Concept, Structural and Analysis Study of a Hybrid VTOL Device "Mini-Bee"

(Final report)

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***Abstract*— The Mini-Bee is a hybrid concept and VTOL vehicle characterized by its low cost, lightness and small size. This research focuses on the architectural study of the Mini-Bee. First, the essential parts of the aircraft will be specified using CATIA 3d experience. Then, using ROBOT structural analysis we will design the aluminum bar that connects the propellers together. Finally a weight estimation will be performed.**

ACKNOWLEDGMENTS

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I. Introduction

A-Context:

The Mini-Bee is a concept vehicle that has the potential to revolutionize the way personal and low cost aviation works. It is a hybrid vehicle to be used as Urban Air Mobility (UAM), which make use of electric motors in conjunction with thermic ones taking into account the characteristics of a multicopter drone and a helicopter. Possessing features such as Vertical Take-Off and Landing (VTOL). This enables it to dispose high mobility as a helicopter, but also, a high cruise speed as a multicopter while taking into account a maximum cost, not exceeding, € 300 000 euros and a Maximum Take Off Weight (MTOW) of 750 Kg.

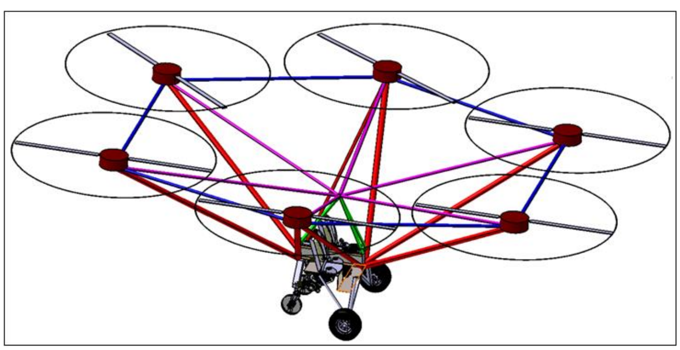

Figure 1 Mini-Bee 3D view

Urban air mobility (UAM) is a way that allows consumers to call VTOL to their desired pickup locations and specify drop-off destinations at rooftops throughout a given city. Rides are unscheduled and on demand as for example ride sharing applications nowadays. In addition, similar to the air metro case, vehicles are piloted and can accommodate 2 to 5 passengers at a time. According to the interviews, surveys and research conducted by NASA [2], UAM served by Electric Vertical Take Off and Landing (eVTOLs) is not a viable market due to technology constraints. However, Hybrid VTOL aircraft are a more attractive option to serve (air ambulance markets, air taxis, last mile delivery services and many others).

According to Pascale, L. and Nicolosi [5] during the last two decades, Tecnam vehicle industries have been on good terms with light and Ultralight (ULM) 2-seat aircraft. The company has quality experience in design of light aluminum alloy aircraft structures and has introduced technological innovation for this class of aircraft. Research activities focused on reducing the empty weight and the aircraft costs. The market of light aircraft is growing and many activities were conducted (like in the University of Naples [1]) in collaboration with Tecnam on structural analysis and tests.

Furthermore, the fast economic growth of developing countries who have not developed a transportation system, has increased the use and extension of light aircraft in those areas. In some areas of South Africa, for example, light aircraft are the only viable solution when taking into consideration poor existing infrastructures, as well as the low acquisition and low running costs of these machines. General aviation and light aircraft can be used in flight schools, for tourist transportation and to perform services such as aerial monitoring all at a reasonable cost. Light aircraft with 2 seats, a flight speed around 250-300 Km/h, a capability of flight altitude up to 1200 ft, have relatively simple and inexpensive construction, with reasonable and low maintenance costs. In addition to a growing market the scope of use of these light aircraft in undeveloped areas is of high relevance. From the take-off and landing capabilities on unprepared airfields, to the characteristic capacities of short take-off and landing runs these aircraft are extremely promising.

Moreover, reducing the structural weight is essential for improving aircraft performance. Lighter and/or stronger materials allow greater range, speed and may reduce operational costs. Article [3] shows recent development in lightweight materials for airframe and engine components. The main focus is on micro structural characterization and on the relationship between the micro structure and mechanical properties of specific material systems. [4], [6]. Finally, one of the main objectives of aeronautical companies is to design lightweight structures and this can be ensured by incorporating composite materials. The recent efforts by Boeing and Airbus (different than general aviation but they both share the same tendency) incorporate composite into primary load carrying structures of large commercial transports and to certify the airworthiness of these structures is evidence of the significant advancements made in the understanding and use of these materials in real world aircraft. One of the most important examples, the new Boeing 787 which is made up of 50 percent of composites as shown in Figure 1.

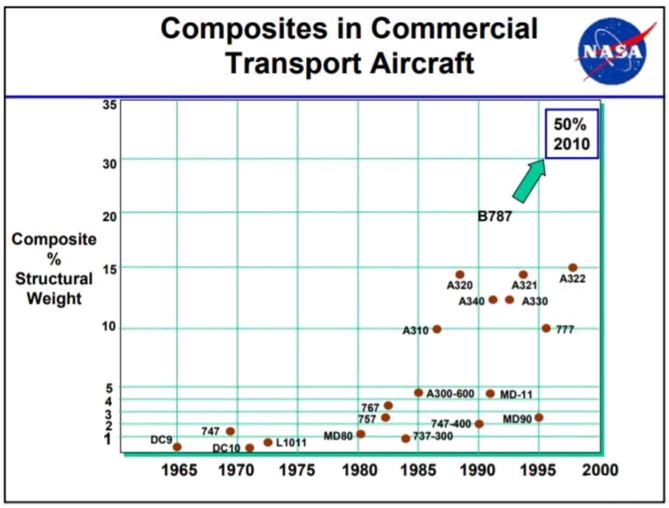

Figure 2 Evolution of Composites in Commercial Transport Aircraft

B-Problem Statement:

This study aims to carry out an architectural design of a hybrid and VTOL aircraft characterized by its low cost, lightness, and small size. Using Catia software, a 3D modelisation will be carried out in which we will create the main parts that constitute an aircraft such as the engine, tank, propellers and seats. These elementary parts will enable us to build the final model of an aircraft. Afterwards, a static simulation will be done on the hollow bars which carry the propellers, to optimize the dimensioning of the bars while leaving the prototype intact. For this study, the pre-dimensioning was made using Euler formula for buckling, and von Mises for the limit of stress yielding. These latter studies were made using structural robot analysis. Finally, in order to achieve one of our main goals in this project a weight estimation study must be carried out on this Mini-Bee.

C-Different Type:

The design and structure of two aircraft was one of the primary objectives of this work. This start up is based on two models. The first aircraft, is a flying ambulance characterized by its ability to take off vertically and it allows the casualty evacuation in inaccessible areas. This aircraft is composed of two Rotax 915is engines, 10 propellers and 4 Passengers (PAX) known as R2H10P4. The second vehicle which we worked on in this article, allows two people to move around, and is composed of a single Rotax 915is, 6 propellers and no wings. It's called R1H6A0.

D-First Study:

To be able to estimate the performances and general characteristics of the Mini-Bee, a research about some light vehicles was conducted. Piper L7, Cessna 152, Robinson R22 and LH212 are four vehicles which will represent the scope of commercial aircraft. In the following, we will go into further details concerning each type of vehicles:

Table I
General Characteristics & Performances of ***Piper L7***

Performance		General Characteristics	
Cruise Speed	200 Km/h	Capacity	2 PAX
Range	306 Km	MTOW	553 Kg
Altitude	9 300 ft	Height	2.03 m

Table II
General Characteristics & Performances of ***Cessna 152***

Performance		General Characteristics	
Cruise Speed	198 Km/h	Capacity	2 PAX
Range	768 Km	MTOW	757 Kg
Cruise Altitude	14 700 ft	Height	2.60 m

Table III
General Characteristics & Performances of ***LH212***

Performance		General Characteristics	
Cruise Speed	160 Km/h	Capacity	2 PAX
Range	450 Km	MTOW	450 Kg
Cruise Altitude	13 120 ft	Height	2.36 m

Table IV
General Characteristics & Performances of ***Robinson R22***

Performance		General Characteristics	
Cruise Speed	177 Km/h	Capacity	2 PAX
Range	386 Km	MTOW	750 Kg
Cruise Altitude	14 000 ft	Height	2.72 m

E-Constraints & Require1ments

Many specifications need to be acquired to perform a distance range between 600 km and 700 km with a high cruise speed of 200 Km/h. This is necessary for the vehicle to reach different branches of the market and an altitude of 20 000 ft to perform the intended task, and to be categorized as a UML as well.

Table V
General Characteristics & Performances of ***Mini-Bee***

Performance		General Characteristics	
Cruise Speed	200 Km/h	Capacity	2 PAX
Range	650 Km	MTOW	750 Kg
Cruise Altitude	14 000 ft	Height	2.80 m

F-Description of past collaborative work

Estaca calculated the power required to lift the Mini-Bee using Froude's theory. In addition, they studied the failure cases as well as the thrust at the fixed point and the rotation speed at the blade tip.

Esiglec studied electric conception and power management. The choice of the thermal engine having already been validated, the first step of the project consisted in studying the thermal engine characteristics, and then comparing the different EMRAX electric motors (188, 208 & 228) to choose the one that would be suitable for the project. To do this task, we carried out a power balance on the electromechanical chain.

Supméca studied mechanical simulation and numerical mock-up. The objective was to validate by the finite elements the structure of the cockpit for different load cases. For this reason, different geometry designs were developed on 3D Experience and validated on ABAQUS.

Centrale Supelec did a design of electric engines and development of the power configuration with innovative asynchronous configuration.

Other universities: check CollaborativeBee for information of the project and task made by all collaborative project members.

G-Initial sketch

Based on the previous four vehicles, a drawing of the initial sketch was made on Auto CAD for different views as shown in Fig. 6 & 7. Knowing that this is just a general preliminary concept and it is probably going to be changed as the development process evolves.

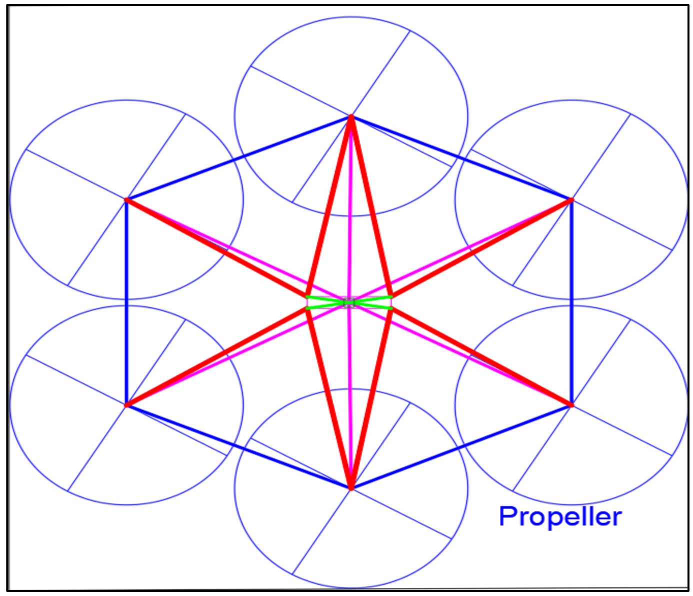

Figure 3 Mini-Bee Top View

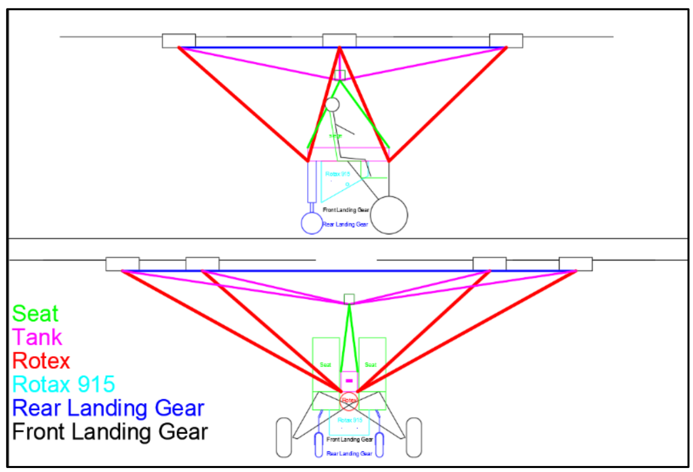

Figure 4 Mini-Bee Front & Side View

Afterwards, each part of the Mini bee will be drawn and explained separately and a general idea will be given about each part.

II. Conceptual Phase

A-Fuel Tank:

A parallelepiped form was chosen for the fuel tank with a dimension of $25\text{cm} \times 30\text{cm} \times 110\text{cm} = 82.5$ L in order to enable the fixation of different parts.

Figure 10 Fuel Tank

• A height of 30 cm was chosen to enable the placing of the board computer and the joystick in order to facilitate for the pilot to control the joystick and to have a more comfortable field of view.

•A width of 25 cm was selected in a way that facilitates the fixation of the board computer and to ensure a distance between the pilot and the passenger.

•A length of 110 cm was picked in a way that fits all the concerning parts (landing gears, thermal engine and electric generator)

• The width and length can be modified if needed while taking into consideration a volume not exceeding 70 and 100L.

B-Thermal Engine:

The Thermal engine is needed to ensure hybrid capabilities, and serves as the main power provider for the vehicle. It should be able to provide enough power to the propellers in order to ensure cruise flight, and to provide power to a generator, to charge the batteries of the electric system during the flight. The choice of the thermal engine was based on these important criterias:

• Range: a thermal engine was chosen as main source of electric power generation in order to achieve a sufficient range of 650km. There is no large battery on board of the Mini-Bee.

• Certification: Thermal engine need to be already certified.

• High power to weight ratio: is a measurement of actual performance of engine or power source and a calculation commonly applied to enable the comparison of one unit or design to another.

• Reliability: represents the ability of a system or component to function under stated conditions during a specified period of time. This characteristic is very important in the aeronautical field because any failure can jeopardize people's safety. Components reliability is usually inversely proportional to the components complexity.

• Robustness: is the ability of a structure to withstand events like fire, explosions, impacts or the consequences of human error, without being damaged to an extent disproportionate to the original cause.

•Smooth rotation of the shaft: with cylinder engine we don't have a perfect continuity in the rotation of the shaft because motion is the result of the succession of the strokes.

• No thermic shock cooling: in a diesel engine during the compression, a temperature about 550 C is reached. During the induction stroke the cylinder is again filled with clean air at low temperature so there is a big difference in temperature. In the rotatory engine we don't have this problem because cold air and exhaust gas are always in the same part of the engine.

• Low purchase cost: Our aim is to ensure a low cost aircraft with a better engine and at a low cost.

• Compact size: the size of the engine is very important in the aeronautical field because it affects the frontal area of the aircraft.

• Simple construction: this characteristic is linked to reliability and maintainability, a less complex engine is easier to repair.

• Low cost fuel: low cost fuel reduces the cost of the aircraft mission.

In accordance with these criterias, we chose the Rotax 915is shown in Fig. 8 as a Thermal engine to work on.

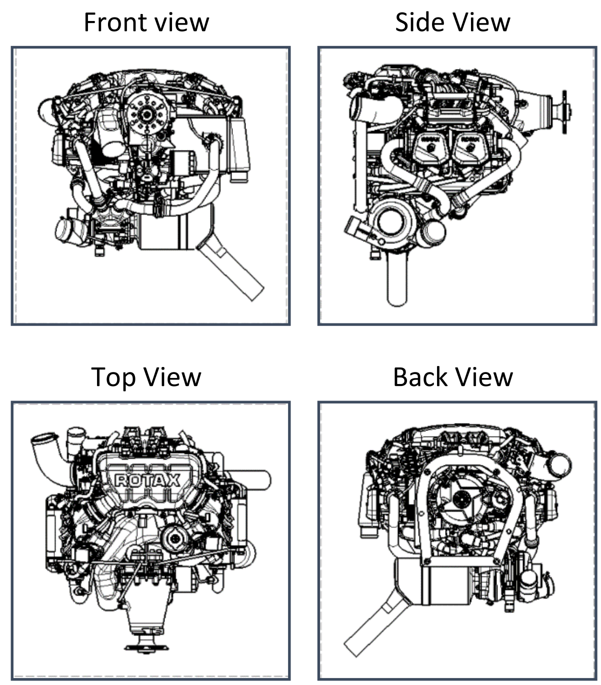

Figure 5 Different Views of the Rotax 915is

Rotax 915is a four-cylinder four-stroke, horizontally-opposed, turbocharged, air and liquid-cooled, gasoline engine design, with a mechanical gearbox reduction drive and Approved to ASTM F2339, the Standard Practice for Design and Manufacture of Reciprocating Spark Ignition Engines for Light Sport Aircraft. In addition some of his main characteristics based on 915is manual are shown in Tab. VI

Table VI

General Characteristics of Rotax 915is

Parameter	Value
Engine Speed at Idle	1 800 rpm
Engine Max. Speed	5 800 rpm
Output Speed	2300 rpm
Power-to-Weight Ratio	1.19 Kw/Kg
Take-off Performance	104 Kw
Continuous Performance	99 KW
Critical Altitude	15 000 ft
Acceleration	0.5 g
Fuel Consumption	33.92 Kg/h
Price	34018.4 €
Weight	84.6 Kg

C-Electric Engine:

An electrical motor is an electrical machine that converts mechanical energy into electrical energy. For the purpose of this project, the Rotex REB 90 will be used because it is especially designed for Electric Powered Small Aircraft (EPOS) projects.

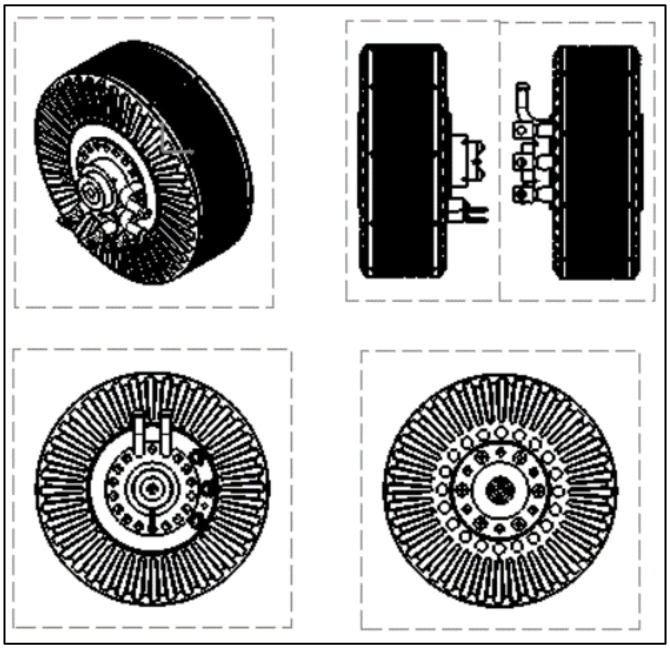

Figure 6 Rotex REB90

Some of the characteristics and performances of the motor is, that its working voltage is 310 to 360 V and can reach a maximum power of 80 Kw. In addition, this motor can rotate at a max speed of 2800 rpm as shown in the following table. Later a 100 Kw electric engine could be used.

Table VII
Characteristics & Performances Rotex REB90

Parameter	Value
Power Output	80 Kw
Power-to-weight Ratio	4 Kw/kg
Voltage	350 V
Engine Max. Speed	2 800 rpm
Length	212 mm
Diameter	270 mm
Dry Weight	22 Kg

D-Front Landing Gear:

There are two possibilities for the landing gear: either similar to a helicopter or an airplane. One of the objectives of the Mini-Bee is to be able to land in places with difficult access. This is why an Alaska Landing Gear was chosen. This Alaska landing gear) has a high damping which make it able to absorb a substantial amount of energy during hard landing and it is sold entirely manufactured by the supplier, which facilitates the assembly of the aircraft.

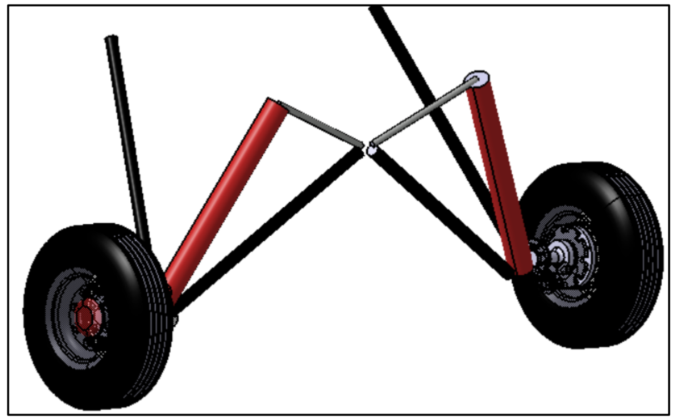

Figure 7 Alaska Landing Gear

E-Rear Landing Gear:

The Vehicle has directional rear landing gear and two rear wheels were added instead of one to prevent the tilting of the mini-Bee.

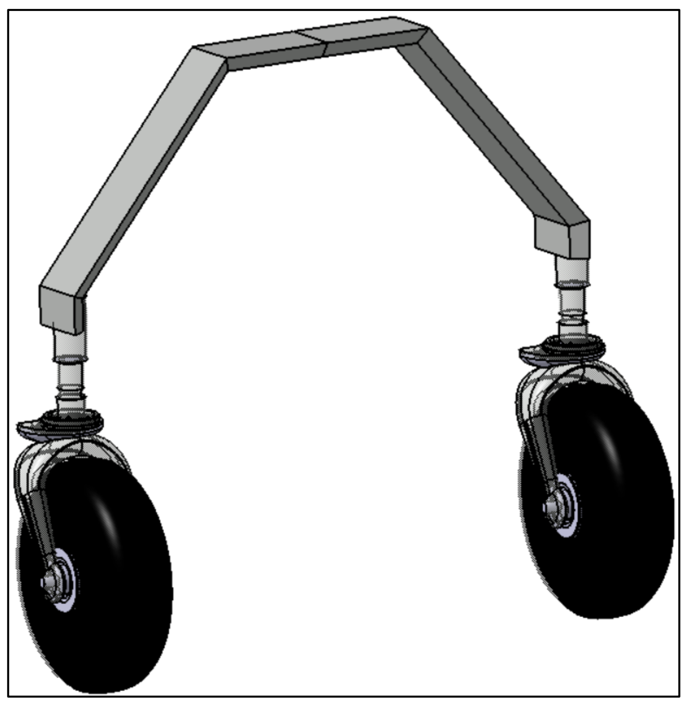

Figure 8 Cassut Landing Gear

F-Material:

The objective of the material choice for a vehicule, is to minimize the mass and cost while keeping a wide elastic range. Several aluminum offer this possibility. However, because of reasons such as weldability and fatigue behaviour our choice is limited between two aluminums: the 6061, an aluminium alloy, with magnesium and silicium as the primary alloying element and 2024 T4 series (heat-treated and naturally aged to a substantially stable condition), an aluminium alloy, with copper as the primary alloying element. As Shown in Tab. 10, aluminum 2024 T4 has a much higher strength and fatigue resistance than alumium 6061 but, aluminum 2024 T4 is poor in corosion resistance that's why it is often cladded for protection. Despite the fact that this may reduce the fatigue strength, the A6061 is easier to work with due to its mechanical properties, he is more weldable and has a higher resistance to corrosion.

Table VIII
The Physical-Mechanical Properties of Aluminum A 6061 & A 2024 T4

Properties	A 6061	A 2024 T4
Tensile Yield Strength	276 MPa	324 MPa
Ultimate Yield Strength	310 MPa	469 MPa
Modulus of Elasticity	68.9 GPa	73.1 GPa
Fatigue Strength	96.5 MPa	138 MPa
Density	2 700 Kg/m^3	2 780 Kg/m^3

G-Seats:

The seats chosen were the lightest and easiest to fix and under each seat, a shock absorber will be placed.

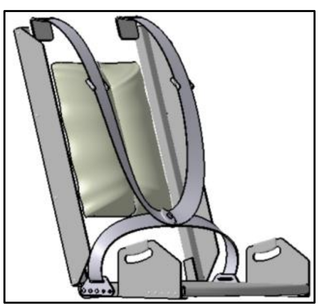

Figure 9 Seat

H-Joystick & Board Computer:

A joystick is an input device composed of a stick that pivots on a base and reports its angle or direction to the device it is controlling. It will be the only control device in the Mini-Bee.

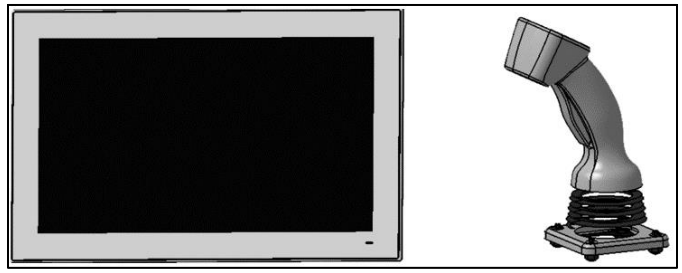

Figure 10 Board Computer & Joystick

I-Assembly:

Many problems hindered our work. The main difficulty we faced were linked to the location of the thermal engine and the location of the structure that supports the propellers. However, the height of the seats and the design of the gas tank caused a minor problem. But, all the problems were solved carefully an

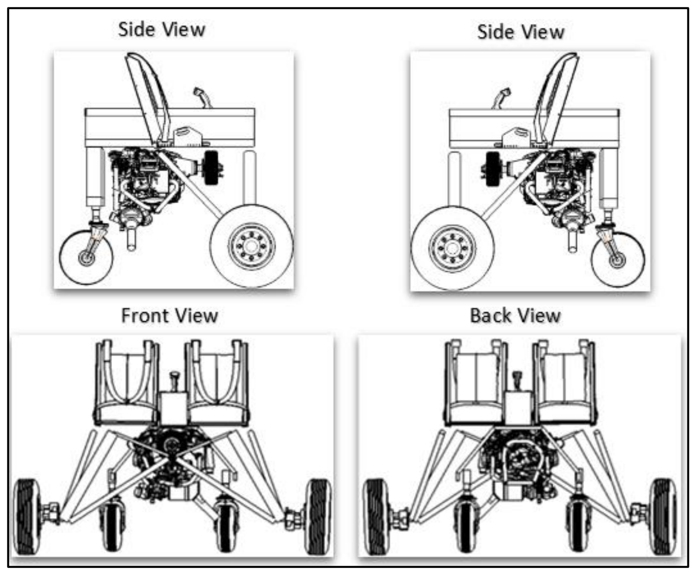

Figure 11 Assembly of the Vehicle

J-Propeller:

A study conducted by Estaca on propeller calculation lead to this point: a larger propeller surface is always the best choice to decrease the downward air flow. In our case, six propellers are available and each propeller has a radius of $S_{propeller} = \pi \times (3.4/2)^2 = 9.01\ m^2$ this makes a total of $6 \times 9.01\ m^2 = 54.47\ m^2$. Vario blade were used with a length of 1.6m and a chord of 9.3 cm.

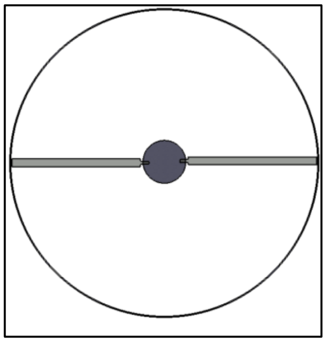

Figure 12 propeller

K-Positioning of the propellers:

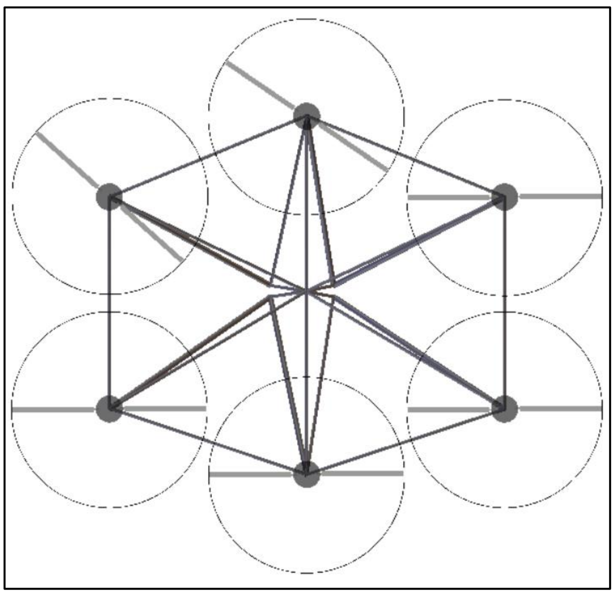

Figure 13 Top View of the Positioning of the Propellers

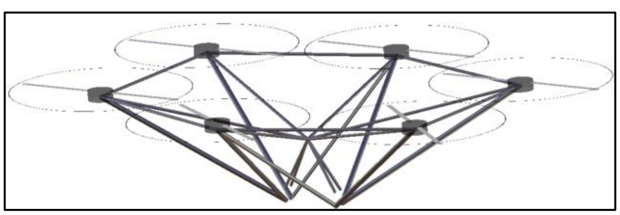

Figure 14 3D View of the Positioning of the Propellers

Numerous iterations were made on the positioning of the Propellers. Different constraints were imposed; we had to respect a minimum height of 2.75m to avoid the risk of accidents and injuries. Knowing that each propeller must have a diameter of 3.4m, the rotor surface is important in comparaison with the size of the main structure. In addition, we reflected on different heights for each rotor in order to prevent the breakage of a rotor from affecting the others. However, In order to ensure the stability and to make the structure stronger, adding a tube between each rotor was a necessity. These tubes hindered the use of different heights.

L-Center of Gravity:

The farther the center of gravity will be away from the vehicle's point of support (landing gear), the more they will be subjected to a significant moment. In other words, the position of a vehicle's center of gravity determines its stability. Hence, making the thermal engine, the center of gravity of the structure including the propeller and the center of gravity of the passengers closer to each other.

Tube Design:

The structural base shape is the connection of three members to form a triangle shape because a polygon with more than three corners is relatively elastic and does not form a stable structure. This stable structure allows us to create a stronger structure while using materials in a very efficient and cost effective way. In addition, this structure is made up of a collection of straight members joined by a pinned connection which means that the members are free to rotate at the joints.

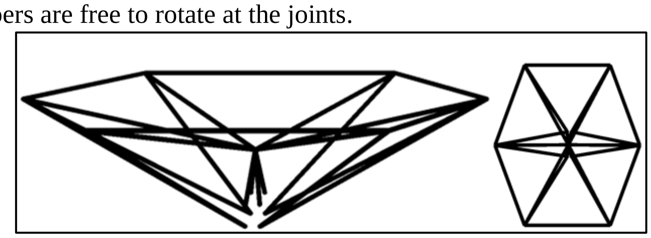

Figure 15 Different View of the Structure of the Tubes.

This picture shows how the design of the tube was made. The aim of this design is to connect the propellers to the vehicle. In addition, First tubes were used to create a Pyramid Shape (a) and then to connect the Top of the Pyramid to the Propellers (b). In addition, tubes were added to connect either a Propeller to another (d) or a Propeller to a Gas tank (c).

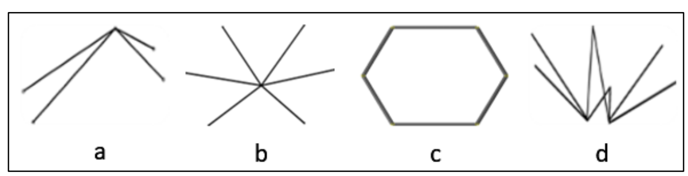

Figure 16 Different Parts Constituting the Structure Holding the propellers

Table IX
Properties of Each Tube of the Structure

Part	Quantity	Length	Radius	Thickness
(a)	6	3.87 m	20 mm	1 mm
(b)	4	4.18 m	20 mm	1 mm
	2	3.35 m	20 mm	1 mm
(c)	4	3.96 m	20 mm	1 mm
	4	3.67 m	20 mm	1 mm
(d)	4	0.91 m	20 mm	1 mm

III. Static Simulation

General Idea:

Our main objective was to design the cross section of each tube and to optimize it afterwards, either by reducing our cross section or by adding an intermediate tube allowing the distribution of the stresses concentrations and thus reducing the buckling generated. To achieve our purpose, many iterations were made. First, two static simulations were done and two cases were considered: take-off and landing. In the take-off case, the force on each propeller's center of gravity was the total weight of the vehicle divided by six and then multiplied by its acceleration which is two. While in the second case, the force taken into consideration was the self-load of each propeller multiplied by a security factor of 5g. The results of the second case showed that the tubes stresses are 35% more important than the second case. Therefore, the following work will be based on the landing case.

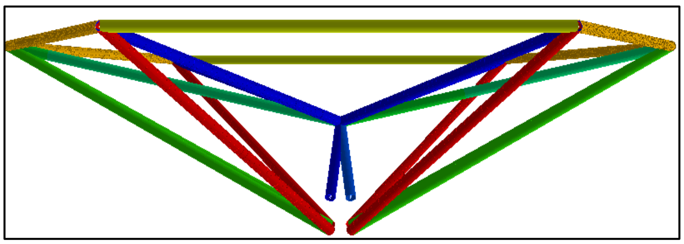

Figure 17 Stresses undergoing in each tube

In the second case, a hypothesis was taken and suggested that each tube had a similar radius and thickness in order to compare which tube was under a higher stress. This study was done using the Von Mises method. The Fig. 16 below is the result of the landing simulation. We noticed that the part (c) is under the highest stresses because this part has the longest tubes. The stresses in part (c) can be divided into two groups, the first one consist of/ is composed of a propeller connected to the vehicle with one tube which will have the highest stress. The second group is connected with two tubes which will reduce the stress by approximately 40% compared to the first group. In addition, the simulation shows that the connection of part (a) tubes with the tubes of the second group previously mentioned, have a greater displacement than the ones connected with/through the first group. For this reason, the tubes constituting part (a) and that are connected in both sides by one tube, have a lesser stress distribution than the ones connected by one tube from a side and two tubes from the other.

As the weight of the structure is significant, another simulation was made while taking into consideration the weight of the structure. Furthermore, the first few simulations were made in perfect conditions but in reality it differs due to the wind forces, the center of gravity and other external perturbation. The result of the maximum stresses acquired by each simulation will be represented in the table X.

Table X
Maximum Stresses of the Different Cases

Case	Maximum Stress
Take-off	11 MPa
Landing	15 MPa
Landing + Self Weight	23 MPa
Landing + Self Weight + Perturbation	47 MPa

To resolve the problem of the tube under a high stress/ the high stress of the tube, multiple solutions can be discussed. The following paragraph will highlight two of these solutions: the first solution is increasing the radius and/or thickness while taking into consideration that these tubes can be found in the market. The stress equation is $\sigma = \frac{F}{S} - \frac{My}{I} + \frac{Mx}{I}$, by increasing the radius the area will increase and the moment of inertia will increase because of the following formula $I = \frac{\pi(D^4 - d^4)}{64}$ which will decrease the stress knowing that M, y, x, F will remain the same. The second solution is adding an intermediate tube between the longest tubes, which will decrease the moment, the force and the buckling. Noting that the weight of the structure must not exceed 100 Kg. The maximum stress found by these simulations times a safety of factor of two must not exceed the yielding stress.

IV. Weight Estimation

This table shows the weight of the different elements of the vehicle. The propulsion is composed of different items; the first item is the thermal engine (Rotax 915is) and its real weight is 85kg. The second item is the electric generator (Rotex REB 90) with a weight of 22kg knowing that a different type might be used, the third item is the fuel tank considered as full of kerosene the weight was calculated knowing the density of the kerosene ($\rho_{\text{kerosene}} = 0.84\ \text{kg/L}$) and the volume of the fuel tank (V=82.5L) resulting in a weight of 69.5 Kg .The propellers are the fourth item and it consists of 2 varios blade of 1 Kg each and an electric engine of 5kg enabling the steering of the vario blade. Six propellers are used with a total mass of 42 Kg. The last item in this section is the electric cables with a mass of 30kg. A study conducted by the University of Esiglec showed that each propeller needs 4 cables and when we connect the cables from the electrical engine to each propeller, the estimation of the cables weight was around 12 Kg. The landing gear is composed of a front landing gear (Alaska landing gear) with a weight of 25kg and a rear landing gear (Cassut) with a weight of 20kg. In the equipment, the weight of the joystick and the board computer together, is maximum 5kg. Whereas As for the battery, it weighs 3 Kg and it's used to start the engine. The seat's weight is 7 Kg and each seat has an absorber that weighs 10 Kg. The parachute weighs 15kg and is used in case of a failure in the aircraft. In the structure, after the architectural design was made, the measures of each tube were identified, and based on the previous simulation, the radius and thickness of each tube were identified which permitted the calculation of the tubes weight: 70 Kg. Concerning the cockpit, the estimation was done according to the Ultra-Light Motorized (ULM) with an average weight of 43 Kg. In addition, an estimation was performed in order to determine the exact weight needed to fix two elements together and an average of 50 Kg was considered. Finally, the approximately weight of the passenger was estimated to be 90 Kg.

Table XI Weight Estimation

Type	Item	Weight
Propulsion	Rotax 915is	85 Kg
	Rotex REB 90	22 Kg
	Fuel Tank	75 Kg
	Propellers	42 Kg
	Cables	30 Kg
Landing Gear	Alaska	25 Kg
	Cassut	20 Kg
Equipment	Joystick	01 Kg
	Board Computer	05 Kg
	Seat	14 Kg
	Seat absorber	20 kg
	Parachute	15 Kg
	12V battery	03 Kg
Structure	Tubes	70 Kg
	Glass cockpit	08 Kg
	Cockpit	35 Kg
	Fixation	50 Kg
Payload	Pilot	90 Kg
	Passenger	90 Kg
Total		700 Kg

Finally, CS-27 stipulate an increase of 5% on the total weight of the vehicle, which lead to a mass of 735 Kg.

V. Conclusion

A-General Idea:

In conclusion, the Mini-Bee composed of one Rotax 915is engines, six propellers and two Passengers known as R1H6P2 and categorized as an Ultra-Light Motorized UML, is a prototype hybrid vehicle with the ability to revolutionize the manner in which personal and low-cost aviation operates and has features such as Vertical Take-Off and Landing. Furthermore, the vehicle is characterized by a range of 700 km, with a high cruise speed of 200 Km/h and an altitude of 14 000 ft.

B-Main Objective:

The studies carried out, emphasized on the elimination of empty weight and aircraft prices. Thus, the reduction of structural weight is essential in order to improve the aircraft performance. However, the choice of lighter materials ensure a greater range, speed and may reduce operating costs.

C-The Purpose of this Article:

This article is a continuity of other articles' work, the main part of this article was the architectural design of each part and specifically how the elements should be assembled. Finally, the most important part was to make a static study for the propellers' structure in order to determine the tubes' design.

D-What Remains to be done:

The vibration analyses, the fuselage and the fixation are three things that should ulterior be done. In the following, an explanation will be given on each concept.

1-Vibration analysis:

First of all, the modal vectors of the structure should be determined using ABAQUS step frequency. Then, a study on the engine start-up impact will be conducted. For this aim, a dynamic explicit step will be used in order to have a lighter simulation and in particular, because we will be dealing with a fast transient regime. Afterwards, a rotational speed will be applied at a reference point which represents the center of mass of the engine. Knowing that the amplitude of the applied rotational speed is the response to a first order function representing the engine start-up.

2- Fuselage:

The position of the pilot is a crucial factor that determines the layout of the fuselage. Several laws govern the visibility that the pilot must be able to ensure. Obviously, this affects the shape of the nose of the fuselage, and in our case, it affects also the location of the electric propellers that do not obstruct the view of the pilot under any circumstances. It is also very important to conduct a study on the correct posture of the pilot and the space he needs.

3- Fixation:

In order to connect each two elements and to determine the exact dimensions and shape, a static simulation should be used.

Finally after finishing the R1H6P2 prototype, the R2H10P4 model should be done. The aim of this model is to create a flying ambulance to carry the sick person in areas with difficult access.

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