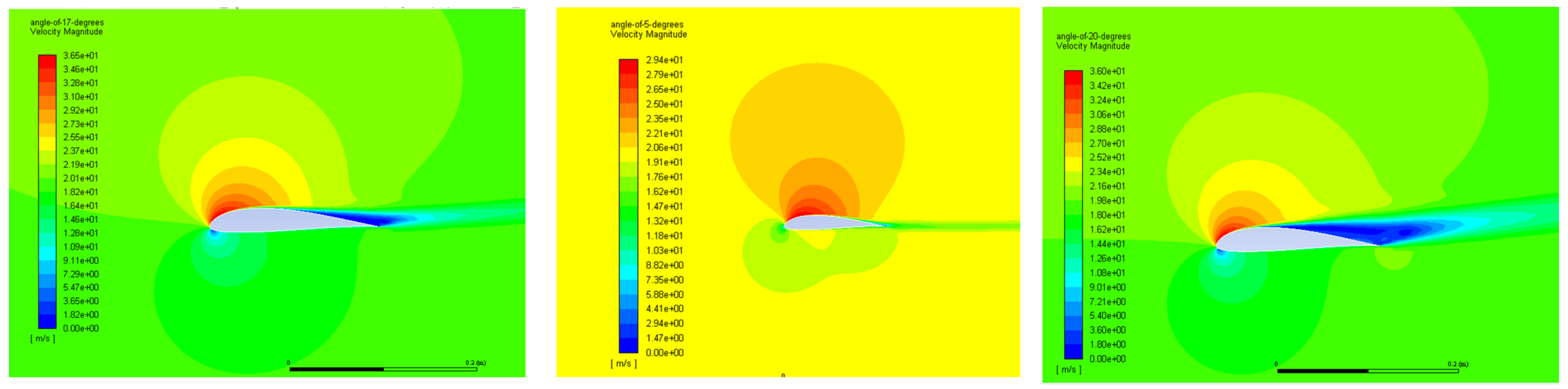


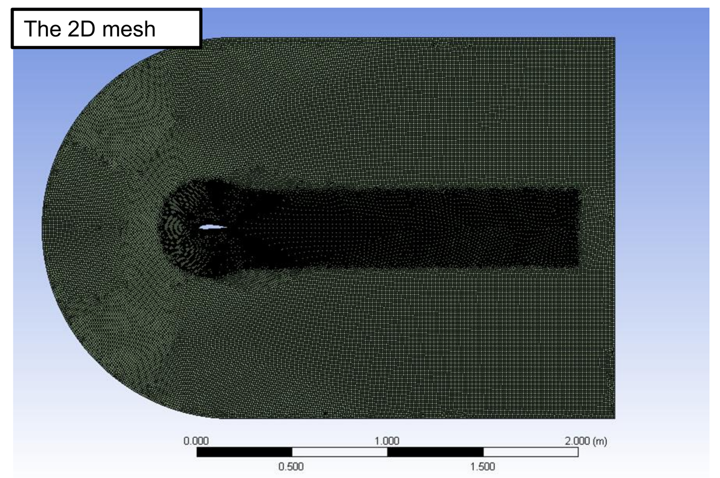
Velocity streamline diagram at $\alpha = 5°$



Velocity streamline diagram at $\alpha = 20°$ with separated flow.

The velocity magnitude contour plots show the increasing flow separation with increasing angle of attack



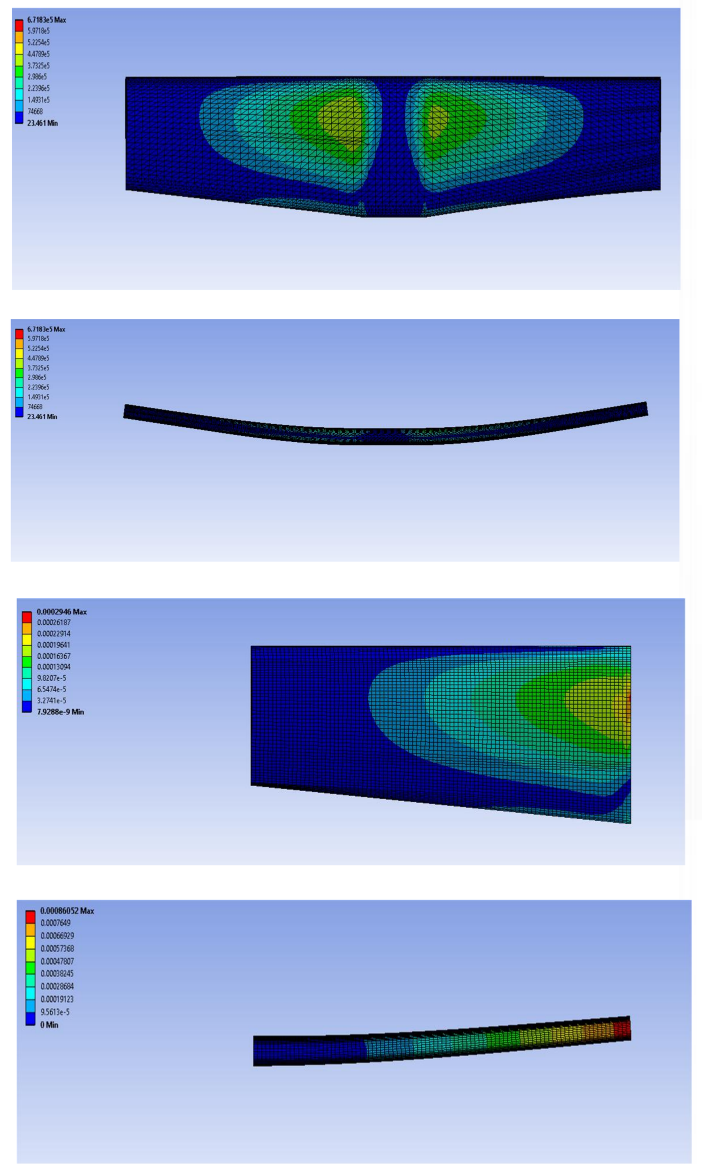

The 2D mesh

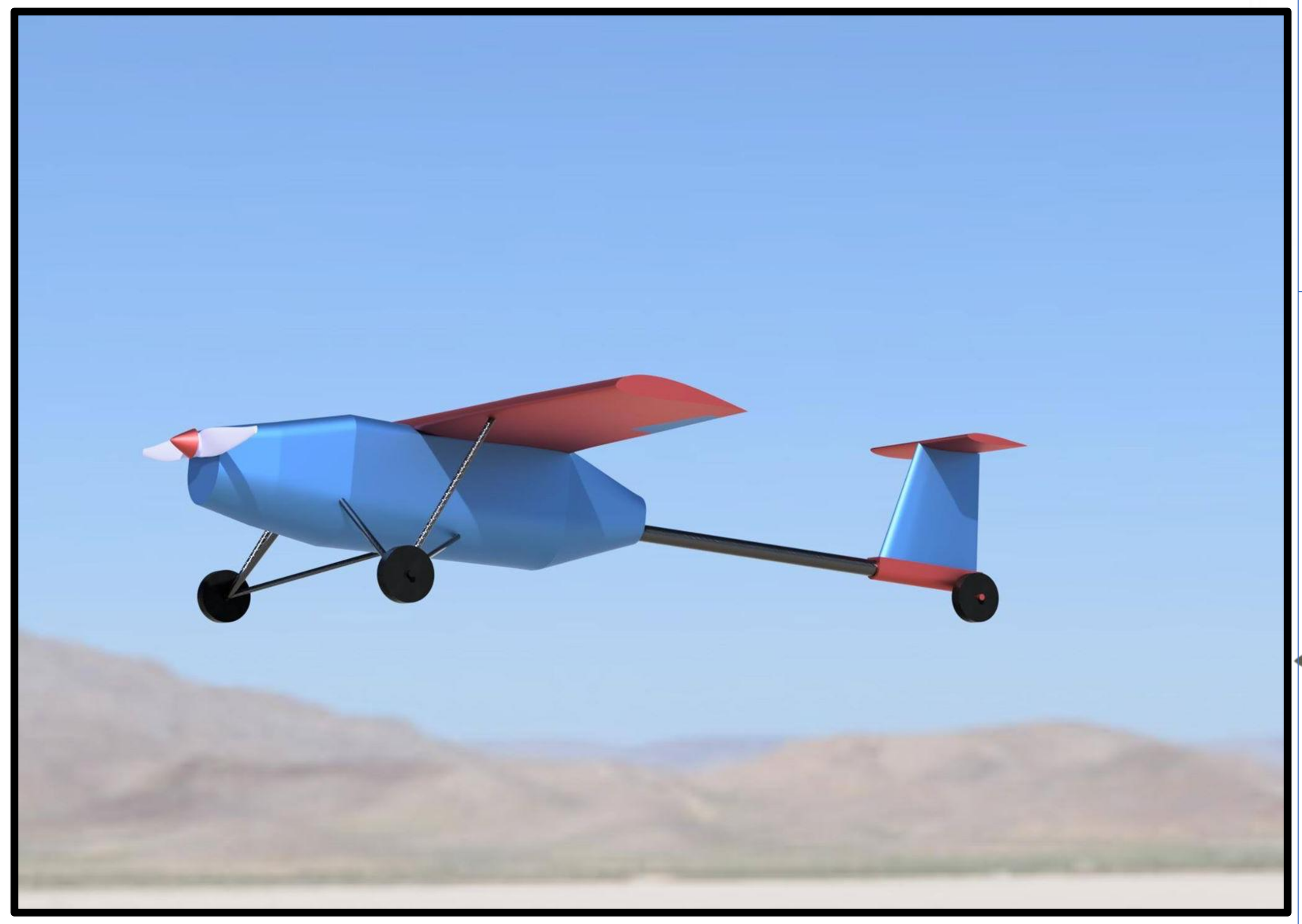
Meshing

The 2D mesh was created using Ansys Meshing software, utilising a combination of proximity and curvature size functions, body and edge sizing and inflation. The final mesh was of a sufficiently high quality to capture accurate results. It had a maximum skewness of 0.70 and a minimum orthogonal quality of 0.52. These are of a much better standard than of the minimum requirements of 0.9 and 0.1 respectively.

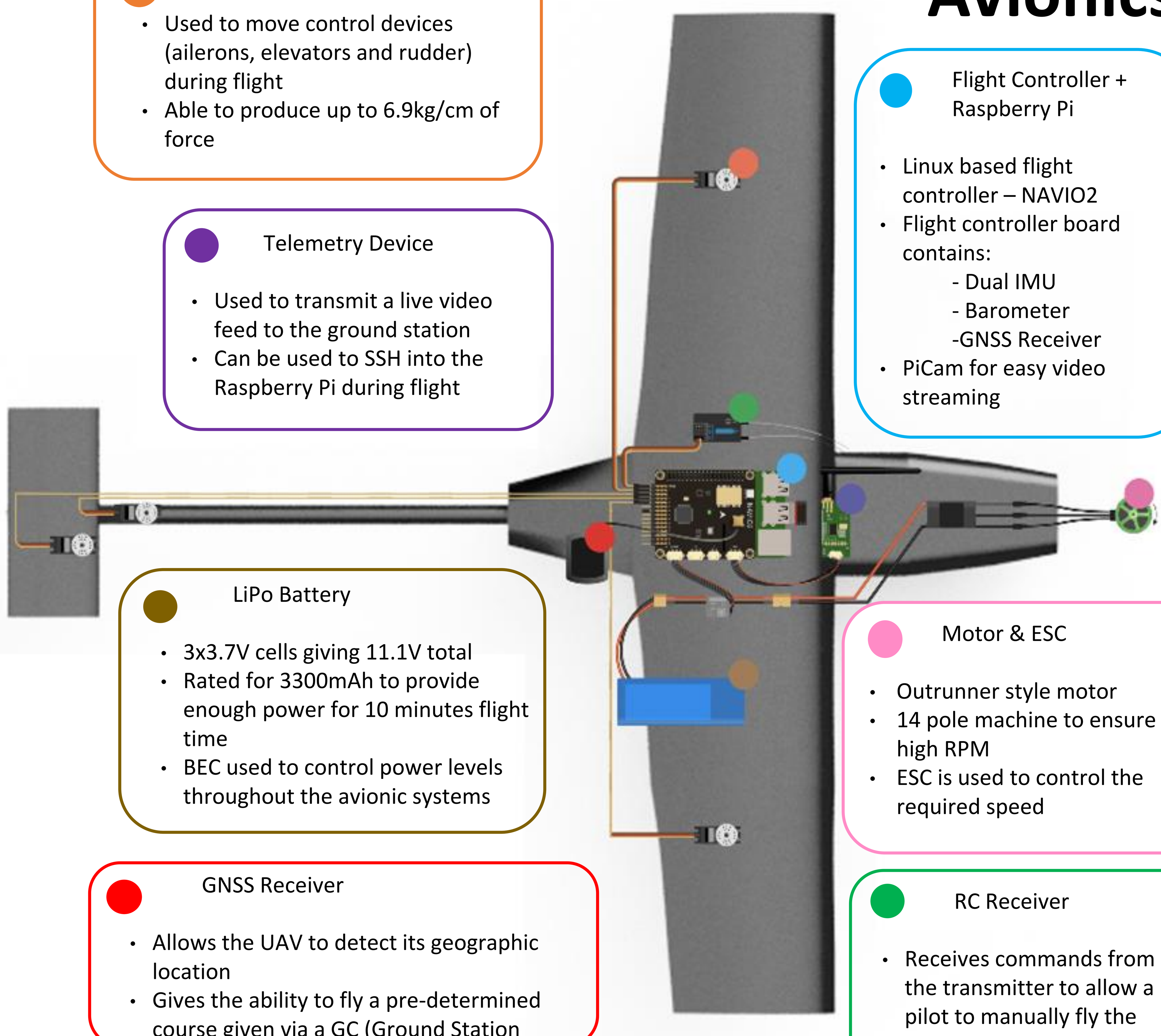
Finite Element Analysis of the Wings

ANSYS was used to test for the maximum stresses in the wing and the location. They were also tested for the max deformation when placed under approximations of flight conditions. Fixed supports and pressure distribution were applied to various structures. Shown here are the stress distributions for the whole wing and half the wing. This allows for approximation of the support in different places. The Fuselage and tail section were also test. The areas shown in red or yellow signify the areas of greatest stress. You can see that these fall at eth wing root which is to be expected. Can ensure stiffness along the wing to counteract the bending, Ensure extra care is taken over root and fuselage connection.





Avionics



Digital Servo

- Used to move control devices (ailerons, elevators and rudder) during flight
- Able to produce up to 6.9kg/cm of force

Telemetry Device

- Used to transmit a live video feed to the ground station
- Can be used to SSH into the Raspberry Pi during flight

Flight Controller + Raspberry Pi

- Linux based flight controller – NAVIO2
- Flight controller board contains:
  - Dual IMU
  - Barometer
  - GNSS Receiver
- PiCam for easy video streaming

LiPo Battery

- 3x3.7V cells giving 11.1V total
- Rated for 3300mAh to provide enough power for 10 minutes flight time
- BEC used to control power levels throughout the avionic systems

Motor & ESC

- Outrunner style motor
- 14 pole machine to ensure a high RPM
- ESC is used to control the required speed

GNSS Receiver

- Allows the UAV to detect its geographic location
- Gives the ability to fly a pre-determined course given via a GC (Ground Station

RC Receiver

- Receives commands from the transmitter to allow a pilot to manually fly the UAV

Propulsion

Table 1. Table showing Aircraft Parameters

Cruise Speed	15 m/s
Stall Speed	11 m/s
Safety Factor	25%
Mass	1.5 kg
Air Density	1.225
Front Area	0.018 m²
Wing Area	0.2 m²
C_D Tail	0.01
C_D Wing	0.015
Gravitational Acceleration	9.81 m/s²
Runway Length	15 m

$$D = \frac{1}{2} C_D \rho V^2 A$$

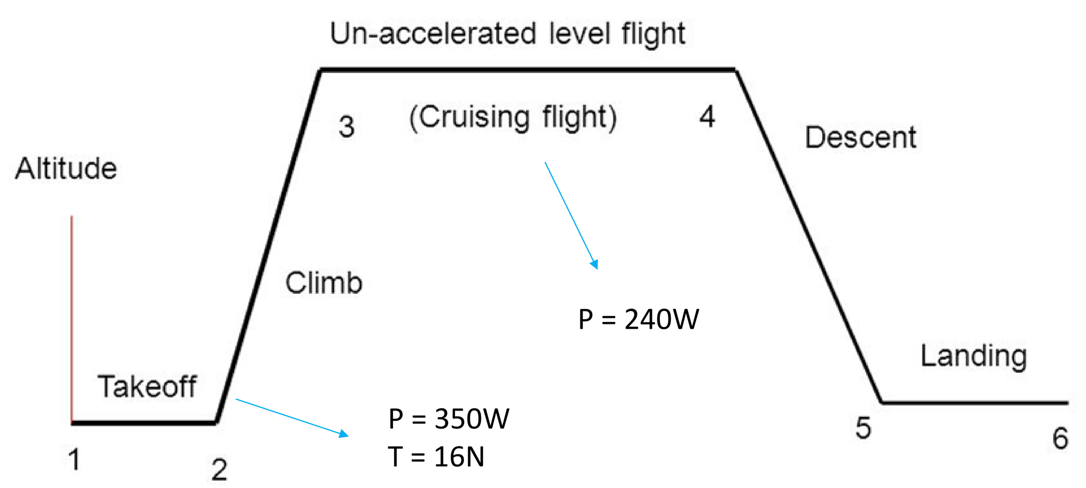
$$T_{TO} = (mxa) + D$$

$$T_C = D$$

$$P = \frac{(T + D)xV}{0.75}$$

Equations 1.1

Mission Profile



Thrust and Power Calculations

The Thrust and power calculations were calculated using the equations 1.1 . The values in the equations all come from table 1. Values for Cd are taken from Javafoil analysis. Runway length, cruise and stall speed are approximated. Only calculated for cruise and take off. As take off requires max thrust. And cruise is the majority of flight time.

Motor selection:
Once thrust and power values are found - see figure 1.1. The Motor can be select: PO-3547-800

Prop Position (Tractor, buried inside fuselage)

- Net thrust greater than a pusher set up.
- Good propeller clearance.
- Better directional stability.

Number of Props (1)

- Lower mass and cost compared to multiple props.
- No need for multiple props as it can glide to land.

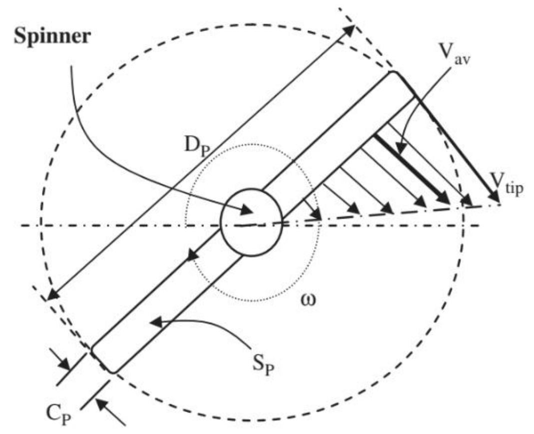
Propeller Sizing Calculations

With the power at cruise and the angular speed of the motor, the propeller diameter was able to be calculated using equation 1. As a range of typical values for aspect ratio and lift coefficient were used, a range of diameters were calculated and an average was taken to be 0.28m (11 inches).

$$D_P{}^2 = \frac{2P\eta_P AR_P}{\rho V_{av}^2 V_C C_{Lp}} = \frac{2P\eta_P AR_P}{\rho(0.7\sqrt{(\frac{D_P}{2}\omega)^2 + V_C{}^2} V_C C_{Lp}}$$

$$0.23m \leq D_P \leq 0.33m$$

Equation 1.2



Materials

Foam Sections

- Very light
- Comparatively easier to manufacture more complicated shapes (hot wire cutting)
- Can cut out cavities for electronic components, make a lid for easy access
- Wires between components will be harder to install
- Much more fragile especially for swept or tapered wings as the foam

High Density Polyurethane Foam

Density = 96 kg/m^3
Tensile Strength = 1060kPa
Cost = £69.16

Laser cut Wooden Ribs/Spars

- Lots of space within body and wing for electronics
- Very good structural integrity and rigidity
- Swept or tapered wings may lead to difficulty when manufacturing due to extra precision so spars can fit through all the ribs accurately
- Once the covering has been applied may be difficult to access electronics within wings and body

Plywood

Density = 650 kg/m^3
Tensile Strength = 30MPa
Cost = £5

Both designs will need some sort of covering. Two iron on adhesive films have been compared below:

Table 2. Table comparing Solarfilm and Oracover

Solarfilm	Oracover
• Iron on self adhesive plastic film. • No time needed sealing, doping, polishing, masking • No odours, spills or mess. • Will not slacken, crack or become brittle for the life of the plane. • Resists punctures and scratching. • Does not show stress-cracks like conventional finishes. • Weight = 50-68 g.s.m (grams per square metre) • Cost = £7.89 for 1.27m x 0.68m	• Polyester film based covering. • Much stronger than solarfilm. • Doesn't need re-shrinking after some time (stays the way you put it on originally) • More sensitive to scratches • Heavier than solarfilm • More expensive than solarfilm • Cost = £16.40 for 2mtr roll