T.C.

GAZİANTEP UNIVERSITY

FACULTY OF AERONAUTICS AND AEROSPACE

AEROSPACE ENGINEERING DEPARTMENT

AERONAUTICS AND AEROSPACE ENGINEERING

# VERTICAL TAKE-OFF AND LANDING UNMANNED AIRCRAFT (VTOL UAV)

GRADUATION PROJECT

MUSTAFA CAN EMRE-201616263

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# ABSTRACT

## VERTICAL TAKE-OFF AND LANDING UNMANNED AIRCRAFT (VTOL UAV)

Our project is VTOL UAV mechanism designed by the students of the Aerospace Engineering Department of the Gaziantep University. I have designed our UAV for easy vertical take-off and landing for short distance flights. With this design aircraft's path can be determined beforehand with computer software and it can start its flight easily. This design can be used in movie making, surveillance and rescue operations. The unique part of this design is that it is a combination of multirotor and fixed wing aircraft to switch between them when the situation is necessary.
Multirotor provides easy take-off and landing which the runway is not needed and fixed wing provides fast flight and efficiency.

**Keywords:** UAV, VTOL, aircraft, drone, multi rotor, autopilot, autonomous, fixed wing aircraft

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# CHAPTER I

## 1. Introduction

A vertical take-off and landing (VTOL) aircraft can provide vertical take-off and landing. VTOL aircrafts are researched many times throughout the years and it expands every year. Most of the VTOLs are using tiltrotor and tiltwing for take-off, landing and thrust which provides horizontal movement. In these situations either the wing or rotor rotate after the take-off for horizontal thrust. I kept take-off and thrust rotors separately which is called Hybrid VTOL UAV. This way I can get more efficiency and producibility. After take-off thrust rotor starts and take-off rotors shut down. So during the flighr our UAV is more like an fixed wing aircraft.

*Figure 1.1 Hybrid VTOL Fixed-Wing UAV Produced by UKRSpecSystems*

# CHAPTER II

## 2. Aircraft Design

### 2.1.Fuselage

I searched some of the fuselages that can be bought but I did not find them suitable for our design. I decided to design our fuselage and I continued with it. The designed aircraft expected to be light but it also has to be able to contain all the electronics. I used XPS foam in our fuselage.

#### 2.1.1. Weight of the Aircraft

I expected our design to be light and as a result I got what I want. Estimated weights of the electronics are as below:

Table 2.1.

*Estimated Weight of Electronics*

| Device | Quantity | Weight |
|---|---|---|
| Battery | 1 | 278g |
| Lifter motor (ESC included) | 4 | 320g |
| Power Distribution Board | 1 | 7.5g |
| Pusher Motor | 1 | 50g |
| Pusher ESC | 1 | 37g |
| Pixhawk | 1 | 15g |
| GPS | 1 | 32g |
| Others | - | 200g |
| Total Weight | - | 940g |

Others refers to servo motors, cables, BECs etc. Estimated total weight for the electronics is 940g. With fuselage, wing, rods etc. I estimated total weight of our aircraft as 2kg.

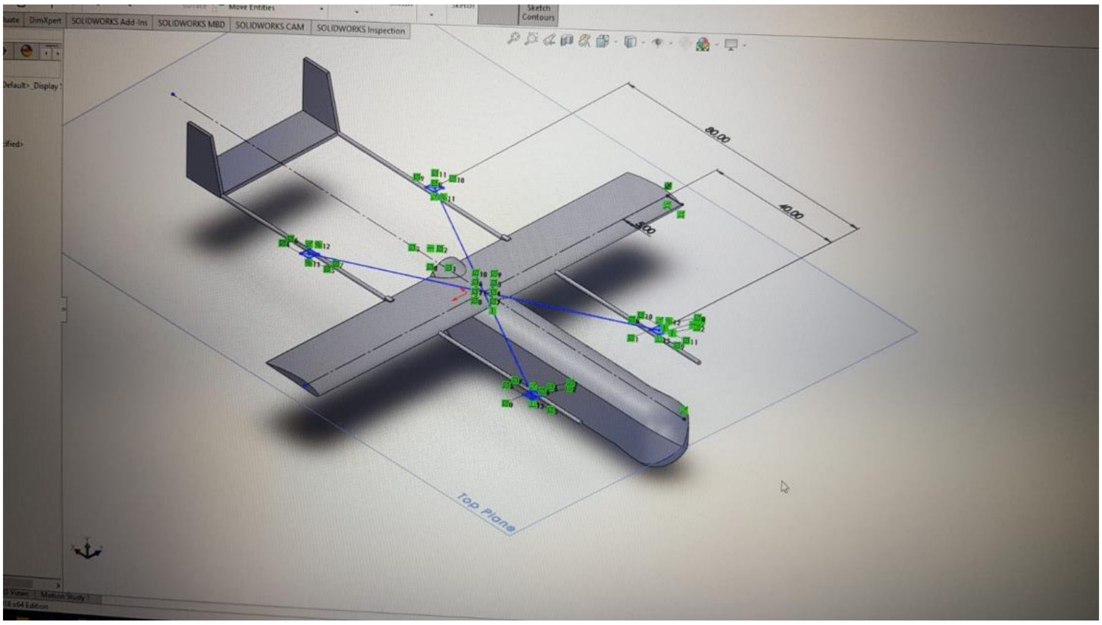


*Figure 2.1. Structural Design with Center of Gravity.*

## 2.2.Wing

I made a comparison between Eppler E422 high lift airfoil and NACA 4412 airfoil. NACA 4412 was more compatible with our design and I chose it.

Table 2.2

*Parameters of the NACA 4412*

| | |
|---|---|
| Wing Span (mm) | 1238 |
| Mean Aerodynamic Chord (cm) | 20 |
| Wing Area ($m^2$) | 0.24 |
| AR | 6.18 |
| Cruise Speed (m/s) | 15 |

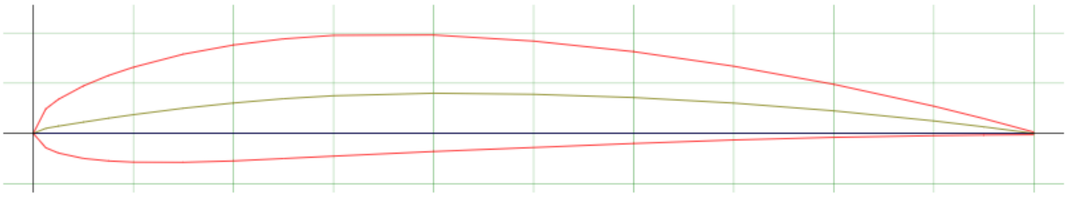


*Figure 2.2. 2D Drawn NACA 4412*

## 2.3.Propulsion System

### 2.3.1. Lifting Motors

Table 2.3

*Parameters for Lifting Motors*

| Name | KV | Max Thrust (gram) | Propeller | Voltage (V) |
|---|---|---|---|---|
| A2212/13 | 1000 | 915 | 10x4.5 | 11.1 |
| DJI E310 | 960 | 800 | 9x4.5 | 11.1 |
| EMax MT2212 | 900 | 850 | 9x4.5 | 14.8 |

Lifting motors will be used in take-off, so there will be 4 of them. Obviously their total thrust should be higher than our weight. I chose the A2212/13 motor for lifting motor.

### 2.3.2. Pusher Motor

Table 2.4

*Parameters for Pusher Motor*

| Name | KV | Max Thrust (gram) | Propeller | Voltage (V) |
|---|---|---|---|---|
| SunnySky X2814 | 900 | 1480 | 11x7 | 12 |
| Emax XA2212 | 1400 | 940 | 8x6 | 12 |
| SunnySky X2216 | 880 | 1050 | 10x4.7 | 12 |

Pusher motor will be used for horizontal thrust so the most of the time pusher motor will be working. Sunnysky X2814 seems to be drawing too much energy and SunnySky x2216 seems to be close with Emax XA2212. At the end I chose Emax XA2212 for accesebility from our country. 30A ESCs are used for all of the motors.

*Figure 2.3. Lifting Motor and Pusher Motor*

## 2.4.Tail

I considered V-tail, A-tail and H-tail for our design. Between them H-tail was standing out. I chose H-tail because it was not just easy to produce but also compatible with our design. With H-tail you just had use rods and I could just use these rods for lifting motors. With that tail design I could just adjust the center of gravity to the point where I want. For tail I considered flat-tail with control surfaces but then I decided on the NACA 0012 airfoil.

*Figure 2.4. NACA 0012 airfoil*

## 2.5.Material Selecting

For fuselage and wing I had three option as material. These are EPS, XPS, EPP foams. I tried EPS foam like in Figure 2.4. but it was not durable and producible. Between XPS and EPP foam, EPP foam was better than XPS foam. I decided to chose XPS foam because it was cheaper and it weighs more than EPP foam. I could afford that weight in our aircraft so XPS foam was chosen. CNC foam cutting machine used for precision. Fuselage and airfoils are drawn from AutoCad and cut from CNC.

Figure 2.5. Failure NACA 4412 with EPS foam

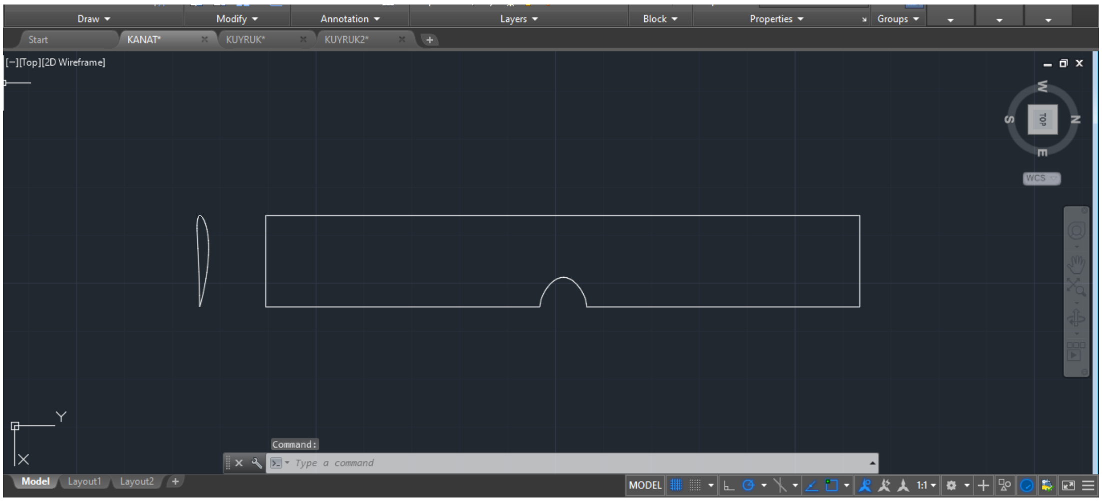


Figure 2.6. NACA 4412 Drawn on the AutoCad for CNC Foam Cutting Machine

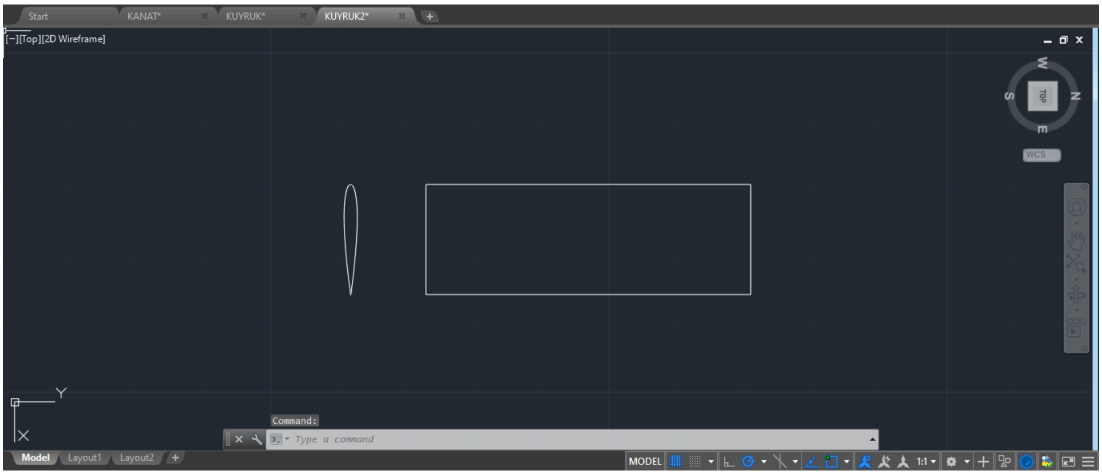


Figure 2.7. NACA 0012 Drawn on the AutoCad for CNC Foam Cutting Machine

## 2.6.Flight Control System Design

I needed a flight controller unit for autonomous flights. Best option at the market was Pixhawk and I chose it for our design. Pixhawk has a powerful 32-bit processor, and failsafe backup controller. Aircraft will be controlled by FPV remote control and autonomous system. Pixhawk allows you to switch between autonomous flight and manual control. It has good results on autonomous flights and navigation. I chose Mission Planner as our ground control system software. Mission Planner seems to most compatible software with Pixhawk. I have Team Orion Rocketsport 3200Mah battery. According to our calculations, it gives us approximately 15 minutes flight time. I will use Flysky Fs-I6 as transmitter.

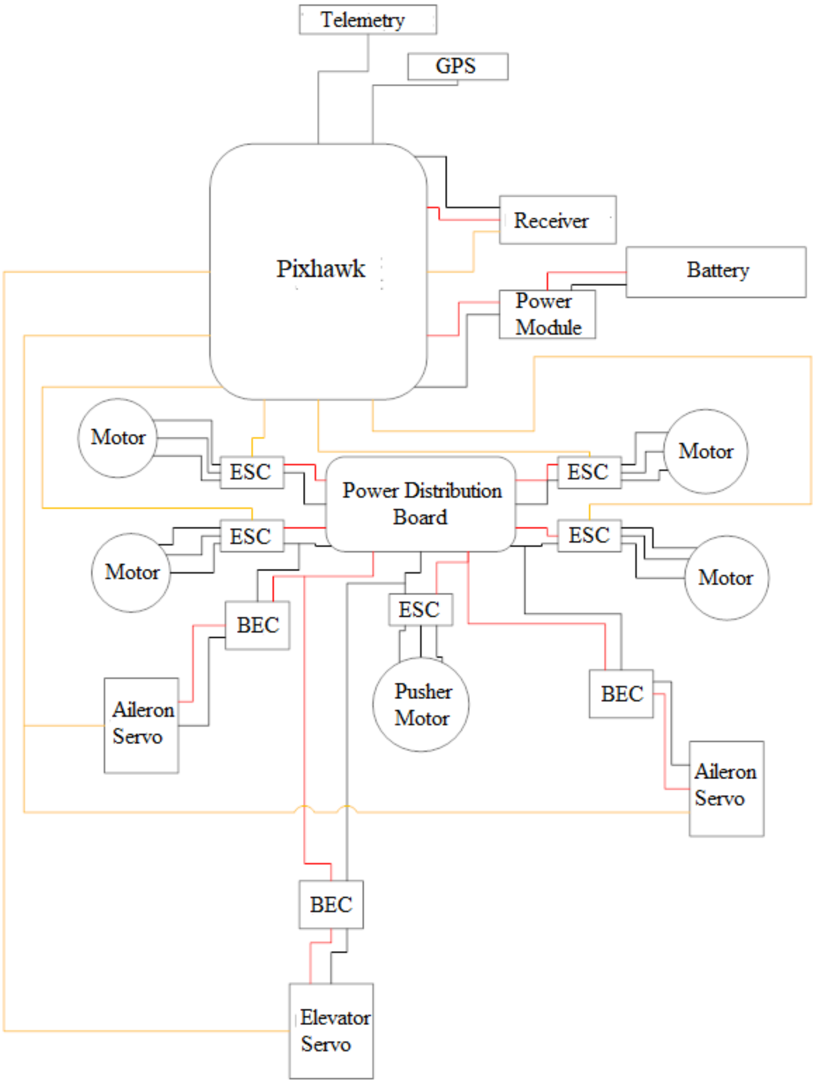


*Figure 2.7. Electronics Scheme.*

*Figure 2.8. Pixhawk Flight Controller*

*Figure 2.9. Team Orion Rocketsport 3200Mah Battery*

Mission Planner 1.3.56 build 1.3.6672.30243

AUTO 115200

Distance: 0.9925 km
Prev: 210.47 m AZ: 61
Home: 181.63 m

GEO 41.2754843
28.7090778
SRTM 141.20m

☐ Grid
GoogleSatelliteMap
Status: loaded tiles

Home Location
Lat 41.27558106
Long 28.70691061
Alt (abs) 132.5627643

Waypoints

WP Radius 30
Loiter Radius
Default Alt 100
Absolute
☐ Verify Height
Alt Warn 0
☐ Spline

| | Command | Dela | | | | Lat | Long | Alt | Delete | Up | Down | Grad % | Angle | Dist | AZ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | WAYPOINT | 0 | 0 | 0 | 0 | 41.2742909 | 28.7059236 | 100 | X | ⇧ | ⇩ | 0.0 | 0.0 | 73.6 | 87 |
| ▷ 9 | WAYPOINT | 0 | 0 | 0 | 0 | 41.2745812 | 28.7068677 | 100 | X | ⇧ | ⇩ | 0.0 | 0.0 | 85.2 | 68 |

*Figure 2.10. Mission Planner.*

*Figure 2.11. Flysky Fs-I6 Transmitter*

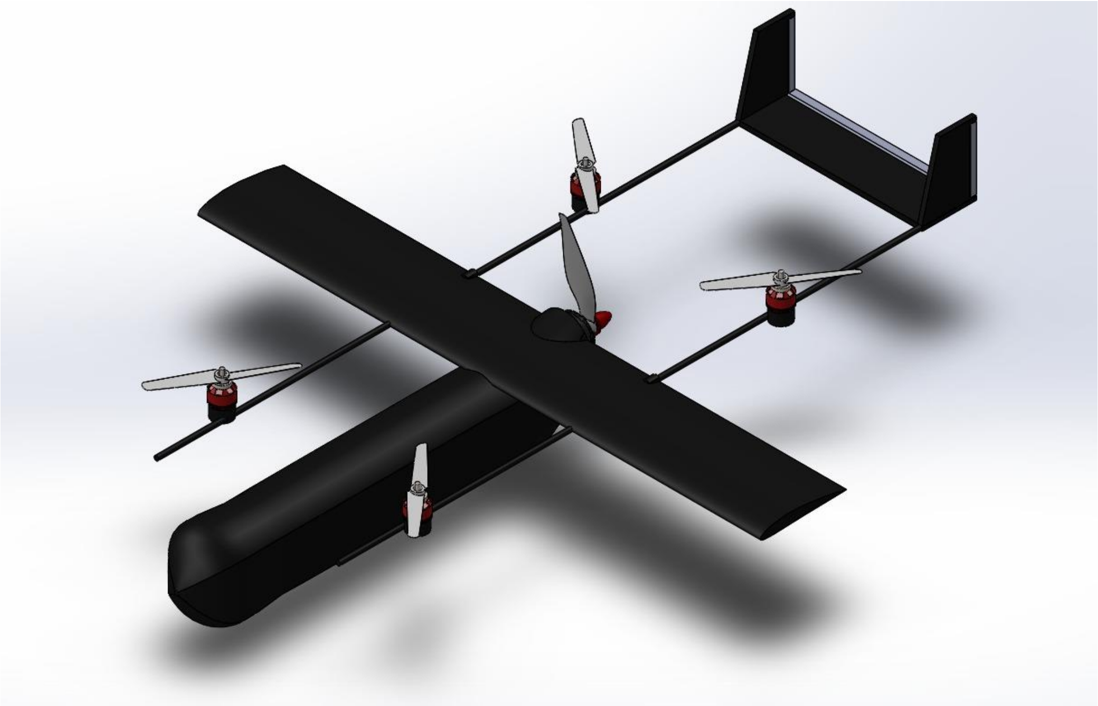
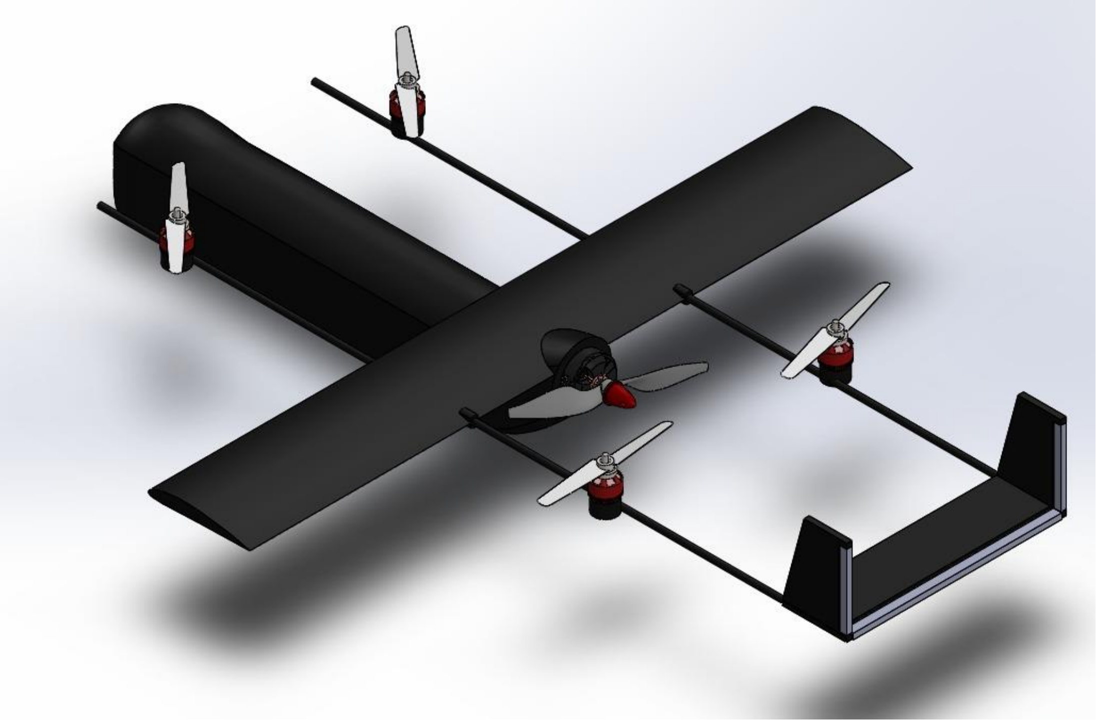


*Figure 2.12. Final Design on SolidWorks*



*2.13. Final Design on SolidWorks*

# CHAPTER III

## 3. Simulation of Aircraft

### 3.1.Preparing the Simulation

Firstly, it is considered that UAV behaves like a drone in take off part of it's own flight. It means UAV will fly in z direction vertically after that it will translate the motion to longitudinal axis system. To simulate this flight a quadcopter model is developed with MATLAB-SIMULINK, parameters are given according to our plane. In the beginning some constants are defined on commend window to make some calculations on Simulink steps(some of them are needed to an initial value to make calculation).After passes to Simulink interface. Two subsystems and constant references positions and scope blocks are seen when "vtoluavdronepart.slx" file is opened on Simulink. First subsystem is controller of rotors and systems and the second one is quadcopter dynamics. By giving different torque values to rotors UAV can work with different scenario.

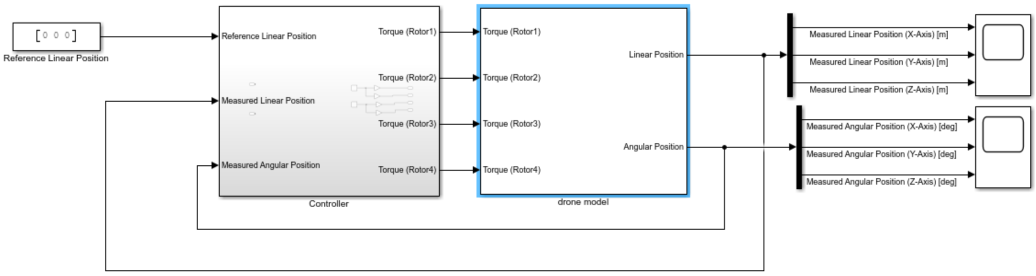


*Figure 3.1. Introduction page of Simulink-vtoluavdronepart*

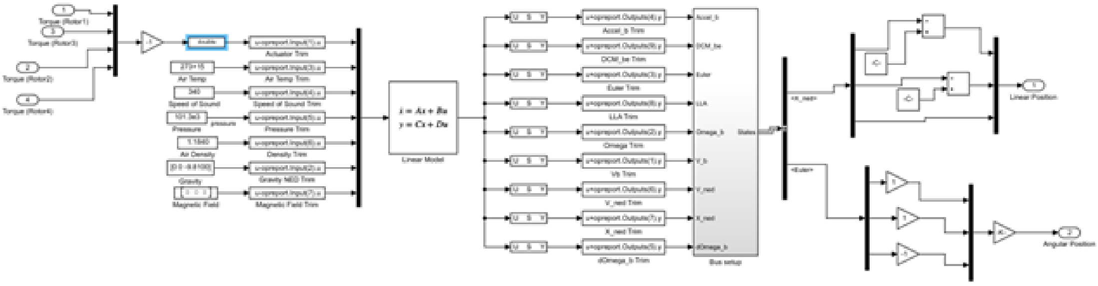


*Figure 3.2. Drone Model Subsystem on Simulink*

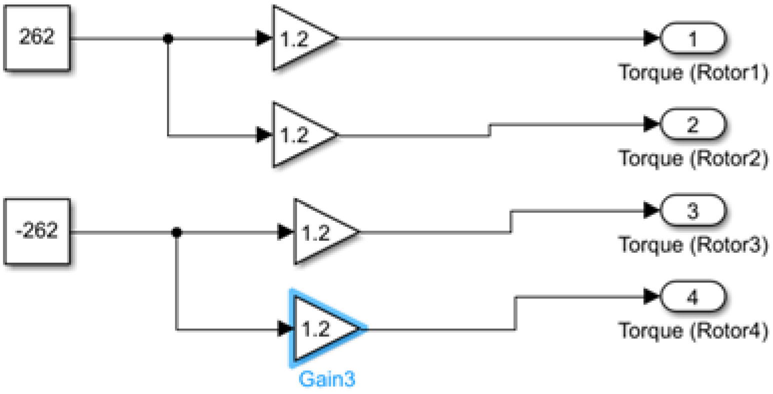


*Figure 3.3. Controller Subsystem on Simulink*

By giving constant values 1 and multiplying them with 262 and -262(constant number of drone rotors) it means UAV is producing a force in vertical direction which is equal to weight of UAV(2kg).

Scope blocks are showing changes of positions and they are too small and can be neglected.

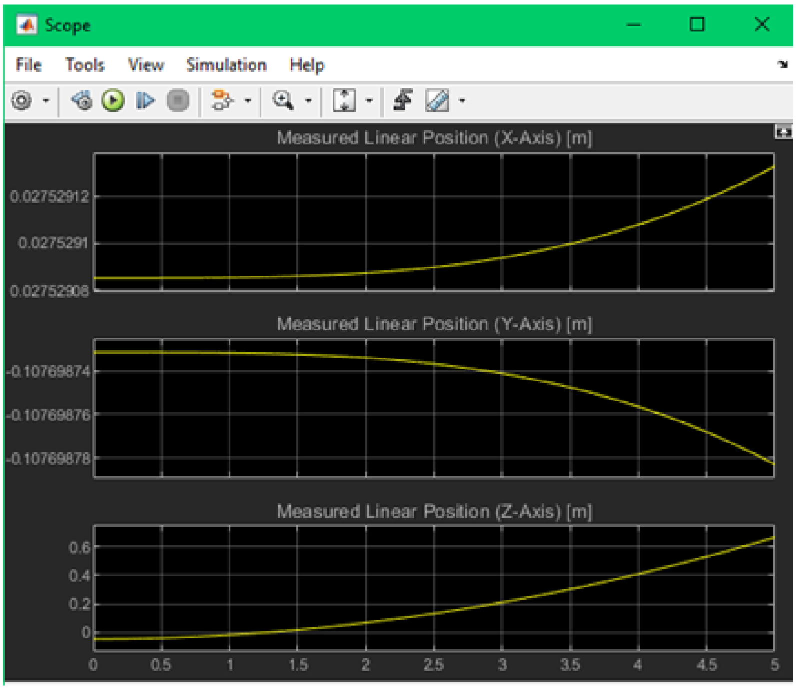


*Figure 3.4. Change of Positions When Gain is 1.0*

When I increase throttle of vertical rotors it means it will multiplied with a greater number of constant such as 1.1 and 1.2 they will response to make UAV flying highly in z direction when enough altitude is gained throttle can be back to 1.0 constant number to make it flying with a constant altitude to transit to longitudinal motion and this altitude values is 30 meter.(can be higher).No any turn with angular position of UAV in drone part so angular positions are not important for this part of simulation.

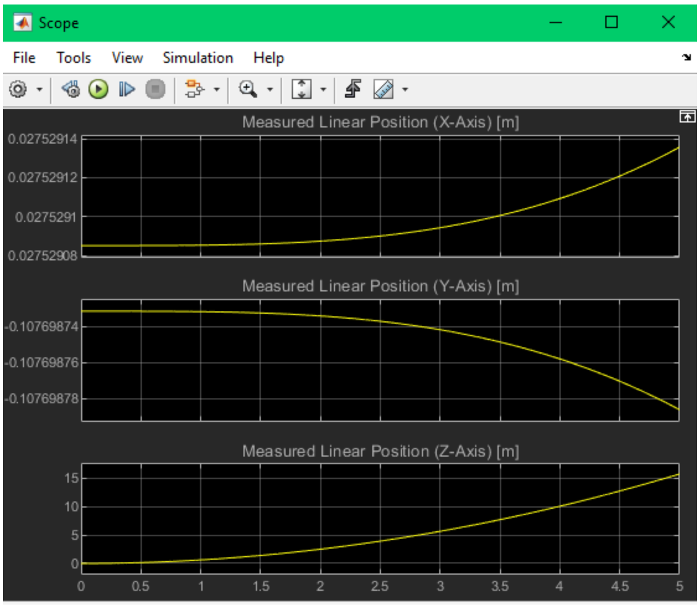


*Figure 3.5. Change of Positions When Gain is 1.1*

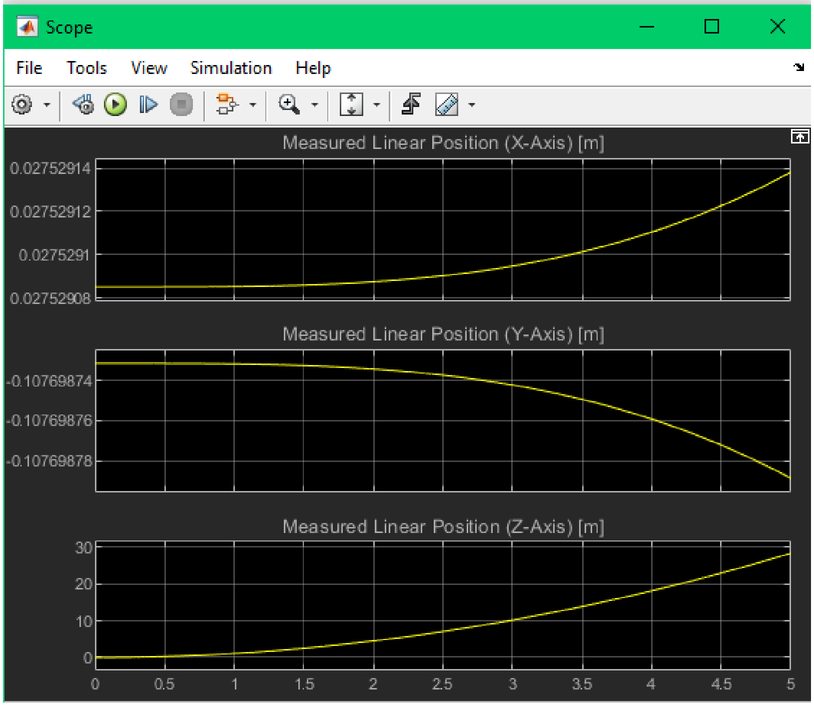


*Figure 3.6. Change of Positions When Gain is 1.2*

### 3.2.DATCOM Input for Simulation

When I pass to fixed wing simulation, I need a DATCOM input file to define UAV onto MATLAB. This is as follows;

```
CASEID ----- VTOL UAV FIXED WING -----
DIM M
 $FLTCON
NMACH=3.0,MACH(1)=0.04,0.05,0.08,NALPHA=9.0,ALSCHD(1)=4.0,6.0,
  8.0,10.0,12.0,14.0,16.0,18.0,20.0,NALT=1.0,ALT(1)=1000.0,
  WT=19.620,LOOP=2.$
 $SYNTHS XCG=0.4, ZCG=0.0, XW=0.2, ZW=0.0, ALIW=0.0, XH=0.8,
   ZH=0.0, ALIH=0.0, XV=+0.8$
 $OPTINS SREF=0.3, CBARR=0.2, BLREF=1.32$
 $BODY NX=8.0,
  X(1)=0.0,0.2,0.3,0.4,0.5,0.6,0.8,1.0,
  S(1)=0.02,0.02,0.02,0.02,0.001,0.001,0.001,0.001$
 $WGPLNF CHRDTP=0.2,SSPNE=0.65,SSPN=0.65,
  CHRDR=0.2,SAVSI=0.0,SAVSO=0.0,CHSTAT=0.25,
  TWISTA=0.0,DHDADI=0.0,DHDADO=-3.0,TYPE=1.0$
 $HTPLNF CHRDTP=0.1625, SSPNE=0.24, SSPN=0.24, CHRDR=0.1625,
SAVSI=0.0,
  CHSTAT=0.25,TYPE=1.0$
 $VTPLNF CHRDTP=0.08,SSPNE=0.15,SSPN=0.15,CHRDR=0.1625,SAVSI=90.0,
  CHSTAT=0.25,TYPE=1.0$
NACA-W-6-63-412
NACA-H-4-0012
NACA-V-6-66-009
DAMP
DIM M
BUILD
PLOT
NEXT CASE
```

Number of alpha is changed depending on incident angle of airplane according to streamlines, and has different values starting from 4 degree ending with 20 degree.3 Mach numbers are defined first one is stall speed second is cruise speed third one is maximum speed of UAV. Altitude is defined from sea level for Gaziantep city (about 1000 meters).

### 3.3.DATCOM Output for Simulation

DIGITAL DATCOM produces to us an output file depending on input file parameters. Output file includes the parameters as following;

```
  *****************************************************
```

```
  *    USAF STABILITY AND CONTROL  DIGITAL DATCOM    *
  *    PROGRAM REV. JAN 96    DIRECT INQUIRIES TO:     *
  *    WRIGHT LABORATORY  (WL/FIGC)  ATTN: W.  BLAKE  *
  *      WRIGHT PATTERSON AFB, OHIO  45433            *
  *    PHONE (513) 255-6764,    FAX (513) 258-4054     *
  ****************************************************
1                          CONERR - INPUT ERROR CHECKING
0 ERROR CODES - N* DENOTES THE NUMBER OF OCCURENCES OF EACH
ERROR
0 A - UNKNOWN VARIABLE NAME
0 B - MISSING EQUAL SIGN FOLLOWING VARIABLE NAME
0 C - NON-ARRAY VARIABLE HAS AN ARRAY ELEMENT DESIGNATION - (N)
0 D - NON-ARRAY VARIABLE HAS MULTIPLE VALUES ASSIGNED
0 E - ASSIGNED VALUES EXCEED ARRAY DIMENSION
0 F - SYNTAX ERROR

0******************************  INPUT DATA CARDS
******************************


 CASEID -----  VTOL UAV FIXED WING -----
 DIM M
  $FLTCON
NMACH=3.0,MACH(1)=0.04,0.05,0.06,NALPHA=1.0,ALSCHD(1)=15.0,
  NALT=1.0,ALT(1)=1000.0, WT=19.620,LOOP=1.0$
  $SYNTHS XCG=0.4, ZCG=0.0, XW=0.2, ZW=0.0, ALIW=0.0, XH=0.8,
    ZH=0.0, ALIH=0.0, XV=+0.8$
  $OPTINS SREF=0.3, CBARR=0.2, BLREF=1.32$
  $BODY NX=8.0,
   X(1)=0.0,0.2,0.3,0.4,0.5,0.6,0.8,1.0,
   S(1)=0.02,0.02,0.02,0.02,0.001,0.001,0.001,0.001$
  $WGPLNF CHRDTP=0.2,SSPNE=0.65,SSPN=0.65,
   CHRDR=0.2,SAVSI=0.0,SAVSO=0.0,CHSTAT=0.25,
   TWISTA=0.0,DHDADI=0.0,DHDADO=-3.0,TYPE=1.0$
  $HTPLNF CHRDTP=0.1625, SSPNE=0.24, SSPN=0.24, CHRDR=0.1625,
SAVSI=0.0,
   CHSTAT=0.25,TYPE=1.0$
  $VTPLNF CHRDTP=0.08,SSPNE=0.15,SSPN=0.15,CHRDR=0.1625,SAVSI=90.0,
   CHSTAT=0.25,TYPE=1.0$
 NACA-W-6-63-412
 NACA-H-4-0012
 NACA-V-6-66-009
 DAMP
 NEXT CASE
1            THE FOLLOWING IS A LIST OF ALL INPUT CARDS FOR THIS CASE.
0
 CASEID -----  VTOL UAV FIXED WING -----
 DIM M
  $FLTCON
NMACH=3.0,MACH(1)=0.04,0.05,0.06,NALPHA=1.0,ALSCHD(1)=15.0,
  NALT=1.0,ALT(1)=1000.0, WT=19.620,LOOP=1.0$
```

```
  $SYNTHS XCG=0.4, ZCG=0.0, XW=0.2, ZW=0.0, ALIW=0.0, XH=0.8,
    ZH=0.0, ALIH=0.0, XV=+0.8$
  $OPTINS SREF=0.3, CBARR=0.2, BLREF=1.32$
  $BODY NX=8.0,
   X(1)=0.0,0.2,0.3,0.4,0.5,0.6,0.8,1.0,
   S(1)=0.02,0.02,0.02,0.02,0.001,0.001,0.001,0.001$
  $WGPLNF CHRDTP=0.2,SSPNE=0.65,SSPN=0.65,
   CHRDR=0.2,SAVSI=0.0,SAVSO=0.0,CHSTAT=0.25,
   TWISTA=0.0,DHDADI=0.0,DHDADO=-3.0,TYPE=1.0$
  $HTPLNF CHRDTP=0.1625, SSPNE=0.24, SSPN=0.24, CHRDR=0.1625,
SAVSI=0.0,
   CHSTAT=0.25,TYPE=1.0$
  $VTPLNF CHRDTP=0.08,SSPNE=0.15,SSPN=0.15,CHRDR=0.1625,SAVSI=90.0,
   CHSTAT=0.25,TYPE=1.0$
 NACA-W-6-63-412
 NACA-H-4-0012
 NACA-V-6-66-009
 DAMP
 NEXT CASE
0 INPUT DIMENSIONS ARE IN M , SCALE FACTOR IS 1.0000

0*** ERROR *** LOOP = 1 AND NALT IS NOT EQUAL TO NMACH (NALT =  3,
NMACH =  1)
               NMACH AND NALT ARE BOTH SET TO  1

1                              AUTOMATED STABILITY AND CONTROL METHODS PER
APRIL 1976 VERSION OF DATCOM
                                                      WING SECTION DEFINITION
0                                   IDEAL ANGLE OF ATTACK =    0.00000 DEG.

                              ZERO LIFT ANGLE OF ATTACK =   -3.10853 DEG.

                                 IDEAL LIFT COEFFICIENT =    1.40000

                  ZERO LIFT PITCHING MOMENT COEFFICIENT =   -0.08886

                             MACH ZERO LIFT-CURVE-SLOPE =    0.10334 /DEG.

                                    LEADING EDGE RADIUS =    0.00993 FRACTION CHORD

                              MAXIMUM AIRFOIL THICKNESS =    0.12000 FRACTION
CHORD

                                                DELTA-Y =    2.61808 PERCENT CHORD


0                           MACH= 0.0400 LIFT-CURVE-SLOPE =    0.10339 /DEG.      XAC
=    0.25750
1                              AUTOMATED STABILITY AND CONTROL METHODS PER
APRIL 1976 VERSION OF DATCOM
```

```
                              HORIZONTAL TAIL SECTION DEFINITION
0                        IDEAL ANGLE OF ATTACK =    0.00000 DEG.

                      ZERO LIFT ANGLE OF ATTACK =    0.00000 DEG.

                        IDEAL LIFT COEFFICIENT =    0.00000

               ZERO LIFT PITCHING MOMENT COEFFICIENT =    0.00000

                     MACH ZERO LIFT-CURVE-SLOPE =    0.09596 /DEG.

                          LEADING EDGE RADIUS =    0.01587 FRACTION CHORD

                      MAXIMUM AIRFOIL THICKNESS =    0.12000 FRACTION
CHORD

                                 DELTA-Y =    3.16898 PERCENT CHORD


0                  MACH= 0.0400 LIFT-CURVE-SLOPE =    0.09603 /DEG.      XAC
=    0.25840
1                     AUTOMATED STABILITY AND CONTROL METHODS PER
APRIL 1976 VERSION OF DATCOM
                               VERTICAL TAIL SECTION DEFINITION
0                        IDEAL ANGLE OF ATTACK =    0.00000 DEG.

                      ZERO LIFT ANGLE OF ATTACK =    0.00000 DEG.

                        IDEAL LIFT COEFFICIENT =    0.00000

               ZERO LIFT PITCHING MOMENT COEFFICIENT =    0.00000

                     MACH ZERO LIFT-CURVE-SLOPE =    0.09870 /DEG.

                          LEADING EDGE RADIUS =    0.00559 FRACTION CHORD

                      MAXIMUM AIRFOIL THICKNESS =    0.09000 FRACTION
CHORD

                                 DELTA-Y =    1.52747 PERCENT CHORD


0                  MACH= 0.0400 LIFT-CURVE-SLOPE =    0.09877 /DEG.      XAC
=    0.26221
1                      AUTOMATED STABILITY AND CONTROL METHODS PER
APRIL 1976 VERSION OF DATCOM
                           CHARACTERISTICS AT ANGLE OF ATTACK AND IN
SIDESLIP
                           WING-BODY-VERTICAL TAIL-HORIZONTAL TAIL
CONFIGURATION
```

```
                                   -----  VTOL UAV FIXED WING -----

 -----------------------   FLIGHT CONDITIONS  ------------------------          --------------
REFERENCE DIMENSIONS  ------------
  MACH    ALTITUDE   VELOCITY    PRESSURE    TEMPERATURE
REYNOLDS           REF.      REFERENCE LENGTH   MOMENT REF. CENTER
 NUMBER                                            NUMBER            AREA       LONG.
LAT.     HORIZ      VERT
            M        M/SEC       N/ M**2       DEG K        1/ M              M**2         M
M         M         M
0 0.040    1000.00      13.46   8.9876E+04     281.651     8.4714E+05            0.300
0.200      1.320      0.400      0.000
0                                            -------------------DERIVATIVE  (PER
DEGREE)-------------------
0 ALPHA     CD        CL        CM        CN        CA        XCP        CLA          CMA
CYB          CNB          CLB
0
  15.0    0.145     1.473     0.5995   1.460    -0.241     0.411     0.000E+00   -NaN
NaN          -2.278E-04    -1.891E-03
0                              ALPHA     Q/QINF    EPSLON  D(EPSLON)/D(ALPHA)
0
                              15.0       1.000       2.442        0.000
1                          AUTOMATED STABILITY AND CONTROL METHODS PER
APRIL 1976 VERSION OF DATCOM
                                        DYNAMIC DERIVATIVES
                                  WING-BODY-VERTICAL TAIL-HORIZONTAL TAIL
CONFIGURATION
                                   -----  VTOL UAV FIXED WING -----

 -----------------------   FLIGHT CONDITIONS  ------------------------          --------------
REFERENCE DIMENSIONS  ------------
  MACH    ALTITUDE   VELOCITY    PRESSURE    TEMPERATURE
REYNOLDS           REF.      REFERENCE LENGTH   MOMENT REF. CENTER
 NUMBER                                            NUMBER            AREA       LONG.
LAT.     HORIZ      VERT
            M        M/SEC       N/ M**2       DEG K        1/ M              M**2         M
M         M         M
0 0.040    1000.00      13.46   8.9876E+04     281.651     8.4714E+05            0.300
0.200      1.320      0.400      0.000
                                      DYNAMIC DERIVATIVES (PER DEGREE)
0          -------PITCHING-------     -----ACCELERATION------     --------------
ROLLING--------------     ---------YAWING--------
0   ALPHA       CLQ          CMQ          CLAD         CMAD         CLP          CYP
CNP           CNR          CLR
0
    15.00    -6.624E-02    -2.784E-02       NDM          NDM       -1.898E+00   -NaN
-NaN          -2.643E+01    -7.075E+00
0*** NDM PRINTED WHEN NO DATCOM METHODS EXIST
0*** VEHICLE WEIGHT =       19.62 N.
0*** LEVEL FLIGHT LIFT COEFFICIENT = 2.89002
```

```
1          THE FOLLOWING IS A LIST OF ALL INPUT CARDS FOR THIS CASE.
0
1 END OF JOB.
```

### 3.4.DATCOM Drawing

By using “drawDATCOMaircraft('vtoldatcominput.INP')” commend on MATLAB I have an three view drawing of UAV with airfoils as following. Tail is one part vertical because there is no input type for DATCOM to make it double vertical tail like our real UAV.

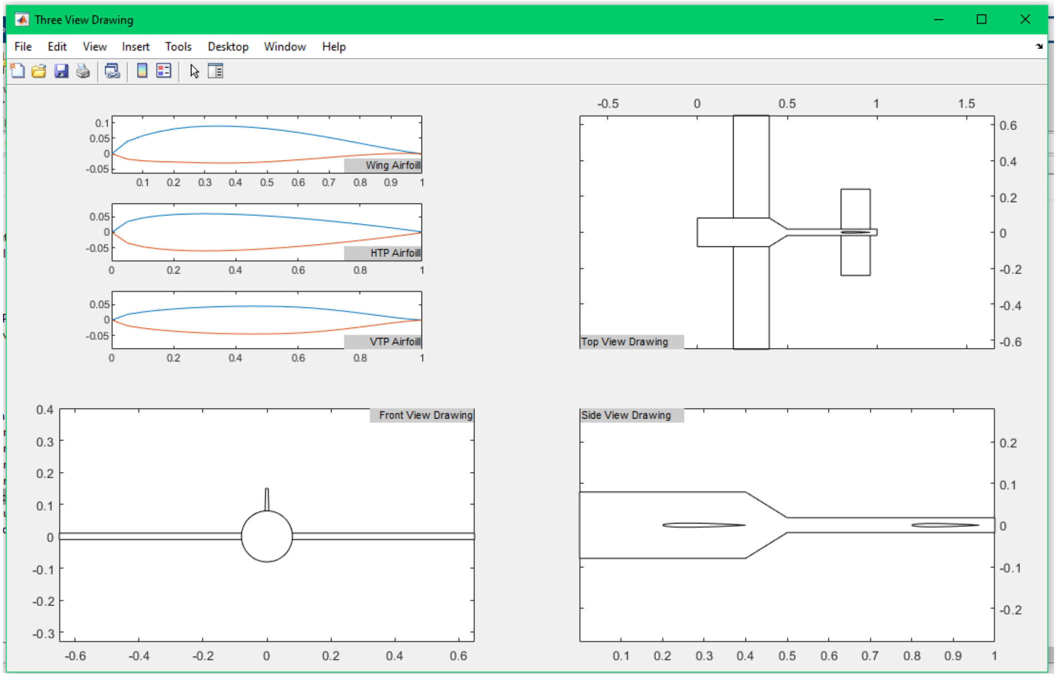


*Figure 3.7. Drawing of DATCOM*

Transition and longitudinal flight parameters are as follows and a video is given to show it on FlightGear.

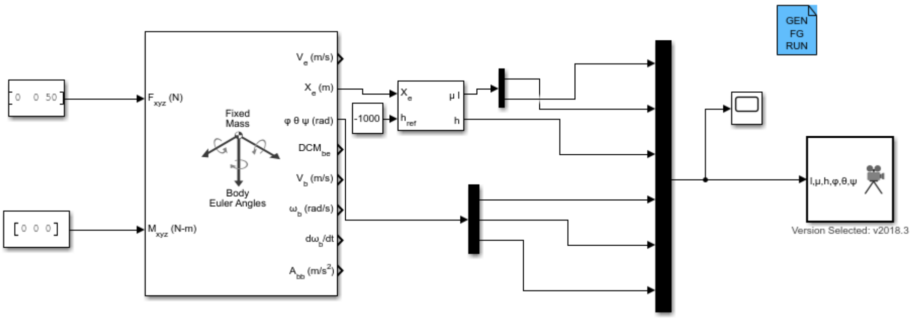


*Figure 3.8. Transition and Longitudinal Flight Parameters*

| | | |
|---|---|---|
| [0 0 -100] | Force | Take off |
| [0 0 0] | Moment | |
| [100 0 40] | Force | Transition to longitutinal motion |
| [0 0 0] | Moment | |
| [100 0 0] | Force | Longitudinal motion |
| [0 0 0] | Moment | |
| [100 0 0] | Force | Up nose motion |
| [0 0.08 0] | Moment | |
| [100 0 0] | Force | Banked turn motion |
| [0.01 0 0.01] | Moment | |
| [100 0 50] | Force | Transition |
| [0 0 0] | Moment | |
| [0 0 50] | Force | Landing |
| [0 0 0] | Moment | |

# CHAPTER IV

## 4. Manufacturing of Aircraft

In the manufacturing part, I started from our fuselage and airfoils. They are XPS foam cut by CNC foam cutting machine.

*Figure 4.1. Fuselage and Airfoils Cut From XPS Foam*

Fuselage, airfoils, and tail are put together. I supported the wing with a rod and fuselage with a balsa wood. Also I use this balsa wood as a stand for electronics.

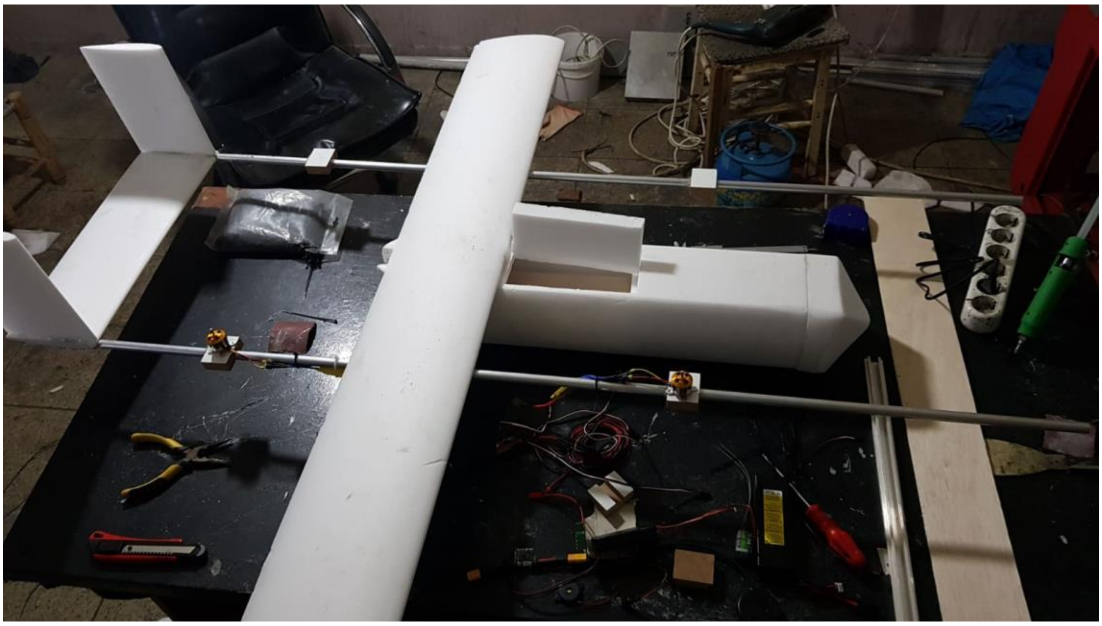


*Figure 4.2. Wing and Tail Mounted on the Body*

*Figure 4.3. Wing Supoorted by a Rod*

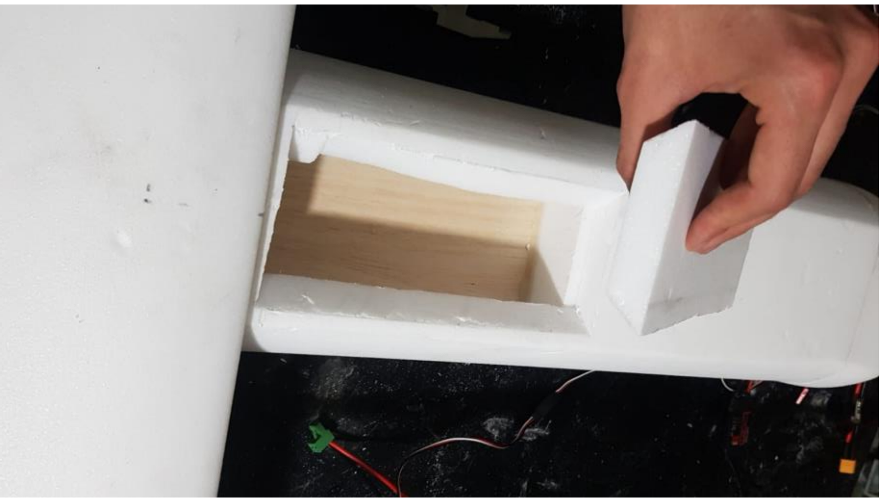


*Figure 4.4. Hatch on the body*

The only thing left was electronics. I prepared electronics and installed everyone of them.

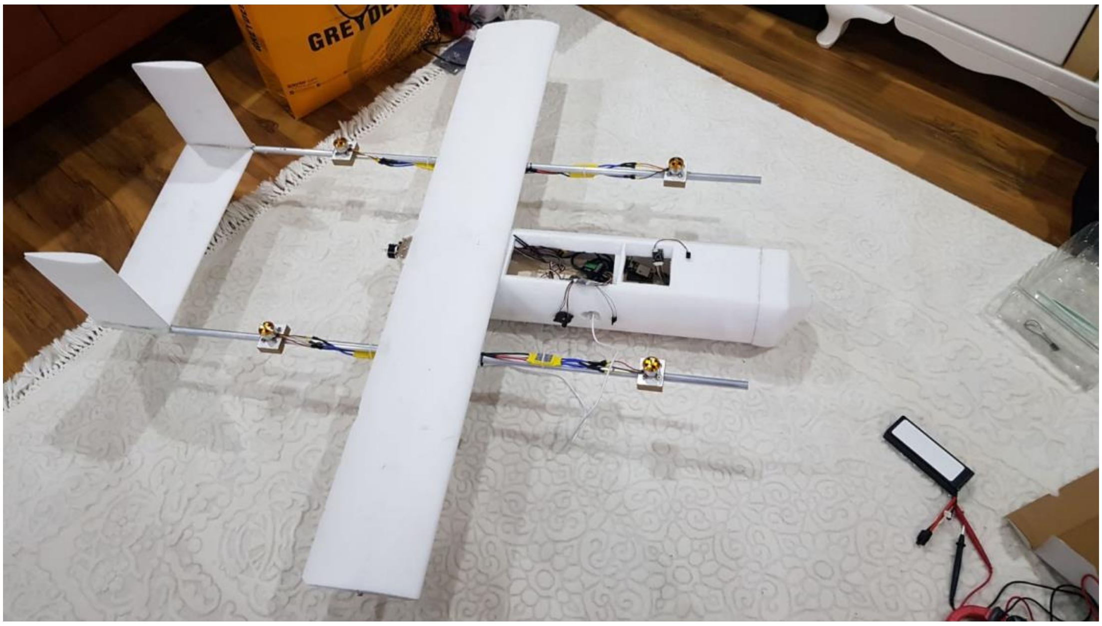


*Figure 4.5. Final Look of Our UAV*

## REFERENCES

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