DBF 2021
Final Report

Team 7

Team Members

Mohamed Ghanem

Mohamed Salah

Yousef Salah

Mazen Hossam

Moaaz Zaki

Submitted on 3/10/2021

Table of Contents

Introduction

Our plane is called DBF-7. A UAV airplane designed for a banner mission consisting of 3 stages: the first one is performing one lap with the banner on board, the second one is deploying the banner and completing two additional laps, and the third one is releasing the banner and doing a final lap before landing.

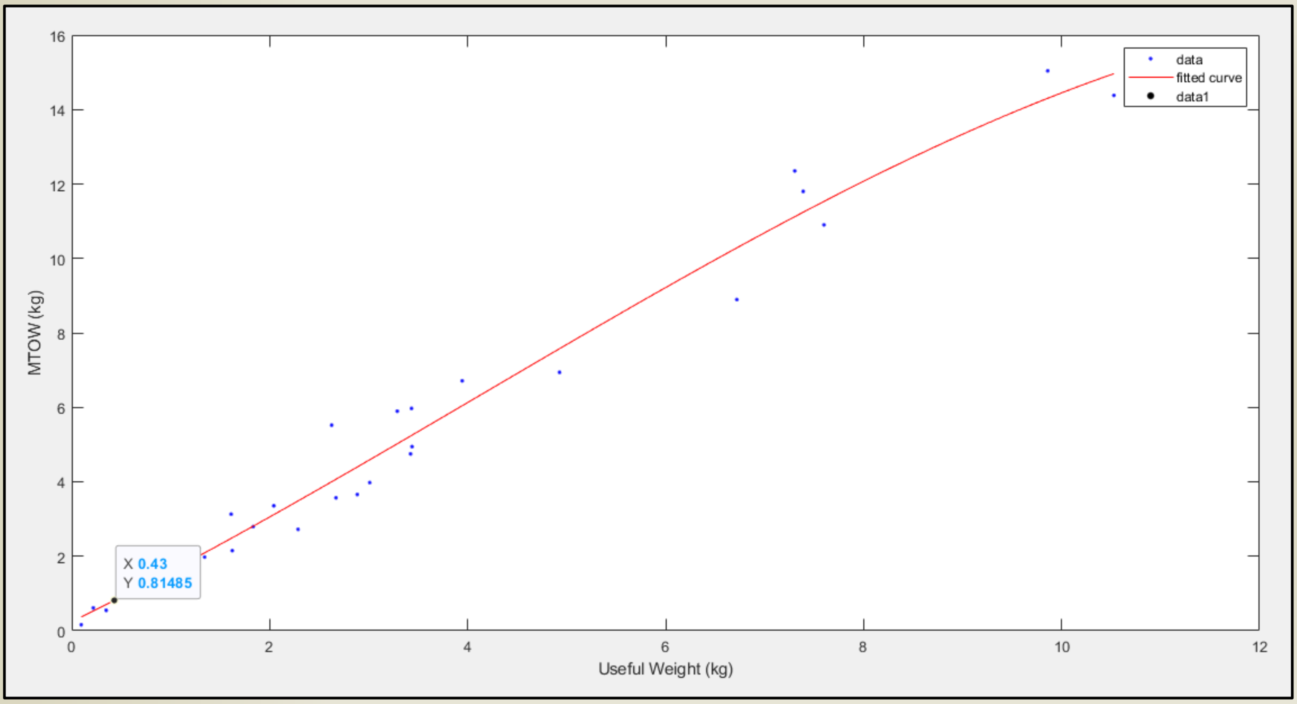
The plane has a conventional configuration which is a high wing with a conventional tail assembly, it best meets the requirements of the mission because it has better aerodynamics data, saves room for the banner, and also well distribution of weight.

Preliminary Design

Weight estimation

The first stage of preliminary design was estimating the weight of the aircraft using statistical data that was supplied by the UDC staff. A graphical model of useful weight against the maximum takeoff weight was built from the data and then used to estimate the maximum takeoff weight of our own aircraft.

$$\begin{aligned} Useful\ Weight &= Weight\ of\ battery + Weight\ of\ mission\ payload \\ &= 0.180 + 0.250 = 0.43\ kg \end{aligned}$$



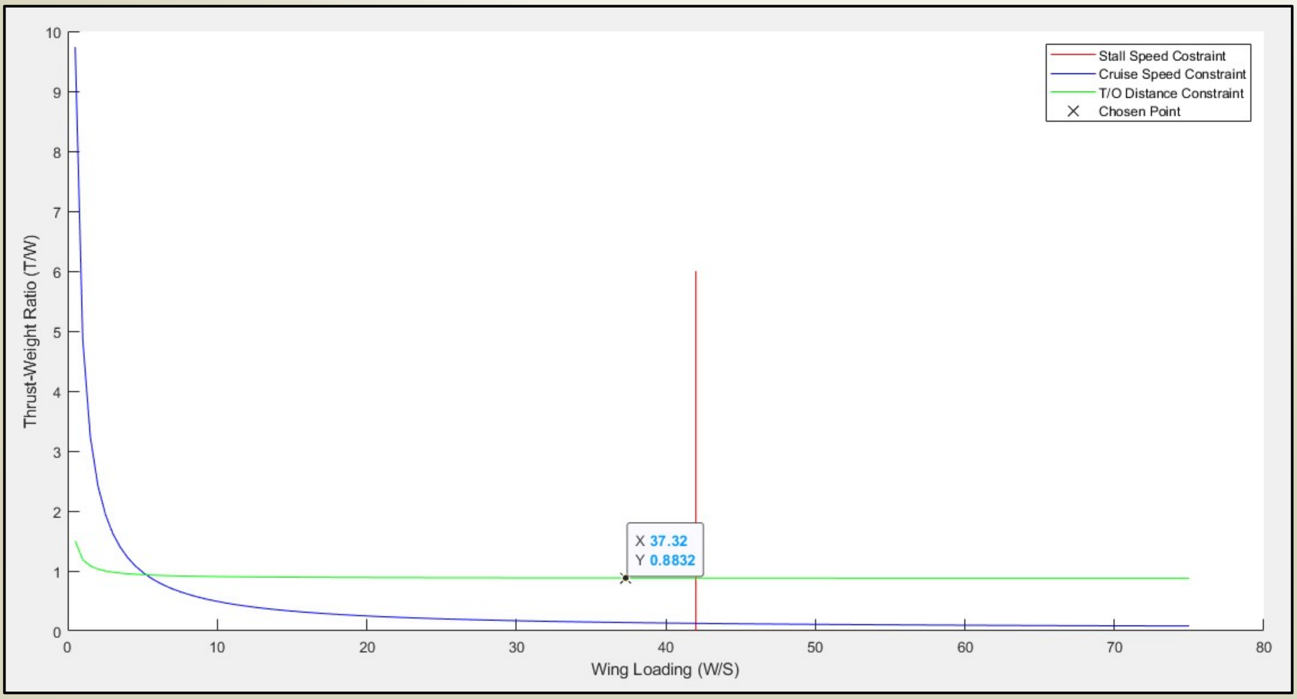
Fitted curve from weight estimation data

Using the model, we have estimated our MTOW (maximum takeoff weight) to be 0.814 kg, however, that was not the weight we used in the latter calculations as it was soon apparent that the data was inconsistent after review by the UDC staff, and the MTOW was later increased to 1.5 kg as advised by said staff.

Constraint graphs

A number of design constraints related to the mission requirements had to be made and used to calculate important parameters of the aircraft. The variables used to model the constraints were either assumed or given by the mission requirements. The following is a list of the variables used in the model.

- Stall speed = 7 m/s
- Cruise speed = 20 m/s
- CL_{max} = 1.4
- Weight = 1.5 kg
- Cd_0 = 0.02
- AR = 7
- T/O speed = 7.7 m/s
- Thrust = 13.23 N
- Throwing speed = 5 m/s
- $Cd_{T/O}$ = 0.03
- T/O distance = 2 m



Constraint Graphs

A point chosen on the graph was used to choose the airfoil and calculate a number of crucial parameters as follows.

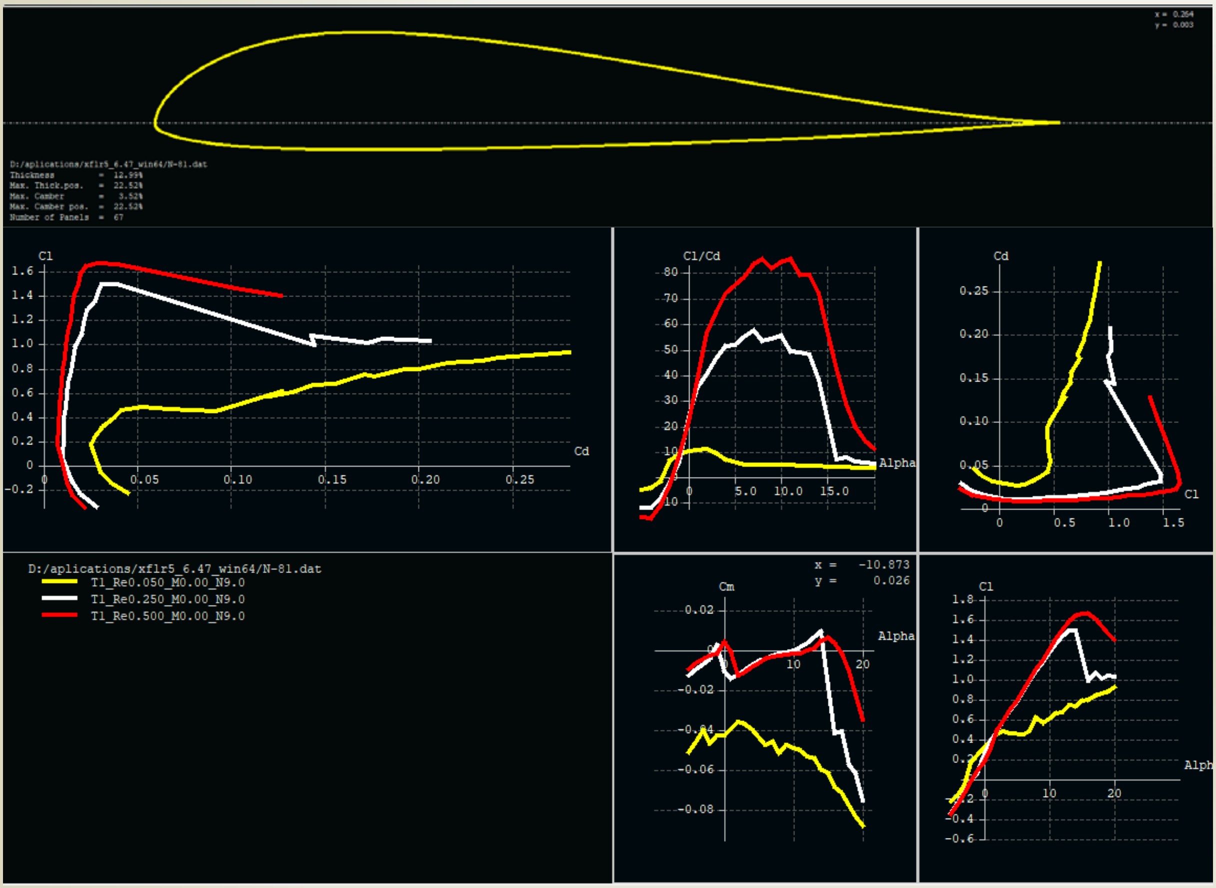
- Weight = 1.529 kg
- Stall speed = 7 m/s
- Wing area = 0.401 m^2
- AR = 5.5
- Wing span = 1.485 m
- Mean chord = 0.27 m
- CL_{2D} = 1.34
- CL_{3D} = 1.244
- Cd_0 = 0.02

Airfoil Selection

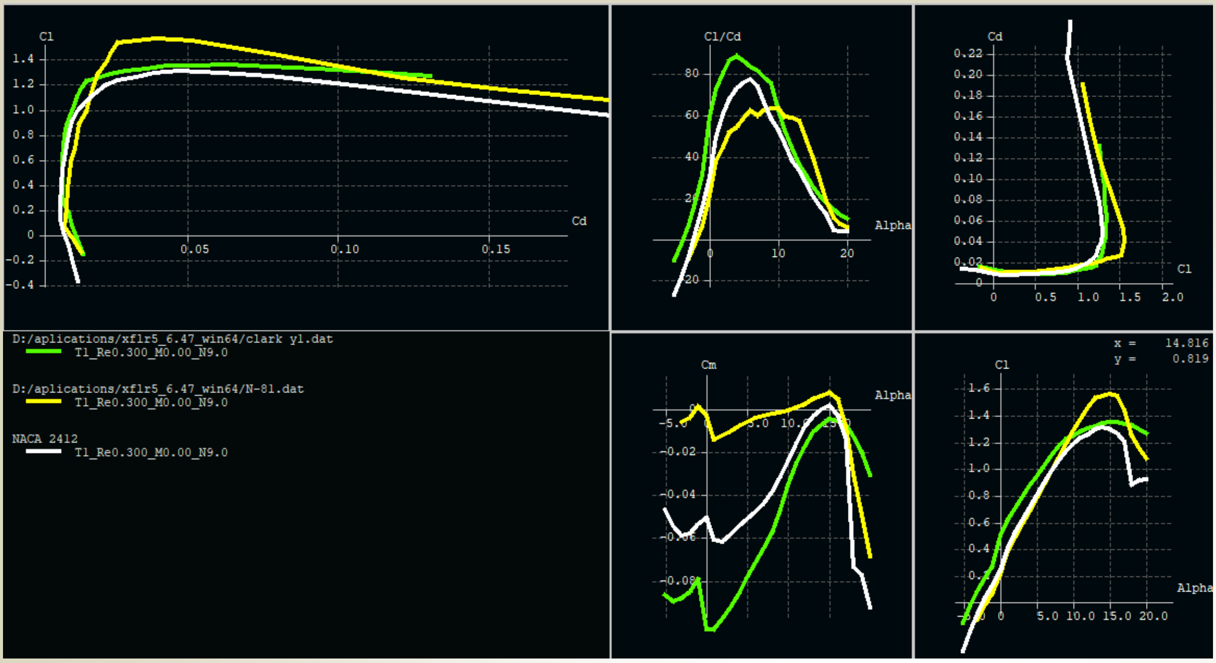
Using the data retrieved from the constraint graphs we have narrowed down the search for a fitting airfoil to 3, namely the Clark Y, N-81, and NACA 2412. After tedious research and consideration, our team settled on the N-81 airfoil owing to its high lift and superior stability.

N-81 Airfoil Specs:

- Maximum thickness = 12.99%
- Maximum thickness position = 22.52%
- Maximum camber = 3.52%
- Maximum camber position = 22.52%



N-81 airfoil XFLR5 analysis



Comparing Clark-Y, N-81, and NACA 2412 airfoil data

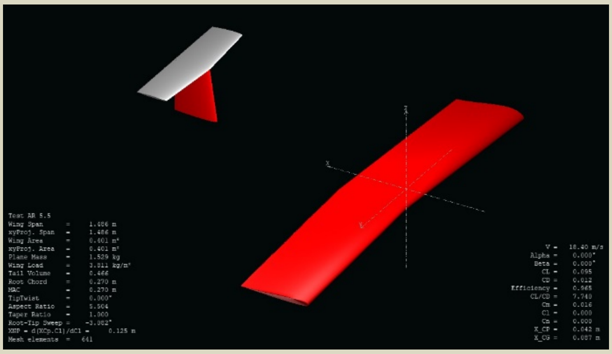
Configuration selection

We have a number of designs combining different wing and tail configurations to reach reasonable stability and performance using trial & error.

We created three configurations: **1.** Low wing, T-tail **2.** Canard **3.** Conventional, high wing.

They nearly have moderate graphs and stability, but we faced other issues which will be discussed in detail.

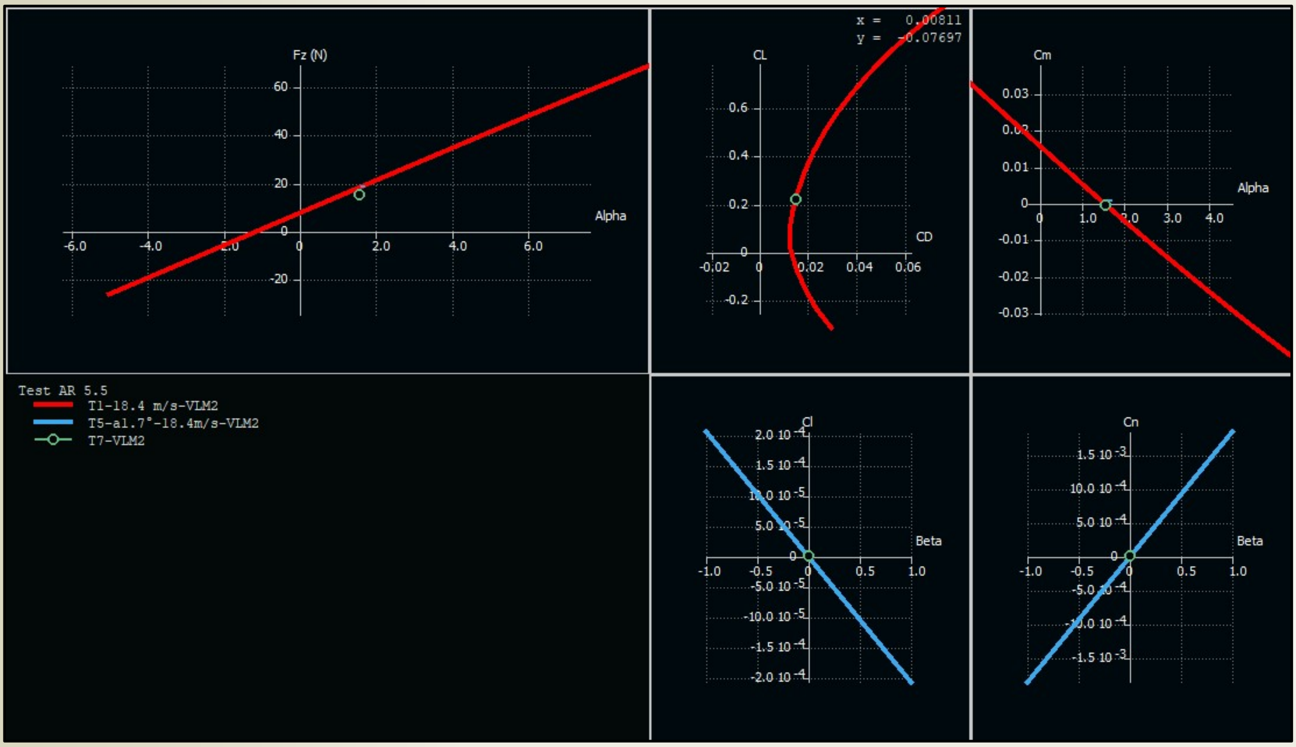
Low wing, T-tail configuration



T-tail configuration

Our first design was a low wing with a froward sweep and a T-tail configuration. We assumed it might be the most suitable configuration for the mission as the flow vortices created by the stabilizers would have a reduced effect on the banner while being towed behind the aircraft. However, after the feedback session from the UDC staff, we were informed that the tail configuration has little effect on the banner towing as opposed to what we first thought. Additionally, the T-tail would have been challenging when it comes to manufacturing, and the forward sweep would have been redundant, if not even disadvantageous as it has a number of flaws relating to structure and increased drag.

So, in summary, the configuration had to be scraped since its original appeal was no longer valid and it had a number of other flaws. Another configuration had to be designed from scratch.

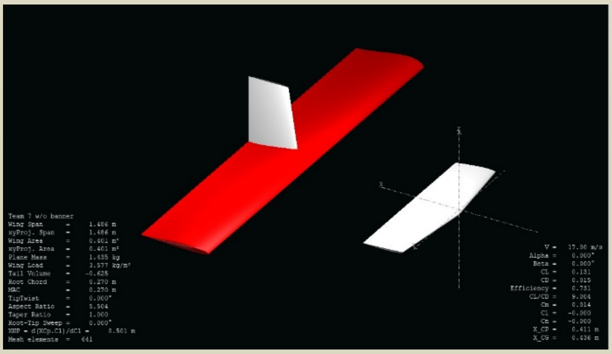


T-tail configuration XFLR5 analysis

Canard configuration

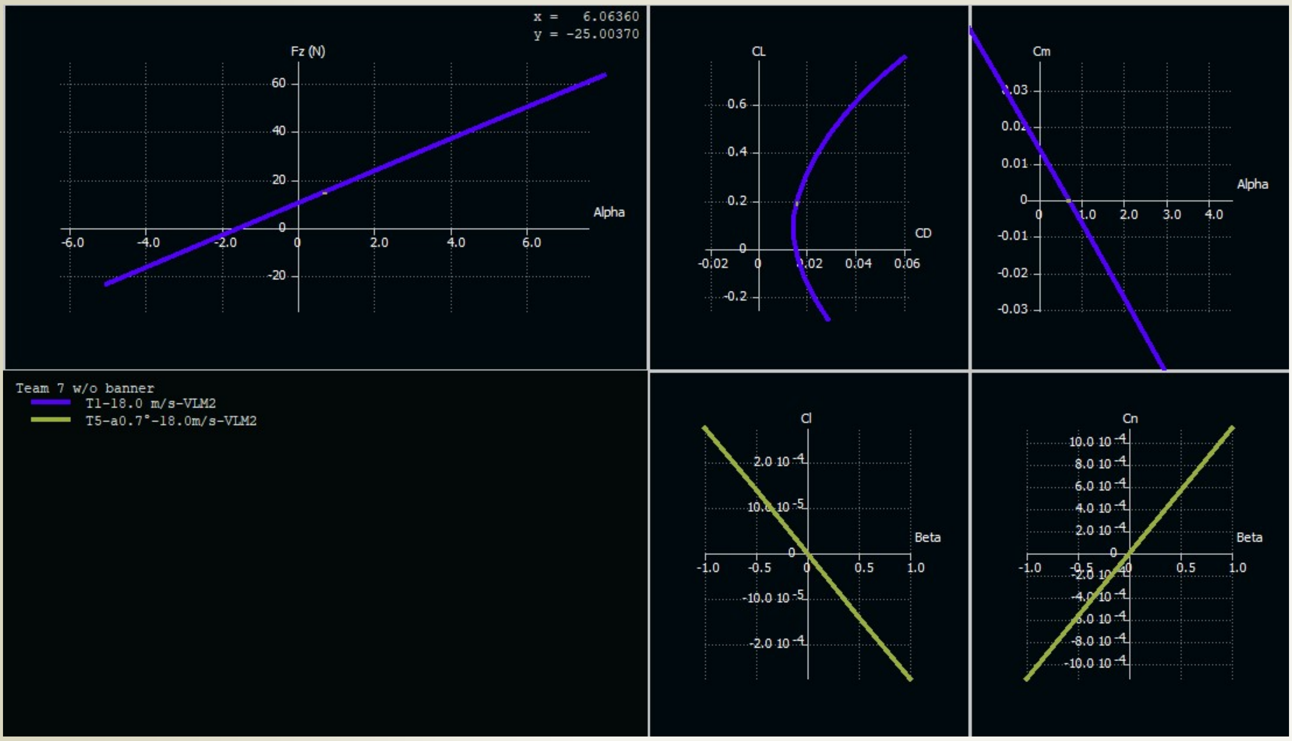
The second try is Canard, which shows the right graphs and stability, but the issue is that the canard configuration inherently has weak stability, it has high controllability.

The mission requires a banner so the extra drag from it will induce moments that make the plane unstable, so it requires high stability, not high controllability.



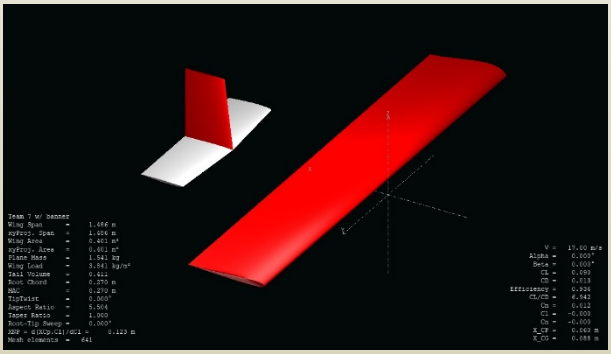
Canard configuration

The same for manufacturing as the previous configuration, also unsuitable for the mission as it requires space for the banner and mechanism, besides the battery and essential stuff which isn't available in the Canard fuselage.



Canard configuration XFLR5 analysis

Conventional, high wing configuration

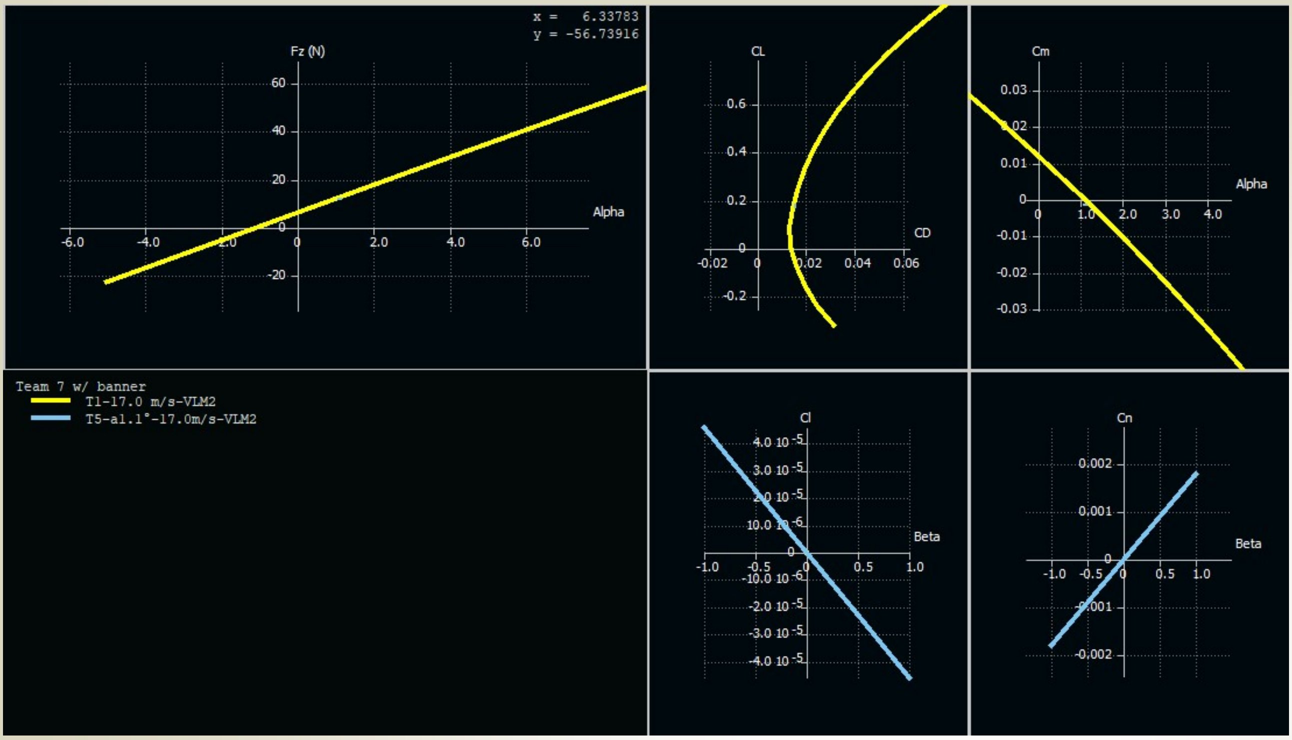


Conventional, high wing configuration

The third one is Conventional. It's the most suitable for the mission as it could handle the disturbance from the banner and provides space for it and the mechanism.

It has a high wing so it's easier for assembly and installs like the battery, mechanism, and other connections.

It's easier in manufacturing overall and has a great distribution of weight, so we decided to go for conventional at last.

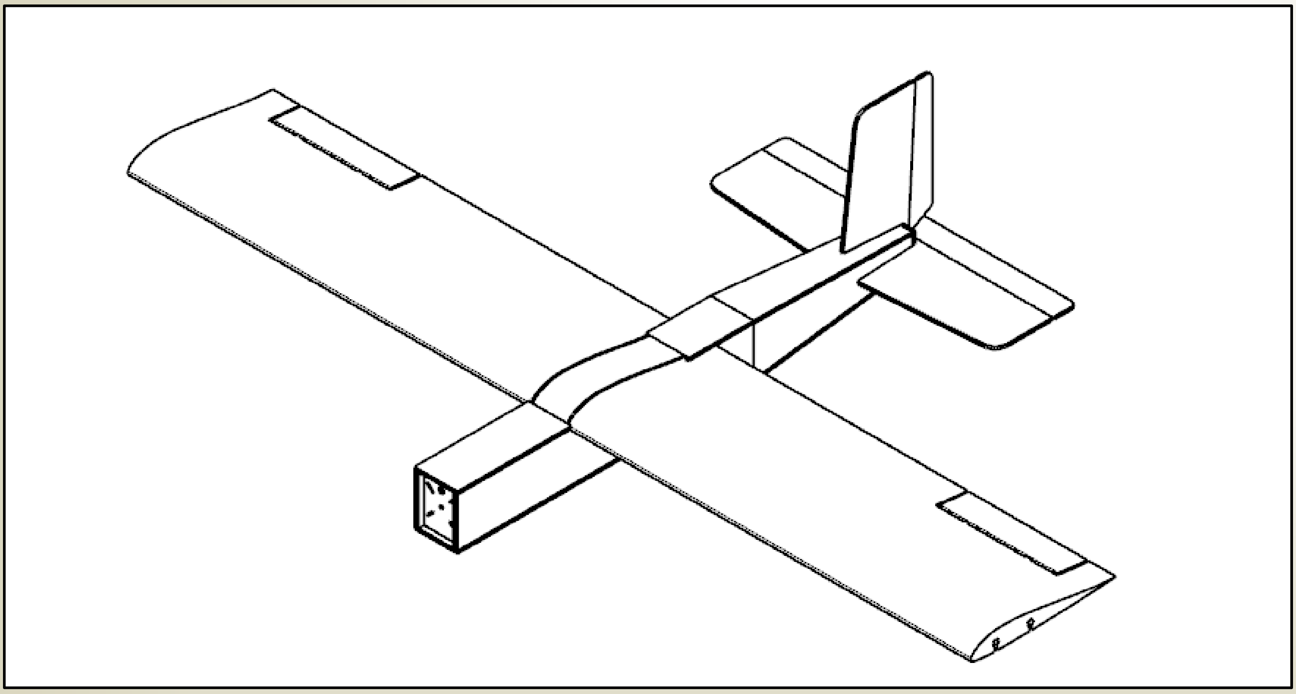


Conventional, high wing configuration XFLR5 analysis

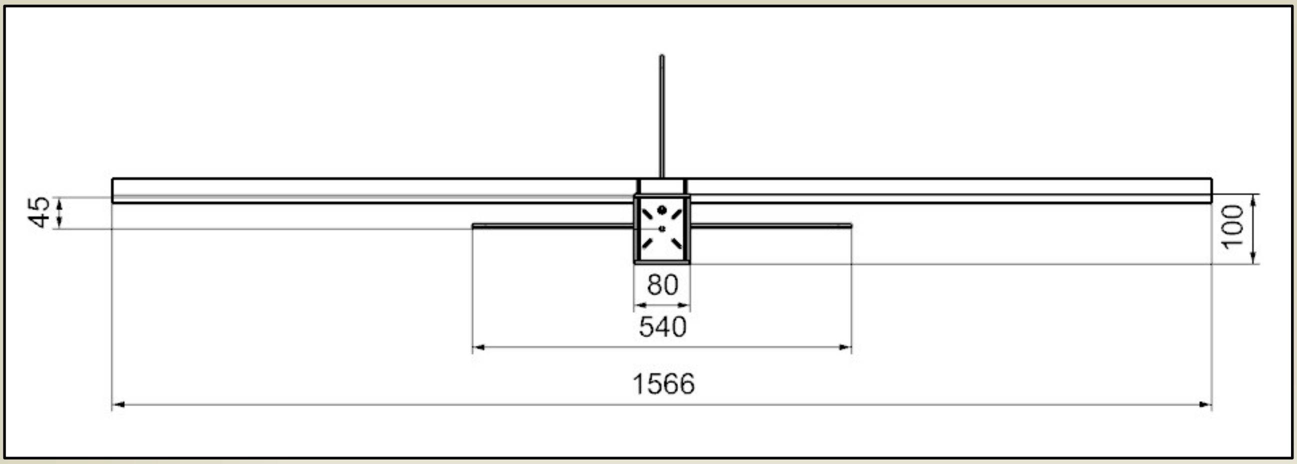
Detailed Design

This section entails various design points and important details in the final design of aircraft. It includes 3 views of the final design in addition to an isometric view, highlighting important dimensions, followed by the design details of individual components of the aircraft, namely the wing, tail assembly and mission related mechanisms.

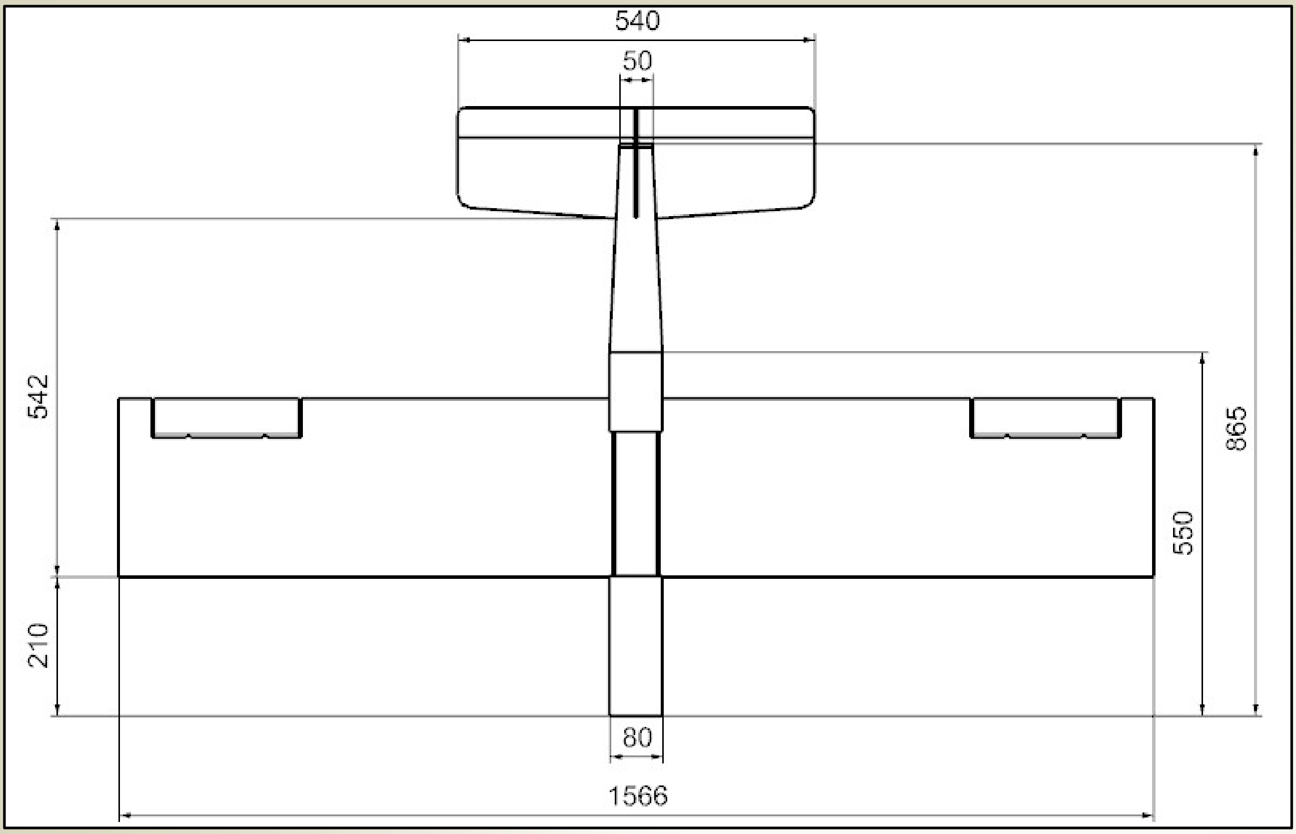
Overview



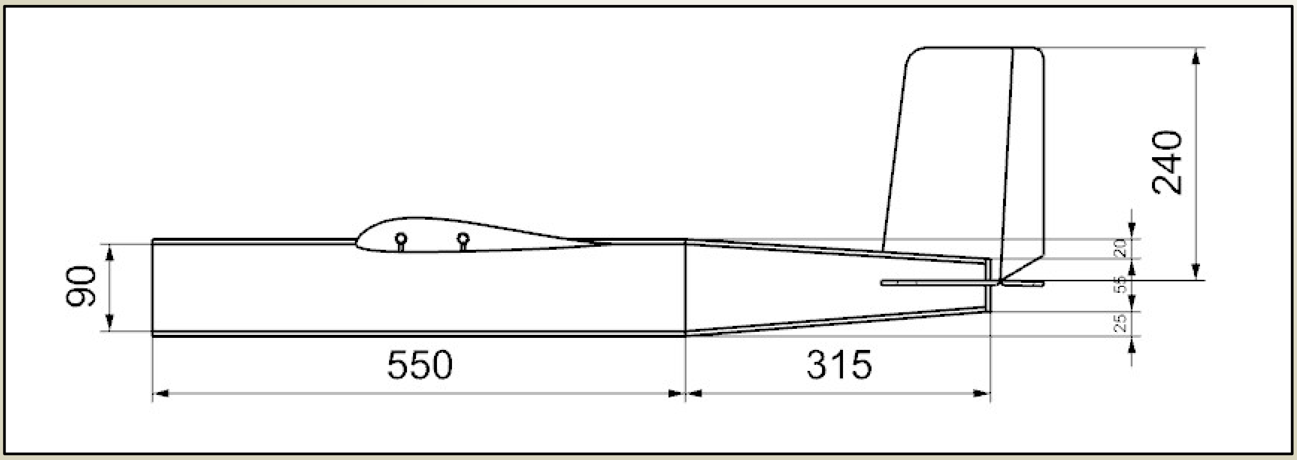
Isometric View



Front View



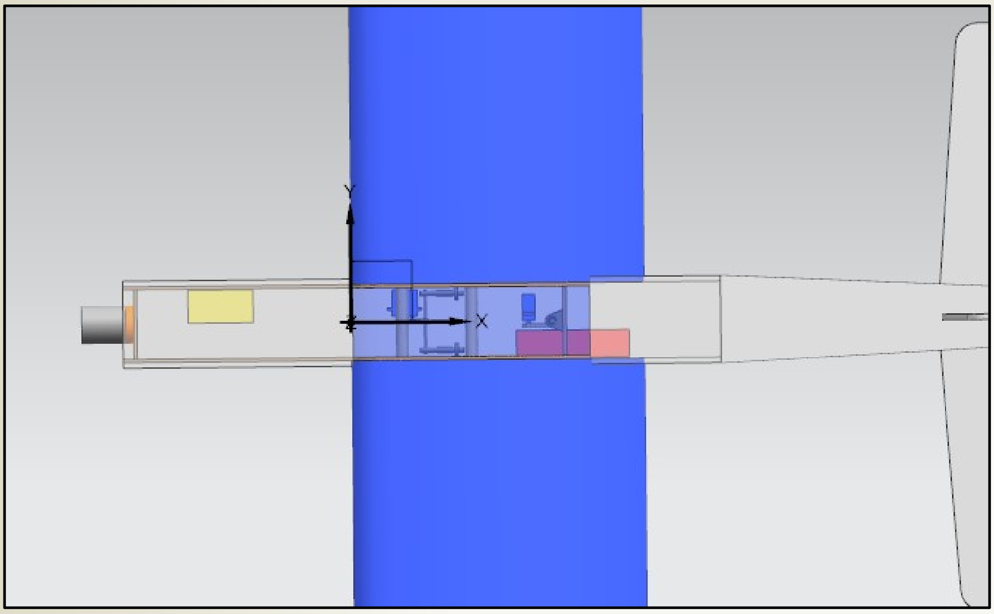
Top View



Side View

Weight Balance Table

The following table was created based on the actual weights and component placements after manufacturing.



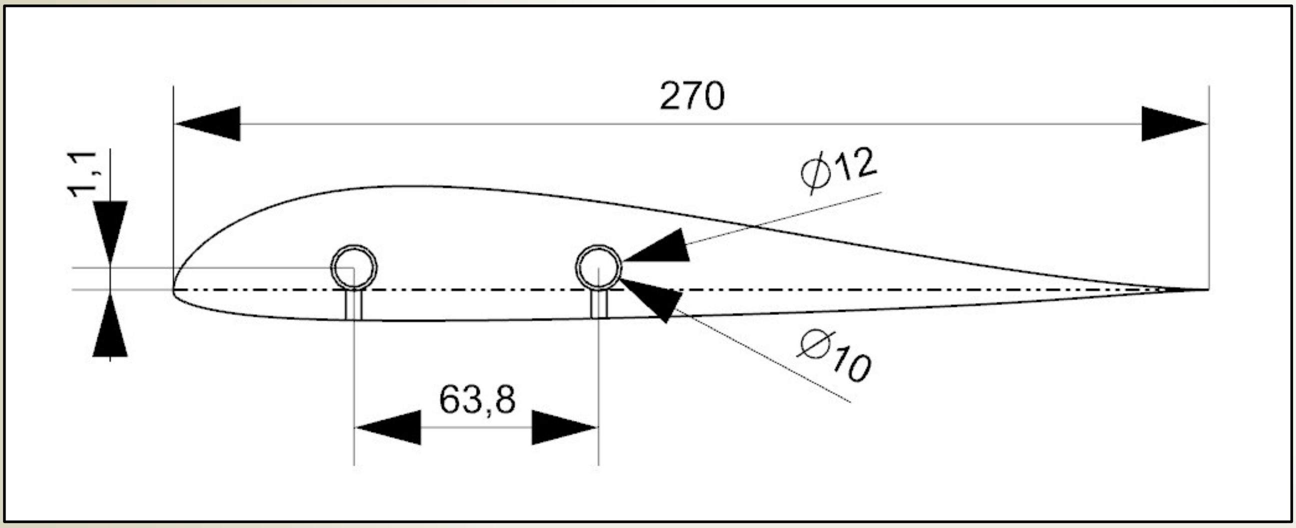
Datum used for distances in the weight balance table

Item	Mass (g)	Cg_X (mm)	Cg_Y (mm)
Fuselage + Wing + Tail Assembly + Mechanisms	820	163	-1
Motor + Propeller	190	-217	0
Esc	27	-106.5	18.5
Receiver	17	-106.5	18.5
Battery	177	162	-23
Extra Weight (coin)	9	100	450
Total	1240	94.6	0

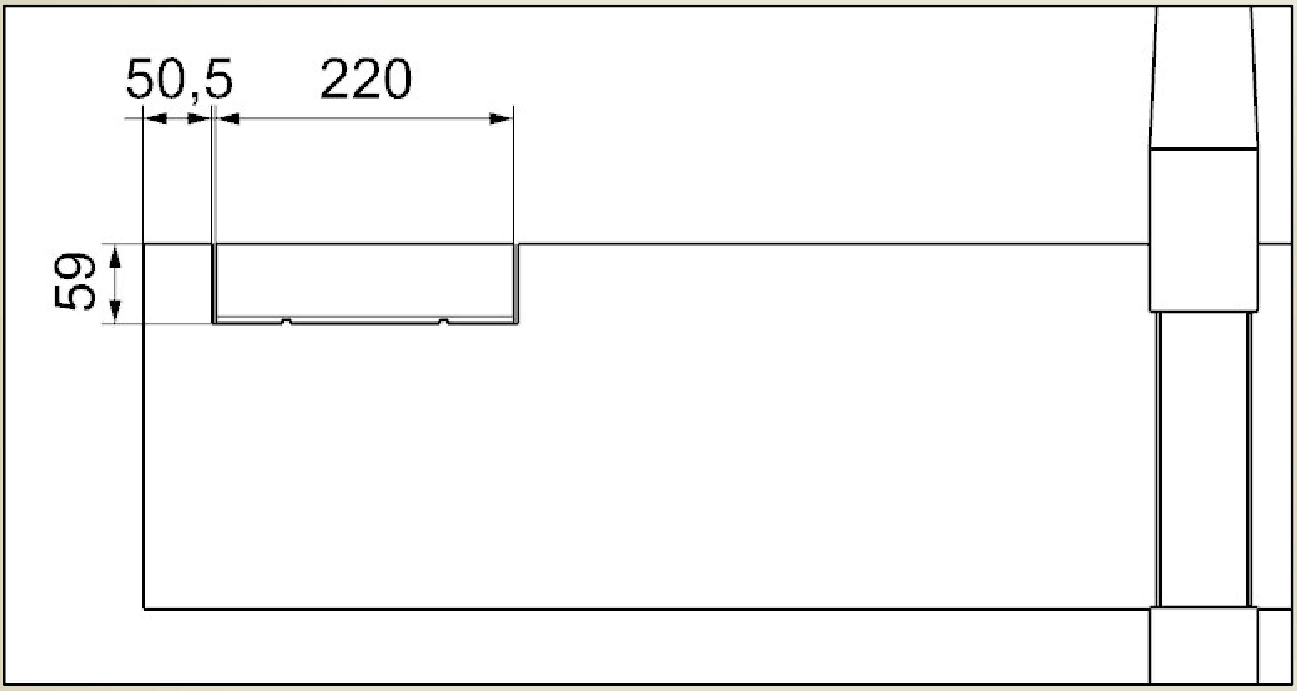
Wing

The aircraft has a straight wing with no taper, sweep, or dihedral angles. All dimensions were calculated at the preliminary design stage.

- N-81 Airfoil
- AR = 5.5
- Wing area = 0.401 m^2
- Half span = 0.742 m
- Root chord = 0.27 m
- Tip chord = 0.27 m
- Taper angle = 0°
- Dihedral angle = 0°



Spar placement



Aileron size and placement

Tail Assembly

Horizontal Tail Data

- Flat Plate
- Root chord = 0.17 m
- Tip chord = 0.15 m
- Half span = 0.27 m
- Tail area = 0.09 m^2
- Elevator span = 100%
- Sweep angle = 3.18°
- Tilt angle = 0 °
- Elevator root chord = 0.045 m

Elevator tip chord = 0.045 m

Vertical Tail Data

- Flat Plate
- Root chord = 0.17 m
- Tip chord = 0.14 m
- Span = 0.24 m
- Tail area = 0.04 m^2
- Rudder span = 100%
- Sweep angle = 5.36°
- Tilt angle = 0 °
- Rudder root chord = 0.045 m

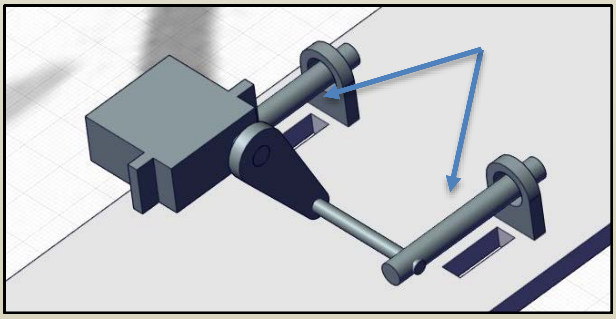
Rudder tip chord = 0.032 m

Mission Mechanisms

Two mechanisms have been created to carry out the mission objectives. One mechanism is for unfolding the banner so it can be towed behind the aircraft in full display, and another to drop the banner completely for the final lap of flight.

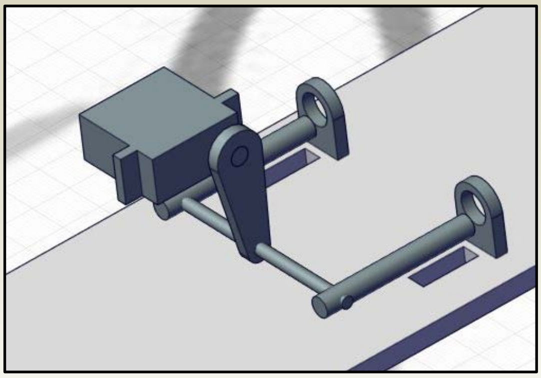
Release Mechanism

The release mechanism is first in the position shown. Two threads hold the banner underneath the aircraft; these threads are fixated in 2 positions each underneath the aircraft while the middle of the threads is wrapped around a spoke.



Initial position of the release mechanism, the two arrows point to the spokes

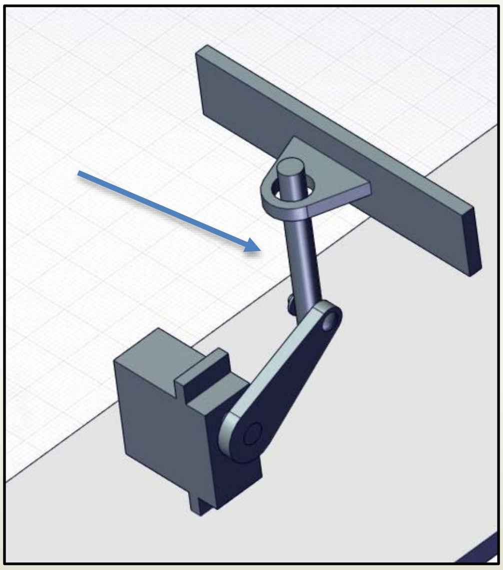
As the mechanism is activated, the spokes move backward, allowing the threads to slide off and out through the oppenings in the underbelly of the fuselage.



Final position of the release mechanism

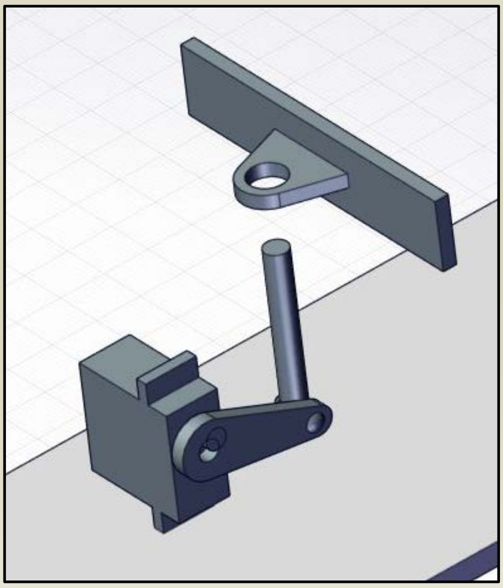
Drop Mechanism

The drop mechanism follows a similar idea to the release mechanism. A fishing line is used to tow the banner behind the aircraft; one end of the line is allowed to slide over the spoke shown in the figure, and then it is led through an opening in the back of the aircraft to finally connect to the banner.



Initial position of the drop mechanism, the arrow points to the spoke

As the mechanism is activated, the spoke is pulled downwards allowing the thread to slide off and effectively drop the banner from the aircraft.



Final position of the drop mechanism

Manufacturing

Materials

- 2 sheets of white foam 5 mm thickness
- One sheet of EVA foam 50 mm thickness
- Balsa wood
- 2 bars of aluminum of 10 mm diameter
- Hot glue and super glue
- White foam for main parts fuselage and tail.
- Blue foam for the wing.
- Plywood for reinforcement, motor mount, and mechanism.
- 2 aluminum rods are used as spars for the wing.

Machines Used

- Laser cutting machine.
- Hot-wire cutting machine for airfoils.

Co2 laser cutting machine

Hot wire cutting machine foam

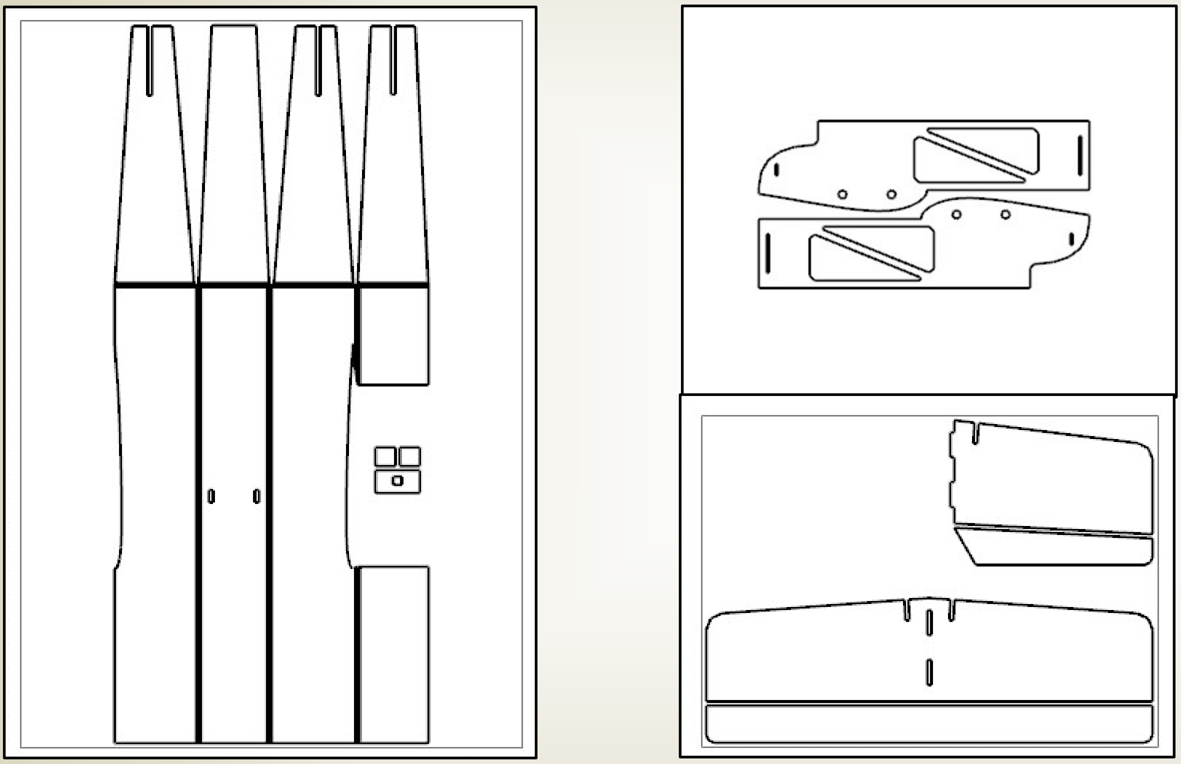
Process

Fuselage

First, we cut the fuselage on a sheet of foam by the laser cutting machine as one piece with half-cut between its parts, then stick it with hot glue, then we cut the supports on a sheet of plywood using the laser machine then the white foam is installed on it using hot glue as well.

T-tail

We cut the tail configuration on a sheet of foam using a laser cutting machine.



Sketches used in the DXF files for the laser cutter

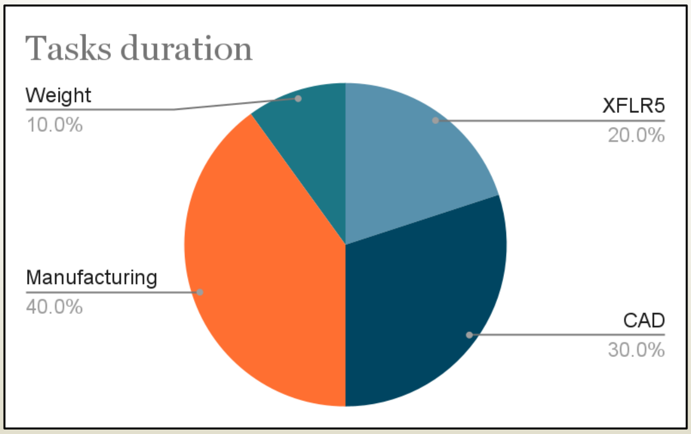
Management Summary

The table below shows as follows: Each member has a main task where they focused on and a side task where they participated in.

Member	Main Task	Side Task
Mohamed Salah	XFLR5, wing CAD	CAD, mechanism design, Manufacturing
Youssef Salah	Report, Tail CAD	XFLR5, Manufacturing
Mohamed Ghanem	Fuselage & assembly CAD, mechanism design	XFLR5, Report, Manufacturing
Mazen Hosam	CAD Demo, Report	XFLR5, Manufacturing
Moaaz Zaki	Manufacturing	-

*All participants shared in design and decisions making.

The following chart shows how much time each task has taken in percent of the whole time which is nearly 90 days starting from July.



Task time distribution

Special thanks to Eng. Mohamed El-Masry and Eng. Mona Ahmed who have been with us every step of the way