C1 Fixed Wing Aircraft Journal

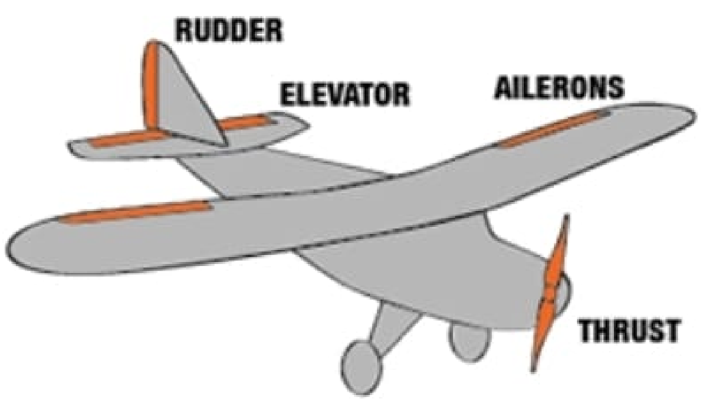
Members: Kow Ming Yuan, Arshul Garg, Soh Kai Xuan, Rajan, Mohit
Started on: 26 January 2022
Completed on: 6 April 2022

Table of Contents:

Plane Description

Firstly, for the design considerations, we considered various plane wing configurations, namely the delta wing, the rectangular wing, the eliptical wing, and the trapezoidal wing. In the end, we chose the **Delta Wing** configuration, specifically the **cropped delta variant**. We chose this wing configuration as it allows for greater manoeuvrability and high speeds. Our aircraft design makes use of delta wings which stall at a high angle of attack of about 35 degrees which results in greater flow separation. This leads to the formation of leading edge vortices on the top surface of the delta wings which reduces air pressure above the wings. Furthermore, the aircraft has low wing loading due to its high wing surface area to plane mass ratio. These factors work together to produce a large lift force on the plane that confers increased manoeuvrability on the aircraft's performance. This allows the plane to better manage the convoluted flight course of the competition.

Secondly, for the control surfaces, we considered 3 different types of control surfaces: **Rudders**, **Elevators** & **Ailerons**.

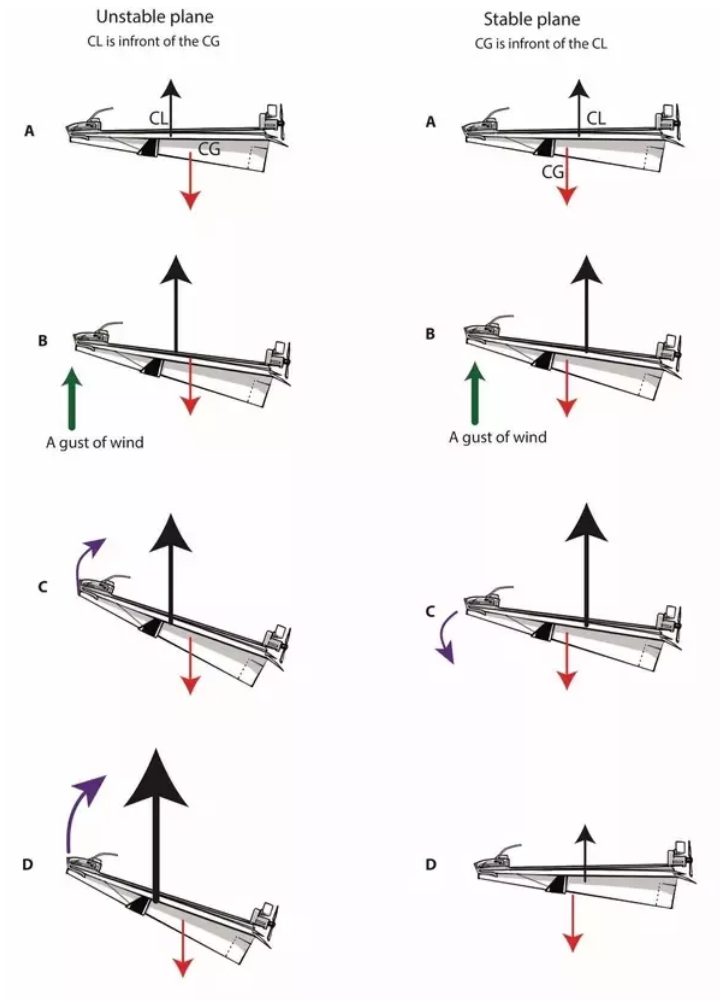


Ailerons are: a hinged flight control surface attached to the trailing edge of each wing, which controls the aircraft in roll, or movement around the aircraft's longitudinal axis, which normally results in a change in heading due to the tilting of the lift vector. Movement around this axis is called 'rolling' or 'banking'. **Elevators** are: a hinged flight control surface at the rear, which controls the aircraft's longitudinal attitude by changing the pitch balance, and so also the angle of attack and the lift of the wing. **Rudders** are: a hinged flight control surface attached to the vertical stabilizer, which is used primarily to counter adverse yaw. A rudder operates by redirecting the airflow past the fuselage, thus imparting a turning or yawing motion to the aircraft. Using a combination of **Elevators** and **Ailerons** yields **Elevons**. Elevons were used since they provide the best manoeuvrability. To roll or bank, the elevons move opposite of each other. To control pitch they move together. This allows for both the flight turning and pitch control to be monitored by just one system. This reduces the complexity of the aircraft control, ensuring that the person flying the plane would be able to control it more effectively, increasing their performance when flying the aircraft during the competition.

Thirdly, for the wing position and type. We considered three unique wing positions: **High, Medium** & **Low**.

Generally the higher the wing, the more stable the flight. The lower the wing is positioned on the fuselage, the nimbler the plane becomes. Therefore, we decided on a **Medium** wing position. This is because we wanted the flight to be somewhat stable as it was our first time flying. At the same time, we also did not want to compromise on manoeuvrability since it was required to complete the turns for the competition.

To ensure flight stability, we made sure to arrange our components such that the center of gravity will be in front of the center of lift of the main wing. This ensures that the aircraft is self-stabilising as shown in the diagram below:

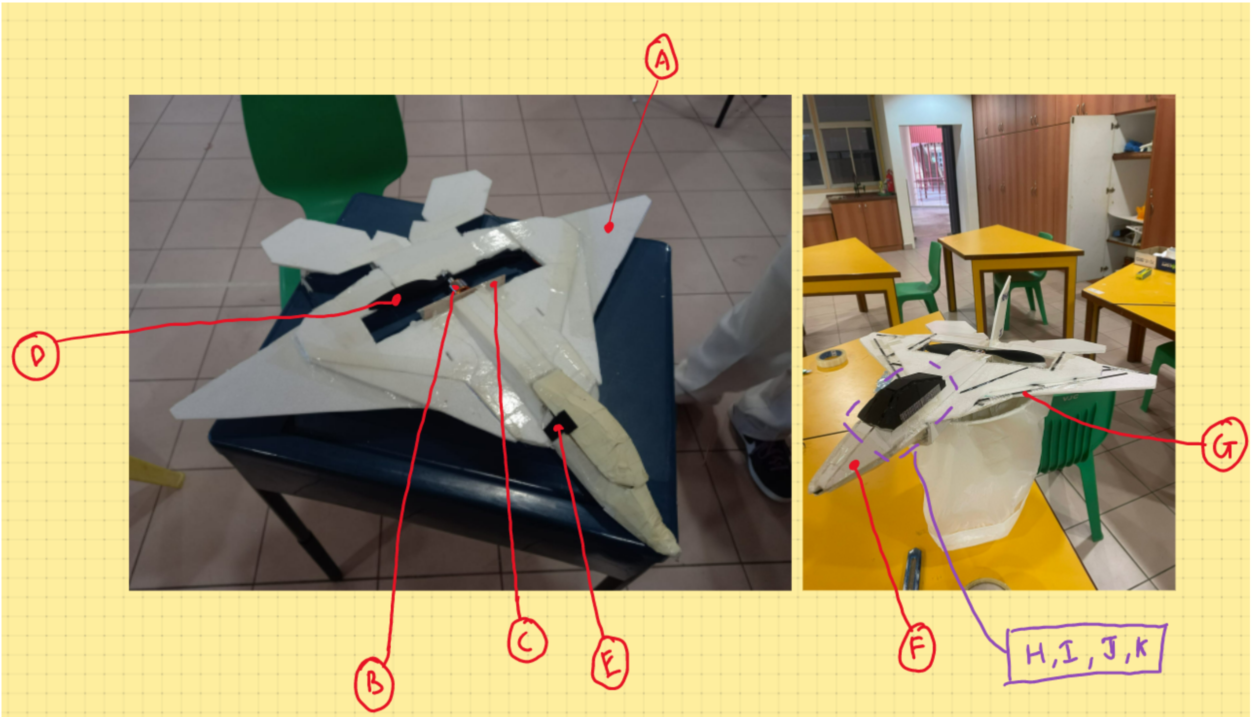


Lastly, for the evolution of design, we increased the propeller size from 6 inch to 10 inch (see data sheet below) to provide even more thrust, added vertical stabilizer to maintain a stable flight path, added carbon rods and thicker foam to increase durability significantly. We also increased the wing and elevon size to produce greater lift and thrust and also created more sensitive control surfaces.

Timeline

Date	Objective
26/1/22	Cut out plane parts and construct plane frame
7/2/21	Construct plane frame and rig electronics onto the plane
9/2/21	Rig electronics onto the plane and test controls
14/2/21	Rig electronics onto the plane and test controls
16/2/21	Rig electronics onto the plane and test controls
21/2/21	Rig electronics onto the plane and test controls
23/2/22	Test Controls
14/3/22	Test flight 1 and repairs and modifications
15/3/22	Test flight 2 and repairs and modifications
16/3/22	Test flight 3 and repairs and modifications
17/3/22	Test flight 4 and repairs and modifications, Submit Proof of Flight and Learning Journey Video
23/3/22	Construction of second prototype
28/3/22	Construction of second prototype
30/3/22	Construction of second prototype and rigging of electronics
31/3/22	Construction of second prototype and rigging of electronics
1/4/22	Test flight, repair and modifications
4/4/22	Test flight, repair and modifications
5/4/22	Practice flight for actual competitions
6/4/22	SAFMC Final Challenge

Materials and equipment used



Name	Description	Remarks / AFOIs
A: Polystyrene Foam (Styrofoam) Specifically, **THP Foam Board** and **EPP Foam**	Was used to make the main body of the plane. We initially used a **thicker**, more **brittle** styrofoam sheet which was prone to cracks and chipping upon impacts while flying the plane. Hence we switched to the [THP Foam Board] which in essence, differs from regular styrofoam sheets due to its laminated paper sides which give it more structural integrity while being lightweight. We used a **mixture** of THP Foam Board and [EPP Foam] for the wings, using the stronger THP Foam Boards for areas more prone to damage such as the **fuselage**. The EPP Foam was used to **reduce weight.**	The THP foam was still prone to damage and had to be repaired using carbon strips, defeating its purpose. Due to the light weight of the EPP Foam, the wing still had to be secured with carbon strips. Hence, in the future,

<table>
<tr>
<td></td>
<td></td>
<td>polystyrene should be used, but can be supported with another layer of foam.</td>
</tr>
<tr>
<td>B: A2212 BLDC Motor
Datasheet:
BLDC_A2...</td>
<td>The A2212 BLDC Motor is a 3-phase out-runner type popular brushless DC motor commonly used in drones and other multirotor applications. The A2212 motor requires an Electronic Speed Controller (see H) to control its speed.

<table>
<tr><td>Motor</td><td>Todd's-Suppo-Welgard A2212/15: 930Kv: 51g: 4A-10A (12A max) 4.26.07, 20A Suppo ESC</td></tr>
</table>
Temperatures (52°C) from Rear mount plate

No load (Suppo): 0.4A @ 10v, Rm = 0.105 Ω [Vintage1 Calc = ~905Kv, ~0.39 Ω]

<table>
<tr><th>Prop</th><th>Volts</th><th>Amps</th><th>Watts</th><th>RPM</th><th>Pitch Speed (mph)</th><th>Thrust (g)</th><th>Thrust (oz)</th><th>g/W</th></tr>
<tr><td>9x5 GWS HD</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Motor 27°C: Set on PS: 7v</td><td>7.0</td><td>3.60</td><td>25</td><td>5220</td><td>24.7</td><td>260</td><td>9.16</td><td>10.40</td></tr>
<tr><td>8v</td><td>7.9</td><td>4.40</td><td>34</td><td>5820</td><td>27.6</td><td>322</td><td>11.34</td><td>9.47</td></tr>
<tr><td>9v</td><td>8.9</td><td>5.20</td><td>46</td><td>6390</td><td>30.3</td><td>398</td><td>14.01</td><td>8.65</td></tr>
<tr><td>10v</td><td>9.9</td><td>6.05</td><td>60</td><td>6900</td><td>32.7</td><td>473</td><td>16.66</td><td>7.88</td></tr>
<tr><td>82mAh, 35°C: 11v</td><td>10.9</td><td>6.85</td><td>75</td><td>7440</td><td>35.2</td><td>541</td><td>19.05</td><td>7.21</td></tr>
<tr><td>+40mAh, to 41°C: 14.2v</td><td>14.0</td><td>9.80</td><td>137</td><td>8910</td><td>42.2</td><td>796</td><td>28.03</td><td>5.81</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>9x7.5 GWS HD</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Motor 34°C: Set on PS: 7v</td><td>6.9</td><td>5.30</td><td>37</td><td>4680</td><td>33.2</td><td>255</td><td>8.98</td><td>6.89</td></tr>
<tr><td>8v</td><td>7.9</td><td>6.30</td><td>50</td><td>5130</td><td>36.4</td><td>311</td><td>10.95</td><td>6.22</td></tr>
<tr><td>9v</td><td>8.9</td><td>7.60</td><td>67</td><td>5640</td><td>40.1</td><td>374</td><td>13.17</td><td>5.58</td></tr>
<tr><td>10v</td><td>9.9</td><td>8.60</td><td>86</td><td>6030</td><td>42.8</td><td>429</td><td>15.11</td><td>4.99</td></tr>
<tr><td>117mAh, 45°C: 11v</td><td>10.9</td><td>9.80</td><td>107</td><td>6390</td><td>45.4</td><td>491</td><td>17.29</td><td>4.59</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Recommended prop for 3s</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>10x5 APC E</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Motor 34°C: Set on PS: 7v</td><td>6.9</td><td>4.70</td><td>33</td><td>4890</td><td>23.2</td><td>309</td><td>10.88</td><td>9.36</td></tr>
<tr><td>8v</td><td>7.9</td><td>5.60</td><td>44</td><td>5400</td><td>25.6</td><td>378</td><td>13.31</td><td>8.59</td></tr>
<tr><td>9v</td><td>8.9</td><td>6.60</td><td>59</td><td>5880</td><td>27.8</td><td>459</td><td>16.16</td><td>7.78</td></tr>
<tr><td>10v</td><td>9.9</td><td>7.70</td><td>76</td><td>6360</td><td>30.1</td><td>543</td><td>19.12</td><td>7.15</td></tr>
<tr><td>109mAh, 41°C: 11v</td><td>10.9</td><td>8.70</td><td>95</td><td>6780</td><td>32.1</td><td>624</td><td>21.97</td><td>6.57</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>10x6 GWS HD</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Motor 26°C: Set on PS: 7v</td><td>6.9</td><td>4.75</td><td>33</td><td>4830</td><td>27.4</td><td>321</td><td>11.30</td><td>9.73</td></tr>
<tr><td>8v</td><td>7.9</td><td>5.70</td><td>45</td><td>5370</td><td>30.5</td><td>394</td><td>13.87</td><td>8.76</td></tr>
<tr><td>9v</td><td>8.9</td><td>6.70</td><td>59</td><td>5850</td><td>33.2</td><td>471</td><td>16.59</td><td>7.98</td></tr>
<tr><td>10v</td><td>9.9</td><td>7.75</td><td>77</td><td>6360</td><td>36.1</td><td>558</td><td>19.65</td><td>7.25</td></tr>
<tr><td>108mAh, 38°C: 11v</td><td>10.9</td><td>8.80</td><td>95</td><td>6750</td><td>38.4</td><td>635</td><td>22.36</td><td>6.68</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>10x8 GWS HD</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Motor 29°C: Set on PS: 7v</td><td>6.9</td><td>6.75</td><td>47</td><td>4290</td><td>32.5</td><td>320</td><td>11.27</td><td>6.81</td></tr>
<tr><td>8v</td><td>7.9</td><td>8.00</td><td>63</td><td>4680</td><td>35.5</td><td>383</td><td>13.49</td><td>6.08</td></tr>
<tr><td>9v</td><td>8.9</td><td>9.30</td><td>82</td><td>5040</td><td>38.2</td><td>444</td><td>15.63</td><td>5.42</td></tr>
<tr><td>10v</td><td>9.9</td><td>10.60</td><td>104</td><td>5400</td><td>40.9</td><td>505</td><td>17.78</td><td>4.86</td></tr>
<tr><td>11v</td><td>10.9</td><td>11.90</td><td>128</td><td>5670</td><td>43.0</td><td>570</td><td>20.07</td><td>4.45</td></tr>
<tr><td>185mAh, 60°C: dropping</td><td></td><td>11.65</td><td>126</td><td>5610</td><td>42.5</td><td>558</td><td>19.65</td><td>4.43</td></tr>
</table>
</td>
<td>We found the motor to be too heavy and powerful for our purposes which resulted in us having to build a bigger than necessary plane body. Remember to take into consideration the weight of the motor and be realistic with the power you need.</td>
</tr>
<tr>
<td>C: Wood</td>
<td>Was used to attach elevons of the plane to the servos. We initially used a lighter, more balsa</td>
<td>Explore other alternatives</td>
</tr>
</table>

	wood which was prone to cracks and chipping upon impacts while flying the plane. Hence we switched to the **plywood** which in essence, differs from balsa wood due to its structural integrity whilst being lightweight.	rather than pasting an external component like wood, which is prone to detaching
D: Propeller	We initially used a 6 inch propeller to give thrust to our plane, but it turned out that is was not sufficient to give the plane the thrust it needed. As a result, we decided to switch to a **1045 propeller**, which was able to provide more than sufficient thrust, and combined with our motor, it was able to provide thrusts of up to 800g, which was about triple the mass of the plane.	May need to consider if there are available propellers in the market thats are lightweight yet durable and less prone to breaking
E: Velcro strips	We used some velcro strips to open and close the cockpit of the aircraft and the bottom trapdoor of the aircraft. However, caution must be take when attaching these velcros as they may leave a gap with may potentially affect the aerodynamics of the aircraft	May need to consider other ‘less bulky ways of closing cockpit such as magnets or try to remove cockpits entirely
F: Tape and Glue	We initially planned on using only glue for the plane but we quickly realised that ZAP glue melts styrofoam as it hardens, weakening our plane. We tried to use foam safe glue, but it takes a long time to dry and it doesnt provide the amount of adhesive strength we wanted.	Test out effects of various types of glue on various types of foam and find the best combination,

	Hence, we decided to use a mixture of tape and glue We initially used masking tape for its lightweightedness However, after the test flight, we determined that they are not that suitable and decided to use fibreglass reinforced filament tape instead, which brings about structural stability at the cost of weight.	minimise the usage of tape when possible.
G: Carbon strip/rod	We used carbon strips to be pasted at the bottom of the plane for structural stability while the carbon rods are for connecting the servo motors to the elevons.	Could potentially plan positioning of carbon rod to reduce usage of carbon strips or rods, which contribute to added weight. Instead of using carbon rods, we could also create foam supports by stacking multiple pieces of foam together to reduce the weight while ensuring structural integrity.

<table>
<tr><td>H: ESC (Hornet 20A BEC)</td><td colspan="2">Used as a electronic speed controller which is attached to the motor and receiver and battery
<table>
<tr><th rowspan="2">Model</th><th rowspan="2">Product No.</th><th>Continuous/Burst</th><th colspan="2">Battery Cell</th><th rowspan="2">BEC Type</th><th colspan="2">BEC Output</th><th rowspan="2">Programmable</th><th>Size(mm)</th><th rowspan="2">Weight</th></tr>
<tr><th>Current</th><th>Li-xx</th><th>Ni-xx</th><th>Voltage</th><th>Current</th><th>L*W*H</th></tr>
<tr><td>Hornet 6A BEC</td><td>1000620</td><td>6A/8A</td><td>2-4LiPo</td><td>5-12NC</td><td>Linear</td><td>5V</td><td>0.5A</td><td>YES</td><td>22*12*5</td><td>6g</td></tr>
<tr><td>Hornet 12A BEC</td><td>1001220</td><td>12A/15A</td><td>2-4LiPo</td><td>5-12NC</td><td>Linear</td><td>5V</td><td>1A</td><td>YES</td><td>24*18*6.5</td><td>11g</td></tr>
<tr><td>Hornet 12A BEC</td><td>1001221</td><td>12A/15A</td><td>2-4LiPo</td><td>5-12NC</td><td>Linear</td><td>5V</td><td>2A</td><td>YES</td><td>24*18*6.5</td><td>11g</td></tr>
<tr><td>Hornet 20A BEC</td><td>1002020</td><td>20A/30A</td><td>2-4LiPo</td><td>5-12NC</td><td>Linear</td><td>5V</td><td>2A</td><td>YES</td><td>30*24*8.5</td><td>21g</td></tr>
<tr><td>Hornet 30A BEC</td><td>1003020</td><td>30A/40A</td><td>2-4LiPo</td><td>5-12NC</td><td>Linear</td><td>5V</td><td>2A</td><td>YES</td><td>30*24*8.5</td><td>21g</td></tr>
<tr><td>Hornet 40A BEC</td><td>1004020</td><td>40A/50A</td><td>2-4LiPo</td><td>5-12NC</td><td>Linear</td><td>5V</td><td>3A</td><td>YES</td><td>52*26.3*11</td><td>43g</td></tr>
<tr><td>Hornet 40A SBEC</td><td>1004030</td><td>40A/50A</td><td>2-6LiPo</td><td>5-18NC</td><td>Switch</td><td>5V</td><td>4A</td><td>YES</td><td>52*25*11</td><td>43g</td></tr>
<tr><td>Hornet 50A SBEC</td><td>1005030</td><td>50A/60A</td><td>2-6LiPo</td><td>5-18NC</td><td>Switch</td><td>5V</td><td>4A</td><td>YES</td><td>52*25*11</td><td>43g</td></tr>
<tr><td>Hornet 60A SBEC</td><td>1006030</td><td>60A/80A</td><td>2-6LiPo</td><td>5-18NC</td><td>Switch</td><td>5V</td><td>6A</td><td>YES</td><td>52*25*11</td><td>43g</td></tr>
<tr><td>Hornet 80A SBEC</td><td>1008030</td><td>80A/100A</td><td>2-6LiPo</td><td>5-18NC</td><td>Switch</td><td>5V</td><td>6A</td><td>YES</td><td>62*35*12</td><td>72g</td></tr>
<tr><td>Hornet 100A SBEC</td><td>1010030</td><td>100A/120A</td><td>2-6LiPo</td><td>5-18NC</td><td>Switch</td><td>5V</td><td>6A</td><td>YES</td><td>62*35*12</td><td>73g</td></tr>
</table></td></tr>
<tr><td>I: Battery</td><td>It is a 7.4 V battery</td><td>NIL</td></tr>
<tr><td>J: Micro Servo motor MG90</td><td>Servo motor is very small and provides enough force and is hence suitable for the elevons</td><td>Servo broke easily and had to be replaced multiple times, should consider using more expensive servos of higher quality.</td></tr>
<tr><td>L: Receiver FS iA6B</td><td>Range, voltage and weight of receiver is suitable and hence was chosen</td><td>NI</td></tr>
</table>

Building Process

Firstly, we had downloaded a template from an external website so as to print our plane. Following that, we printed it on a large A1 piece of paper so we can place it on top of styrofoam and start tracing and cutting it out. Once we cut it out, we decided to label the parts where we are going to attach the parts together so it is easier for us in the future to place the glue and the tape.

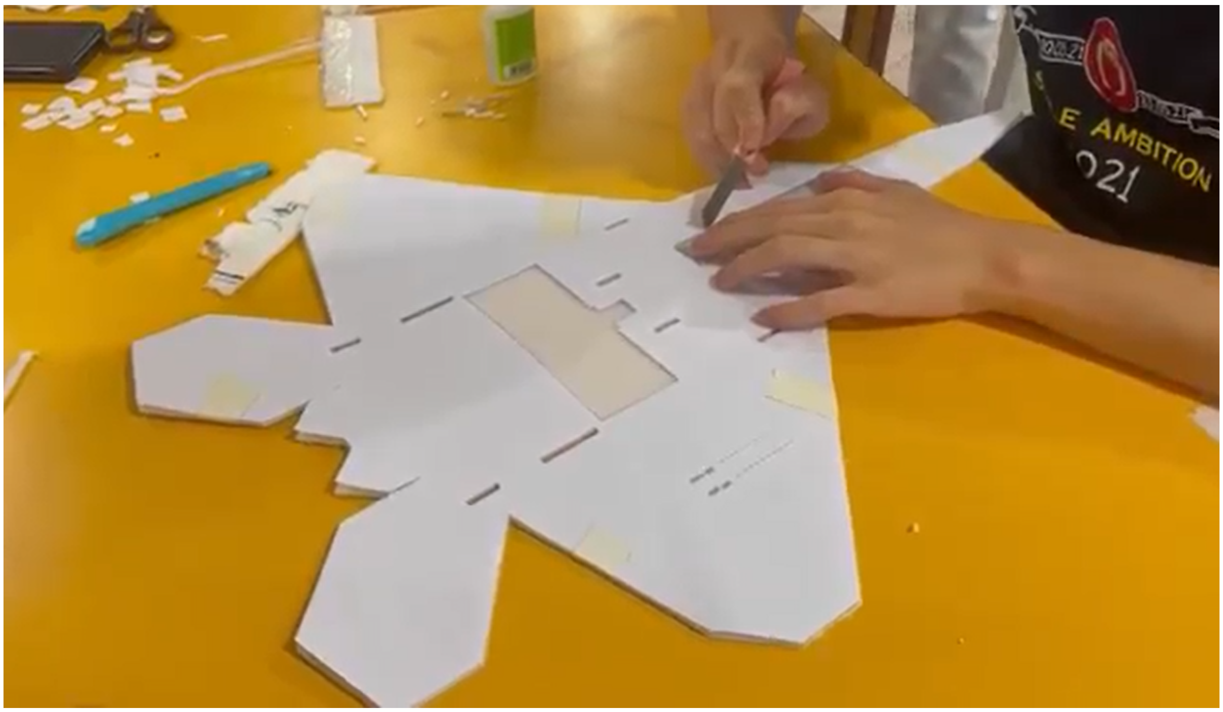


Figure 1: Cutting plane

When we were placing our parts together, we had to make sure we did not make any mistakes in the process so as to ensure our plane is perfect as we needed it to be aerodynamic. We ensured that the lines we traced out coincided with one another to ensure that when we placed it it had no errors. We also checked it from multiple angles to prevent any parallax error to ensure our plane is as straight as possible.

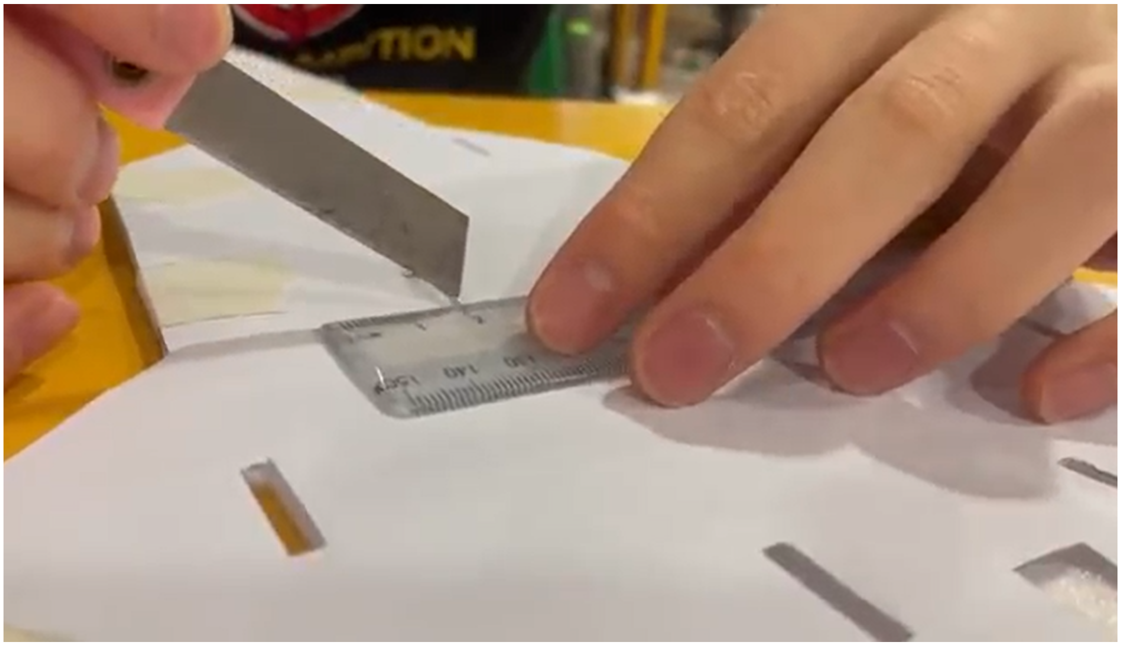
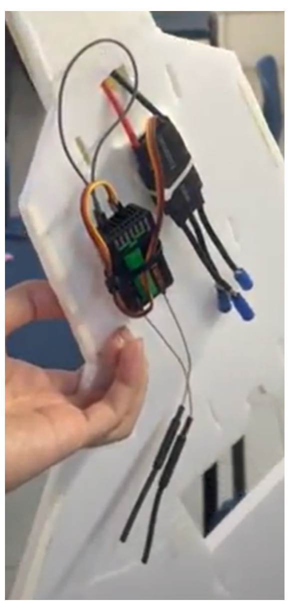


Figure 2: Cutting Plane

Once the plane has been pieced together, our next task was to wire the components together and place them inside the plane. We also considered how the centre of gravity of the plane will be affected and we determined that the centre of gravity should be closer to the front of the plane to ensure flight stability.



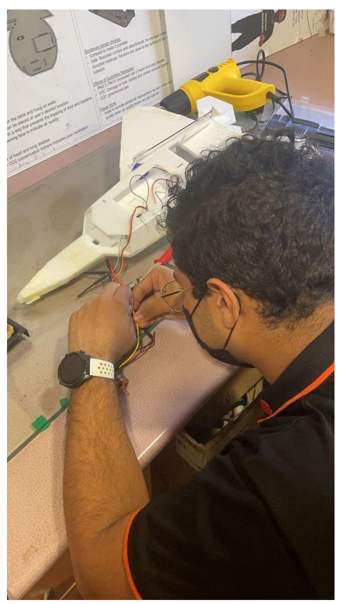


Figure 3: Circuit of plane Figure 4: Arshul connecting wires

Figure 5: Soldering

Followed by that we realised that we need to increase the structural stability of the plane and hence added carbon strips. Additionally, we added carbon rods together with servo motors to create the control surface for the elevons of the plane.

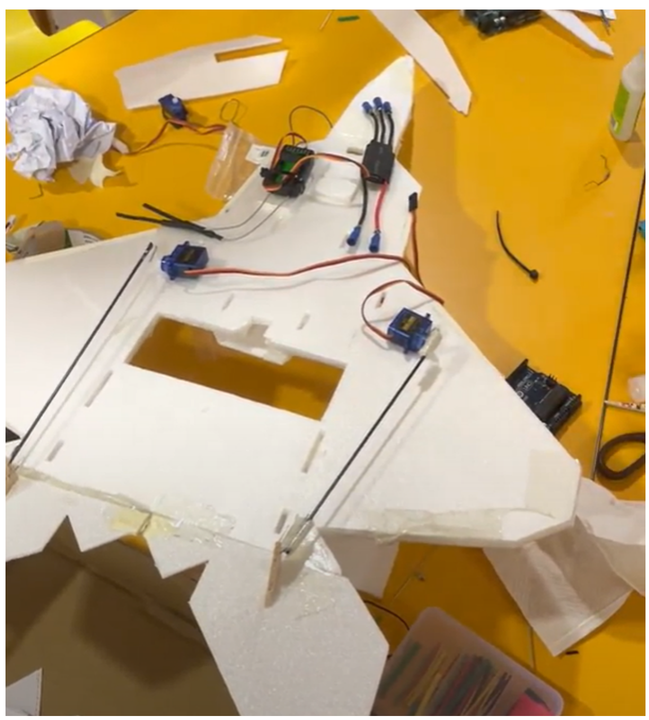


Figure 6: Plane frame with Servos attached

Second we added brushless motors, to act as the propeller for a plane. Followed by that we added a 6 inch propeller (changed to 1045 propeller in later stages for increased thrust) which is pretty powerful at controlling our plane forwards. We screwed the motor to balsawood (changed to plywood for greater structural integrity) so that we could hold the motor in place on the plane. When added a hole on the centre so that the shaft can spin freely. We also used smaller screws as well discovered later on that long screws, when fully screwed in, restrict the ability of the shaft to spin.

Figure 7: Attachment of motor and propeller to the plane frame

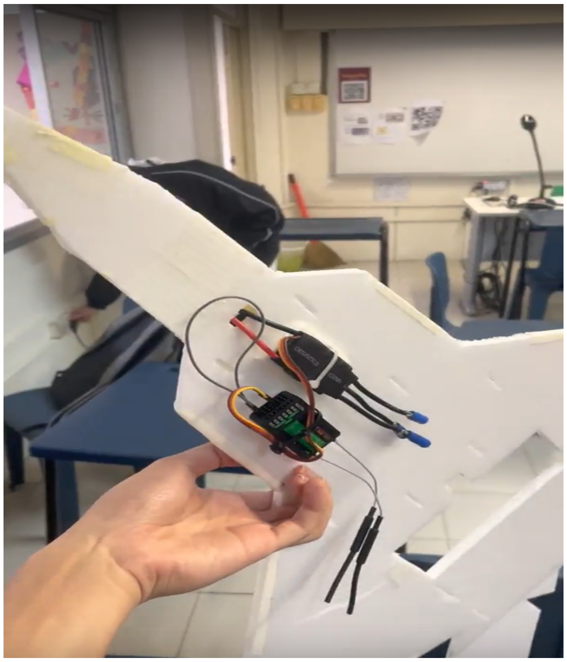
With that, the first prototype of our plane, fKH-69 has been constructed.

Figure 8: First prototype of the fKH-69

FKH-69 MK I

The FKH-69 MK I was our team's first collective effort in the creation of a RC foam plane. As expected for a first plane, the design had several flaws that we had to work out in the form of **insufficient lift generated**, **ineffective control surfaces**, **limited power** and **poor structural integrity** of the plane’s body . Let us now discuss each issue in greater detail and the modifications we made to the plane which improved its overall performance as demonstrated by the extended test flight durations of the FKH-69 MK II.

The first issue was the **limited lift generated**. The small plane wing area was greatly outweighed by the large mass of the plane body. This mass was primarily contributed by the dense foam and excessively large circuit compartments used because we overestimated the space required for our RC circuit. This high wing loading greatly limited the lift generated during the plane’s course of flight, preventing it from achieving any significant air time. We hence increased the wingspan of the aircraft by attaching wing extensions to both sides of the plane. This helped to increase the lift generated by the aircraft.



The small 6 inch propeller failed to generate sufficient power to lift the plane off the ground. To circumvent this issue, we replaced the original propellor with a larger 10 inch propeller. This helped to generate a much larger thrust that helped to carry the aircraft off the ground, allowing take-offs to take place much more swiftly and efficiently.

The manoeuvrability of the aircraft was greatly restricted by the small surface area of the elevons used to control the plane pitch and row. Therefore we were unable to effectively control the flight path of the FKH-69 MK I. To counter this, we greatly increased the surface area of the elevons and increased their tilt angle so that they could contribute more to flight control.

The aircraft initially had poor structural integrity due to the lack of rigidity of the foam we used. This caused the aircraft to be more flimsy which caused its flight path to meander, further restricting our control over it. Not only that, it caused it to damage severely as we conducted test flights. Therefore we increased our usage of carbon rods throughout the plane body to improve its overall rigidity. This proved to be effective in ensuring the aircraft took a more stable flight path.

Overall, the several aforementioned issues identified with the FKH-69 MK I and the corresponding structural reforms we made to improve it ended up being greatly effective in boosting the aircraft's performance. This can be seen from the tripled air time of our test flights with the FKH-69 MK I compared to the first prototype and the more precise plane control exhibited in these test flights (From not being able to fly, to slowly being able to achieve stable flight for about 20 seconds from an elevated position).

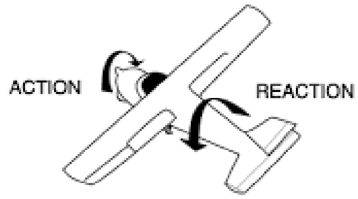
FKH-69 MK II

Due to the weight limit of the competition, high wing loading and the poor structural integrity of the fKH-69 MK I after multiple test flights, we decided to rebuild the plane frame with several modifications, resulting in the fKH-69 MK II.

Firstly, we decided to change the type of foam we used for the plane frame. For the fuselage, we decided to switch from polystyrene to THP Foam, as we wanted our fuselage to be more sturdy and less prone to damage from the test flights, For the wing, we switched to EPP foam as it lighter, strengthened using carbon strips. Not only that, we modified the design of the fueslage, making it slimmer in order to reduce unnecessary weight added. However, from the test flights with MK II, it proved to be not as effective as we thought. The new plane only had a reduced weight of about 30 grams, and after multiple test flights, we had to add carbon strips in order to secure the fueslage as the THP foam was brittle and easily broke from crashing. As the EPP foam was too light, more carbon strips than expected was needed in order to secure the wing, and after a few test flights it became flimsy, affecting the lift generated and requiring extra strips to secure it. Hence, we feel that, for future planes, polystyrene should still be used, but strengthened **with another layer of foam as a foam support**, to ensure the structural integrity while also keeping it lightweight.

Furthermore, the plane was still over the weight limit. However, this was a flaw in the design of the plane from the start, due to our inexperience in making planes and the lack of any proper training. To improve on this, in the future, the plane fuselage should be built using **one vertical foam piece**, with the components attached to the side, which will greatly reduce the weight.

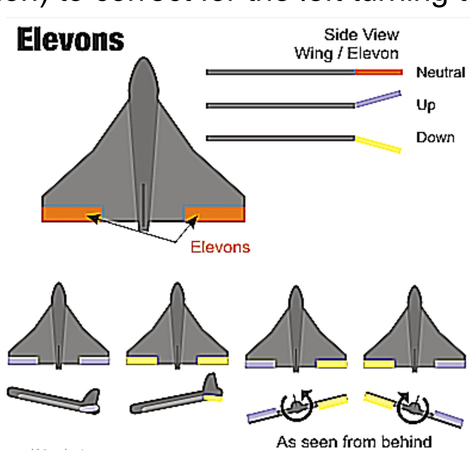
During the test flights, we also faced several problems.



Torque Reaction

One of the problems we faced was the torque roll phenomenon. This occurs due to Newton's third law of motion, which states that when object A exerts a force on object B, object B will exert back a force on object A that is equal in magnitude and opposite in direction. Hence, when the motor shaft rotates, there will be a torque exerted on the plane that is in the opposite direction to the torque of the shaft, resulting in the torque roll phenomenon. When the motor shaft rotates clockwise, it will result in a anticlockwise torque on the plane, and hence the plane will roll left. This is one of the common left-turning tendencies places face (others include p-factor, slipstream etc).

To correct this, we trimmed the elevons such that the right elevons is slightly higher than the left (roll right configuration) to correct for the left turning tendency of the plane.



Another problem we faced was that our plane reached stall torque very quickly. This was not a problem we faced at first, but only during the last few flights of the plane. We identified it to be possibly due to the lack of thrust and hence lift, as after several test flights, the trailing edge of the wing was drooping down slightly, which may have caused thrust vectoring. However, this was a problem we were unable to solve for despite our best efforts, and we hope to continue testing and researching to find out the cause of the problem.

Areas of improvement

Timeline

- Timeline was very tight due to the sudden switch from one project to another and hence we had only had **about a month** to build and test fly the first prototype
    - Area of improvement: Make sure that there is **ample time** for the completion of the project before embarking on it and **ensure good time management**, **get someone experienced** to help you with the project to reduce the runtime

Equipment and logistics

- Equipment took way too long to be purchased which affected our tight schedule even more. Some equipment **had to be purchased by our own members** as we needed it urgently, which we could not do so using the school's procedure as it would take too long. This is due to the fact that the equipment we had was broken or we failed to account for it previously.
    - Area of improvement: **Streamline the process** for purchasing equipment and create **a stockpile** of equipment every year so that we have reserves. Ensure that the equipment we purchase is **of high quality**, and is **well maintained and kept** by the club.

Knowledge Accquisition

- All of us in the team started this project with 0 knowledge and hence had to learn on the fly while building the plane. This led to us making many mistakes that could have been avoided if we had the proper knowledge and guidance from the start, slowing down our progress in building the plane.
    - Area of improvement: **Get someone experienced/a trainer** to guide us through the process of making the plane so that we can speed up the process of building the plane and design a more efficient plane frame that can perform better

Plane building process and test flights

- Due to our lack of knowledge in aerodynamics and foam plane building, there were several features of the plane that could be improved on. Generally, the group feels that we **require better guidance from a trainer** who can provide the feedback we seek for in order to build a better plane and impart to us knowledge that we may not be able to obtain on our own.

1. Fuselage: Replace it with a **vertical foam plate** and attach the components to the side to reduce the weight of the plane and thrust required.

2. Carbon Rods: Instead of using carbon rods to ensure the structural integrity, **add multiple pieces of foam together as foam supports** to ensure the structural integrity while remaining lightweight, and reduce the usage of the rods to a minimum.

3. Plane wing configuration: A delta wing is not very optimal for the competition due to its high speed and manoeuvrability, making it difficult to control. Instead, a **rectangular wing or elliptical wing may be more appropriate** as the aircraft will fly at a lower speed, making it more easy to control especially for beginners like us.

4. Control surfaces: **Add a rudder** in order to allow for control of the yaw of the plane to ensure a more stable and controlled flight of the aircraft.

Reflections

<u>Ming Yuan</u>

In general, I felt that the C1 fixed wing project was very fulfilling and allowed me to learn a lot about building Radio Control planes and planes in general. I learnt about the different considerations put in designing a plane such as control surface type, wing type and size, vertical stabilisers, etc. I also learnt various aerodynamic principles such as torque roll, p-factor, and how the 4 basic forces acting on any aircraft correlate and affect the flight of a plane. Not only that, I learnt about the considerations put into constructing a RC plane frame, such as joining techniques, materials used and their differences, such as Balsa Wood vs Plywood, and foam board vs polystyrene. The technical knowledge I picked up through this project will definitely be useful in building future projects, and are also transferable to non-RC plane projects.

Technical things aside, this project has also allowed me to hone my leadership skills. Being the leader of the C1 team, it definitely was not easy to lead the team to the completion of the project, and preparing for SAFMC. Having to switch from one project to another suddenly, we had to adapt and find the motivation within ourselves to suddenly ditch all the work we have done and restart on something else. I definitely struggled to bring the team together at the start as we all had no experience in fixed wing aircraft construction and this tall barrier was overwhelming for us, and hence it was harder for me to push them to work on the plane. However, I think over time, as we got used to it and became more knowledgeable, it became easier to work on the plane as we actually knew what we were doing and could visualise the end goal. This project has really taught me the importance of splitting the work into steps, and from there allocate accordingly, as with projects like these which can be very overwhelming at the start, it is very important to make it more manageable for the team by charting the road ahead in steps so that we can progress without feeling overwhelmed. I also wanted everyone to make the most out of this project and learn something, and hence made sure everyone could try out the different parts of the project at least once, such as making everyone take turns to solder as they did not have much experience doing so, and making sure everyone had the chance to test fly (if they wanted to). I think most importantly, I learnt that leadership is not just about the task, it is about the team. Without the team, you are nothing, and as leaders, we cannot take our team and their work for granted. I realised that, for the project to be a success, one must make sure everyone feels included and that they have a stake in the success of the project, and that they are all taken care of. Hence, I tried to make sure that they enjoyed the more mundane sessions where we are just repairing the plane by keeping it chill and talking to them while doing work, and not taking it too seriously. I also made sure to give my teammates positive affirmations, such as thanking them for their work and commending them when needed.

On the things we can improve on, I feel that we could have considered the weight limit of the plane right from the start. We did not consider the weight limit too seriously at the start as we were inexperienced and didn't think that we would exceed the limit. Another thing is to stick strictly to the rules. Even though we did email the organisers about the weight limit and they told us that it would only be a penalty, I feel that we should have played it safe and kept within the limit as in the end, it let to us frantically trying to cut weight at the risk of being disqualified and not being able to fly our actual plane at the competition. I also feel that we could have come up with a better plane design. We should have considered the challenge requirements more, but then again, we did not have any experience and we didn't really know how much it would affect how easy it was to fulfil the challenge requirements.

Throughout the course of the project, there were also several challenges we faced that were out of our control. One was the procurement of logistics. It took us very long to purchase the logistics we needed, and during the building of the plane, there was equipment we had to purchase on our own as we needed it urgently. I believe that a better system for purchasing logistics is needed, as it doesn't make sense that it takes so long for us to purchase items that we need, such that we can only predict what we need and purchase everything beforehand, as there is definitely equipment we did not foresee we needed due to the changing circumstances, the lack of experience or the breaking of equipment. Not only that, most of the team were amateurs in RC plane building and it was difficult for us to build the plane, with little to no guidance by any trainer. I believe that for future C1 teams, we should get a trainer or have the teachers guide us as it is not as easy as it sounds and there are many things we need to consider that we simply wouldn't know without a trainer, especially given the timespan we had to learn and build a working plane simultaneously. Lastly, we faced the lack of time to build and practice flying the plane. Our team had a very tight timeline having to switch from one project to another, and we only barely had enough time to construct our plane, and did not have enough time to properly practice flying, and whatever time we had flying was spent on test flying and modifying the plane rather than actually practicing flying the course. I feel that more support is required from the teachers in the areas mentioned above where possible, rather than just asking us about our progress.

Overall, there were many lessons learnt from this project, and I feel that we have achieved our goal with this project, but more support for the students is needed. We only aimed to participate in SAFMC as we had a lack of time, knowledge and resources and yet we managed to make a plane that can achieve stable flight and actually participated in SAFMC all the way to the end. There were a lot of lessons learnt through this project that would be very useful for future projects. Through this project, it has definitely sparked my interest in aerospace engineering and building RC planes and I will definitely continue to learn more about aerodynamics and RC planes, and work on my own RC plane projects. :)

Arshul

Throughout my journey in this competition, we had faced many challenges while working on this plane. Overall I think that I have learnt a lot not only about RC planes but also about myself.

Our team had been thrown into a very unfamiliar situation for us. We were the Electronics Spec, we specialised in electronics like Arduinos. Yet, we were put in a Remote Control Plane competition that largely requires knowledge and experience in aviation and planes which we did not possess. When we first began, we did not really know where to begin.

Kai Xuan

The journey was tough but rewarding. It was a continuous learning process - of which I’ve learnt many technical knowledge, skills and values. In terms of technical knowledge, I have learned many different aerodynamic concepts such as the angle of attack, Bernoulli's principle, lift etc. Beyond this theoretical knowledge, I also had many opportunities for hands-on experience with tinkering on the inner intricacies and skeleton of the plane giving me a better appreciation for electronics in general. Furthermore, through the creation of the plane, I was able to connect prior knowledge and realise its application in real life. Imperatively, I have sharpened various competencies such as collaboration, communication and critical thinking, valuable skills which I will carry forward in life.

Nevertheless, through this journey, there have been many highs and lows and areas for improvement. Personally, I felt that we could’ve been more critical in the ideation phase to check for the feasibility of ideas before embarking on them. One striking memory would be the fact that after the foam was cut and the plane was built, the plane was too flexible and thus unable to fly effectively due to it bending mid-air. Therefore, as a team, if we had anticipated these issues, we would’ve been able to avoid costly and time-consuming mistakes. In spite of all the hardships, I am truly grateful and honoured to be able to take part in this competition with my amazing team.

Rajan

This journey has given me an opportunity to explore my interests, have good communication skills and problem solving skills, amidst other valuable lessons

Having no particular future courses in mind that I would like to take after my A levels, I was willing to explore any fields that pique my interest. Through this competition, I was able to get a better understanding of two particular courses - aircraft engineering and aviation. While building the aircraft, we took some time to research what makes a plane good at flying. After looking through multiple aircrafts and the various features they have, we chose the delta wing, as it had a good mix of both functionality and aesthetics (at least in our opinion). While exploring features like these, I also learned some concepts important to ensure a fully functional flight, such as lift, centre of balance, and drag, which also later helped us when repairing and modifying the plane. While going through the process of building the aircraft, I found the part on designing the plane very exciting and hence I feel that aircraft engineering is a potential course I may be willing to take up in the future. As the “pilot” of our aircraft, I was able to get a basic feeling on how flying an aircraft, specifically a high speed jet, is like. After going through this experience, I am able to say with certainty that flying an aircraft is not for me. While being the pilot of our aircraft, I realised that a pilot needs quick reflexes and the ability to think straight under pressure. I feel that I may be lacking in such qualities and while these qualities could be trained, it would require high amounts of practice which I am not sure I am willing to undergo. Despite that, I still feel that it was a good experience and do not have have an ounce of regret on choosing to attend this competition

While this aircraft is made by 5 individuals, it was made by the same mind. We all came to the consensus that all of us must agree on what are the features of the aircraft and how they are made. While this may make our rate of progress slower as more time was spent for discussion, we faced relatively less hindrances arising from creative differences in the making process of our aircraft. This resulted in an overall quick rate of progress and allowed us to develop an aircraft that not only works, but one that satisfies all 5 member’s expectations. This skill of communication that we acquired will serve us long, even after the end of this project, be it in the workplace or at home.

While we didn't face major problems because of our team members, we did face many problems, as we are inexperienced and made several fallacies in the process of making the aircraft. For example in our first test flight, our flight was travelling in an unstable manner, often tilting and nosediving. We figured out that we needed a vertical stabiliser. Other than that, we also faced another problem in the first test flight. After the first test flight, our flight faced significant damages, and we realised that we needed to add carbon rods for more structural integrity of the aircraft. In both these cases, we were exposed to new problems that we have to ideate solutions for. We were able to practice our problem solving skills, and come up with solutions that are both efficient and effective.

We also learnt other valuable lessons from this project. We discovered the importance of planning. By having a more comprehensive understanding of how the aircraft works, we could have come up with a more complete list of items that we needed. Another lesson we learned is that we do not need to completely follow what theory might state. For example, while theoretically, the angle of launch of the aircraft is 15 to 30 degrees, such precise launching angles need not be followed in real life. Perhaps the most crucial lesson we failed to follow was to take time to reflect and ensure we are on the right trajectory to achieve our goals. During the actual competition, we almost had to cut off half of the plane by volume to meet the weight limit. Had we internalised the entry requirements earlier and corrected our mistakes earlier, perhaps we would have gotten a better result. But we still acted sportively and consoled ourselves, as we had tried our best.

All in all, the competition was a wonderful experience and I was able to acquire many lessons in this journey that will stick with me throughout my lifetime.

<u>Mohit</u>
Through my experience in the C1 plane project, there is much that I have gained in the form of knowledge, experience and teamwork.

Firstly, I have now achieved greater insight on the inner workings of an aircraft. During the group's ideation stage where we were thinking about how to design our aircraft, I came across physics concepts such as Bernouli's Principle which explained how uneven fluid velocities above and below the wings of the aircraft helps to generate lift. Upon reviewing further discussions online I learnt about different wing types and how they manipulated lift to drag ratios, angle of attack of relative wind and wing loading to cater to different purposes such as speed and manoeuvrability of the aircraft. Additionally, I am now also equipped with the knowledge of the different control surfaces that aircrafts use to control their movement mid-flight (ailerons control row, rudders control yaw and elevators control pitch).

Secondly, I have now gained experience in building Remote Controlled foam aircrafts. Through the group's journey in modelling the aircraft, there had certainly been failures. Our first prototype plane failed to fly as its limited wing surface area generated insufficient lift to keep the aircraft off the ground. Furthermore the lack of rigidity of the elevons reduced the stability of the aircraft and caused it to meander during flight. After analysing the flaws of the aircraft, we proceeded to engineer a new one. I took charge in expanding the aircraft's wing area by designing new wing add-ons and increasing the size of the elevons. I also crafted a smaller plane body to reduce the weight of the aircraft, thereby reducing wing loading. The second attempt was much more successful as the plane managed to take off and could be controlled.

Finally, I now have more experience working with a team. I realised that having a team with members that are collectively motivated to achieve the same goal is the key to success of the group. Moreover, effective communication is also crucial to ensure efficiency of the team. Handling disagreements maturely without biassed opinions contributes to a conducive atmosphere where decisions are made swiftly and the team morale stays concrete, boosting group effectiveness. This is exactly how my team worked and I would attribute our success in building a fully functional plane within the short timespan of 2 months to our such qualities. Overall, working with the team and the theme of the project itself was very enjoyable for me and I am thankful for this opportunity to participate in this competition.