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Submission by (Name):	**Student ID (XXXX1234)**	**Signature**	**Section**	**Work Distribution**	**Work Distribution %**
Clement Sayah	XXXXX3466	Clement	1	Tail Design, Manufacturing,	20%
Alec Tabachnik	XXXXX5432	AT	1	Manufacturing Process Writeup, Manufacturing	20%
Shiv Pinteshkumar Patel	XXXXX0090	S.P	1	Wing Cad Design, Fuselage Design and report	20%
Aradhya Roy	XXXXX1206	Aradhya Roy	1	Manufacturing, Tail Clamp CAD Design, Report Introduction	20%
Ahnahf Alvee	XXXXX1241	AA	1	Discussion, Manufacturing	20%

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1: Introduction

The goal of this project is to design and construct a glider aircraft that is capable of flying the furthest possible distance while weighing the least amount possible for a gliding competition. The materials were provided in advance during lab sessions by the teaching assistant, along with the mould for the NACA M22 airfoil that was used to manufacture the actual wing. All of the components other than the wing were designed using a CAD program and manufactured using processes such as laser cutting and 3D printing. Materials were chosen to optimise both weight and durability of the design.

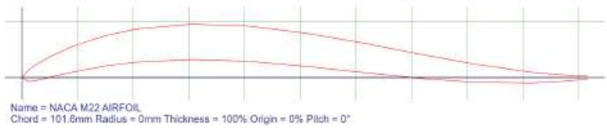
Several requirements had to be met for the contest. The wing that was given had already satisfied the 29.5 inch wingspan requirement and a chord length of 4 inches. The length of the final design has to be under 29.5 inches, and the width of the fuselage has to be less than 2 inches. The area of the tail fins has to be less than 30% of the area of the wing. The competition scores the final design based on the glide distance divided by the final weight. The final glide distance is taken from the best out of 3 flight attempts, for which the glider must also survive. All of these factors were taken into account during both the design and manufacturing phases.

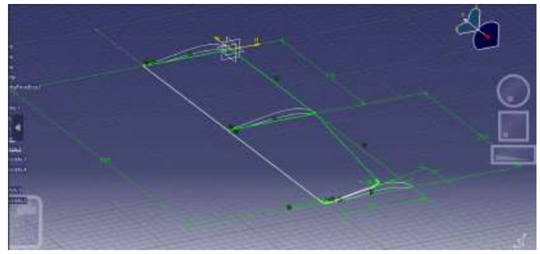
The following report details the design choices for the aircraft and the justification behind them. It also describes the manufacturing processes and defects that occurred. Finally, the report will discuss the aircraft's performance during the competition, any complications that the team had to correct, and possible improvements that would be made if the project were repeated.

2: Wing Design and Analysis

Wing Shape

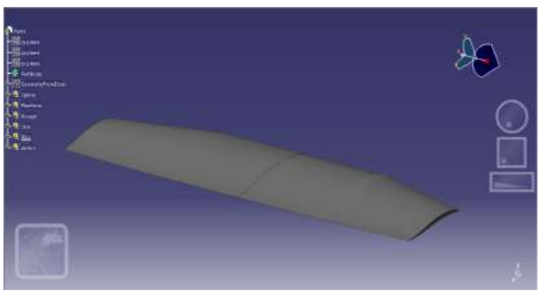
Figure 2.1 & 2.2: The NACA M22 airfoil and initial sketch of the CAD.

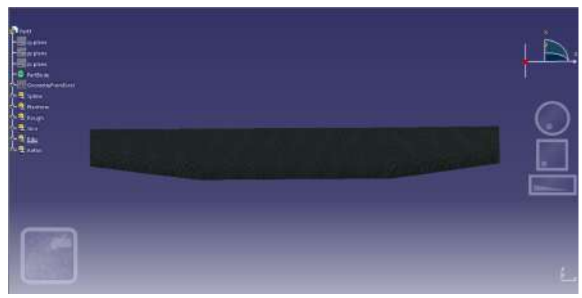




The wing used the NACA M22 airfoil, obtaining this shape using a given mould. The top skin was a carbon fiber and epoxy composite while the bottom skin was a fibreglass and epoxy composite. A styrofoam "skeleton" was used to support the shape of the wings.

Figure 2.3 & 2.4: Rendered carbon fiber skin on the wing.





The wing shown above in Figures 2.2 to 2.4, was 3-D modeled using the generative shape design tool in the CATIA V5 R23 model. This is the rendered model of the wings using carbon fiber skin to replicate the real life wing that was manufactured. The wing is 750 mm long and the root chord length of the wing is 102 mm and the tip chord length is 80 mm long. The wing is tapered towards the tip with an angle of 8 degree with the horizontal.

Composite Wing Analysis: Properties

As the top and bottom sections of the wing were composites consisting of an epoxy matrix and fibre strands, an analysis of the modulus of elasticity and tensile strength were conducted assuming a longitudinal loading parallel to the fibres. Using the masses of each material while constructing the glider, the following analysis was performed.

As the same dimensions of cloth were cut for both fibreglass and carbon fibre, that would mean the amount of volume each cut takes up would be roughly the same for each. Knowing the mass of the two combined cloths at 21.1g, the following equation was used to determine the volume of each cut and rearranged to solve for V: $m = V(\rho_{cf} + \rho_{fg})$ where V is volume, m is the total mass, and ρ is each cloths' density. With the volume of each cloth known, we could conduct a separate analysis of the top and bottom surfaces. For the modulus of elasticity: $E_{surface} = E_f f_f + E_m f_m$ where E is the modulus of elasticity and f is the volume fraction, given as $f_f = \frac{V_f}{V_f + V_m}$, $f_m = 1 - f_m$ and $V_m = \frac{m_m}{\rho_m}$. For the tensile strength: $TS_{surface} = (\alpha + 1) TS_f f_f$ where $\alpha = \frac{E_m f_m}{E_f F_f}$. The following data was obtained assuming 60% of the epoxy mass was used on the top surface with the total epoxy mass being 39.4g.

Table 2.1: Material properties.

Material	Density (g/cm^3)	Modulus of Elasticity (Gpa)	Tensile Strength (Gpa)
Carbon Fibre	1.8 [1]	294 [1]	5.507 [1]
Fibreglass	2.5 [2]	80 [2]	2 [2]
Epoxy	1.15 [3]	3.1 [3]	0.072 [3]

Table 2.2: Composite wing properties for each individual surface.

Surface	Cloth Volume (cm^3)	Epoxy Volume (cm^3)	Cloth fraction	Epoxy Fraction	α	Modulus of Elasticity (Gpa)	Tensile Strength (Gpa)
Top (carbon fibre)	4.907	20.557	0.1927	0.8073	0.0441	59.16	1.088
Bottom (fibreglass)	4.907	13.704	0.2637	0.7363	0.1082	23.38	0.5844

The previous analysis is for each individual surface of the wing. If we wanted to approximate E and TS for the entire wing, we would have to consider each component the combined equations $E_{wing} = E_{cf} f_{cf} + E_{fg} f_{fg} + E_e f_e$ and

$TS_{wing} = TS_{cf}f_{cf} + TS_{fg}f_{fg} + TS_{e}f_{e}$. Continuing the assumption that the volumes of the cloths are the same at 4.907 cm^3, the volume of the epoxy with the given mass and density would be 34.26 cm^3, giving a total wing volume of 44.074 cm^3. The corresponding volume fractions would then be $f_{cf} = f_{fg} = 0.111$ and $f_e = 0.777$. This would give a combined E of 43.92 Gpa and TS of 0.8892 Gpa.

Composite Wing Analysis: Bending

To analyze the stress and bending along the wing, we will approximate half of the wing's bending as a cantilever beam of uniform material. For an airfoil, the cross-sectional area and moments of inertia are approximated with the equations $A = K_A c^2 \tau$ and $I = K_I c^4 \tau(\tau^2 + \varepsilon^2)$ respectively where $K_A = 0.6$, $K_I = 0.036$, c is the chord length of 4 inches (0.1016 m), τ is the thickness ratio at $\frac{max\ thickness}{cchord}$, and ε is the camber ratio at $\frac{max\ chamber}{chord}$. For the NACA M22 airfoil at a 4 inch camber, the ratios for both thickness and camber are 0.063. Taking half the final weight of the wing from manufacturing at 29.3g (0.0293kg) and the corresponding force (0.28714 N) as a distributed loading on the section.(2.826 N/m), we could find the deflection at the tip, otherwise known as the max deflection. The equation to use is $\delta_{max} = \frac{w_d L^4}{8EI}$ where w_d is the distributed loading and L is half of the span at 14.75 inches (0.3747 m). The associated bending stress would be concentrated at the midpoint as the weight was approximated as a distributed load. The bending stress would then be $\sigma_{bend} = \frac{(w * \frac{L}{2}) * \frac{t}{2}}{I}$ where t is the thickness at 0.0064m and w is the weight of the wing.

As our calculated E are in Gpa, we are using SI units for this process and assuming a longitudinal loading on the fibres. This analysis only accounts for the wing under the stress of its own weight as the payload was assumed to be under the fuselage and not along the wing.

Table 2.3: Composite wing bending with each uniform material assumption.

Material	A (m^2)	I (m^4)	δ_{max} (m)	σ_{bend} (Pa)

Assumption				
Carbon Fibre composite	0.0003902	1.9033e-9	6.184e-5	9229.2
Fibreglass composite	0.0003902	1.9033e-9	1.5648e-4	9229.2
Carbon Fibre + fibreglass composites	0.0003902	1.9033e-9	8.330e-5	9229.2

Payload-To-Weight Ratio and Cost

With the glider at a weight of 171.7g and an expected payload of 200g, the glider's payload-to-weight ratio is 1.1648 at the end of manufacturing.

It is important to note that the bending stress is the same for each version of the wing but the deflection, and thus strain, changes. While one may want to choose carbon fibre as it bends less under the weight, it is much more expensive at around 40-80 per kg for aerospace applications [4]. Fibreglass is cheaper at 1.8$ per kg [5] but much weaker and heavier. Using a combination of both ensures we still have a strong and light wing thanks to the carbon fibre while keeping costs low. The cost for this wing from the cloths alone with their given volumes and densities are 0.35$ at least for the carbon fibre and 0.02$ for the fibreglass, giving a total of 0.37$ for the raw material of just this one wing.

3: Tail Design

Tail Design Choice

There were two main options to consider for the design of the tail; a V shaped tail with two fins or a more standard design with dedicated horizontal and vertical stabilizers using 2-3 fins. Between the two choices, a best-in-class decision matrix was made to determine the design moving forward.

Table 3.1: Decision matrix for the tail design.

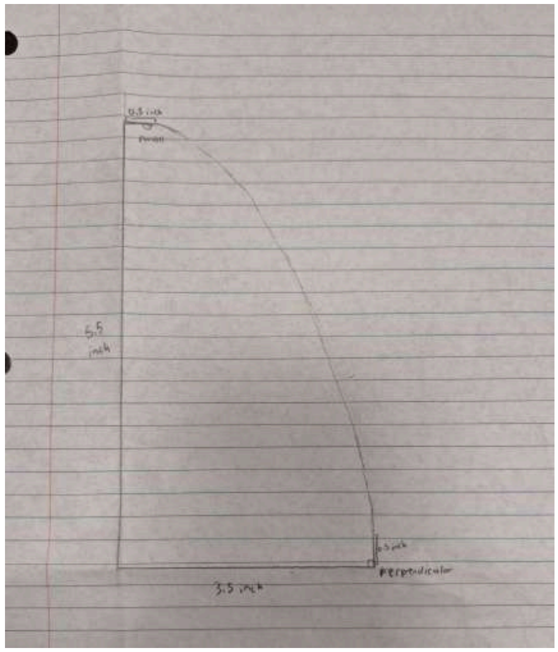
Design	Weight	Stability	Material Usage
V shape	1	2	1
Horizontal and Vertical fins	2	1	2

The decision to use a V shaped tail was because of the benefits it had over the other design. While dedicated vertical and horizontal stabilizers could offer more stability, the weight and material reducing benefits of the V design were what led us to using it overall. The loss of stability would be made up for by making the fins bigger and orienting them in such a way that each fin could offer equal pitch, roll, and yaw stability.

Fins

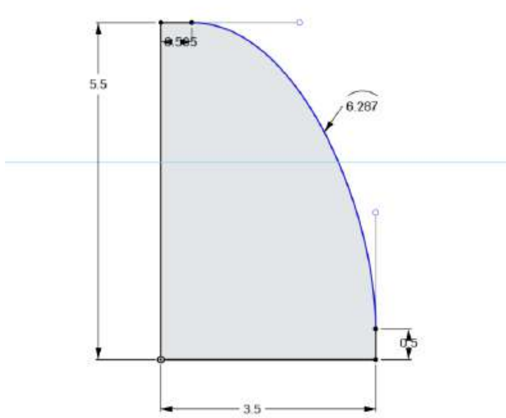
When discussing the design and parameters of the glider's tail, we opted for a V shaped tail with fins at a 45 degree angle to the horizontal, much like the design of the toy glider used for the original project. Considering the area of the fins could not exceed 30% of the 108 in^2 wing area (32.4 in^2 total), we drafted a design for a single fin with the intention of laser cutting the fin from the provided balsa wood.

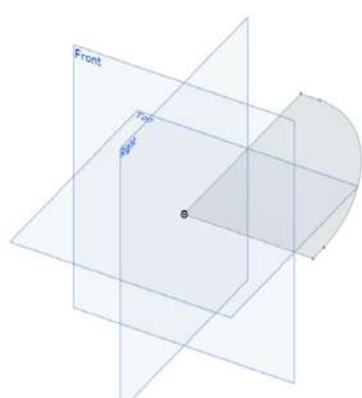
Figure 3.1: Initial sketch of a single fin design



The fin was 3.5 inches in length and 5.5 inches in height. While approximating as a square would yield a combined area of both fins for 38.5 in^2, the actual area would be smaller due to the spline on the leading edge of the fin. We designed an extra half inch extending perpendicular from the bottom and trailing edge of the fin for space to fit the fins into our chosen mounting design. A sketch was drawn in Onshape to both get the area of the fin and export the design as a dxf file to cut later.

Figures 3.2 & 3.3: Onshape sketches and dimensions of the fins



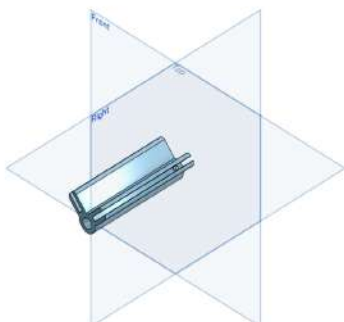


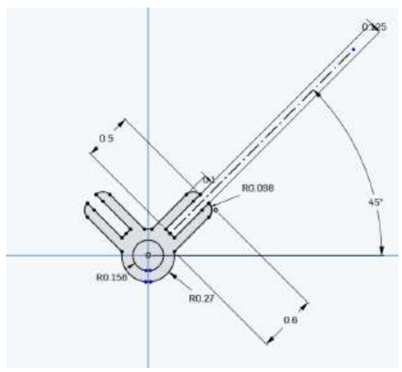
The area of the given sketch was 15.599 in^2, giving a combined area of 31.198 in^2 which met the requirements.

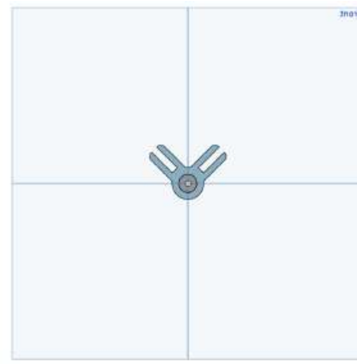
Mounting Clamp

Knowing the fins were to be made of 1/8th inch thick balsa wood, we would need to design an appropriate mounting piece. As previously mentioned, we opted for the fins to be at a 45 degree angle to the horizontal with the reason being for the two fins to provide stability during flight. Additionally, the piece must attach to the carbon tube of 7.9mm (or 0.311in) diameter. With these parameters in mind, a mounting clamp was made in Onshape with the intention of being 3D printed.

Figures 3.4, 3.5 & 3.6: Onshape renders and dimensions of the mounting clamp.



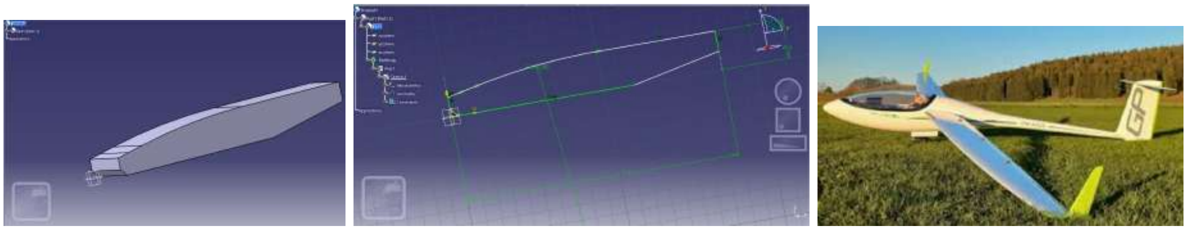




The clamp extends 3 inches to hold most of the fin from the bottom and to slide onto the carbon tube in a tight friction fit. The small hole in the back of the mounting clamp was to push air out while the clamp is being slid onto the carbon tube. The fins would also be fitted by the tight tolerance of the clamp but additional adhesives would be needed to ensure the fins do not move or fall out during flight. Once the design was made in Onshape, it was exported as an stl file to be 3D printed during the manufacturing process.

4: Fuselage Design

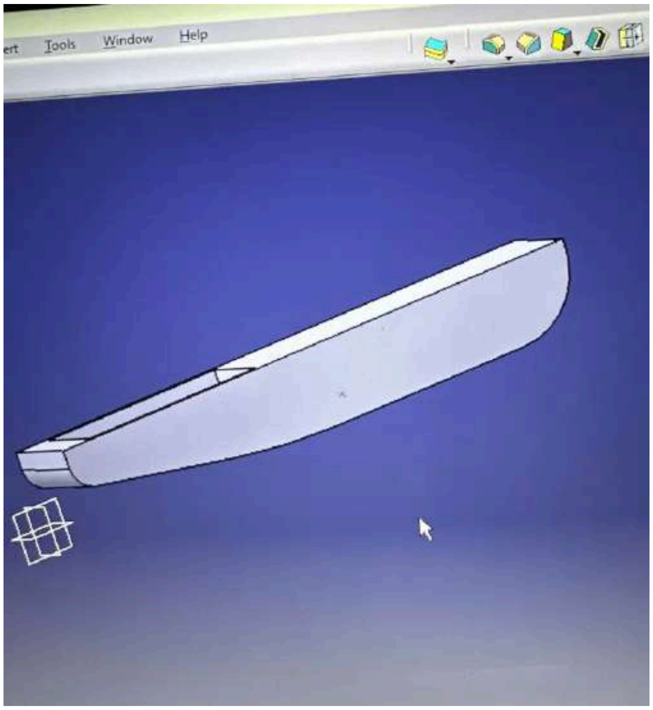
Figure 4.1, 4.2, & 4.3: The design and inspiration for the fuselage.

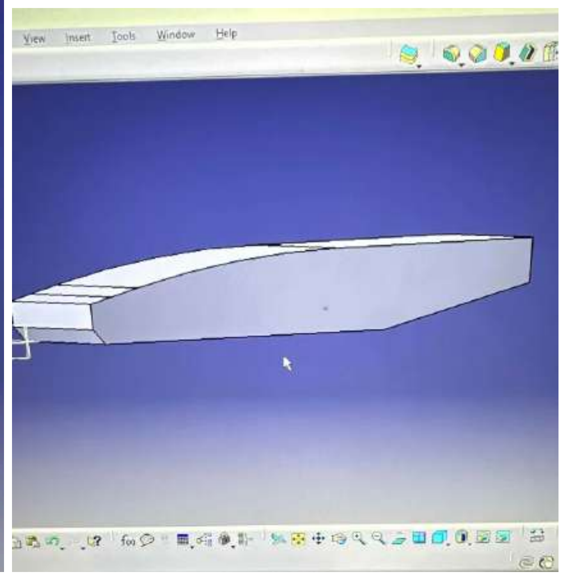


The fuselage was designed on CATIA V5, the fuselage measured up to 7 inches long, 1.5 inch tall and 1 inch wide. The fuselage design was inspired by a classic glider design with increased width and increased length from the top to keep the airflow intact while the glider flies. The bottom of the glider was kept straight to maintain the airflow along its body. The glider was transferred to a laser cut machine via DXF file. The laser machine was then used to cut out an intact shape of the glider. Using the variable power mode of the laser machine the center of the fuselage was kept intact with the foam board which then was cut and folded manually by removing the foam between the sheets. This ensured a one piece complete model of the glider reducing time spent on manufacturing and increasing its efficiency and aerodynamics.

A decision matrix was used to finalize the fuselage design for the glider. Initially with 2 3-D designs of the fuselage shown below, The design on the right hand side provided a sleeker and aerodynamic shape than the initial design. The design matrix for finalization of the fuselage goes as follows.

Figure 4.4 &4.5: Different iterations of the fuselage.





Property	**Gradings (X/5): Total 15 Points**	
	Design 1	**Design 2**
Manufacturing	2/5	3/5
Aerodynamic efficient	3/5	4/5
Structurally Feasible	3/5	3/5
Total	**8/15**	**10/15**

With reference to the above matrix that was used to identify the choice design for the glider, design 2 being our final choice for the glider provided more aerodynamic shape and a structurally stronger design with being able to hold more impact force than the first one. The first design had a flat top which disrupted the flow of the air and made it prone to damage on impact. It also provided stability to the wing as the wing would be placed on the top of the fuselage.

With the final design having joints and holes made in the design which enabled the wing to be placed on the top of the fuselage and the payload to go in the middle section of the fuselage. This middle section was cut out fully and was installed with foam to provide insulation of impact and hard landing.

5: Manufacturing Process

Composite Wing

The first and arguably most important component of the glider that was constructed was the carbon fibre wing. The main purpose of this portion of the manufacturing process was to create as light and as strong of a wing as possible. Most of the weight came from resin and hardener, which also gave stability to the wing.

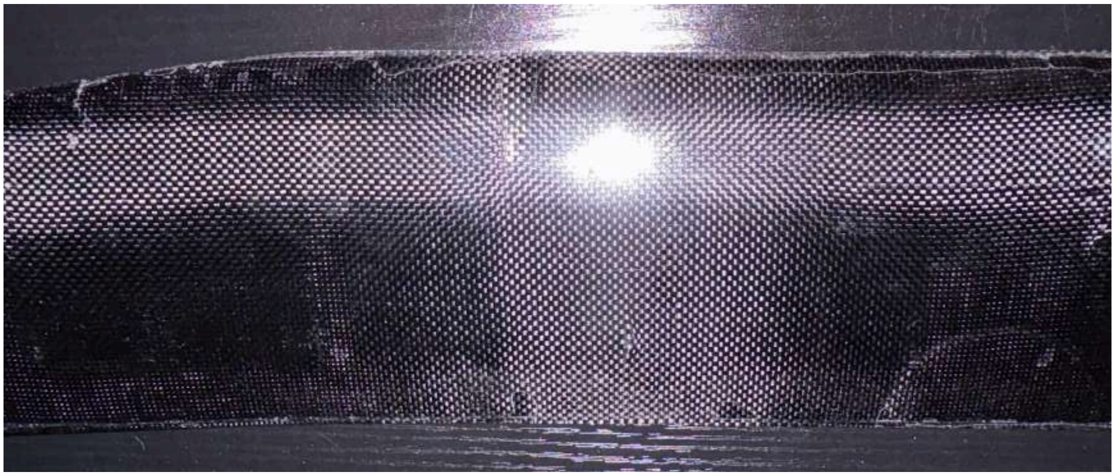
The actual manufacturing process of the wing began by laying the glass cloth on top of the mold, allowing for an inch overlap on each side. 'V' shaped cutouts were made on the dimples and screw holes in the mold to prevent any fitment issues between the top and bottom mold. The foam strip was then brought to the CNC machine to make the desired cutouts. Once the foam has been cut, the glass cloth was then rolled over the ribs, ensuring the full rib is covered lengthwise (from L.E to T.E) with no overlap. There was however an overlap of around 1.5 inches on the width. This was done for each rib, including the middle one. While this was being done the carbon fibre sheet was laid on the mold, and cutouts were made on the dimples and screw holes. The resin was then mixed, in our case featuring 33.6g of resins and 5.8g of hardener. Some of this mixture was then poured over the carbon fibre sheet which was laid over one of the molds. Several group members worked to spread the resin into an even layer along the full sheet, ensuring the sheet covered all creases. After this layer was covered the same procedure was repeated with the cloth sheet. Once the cloth sheet was fully covered and laid perfectly onto the mold the foam strip was laid on top, and the cloth cutouts for the ribs were put over the ribs, ensuring they stick to the side of the rib (with the help of the resin wetting the cloth). The resin takes a little longer than 10 minutes to start curing, which gives our group time to remove as much 'hair like' particles floating in the resin. This was a very tedious process of picking them out one by one with our fingers, but it turned out to be very worth it with almost no imperfections in the resin (with the exception of air bubbles). Once both sides of the mold were ready, the side holding carbon fibre was laid on top of the foam part, ensuring the dimples and screw holes align. Alignment pins were used to ensure the mold stayed together.

Figures 5.1 & 5.2: Carbon fibre sheet weighing and laying process

Figures 5.3 & 5.4: Resin mixing; pouring and spreading along molds

The next portion of the procedure pertained to the trimming process of the wing. The molds were left for a total of 2 weeks (consecutive lab sessions), after which the wing nuts were unscrewed and the molds were forcefully pulled apart. Once the untrimmed wing was removed the total weight was measured and recorded as 74.5 g. With the use of a blade saw rough cuts were made around the wing leaving around 1/16 of an inch for sanding. Dust masks and safety glasses were worn during the cutting and sanding process. After cutting the leading edge was sanded down to as little of a lip as possible, and the trailing edge lip was left around double the length of the trailing edge lip. After the full trimming procedure all of the dust was wiped off the wing and the trimmed weight was measured and recorded as 58.6 g. Imperfections were noted on both the leading and trailing edges of the wing as seen in the image below (LE facing upwards). This concludes the full manufacturing process of the composite wing.

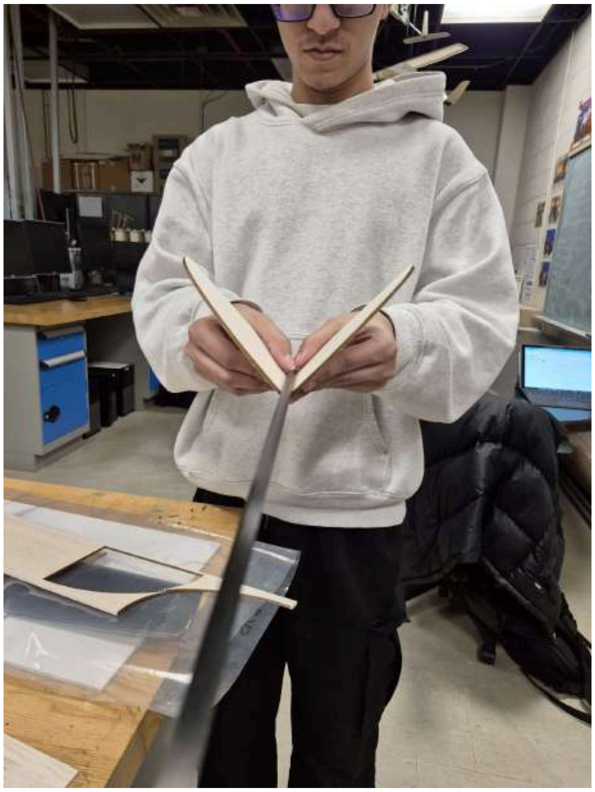
Figure 5.5: Imperfections along the leading and trailing edge (LE oriented up)



Fins

The second component that was manufactured for the glider was the fins and the bracket to hold them. The bracket was designed by a team member on Onshape, and 3D printed by a classmate to save lab time. The fins were designed on Onshape as well, and then cut out using the CNC machine on 1/8th inch thick balsa wood. A carbon fibre rod was given, the length of this rod was not trimmed, and the fin bracket slid on the end and friction fit onto the rod. The bracket was designed to allow for friction fitting of the fins, however before final assembly the fins were superglued into the bracket to ensure they don't misalign or fall out. The first manufacturing problem occurred at this step; one of the fins went in perfectly aligned with the bracket and the instant cure glue stuck it in place, while the other fin went in slightly unaligned. This fin was stuck on and was around 1-2 cm behind the other fin. This was unacceptable and the fin had to be removed from the bracket. This was a very tedious process as balsa wood is very fragile and left behind a lot of small pieces stuck to the bracket. These pieces had to be individually picked out of the bracket before another 2 copies of the fins were cut on the CNC machine. The second attempt of aligning the fins was successful, which concludes this stage of the manufacturing process.

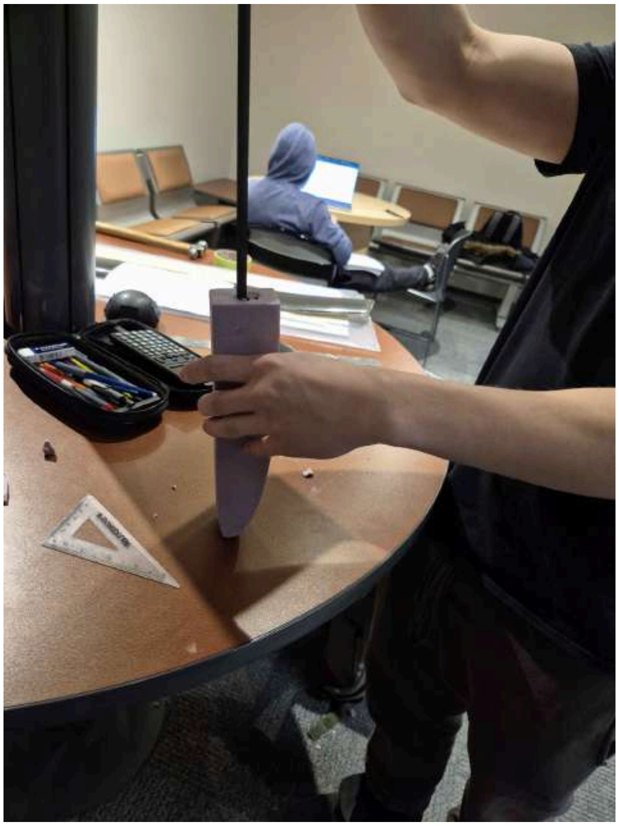
Figures 5.6 & 5.7: Fin cutout and orientation with respect to carbon fibre rod

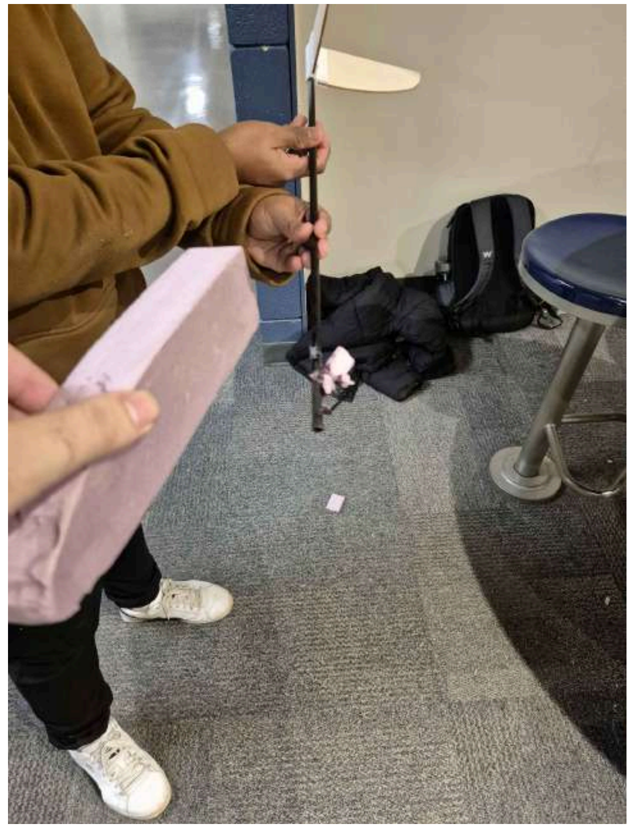


Fuselage

The final component of the glider that was manufactured was the fuselage. The initial idea was to produce the fuselage out of foam to save as much weight as possible, and use batteries to displace the centre of gravity to the desired position. A rough shape was outlined with a sharpie on a foam block based on a CAD design made by one of the group members. The shape was then cut out using a bandsaw, and sanded until all edges were smooth. The carbon rod was fit in through the use of force and torsion, digging 3-4 inches into the fuselage. In order to keep the carbon rod from spinning (and keep the fins perfectly straight) the carbon rod was secured to the fuselage using superglue. This superglue had acetone inside which reacted with the foam causing it to melt, which is the second issue faced during the manufacturing process.

Figures 5.8 & 5.9: During and after pouring superglue into foam fuselage





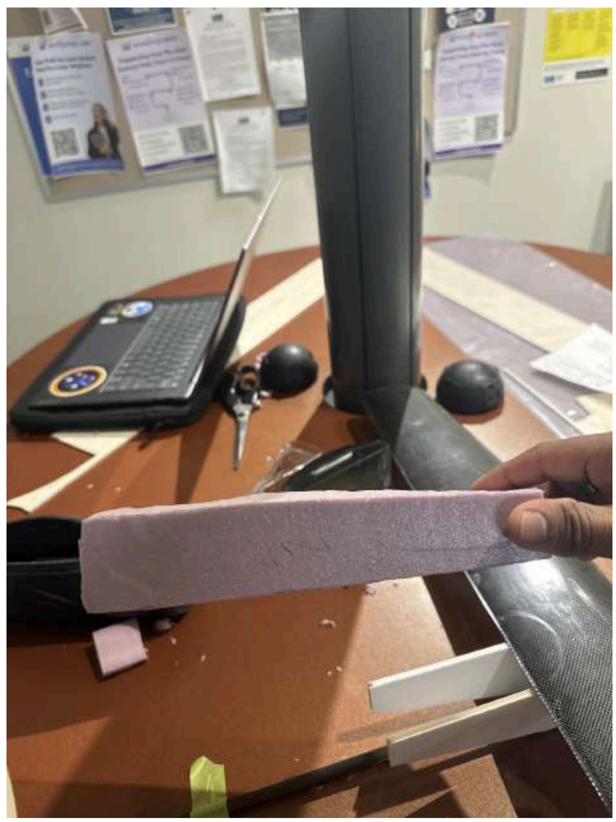
The timing for this mistake could not have been worse, the glider was due to fly in 4 days, out of which the lab was only open for 2 days. A design matrix was made to determine the most optimal manufacturing method, which led to an emergency redesign of the fuselage. The decision matrix pointed towards a foamboard ‘skin’, featuring a centre made of foam to ensure structural stability. The new design required the use of the CNC machine on the foamboard, and bandsaw to shape the foam to an appropriate shape. The carbon fibre rod was then glue-gunned to the foam, ensuring it doesn’t slide out or rotate. This left 2 parts for the final assembly, the foam with carbon rod and fins, and the foamboard ‘skin’.

Table 5.1: Decision making matrix pertaining to fuselage materials used

Selection Criteria	Weight (100%)	Foamboard	Skinned Foamboard	Foam	Skinned Foam	Foamboard and Foam

Lightweight	30%	4	3.5	4.5	4	3.5
Sturdiness	40%	2	3	2	3	4.5
Adjustability	10%	2	2	2	2	2
Manufacturing Time	20%	4	2	4	2	3.5
Total	100%	3	2.85	3.15	3	3.75

Figures 5.10 & 5.11: New foamboard and foam fuselage cutouts



Final Assembly

Once all of the individual parts are assembled, the full glider can be put together. The procedure consisted of taping the foam insert to the foamboard ‘skin’. The centre of gravity of the glider was then found, around which the wing was placed and secured with the use of rubber bands. 6 AA batteries were taped to the front of the glider to experimentally move the center of gravity based on flight performance. Over a series of 6+ tests the final orientation of batteries and wing position was determined to be optimal based on the glider's shape/setup. The adjustable nature of load (batteries) and wing allowed for last minute changes leading up to the competition. A decision matrix was made to determine which components should and should not be adjustable, which influenced the manufacturing methods used.

Figures 5.12, 5.13 & 5.14: Finished glider from front / top angles, CAD Assembly for Glider

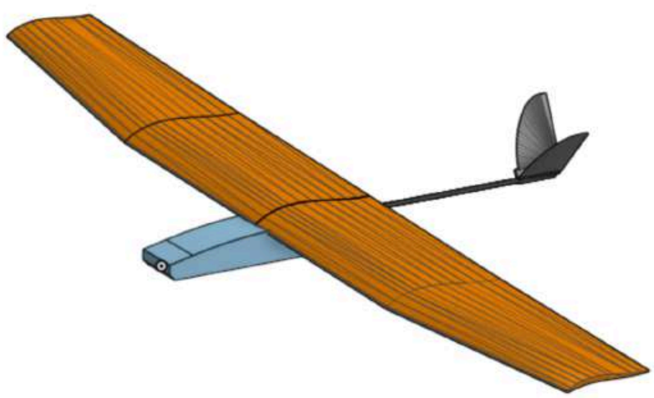


Table 5.2: Decision making matrix determining load application

Selection Criteria	Weight (100%)	Taping Batteries in Place	Glueing Batteries in Place	Taping Coins in Place	Glueing Coins in Place
Adjustability	50%	5	0	5	0
Sturdiness	30%	3	5	3	5
CG impact	20%	3	3	1	1
Total	100%	4	2.1	3.6	1.7

6: Discussion

Maximising the payload to weight ratio was an important design goal for this project. With the payload fixed at 200 grams along with the weight of the wing in the load profile, maximising this ratio meant minimizing the weight of the wing to as little as possible while maintaining its ability to not fail under the bending load.

The balance between the lightweight design and the material and manufacturing cost was another aspect to consider for the project. Multiple calculations, design concepts and iterations were done for the surface area, volume and density of the fuselage and tail fins to find the best possible design for the glider. The selected design was then applied to various different materials to find the best match in terms of metrics like cost per piece or cost per any arbitrary unit of measurement (kg, cm, etc). After going through all the calculations, the best material was then selected as per its manufacturing and labor costs along with an acceptable weight and strength. After a design has been proposed and its cost factor has been determined, further adjustments are then taken into consideration while maintaining the design and budget constraints to make sure the best possible version of the design is built.

In theory, it is possible to calculate the lift force required to make it equal to the weight of the payload. For example, if applied in a wind tunnel experiment, we can determine airfoil values such as lift and drag at various angles of attack at preset conditions. The drawback of this method is that a wind tunnel only assumes a certain fixed velocity which does not completely translate to real life conditions thereby meaning the lift force calculated is not fully accurate. Other analysis methods include using CFD software like ANSYS or a specific airfoil analysis software like XFOIL through which we can analyse different designs of the airfoil to calculate required values. With these softwares, performing the necessary calculations becomes much easier as the program essentially does it after the constraints are set. Depending on the preset values given to the software, determining the lift force for the payload can easily be done. However, just like before, designing wings through these softwares is also mainly theoretical and as such, has some discrepancies with real-life scenarios. Other factors such as human errors also come into play along with material and tool defects which also negatively affect the designing of the wing.

While the test runs for our glider were mostly effective, some notable drawbacks during the competition throws occurred mainly related to stalling of the glider, possibly due to misalignment of the wing when compared to the centre of mass from the rest of the body. Adding extra weights to the glider also proved ineffective as it increased the weight by a lot, leading to the flight distance being drastically reduced as compared to other gliders. This was further highlighted when comparing our glider to other ones as ours was one of the heaviest gliders in the competition, which when compounded with the reduced flight distance also led to a lower flight score compared to other gliders.

Opting for a V-tail was also a design choice that could have contributed to some minor inconveniences during the flight of the glider. Although it reduced drag and weighed lesser comparatively to a standard configuration, it was not as stable and as such, could have resulted in a lesser controlled flight due to needing greater care in handling and throwing which may not have been practised enough before the competition.

7: Conclusion

Overall, while the glider had some issues during manufacturing and its flight performance, the project served as an effective lesson combining both manufacturing and aerodynamic performance. Different manufacturing processes could affect the performance of the glider by changing the weight and center of mass, making it fly shorter distances or become unstable during flight. In the case of our glider, the extra counterweights used to push the center of mass forward added a lot of weight, shortening the flight distance when compared to other designs as was seen in the second throw. Furthermore, the wing would sometimes be aligned too far forward from the center of mass rather than directly over it which would cause it to drastically pitch up during flight as was seen in the first and third throw. For each attempt, the glider did survive landing with no fatal breaks or structural issues which meant that the glider was well suited to survive rough landings or impacts. Despite the flaws in the glider affecting its performance, a lot was learned regarding the design and manufacturing practices which would allow us to improve upon and refine further designs of not just this glider, but other aircraft we may design in the future.

8: Citations

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9: Appendix

Wing Analysis Sample Calculations

Sample calculations pertain to carbon fibre and top surface where applicable (such as for finding V, E, fractions, etc) due to the similarity of many of the calculations.

- Carbon fibre and fibreglass cloth volume [cm^3]: $\frac{21.1}{1.8+2.5} = 4.907$
- Epoxy volume (individual surface) [g/cm^3]: $\frac{23.64}{1.15} = 20.557$
- Cloth fraction (individual surface): $\frac{4.907}{4.907 + 20.557} = 0.1927$
- Epoxy fraction (individual surface): $1 - 0.1927 = 0.8073$
- Modulus of elasticity (individual surface) [Gpa]: $294(0.1927) + 3.1(0.8073) = 59.16$
- α: $\frac{(3.1)(0.8073)}{(294)(0.1927)} = 0.0441$
- Tensile Strength (individual surface) [Gpa]: $(1 + 0.0441) * (5.507 * 0.1927) = 1.088$
- Carbon and fibreglass cloth fractions (combined materials): $\frac{4.907}{4.907+4.907+\frac{36.4}{1.15}} = 0.111$
- Epoxy fraction (combined materials): $1 - 0.111 = 0.777$
- Modulus of elasticity (combined materials) [Gpa]: $(297)(0.111) + (80)(0.111) + (3.1)(0.777) = 43.92$
- Tensile Strength (combined materials) [Gpa]: $(5.507)(0.111) + (2)(0.111) + (0.072)(0.777) = 0.8892$
- Wing cross section area [m^2]: $0.6 * 0.1016^2 * 0.063 = 0.0003902$

- Wing moment of inertia [m^4]: $0.032 * 0.1016^4 * 0.063(0.063^2 + 0.063^2) = 1.9033e-9$
- Bending deflection (uniform material) [m]: $\frac{2.826*0.3747^4}{8*(59.16e9)*(1.9033e-9)} = 6.184e-5$
- Bending deflection (combined material) [m]: $\frac{2.826*0.3747^4}{8*(43.92e9)*(1.9033e-9)} = 8.330e-5$
- Bending stress [pa]: $\frac{0.0293*\frac{0.3747}{2}*\frac{0.0064}{2}}{1.9033e-9} = 9229.2$