FEEG1201 – Introduction to Engineering Design

Semester 2 Portfolio

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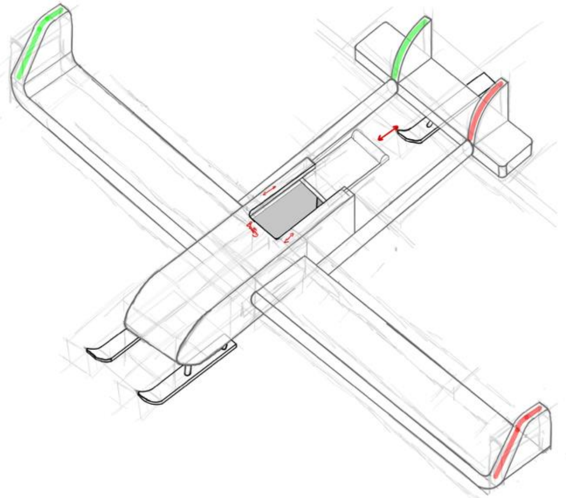
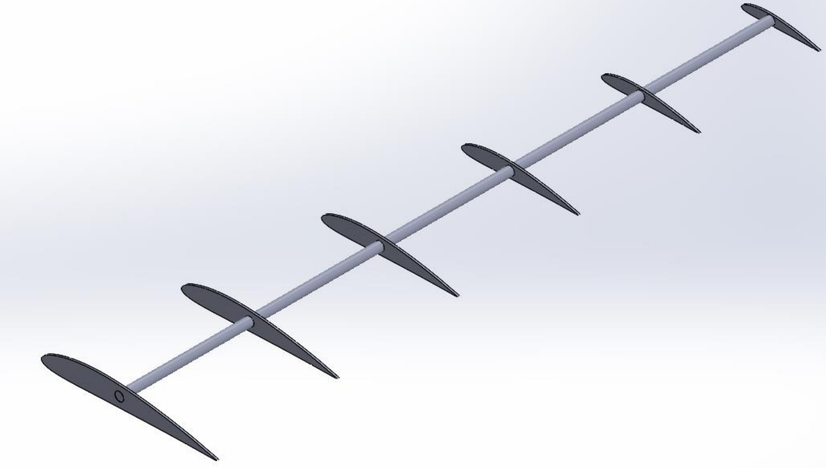
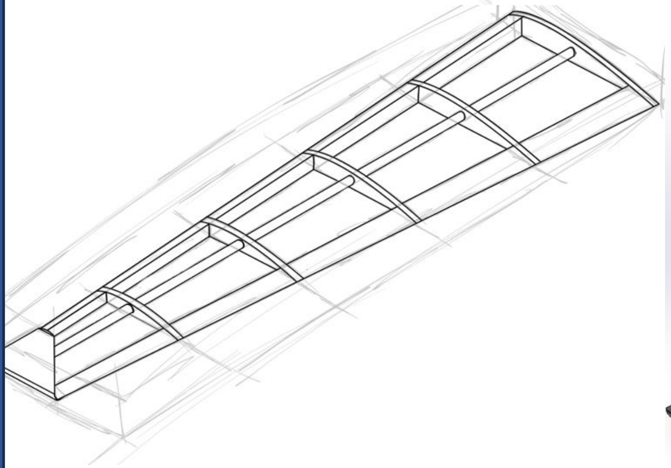
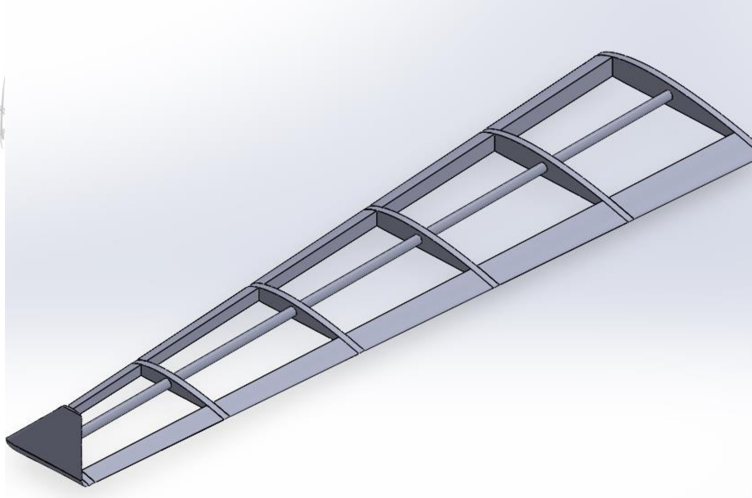
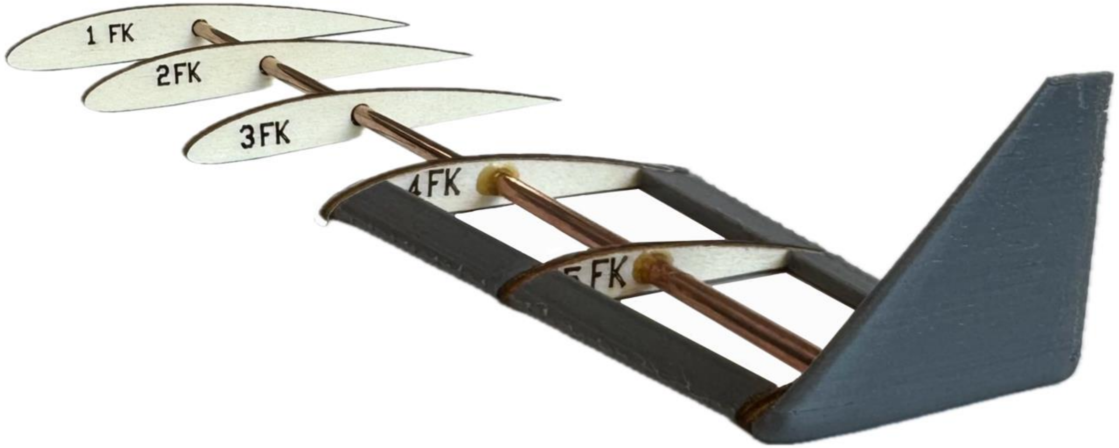
University of Southampton

Semester 2 – Long Project

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Section 2: Concept design process

- Initial sketches
- Concept selection process
- Final concept
- Section 3: Analysis of design development
- Constraint analysis
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Section 1: Design specification

Design Specification

Title: A small Unmanned Aerial Vehicle (UAV) to aid in the detection and recovery of people stuck in avalanches.

1.0 Scope

This specification relates to a small UAV which will assist in the detection of people caught in avalanches. This should prevent and reduce the number of injuries and deaths in avalanches.

2.0 Background

According to the EAWS(European Avalanche Warning System) 120 people are annually killed in avalanches in ski resorts within Europe. These are typically people engaging in extreme sports such as skiing or hiking in mountainous regions.

An avalanche is when a large mass of snow, ice and rock rapidly falls down a mountainside. This can happen naturally, typically after large snowstorms or when the weather warms, causing the snow to melt and become denser. This means that the snow can no longer support its own weight so moves down the mountain.

90% of incidents involving the death of someone in an avalanche are triggered by human error. This makes it difficult to pre-empt when an avalanche will occur.

People typically die in an avalanche due to being trapped under the snow and ice and running out of oxygen before rescue teams can find them and dig them out.

3.0 Details

3.1 Performance

3.1.1 Product must adhere to International Standards, such as the IEC

3.1.2 Product must adhere to Small Unmanned Aircraft Standards & Regulations

3.1.3 Product must be able to glide over ski resorts for several hours with minimal input or interaction with people.

3.1.4 Product must be able to monitor and detect avalanches in real time if they occur.

3.1.5 Product must be able to detect people possibly trapped under the snow.

3.1.6 Product must aid rescuers on the ground in locating the trapped persons.

3.1.7 Product must be easy to launch and recover with minimal training for operators.

3.2 Ergonomics

3.2.1 Product must be safe for people to launch without risk of injury

3.2.2 Product must have quickly interchangeable batteries which can be changed without the use of tools

3.3.3 Product should be light enough to allow one person to put it into storage.

3.3.4 Product should use contrasting colours to be visible & indicate dangerous areas such as the propeller.

3.3 Materials

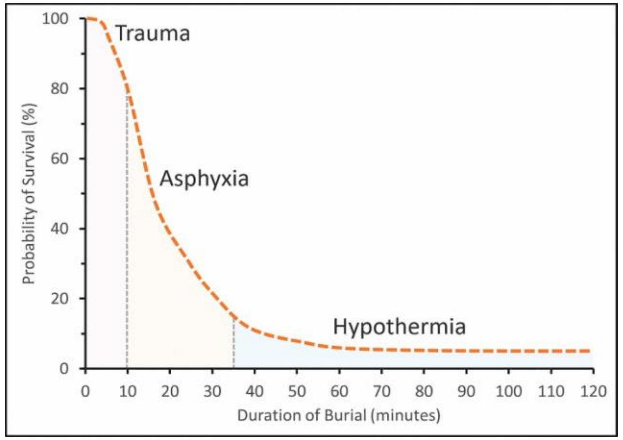
3.3.1 Materials should ideally be easily recyclable after the UAV's life in service

3.3.2 Materials should be able to withstand frigid environments and resistant to bending and tearing

Deaths caused by avalanche

Country/Year	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	Total
Andorra	1	0	0	0	0	0	0	**1**
Austria	10	22	14	14	18	15	14	**107**
Czechia	0	0	0	2	0	0	0	**2**
Finland	0	0	0	0	0	0	2	**2**
France	37	13	12	40	9	25	16	**152**
Germany	2	3	0	0	4	0	1	**10**
Iceland	0	0	1	0	1	0	0	**2**
Italy	44	15	13	25	8	24	13	**142**
Liechtenstein	0	0	0	0	0	0	0	**0**
Norway	6	13	3	9	5	8	4	**48**
Poland	0	0	0	0	2	3	2	**7**
Romania	7	3	1	0	2	1	2	**16**
Slovakia	5	4	1	2	5	4	2	**23**
Slovenia	1	0	0	3	0	0	0	**4**
Spain	4	1	1	4	2	0	2	**14**
Switzerland	27	21	7	32	14	23	20	**144**
United Kingdom	0	0	1	0	0	1	0	**2**
Total	**144**	**95**	**54**	**131**	**70**	**104**	**78**	

[Figure 1]



[Figure 2]

As this graph illustrates, locating and removing people who are stuck under the snow and ice is very time critical. For this reason, our drone will primarily aid in the location of people who are stuck. Traditionally, when an avalanche is detected, a rescue helicopter is launched. This takes a considerable amount of time which the victim may not have. Our UAV will reduce this time as it can constantly be gliding over ski resorts, monitoring for avalanches. If it detects an avalanche, a pilot can fly it remotely and closely monitor the affected area. The UAV will feature equipment to help detect people.

References:

Figure 1: https://www.avalanches.org/fatalities/fatalities-2024-25/

Figure 2: https://avalanche.ca/fr/blogs/rescue-practice-keeping-it-real

Section 1: Design specification

3.4 Safety
3.4.1 Product’s vital electronic systems should be exposed in any place on the product
3.4.2 Electronic systems that require access need to be safely sealed with components requiring a tool such as a screwdriver.
3.4.3 Any choking hazards that the product contains should not be removable.
3.4.4 Product should not contain any toxic materials considering the regular handling it requires by maintenance staff.
3.4.5 Product should have no sharp edges where lacerations could occur.

3.5 Environment
3.5.1 The product must be able to withstand temperatures of up to -20°C during operation
3.5.2 The product must be able to maintain search abilities in low visibility conditions
3.5.3 The product must be able to withstand wind speeds of up to 35 mph
3.5.4 The product must have gust handling of up to 50 mph
3.5.5 The product must contain a weatherproofing level of at least IP67
3.5.6 The product must be able to maintain a suitable battery life in cold conditions
3.5.7 The product must contain thermal insulation around critical electrical components

3.6 Manufacture
3.6.1 Electrical components should be sourced from high quality suppliers
3.6.2 Product should have a modular design for easy repair
3.6.3 Precision components should be made with CNC machining
3.6.4 Product should be made with automated assembly lines for consistency

3.7 Cost
3.7.1 The product should cost approximately £15000 to manufacture
3.7.2 The product should retail for around £25000

3.8 Aesthetics
3.8.1 The product should be made with high visibility colours such as yellow and orange
3.8.2 The product should have a matte finish to avoid high levels of glare in sunny and snowy conditions
3.8.3 The product should have an aerodynamic shape to improve wind resistance and efficiency
3.8.4 The product should contain obvious visual cues for maintenance such as battery replacement

3.9 Weight
3.9.1 Product should weigh a maximum of 10kg including any payload
3.10.1 Users of this product will likely be ski resort staff, with minimal flying experience and limited knowledge regarding payload loading restrictions
3.10.2 Users may have limited technical knowledge with regards to servicing the product as well as the systems onboard the product
3.10.3 Users of this product may not speak fluent English

3.11 Market
3.11.1 The product is aimed primarily at ski resorts, however, may also be provided to emergency and search and rescue departments
3.11.2 Must conform to EASA drone operations guidelines (Delegated Regulation (EU) 2019/945).

3.12 Size
3.12.1 Product should not occupy a volume larger than 6.33m3. This is the volume occupied by placing an average length ski (1.85m) in the x, y and z dimensions. It is reasonable to assume a ski resort will have enough volume in ski storage sheds to accommodate a UAV of this size.

3.13 Life in service
3.13.1 With Regular maintenance we would aim for a 2-year service life which is on the lower end of the normal commercial drone service life due to the harsher environment such as the cold for example.
3.13.2 Lithium batteries degrade in colder conditions so these will need replacing at 80% of its original capacity.

3.14 Disposal
3.14.1 All electric components apart from removeable parts such as batteries should be fully recyclable
3.14.2 Materials of the product should be able to be separated for proper disposal
3.14.3 Carbon fibre composite frames should be used where possible to ensure the majority of the UAV is recyclable
3.14.4 Electrical systems within the product should comply with WEEE directives
3.15 Quantity
3.15.1 There are 1154 ski resorts in the alps (skiresort.info) factoring in the larger slopes where multiple will be required as well as spares in cases of damage, we will produce 5000.
3.16 Product Life Span
3.16.1 We would have a life span of approximately 5 years

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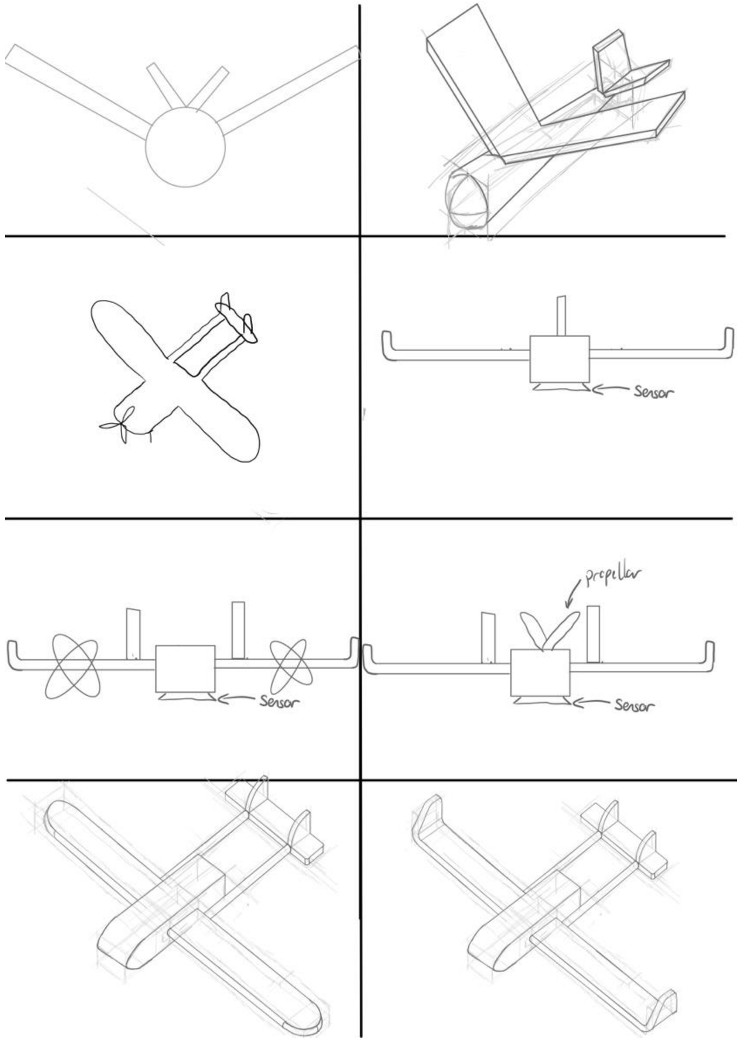
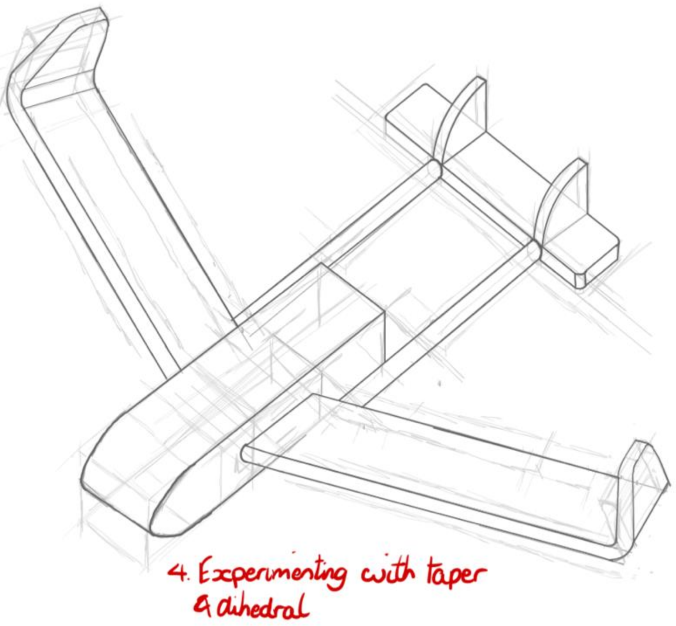
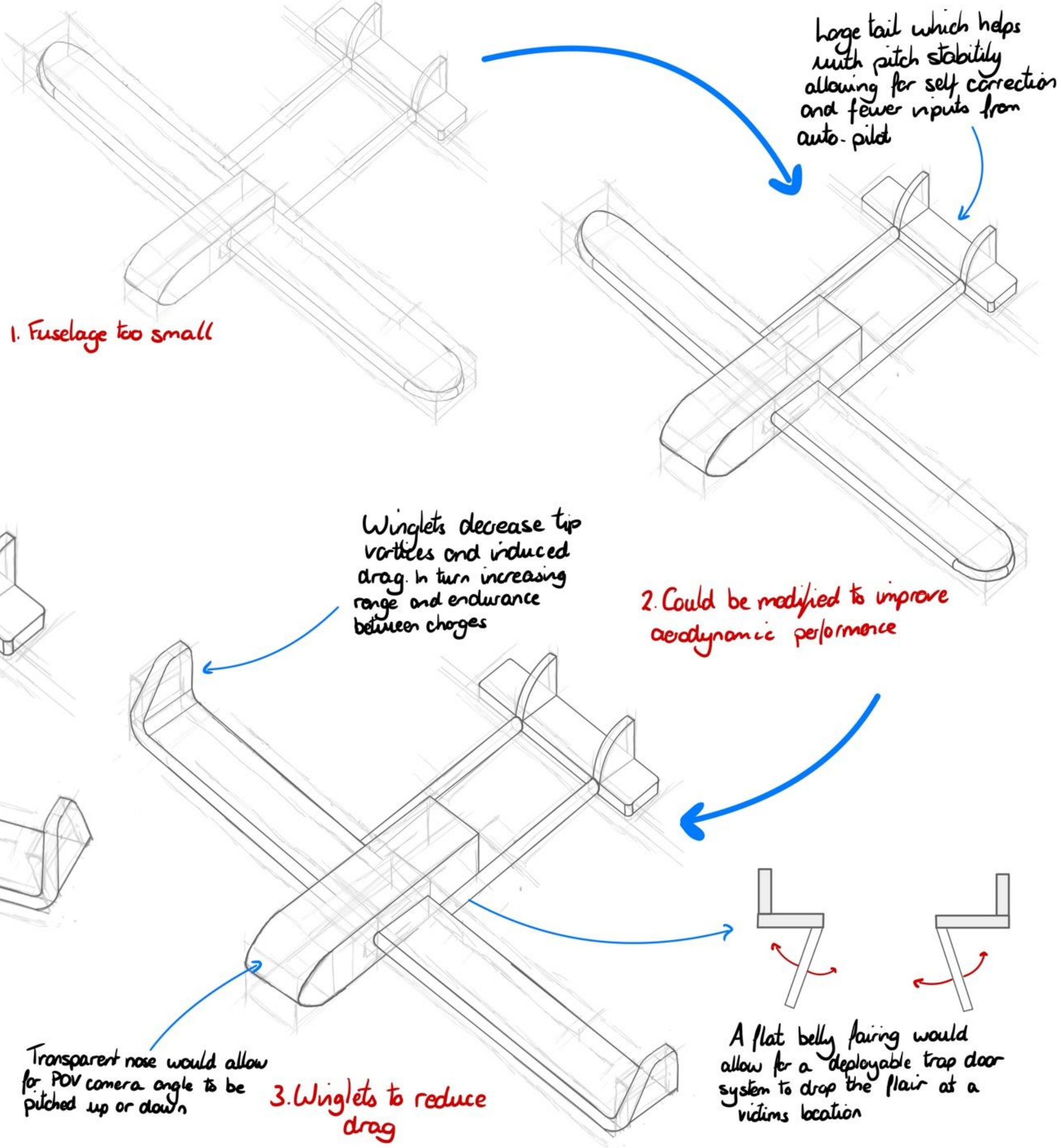
Section 2: Concept design process-Initial sketches



I used the Crazy-8 ideation process to quickly generate some initial designs. I chose the square fuselage design.





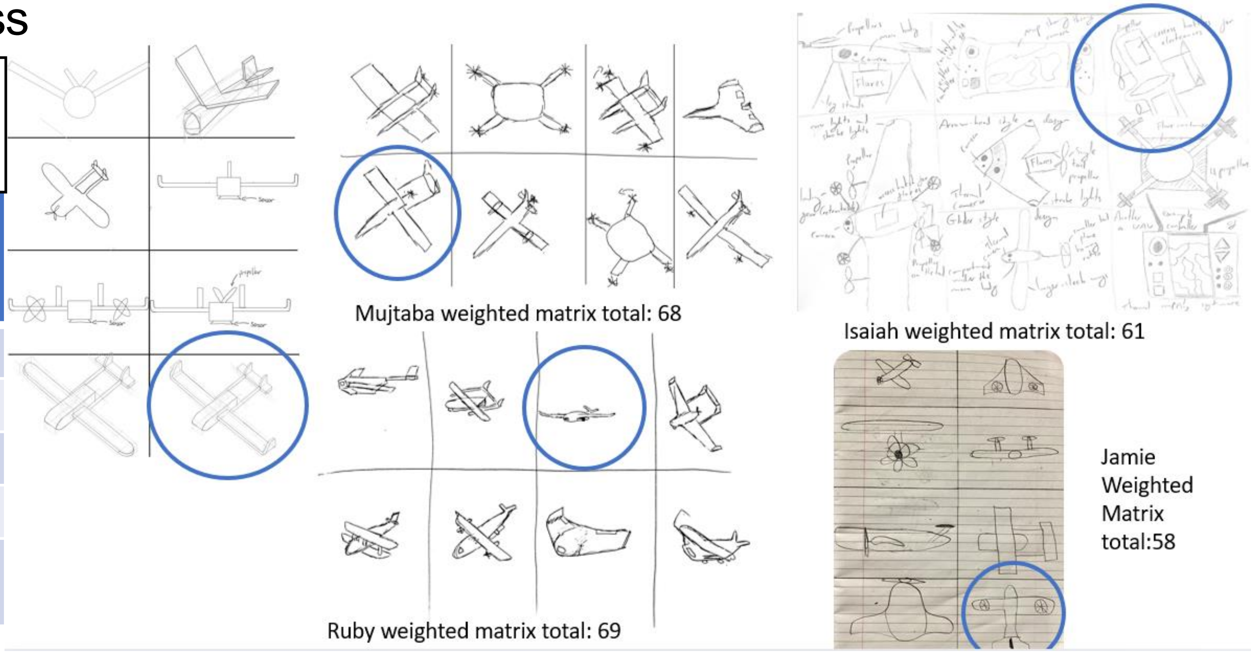
I used the Crazy-8 ideation method as it prioritises quantity over quality, as you only have 8 minutes to produce the 8 sketches. This helps one's mind produce concepts often conceived as weird or impractical, but these can later be refined into a more practical concept.

Section 2: Concept design process-Concept selection process

For the concept section process, each member of the group selected their favourite and best design from the crazy 8 process. We then used a weighted matrix to assign numerical scoring to each member's design.

	Performance 5	Environment 4	Safety 3	Manufacturing 3	Users 3	Aesthetics 2	Ranking x Weighting
Freddie	4	4	3	3.5	4	3.5	74.5
Jamie	2	3	3	2	4	4	57
Ruby	3	3	4	4	4	3	69
Isaiah	4	3	3	2	3	3	61
Mujtaba	4	3	3	3	4	3	68

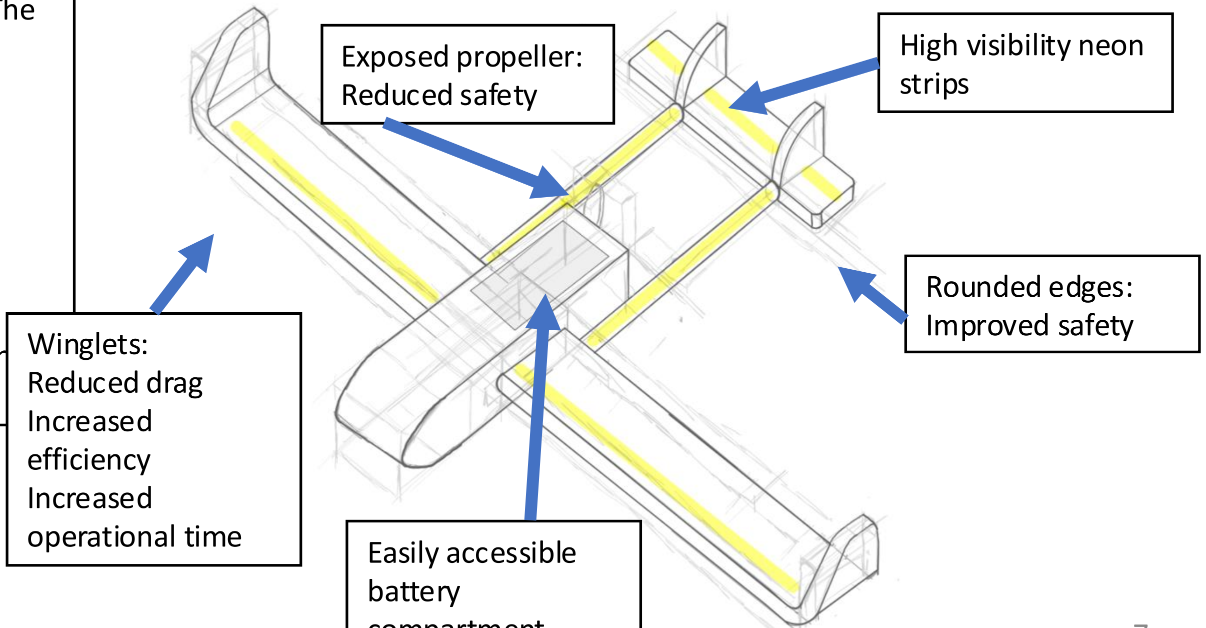
[Figure 3] Weighted matrix from group design stage



We used a scoring process ranging from 0 to 5, with 0 being the worst and 5 being the best. The first step with this was deciding the weighting of each factor. We decided to use the specification points we deemed most important and ranked them accordingly.

Because of the purpose of our UAV, we decided that performance was the most important factor. Our UAV must be able to perform perfectly in order to help save lives. Environment followed second as our UAV will be operating at extreme altitude and temperature, so it is extremely important that our design caters for this.

As a group, we then scored each design out of 5 for each of the factors. Once we had done th we added up the rankings multiplied by the weightings, to get a final score out of 100.

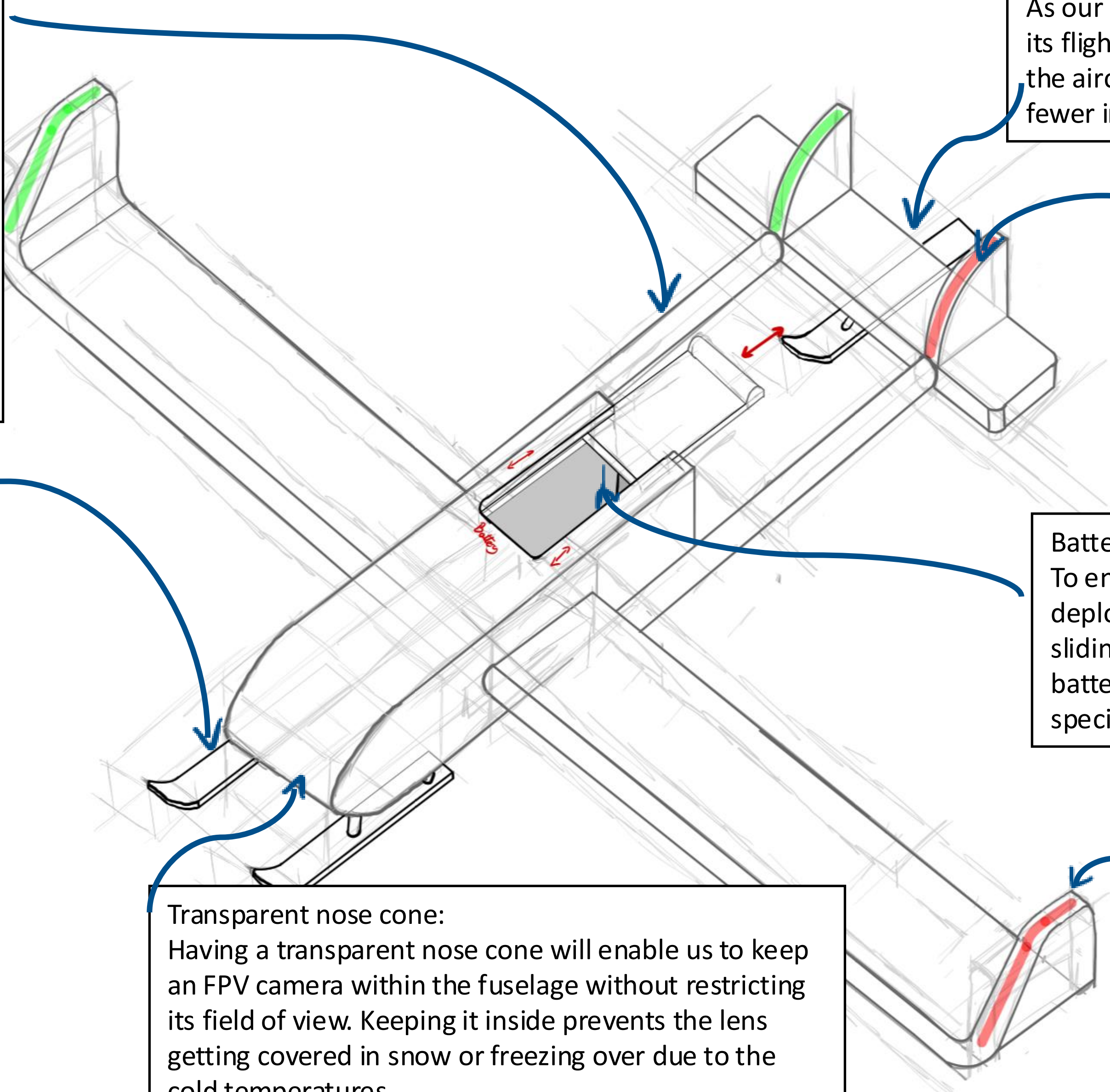


[Final group design]

Section 2: Concept design process-Final concept

After getting a rough design of what the UAV looked like I decided to use elements of the design specification to try and enhance it.

Carbon Fibre rods:
Using carbon fibre rods to attach the tail has several advantages. For a start it has a very high strength to weight ratio, which is critical when designing our UAV as it will help decrease the weight of the aircraft, making it more manoeuvrable . The hollow-tube design also allows us to run wires from the main body to the tail. These will power lights and servos to operate the control surfaces.



As our UAV will be flown by autopilot for the majority of its flight time it will feature a large tail to help increase the aircrafts stability and ability to self-correct. Meaning fewer inputs are required from the autopilot.

High-visibility lights:
These lights help achieve both 3.1.2 and 3.8.1. They are crucial to adhering to small UAV regulations as they ensure other aircraft can easily see and identify the UAV when it is in flight. It also increases visibility in landing and take-off conditions, such as thick cloud.

Landing gear:
As our UAV is going to operate in ski resorts, it needs to be easy to launch and recover (3.1.7) it makes sense for it to utilise skis for its landing gear. This will mean it can be launched from the pistes or surrounding areas without a tarmac area which would be required if it had wheels.

Battery compartment:
To ensure the product has minimal down-time between deployments and to adhere to 3.2.2. I have added this sliding cover to the battery compartment, this will mean batteries can quickly be swapped without the need of any specialist tools.

Transparent nose cone:
Having a transparent nose cone will enable us to keep an FPV camera within the fuselage without restricting its field of view. Keeping it inside prevents the lens getting covered in snow or freezing over due to the cold temperatures

Winglets:
Winglets are a common sight on modern gliders and aircraft as they reduce the wingtip vortices. In turn this reduces the induced drag the aircraft experiences so will increase our lift to drag ratio. Which will result in a greater efficiency & operational time between charges.

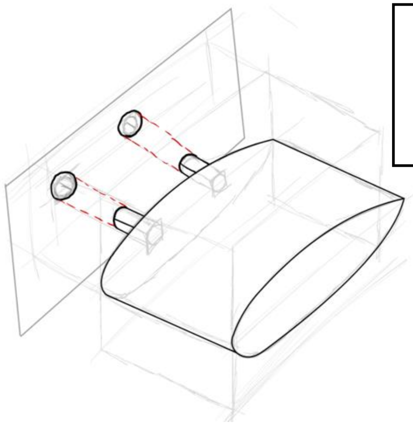
Section 3: Analysis of design development-Constraint analysis

Before moving on to the design of my wing, I used the pre-determined constraints to calculate the key values of the wing such as the area.

Given Values	Symbol	Value	Unit
Maximum UAV mass	W	10	kg
Cruise Speed	V_c	20	m/s
Stall Speed	V_s	10	m/s
Maximum Speed	V_{max}	24	m/s
Maximum Positive Load factor	n_{max}	2	
Maximum lift coefficient	Cl_{max}	2	

After calculating this wingspan, I knew that there would be a conflict with our design specification constraint. In point 3.12.1 we had agreed on a maximum span of 1.85m. The issue with this value, is a wing of this span would have a very large aspect ratio and would therefore have significant profile drag so would not be able to achieve a high lift to drag ratio.

To adhere to the size constraint, the wings of the aircraft could always be removed. This would allow for a wingspan of 3.7m as each side of the wing could be detached and stored separately.



By using 2 pins fixed into the wing, they could be slotted into the fuselage therefore making them detachable.

Using the given values, we can find the minimum wing area by using the Cl_{max} as a constraint. During cruise, the Lift = Weight. We can use this to solve for a minimum wing area *S*. We use the V_s as this is when Cl will be 2.

$$L = \frac{1}{2}\rho V^2 S C_{L\ Max}$$

This can be rearranged to:

$$S = \frac{2L}{\rho V^2 C_{L\ Max}}$$

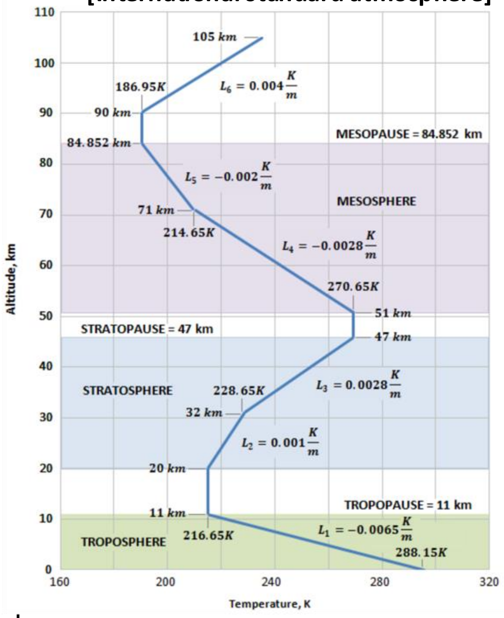
Before we can solve this, we must also consider that our UAV operates in extreme conditions and at high altitude. Ski resorts tend to be situated at an altitude of 2000-3000m, so we need an operational altitude of up to 3000m.

Using this altitude, we can use the international standard atmosphere to calculate a temperature of 262.15K and an air density of 0.819/m^3.

$$S = \frac{2\times10\times9.81}{0.917\times10^2\times2} = 1.07m^2$$

The stall velocity *Vs* Is used here as that is when Cl_{max} will occur.

[International standard atmosphere]



[Calculating air temperature]

$$T = T_0 + L\cdot h$$

Altitude

Lapse rate

$$288.15 - (0.0065\times3000) = 268.65K$$

[Calculating air pressure]

$$p = p_0 \times \left(\frac{T}{T_0}\right)^{\frac{-g}{R\cdot L}}$$

$$101325\times\left(\frac{268.75}{288.15}\right)^{\frac{9.81}{287\cdot0.0065}} = 70232Pa$$

[Calculating air density ρ]

$$\rho = \frac{p}{RT}$$

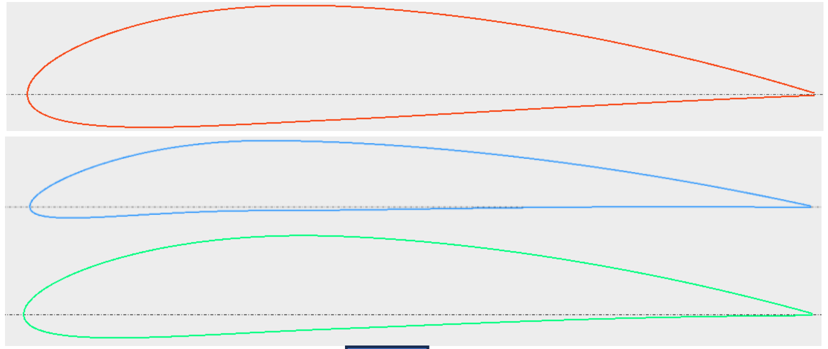
$$\frac{70232}{287\times268.75} = 0.917k\ g/m^3$$

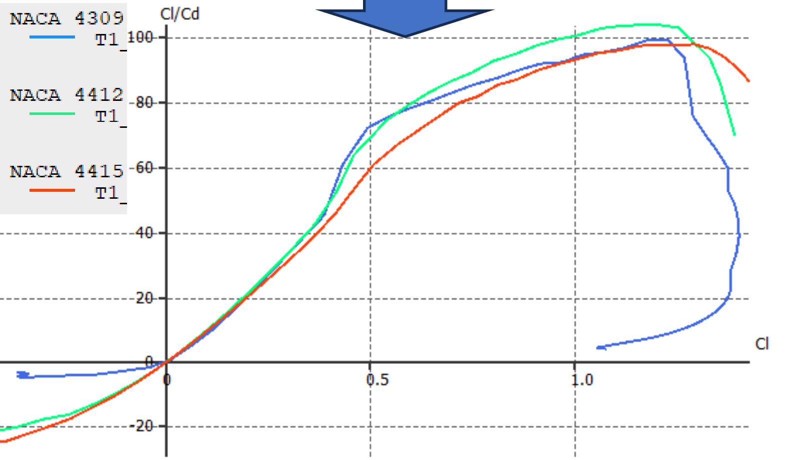
References:
International standard atmosphere diagram: https://agodemar.github.io/FlightMechanics4Pilots/mypages/international-standard-atmosphere/

Section 3:Aerofoil analysis & basic wing design

To start my design of the wing I first needed to consider the aerofoil I would use. I decided to use a NACA 4-digit foil as these are easy to integrate into XFLR5 and cover most bases for aerofoil design.
I asked an AI model to provide me with some commonly used foils which provide high L/D ratios. The 3 different foils suggested were 4412, 4415 and 4309. These foils all had their own advantages & disadvantages. The 4309 provided a smaller cross section, which doesn't allow for a large spar which would ultimately increase deflection. I tested all 3 foils under fixed velocity conditions of 20m/s and varied the angle of attack.

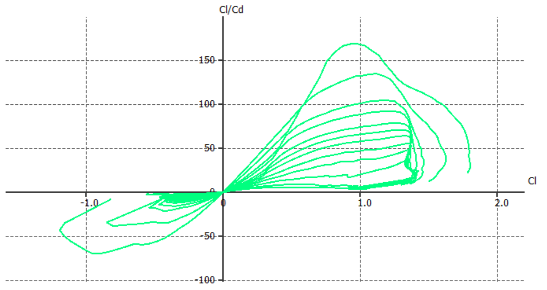
[Shape of different NACA Foils]

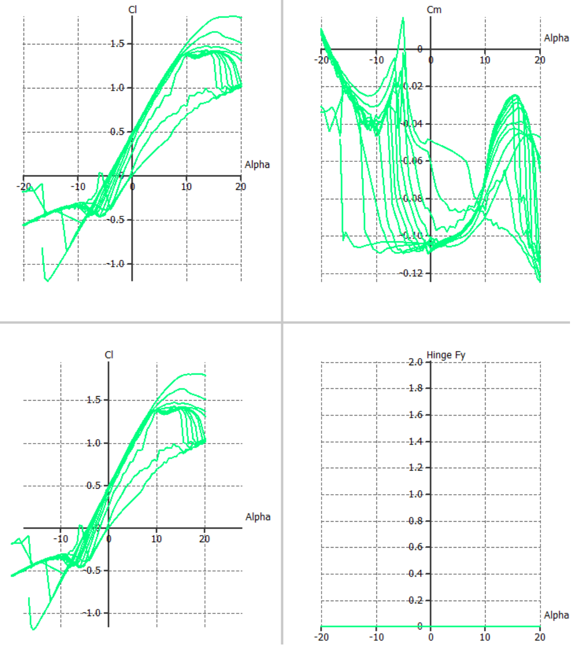




[Graph analysing aerofoil performance]

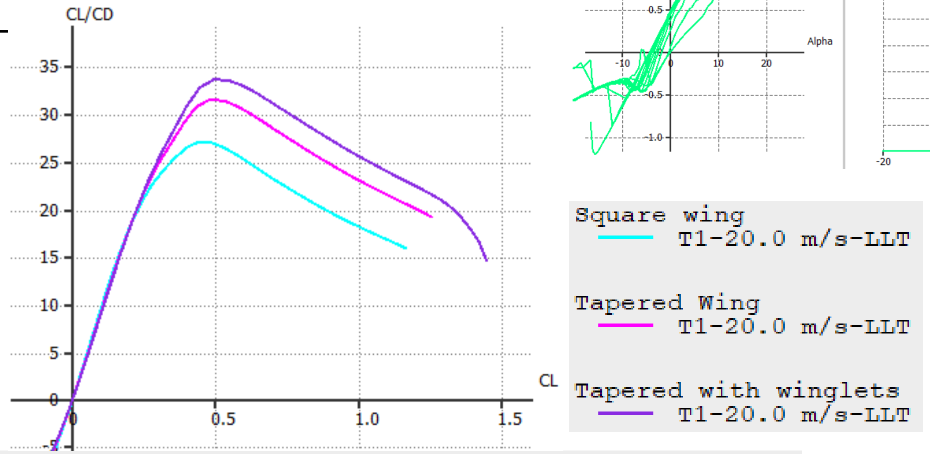
After choosing to use the NACA4412, I performed a batch analysis on the foil at different Reynolds numbers. This allowed me to move onto the wing & plane analysis.



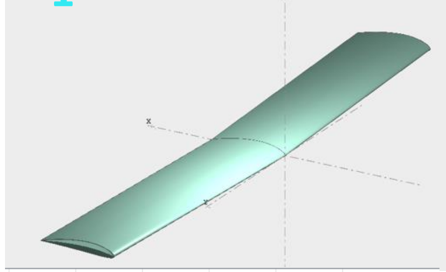


I started off with wing 1. This was a simple rectangular wing; it had a max Cl/Cd of 27. Using knowledge I'd learnt in the SESA1015 module, I started making different iterations, first making the wing tapered and reducing the aspect ratio. Because of this I had to increase the span to ensure the minimum wetted area was maintained. This increased the Cl/Cd to 32.

I also experimented with adding winglets, which proved very affective, increasing Cl/Cd to 34. I then continued to iterate this wing to try and get the best Cl/Cd, ensuring to maintain a wetted area of at least 1.07 m^2.

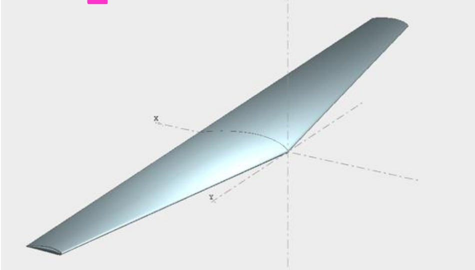


1



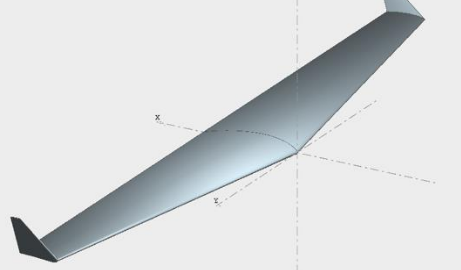
y ()	chord ()	offset ()	lihedral(°	twist(°)	foil
0.000	0.360	0.000	0.0	0.00	NACA 4412
1.500	0.360	0.070		0.00	NACA 4412

2



	y ()	chord ()	offset ()	lihedral(°	twist(°)	foil
1	0.000	0.500	0.000	0.0	0.00	NACA 4412
2	1.700	0.200	0.300		0.00	NACA 4412

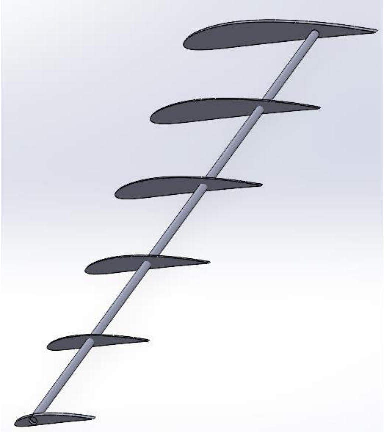
3

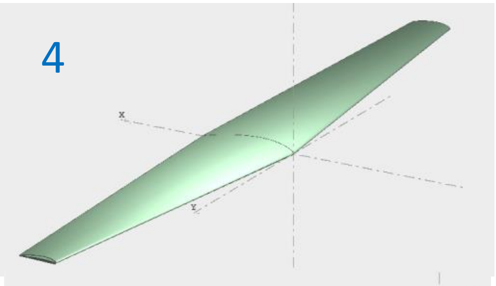


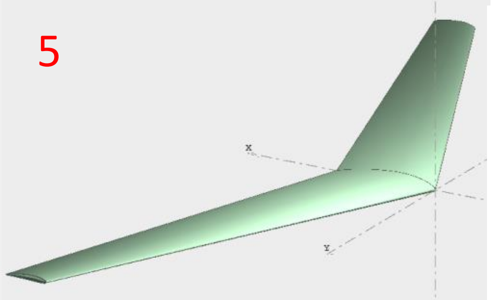
	y ()	chord ()	offset ()	lihedral(°	twist(°)	foil
1	0.000	0.450	0.000	0.0	0.00	NACA 4412
2	1.700	0.185	0.265	90.0	0.00	NACA 4412
3	1.850	0.050	0.400		0.00	NACA 4412

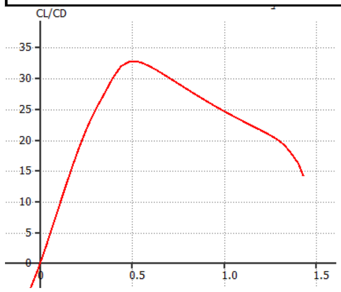
Section 3: Analysis of design development – wing performance

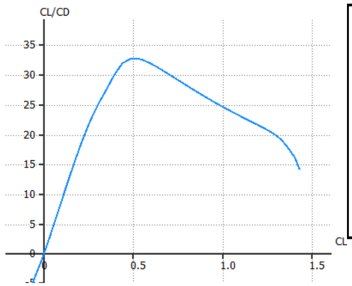
Originally, I planned on using a design like this. It had a relatively large offset which resulted in a straight trailing edge. However, when I came to model this in CAD, I realised it makes fitting a spar very difficult, as illustrated.
The small chord of the outer edge of the wing meant I could only fit a spar with a height or diameter of 18mm. This spar did not align centrally with many of the ribs, meaning an additional one would have been required to resist twisting of the wing. I was keen to avoid this as it would add complexities to both the deflection testing but also to the manufacturing processes, should this wing be put into production.
Because of this, I experimented with increasing the outer edge chord, therefore increasing its thickness. Because of this, I had to decrease the span to make sure the area was still roughly1.07m^3.
However, this decreased my L/D ratio quite drastically.
I then tried decreasing the offset and taper of the wing. This would eliminate the need for 2 spars as the spar could run through a more central position of each rib.
I did this by creating 2 wings with the same span, centre chord and outer chord.





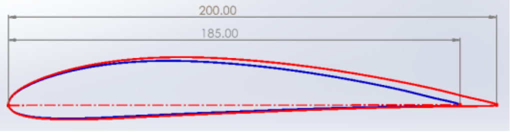


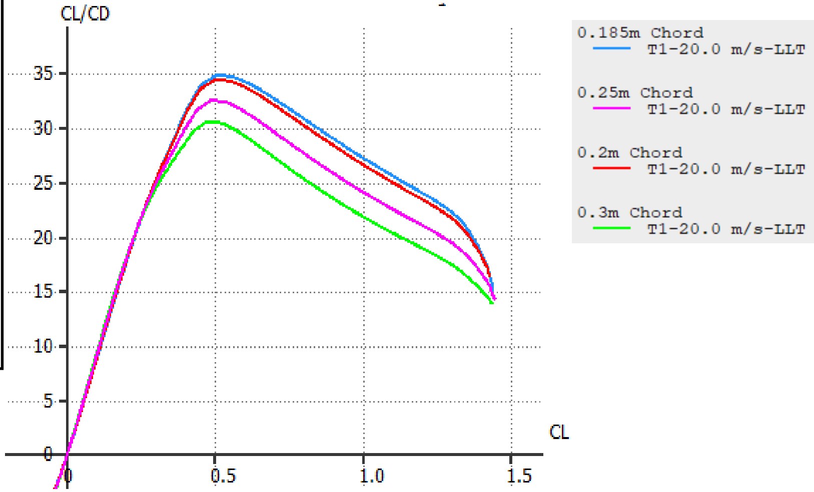


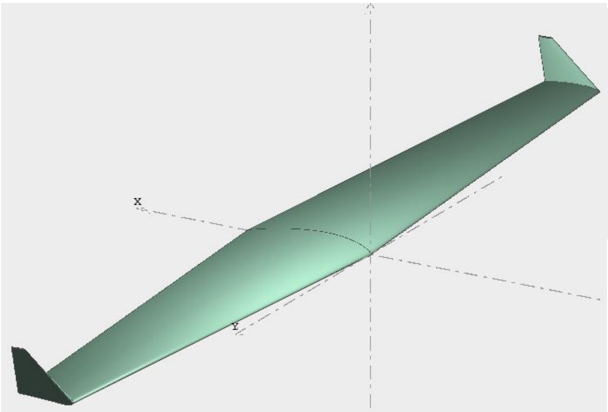


As you can see from these graphs, the taper of the wing was independent from the L/D ratio, even at an extreme offset of 700mm the Cl/Cd ratio was the same.

After solving the issue with the taper. I also wanted to see the impact of changing the outer chord. To do this, I left the root chord constant at 0.450m and changed the span and outer chord to keep the wetted area constant.
As you can see, changing the outer chord & therefore the aspect ratio has quite drastic implications on the Cl/Cd. Because of this, I will instead only marginally increase the chord from 0.185m to 0.200m. This increases the area to fix a spar to.



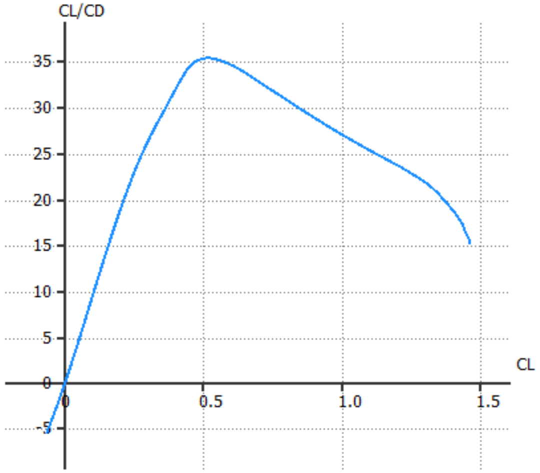




```
Plane Name
Wing Span      =      3.650 m
xyProj. Span   =      3.350 m
Wing Area      =      1.126 m²
xyProj. Area   =      1.089 m²
Plane Mass     =      0.000 kg
Wing Load      =      0.000 kg/m²
Root Chord     =      0.450 m
MAC            =      0.334 m
TipTwist       =      0.000°
Aspect Ratio   =     11.829
Taper Ratio    =      0.111
Root-Tip Sweep =      6.254°
XNP = d(XCp.Cl)/dCl =      0.118 m
Mesh elements  =    572
```

	y ()	chord ()	offset ()	lihedral(°	twist(°)	foil
1	0.000	0.450	0.000	0.0	0.00	NACA 4412
2	1.675	0.200	0.125	90.0	0.00	NACA 4412
3	1.825	0.050	0.275		0.00	NACA 4412

This was my final wing design. As you can see, it had a projected span of 3.350m, a root and tip chord of 0.45m and 0.2m, and winglets of length 0.15m at an angle of 90 degrees.
This wing gave me a high L/D ratio of nearly 35 at cruise velocity making it optimal for the endurance requirements for the drone to constantly monitor the ski resort.



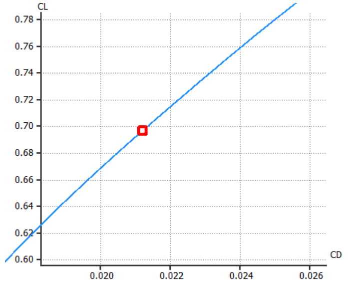
Section 3: Analysis of design development-Deflection Analysis

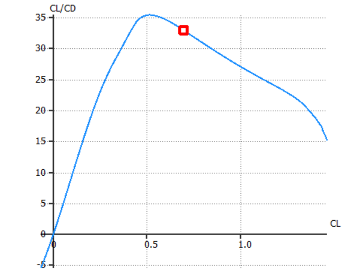
The next step in the process was to design the structure of the wing. As previously mentioned, I was going to use a design featuring a central spar connecting all the ribs together. I decided to first test with aluminium as this would be much cheaper than carbon fibre or other materials but still has a high strength to weight ratio.

I now moved onto the structural analysis with python.

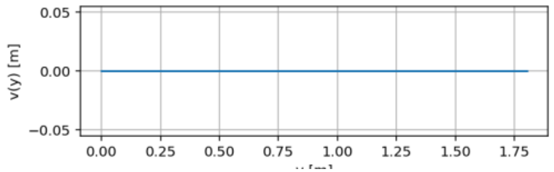
Before I could start the analysis, I needed to set the inertia of my aircraft and calculate the Cl of my wing during a turn. As my UAV will have a mass of 10kg and must be able to withstand a load factor of 2 I modelled the inertia in XFLR5 as 20kg . Because I am testing at the extreme conditions the UAV will encounter, I will run my test at a velocity of 24m/s. Using this formula, I could calculate a Cl of 0.688. I then exported the data from this point in XFLR5.

$$Cl_{turn} = \frac{nmg}{0.5\rho v_{max}^2 S}$$





The supplied code for python needed some adjustment to work with my data. I was initially getting flat graphs reporting 0 deflection and an index error 'IndexError: index 19 is out of bounds for axis 0 with size 19'

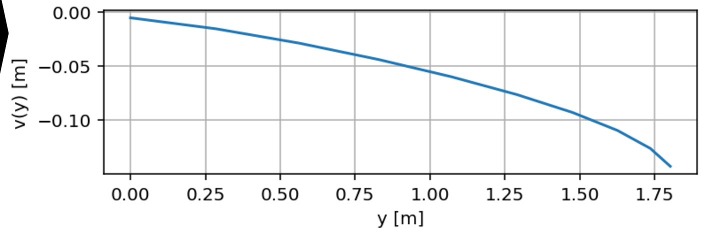


As I had less lines of data from XFLR5 than the example table, I had to change the point at which the y=0 value was chosen from by python. This was easily done by changing the value of M from 19 to 9.

```
# Cut away data on left wing and insert a point at y=0
M = 10
y_span_right = np.insert(y_span[M:], 0, 0)
BM_right = np.insert(BM[M:], 0, BM[M])
```

After adjusting this line of code. I checked to see that python was able to read the correct bending moments from the table. After doing this I was then getting the correct graphs. Because I was planning on using a cylindrical spar, I had to adjust the code to use the correct second moment of area formula for a circle. I also had to use the 'import math' function to allow for the use of Pi.

```
# Material properties and cross-section parameters
E_wing = 72 * 10**9   # [Pa] Elastic modulus of the spar material
d_wing = 0.022
  # [m] diameter of the circular cross-section
I_wing = (math.pi*(d_wing**4)) / 64   # [m^4] Second moment of area for a circular
```



This graph gave me the deflection of the wing in metres, I could use this however I couldn't accurately read the final deflection.

I decided to change the code, so my graph plotted the deflection as a percentage of the half span. This would make it clearer to see if the deflection was <10%. To allow me to optimise the diameter as much as possible, I also asked for the deflection to be returned as a number as the scale on the graphs wasn't very accurate.

```
plt.subplot(211)
plt.plot(y_span_right, (v/1.675)*100)
plt.grid(True)
plt.xlabel("y [m]")
plt.ylabel("%v(y) [%y]")
```

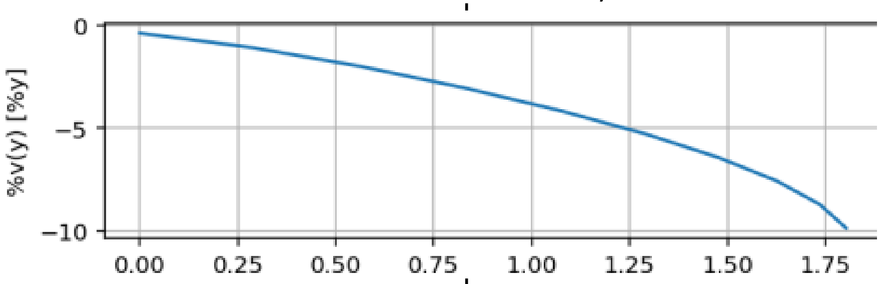
```
plt.show()
print("Deflection (m):")
print(v)
print("Deflection (%):")
print((v/1.675)*100)
```

$$I_{zz} = \frac{\pi d^4}{64}$$

[Second moment of area for a circle]

$$\frac{3.350m}{2} * 0.1 = 0.1675m$$

[Maximum allowable deflection]




```
Deflection (m):
[-0.00590938 -0.01772815 -0.03320945 -0.05077298 -0.0693956  -0.08848029
 -0.10772498 -0.12700718 -0.14629355 -0.16557988]
Deflection (%):
[-0.35279903 -1.05839709 -1.98265396 -3.03122257 -4.14302095 -5.28240508
 -6.43134233 -7.58251805 -8.7339419  -9.88536574]
```

[Engineer's bending equation]

$$\sigma = \frac{My}{I}$$

$$= \frac{77.8192 \times 0.0106}{\frac{\pi \times 0.0212^4}{64}}$$

=83.19x10⁶Pa

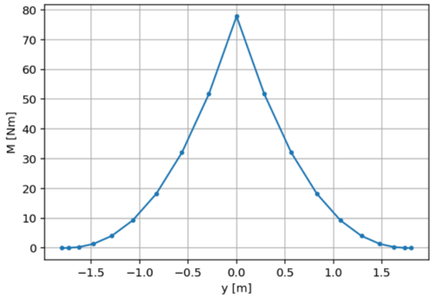
To minimise the weight of my spar, I used an iterative approach. I minimised my value of **d** until I got a deflection of just less than 10%. This gave me a final spar diameter of 21.2mm.

The final step was to make sure my wing would not exceed the UTS of the aluminium. To do this I could simply use the engineer's bending equation and the maximum bending moment outputted by XFLR5

BM
0.0000
0.0364
0.3284
1.4015
4.0470
9.2762
18.2373
32.0786
51.7578
77.8192
51.7578
32.0786
18.2373
9.2762
4.0470
1.4015
0.3284
0.0364
0.0000

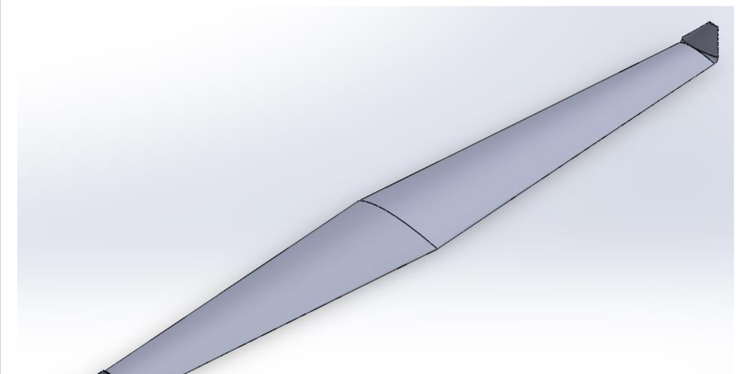
Adding in a safety factor of 1.2, gave me a UTS of 99.83x10⁶Pa.

After doing some research I found the UTS of Aluminium2024 (an aerospace grade aluminium) to be 469MPa so my spar would be perfectly fine.



Reference: Aluminium UTS: https://asm.matweb.com/search/specificmaterial.asp?bassnum=ma2024t4

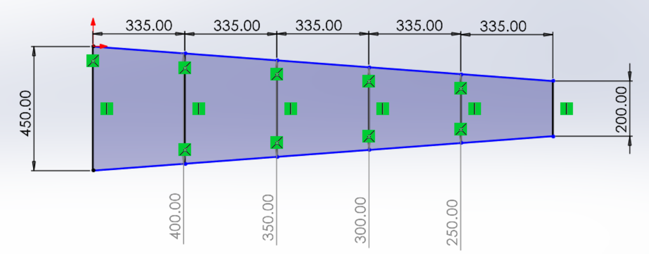
Section 3: CAD development



[Solid Wing Design]

This was the final design of my wing, modelled in SolidWorks.

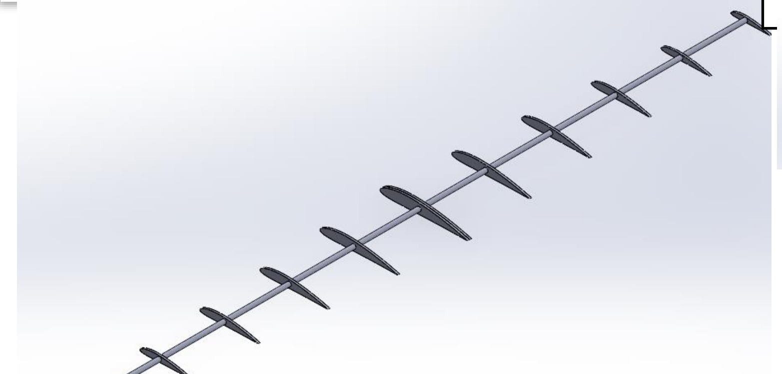
I had originally planned to have my spar run through the half chord point of each rib. However, when I modelled this in SolidWorks, I realised this would leave very little material between the edge of the rib and the spar. To overcome this, I slid the centre point of the spar forward by 25mm as the thickness of the rib was larger here.



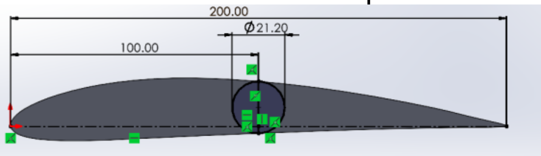
[Rib dimensions & layout]

I used this quick sketch, done in SolidWorks, to get the chord length for each of my ribs.

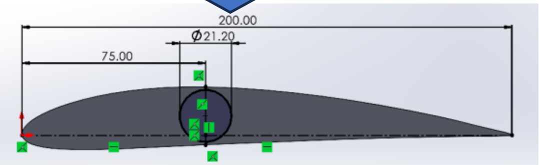
To make this SolidWorks model, I followed YouTube videos. First exporting my NACA foil as coordinates and importing this as a curve to SolidWorks. From here I made different models increasing in complexity. Starting with just ribs and a spar and then adding a leading and trailing edge and finally adding my winglets.

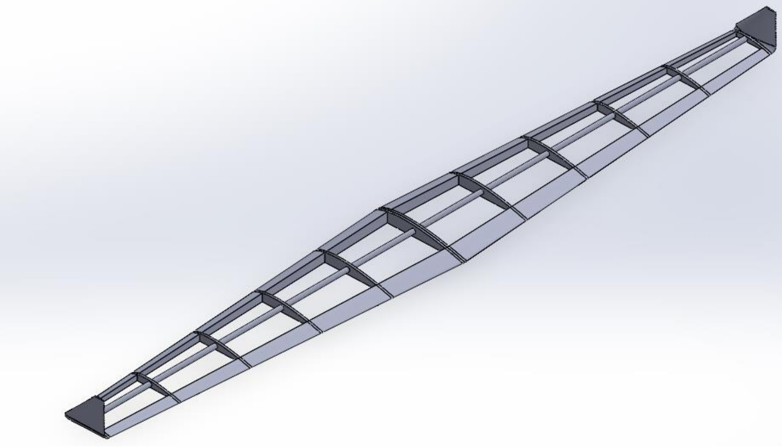


[Spar & Rib structure]



[Change in spar location]

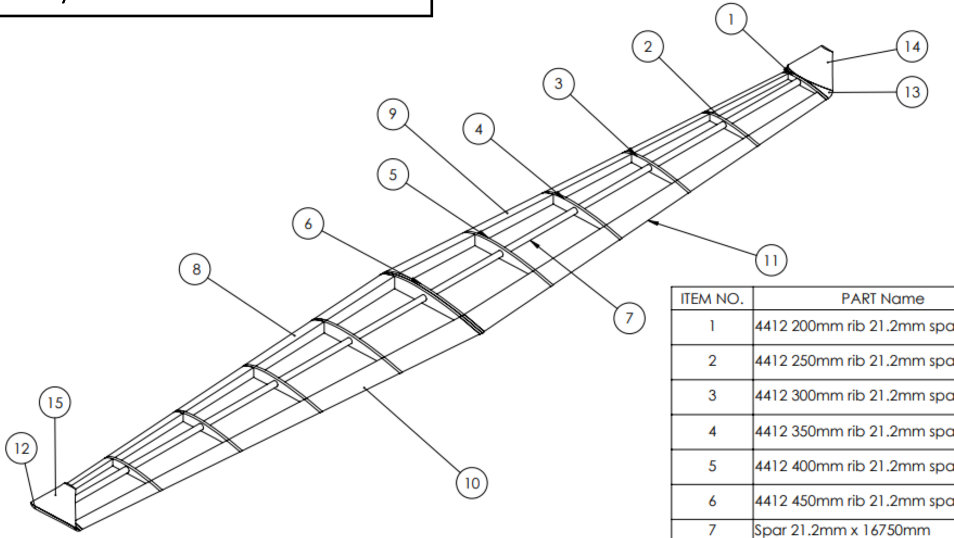




[Spar & Rib structure with leading & trailing edges]

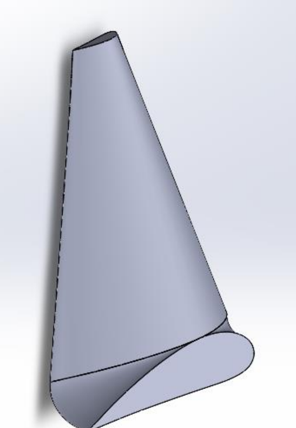
This is a CAD model of the scale model I intend to make. I had decided to use a scale of 0.2 as this would give me a scale span of 335mm which fits the 400mm maximum size.(This later changed to 200mm as explained on page 15)

I had originally planned to make the winglet, leading edge & trailing edge art by using the SolidWorks slicing feature to cut these into several thicknesses of 3mm. These could then be cut out on the laser cutter, glued together to form the rough shape and then sanded to get the rounded effect of the foil. Unfortunately, due to an injury I wasn't able to do this process. Instead, I decided to 3D print these parts.



ITEM NO.	PART Name	QTY.
1	4412 200mm rib 21.2mm spar	2
2	4412 250mm rib 21.2mm spar	2
3	4412 300mm rib 21.2mm spar	2
4	4412 350mm rib 21.2mm spar	2
5	4412 400mm rib 21.2mm spar	2
6	4412 450mm rib 21.2mm spar	2
7	Spar 21.2mm x 16750mm	2
8	Leading Edge-Left	1
9	Leading Edge-Right	1
10	Trailing Edge-Left	1
11	Trailing Edge-Right	1
12	Winglet Angle-Left	1
13	Winglet Angle-Right	1
14	Winglet Tip-Right	1
15	Winglet Tip-Left	1

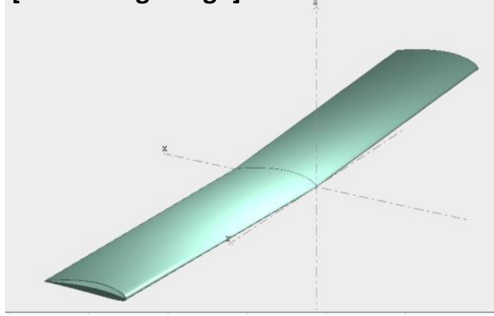
[Assembly drawing of wing]



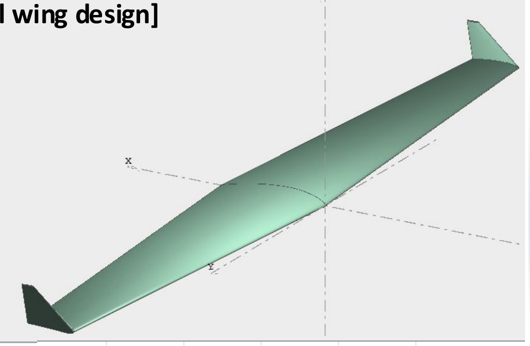
[Left Winglet]

Section 4: Final iteration of design

[Initial wing design]



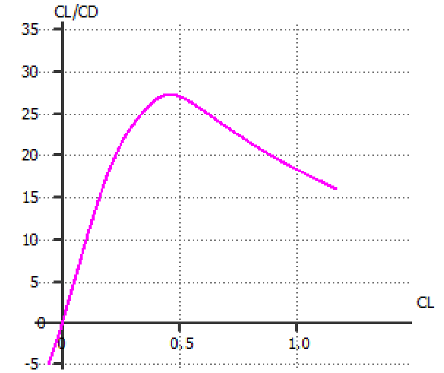
[Final wing design]

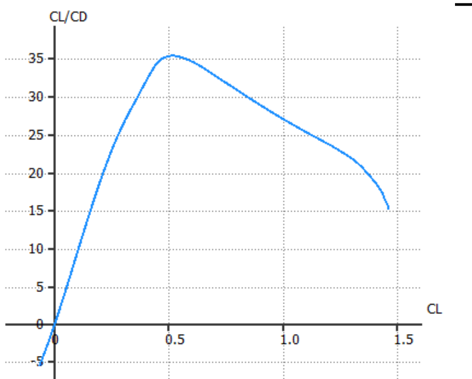


y ()	chord ()	offset ()	lihedral(°	twist(°)	foil
0.000	0.360	0.000	0.0	0.00	NACA 4412
1.500	0.360	0.070		0.00	NACA 4412

y ()	chord ()	offset ()	lihedral(°	twist(°)	foil
0.000	0.450	0.000	0.0	0.00	NACA 4412
1.675	0.200	0.125	90.0	0.00	NACA 4412
1.825	0.050	0.275		0.00	NACA 4412

These are my initial and final wing designs. As you can see there are few similarities between them. They both utilise the NACA4412 aerofoil and have the same wetted area, but they have very different performance characteristics. With the final wing having a lift to drag ratio of 35 compared to the initial 27.

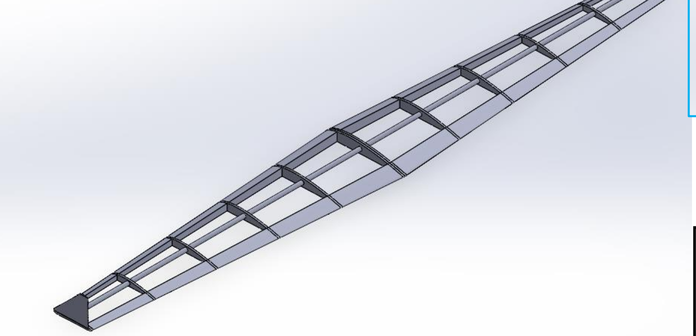




This high lift to drag ratio means our UAV can cruise around the mountain range using minimal power. This means the UAV can monitor for avalanches for hours with minimal downtime.

Having the offset of 125mm means the wetted area of the wing is symmetrical about the half chord point so the spar can run straight through the thickest part of the wing.

[Final wing structure]

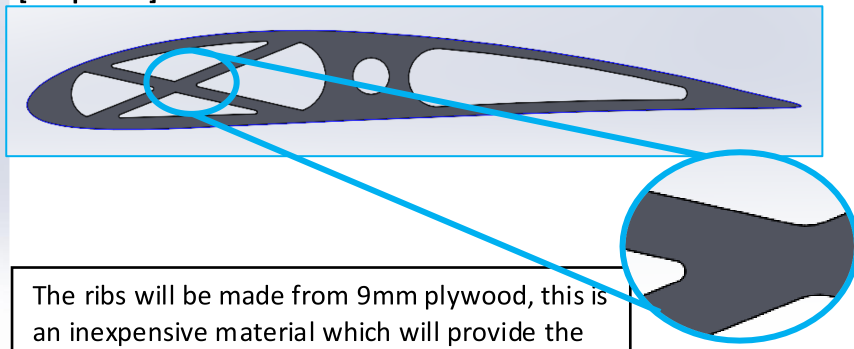


For the spar, the wing uses an aluminium rod with a diameter of 21.2mm. This gives a deflection of 9.89% of the half-span, resulting in it being as light as possible whilst still abiding by the constraint. Carbon fibre was another option for the spar as it has a much larger strength to weight ratio however its price compared to aluminium was hard to justify when I could make aluminium work.

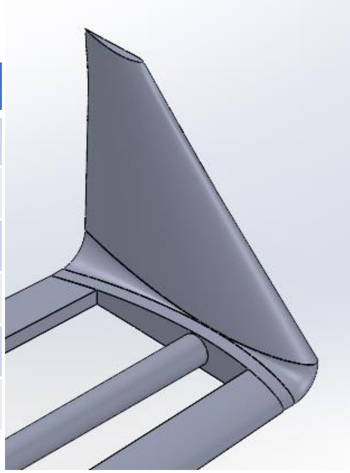
[Final wing geometry]

Dimension	Value
Projected Span	3.350 m
Projected Area	1.089 m^2
Root Chord	0.45 m
Aspect Ratio	11.829
Taper Ratio	0.111
Tip Chord	0.2 m

[Rib profile]

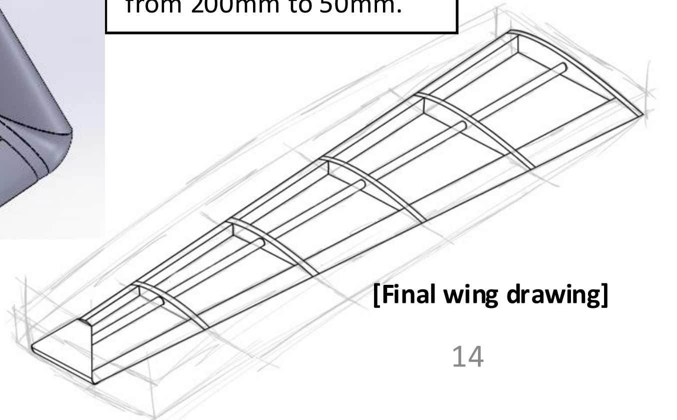


The ribs will be made from 9mm plywood, this is an inexpensive material which will provide the necessary strength requirements. The ribs can then easily be cut using a CNC router or laser cutter. There will be 11 ribs in total, with a spacing of 335mm(centre to centre) To reduce the weight of the UAV, the ribs will feature weight-saving cutouts. To remove stress concentration points, which may lead to failure of the rib, all the corners must be filleted.



[Winglet]

My final wing also uses winglets to decrease the profile drag, increasing the lift to drag ratio. These are at an angle of 90 degrees and taper from 200mm to 50mm.



[Final wing drawing]

Section 5:Physical modelling

For my physical model I first needed to find a suitable scale. I knew the maximum spar length could be 200mm for the half wing. With uniform scaling, this could be a scale of $\frac{200}{1675} \approx 0.1$ The problem with this scale is it would mean my end rib would only have a chord of 15mm, and the thickness would make it very difficult to attach the spar. Because of this I decided to opt for non-uniform scaling and scale the ribs by a factor of 0.2. I could also scale down the spar diameter by this factor giving me a scale diameter of 4.24mm.I decided to use the 3.2mm aluminium bar available as this would give a close representation of how my model would look.

Materials used:

- 3mm poplar laser ply
- 3.2mm⌀ aluminium rod
- Araldite 10-minute epoxy
- PLA 3D Printer filament
- Loctite superglue

Tools used:

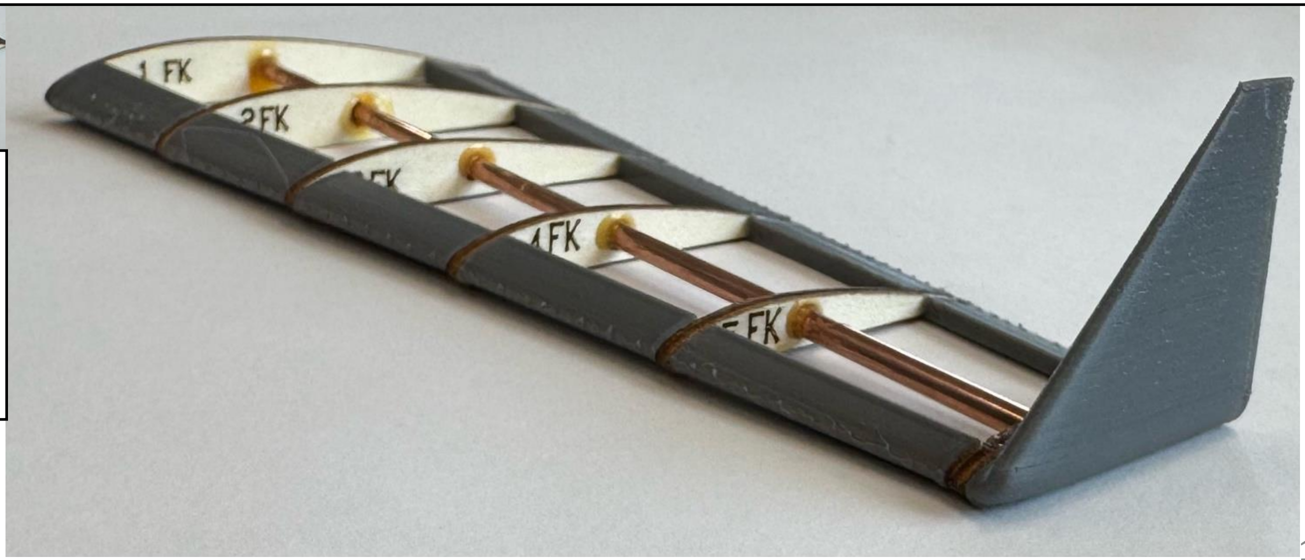
- Laser cutter
- 3D printer
- Hacksaw
- File
- Clamp
- Ruler
- Sharpie marker

Procedure

1. I first exported my SolidWorks drawing as a DXF file. This could then be imported into the laser cutter software. I also added numbers to each rib to ensure I had them in the correct order
2. I could then cut out my ribs using the laser cutter.
3. 3 using the hacksaw I could cut down the aluminium rod to the required 200mm
4. Using the ruler and a sharpie marker I drew small lines every 40mm along the rod.
5. I then mixed a small amount of the 10-minute epoxy before applying this to the hole in the rib and slotting it onto the spar. Ensuring it was lined up with the sharpie mark.
6. I then let it all dry.
7. I could then use the Loctite superglue to attach the 3D printed parts (leading edge, trailing edge & winglet)

The scale model was incredibly helpful with informing my design process. One issue that was highlighted was the number of ribs I had. I had chosen to use 6 and this looked great on the model and the spacing between them seemed correct and would be strong. However, this was on a spar which was half the length relative to the ribs. Because of this I will now add more ribs to my design and will instead use 10 over the half-span.
Another issue which was indicated was how the winglet was attached. I had just glued this onto the outer spar however in future models and the actual wing I would extend the spar so that the winglet could slot onto it much like the ribs do. This not only makes assembly easier as the winglet can be aligned simply with the hole but also greatly increases the strength.

This is how my model initially looked. I was very happy with it, but I thought it still was still difficult to visualise how the final wing would look. Because of this I decided to add features such as the leading and trailing edge and the winglet. These were added using 3D printed parts from my SolidWorks model which I could scale down. This was a vast improvement to my model and really helped me to visualise the wing.



NB: This page is for information only. Please complete the declaration on the next slide.

GenAI Declaration Form

Generative AI (GenAI) is defined* here as Artificial Intelligence (AI) technology that automatically generates content in response to user prompts. The generated content includes texts, software code, images, videos, and music.

Student: Complete "2. Declaration" and submit with your assignment.

Definition:

Tier 1: No use
Students are prohibited from using any GenAI tools for their assessed work. This includes entering any part of an assignment or assessed work to GenAI, whether by pasting/typing text, uploading files, or describing content directly or through plugins. Basic tools that assist spelling and grammar, translation and calculation without generating new content or ideas, can be used unless specified otherwise by the assessment setter. GenAI may be used to explain lecture slides and notes to enhance understanding of relevant topic areas.
Tier 2: Assistive use
Students may use GenAI to help achieve intended learning outcomes, which are still achievable without GenAI use. The assessment setter must specify allowed use cases using the **Specification Table.** Students must complete **"2. Declaration"**.
Tier 3: Integral use
Students must use GenAI tools to achieve the intended learning outcomes. The assessment setter must specify the allowed use cases using the **Specification Table**. Students must complete section **"2. Declaration"**.

1. Tier Specification

Enter "All" if applied to entire assignment, or specify applicable question numbers/parts:

Module Code	Assignment name / description
FEEG1201	Semester 2 Portfolio Assessment
Applies to	**Assigned tier**
	Tier 1: No use (no further information is required on this form)
All	Tier 2: Assistive Use (fill **Declaration Requirement** and **Specification Table**)
	Tier 3: Integral Use (fill **Declaration Requirement** and **Specification Table**)

Declaration Requirement (Tier 2/3 only): For Tier 2 and 3 students must complete the standard declaration at the end of this form unless it is explicitly stated as unnecessary below. Additional and other requirements should be specified here (modify the default 'Applies to' entries as required):

Applies to	Additional GenAI declaration requirements
Not needed	Full chat logs must be submitted (additional)
Not needed	Annotated version of assignment must be submitted (additional)
	Standard declaration not required (student info and academic conduct boxes are still required), e.g., if GenAI declarations already form part of the main submission
Not needed	Other (please specify below)

Specification Table (Tier 2/3 only): Enter "All" or specify applicable question numbers/parts:

ID	Applies to	GenAI use case	Definition	Example prompts
Assistive: A1-6 are assistive GenAI use cases where "outputs produced by GenAI are not a part of the final submission material".				
A1	All	Debugging code	Inputting code and error messages into GenAI to identify syntax or logical errors.	"Here are 20 lines of Python code and an error message. Identify why this error is occurring."
A2	All	Critiquing spelling punctuation and grammar	Using GenAI to identify and suggest corrections for spelling, punctuation, and grammar mistakes without changing the overall meaning.	"Check my technical report on fluid dynamics for spelling, punctuation, and grammar mistakes without altering the overall meaning."
A3		Essay planning	Using GenAI to help outline the structure and subsections of an essay based on the topic and research findings.	"Create an outline for an essay on the impact of automation on manufacturing, including suggested sections and subsections."
A4	All	Source recommendations	Using GenAI to find and suggest relevant academic or credible sources related to the assessment topic.	"Find peer-reviewed articles on renewable energy solutions for my mechanical engineering research project."
A5	All	Suggesting design solutions	Using GenAI to generate ideas and suggestions for solving specific design challenges.	"Suggest amplifier circuits that require low power consumption while having little noise."
A6		Function and library recommendations	Using GenAI to suggest appropriate functions or libraries to use in programming tasks.	"Recommend Python libraries suitable for simulating electrical circuits."
Generative: G1-6 are generative GenAI use cases where "outputs produced by GenAI are a part of the final submission material".				
G1	All	Generating or correcting a segment of Code	Using GenAI to write or correct a segment of code based on a given prompt describing the desired functionality.	"Write Python code to control a servo motor using a Raspberry Pi."
G2	All	Rewriting written material	Using GenAI to help restructure and modify the text in a document, including grammar and stylistic improvements.	"Rewrite my technical report on the design of an electronic circuit to improve clarity and coherence."
G3	All	Generating images / figures	Using GenAI to create diagrams, charts, or figures for use in a report or presentation.	"Generate a schematic diagram of a microcontroller-based temperature control system."
G4		Language translation	Using GenAI to translate text from one language to another and correct grammar mistakes in the translated text.	"Translate this technical documentation from German to English and correct any grammar mistakes."
G5		Writing sections of a report or producing slides in a presentation	Using GenAI to generate parts of a report, such as abstracts, introductions, or conclusions.	"Write an abstract for my research paper on the optimisation of power systems."
G6		Analyse data that is not subject to additional ethics approval	Inputting large datasets into GenAI to identify trends, correlations, and insights.	"Analyse this dataset of sensor readings from an IoT network to identify trends and generate visualisations."

ID	Applies to	Other allowed GenAI use cases (define below and assign an ID)

For more information on completing this form visit: https://sotonac.sharepoint.com/sites/FEPSGenAI

Declaration

All students must complete this section for all Tier 2 and 3 assessments.
One declaration is required for each student.

Answers on this form will NOT IMPACT your marks unless an Academic Responsibility and Conduct breach is found.
General university guidance regarding GenAI can be found via the library

Name		Student ID
Frederick Knight		34926178
Module Code		Assignment name / description
FEEG1201		Semester 2 Portfolio Assessment
Have you used GenAI? (Yes/No)	Y	Date: 26.03.25
Which GenAI tools have you used? (Include version / leave blank if not used)		
Answer here ChatGPT 4.0		

Standard declaration: Complete this for all Tier 2 and 3 assessments unless specified as not required

For each GenAI use (see definitions and codes on previous slide), summarise which slides and how each was used (suggest 1 or 2 sentences per use category)
A5: Page 9-I asked AI what formulas would I need to calculate the air density at a specific altitude when using the international standard atmosphere? A5: Page 11- Ai was used to generate 3 high performing aerofoils in order for me to start my analysis using XFLR5.

Academic Conduct	**Yes/No**
I acknowledge I have answered honestly on this declaration form (Y/N)	Y/N
I understand if I was unsure about whether my actions met academic conduct requirements, it is my responsibility to confirm with the teaching team prior to submission (Y/N)	Y/N
I am aware of and have critically reviewed the content generated by GenAI used in this submission. I accept responsibility for this content and can be asked about it in the future (Y/N)	Y/N