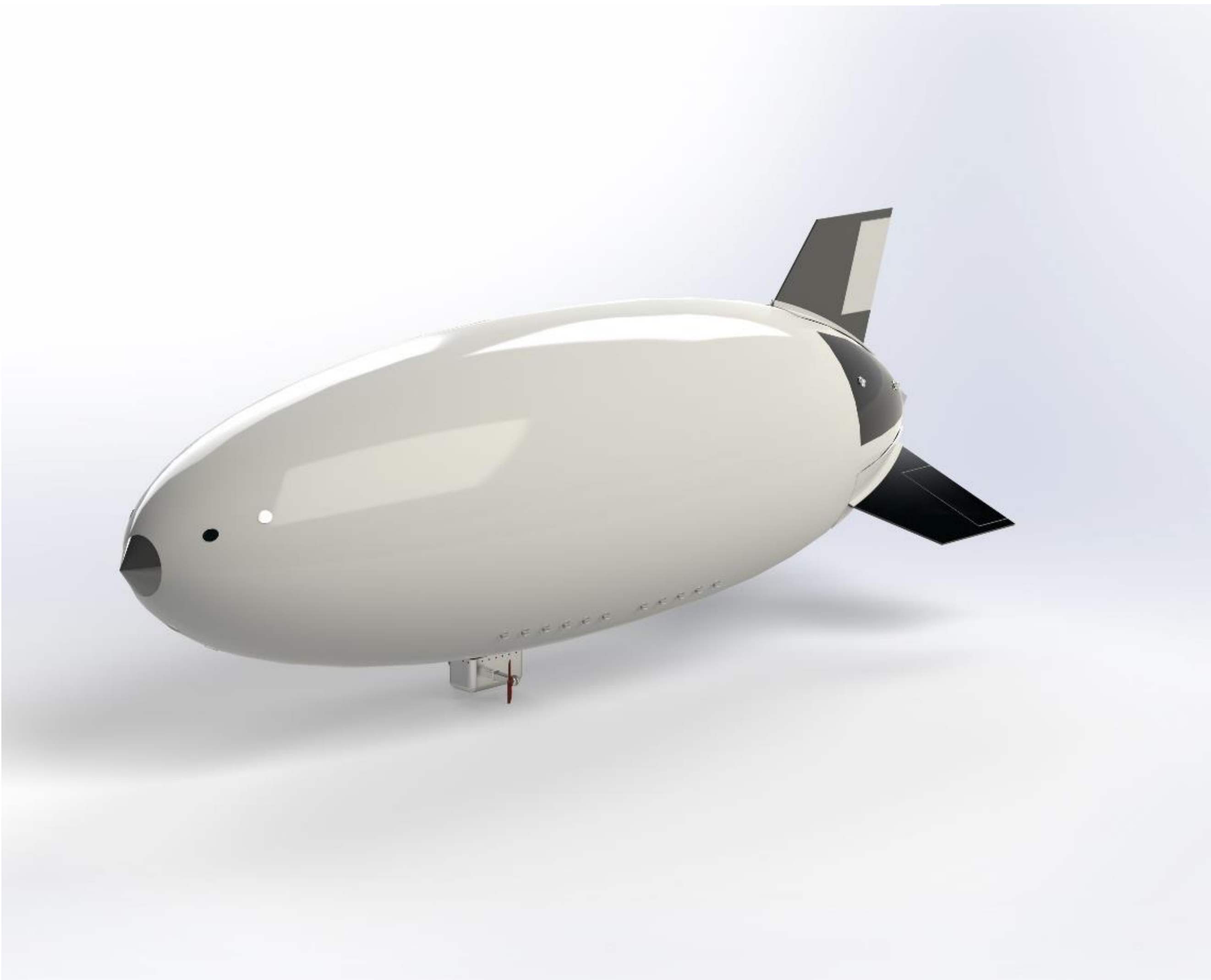
# ISEIC 2022



## On-air

"Online Everywhere "

***Cairo University*** ***Facility of Engineering*** ***Aerospace Department***

# Acknowledgements

*We gratefully acknowledge and express our sincere gratitude to Prof. Deyaa el Haq Nabil El Shebiny, for his valuable guidance and support in the preparation of this project.*

*We would also like to thank our parents not only for their unfailing emotions but also for helping us the most in the completion of the project.*

*Moreover, we also like to extend our thanks to the Space System Technology Laboratory for their help in offering me the resources in running the program.*

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# 1 Introduction

## 1.1 Problem definition

It’s crystal clear that nowadays, people can’t go on with their daily lives without using the internet, it is almost used in every part in our daily lives, it is used in work, schools, colleges, financial & government related transactions, especially in these days where we are experiencing a global pandemic and most people have transitioned to work, learn, even do family meetings from home, but in rural cities and smaller villages with few resources and little to no infrastructure it is hard to provide working consistent internet services to these places.
The internet plays a critical role in education, which is an essential aspect for any nation or society that is looking forward to progress. The internet offers golden opportunities of free Educational Resources, Interactive Learning in places where it’s not possible to attend school due to global pandemic or difficulties to reach schools.
Additionally, Businesses can’t operate efficiently without the use of the internet as it is important for digital marketing, online shopping, online meetings, and the globalization of the brand.
Moreover, the internet has a tremendous number of other applications such as Communication in general, News updates, entertainment, online hospitals, public services, and worldwide connectivity.

## 1.2 Proposed solution

To solve this problem, we decided to make a fleet of relatively small solar-powered dirigible airships that are low cost, low maintenance and easy to deploy, with wide area access point, that can be used and controlled to provide stable internet service on demand.

Making an efficient infrastructure will cost a fortune and, will take a lot of time/effort to build. Using a drone instead of the airship won’t be efficient as it’s not durable and will not be able to carry as much payload as the airship and not to mention the noise pollution that is caused by the drone. Furthermore, a drone will not last for a long time during the operating time like an airship which may last for days.
Finally, a satellite such as Star-link would have a lot of problems as the launch would cost around $50,000 additionally, it is impossible to perform maintenance to a satellite once it’s launched. Additionally, it is way more complicated than an airship.

## 1.3 Motivation

Our motivation is to try to solve this problem with a simple, creative, economical, and eco-friendly way.

Our beloved Earth is currently passing through a terrible time, People are increasingly influencing the climate and the earth's temperature by burning fossil fuels and cutting down forests, which causes ice melting in the two poles causing some major cities to sink and not to mention the increase in temperature which results in a huge distribution in our planet’s ecosystem. Consequently, a lot of agreements are being signed annually between the world’s governments in hope to slow down or find a solution to this fatal problem. Thus, our airship will be completely operated by clean energy (solar powered) and will not emit any type of pollution or any green gas.

Moreover, it will give us a chance to be pioneers in this field. Additionally, it will open new opportunities in this field and won't only be restricted to travelling and tourism. Not to mention, it will have a major impact on the upcoming generations and for our country to carry on research on this topic and be a pioneer country in for the lighter than air aircrafts like we used to be in the field of heavier than air aircrafts back in the forties/fifties when we designed Helwan/Cairo – 200/300

## 1.4 Inspirational power

The project idea was inspired by Loon LLC which had the same goal of providing internet access to rural areas, but while they used high altitude balloons in the stratosphere, we are going to use low altitude small dirigible airships.

## 1.5 Presence in market

This could be a profitable commercial activity for ISPs (Internet Service Providers) companies, In addition to the countries and private companies who are eager to use the space technologies for their benefits but doesn't have the required funds to launch their own satellite or space program as the airship can do most of the satellite's mission for instance, remote sensing, communication, and navigation but on a smaller scale. Finally, the airship can be used commercially by promoting many products and advertising for many companies as it floats. The Aerial advertisement is so effective and is such a profitable business for any company.


*Figure 1 Advertising*

## 1.6 Objectives

It is intended to introduce a preliminary design of the airship with a simple algorithm, depending only on the weight of the access point, to determine the dimensions of the unit, and so the power required for the thrusters, battery specifications and internal components aka the control unit.
Further we are going to go through the manufacturing process, the dimensions required for every part, the materials used and the connections/fittings between every part.
Furthermore, we are going to talk about basic concepts regarding the airship aerodynamics and control and the following sections will go on details about our methodology and approach then our prototype, after that we will conclude our project with what we achieved so far and what can we do next in the future to improve it.

# 2 Basic concepts

In aeronautics there is two types of aircrafts: heavier than air (HTA) and lighter than air (LTA) aircrafts, as the Aeromechanics is divided into Aerostatics and Aerodynamics. Airships is an Aerostatics application follows the famous principle described by Archimedes, The Buoyancy. According to Archimedes, "If a body is fully or partially submerged in water, it will experience a force due to the pressure applied by the surrounding water called the buoyant force that has a magnitude equal to the weight of the water displaced by the body and is directed vertically upward." This principle is described by this equation

$$F_B = \rho_w V g$$

Where $\rho_w$ is the density of the water, V is the displace volume and g is the gravitational acceleration? For a body submerged in water, it will experience a buoyant force directed upward and another downward force due to his own weight, the resultant force here equals the difference of the two forces and the greater force will determine the direction, and the previous equation can be written as

$$F_{net} = F_b - W = \rho_w V g - mg$$

If both forces equal each other, the net force is zero and body will be in balance in its position. Buoyancy is generalized to all fluids including air, so, considering a container filled with helium which is a gas less dense than air, placed at sea level and assuming that the container is weightless, the container will experience a net force equal:

$$F_{net} = (\rho_{Air} V - m_{He})g = (\rho_{Air} - \rho_{H\theta}) \cdot Vg$$

since the helium is lighter, the net force will direct upward and lift the container
This is exactly wat the airship is experience, now considering the weights of the airship envelope, structures, and the payload it carries, the lifting force of an Airship will be a function in the densities of air and helium (or the used lifting gas) and its payload. As shown in this equation.

$$F_{net} = (\rho_{Air} - \rho_{He}) \cdot Vg - W_{\text{pay load}}$$

When the airship is at sealing level the density of air decreases to a value where the buoyancy will equal the airship total weight, and now it will float.

# 3 Methodology

## 3.1 Methodology outline

The first step is to determine what required characteristics the airship is to operate with, payload, service sealing, atmospheric condition (pressure and temperature) and operating velocity. Next step is to calculate the theoretical characteristics of the airship which is mainly the volume of the airship its internal pressure and the amount of helium to be filled, based on it the rest of the design takes its shape. Then the characteristics of the materials and components is to be considered in the design and the initial design parameters is to be entered, from the initial parameters an optimization loop will start, and the initial characteristics will be optimized and changed till they approach the theoretical characteristics. If done, a comparison with the materials and components requirements will determine the validation of the characteristics or not. If not, an optimization process is to be run on the materials to select more reliable and suitable specifications then it will enter the loop again. If it is suitable then the design is ready to be manufactured.

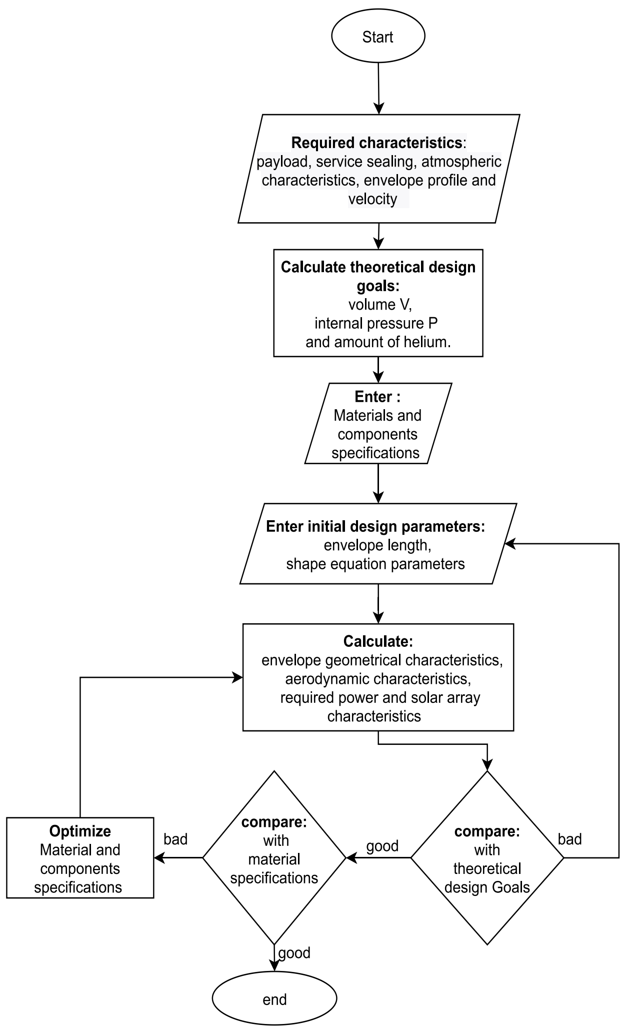



*Figure 2 Flow chart of the methodology to design the airship*

## 3.2 Envelope

### *3.2.1* shape selection

Depending on the mission and speed of the airship the selection of the envelope profile is considered. According to Wang, the high-altitude high-speed airships should have bigger fineness ratio ($\lambda$) which is the length of the airship to the maximum diameter. The profile curve equation used to build the envelope is as follows:

$$y(x) = \frac{\sqrt{a(l-x)\left(bx - l\sqrt{c} + (\sqrt{cl^2 - dlx})\right)}}{8}$$

Plotting the function along the length will result the following shape:

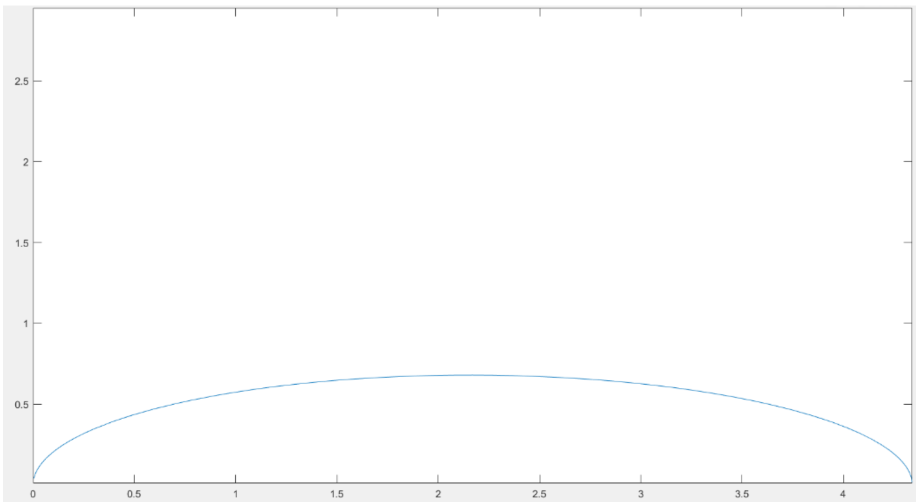



*Figure 3 The profile curve function along the length*

The envelopes based on this profile equation generally has good fineness ration and lead small drag coefficient to it is chosen over the conventional envelope shape which is composed of front and rear parabola cones and a cylinder in the middle.

### *3.2.2* Characteristics

From the profile equation, the volume of the envelope can be obtained by the theory of revolving the area under the curve. The volume equation will be:

$$V_e = \pi * \int_0^l y^2 dx$$

and the surface area can be calculated by revolving the profile line. The equation of the surface area is:

$$A_e = 2\pi \int_0^l y.\sqrt{1+\left(\frac{dy}{dx}\right)^2}\,dx$$

The location of the maximum diameter can be determined by calculating x from the first derivative of the profile equation as follows:

$$y'(x) = \frac{dy}{dx} = 0$$

The location of the center of gravity theoretically the same as the center of pressure due to the symmetry about the mid plane of the profile. And can be calculated by:

$$X_{CG} = \frac{2\pi \int_0^l xy.\sqrt{1+\left(\frac{dy}{dx}\right)^2}\,dx}{A_e}$$

### *3.2.3* Aerodynamics

The volumetric drag coefficient of the envelope is obtained by an empirical equation developed by (Khoury, G.A. and Gillett, J.D., 1999) based on the fineness ration ($\lambda$) as follows:

$$C_{DV} = \frac{0.172(\lambda)^{\frac{1}{3}} + 0.252(\lambda)^{-1.2} + 1.032(\lambda)^{-2.7}}{Re^{1/6}}$$

$$Re = \frac{\rho_a v l}{\mu}$$

The drag on the airship can be obtained as:

$$F_D = \frac{1}{2}\rho_a v^2\, V_e^{2/3} C_{DV}$$

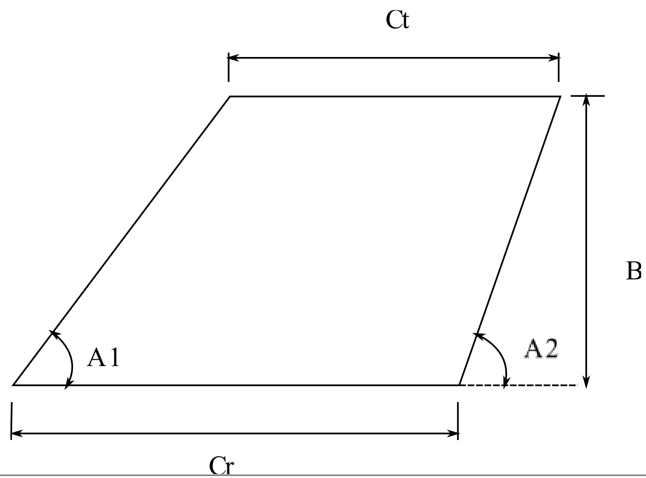
## 3.3 Tail assembly

The function of the tail assembly is to stabilize and control the direction of the airship. Tail assembly is composed of a horizontal and two vertical stabilizer fins. Each stabilizing fin carry a control surface to control direction, for the vertical stabilizer it is the rudder and for horizontal stabilizers it is the elevators

The tail assembly configuration was chosen based on some analysis and investigations made on current commercial airships with similar operational conditions: high speed and altitude. The inverted Y configuration is selected due to its aerodynamic advantages over the inverted T and X configuration.

### *3.3.1* Characteristics and dimensions

from the analysis results, the tail dimensions Cr, Ct and B were obtained as shown in the following table.




| | | |
|---|---|---|
| **B** | Tail span | |
| **A1** | Thrust angle of the leading edge | $52^{o}$ |
| **A2** | Angle of the trailing edge | $74^{o}$ |
| **Cr** | Root cord | $1.845 * \mathrm{B}$ |
| **Ct** | Tip cord | $1.36 * B$ |

The area of the fins is usually determined based on how stable the airship is desired to be in case of motion or sudden gust, stability and calculated flow analysis is required if the optimum area is to be determined.

## 3.4 Gondola

### Function

The function of the gondola is to carry the payload as well as any hardware and the battery. In non-rigid airship configurations, the propellers are commonly fixed in the gondola because it is the most rigid part in the whole craft. The gondola does not have specific shape design, but it is recommended to be streamlined to minimize drag and a good fixation method should be considered, it is preferred to be tied with wires into integrated loops in the envelope itself due to the lack of internal structure.

## Location

This part was such a tricky part that required a lot of trial-and-error process but in the end, we found out the best location is just below the center of mass of the whole airship so it won’t affect the stability of the airship and will make the airship able to carry the maximum weight that is possible according to the design.

## Fittings

The gondola is going to be attached to the body by fine strings connected between the holes at the top of the gondola and the bottom of the airship. The Sides of the gondola has a circular shape holes which are required to hold the 2 propellers which will be used for the propulsion and the control/stability of the airship.

Here is the final design

*Figure 4 Gondola*

# 3.5 propulsion system

## *3.5.1* power calculation

To design the airship, we needed to know the amount of power that will be required by it. And after a lot research, we found out we can calculate the required power the following equation

$$Power = \frac{Velocity * Drag\ Force}{Efficiency} + Power\ of\ Control\ Unit$$

Power of Control unit is assumed to be 30 Watts, as both the Arduino and Wind Tracker uses 1 Watt, the servo uses 6 Watt, and we are going to use 3 servo motors and for safety we added extra 10 Watts consumption.

The motor that we are using consumes around 150 watts which results in 170 watts needed in the end

For the Total Thrust we used the following equation

$$Tatal\ Thrust = Motor\ thrust * Number\ of\ arm\ axis * motor\ effieciency$$

And based on the motor thrust requirement, we selected 1400KV Brushless Motors together with the 5.6” propellers and one DNK-LIP3S1P8A battery to supply the electric power.

## 3.5.2 Components

- Solar system/Batteries
- Microcontroller
- Motor drivers
- Brushless Motors
- Propellers

## *3.5.3* How it works

The Microcontroller sends the required thrust velocity and direction to the motors drivers which in turns activate the propeller, then a feedback signal is sent back to the Microcontroller to verify if the system reached the required or not.

## 3.5.4 Placement

The propulsion system will be mounted on the side of the gondola because it is the most rigid part of the airship which makes it able to endure any vibrations coming from the system

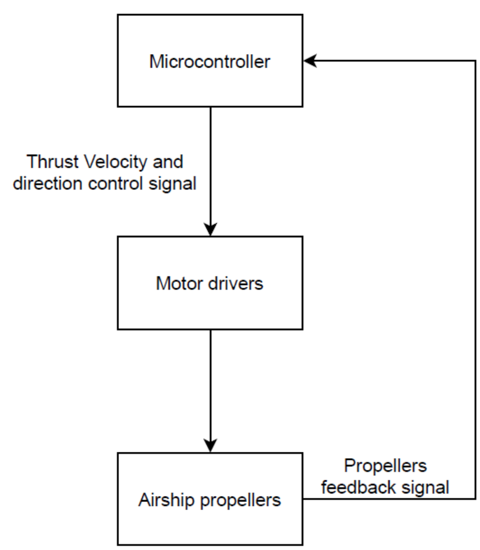



*Figure 5 Placement*

# 3.6 Control system

## 3.6.1 Fins control and maneuver

### 3.6.1.1 Components

- Microcontroller
- Tail & rudder Servos

### 3.6.1.2 How does it work

The Microcontroller sends the required maneuver signal to the tail/rudder servos which in turn move that part, so for example if we want to make the Airship yaw (rotate around the vertical axis) we send a signal to the tail servo which in turn move that control surface to do the maneuver.

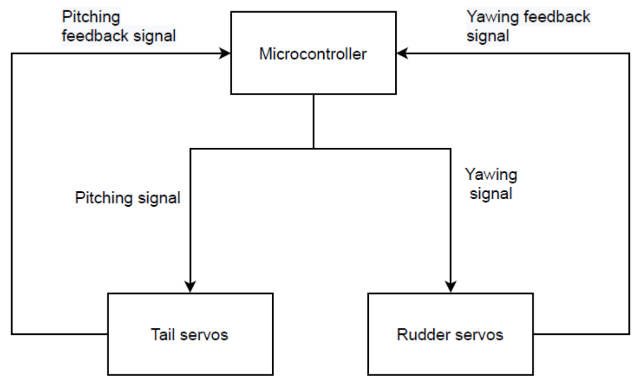



*Figure 6 How does it work*

### 3.6.2 Wind tracker

Wind tracker system is useful in both hover and in travel. As in hover it helps keep the airship in place in travel it contributes to power consumption by make use of the force of the wind if it blows in the same or closely to the travel direction. When the airship is to hover, the wind tracker device will measure the wind speed and direction, send their values to the microcontroller, the microcontroller is to send signal to the ruder to adjust the airship direction. The rudder effect itself will not stabilize the airship but will accelerate the action. When the airship adjusts its direction against the wind, the thrust system will work on to equalize the resistant force from the wind. When the airship is to forward in a specific direction, the similar process will be running, to calculate the angle between the wind and the travel direction. If it were to be near $180^o$ i.e., the wind will blow form the back. The rudder is to maintain the direction from being deflected. And the airship will make use of eth wind direction to reduce the power needed to reach travel speed. A simple algorithm was made to illustrate the system in the two moods in case of wind direction is parallel to the envelope length:

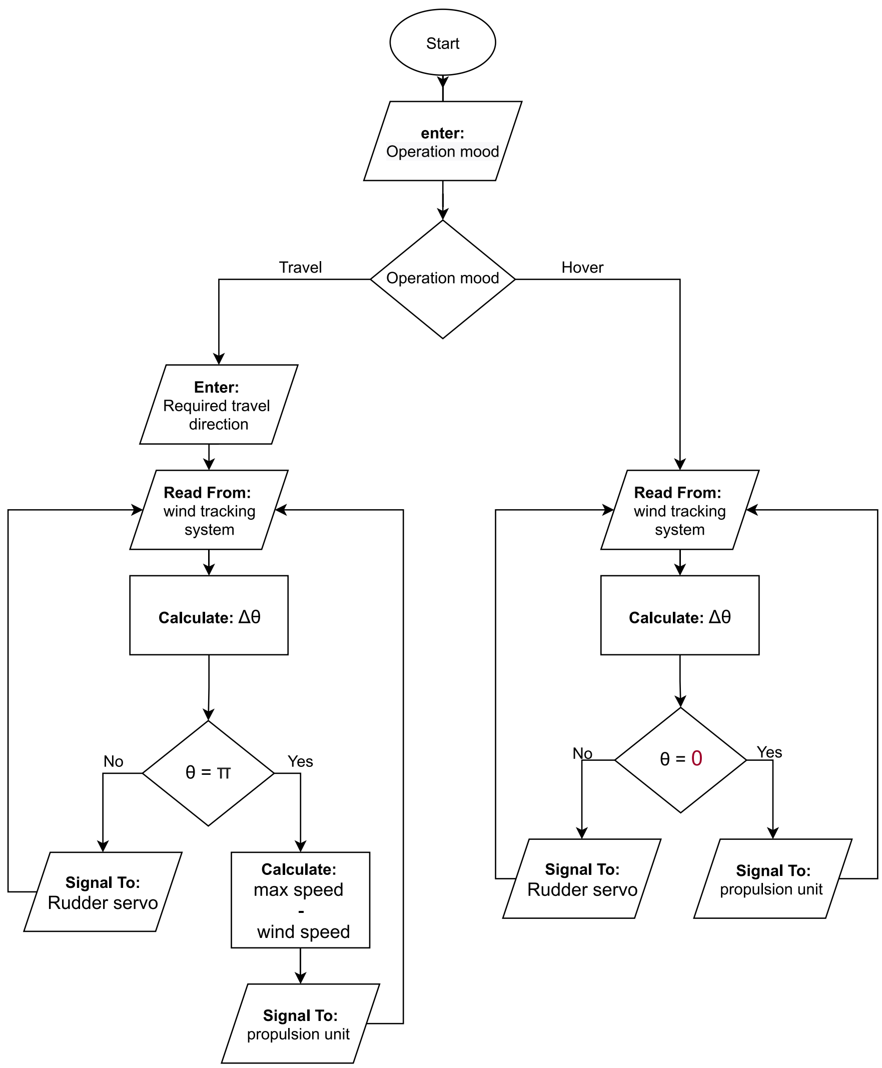



*Figure 7 Wind Tracker*

## 3.7 Hybrid Solar Power system

### *3.7.1* Operation

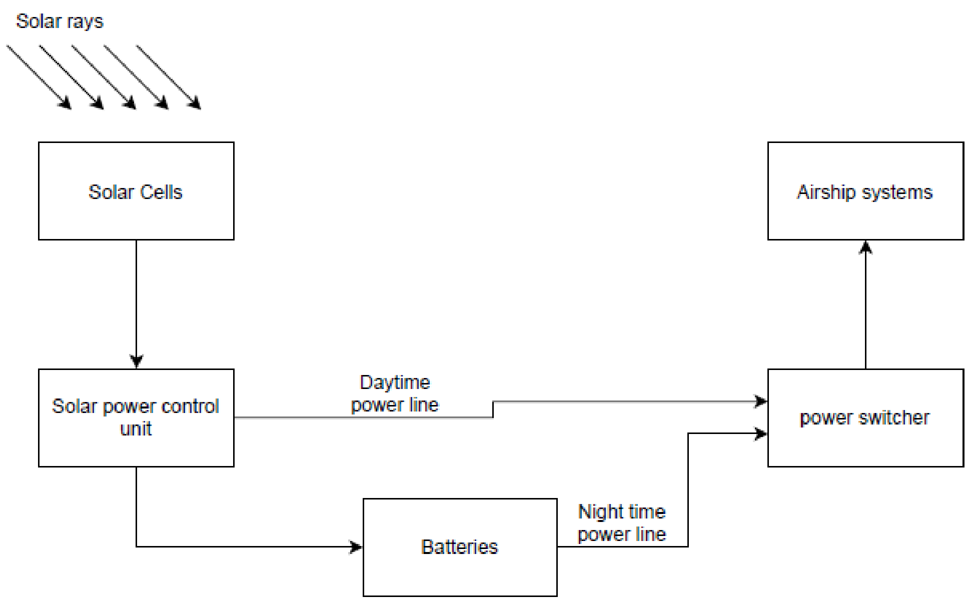



*Figure 8 Solar System*

This airship power system operates using electrical power source, either from the solar power unit directly (during the day) or using the batteries (during the night).
The solar cells power output also charges the batteries of the system with any remainder power.

### *3.7.2* Calculation of matrix area and Produced power

The required Total Output Power is Factor multiply the power required 2.667 x 150Watts (4 panels x 100 Watts), and the Solar Irradiance for a surface perpendicular to the Sun's rays at sea level on a clear day is around $1000\frac{Watt}{m^2}$ and the Conversion Efficiency of the solar cells is 18.7%.

$$\text{Total Power Output} = \text{Total Area x Solar Irradiance x } Conversion\ Efficiency$$

Consequently:

400 Watts = Total Area x 1000 $\frac{Watt}{m^2}$ x 0.187 → Total Area required = 2.139 $m^2$

And so, this is a rough estimate of the space required by the solar panels of the system.

Additional point to keep in consideration, solar panels will be installed at an angle to the surface, and this may change the results.

# 4 Prototype

"In this section it should be presented the applications on the methodology, or any approach used to design a part of the prototype. The methods of manufacture should be discussed if needed, and the results should be obtained"

### 4.1.1 Envelope

based on the calculations in the methodology the obtained results are listed in the following table

| Envelope characteristics | Value |
|---|---|
| Length:<br>Equation parameters: a, b, c, d | 4 m<br>0.812, 8.766, 9.997, 6.051, |
| Max diameter | 1.25 m |
| $X_{cg}$ for envelope | 2 m |
| Volume: | 3.3 m3 |
| Surface area: | 12.8 m2 |

Figure 9 The Envelope

### *4.1.2* Tail Assembly

The obtained geometry of the tail is listed the following table. The span of the tail is assumed to be 0.08 of the envelope length based on some statistics on real airships

| | | |
|---|---|---|
| B | Tail span | 0.32 m |
| A1 | Thrust angle of the leading edge | 52º |
| A2 | Angle of the trailing edge | 74º |
| Cr | Root cord | 0.59 m |
| Ct | Tip cord | 0.435 m |

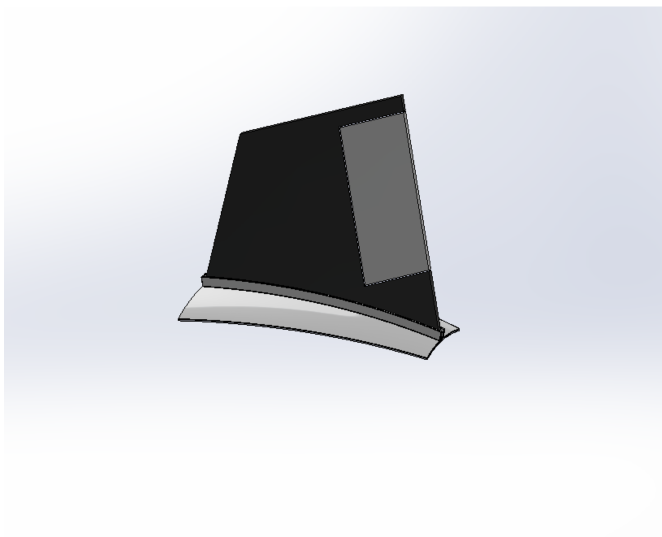


*Figure 10 Tail*

### 4.1.3 Materials

The envelope must be air-tight to keep the helium inside, based on some research on the airships being manufactured now, their envelopes are commonly a combination of Tedlar and polyester to strengthen it. To save costs when the airship is small (RC Airship) some use mylar or melinex. Tedlar is recommended to be used due to its good characteristics and its density is nearly the same as the mylar. But for its high cost, for the prototype mylar is selected to manufacture the envelope.

The tail is recommended to be made of twin-wall lightweight polycarbonate. And the tail base which will be fixed on the envelope of relatively flexible lightweight polycarbonate.

The gondola is to be made of thin lightweight plastic.

### 4.1.4 Fixation

To fix the fins in its position, a strong adhesive will be used, and it will be tied with ropes to integrated loops in the envelopes to keep it straight.

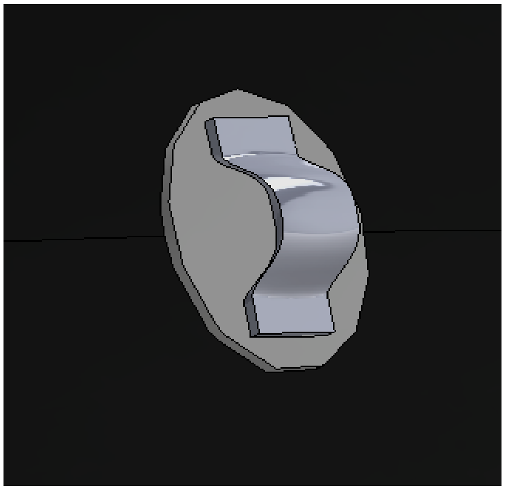


*Figure 11 Fixation*

The gondola will be fixed in its place using the same method with integrated loops in the bottom of the airship

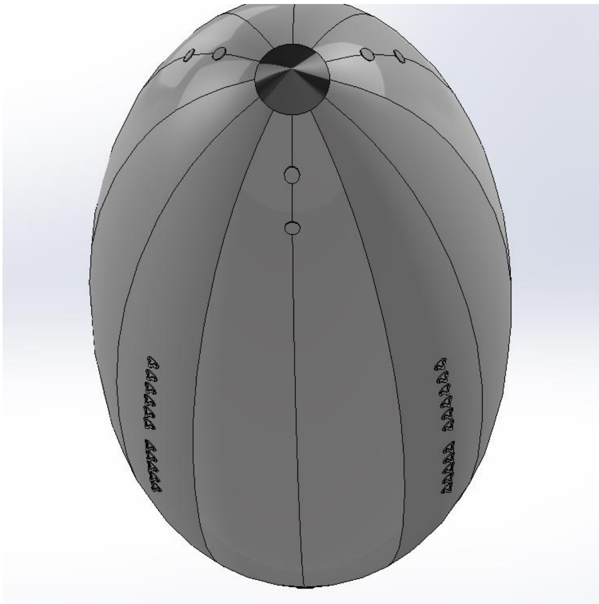


*Figure 12 Airship Fixation*

## *4.1.5* Subsystems

### 4.1.5.1 Control system

For our prototype we choose these components:

- Arduino UNO as our microcontroller
- 3.2 kg.cm servos for the control surfaces


### *4.1.5.2* Wind tracker

### 4.1.5.3 Propulsion system

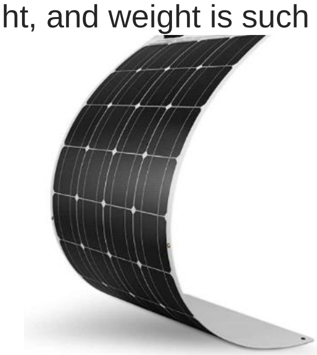
For our prototype we choose these components:

- Arduino UNO as our microcontroller
- L298 as our motor driver module
- 1400KV Brushless Motors
- 5.6” propellers




### 4.1.5.4 Hybrid solar power system

We are going to use flexible solar cells as they are Lightweight, and weight is such an important factor in our project. They are compact and durable too which is an amazing feature as the airship will remain in operation for relatively long time. Furthermore, they are flexible, adaptable and have better conversion rates in overcast weather. We are going to use Renogy 100-Watt Solar Flexible cells for their cost, efficiency, and flexibility.



The placement of the solar cells will be on the horizontal stabilizer and the upper surface of the airship so that they will be facing the sun most of the time. The angle or tilt of a solar panel is also an important consideration. The angle that a solar panel should be set at to produce the most energy

For the Battery, we are going to use Lithium-ion batteries which are a popular choice for solar systems all over the world. Its prismatic form allows for ventilation and benefits use in solar systems. Moreover, they have a unique voltage range and response to charging and can be charged with a voltage regulator charge controller. Additionally, they can supply more cycles than other rechargeable batteries. Thus we are going to use DNK-LIP3S1P8A in this project

# 5 Airship Ground Station

**What does the ground station do?**

Overall, it controls the airship and give it the specific location of the wanted area to be covered and represent the status of the airship and the covered area like the airship's speed, altitude, acceleration, and the area's pollution percentage.

We used a variety of sensors for each mission like: (MPU6050-BMP180-GPS NEO6-DHT 11-MQ135). We coded them on Arduino IDE then integrated the entire code with LabView to represent these sensors using the code attached in the figures below. There's also some status data like (Number of connected devices & battery percentage) that were coded also and represented in LabView


*Figure 13 GUI*

**MPU6050:**

MPU6050 is used to get the acceleration and the speed of the airship

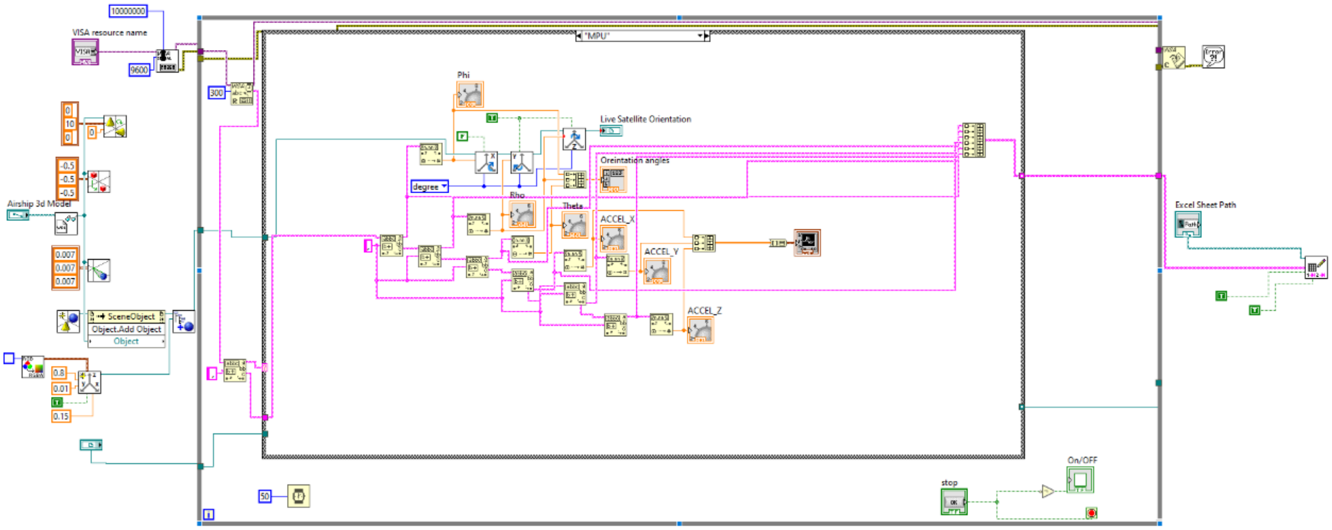


*Figure 14 MPU6050 LabView Code*

**GPS NEO6:**

We used the GPS to give the airship the coordination of a specific area that wanted to be covered and determine the location of the airship

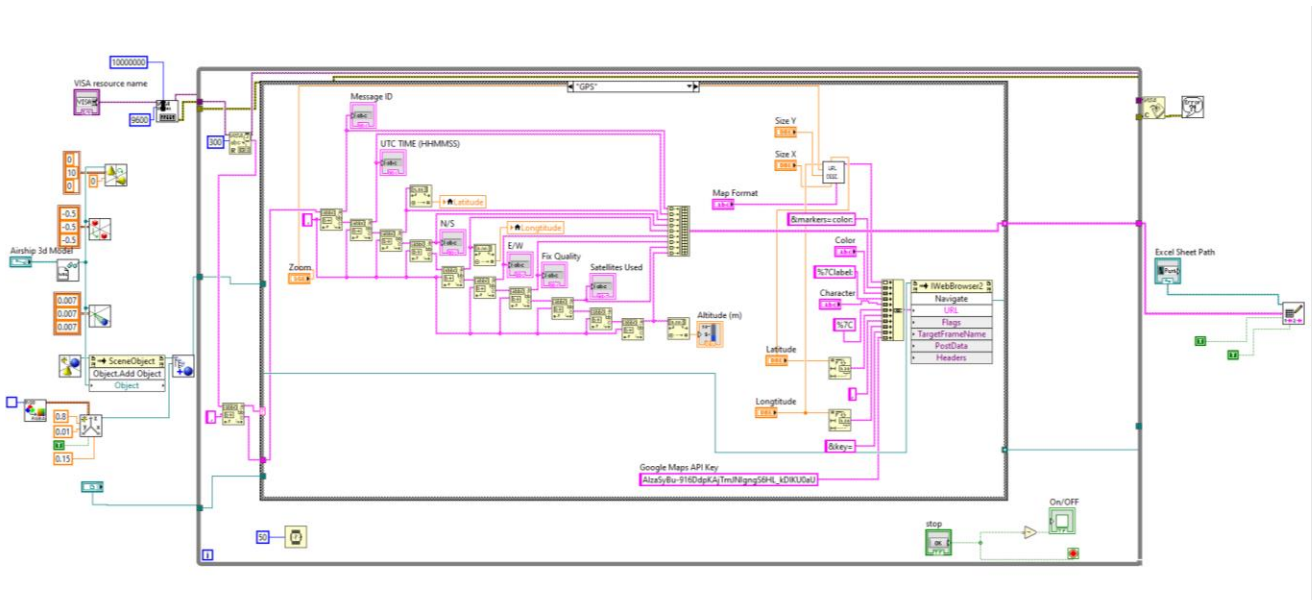


*Figure 15 GPS Code*

**DHT 11 & BMP 180:**

These two sensors were used to measure temperature, relative humidity & the air pressure of the surrounding area of the airship.

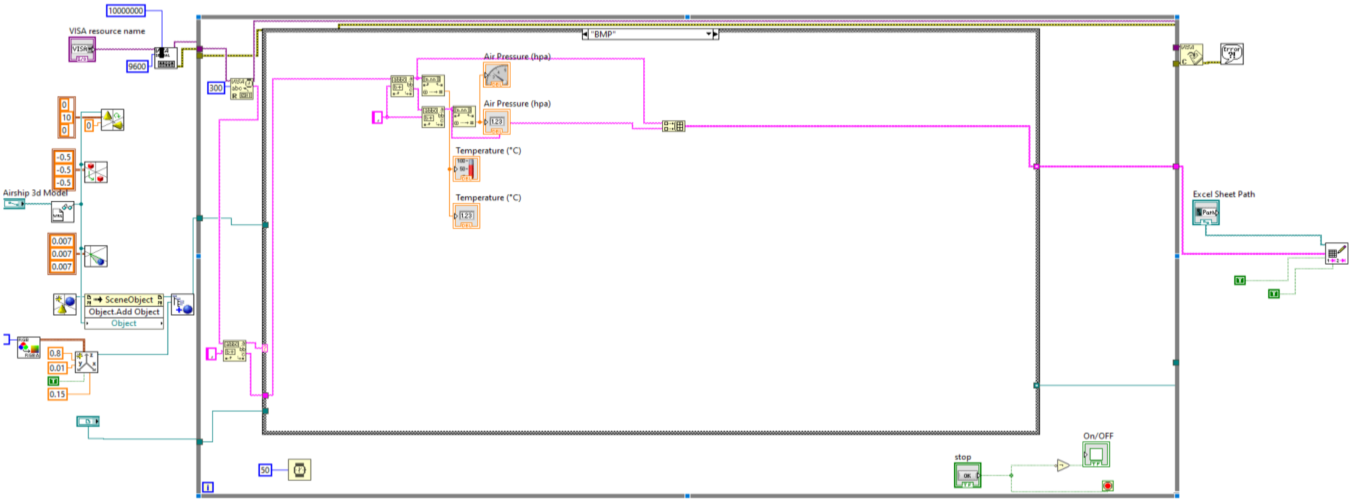



*Figure 17 BMP*

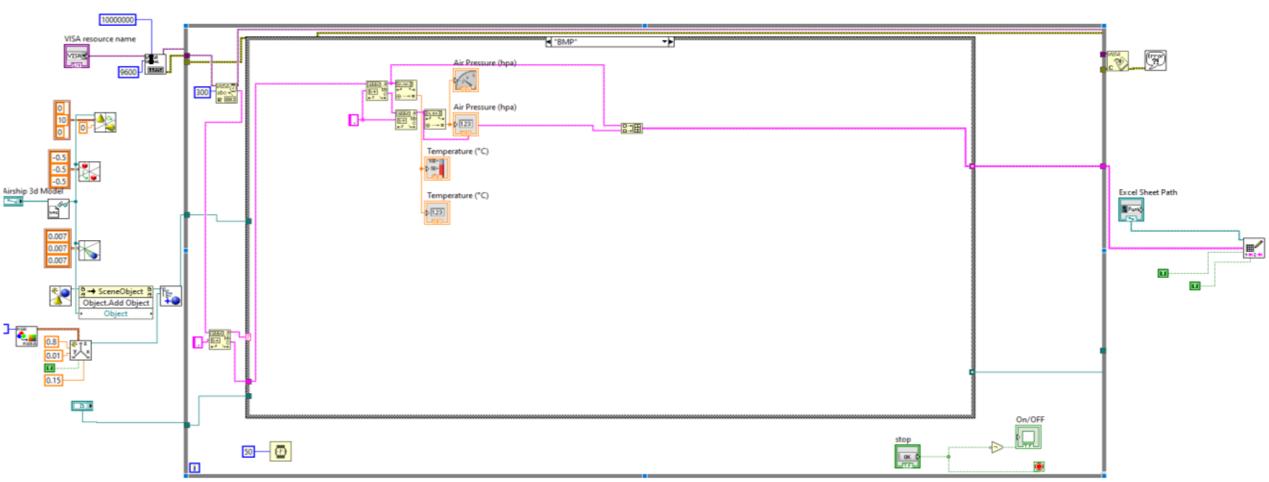



*Figure 16 DHT 11*

**MQ135:**

in addition our internet service we also our goal to keep the world clean and safe so we have added this sensor to measure the pollution percentage and determine if it’s in the safe limit or not, if not, the airship will send alerts to the competent authorities.

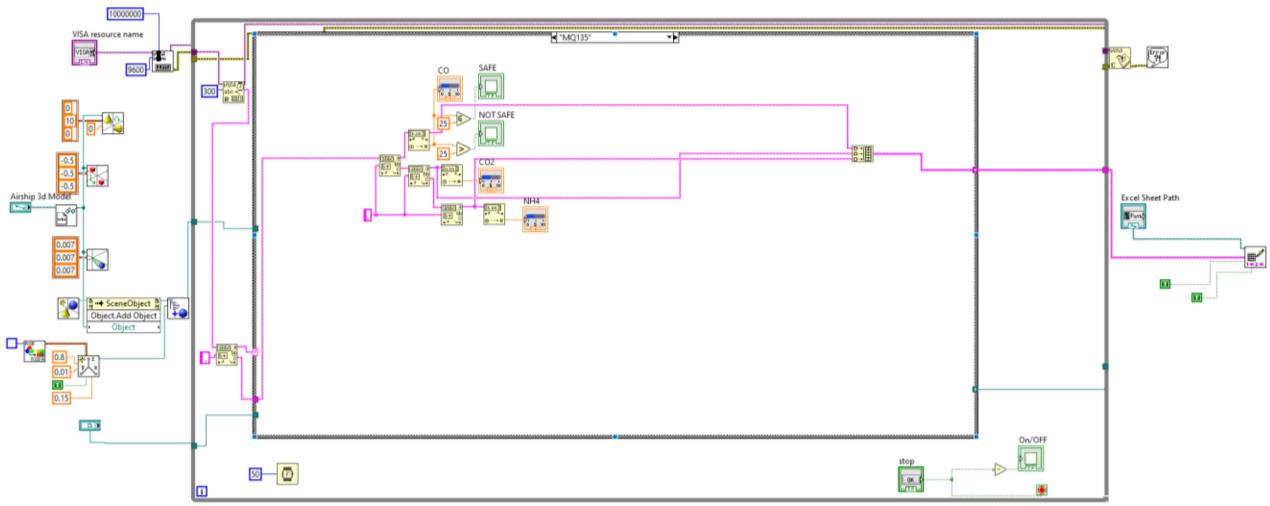



*Figure 18 MQ135*

# 6 Conclusion

A Wi-Fi airship is a brand-new idea, proposes a solution for the internet connection problems along with opening new gate for investments. The world is shifting toward more ecofriendly inventions and among aircrafts. airships are the best, not only for Wi-Fi, but it can also be of great benefits in other fields such as advertisements, transmitting and observation applications. Investing in small airships gives the opportunity to be pioneers in this field. The methodology constructed will lead the basic understanding airships main concepts and give an idea how the shape will be and how the hardware will work. For the prototype some results were obtained from the methodology like the envelop characteristics and the tail assembly. The results along with some assumptions were used to construct baseline characteristics for the prototype, the component in the prototype is chosen to achieve goal of the project but it need laboratory experiments and tests to validate them and the based calculations, which weren’t studied due to the lack in resources and finances.

# 7 Recommendations and further improvements

Further study and development of the envelope materials is to be conducted due to the extreme conditions the airship is to operate in, including storms and long periods exposure to UV rays.

A calculated flow dynamics analysis is to be made on the airship to validate its stability and drag calculations.

There are several gaps in our knowledge around some of the topics stated in the report, we would benefit from further research, including realistic evaluation, accurate data, and further experiments to test the idea’s reliability. Additionally, we lack the knowledge to design the Internet supplier and communication system between the airships and the ground station.

Further Improvements would involve a wind turbine to make use of the air to improve overall power cycle efficiency, Additionally, a remote sensing camera would be fascinating as it can be used in tremendous number of applications such as analyzing the condition of rural roads, creating a base map for visual reference, detecting land use and land cover, locating construction and building alteration and the list goes on.

# 8 Appendix

Used MATLAB code in the calculations.

input parameters:

```
% Operation data

h_service = 500;                    %  service ceiling (meter)

P_L  = 3;                           %  pay load (Kg)

P_h  = 95299;                       %  ambiant pressure at service ceiling (pa)

T_h  = 11.5 + 273;                  %  ambiant temperature at service ceiling  (K)

v    = 20;                          %  expected airship Velocity    (m/s)

AOA  = 6;                           %  AOA of the Airship



% Standard Sea level data

P_SL    = 101325;                      %  ambiant pressure      (pa)

T_Sl    = 288.15;                      %  ambiant pressure      (k)

rho_SL  =1.225;                        %  ambiant air Density   (Kg/m^3)

g       = 9.806;                       %  gravity acceleration  (m/s^2)

mu_Air_SL  = 1.78938e-5;               %  dynamc Viscosity       (N s/m2)

MW_gas = 4;                            % Helium molicular mass  (Kg/Kmol)



% Geometrical Parameters

a=0.812;            % profile equation parameters

b=8.766;            % profile equation parameters

c=9.997;            % profile equation parameters

d= 6.051;           % profile equation parameters
```

```
l=4.0001;           % envelope length


% Systems Specifications

t_material  = 0.002;     % thickness of envelope

prop_eff    = 0.95;     % eff of the prepeller

Pw_control  = 30;       % power of control system  (watt)

t_day       = 12;       % time of day (hour)

t_night     = 12;       % time of night (hour)

eff_bat     = 0.99;      % fuel cell (battery) efficiency

Pw_sc       = 200;      % assumed power of solar array (watt/m2)

eff_sc      = 0.187;    % fuel cell (battery) efficiency

As          = 2;        % solar Array Area
```

calculations theoretical design requirements:

```
rho_Air     = P_h/(287*T_h);              % Air dinsity at service ceiling    (Kg/m3)

rho_Gas     = P_h/(8314/MW_gas *T_h);     % LTA Gas dinsty at service ceiling (Kg/m3)


V_th        = P_L/(rho_Air - rho_Gas);    % theoretical volume - bouyency theory (m3)

V_Req       = 1.1*V_th;                   % Required volume - with 1.2 safety factor

M_Gas       = rho_Gas * V_Req;            % required mass of LTA Gas


P_Gas_SL    = rho_Gas*(8314/MW_gas)*T_Sl; % Pressure of the Gas inside the ballonates
```

Design Calculatios (all geometrical calculation considering origin at leading edge)

```
% Geometrical Design Calculation

syms x
```

```
y = 1/8*sqrt(a*(l-x)*(b*x-l*c^0.5+sqrt(c*l^2-d*l*x))); % profile curve equation

Dy = diff(y,x);                                        % first derivative of the equation



Ve=double(pi*int(y^2,x,[0,l]));                        % required volume - revolved area
theory

Ae=double(2*pi*int(y*sqrt(1+Dy^2),x,[0,l]));           % required surface area - revolved
line theory



x_Cp = real(double(int(x*y,x,[0,l])/int(y,x,[0,l])));  % center of pressure
theoreticalcalculation

x_Cg = double(2*pi*int(x*y*sqrt(1+Dy^2),x,[0,l])/Ae);  % center of gravity theoretical
calculation

D_Cg = double(subs(y,x_Cg)*2);                         % diameter at center of gravity



x_D_max = min(double(solve(Dy==0,x)));                   % max diameter and location

D_max = double(subs(y,x_D_max)*2);

AR = l/D_max;                                 % Aspect ratio of length to max diameter



% hoop stress calculation  at sea level  (am not sure with the results...)

P_static = 0.2308*rho_SL*g*D_Cg*(AR)^2;             % static pressure on the envelope

P_dynamic = rho_SL* v^2 * Ve*0.44*(sind(2*AOA)/(pi*D_Cg^3));% dynamic pressure on the
envelope

P_diff   =  1.722*g*rho_SL*D_max*AR*sind(AOA);        % internal differential pressure

P_delta  =  P_static + P_dynamic + P_diff;            % minimum inner pressure

Hoop_stress = P_delta*D_max/t_material;               % hoop stresses on the material
to keep it rigid



% Aerodynamic calculations

Re  =  rho_SL*v*l/mu_Air_SL;                                      % Reynolds number at
specified speed at Sea Level
```

```
Cdv = (0.172*(AR)^(1/3)+0.252*(AR)^(-1.2)+1.032*(AR)^(-2.7))/(Re)^(1/6);   %Volumetric
drag coeff.



Fd=0.5*rho_Air*v^2*Cdv*Ve^(2/3)/2;                                    % Drag on the envelope



% power of the propeller

Pw_prop = Fd*v/prop_eff;                                              % power needed to
overcome the drag





% total Power required

Pw_t = Pw_prop + Pw_control;
```

# 9 References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