FIRNAS COMET Y4

DESIGN JUSTIFICATIONS

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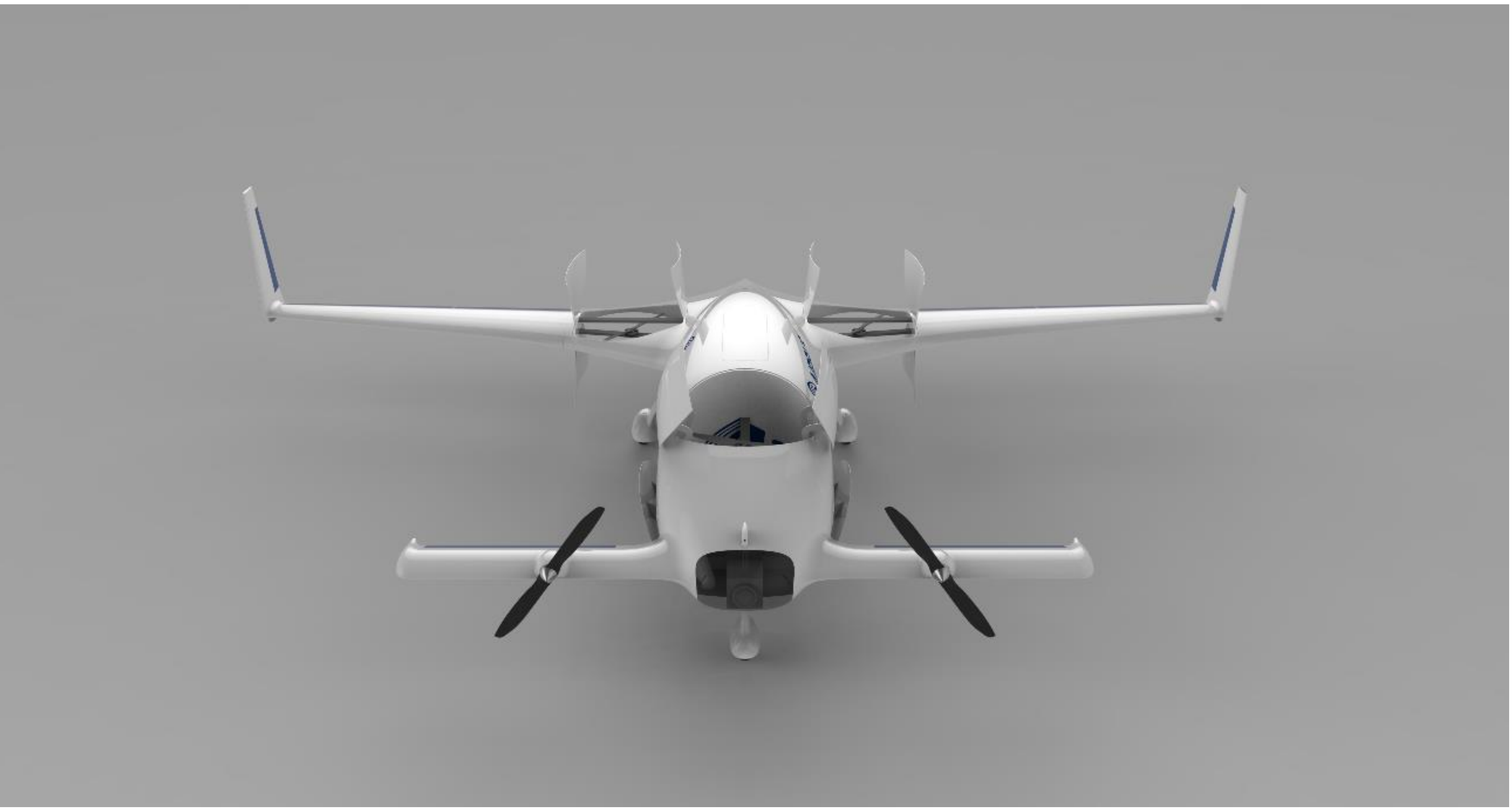


BASIC CONFIGURATION

- **Canard Design.** The UAV has a typical canard configuration, with a small forewing which will provide enough pitch control and stability. Two motors mounted over these canards will provide the forward thrust. This location of the motors has the advantage of a clean and undisturbed flow faced by the propellers, increasing thereby the efficiency during forward flight.

- **Slightly swept-back wings**. In order to move backward the centre of pressure of the wings, they present a slightly swept-back configuration. Furthermore, the airfoil "Nasa LS(1)-017" has been chosen as the wing profile for the same reason (as well as other beneficial aerodynamic performances at low Reynolds numbers). Typical ailerons and flaps are installed near the wingtips for roll controllability and better landing and take-off performance.

- **Conventional winglet.** They are located at the end of each wing obtaining both, directional stability and increased efficiency (reducing induced drag). The shape and wetted area has been optimized for directional stability.

- **VTOL/STOVL capabilities.** As indicated in the requirements, the UAV presents different motors for hovering than the ones used for forward flight. The VTOL capabilities are provided thanks to the installation of a Y4 copter design, with a coaxial propeller configuration.

  The biggest percentage of the flight mission is meant for be during forward flight, so care must be taken to maintain a low drag coefficient. This is the reason why all the propellers have been place inside the fuselage and wings, with access doors that will be open only when necessary during hovering. CFD simulations of different configuration has been performed, showing that an uncovered hole in the middle of the fuselage will cause an increment in drag completely unacceptable. Similar results are expected for uncovered / unprotected propellers, due to the turbulence generated and the increase in frontal area. The rear motors are also protected inside the wing platform, without increasing the frontal area of the plane.

- **Landing Gear.** A typical tricycle landing gear will allow the plane to take off in a conventional way, with the advantage of shortening the runway if the VTOL motors are running at the same time during take-off (calculations will be made in further stages of the design).m^2

The following table shows some of the most important geometry data of the drone:

Wingspan, b [m]	3.89
Wing Surface, S [m^2]	1.27
Aspect Ratio	11.9
Wing Airfoil	LS(1)-017
Canard Profile	GA(W)-1
Canard Surface	0.25
Wing incidence [°]	0
Canard incidence [°]	4
Wing loading [kg/m^2]	19,69
Front Propeller Diameter [inches]	16
Front Propeller Diameter [m]	0.406
Front Propellers Area (2 propellers) [m^2]	0.228
Rear Propeller Diameter [inches]	16
Rear Propeller Diameter [m]	0.406
Rear Propellers Area (2 propellers) [m^2]	0.228
Disc Loading [kg/m^2]	48.28
Fuselage Length [m]	2.43
Fuselage Max. Diameter	0,543
MAC	0,506

AERODYNAMICS

Several CFD simulations have been done in order to achieve the most efficient design. Previous simulations showed, as mentioned before, that the drag coefficient associated with non-protected propellers will cause a significant increase in the drag coefficient, making even impossible to achieve the mission requirements with a drone under 25 kilograms.

For this reason, the current design presents all the propellers protected and inside the fuselage/wings during forward flight. Thanks to this, and to an overall really clean design, it has been possible to obtain outstanding aerodynamic performances.

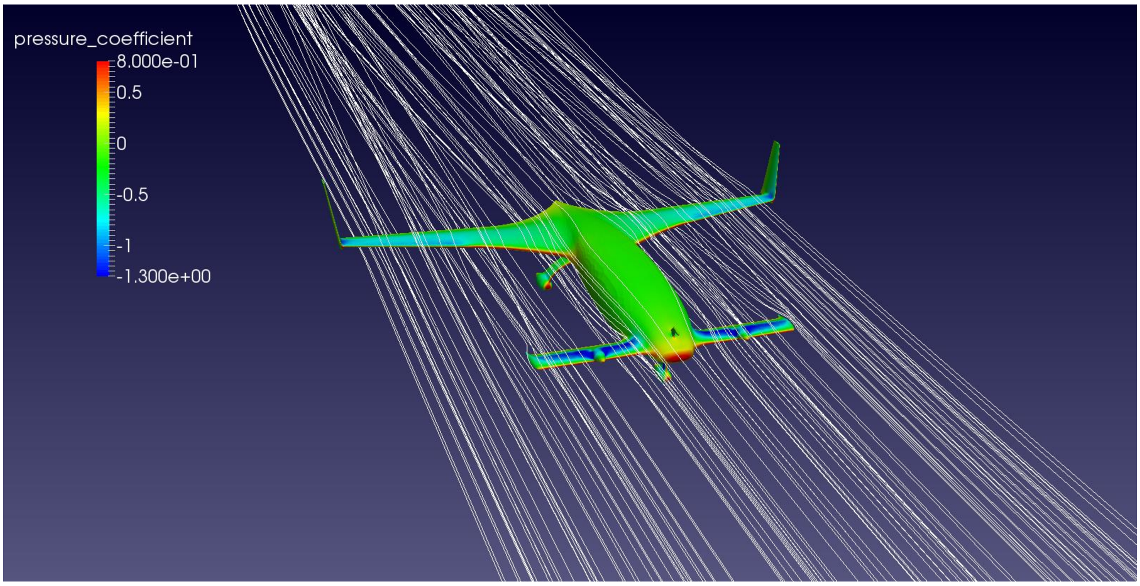


Figure 1: Pressure Coefficient and Stream-lines around *Firnas Comet Y4.*

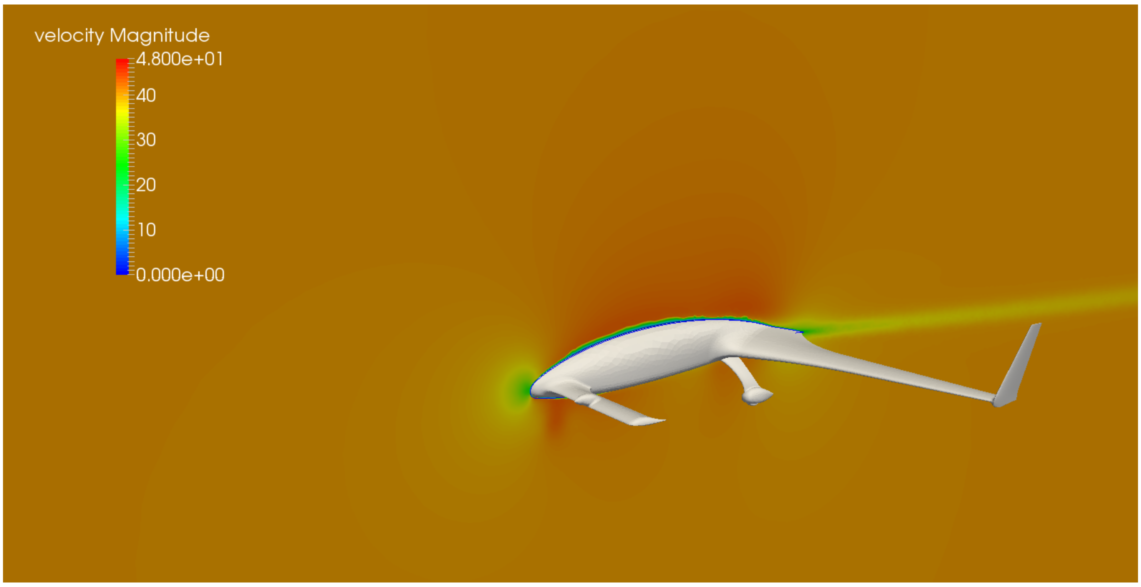


Figure 2: Velocity Contours in the Symmetry Plane.

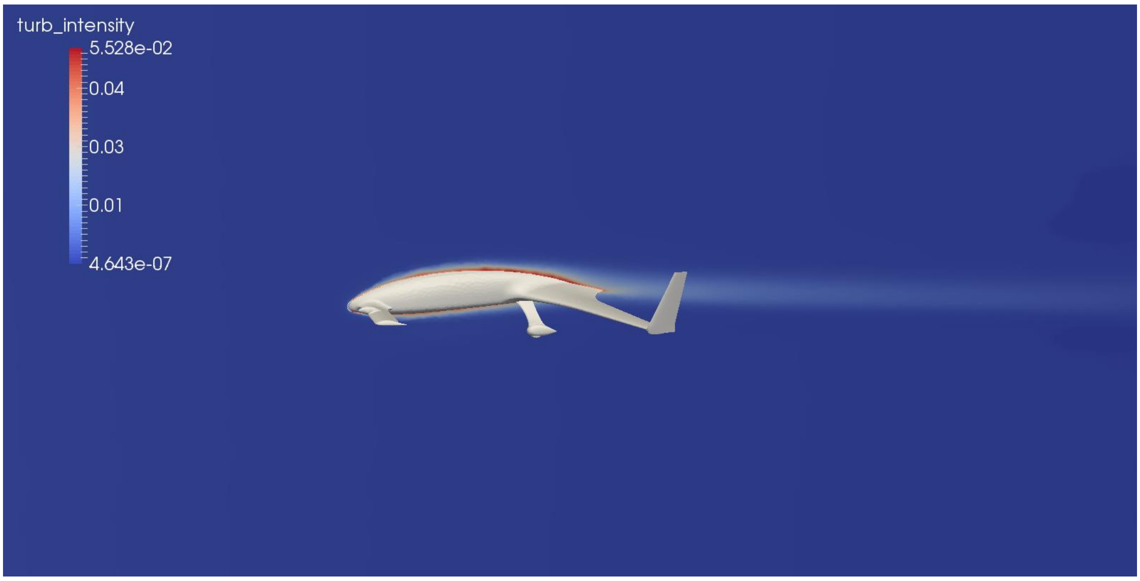


Figure 3: Turbulence Intensity.

As it can be seen in the previous pictures, during forward flight the drone has a very small disturbance over the incoming air, resulting in a really low drag coefficient. After several iterations at different angles of attack, the following drag polar has been obtained:

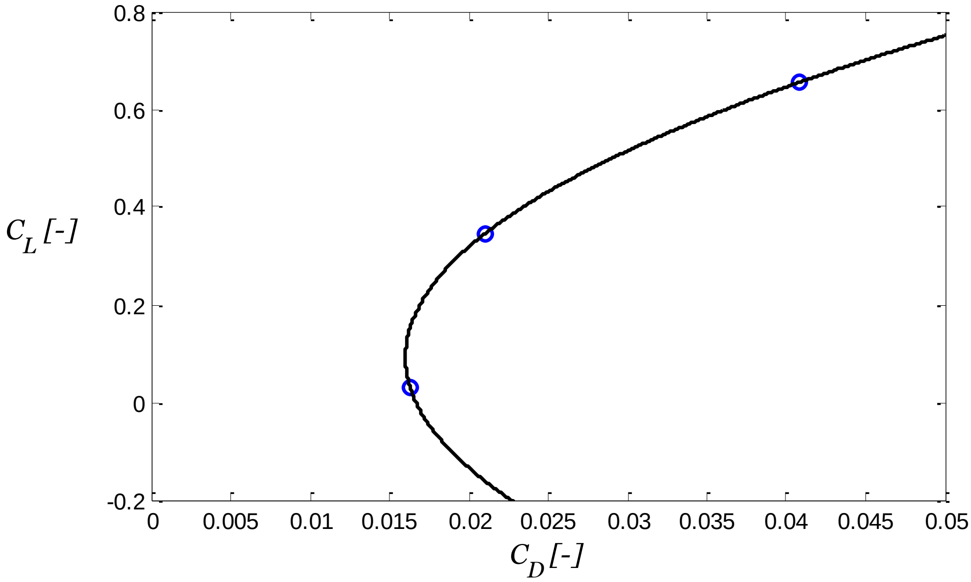


Figure 4: Drag Polar during Forward Flight

Obtaining $C_{D0} = 0.016$, which is a really low drag coefficient.

Regarding the efficiency, it is shown in the following picture:

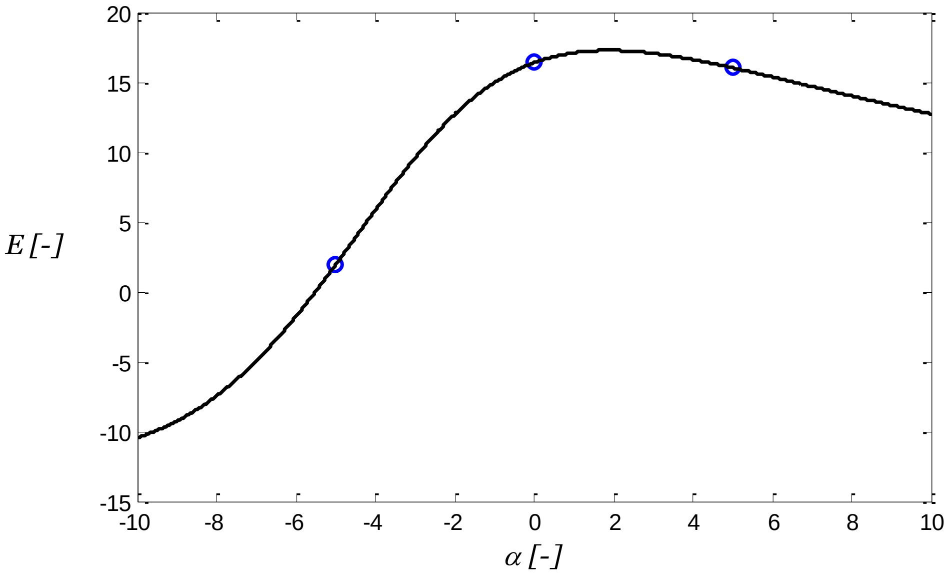


Figure 5: Efficiency vs angle of attack.

The maximum efficiency has a value of 17.27 at an angle of attack of 1.9°**.** This values where carefully selected in order to obtain the maximum efficiency during forward flight.
In the following figure it can be seen the required thrust during forward flight at different velocities:

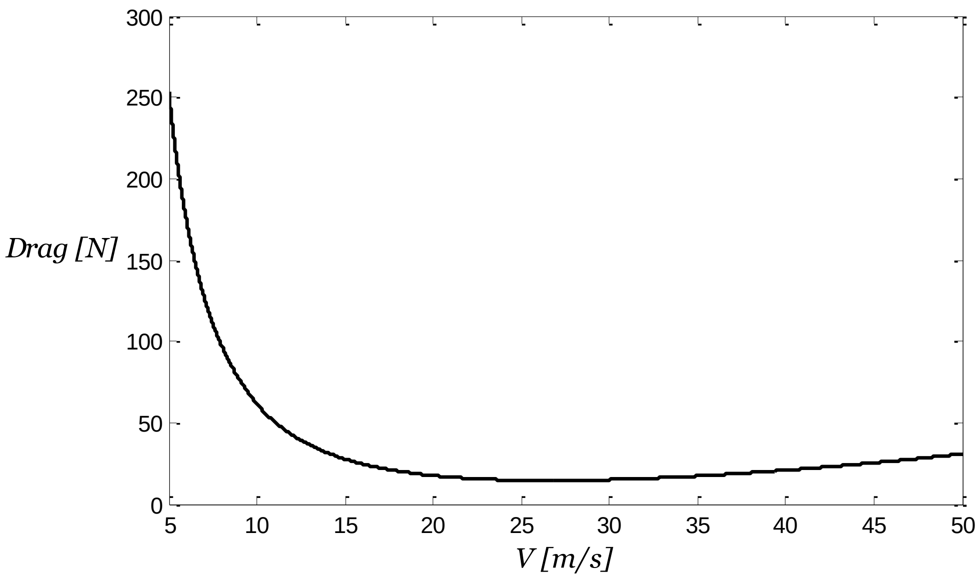


Figure 6: Drag / Thrust needed during forward flight.

At 40 m/s (cruise speed), a total thrust of 20.75 N is needed. Dividing this needed thrust between the two motors, we obtain a needed thrust per motor of 10.75 N.

The propeller diameter and pitch has been carefully chosen in order to achieve the maximum performance of both (engine and propeller) at 40 m/s cruise speed. The chosen engine should have the following properties, which can be found easily in the market:

KV	300
Weight [grs.]	1.27
i_{max} $[A]$	60
Internal Resistence, R	0.04

Table 2: Motor Properties

Regarding the propeller, a 20x16 APC has been chosen. Its properties are shown in the following figures:

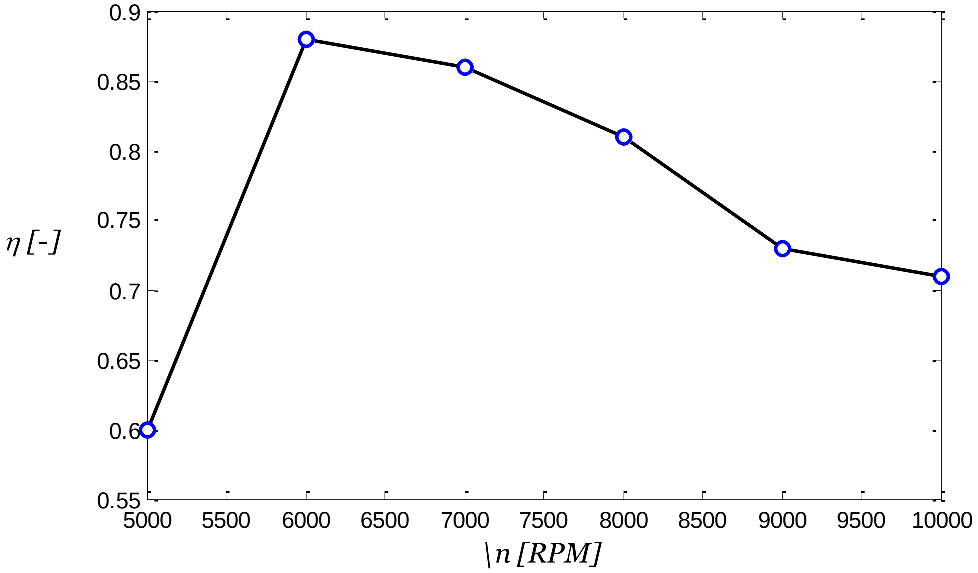


Figure 7: Propeller efficiency vs RPM

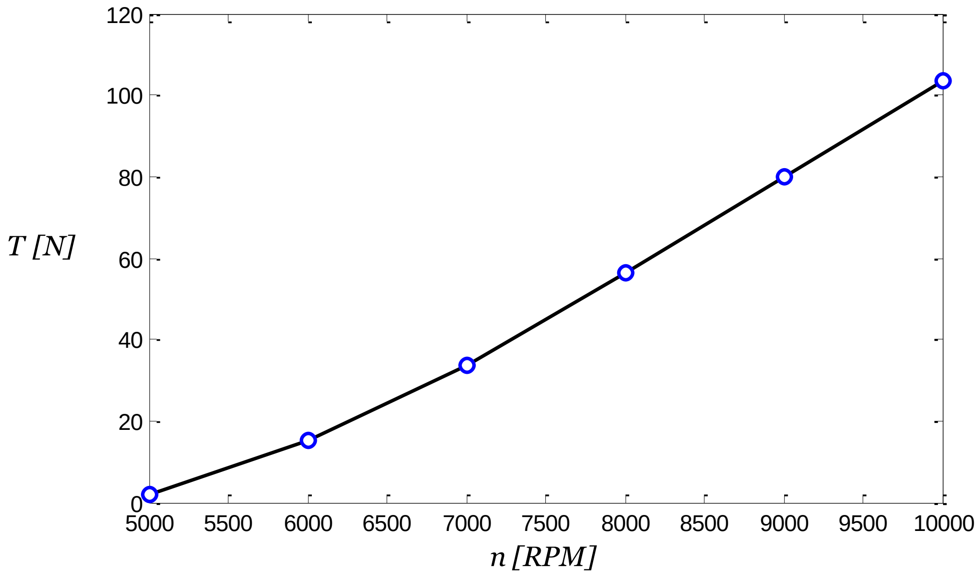


Figure 8: Propeller Thrust vs RPM

The chosen propeller will have an efficiency of 0.88 at cruise speed, operating at approximately 6000 RPM and 40 m/s. The selected motor will have to give the needed power in order to maintain the propeller spinning at that RPM and speed. To evaluate this performance, a general torque matching method have been used:

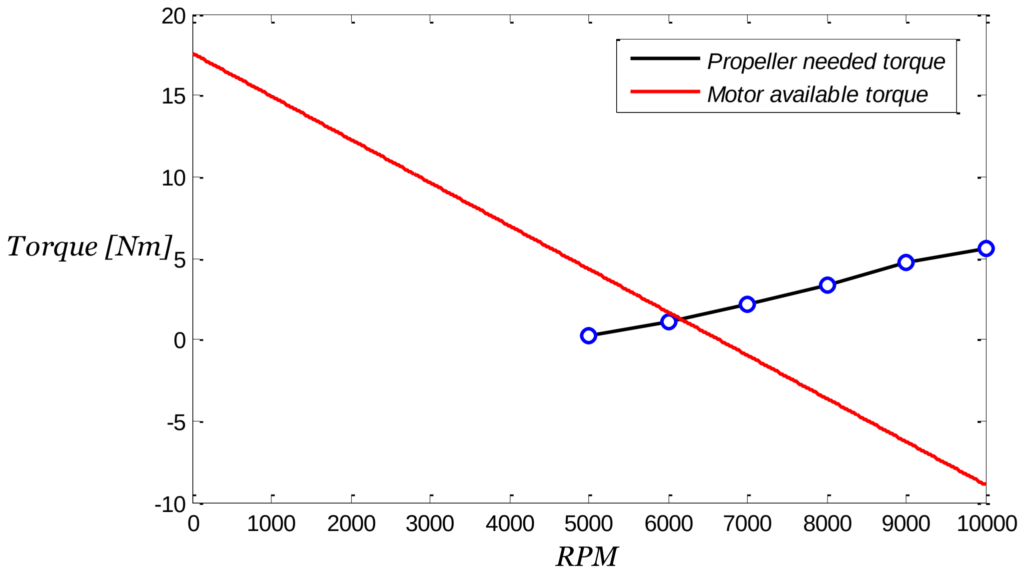


Figure 9: Available torque vs needed torque.

The torque match takes place, as it can be seen, at approximately 6000 RPM. Furthermore, the engine efficiency can be plotted versus the RPM:

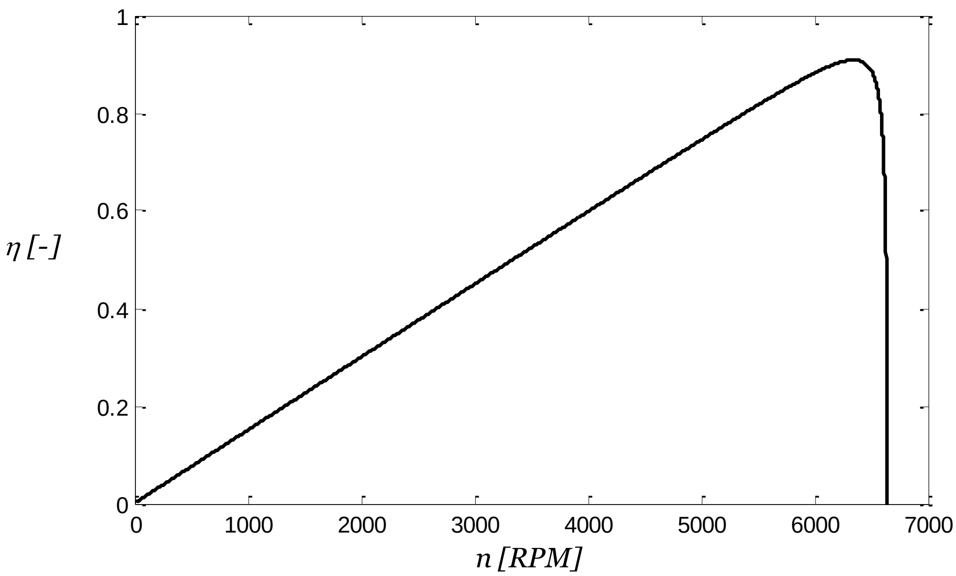


Figure 9: Engine Efficiency vs RPM

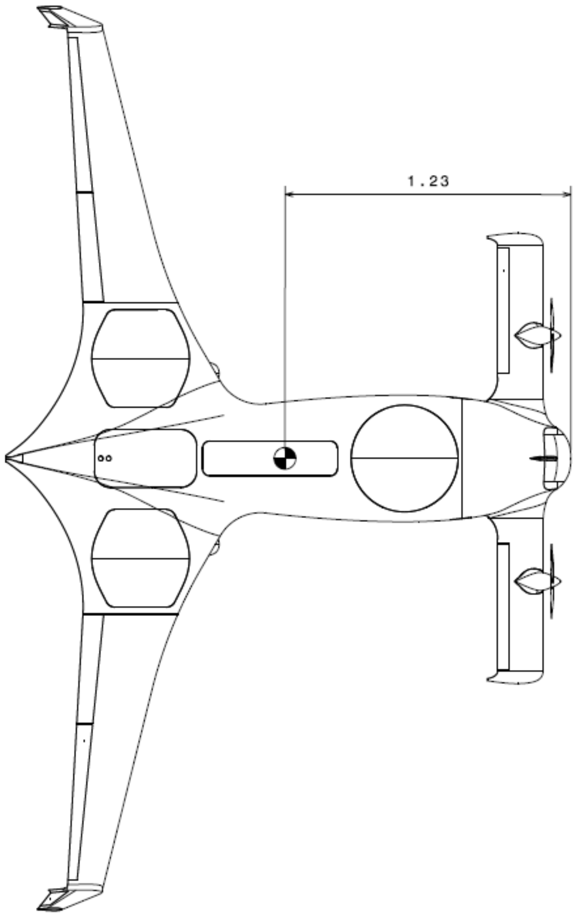
Obtaining an engine efficiency of 0.91 at the selected speed.

WEIGHT AND BALANCE

The following table shows the weight of the different parts of the structure:

Component	**Weight [Kg]**	**Quantity**	**Sub-total [Kg]**
Flight Contol computer	0,58	1	0,58
IMU	0,0575	1	0,0575
ADS-B Transponder	0,115	1	0,115
Antennas and external mounted Systems	0,13	1	0,13
Flight Termination Parachute	1,02	1	1,02
Flight Termination Launcher	0,18055	1	0,18055
Camera System	0,483	1	0,483
Communication System	0,575	1	0,575
Air Data System	0,1265	1	0,1265
Adittional Wiring Mass	0,5	1	0,5
Wing Assembly	0,615	2	1,23
Main Landing Gear	0,753	1	0,753
Front Landing Gear	0,323	1	0,323
Canard Assembly (without motor)	0,383	2	0,766
Nose Cone (without payload)	0,445	1	0,445
Fuselage skin	0,781	1	0,781
Fuselage Structure	0,932	1	0,932
Rear Lift Motors	0,36	2	0,72
Front Lift Motors	0,36	2	0,72
Forward Motors	0,36	2	0,72
Servos	0,08	20	1,6
Payload	3	1	3
Batteries	4,32	2	8,64
Total			**24,39**

Regarding the gravity centre, it has been calculated using a CAD software. The location reported shows that it is located in the right place in order to make the drone stable in both, forward flight and hovering.



The static margin can be calculated as follow:

$$SM = \frac{x_{AC} - x_{cg}}{MAC} * 100 = \frac{0.093}{0.506} * 100 = 18.38\ \%$$

$$c_{m\alpha} = -0.71$$

Note: In a canard configuration, normally is expected a higher Static Margin.