



## **Glider Project (Group No. 7)**

### **537314 FLIGHT MECHANICS**

**Submitted by**

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## ***Preface***

This report is a part of the 537314 Flight Mechanics. The purpose of this report is to explain whole about of glider which we design whether why we need design like this. It's just not only about to glider design but include manufacture, flight testing, inspection after flight testing and financial report. We describe step by step for who want to learn how to produce some small glider by our concept.

This project is full of obstacles, because we just study the mechanics of flight and don't know as much about aircraft design. Therefore, we used all the knowledge from aerodynamics and this subject by the full of power for produce the best glider as we can.

Finally, If you read to this. We hope you to get the highest of knowledge by our report.

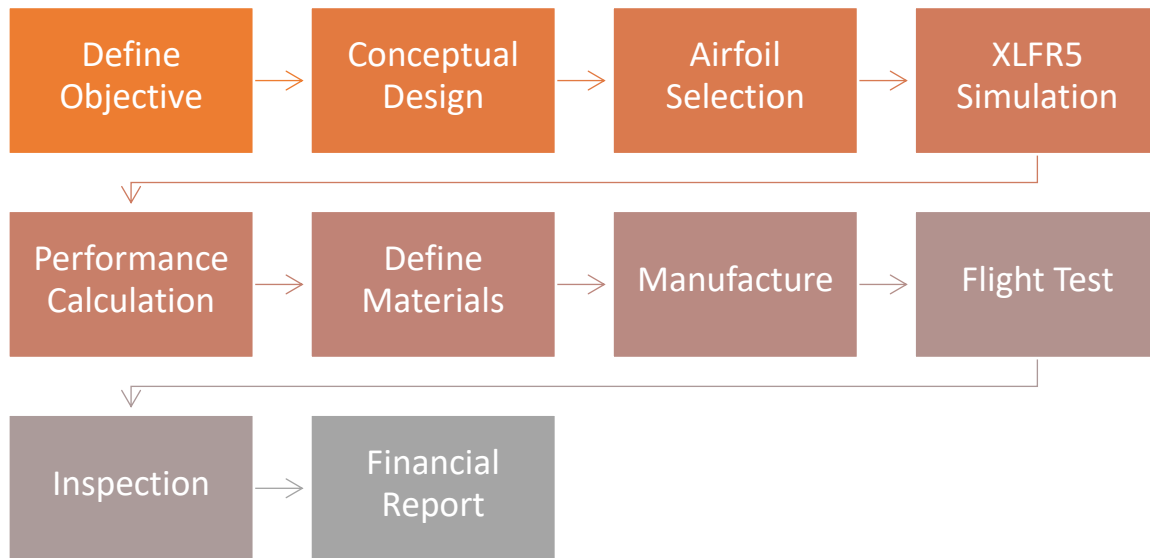
Sincerely

project organizers

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## *Glider Design Flowchart*



### *Define Objective*

1. Wingspan 1 m
2. Reynold number  $\leq 400000$  (Incompressible Flow)
3. Initial attitude 2 m
4. Longest range gliding
5. Low weight
6. High  $CL/Cd$  and AR
7. High stiffness

### *Conceptual Design*

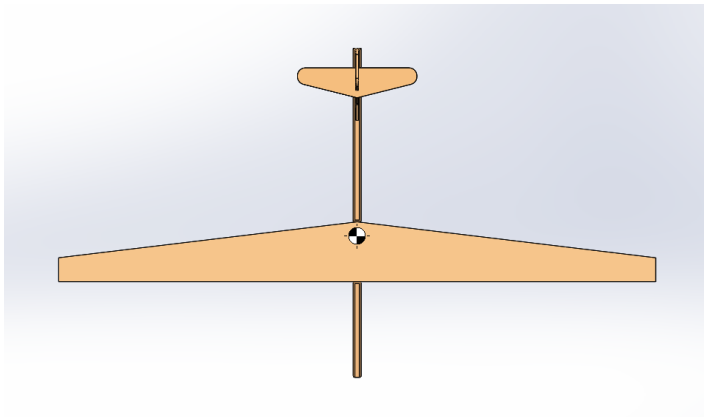
The most important of glider is about to design for low weight, high  $CL/Cd$  and AR, but in this project. We must design for high stiffness for structural test in another project.

First step. We need to define wing shape. From objective we need high  $CL/Cd$  and AR then we define chord about 100 mm and we are all know as the best wing shape is elliptic wing (For lift produce on wing. Because elliptic wing has Oswald efficiency number = 1) But elliptic wing is hard to manufacture. Then taper wing is better to manufacture. Taper wing give speed more than

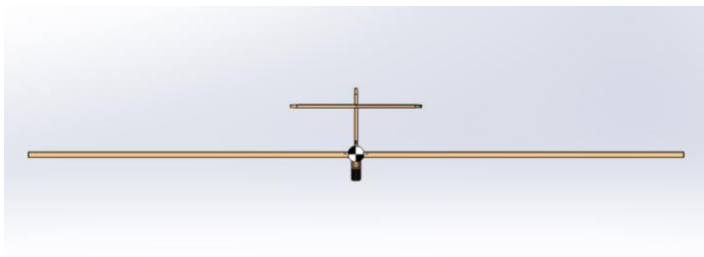
rectangular wing for long range gliding. The good taper ratio are about 0.3 to 0.4. We choose taper ratio 0.4 and sweep angle 0 degree because is easy for manufacture. Then choose T tail for stable.

Next step. We used the RC plane calculator website to define all dimension and improve some dimension for suitability to structure.

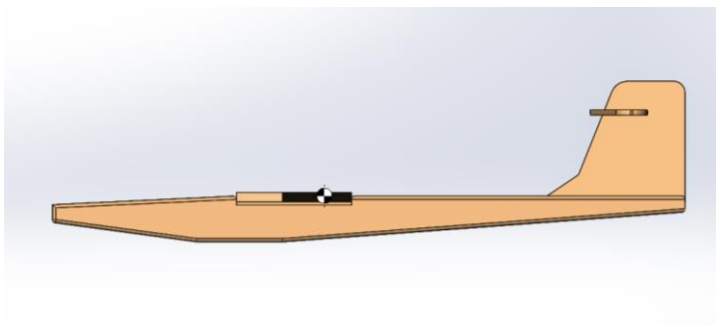
Finally. We used Solidworks CAD software to design this glider, find center of gravity and calculate empty weight. Assume material to balsa wood.



*Figure 1 Top view*



*Figure 2 Front view*



*Figure 3 Right view*

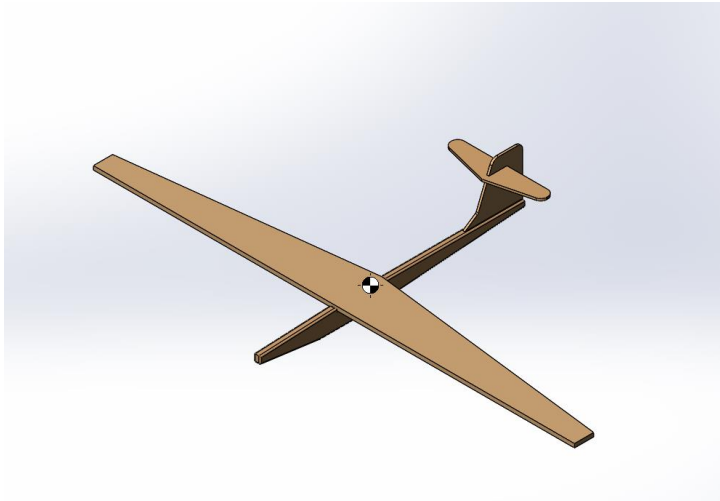


Figure 4 Isometric

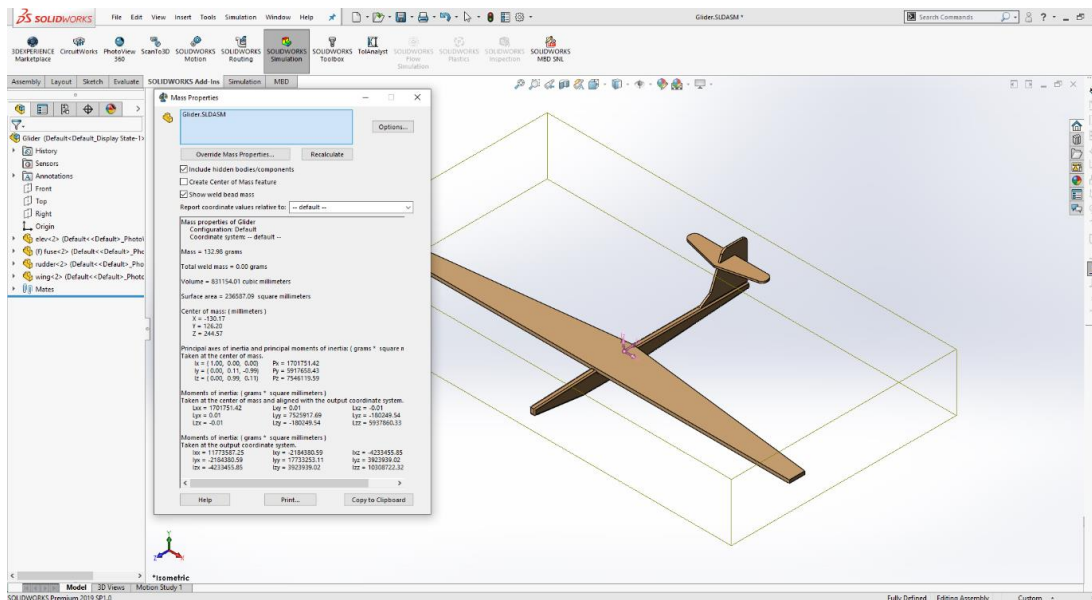


Figure 5 CG and mass calculation

Mass = 133 g; Center of Gravity (x, y, z) = (-130.17 mm, 126.20 mm, 244.57 mm);

## Airfoils Selection

This step is also equally important, Because to improve  $C_L/C_d$  we need to be meticulous with airfoil selection.

First step is about collection airfoils data. (We choose only NACA airfoils for standard) Go to "Airfoil Tools" website and collect all NACA airfoils coordinate point to JavaFoil. In JavaFoil set all

parameters (Standard sea levels condition,  $Re = 400000$ ,  $M = 0.3$ ) for simulation to find the angle of attack to that give  $Cl = 0.5$  and calculate  $Cl/Cd$ .

Then analytics all data with Python coding and do some machine learning with Scikit learn module to choose the best airfoils.

```
In [1]: #Basic Library
import numpy as np
import pandas as pd
```

```
In [2]: #For data visualize
import matplotlib.pyplot as plt
```

```
In [3]: #For machine Learning
#model = tree.DecisionTreeClassifier()
from sklearn import tree
from sklearn.model_selection import train_test_split
```

```
In [4]: #Read File
df = pd.read_csv("Airfoil (NACA).csv")
df.head()
```

```
Out[4]:
```

|   | Airfoils     | AoT_Cl0.5 | Cd      | Cl/Cd     |
|---|--------------|-----------|---------|-----------|
| 0 | NACA 63A010  | 4.1       | 0.01236 | 40.453074 |
| 1 | NACA 63012A  | 4.0       | 0.01244 | 40.192926 |
| 2 | NACA 63-015A | 3.9       | 0.01364 | 36.656892 |
| 3 | NACA 63-210  | 2.4       | 0.01117 | 44.762757 |
| 4 | NACA 63-212  | 2.3       | 0.01127 | 44.365572 |

```
In [5]: #Data size
len(df)
```

```
Out[5]: 120
```

```
In [6]: labels = df.columns.tolist()
labels
```

```
Out[6]: ['Airfoils', 'AoT_Cl0.5', 'Cd', 'Cl/Cd']
```

```
In [7]: #Define the coordinates of data for find relation.
X = df[["AoT_Cl0.5", "Cl/Cd"]]
y = df["Airfoils"]
```

```
In [8]: #Creating model
model = tree.DecisionTreeClassifier()
model = model.fit(X, y)
```

```
In [9]: #We need to know the max of Cl/Cd in our data to predict what airfoil are highest Cl/Cd and have AOT and Cd reach to 0.
print(df["Cl/Cd"].max())
```

```
49.85044865
```

```
In [10]: for index, row in df.iterrows():
    if(row["Cl/Cd"] == df["Cl/Cd"].max()):
        print(row)
```

```
Airfoils      NACA 64-206
AoT_Cl0.5      2.6
Cd             0.01003
Cl/Cd          49.8504
Name: 33, dtype: object
```

```
In [11]: #Predict data
Airfoil = model.predict([[df["AoT_C10.5"].min(), df["Cl/Cd"].max()]])
Airfoil
```

```
Out[11]: array(['NACA6409 9%'], dtype=object)
```

```
In [12]: FinAndRudder = model.predict([[df["AoT_C10.5"].max(), df["Cl/Cd"].max()]])
FinAndRudder
```

```
Out[12]: array(['NACA 0008'], dtype=object)
```

```
In [13]: for index, row in df.iterrows():
          if(row["Airfoils"] == Airfoil[0]):
              print(row)
```

```
Airfoils      NACA6409 9%
AoT_C10.5      -2.3
Cd             0.01027
Cl/Cd          48.6855
Name: 86, dtype: object
```

```
In [14]: for index, row in df.iterrows():
          if(row["Airfoils"] == FinAndRudder[0]):
              print(row)
```

```
Airfoils      NACA 0008
AoT_C10.5       4.3
Cd             0.01037
Cl/Cd          48.216
Name: 88, dtype: object
```

```
In [15]: #Score by train data.
model.score(X, y)
```

```
Out[15]: 0.9833333333333333
```

We used tree decision model because to define what if we need airfoil that have angle of attack and  $Cl/Cd$  by some value we expect. If wing we need lowest angle of attack and highest  $Cl/Cd$  for easy to launch the glider. If stabilizer we need symmetry airfoils and highest  $Cl/Cd$  for not disrupt the aerodynamics performance of the wing. what are airfoils we should get. And model score is 0.9833.

Thus, the result is NACA6409 for wing and NACA0008 for stabilizer (But used flat plate for tail because it's can't produce in reality for us).



## XFLR5 Simulation

XFLR5 is free software and easy to use for RC plane simulation. This software can analysis airfoils and analysis RC plane. Then pull all information from conceptual design for define boundary conditions and get result below. Assume  $V = 9$  m/s.

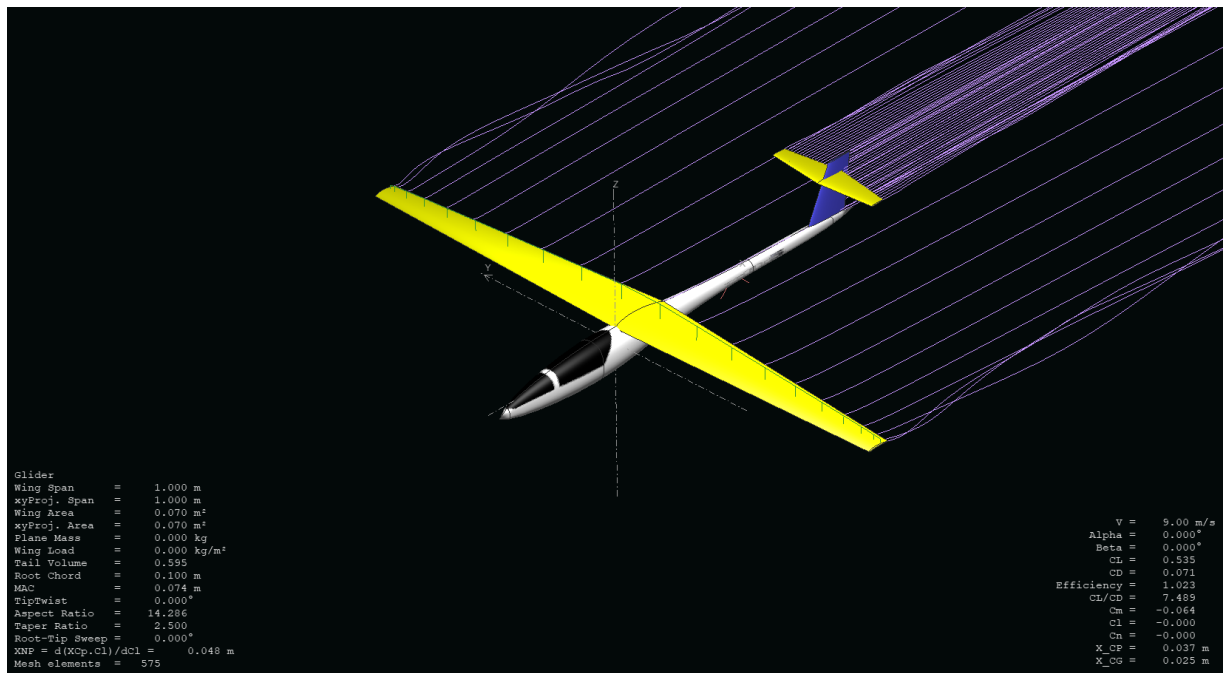


Figure 6 Streamline

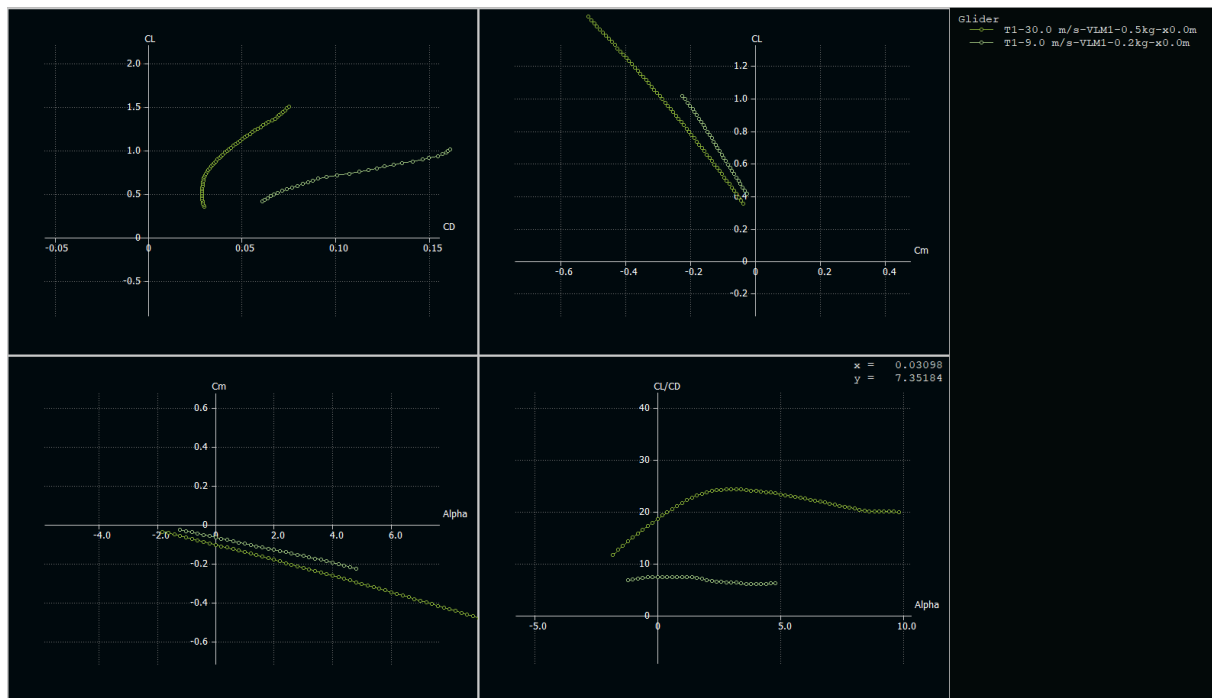


Figure 7 Polar graph

```

Glider
Wing Span      =      1.000 m
xyProj. Span   =      1.000 m
Wing Area      =      0.070 m²
xyProj. Area   =      0.070 m²
Plane Mass     =      0.000 kg
Wing Load      =      0.000 kg/m²
Tail Volume    =      0.595
Root Chord     =      0.100 m
MAC            =      0.074 m
TipTwist       =      0.000°
Aspect Ratio   =      14.286
Taper Ratio    =      2.500
Root-Tip Sweep =      0.000°
XNP = d(XCp.Cl)/dCl =      0.048 m
Mesh elements  =      575

```

Figure 8 Glider information

AR = 14.286

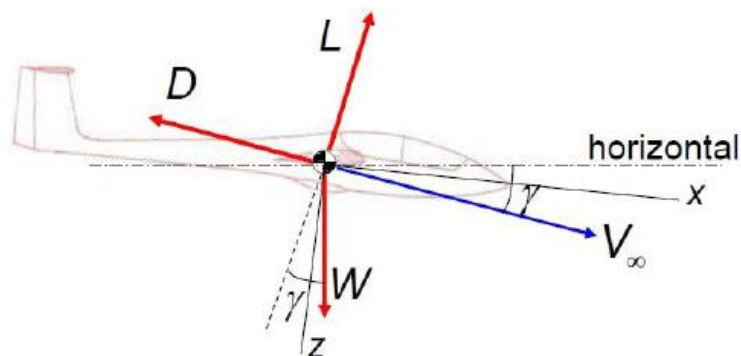
|              |          |
|--------------|----------|
| V =          | 9.00 m/s |
| Alpha =      | 0.000°   |
| Beta =       | 0.000°   |
| CL =         | 0.535    |
| CD =         | 0.071    |
| Efficiency = | 1.023    |
| CL/CD =      | 7.489    |
| Cm =         | -0.064   |
| Cl =         | -0.000   |
| Cn =         | -0.000   |
| X_CP =       | 0.037 m  |
| X_CG =       | 0.025 m  |

Figure 9 Glider performance

By plane analysis at angle of attack = 0 deg,  $CL/CD = 7.489$ ,  $Cm = -0.064$ ;

### Performance Calculation

Consider an airplane in power off flight. The force acting on glider are lift, drag and weight. Thrust is zero because power off glider. Assume glider is constant velocity and flight path is horizontal parallel with ground. ( $L = W$ ;  $T = D$ ;)



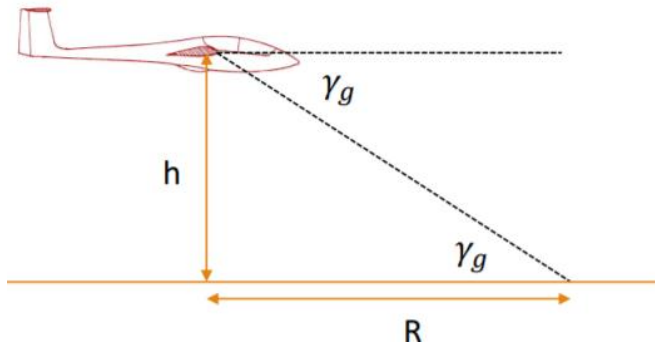
By the free body diagram is clearly whether if less of theta then range of glider will increase. If we want to know how far of glider can gliding. By following.

$$\tan \gamma = \frac{1}{\frac{C_L}{C_D}}$$

From that formula. Calculate gliding distance.  $\frac{C_l}{C_d} = \text{Glide Ratio} = 7.489$

$$\tan \gamma = \frac{1}{7.489} = 0.134$$

Maximum range.  $h = 2 \text{ m}$



$$R = \frac{h}{\tan \gamma} = \frac{2}{0.134} = 14.925 \text{ m}$$

$$\gamma = \tan^{-1}(0.134) = 7.63 \text{ deg}$$

Sink rate.

$$\text{Sink rate} = \frac{\text{Air Speed}}{\text{Glide Ratio}} = \frac{9}{7.489} = 1.2 \text{ m/s}$$

Endurance.

$$E = \frac{h}{\text{Sink rate}} = \frac{2}{1.2} = 1.67 \text{ sec}$$

Thrust required.

$$T_R = \frac{W}{\frac{C_l}{C_d}} = \frac{0.133 * 9.81}{0.134} = 9.74 \text{ N} \approx 1 \text{ kg}$$

## Define Materials

At the first on conceptual Design. We assume all aircraft is filled by Balsa wood because Balsa wood is easy for manufacture, low cost and low weight. But in reality we can't do that because we need to care about structure. Then we need to do some composite materials for more stiffness. And finally following the table below.

| Materials                 | Part                    |
|---------------------------|-------------------------|
| Balsa Wood + PE Foam      | Fuselage and Stabilizer |
| Balsa wood + Carbon Fiber | Wings                   |
| Kite Paper 50 gram        | Wings Skin              |

\*\*\*Carbon fiber spar has low weight and can improve stiffness for wings in vertical and axial load.

## Manufacture

This process is full of obstacles. Because We have tools and resources in finite. We need to take carefully when we do all the parts by part of aircraft. We do "Handmade Workshop".

### Step by step

1. Fuselage: Cut the balsa wood and PE foam then stick together then fillet.
2. Stabilizer: Cut PE foam for 2 pieces first is vertical stabilizer second is horizontal stabilizer. Then cut some stick of balsa wood and stick together finally stick all to fuselage.
3. Airfoils: Cut come balsa wood and rasp to airfoils shape we select in first (7 pieces).
4. Wings: Used 2 carbon stick for wings spar and stick together with airfoils the cut some balsa wood to do bones of wings.
5. Wings Skin: Attach kite paper to wings.
6. Finally Step: Attach wing with fuselage by tape.

To more clarify whether how to manufacture.

| Tools  | Materials           |
|--------|---------------------|
| Cutter | Balsa Wood, PE Foam |
| Rasp   | Balsa Wood, PE Foam |

| Tools      | Manufacture                                  |
|------------|--|
| Glue       | Stick all the materials together             |
| Tape       | Attach wings to fuselage                     |
| Plasticine | Attach to glider for more weight and balance |

| Measured Tools  | Used when                    |
|-----------------|------------------------------|
| Vernier Caliper | Measured thickness           |
| T Ruler         | Check vertical or horizontal |
| Tape measure    | Measured long range          |
| Scales          | Measured weight              |

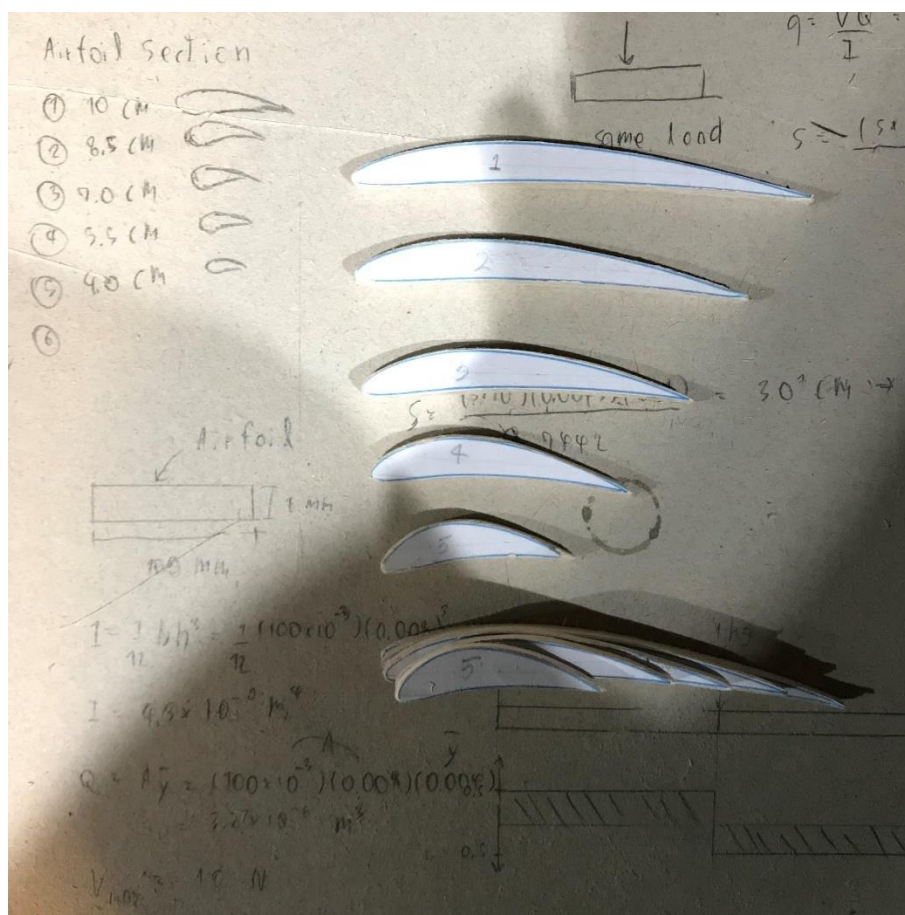


Figure 10 Airfoils NACA6409



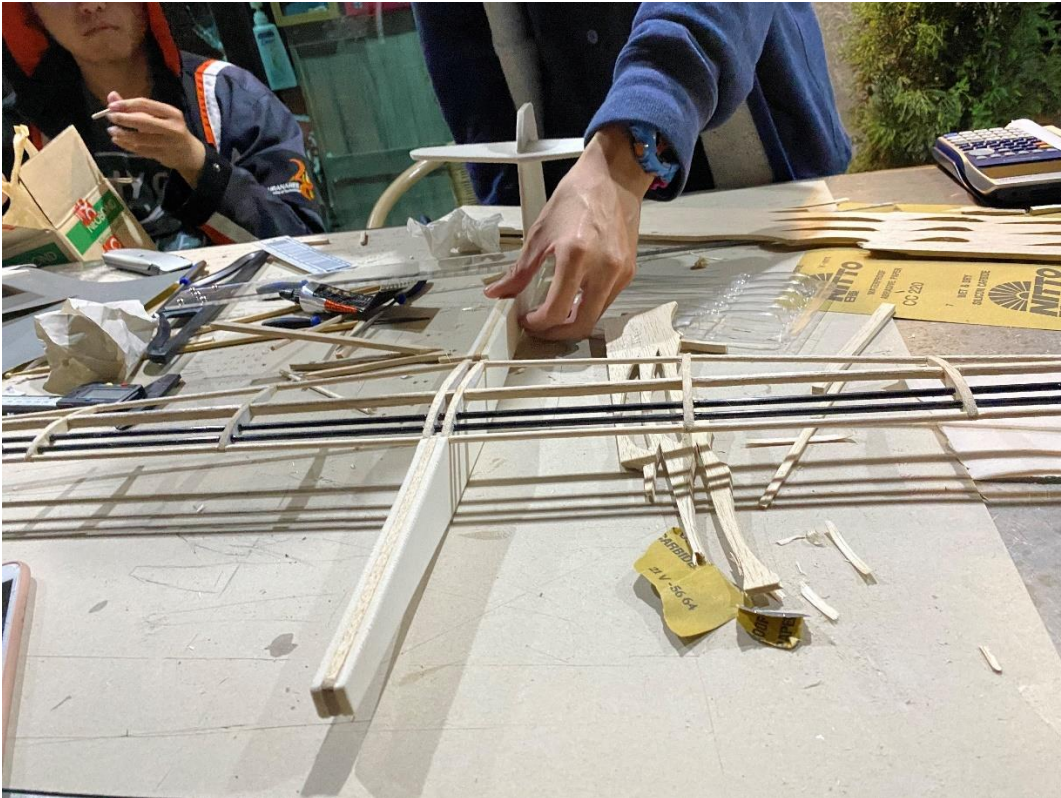


Figure 11 Our glider





*Figure 12 Finish*

## ***Flight Test***

We took too many times for flight test and back to fix our glider. We do more and more to find the best result as expect. The link below is show some flight test.

[Click here!](#)

Result on the real day test our glider can glide about 12.6 m error from theory by 16%.



## Inspection

On the real test day our glider got some problem. There's no stabilize because the last day before real flight got some damage with the trees too many times. Every time we fix we need to attach glue that will cause to no balance weight. Another problem is about stabilizer is not manufacture good enough.



Figure 13 Damaged

## Financial Report

| Materials                 | qty. | price (Baht) | Total (Baht) |
|---------------------------|------|--------------|--------------|
| Balsa plate 100*1000*4 mm | 2    | 140          | 280          |
| Balsa stick 4 mm          | 4    | 20           | 80           |
| PE Foam 500*500*4.5 mm    | 4    | 75           | 300          |
| Carbon Fiber Stick 4 mm   | 2    | 120          | 240          |
| Kite Paper 50 grams       | 4    | 5            | 20           |
| Nitto Tape                | 2    | 27           | 54           |
| Glue UHU                  | 1    | 75           | 75           |
| Plasticine                | 1    | 27           | 27           |
| Sandpaper 220             | 1    | 13           | 13           |
| Sandpaper 660             | 1    | 13           | 13           |
| Sandpaper 1000            | 1    | 13           | 13           |
| Rasp                      | 1    | 258          | 258          |
| <b>Total</b>              |      |              | <b>1373</b>  |

## Appendix



Figure 14 This is photo of our group after finish flight testing.

**For more information about coding.**

**Github repository:** <https://github.com/Rayato159/Glider-Project>

**And finally, We need to say thanks to Mr. Sanya Phanprasert (He is our friend but not study with us.) for facilitate us to used workshop place and borrow tools to work.**

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