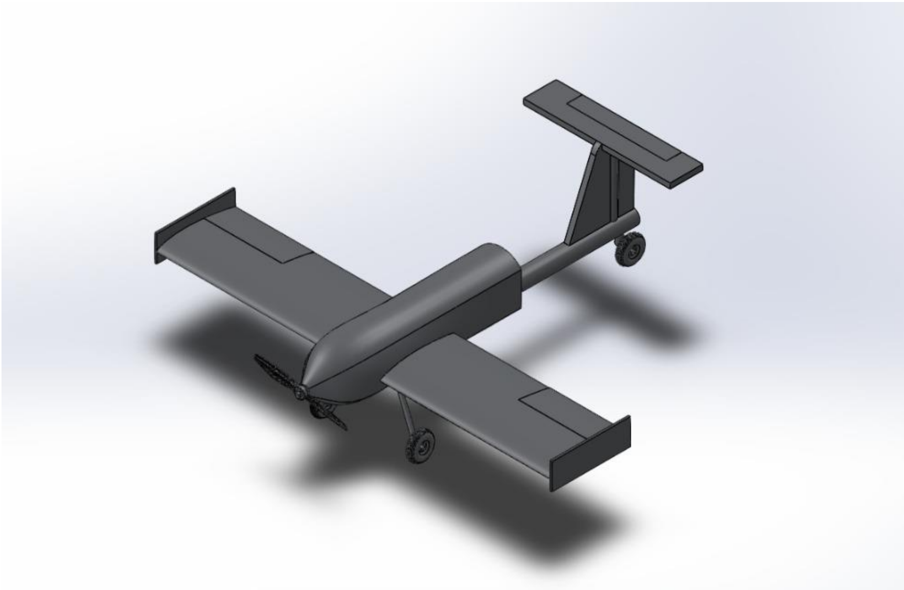
UNIVERSITY OF GAZIANTEP

DEPARTMENT AERONAUTICS AND ASTRONAUTICS ENGINEERING



AIR CREW

2018 TUBITAK INTERNATIONAL UNMANNED AERIAL VEHICLE COMPETITION

CONCEPTUAL DESIGN REPORT

T003 / AIR CREW

VEHICLE: FIXED WING / TOLAN I

UNIVERSITY OF GAZIANTEP

ADVISOR: PROF. DR. İBRAHİM HALİL GÜZELBEY

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1. EXECUTIVE SUMMARY

This report aims to show designing, producing, and testing stages of a UAV (Unmanned Aircraft Vehicle) that will be designed by Air Crew Team for Tubitak UAV Competition. In this competition there are 3 assignments which are required lap, drop with two payloads, and autonomous flight. The development and design of the aircraft is still in progress. The team is aiming to produce an aircraft that maximizes the score according to the rules of the competition.

1.1. Key Mission Requirements and Design Features

The Air Crew Team aims to achieve best results for the aircraft. There are many airfoils and wing configuration for the design of the aircraft. Therefore the best result can achieved through an analysis. Design of the aircraft contains fuselage, one or more wings, and empennage.

In this competition we have a drop mission. Therefore we decided to have one mid-wing because aerodynamically, the mid-wing has less interference drag compared to the high and low wings. Mid-wings create room for cargo in the belly of the aircraft. Low wings reduce the height of the undercarriage. This design analysed to reflect important mission variables which are stability, control, weight, drag, speed, and manufacturability. We found out that the empty weight, number of servos, and maximum speed are the key mission requirements. According to two circular payloads empty weight and maximum weight can be predicted.

1.2.Design and Performance Highlights

The aircraft has a mid-wing design with elliptic fuselage. The aircraft is sized to 1.5 m wingspan, 0.3 m chord, and $0.800\ m^2$ total wing area with aspect ratio of about 5. For now, we have four possible airfoils; WORTMANN FX M2 AIRFOIL, WORTMANN FX 63-100 AIRFOIL, EPPLER E392, and SELIG/DONOVAN SD7032-099-88. Aircraft will be controlled by remote control and autonomous system.

Selected motor for the aircraft is Emax Grand Turbo GT2815-07. The battery pack is 3 cell 2200 mAh and the propeller is Xoar 10 ×5 and 11 ×6.

2. MANAGEMENT SUMMARY

The Air Crew Team has three students which all of them are freshman and one advisor Professor from Gaziantep University Department of Aeronautics and Astronautics Engineering.

2.1. Team Organization

Working groups are as follows:

- **Aerodynamics:** Airfoil selection, aerodynamic calculations, stability and control analysis.
- **Design:** Deciding the design, and to provide 3D design by using 3D software. Selecting materials, structural and material testing. Configuration of cargo space and cargo distribution in the cargo bay.
- **Electrical and Propulsion:** Connecting electronic systems, calculating battery life and power of battery. Selecting convenient propulsion system and testing these propulsion systems.
- **Software:** Writing the C++ software for autonomous systems.
- **Pilot:** Pilot will use the aircraft during the competition.

ADVISOR

Faculty Dean

Prof.Dr. Halil İbrahim Güzelbey

Team Captain

Mustafa Can Emre

*Design

*Aerodynamic

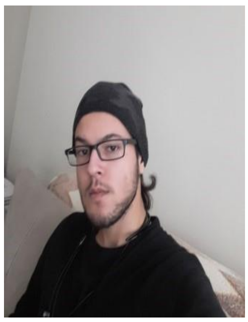
Pilot

Mansur Erhan Taşkın

*Design

*Aerodynamics

*Propulsion



Team Member

Can Gökdeniz

*Software

*Electrical

2.2. Milestone Chart

The project schedule is spread over one semester. In this period of time, the implementation of a schedule is important to develop a competitive design of the aircraft. The development schedule is shown and outlines the sequences of critical tasks for successful project completion.

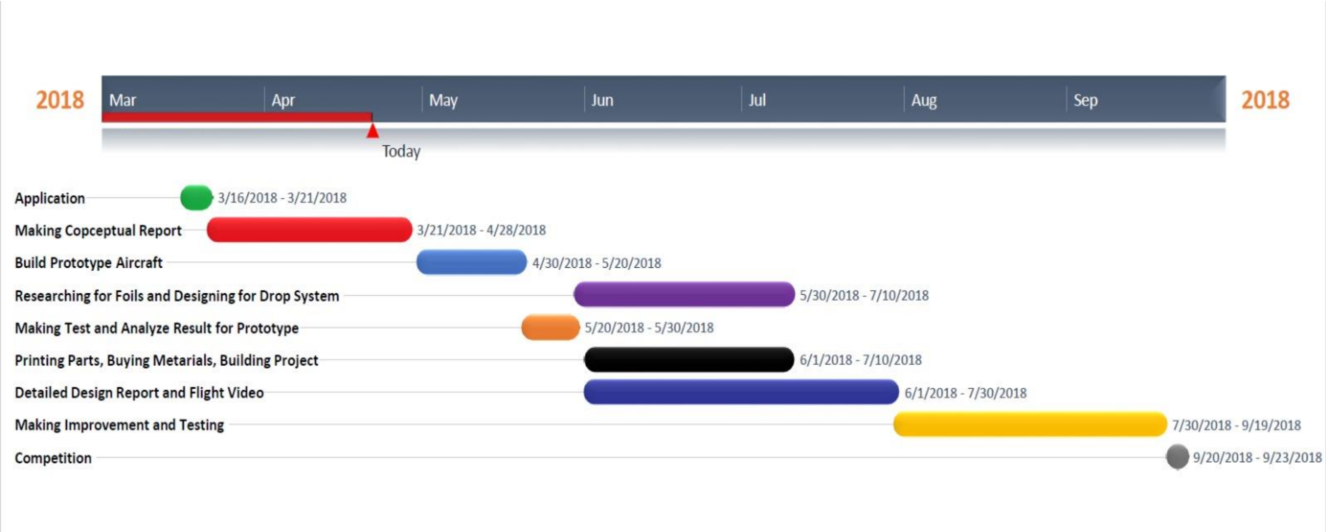


Figure 2.1

3. CONCEPTUAL DESIGN

In this section the team describes in detail the conceptual design for the aircraft. Possible aircraft configurations were explored with morphological matrices. Many of these configurations have been eliminated in the course of their mission requirements.

3.1. Mission Requirements For The Project

The competition includes three flight mission. Our aircraft and its system must meet several performance, propulsion, structure and payload requirements. In this part, we will describe missions and their requirements.

3.1.2. Mission 1

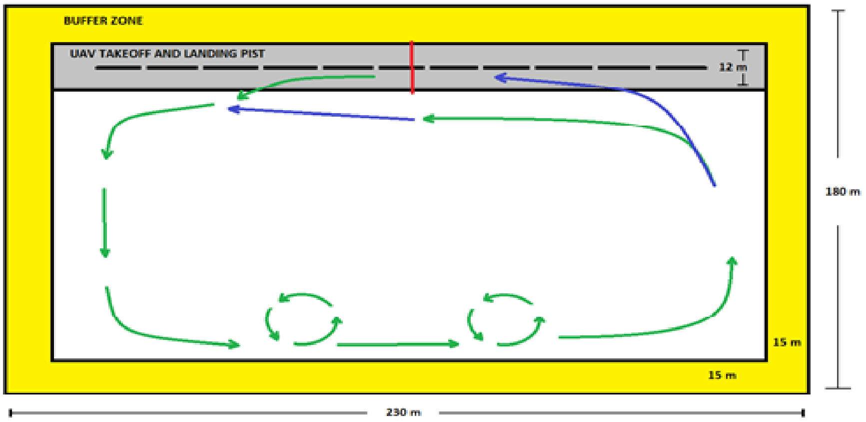


Figure 3.1 (Mission 1)

This mission's aim to test UAVs maneuvrability and stability. Mission has two tour and UAVs will loop two times in a tour. UAVs must be controlled by a pilot. And also flight path will be checked on telemetry.

3.1.3. Mission 2

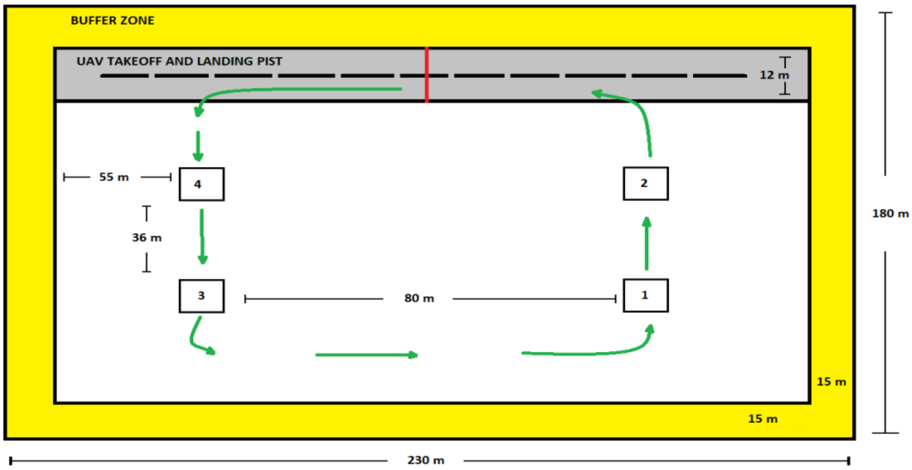


Figure 3.2 (Mission 2)

In this mission, UAVs will be tested for autonomous flight, load handling, and load-releasing capabilities in the appropriate order for the specified area. Number of payload will be decided by the team so we decided to carry only two payload (ball). In the Figure we estimate our flight path in this mission. In the competition our squence of dropping payload will be clear. We defined general mission below.

3.1.4. Mission 3

In this mission all of the manoeuvres will be autonomous including take off and landing.

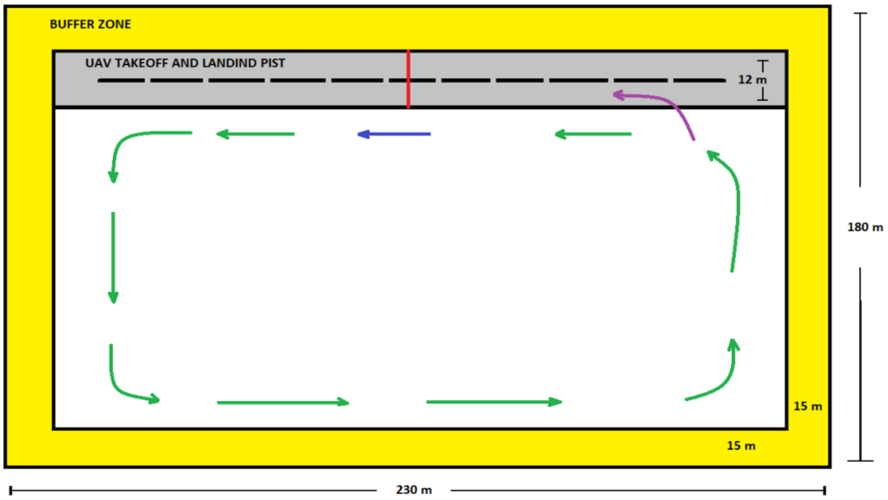


Figure 3.3 (Mission 3)

General Rules for the Missions: Each team has maximum 5 flight (as long as the duration of the competition allows).The flight orders of the teams will be determined according to the points they receive from the detailed design report. The team doesn't come to flight line will lose flight order. Each mission has to be completed in 6 minutes. The elapsed time between the start and finish lines will be flight time. Missions will be performed in order. Before the first mission is succecfully completed, flight can not be performed for the second mission. In all missions, telemetry system will be checked before the flight and sending data: speed, altitude and location information, will be monitored throughout the flight. Each team brings their telemetry system. In case of telemetry doesn't work, flight will be permitted but valid score will be 75 percent of score on that mission.

Report	Mission 1	Mission 2	Mission 3	Total
25	25	25	25	100

Mission	Formula
I	$15(t_{min}/t_{tm})+10(W_{min}/W_{tm})$
II	$25(NB_{tm}/NB_{max})$
III (for fixed wing)	$25(DFL_{tmin}/DFL_{tm})$

Figure 3.4

W_{min}: The lowest take-off weight for all teams	W_{tm}: The team's take-off weight
t_{min}: The lowest flight time for all teams	t_{tm}: The team's flight time
NB_{tm}:Number of payload of the team's succesfully left to the target.	NB_{max}: The maximum number of payloads left to the target succesfully for all teams.
DFL_{tmin}: The lowest distance to finish line for all teams.	DFL_{tm}: The team's distance to finish line.

Figures 3.5

3.2. Design Requirements

In order to understand the suitable design requirements for the competition. We have to analyze scoring formulas. In the 2018 TUBITAK UAV Competition, there are three missions. First mission is about to being light and fast but we need to consider wind that can corrupt our flight path. Our team consider lowest weight that can make high score and suitable for windy weather. Second mission autonomous payload releasing. This mission tests directly our autonomous ability indirectly stability because payload must be down specified area to make point. In not stable situations payload can be down out of the target area. Third mission tests autonomous ability and stability likely second mission. Conclusion requirements tabled below

Mission Requirement	Design Requirement
Completing flight course laps as fast as possible	Maximize propulsion system Low drag at course High maneuverability
Being stable in windy condition	Lateral stability
Takeoff and land succesfully	Static and dynamic stability
Drop payload target area	Use good sensors

Figure 3.6

3.3. UAV Configuration

This section decribes the team's required configuration. According to requirements the team's aircraft must be manoeuvrable and support payload to transport. Diferrent types of configuration and their advantages and disadvantages considered by the team and chosen; monocraft and and aspect ratio 5 wingspan 0.3 m rectangular wing platform and main area 0.45 m^2. We consider undercarriage immobile because of stability. Motor configuration will be single tractor because of manucfacturability and efficiency.

In the competition, we need a structure that is as maneuverable as it is stable in the wing configuration. Also, if we look at the competition score, we have to think about the weight because the low weight has a big contribution to the score. Conventional wing meets our competition requirement.

					
Wing configuration	**%**	**Canard**	**Biplanes**	**Lifting Body**	**Conventional**
Lift/Drag	30	3	2	4	3
Maneuverability	20	5	4	4	3
Weight	20	2	3	3	3
Stability	15	3	4	2	5
Payload Integration	10	1	3	4	4
Manufacturability	5	3	3	2	4
Total	100	3	3.05	3.4	3.65

Figure 3.7 (Wing Configuration)

Similarly, during the consideration motor configuration we have to choose the right configuration that can be provide us high mission score with its characteristic. When our configuration is stable as it is maneuverable and fast, we can make high score in competition.

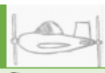
					
Motor	%	Single Tractor	Single Pusher	Double Tractors	Counter-Rotate
Thrust to Weight	50	5	3	4	3
Stability	30	3	1	4	2
Size	20	4	3	2	2
Total	100	4.2	2.4	3.6	2.5

Figure 3.8 (Motor Configuration)

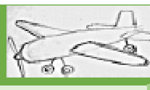
					
Landing Gear		%	Tricycle	Taildragger	Skids
Weight		50	1	2	3
Integration		25	2	3	1
Takeoff capability		25	2	3	1
Total		100	1.5	2.5	2

Figure 3.9 (Landing Gear Configuration)

3.3.1. Mechanical Systems

a) Fuselage:

Fuselage is body for aircraft all thing come together with this part. Payload and required instrument placed inside the fuselage. Fuselage shape is determined with this parameters. In the competition we have to carry spherical payload and our instrument because of these reasons we design a fuselage can carry payload and instrument.

b) Main Wing :

The main wing is the most important part of our design because it is the starting point of aircraft dynamics and calculations. To begin designing the main wing, there preliminary information such as, the Reynolds Number, airfoil structure, stall speed, the weight that the wing should carry.

Reynolds Number:

$$Re = \frac{\rho v_s d}{\mu} = \frac{v_s d}{\nu}$$

Our speed interval 10 m/s and 30 m/

The Reynold Number allows to determine Cl-α curve depending on the air density, the dimensions of the wing and the speed of aircraft. During the competition in Istanbul air density is 1.21164 Pa and viscosity is 1.8111E-5. (Estimated height 100 m and 20 celcius degrees)

R.N = 198.531 – 595.593 This Reynold Number interval is good for us. However, for practical causes we will use 200.000 – 500.000 interval.

Stall Velocity:

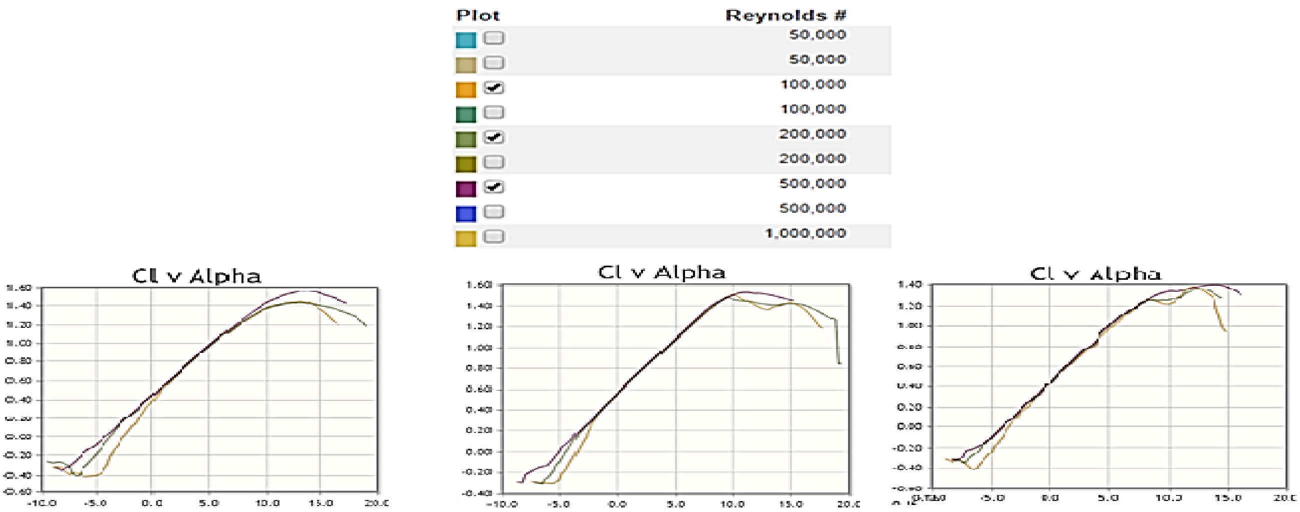
There are 2 possible wings available. To compare them we need to review and decide the cl-α graphs. Cl value can be found from the basic formula of aerodynamic **L = (1/2) *d *v^2 *s *CL** from this formula cl;

$$Cl = \frac{2\,L}{\rho \times V^2 \times A}$$

Our estimated stall speed is 10 m/s. Cl = 0,798256 is suitable for our aircraft Talon I for stall speed 10 m/s.

Airfoil Selection:

Figure 3.10 (Rejected Foils)



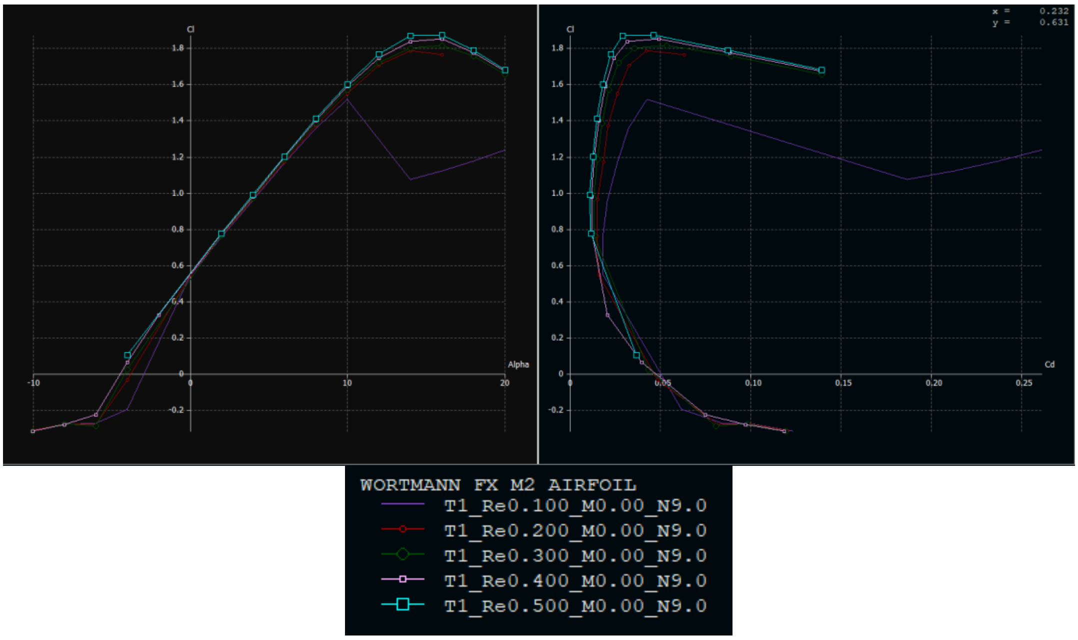
GOE 174 – Inefficient lift-1
Cl range is not enough for aircraft and at a=0 cl value is not enough.
(Re no:100.000 – 500.000)

SD7032 – Inefficient lift
Cl range is not enough for our aircraft and at a=0 cl value is not enough.
(Re no:100.000 – 500.000)

EPPLER 392 – Inefficient lift
Cl range is not enough for our aircraft and at a=0 cl value is not enough.
(Re no:100.000 – 500.000)

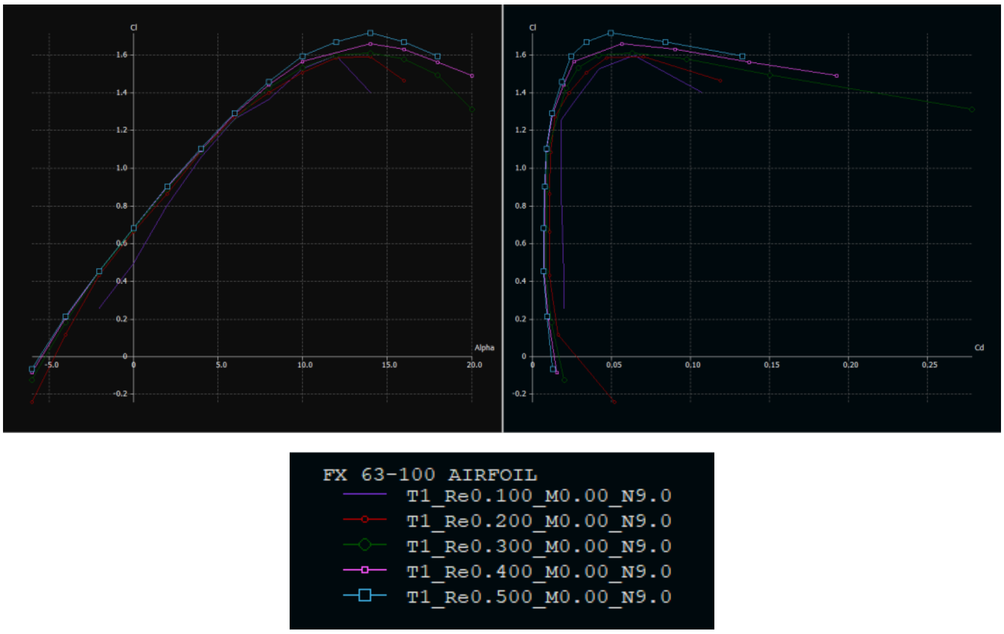
Possible Foils:

WORTMANN FX M2



Figures 3.11 (XFLR5 Analysis)

WORTMANN FX63-100



Figures 3.12 (XFLR5 Analysis)

We analyzed our possible airfoils on the XFLR5. FX 63-100 has a Cl value 0,6978 at α=0 and FX M2 has a Cl value 0,3687 so we decided to use FX 63-100.

Wing Platform:

Our main wing has rectangular shape. We will use winglets to reduce induced drag because of wing tip vortices. Wing will be built from depron foam and support carbon fiber rod. When we build up our wing, we will use hot wire cutting technics. Aircraft wing's weight will be the lowest with this technic. There is no joints in the wing so it will be stronger than the wing that has joints.

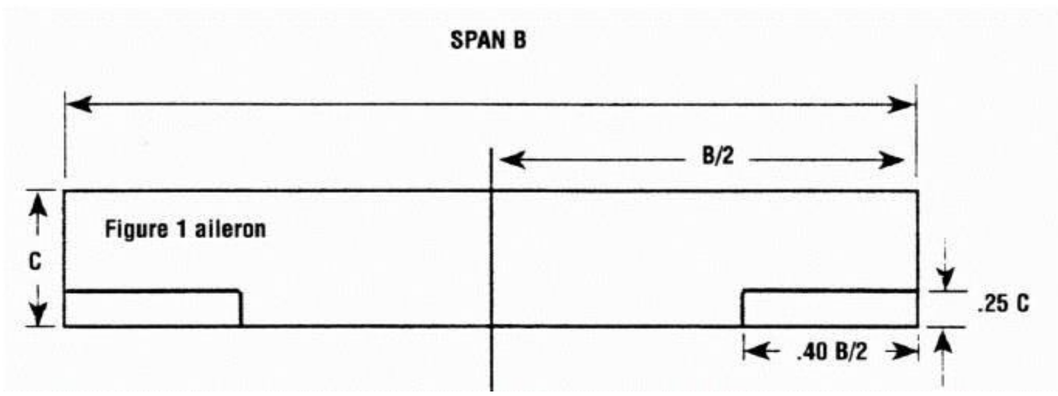


Figure 3.13

3.3.2. Payload Dropping System

In the competition we have mission 2 which tests our cargo drop ability. This ability depends on flight controller, flight speed, and drop system accuracy. If the drop system fails, mission fails and our cargo must be stable to not disturb to flight. We design a cubic cargo house inside the aircraft. Its shape provides cargo is stable. Easy opened door provides right timing to the dropping.

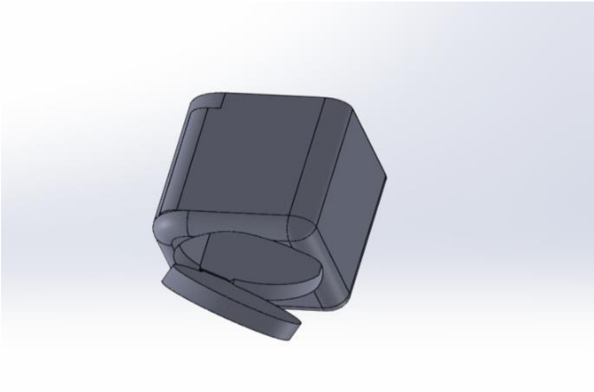


Figure 3.14 (Cargo Section and Drop System)

3.3.3. Electronic Scheme

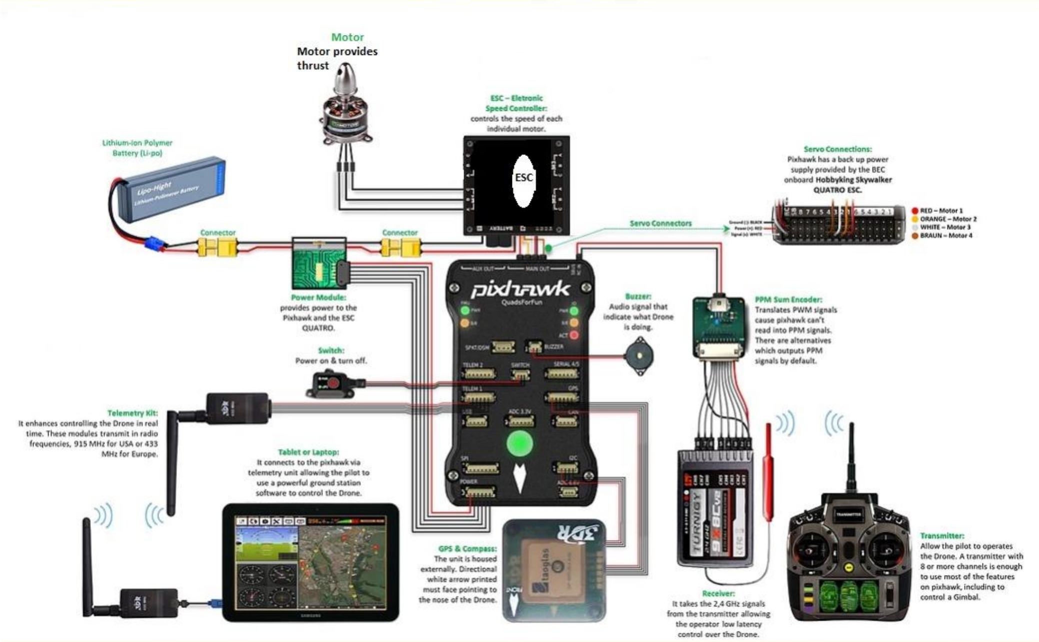


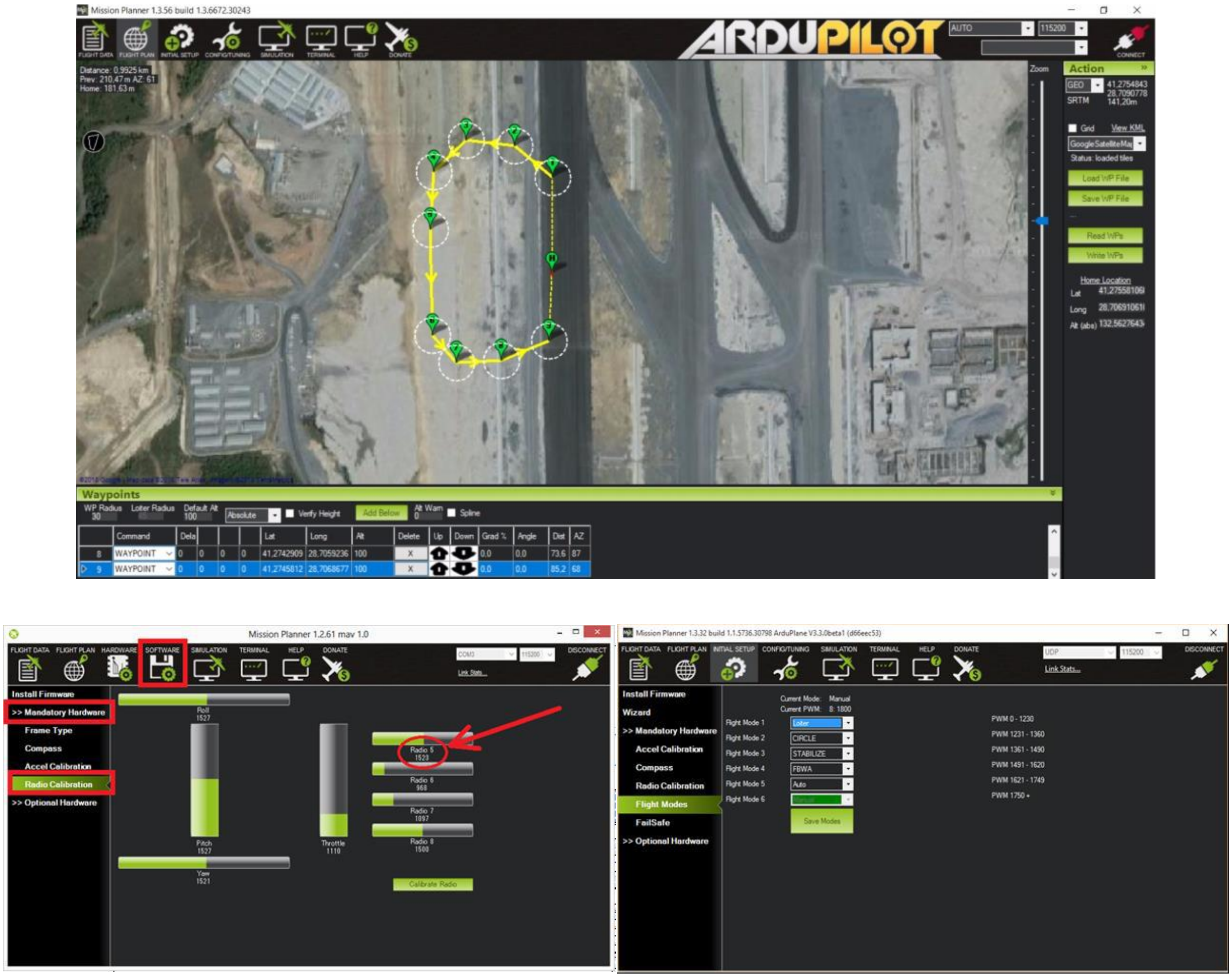
Figure 3.15

Our electronic circuit system will be close to the system above. We will use Pixhawk as flight controller. Pixhawk has a powerful 32-bit processor, and failsafe backup controller. Aircraft will be controlled by FPV remote control and autonomous system. We will use Rctimer NFS ESC 45A Multi-Rotor ESC with SimonK

Firmware, six Tower Pro SG90 RC Mini Servo Motors, and Emax GT 2815-07 Outrunner Brushless Motor with RPM/V: 1100KV.

3.3.4. Electronic and Flight Control System

In the competition to success autonomous missions, we will use Pixhawk autonomous system. This control system has a GPS, gyroscope and this system can be controlled with Mission Planner. Mission Planner provides us control our aircraft without a pilot and when the signals cuts out, it has system to land aircraft safely. This failsafe mode and in the competition this mode is important for safety. This control system has more accurate value calculated by sensors but it is hard to programme Pixhawks card we will use suitable prepared modes. In the autonomous missions, our team's pilot will be ready to take control when our control system doesn't work.



Figures 3.16

We will connect the receiver to PPM Sum Encoder. Then we will connect PPM Sum Encoder to Pixhawk. Because Pixhawk cannot read PWM signals, so we need an encoder for combining all 8 PWM signals into a single PPM to send to pixhawk. We will use a transmitter to control the aircraft. Transmitter is RadioLink T6EHP-E 2.4G 6CH. We need GPS for autonomous flight and tracking aircraft. We will connect GPS and compass to Pixhawk and Telemetry Kit. Telemetry Kit will provide a connection between Pixhawk and a computer. From computer we will use Mission Planner software as ground station software. We can plan an autonomous flight and track our aircraft through Mission Planner. We will use a Kypom 11.1v 2200 mAh LiPo battery. Battery will be connected to power module and we will connect the power module to Pixhawk and ESC. Power module provides power to the Pixhawk and ESC.

3.4. Estimated Weight

Fixed Weights		
Product	**Weight**	**Purpose**
Brushless Electric Motor	1 x 120 = 120 g	Thrust
Li-po Battery	1 x 167 = 167 g	Power
ESC (Electronic Speed Control)	1 x 20 = 20 g	Converter
9 g Servo	6 x 9 = 54 g	Surface Control
Propeller	1 x 50 = 50 g	Thrust
Pixhawk Card	1 x 38 = 38 g	Autonomous
Landing Gear System	1 x 100 = 100 g	Taxi
Total = 549 g		

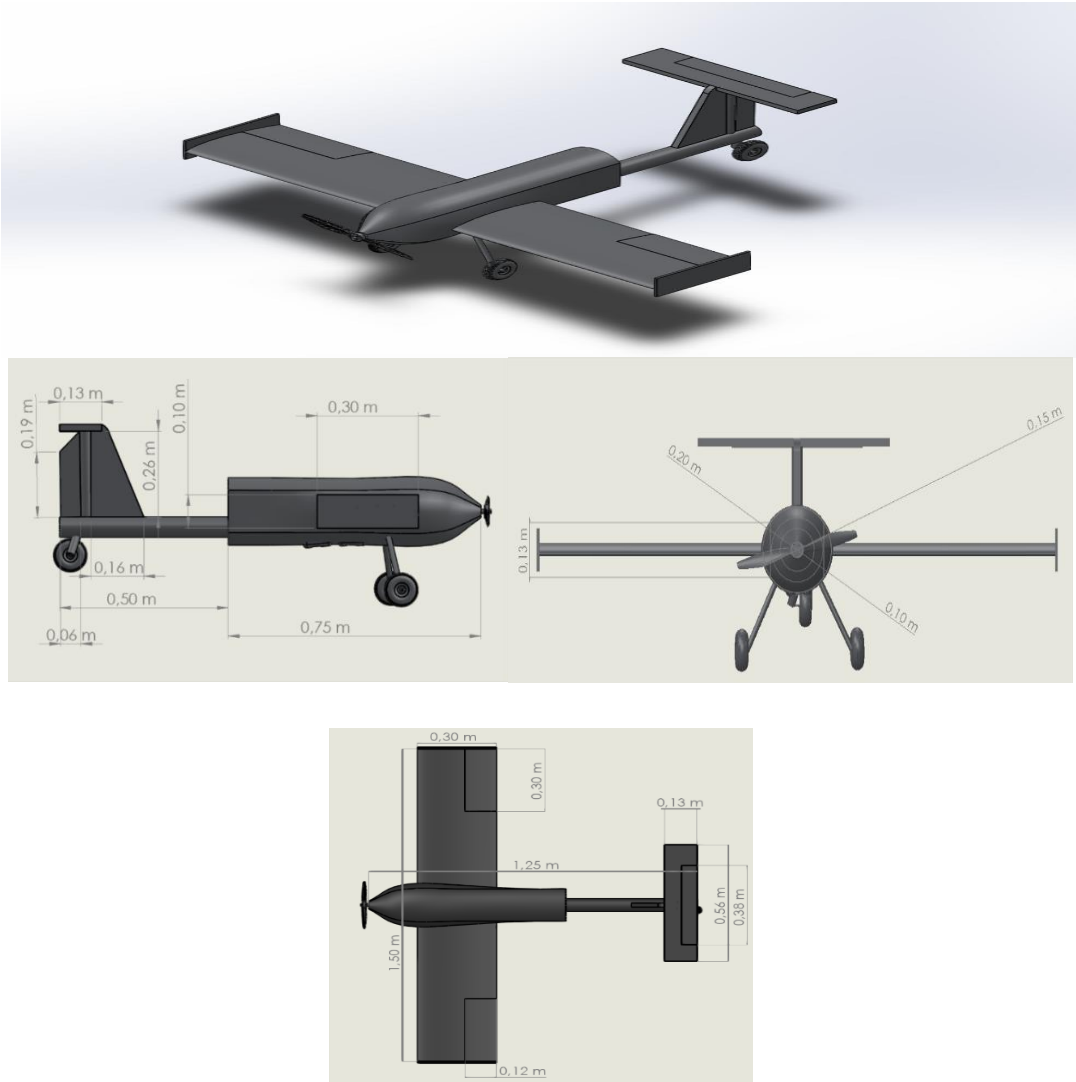
Figure 3.17

Variable Weight	
Wing: In our aircraft, we will use only depron foam (3cm x 30cm x 150cm) for main wing depron has a density 0,04 g/cm³ so main wing (540 g)and for support cylindrical carbon fiber rod (170 g) epoxy ingredient (40 g)	Total Wing Weight = 750 g
–Horizontal Tail: Our horizontal tail will be made from depron, too. (2 cm x 38 cm x 13 cm) Depron density 0,04 g/cm³. Epoxy (40 g)	Horizontal Tail Weight = 90 g
Vertical Tail: Vertical Tail made from depron (2 cm x 26 cm x 25 cm) and cylindrical carbon fiber (40 g)	Vertical Tail Weight = 92 g
Fuselage: We will use a carbon fiber skeleton for support to depron fuselage shell. Estimated skeleton weight 200 g. Depron fuselage shell weight 300 g. And after body cylindrical second fuselage (50 cm x π x (6 cm)^2) (100 g) 50 cm carbon fiber (20 g)	Fuselage Weight = 620 g
Payload Drop System: For two payload 2 cubic boxes (2 x 50 g)	100 g
Payload: 2 x 100 g ball	200 g
Total = 1852 g	
Total Aircraft Weight = 2400 g	

Figure 3.18 (Estimated Weight Tables)

3.5. Final UAV Consept

The AIR CREW team has determined requirements for the competition, firstly. Then sources scanned for the ideal aircraft. Configurations were determined, then one of them was chosen. General calculations were done to the determine aircraft dimension and required lift. Airfoil datas scanned and possible airfoils were analyzed. Material and electronic equipment were determined. Ground system was chosen. Finally, all of these process were written.



Figures 3.19 (Final Consept)

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