Glider Project Final Report

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Aerospace Practicum Section 02

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Introduction: Project Scope and Requirements (Carter Batt)

In this assignment, we, as a team, brainstormed different ideas to build the most successful glider for the cheapest cost possible. To make this a successful glider, different factors are required to make this possible. These requirements include sizing of aircraft components, Reynolds Number, lift and drag, glide ratio, predicted range and endurance, horizontal and vertical tail volume ratios, total aircraft weight, and location of the center of gravity (with and without payload). In addition to these requirements, we also have created a CAD model of the glider in NX to better understand how the glider will work and have a visual of the glider itself. This also includes a scale drawing of the glider components. By completing all of these requirements, we were able to design the most efficient possible glider for the cheapest cost. While we did not actually construct the glider, based on our research and designs, we believe this would be a successful glider.

Design Alternatives Considered (Authors-Kendall & Nathan)

The alternative airfoil was the Peter Wick PW1211 (pw1211-pw) airfoil. This airfoil was considered for its high lift-to-drag ratio, which is necessary for a glider. This would have allowed our glider to traverse a long distance. However, this airfoil would be slightly harder to construct in comparison to the AG47 airfoil. The AG47 also has a higher lift-drag ratio making it a better choice for the glider as it would be better able to carry the payload and go further than the PW1211.

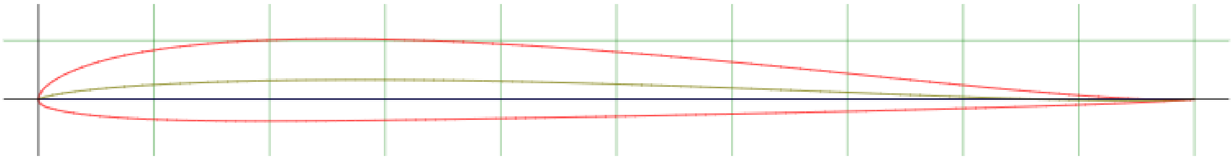


Figure 1: PW1211 (pw1211-pw) airfoil

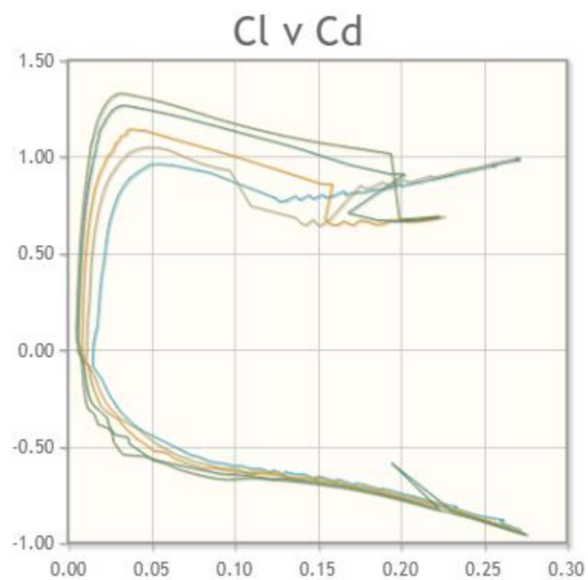


Figure 2: Cl vs Cd of PW1211 Airfoil

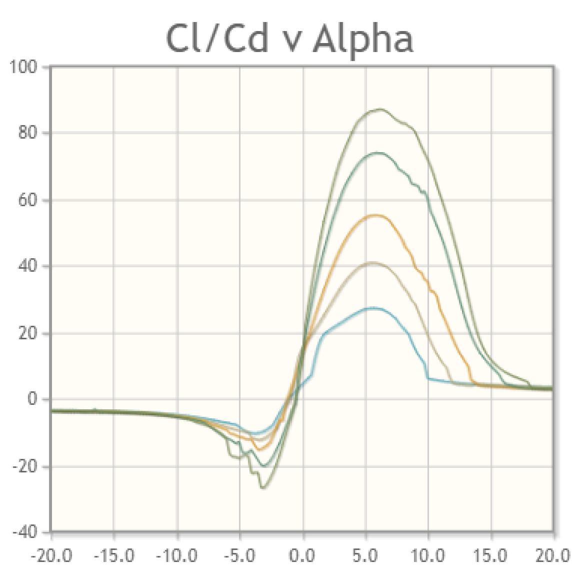


Figure 3: Cl/Cd vs Angle of Attack of PW1211 Airfoil

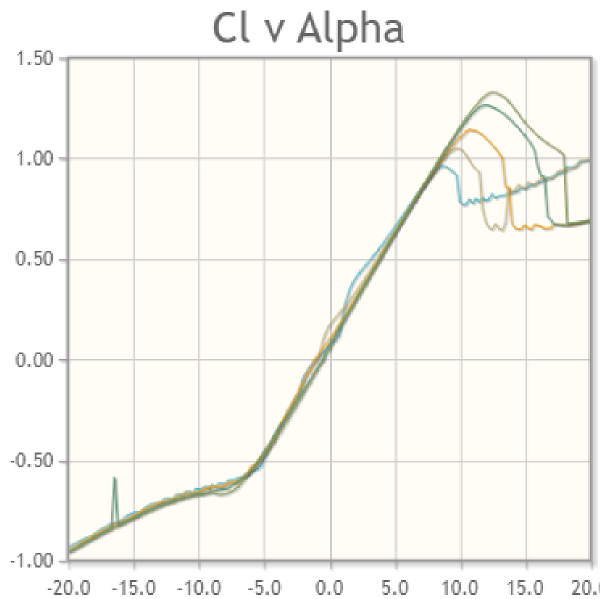


Figure 4: Cl vs Angle of Attack of PW1211 Airfoil

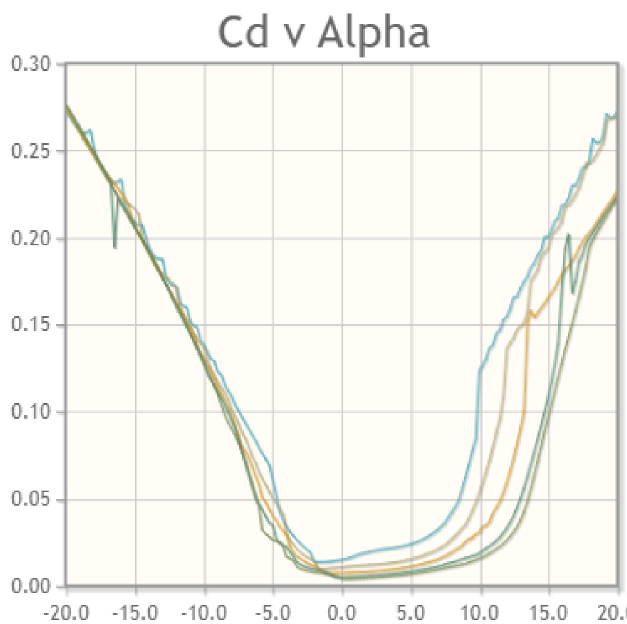


Figure 5: Cd vs Angle of Attack of PW1211 Airfoil

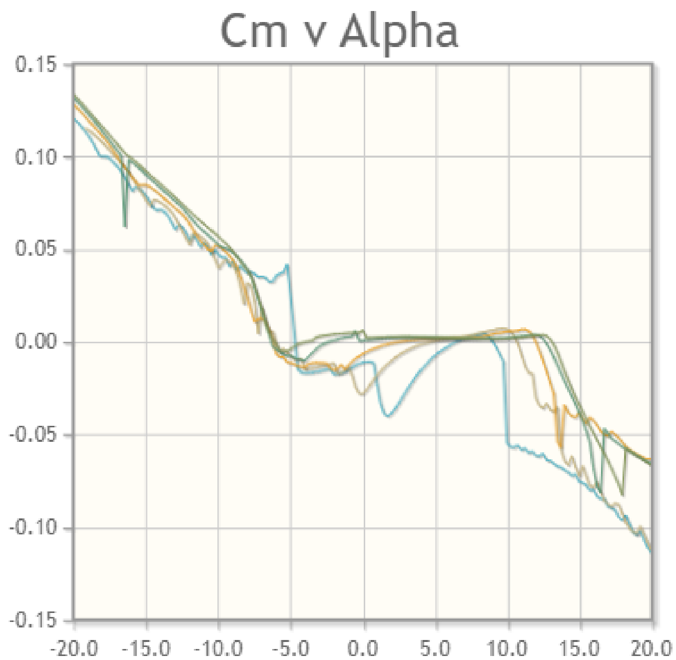


Figure 6: Cm vs Angle of Attack of PW1211 Airfoil

The alternative design to our glider was going to be a flying wing which would have stored the payload in the center of the glider's body. However, this design would not have been as stable as our chosen design and would have been more complicated and expensive to create. This design also would be less reliable as with the body and wings integrated together. Any damage can lead to more work being done to repair it. Due to these issues, we went with a traditional glider design.

Materials we considered using were polystyrene foam and balsa wood for the wings and body. Both foam and balsa wood are light, but we decided to go with polystyrene as it is a cheaper material and easily available.

Figure 7: Flying Wing Alternative Design example

Final Glider Design Approach (Authors- William, Carter, Emily)

The airfoil selected for the final design was the Drela AG47c -03f airfoil (Figure 8).

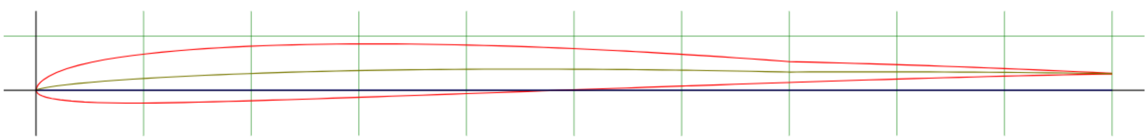


Figure 8: Drela AG47c -03f Airfoil

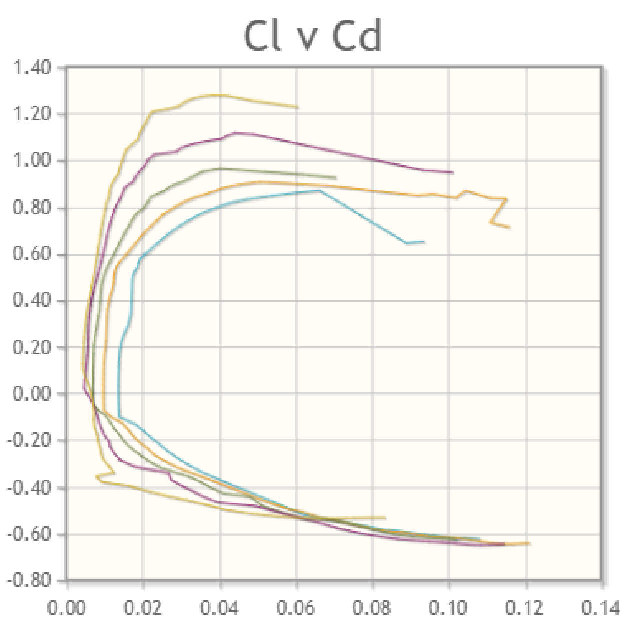


Figure 9: Cl vs Cd of AG47c -03f Airfoil

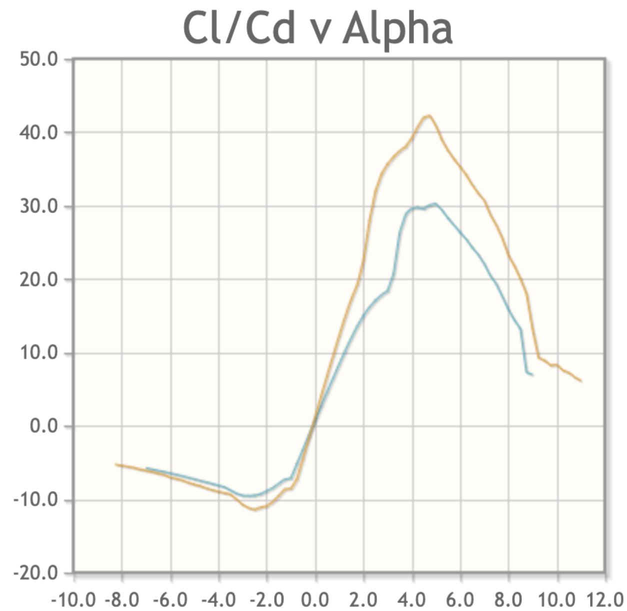


Figure 10: Cl/Cd vs Angle of Attack of AG47c -03f Airfoil

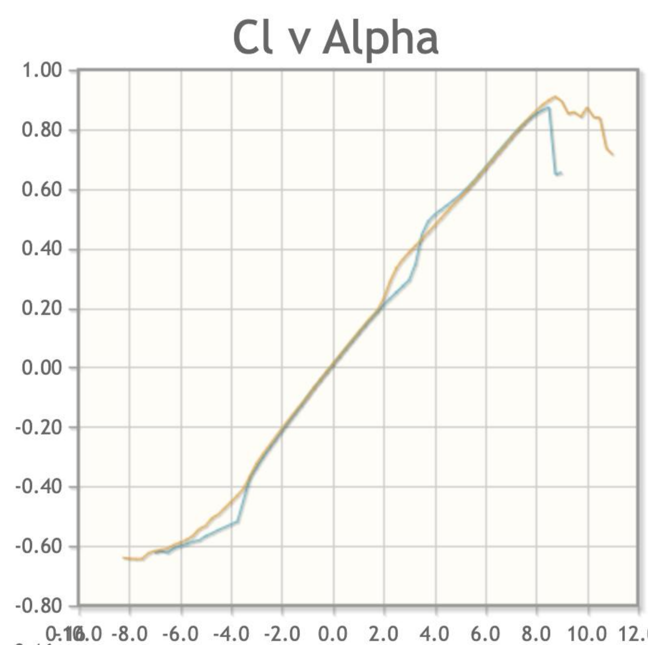


Figure 11: Cl vs Angle of Attack of AG47c -03f Airfoil

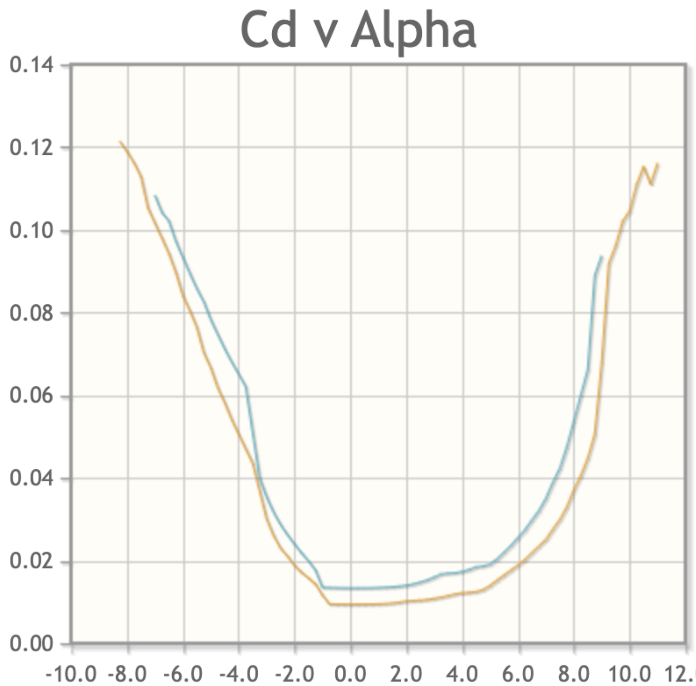


Figure 12: Cd vs Angle of Attack of AG47c -03f Airfoil

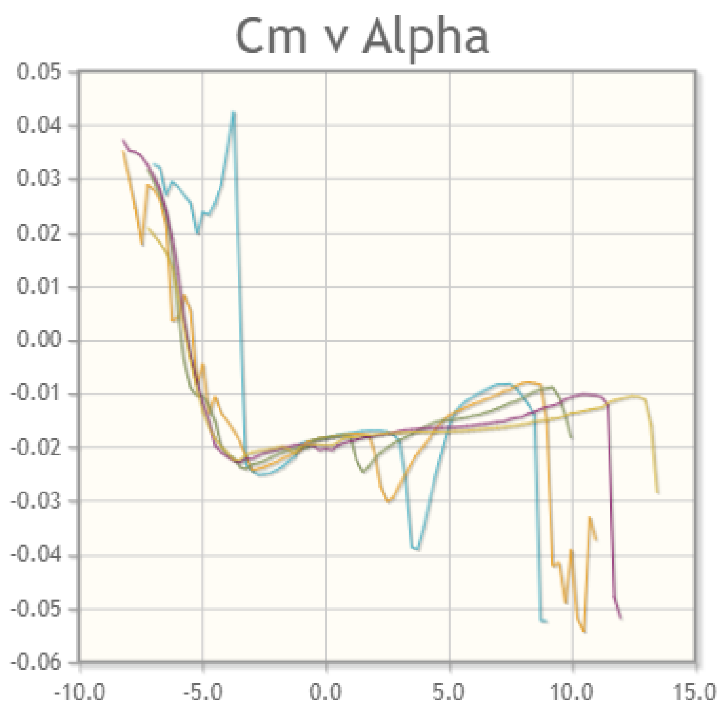


Figure 13: Cl/Cd vs Angle of Attack of AG47c -03f Airfoil

CAD Models (Emily, Carter)

Figure 14: CAD Model (Isometric View)

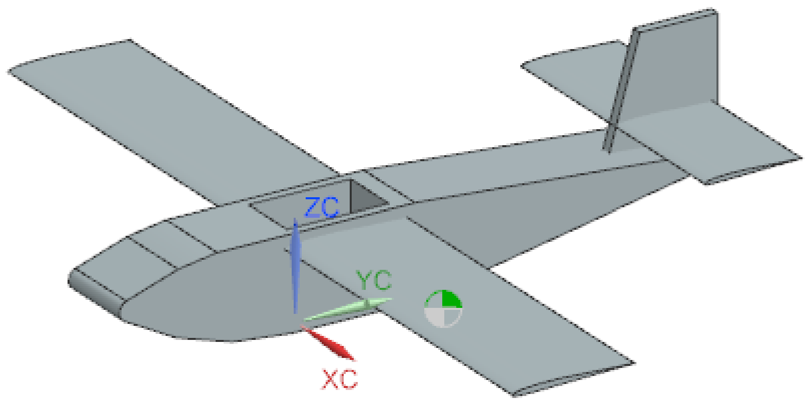


Figure 15: CAD Model (Side View)

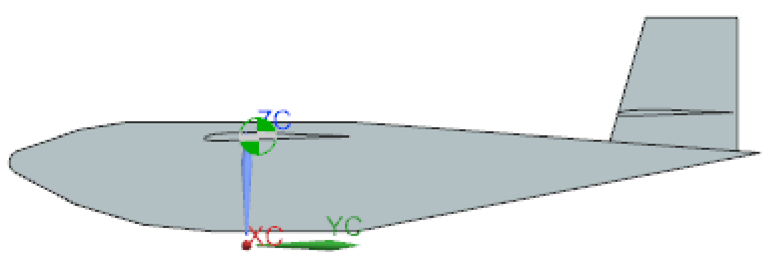


Figure 16: CAD Model (Top View)

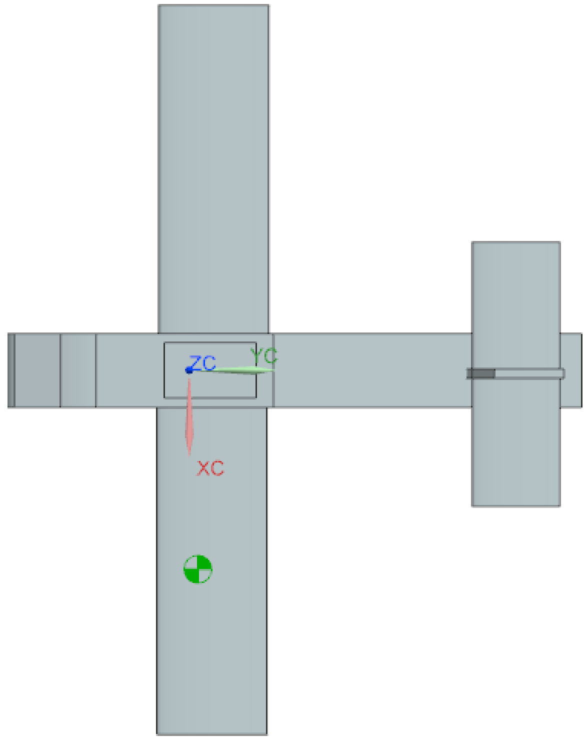


Figure 17: CAD Model Dimensions

Figure 18: Glider wing

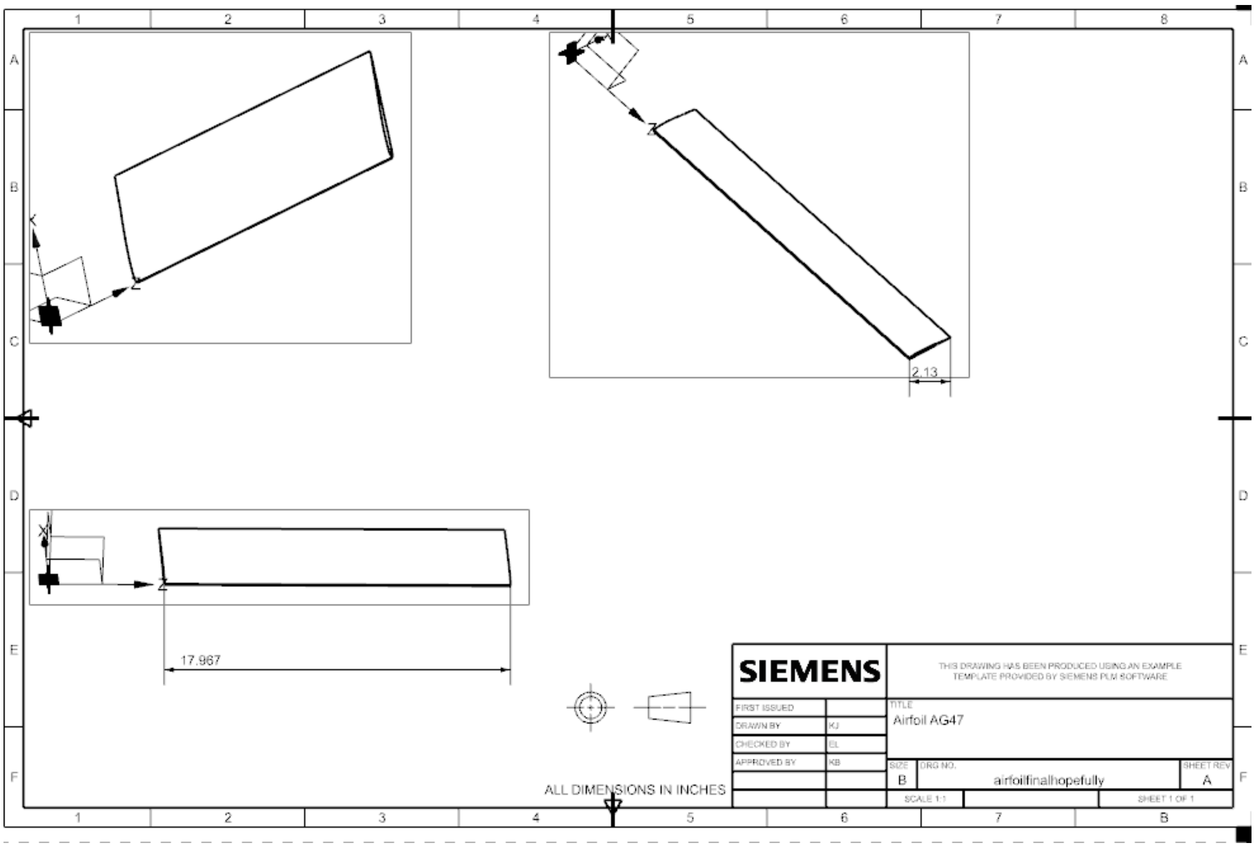
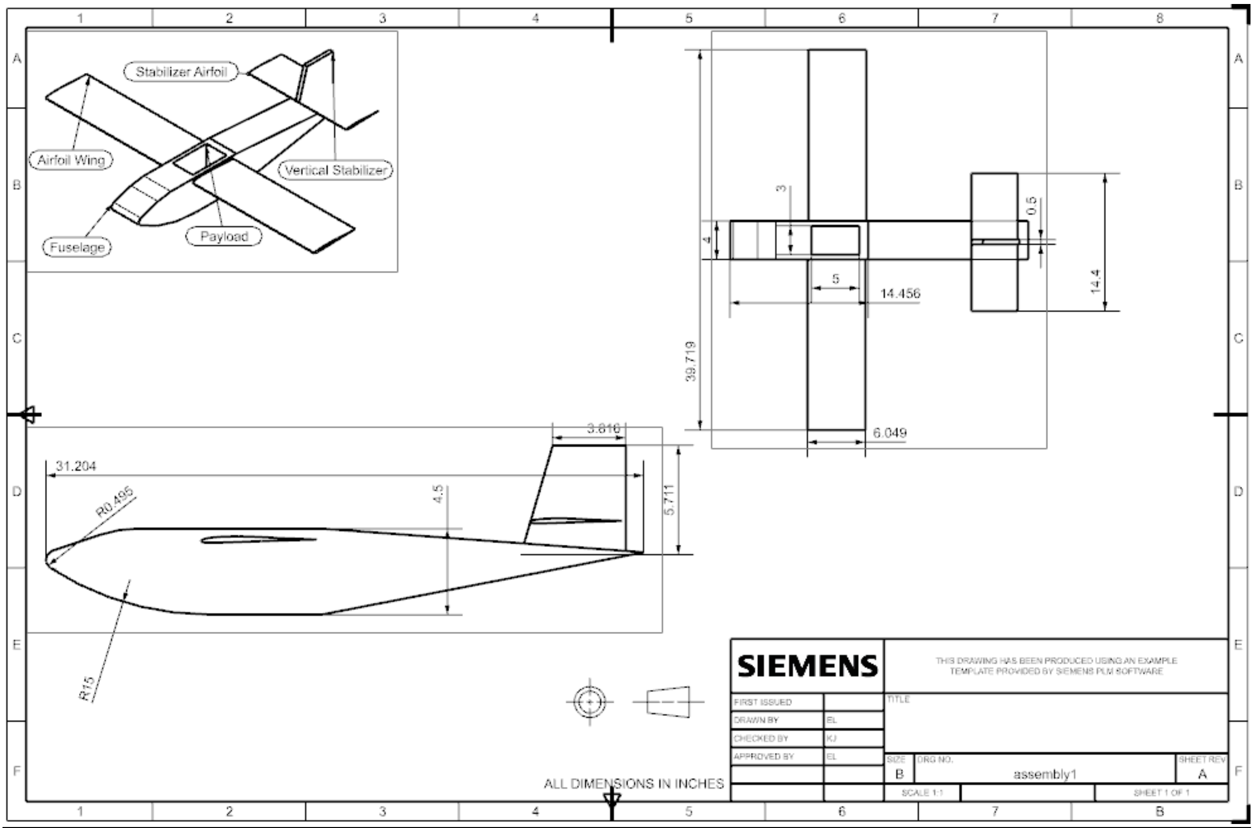


Figure 19: CAD Model



Calculations: (William, Carter)

Table 1: Dimensions of Glider Components

	Meters (m)	Inches (in)	Feet (ft)
Glider Length	0.79	31.2	2.6
Chord (c)	0.15	6.00	0.5
Wing Length (l)	0.45	17.9	1.97
Stabilizer Chord (sc)	0.124	4.87	0.41
Stabilizer Wing Length (sl)	0.366	14.4	1.2
Fuselage Width (w)	0.10	4.00	0.33
Fuselage Height (fh)	0.11	4.50	0.38

Fuselage Length (fl)	0.79	31.2	2.50

Figure 20: NX Calculations

1	MassPropMass	18.2006	lbm
2	MassPropWeight	18.2006	lbf
3	MassPropDensity	0.0483	lbm/in³
4	MassPropVolume	376.4576	in³
5	MassPropArea	1154.5085	in²

To calculate the wingspan (b) of the glider, the length of each wing must be added to the width of the fuselage:

$$b_{wing} = 2l + w \; = 2(0.45) + 0.10 = 1.0m$$

The surface area of the wing can be calculated by using the length and chord of the wing since it is rectangular:

$$S_{wing} = l \times c = 0.45 \times 0.15 = 0.0675m^2$$

In order for the airfoil to be most efficient the highest aspect ratio (AR) is desired. This can be found by squaring the wingspan and dividing by the surface area of the wings:

$$AR_{wing} = \frac{b^2}{S} = \frac{1.0^2}{0.0675} = 14.8$$

In order to find the same information regarding the stabilizer wing, the same calculations were performed, other than the wing span because the stabilizer is one piece:

$$b_{stabilizer\ wing} = 0.366m$$

$$S_{stabilizer} = sl \times sc = 0.366 \times 0.124 = 0.0454m^2$$

$$AR_{stabilizer} = \frac{b^2}{S} = \frac{0.366^2}{0.0454} = 2.95$$

<u>Reynolds Number:</u>

To acquire the accurate Reynolds number, the density of air (ρ) at the point of launch must be calculated by using the average temperature (T) and pressure (P) in Melbourne, FL. The average pressure in Melbourne during April was found to be 30 "Hg, and the average temperature was 74°F. Respectively, these can be converted to 101,592 Pa and 296.483 K. The specific gas constant for dry air (R = 287.058 J/(KgK)) was used in the calculations:

$$\rho = \frac{P}{RT} = \frac{101592}{287.059 \times 296.483} = 1.194 \frac{kg}{m^3}$$

An estimated initial velocity of 6 m/s was assigned to the glider, as it was going to be thrown by a team member. This estimation was determined by the average throwing speeds of objects with a similar mass. This is the velocity used in the calculation of the Reynolds Number, along with air viscosity (μ = 1.79 x 10^{-5}) that corresponds to the altitude of Melbourne:

$$Re_{wing} = \frac{\rho V c}{\mu} = \frac{1.194 \times 6 \times 0.15}{1.79 \times 10^{-5}} = 6.0 \times 10^4$$

$$Re_{stabilizer} = \frac{\rho V s c}{\mu} = \frac{1.194 \times 6 \times 0.124}{1.79 \times 10^{-5}} = 5 \times 10^4$$

Lift/Drag:

In order to determine the coefficient of both lift and drag, the graphs found on airfoiltools.com were used. The best angle of attack was found to be $\alpha = 4.8^{O}$ for the highest lift-to-drag ratio. This was found from the maximum value of the function on the graph in Figure 10.

By using the optimum angle of attack found prior, the coefficients of lift and drag can be determined from graphs (Figures 11 & 12). The values corresponding to the angle of attack are c_l = 0.67 and c_d = 0.02.

After the values of c_l and c_d were acquired, they can be used to calculate the lift and drag, respectively, of each pair of wings:

$$L_{wing} = \frac{1}{2}\rho v^2 S_{wing} c_l = \frac{1}{2} 1.194 \times 6^2 \times 0.0675 \times 0.67 = 0.97N$$

$$D_{wing} = \frac{1}{2}\rho v^2 S_{wing} c_d = \frac{1}{2} 1.194 \times 6^2 \times 0.0675 \times 0.02 = 0.029N$$

The same process must be executed to find the lift and drag for the stabilizer wing:

$$L_{stabilizer} = \frac{1}{2}\rho v^2 S_{stabilizer} c_l = \frac{1}{2} 1.194 \times 6^2 \times 0.0454 \times 0.67 = 0.65N$$

$$D_{stabilizer} = \frac{1}{2}\rho v^2 S_{stabilizer} c_d = \frac{1}{2} 1.194 \times 6^2 \times 0.0454 \times 0.02 = 0.020N$$

Now that the lift and drag of both sets of wings have been found, this allows for the calculation of the lift and drag of the glider as a whole.

$$L = L_{wing} + L_{stabilizer} = 1.62N$$

$$D = D_{wing} + D_{stabilizer} = 0.049N$$

<u>Weight of Glider:</u>

Density of Polystyrene (d): 25 kg/m^3

Volume of Glider (V): 6.17 x 10^{-3} m^3

In order to find the weight of the glider the mass must first be found. This can be done with the density and volume of the glider and its materials. The average density of polystyrene is approximately 25 kg/m^3:

$$\rho = \frac{m}{V} \rightarrow m_{glider} = \rho V = 25 \times 6.17 \times 10^{-3} = 0.154kg$$

The glider must be able to support a payload of $m_{payload}$ = 0.043 kg. The total mass of the glider with the payload is:

$$m_{total} = m_{glider} + m_{payload} = 0.154 + 0.043 = 0.197kg$$

Now the total mass can be used to find the weight, by multiplying it by earth's gravitational acceleration(g = 9.8 m/s^2):

$$W = mg = 0.197 \times 9.8 = 1.93N$$

Center of Gravity:

The aerodynamic center of the airfoils are assumed to be found at one-quarter of the chord length. Therefore, using the chord length, we find:

$$AC_{wing} = 0.25 \times c = 0.25 \times 0.15 = 0.0375m$$

$$AC_{stabilizer} = 0.25 \times sc = 0.25 \times 0.124 = 0.031m$$

The distance between the aerodynamics centers of the airfoil was found to be d = 0.429 m on NX. With this distance and the surface area of the wings, the below equation produces the induced drag factor:

$$K = d\frac{S_{stabilizer}}{S_{wing} + S_{stabilizer}} = 0.429\frac{0.0454}{0.0675 + 0.0454} = 0.173m$$

The distance of the aerodynamic center of the glider from the leading edge is found by adding the induced drag factor to the aerodynamic center of the wing:

$$AC_{LE} = AC_{wing} + K = 0.0375 + 0.173 = 0.211m$$

We can use this value to find the distance between the nose of the glider and the aerodynamic center by adding the distance between the nose and the leading edge():

$$AC_{nose} = d_{LE\rightarrow nose} + AC_{LE} = 0.206 + 0.211 = 0.417m$$

Tail Volume Ratios:

The aerodynamic center of the airfoils are assumed to be found at one-quarter of the chord length. Therefore, using the chord length, we find:

$$AC_{wing} = 0.25 \times c = 0.25 \times 0.15 = 0.0375m$$

The distance between the aerodynamics centers of the airfoil was found to be d = 0.429 m on NX. With this distance and the surface area of the wings, the below equation produces the induced drag factor:

$$K = d\frac{S_{stabilizer}}{S_{wing} + S_{stabilizer}} = 0.429\frac{0.0454}{0.0675 + 0.0454} = 0.173m$$

The static margin is required in order to calculate the horizontal tail volume ratio. It is approximately 10% of the distance from the leading edge to the aerodynamic center of the wing.

$$SM = \frac{AC_{wing}}{10} = \frac{0.0375}{10} = 0.00375m$$

The horizontal tail volume ratio was determined by using several parameters, including the area of the wing, the area of the stabilizer wing, the induced drag factor, the static margin, and the distance from the leading edge to the aerodynamic center of the wing:

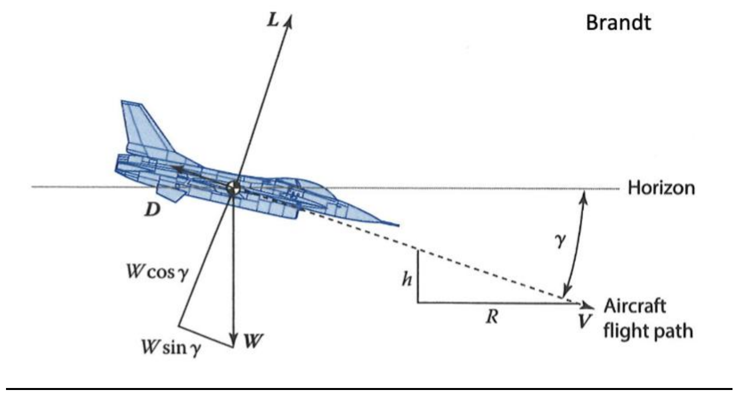
$$V_{ht} = \frac{S_{stabilizer}(d-K+SM)}{S_{wing}AC_{wing}} = \frac{0.0454(0.429-0.173+0.00375)}{0.0675(0.0375)} = 4.66$$

The vertical tail volume ratio was determined through the area of the vertical stabilizer obtained through NX (measured to be 0.0171 m^2), along with the wing area and wing span.

$$V_{vt} = \frac{S_{vertical} \cdot\times d}{2 \times S_{wing} \cdot\times b} = \frac{0.0171 \times 0.429}{2\times 0.0675 \times 1.0} = 0.0543$$

Endurance and Range Results (William)

Figure 20: Gliding Flight



Above is a diagram depicting a plane that is gliding (Figure 8). h represents a vertical component of its flight path, and R represents a horizontal component, or the glide range. The angle of the flight path is represented by γ. γ can be found from the below equations:

$$tan\,\gamma = \frac{1}{L/D}$$

$$tan\,\gamma = \frac{h}{R}$$

Therefore, these equations can be set to each other and solved. The glider is predicted to be starting at a height of 2.5 m since it is held by a team member over their head. h is equal to the starting height of the glider:

$$\frac{h}{R} = \frac{1}{L/D} \rightarrow R = \frac{hL}{D} = \frac{2.5 \times 1.62}{0.049} = 82.7$$

As a result of the above calculations, the glide ratio (the horizontally traveled distance to the vertically traveled distance) is 33.1:1 and the Glide Range is 82.7 m.

The endurance can be calculated by finding the sink rate:

$$Sink\ Rate = vsin(\gamma) = v\frac{D}{W} = 6\frac{0.049}{1.93} = 0.152m/s$$

The glider will descend 0.152 m per second in flight. The sink rate can be further used to predict the flight time:

$$T = \frac{\Delta h}{Sink\ Rate} = \frac{2.5}{0.152} = 16.44s$$

The glider is estimated to remain in flight for 16.44 seconds.

Project Conclusions and Lessons Learned (Authors-Kendall, Carter, Nathan)

This project aimed to design a low-cost glider capable of carrying a payload. Through teamwork, we successfully developed a glider with a selected airfoil capable of traversing a long distance. While designing this glider, we had to combine our technical skills and knowledge of aerospace to complete this project. Of the many skills we had to use, time management, critical thinking, communication, and teamwork were the basis for our success. Utilizing the design process, we selected a suitable material, airfoil, and aircraft design for our glider. We had to perform trial-and-error calculations with various materials and designs to determine the most ideal. The project also helped us expand our knowledge of airfoils, further understand aerodynamic concepts, and learn new concepts. Our Cad skills were also used and strengthened due to this project, as we had to learn how to import airfoil coordinates into SIEMENS NX to create our models and learn new commands to fix various issues we encountered. From searching for airfoils to glider designs to NX commands and formulas, each team member also had to learn and utilize research skills throughout this project. Ultimately, the project taught us to work together and use our knowledge and resources to design a successful glider.