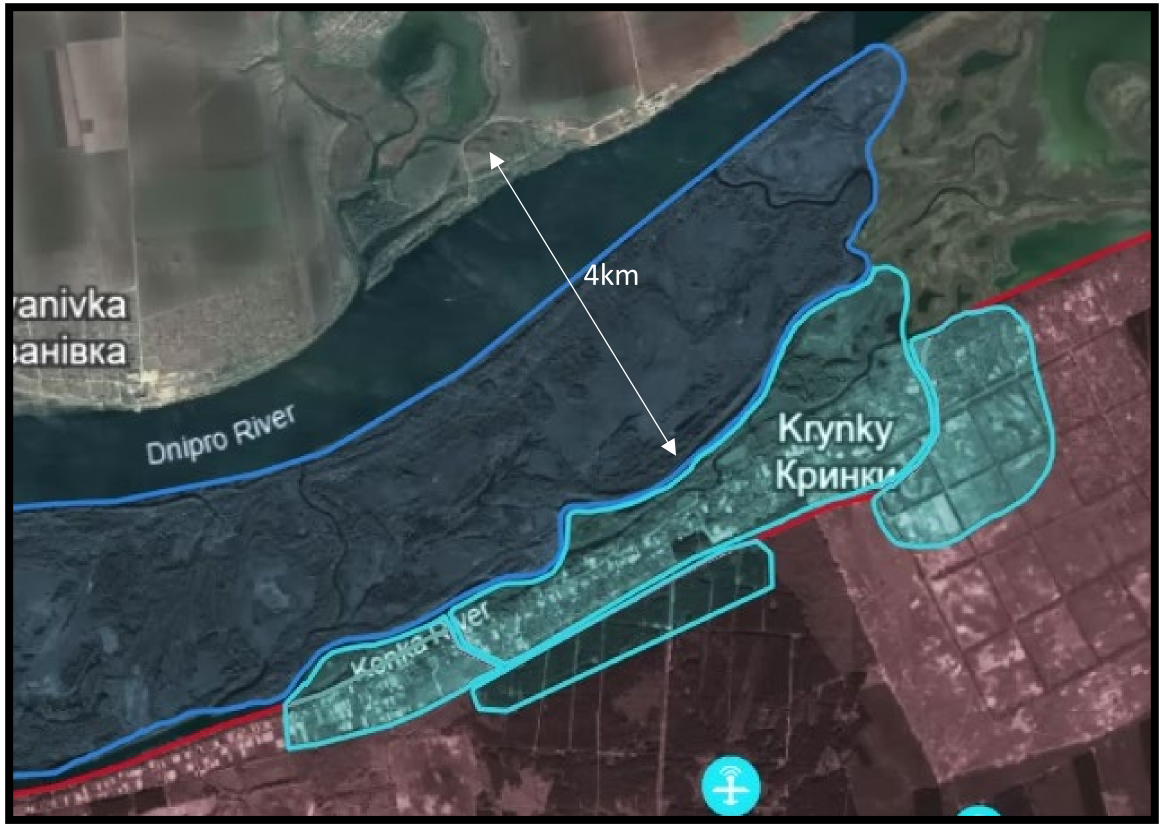
Personal Plane Proj

Deliver Supplies to Ukrainian Forces

What is being delivered?
IFAK medical kit, dimensions of 21 × 8.5 × 14 cm L x W x H, with a weight of 0.4kg
Or
2x Magazines of [5.45×39mm ammunition](), weighing 470g , with dimensions of 26x7x3cm LWH (40 Rds)
Where could this be used?
Recently, the Ukrainian village of Krynky has been a point of crossfire between Ukraine and Russia. With 4km of distance from the Dnipro River, the drone must be able withstand the flight time to deliver the payload to the soldiers without as much reliance on bridges built to cross the river. An example of the struggles seen crossing the river can be seen on the right where Russian forces have shelled a bridge for supply lines for Ukrainian troops across the Dnipro River. This project could effectively act as a alternative for transportation of supplied if land supply lines have been damaged.



Payload Options

IFAK Kits

The standard IFAK (International First Aid Kit) used by Ukrainian forces (pictured on the right), is a choice of payload for delivery of my RC plane. The payloads will be attached to a small parachute to slow the decent of the kits and avoid impact damage to the contents, potentially ruining the supplies. To be securely latched onto the plane fuselage, the product will be secured with a series of zip ties that have a space for a servo to hold onto, and release when being deployed.

5.45 Magazines

Considering the Ukrainian standard rifle is an AK-74, it is most sensible to allocate the payload to be the most compatible ammo type. According to research from the internet, 2x40 round magazines for 5.45x39mm rounds would weigh about 470g, a slightly heavier payload than the IFAK kit above. To safely secure the magazine to the fuselage of the plane, I will use the same method for above, where I will use a series of zip ties and an additional loose one to hold on to for the servo to latch on. This will also be followed with an attachment of a parachute to prevent possible damage to the payload. I will implement a coded system within an Arduino to the plane to signal the [2 letter country code]()for Ukraine, UA, in morse code via 2 LEDs attached to the edges of the plane to signal towards Ukrainian soldiers of a delivery location.

Evaluation
Carrying IFAK kits is a much easier process in comparison to 5.45 Magazines because of how they are suitably packaged, but this is easily overcome through the use of an added structure for the servo to latch on to secure the magazine until deployment is required.

4km of distance to cover is not such a demanding task for the RC plane itself, but rather a question of the distance of operation the planes over the distance as the signal may not reach such as required. After making this RC plane, I may build my own transmitter with an 8dbi Grid antenna (5km) to fit to the design criteria more, but this no problem for Ukrainian military if it were to be developed, so I will be using an antenna quality that is sensible for a personal project to lower cost for myself.

Aerodynamics Theory Study (real)

Overview

This task is required for me to develop understanding of general concepts of the physics and engineering of aerodynamics. It will show a wide range of aspects being covered over the numbers/formulas of flying and how they will be applied to a real practical concept when I will make the working plane.

What will be covered?

According to a source by Sagun Bajracharya and his team members, in order to create a successful conceptual design, it was determined that a number of parameters needed to finalized. The goal of the first phase of design was to first find these parameters within existing R/C designs and then pass this information through (my) requirements and morph the parameters.

Cargo type & amount
Wing aspect ratio (AR)
Optimum Airfoil lift (CL)
Thrust to Weight Ratio
Wing Loading

Wing Cube Loading

This is the measurement of the flight handling, using a 1-15 scalability for the ease of control, the higher the harder to control. Having a larger ratio of wing area to weight is essential for a stable and reliable flight, so I will initially aim for 4 and below for comfort as I have a lack of experience. I will be using the website here to calculate the WCL to eliminate room for error.

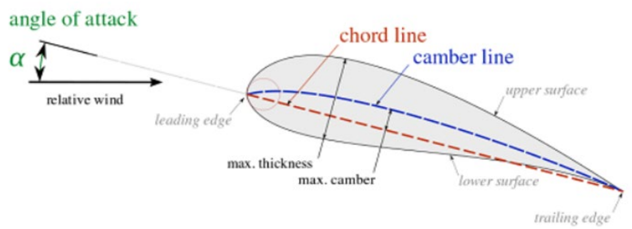
Wing AR

This simply means the aspect ratio of the wing, taking by dividing the wing length (full 2 side) to the wing chord. High aspect ratio wings are generally used for trainer models, while low aspect ratio wings are used for aerobatic models. A high aspect ratio basically means the wing will be long and thin, while a low aspect ratio wing will be short and wide. Higher AR tends to create lower drag.

Lift and Aerofoil Design

Wing Shape (Aerofoil): The wing of an RC plane, like a full-scale aircraft, is designed with a specific aerofoil shape to generate lift. The most common aerofoil shapes for RC planes include symmetrical and semi-symmetrical designs, with some dihedral (upward angle) for stability.

Angle of Attack: Lift is generated by the angle of attack, which is the angle between the chord and the airflow. Because there is a higher force exerted on the lower surface than the upper, this effectively creates lift from the movement of air. Adjusting the angle of attack helps control lift. (Visual Aid below). The effectiveness of lift of a particular shape of aerofoil can be tested with CAD simulations e.g Solidworks flow simulation.



The Optimum Aerofoil

Wing Cl is the coefficient of lift, which is determined by the type of aerofoil and angle of attack. I will be using a flat bottom aerofoil to ease the process of making the aerofoil with limited tools at home. For the angle of attack, it will remain at 0 on the base plane but will change when suspended in air due to the elevators.

Flat bottom aerofoil

Thrust to Weight Ratio

This calculation is similarly used like wing cube loading and the wing AR, where it is highly based on manoeuvrability of the plane. According to many other RC plane enthusiasts, thrust should be around 60-80% of the weight of the plane for slow training planes. A middle plane 100% and more than that to increase the acrobatic ability of the plane. Some also base it from watts to pound, but the earlier method is more popular.

To calculate the thrust of the plane, I will be using **this** website to find an accurate figure for reference.

It is also very important to note that thrust to weight should be at least 0.5 in order for the plane even fly.

Drag

This force is something to consider when understanding how our plane will be designed. In best interest, reducing drag will increase the efficiency of the rc plane and will fly greater distances. Drag has many forms, but there is a type particularly studied when looking at flight.

Parasitic Drag: This term is used to refer to a combination of Friction Drag, Form Drag and Interference Drag.

Friction Drag: This type of drag describes how drag is caused by the friction of a fluid against the surface of an object that is moving through it. This correlates with the surface area; a larger surface area will experience more friction drag. To reduce friction drag, shape the object to allow laminar (smooth) flow, e.g an aerofoil, and/or reduce the surface area.

Form Drag: Also called Pressure Drag, is mostly dependent on the shape of the object. It is caused by the lower pressure acting behind the object as the airflow cannot meet at immediate angles.

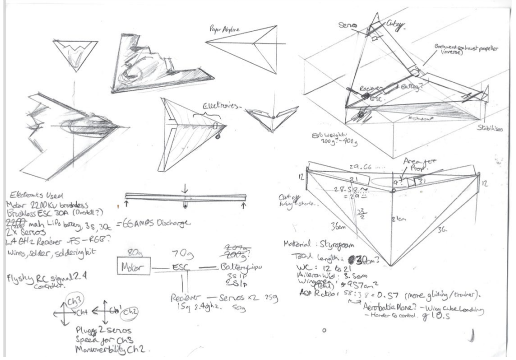
Interference Drag: sss

1st Design

Introduction
To understand and practice my theory knowledge, it is important to test my ability to demonstrate my practical skills. I aim to achieve a working, usable RC plane that can fly, steer and take off without physical assistance. In doing so, I will secure my confidence in my understanding of aerodynamics and therefore will be more than prepared to make the final delivery plane.

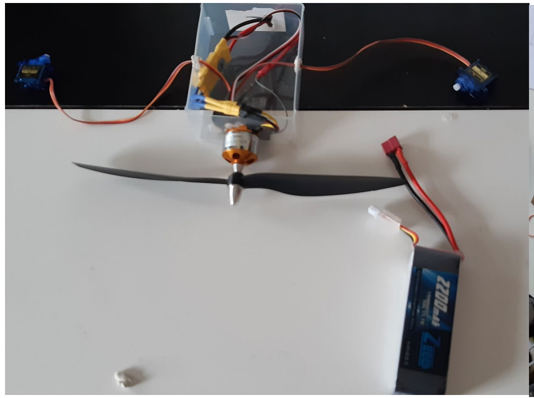
Method
To produce this plane, I was first inspired by the design of stealth aircraft, with its V-shaped design and aesthetic, it was immediately a source of inspiration. More notably, the Northrop Grumman's B-2 Spirit, seen on the right, we can clearly see the similar qualities in shape in comparison to my drawings of possible designs (below)


Northrop Grumman's B-2 Spirit



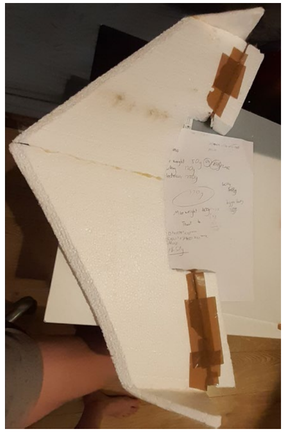
Drawings/Rough Plan (left)
In order to get a clear idea of what I will be making, I drew various drawings and measurements to visualise the shape and form of plane I was making. I then estimated weights and the type of motor I am going to use in order to calculate the necessary formulae for successful flight. The strong use of sweep was influenced by both the plane inspiration, but this can also reduce drag on wings whilst improving stability, inferred from this study on pg. 18.

Electronics + Other Info
Specifications include: 2200KV brushless motor, 1200mah 3s 1p LiPo battery, 2 9g servos, 30A ESC and a 6x4.5 inch Propeller. This electronic system was calculated to weigh about 400g along with the weight of the plane material. The motor will draw around 55w, producing a thrust of about 200g – this means the thrust to weight ratio was about 0.54, so it may more take time to gain altitude.
Materials Include: Stock Styrofoam board – 60x50x5cm, parts of a Polycarbonate box for the motor to be fixed in place, 5mm Diameter dowels for structural support, brown tape to increase all round strength and less frictional drag from eliminating irregularities in the polystyrene shaping.



Problems and Solutions
The initial 2200mah battery at 200g was too heavy for a clean and stable lift-off for the plane, so I opted to change this to a 1200mah 3s LiPo instead. This fixed these issues and allowed for a safer and more controlled flight.
Another major problem that occurred was the lack of structural integrity; as wheels were too heavy for the design of the plane; too nose heavy and inefficient, the only way to land was to absorb some impact into the ground on the nose. As a result of no protection, I had destroyed the polystyrene nose completely on the first model (seen above). I produced an identical plane body and decided to improve its structural integrity by installing wooden dowels (on the left), and additionally to prevent extensive nose damage, I covered the plane with brown tape (up right image). This effectively solved the problems I encountered while making the plane, without much sacrifice, regarding the increased weight.

Construction Process
Using my template I cut out of paper, I cut out the necessary parts to a sensible degree of accuracy with the use of a pen knife. I did consider using a hot wire; however, I do not have access to such equipment due to it being a home project. The aerofoil was shaped with the use of sandpaper to help smoothen the surface of the plane and ensure low drag, increasing efficiency. In order to make the flaps, I used a layer of tape (seen on the right) as a pivot as this allowed for a free-flowing movement and less energy for the servos to move them. To hold the brushless motor in place on the plane body, I cut out a plastic shell to mount the motor onto with screws. This shell was then mounted to the hull through hot glue and more cello tape. The two servos were placed on either side of the wing for the control of the ailerons, where they were taped down to the body. The ESC, battery and wiring were all placed on the surface of the plane, in case I needed quick access to the components if anything were to go awry.
When testing the plane for flight, I had to do a ground take-off as there were no wheels for ground navigation, but in the end, the plane was able to sustain flight, with sufficient control in the air.



Evaluation
I have learnt a lot about flight and how sensitive control is to the aerodynamics of the plane. The shape and size of the plane are incredibly important alongside with the electronics' specifications, and gives me less room for error when I make the 2nd plane that will be used for the real task. With the next task, there will be more features to incorporate, thus possibly leading to additional challenges. This will help me learn

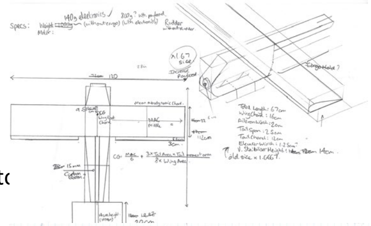
Delivery Drone Project

Introduction

This was the original aim of the plane: to deliver a payload of at least 470g to a defined destination without damage to the contents. I aim to achieve lift with a

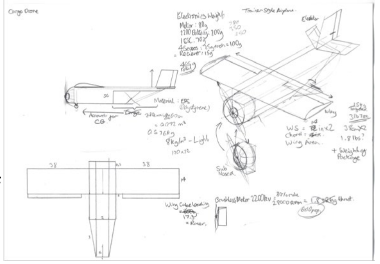
Method

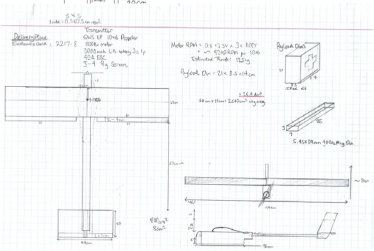
This RC plane design was rather based on functionality rather than a design aesthetic, but the looks have not been ignored. This plane will go into much further depth in analysing the statistics and numbers of the plane to have a more accurate project as a whole, additionally with more features compared to the initial plane e.g Lighting.

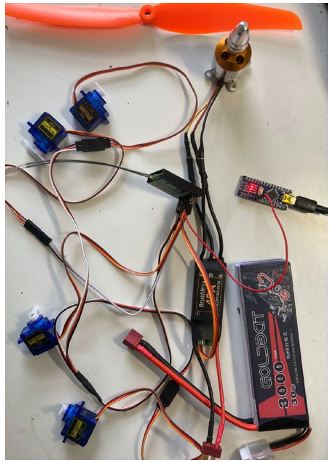


Drawings + Roughs

On the right are my preliminary sketches of the potential plane, just basic possible features of the plane including its aerofoil, form, shape, size and most importantly, dimensions. The dimensions will determine the wing cube loading and wing AR, and also the size of the plane as a whole. This ultimately determines all other specifications of the plane e.g Motor type as the appropriate thrust and components need to be carefully considered.







Electronic Parts List

This part will show you each component of the RC plane and their justification for being part of the process.

1100KV Brushless Motor: This motor will produce around 9260 RPM, which calculates to about 1260g of thrust from the motor using [this] calculator, using a **10x6 GWS EP propeller**. This means we can estimate a maximum load of 2500g according to the Thrust-to-weight ratio spectrum where it will be able to lift off the ground sufficiently.

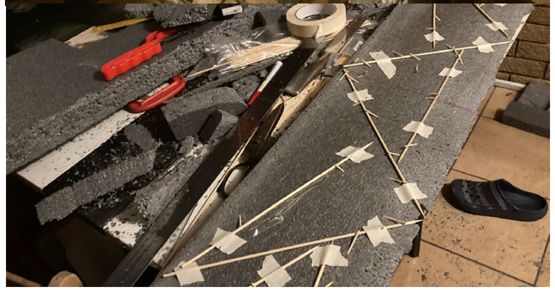
40A Electronic Speed Controller: This electronic speed controller was used because of its high resistance to possible overloading and reduce possible bottlenecking for the battery and motor to be sufficiently powered throughout flight.

3000mah 3s 1p LiPo: With this amount of capacity, the plane will be able sustain flight at 20m/s, for 15 mins. This is more than sufficient for a fully flight of 2x4km to fly to the location and back.

9g Servos: With a torque of 1.8 kgf cm, the highest force needed to pull is the payload of 470g of force.

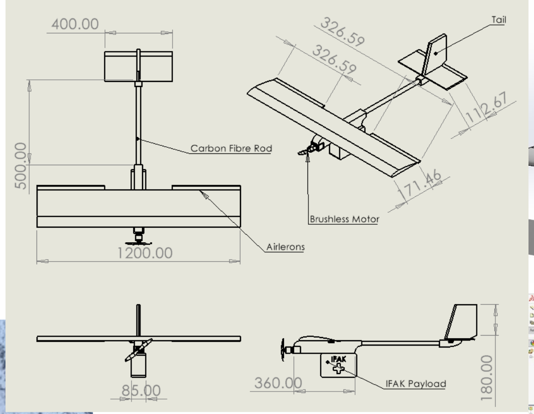
Production Process

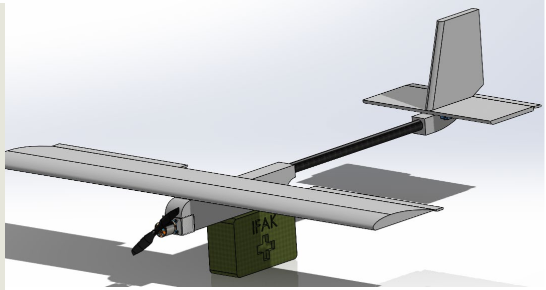
To cut the polystyrene stock board into my desired pieces, I used a sharp kitchen knife and mini hacksaw to cleanly cut the pieces out (seen on the right). The curvature of the aerofoil of the wing was refined using sandpaper to retain the quality. As a safety hazard of fine particles of polystyrene, I had to wear a disposable respirator for my own safety. After cutting out all pieces, I used a previous technique of reinforcing the polystyrene structure through using a mixture of wood dowel and cocktail sticks within the body of the pieces (seen bottom right). I found that using cocktail sticks was very effective as I could slide them through into the body of each piece. I then covered each part with cello tape to further improve its structural integrity. This technique also helps to reduce friction drag as the dowels were not exposed to the flow of air, increasing its aerodynamic properties. Each part of the plane was hot glued together, and secured with additional tape and wood dowels. I organised a layout for the electronics to align the centre of gravity, in which the battery weighing 200g, was the most strategically placed component.

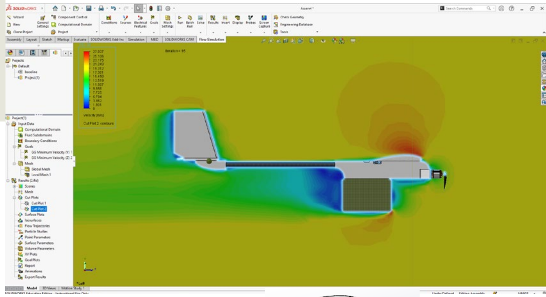


CAD Model + Flow Simulation

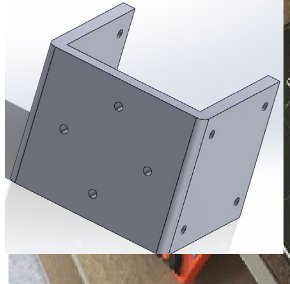
I produced a to-scale CAD model of what I believed would be an accurate representation of what I would produce in real life. In doing so, I could easily visualise how I would make each part of the plane and what tools I would use. Most importantly, this allowed me to produce a fluid simulation of the plane to understand the aerodynamics of the plane and how the air would interact with the plane in a 20 m/s environment. More detail is covered on the next page about the flow details.







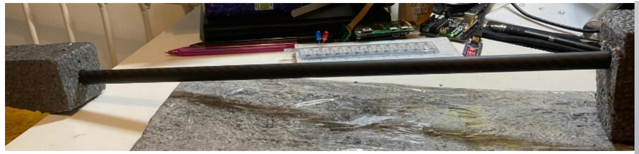
On the right we can see parts I have designed on Solidworks, which I printed for use on the RC plane. The first image shows the hook that connects to the servo that latches the cargo. This is particularly shaped so that the hook can have a firm grasp on the payload zip tie with the curved head, but easily release when desired. The other image is the motor mount onto the front of the plane. This is particularly designed to fit the exact size of the nose of the plane to ensure a tight fit. The servo module will be printed with a denser structure, as it will be suited to carrying the 470g payload. It was also 4x thicker in case it were to be unable to carry the payload during the whole flight without trouble. This also keeps stability issues to a minimum when the load is carried to the body of the plane during flight

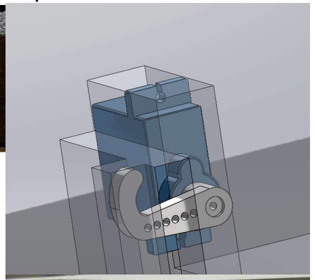


Additional Info

Further production

These plane parts were further secured with each other by using long dowel, hot glue and tape. As the plane is only experiencing around 1.2kg of carry weight, I was debating whether to use aluminium for fixing the joints, however the speed of the RC plane was fairly low, so I decided that was not necessary. The 3d parts were bind to the body of the plane through double sided tape, hot glue and clear tape. These fixings helped to secure the motor to the head of the plane, and the servo to the ailerons, and make for clean movement thus stable manoeuvrability in the air.
To connect the fuselage to the tail of the plane, I used a 50cm carbon fibre rod (seen below) due to its properties including a high strength to weight ratio. This is ideal for my plane specifically because it is notably stronger than steel, and lighter than aluminium. In comparison to a full polystyrene body, this would be very likely to snap during landing due to the force of the weight of the plane.





Payload Latch Design

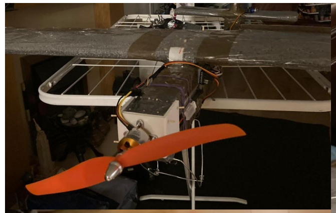
I made my own custom hook for the IFAK kit to hang onto, to fit on the 9g servo perfectly. This hook was notably thicker than of the ones used in the stock joints that come with the servo. This is particularly because I wanted to ensure the hook would be able to fully take on the weight of the package. Using this simple mechanism I made in Solidworks, within the fuselage, I can release the payload to the approximate location whenever send the signal from the transmitter.

Arduino Nano

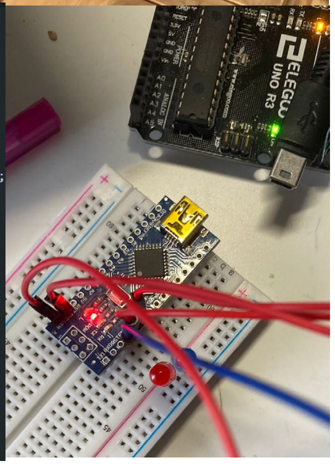
To signal to Ukrainian troops that there was an overhead delivery, I have coded for LED's to blink in morse code of the 2 letter code of Ukraine, which is UA. To do this, I made this signal triggerable from the transmitter so that when a certain frequency is detected, the sequence of LED flashing would begin and signal the ISO code. This was done using the C++ Arduino IDE with the Arduino nano board. In order to power the Arduino sufficiently, I linked the ground pin of the board to the ground of the receiver, as the power would be linked through the 4.5-6v receiver, and the positive voltage to the VIN pin of the Arduino to deliver the power. The LED is then linked to be triggered when the code detected a significant change in the pulse width on the 5th channel on the transmitter. On the right we can see that I have coded for the Arduino to receive the pulse width for the signal output from the receiver. This is 'printed' for debugging and a visual representation can be found using the serial plotter at 9600 baud. The code takes this integer and if the pulse width experiences a significant change (middle) or is at the maximum value (bottom), the sequence for the lighting will proceed once. The LED's are connected through the 2nd pin and back to the ground to complete the circuit. This whole system can be easily configurable for other purposes too.

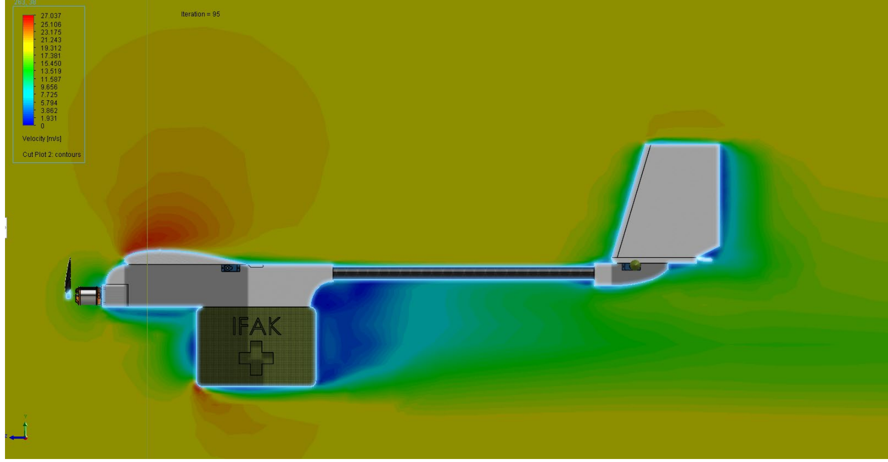
Interpretation of Fluid Simulation (refer to image on right)

This 2d velocity plot can draw attention towards potential problems that can arise during the flight. The recirculation zone is represented blue behind the payload. The less recirculation zone there is, the less turbulence is produced, which ultimately results in less drag. In this blue area, we can see a slower speed of close to 0m/s, meaning a vacuum has been created behind the payload. This can lead to turbulence during the flight. However, the IFAK will not be sealed to the body of the plane, so this evaluation may be inaccurate, as some air will pass between the IFAK and the plane during full speed flight. Another area of interest is the red area above the wing; this shows the high velocity gradient of the wing. Using this we can also see where turbulent and laminar flow will appear by enabling the streamlines overlay.



```
const int receiverPin = 3;
const int ledPin = 2;

void setup() {
  pinMode(ledPin, OUTPUT);
  Serial.begin(9600);
}

void loop() {
  int pulseWidth = pulseIn(receiverPin, HIGH);

  Serial.print("Pulse Width: ");
  Serial.println(pulseWidth);

  if (abs(pulseWidth - 1500) > 50) {
    blinkMorseCode("U");
    delay(1000);
    blinkMorseCode("A");
  }


  if (pulseWidth >= 2000) {
    triggerLEDSequence();
  }
}
```



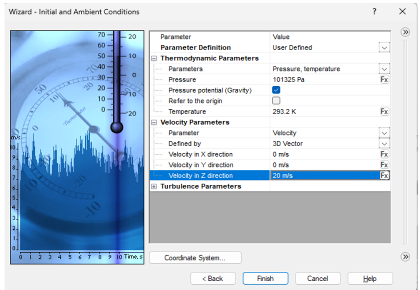


Analysis

The importance of aerodynamics is covered in this section; Not only it improves the efficiency of the plane, but also it reduces power consumption thus leading to a longer flight time. The analysis of the RC plane with different shapes and add-on aerodynamic devices were studied using Computational Fluid Dynamics (CFD) simulation in this report. The lift force and drag force are calculated by default in CFD and the drag coefficient is calculated manually through this equation:

$$Cd = \frac{2F}{\rho v^2 A}$$

It has been found that different add-on devices can influence aerodynamic drag. To reduce drag, it is favourable that the flow is attached to the vehicle's body as long as possible. A streamlined body would result in less flow separation, which would cause less turbulence.
For the Simulation, I chose to work at a constant 20m/s environment, due that being the theoretical maximum speed of the plane, calculated using an online RC plane calculator that took in the electronic components, propeller size and pitch, and wing AR as variables.



Here are some of the parameters I set to execute the fluid simulation for the plane.

Evaluation

Overall, I can improve the plane in many different ways to heighten its quality, function and even visual aesthetic design. Below are some ready ideas for another revised edition of the plane.

Adding 2 Motors instead of 1:

This would benefit in the sense that ground navigation for the plane would be a lot more manoeuvrable on ground due because we can independently control each motor. By increasing throttle on one side more than the other, differential thrust is created, which acts like rudder control on the ground. This allows for sharper turns and more precise steering during ground control.

Bigger Plane:

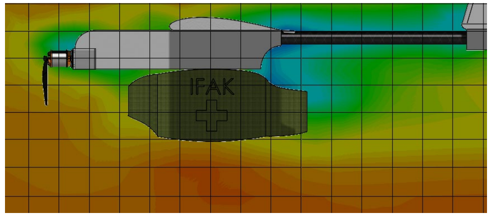
One of the more simple ideas, making the plane on a large scale gives a lot of room for scalability; this will mean more payload can be carried on the plane, meaning less planes are needed for the same amount of supply. However a larger aircraft means a higher quality motor is required, alongside LiPo battery and possibly servos.

Alternative for Polystyrene:

As we all know, the world is facing a problem with environmental factors, thus I have come up with a solution by completely switching the use of polystyrene with the use of either cardboard (trees able to be regrown), or recycled plastics. A downside of this may be the desired density of plastics is harder to obtain for recycled products, but nonetheless will be a better alternative than using harmful polystyrene.

Aerodynamic Package:

This idea involves tailoring the shape of the payload location to have a modelled aerodynamic casing to reduce the turbulence of the package delivery, as seen from the Solidworks fluid simulation. We can apply our theory and use a ‘spiller’ shaped to the box of the IFAK, similar to how cars can have one at the rear of the vehicle. This design reduces room for a recirculation zone, which is the area where the airflow creates turbulence in a circular-like behaviour.

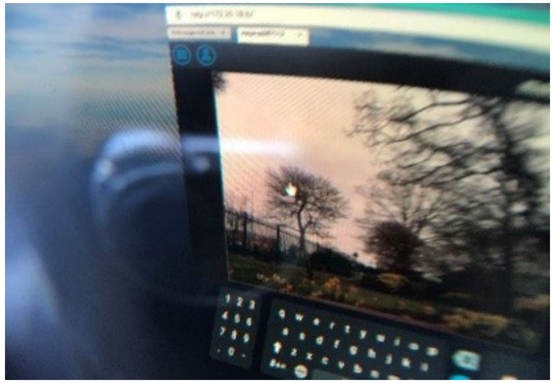


When flying the plane in real life, the carbon fibre rod that connected the fuselage to the elevator and rudder came loose during flight time. I have decided to fix this issue by extending the rod further into the fuselage, to a point where it reaches the front line of the wing, and is placed in an extruded cut on the top surface rather than the weak polystyrene centre of the plane. This does account for the fact that the distance between the fuselage and the elevator + rudder will be shorter, however I can easily extend the rod by connecting an additional rod to the ends.

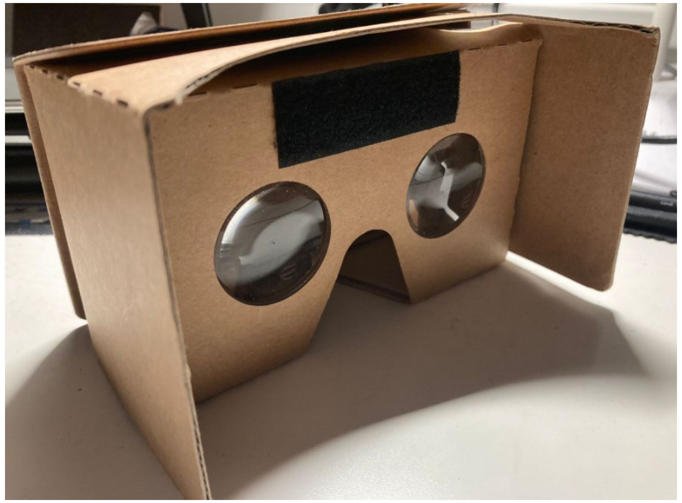
Live Camera to Plane Development

For a live camera feedback system, I had two choices: connecting the camera to another Arduino and creating a custom image processor for the laptop application, or using a Raspberry Pi using [Motion Eye OS] (the Raspberry Pi would have a PiSugar as its battery). The advantages of the Arduino camera are that the drone would be lighter, as only one battery and chip are required to make the system fully functional. The main advantage of the Raspberry Pi camera is that I have already set one up before, therefore would take less time for me to implement this system to readily use (image on the right).

If this were to be used for the military plane, this live feedback system would be connected via data from 4g networks (which are already so common everywhere), and thus provide a frontal view to drive the plane safely to the allocated location, being the village Krynky from 4km away. The driver of the rc plane can use this google headset (seen at bottom), enabling a VR view from a Google Cardboard in a browser which makes for a very easily controllable plane from kilometres away.



The camera features recording video and taking photographs. This is currently done by the Raspberry Pi connecting to a Wi-Fi hotspot and a mobile phone or laptop that supports a browser. The user would need to access the IP address page and has the ability to control the camera. The user (soldier in this case) may also set up their own password to protect other people accessing the administration page. The user can view the saved photos and videos from the main page. All of the photos and video are saved in the cloud so if the RC plane is stolen or the PiSugar battery runs out, the user will have all the data sent to them. Another feature is that the user can switch the camera to fast network camera where the frames per second will increase rapidly so every detail of the environment can be seen clearly. Unfortunately, the cost to this feature is that no photos or videos can be taken during the high frame-per-second mode.



Next Stages

For the next stage of my project, I will understand and study the usage of parachutes in cargo delivery. This will be the main method of delivery for my plane to offload as this would be the most effective, in comparison to strengthening the package as this would increase payload weight, which would cause many problems during flight. By using the compression of air, I can comfortably and safely deliver the IFAK kit using the required design of parachute attached to it. I will be testing the impact force, as well as one again using a CFD to calculate and simulate a real life version of what I will be offloading for the project. It can also involve methods of attachment