

TACTICAL UNMANNED AERIAL VEHICLE SIZING

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Abstract:

During the last 8 years, Nostromo Defensa S.A has been developing low cost solutions for small aerial targets and UAS. These aerial vehicles have been designed, produced, tested and fielded for a variety of applications. The experience gained during this process allow to the engineering team in the last two years, to produce some innovative concepts for tactical UAVs, some of them already developed, produced, tested as well as fielded. The design team also has in development other concepts for small tactical UAS, with dedicated applications for Special Forces and fast deployment. All the Nostromo UAVs are based in the concept of a family, which means that one baseline configuration is being used and adapted to fulfill the requirements of the customers and users. During the conceptual stage of the UAV, a fast assessment of the configurations under study is needed, so a preliminary sizing procedure suitable for small tactical UAV was developed and is presented here.

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**1. Nostromo Defensa Aerial Targets and UAV Development History and UAV Family Concept**

Nostromo started the development of unmanned systems in 1999, due to a requirement of the Argentina Navy for a low cost aerial target for anti-aircraft guns and ground to air missile training. The first aerial target developed was the Vampiro (Fig 1).



Fig 1 Low cost aerial target Vampiro Mk1



Fig 2 Low cost aerial target Vampiro Mk3

The Vampiro Mk3 was used as platform to fly as an experimental UAV. This vehicle was the first UAV flying in Argentina as a private development.

Since this development stage, several prototypes and series production UAVs have been designed, integrated and produced, being the tactical field the center of gravity of the development effort. The driven concept for this development effort is the so-called "Configuration Family", which means that a basic configuration has been adopted, and all the experience gained in that basic configuration is applied to adapt it to the operational requirements of the UAV being designed (Fig 3).

During the process of analyzing operational requirements and generate from them, the technical requirements, the design team requires some fast analysis method to generate options for the concept to exploit as well as to assess the potential competitors capabilities.

A fast tactical UAV sizing method is one of the answers to the above need. In the next paragraph, a simple sizing method for small tactical UAV is described.



## 2. Small Tactical UAV Sizing Method

The sizing presented in this paper for small tactical UAV is very useful for initial estimate of the main parameters of any UAV system.

The method is based in correlation of statistical data and basic performances relationships.

The original method was developed in Ref (1) , for four strokes internal combustion engines and it has been extended for two strokes engines as well as electrical powered UAV.

A brief discussion will presented and some results also will be displayed to asses the method capability.

### 2.1 Basic Relationships

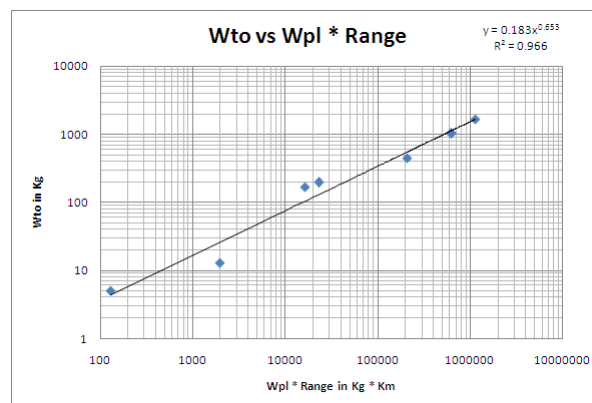
The basis for the calculations is to assume the following parameters as input from the designer. The original work of Ref (1) , was done for 4 strokes gas engines, we include our correlations for 2 strokes gas engines:

Range (Km) – R

Take-off weight (Kg) Wto

Endurance speed (Kph)

### Take -off weight Correlation



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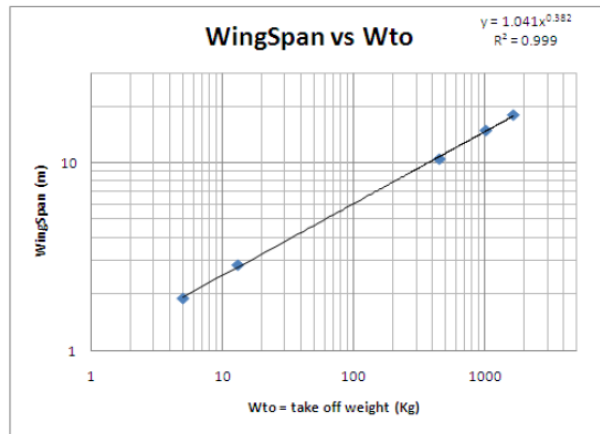
$$W_{To} = 0.183 * (\text{Range (Km)} * W_{\text{Payload}})^{0.653} = [\text{Kg}] \quad (\text{4 strokes gas engine})$$

$$W_{To} = 0.175 * (\text{Range (Km)} * W_{\text{Payload}})^{0.653} = [\text{Kg}] \quad (\text{2 strokes gas engine})$$

- WTo = takeoff weight in Kg
- WPayload = payload weight in Kg
- Range in Km

**Wingspan**

The correlation is based on the wingspan (m) vs the Wto (Kg) using several representative UAV data.



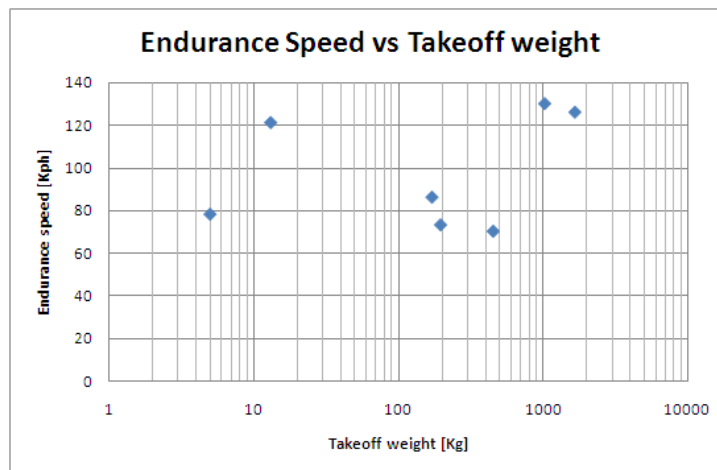
$$\text{WingSpan} = 1.041 * W_{To}^{0.382} = [\text{m}] \quad (\text{valid for 2 and 4 strokes})$$

**UAV Length**

The correlation is:

$$\text{Length} = \text{WingSpan} / 1.775 = [\text{m}]$$

**Endurance Speed**



In this case the scatter of the data does not allow producing a simple relationship, for more of the small tactical UAV of interest, the endurance speed can be assumed as

endurance speed = Vendure= 100 Kph

However the endurance speed can be set as input in the sizing method if the designer wants to see the sensibility of the design being made to the endurance speed.

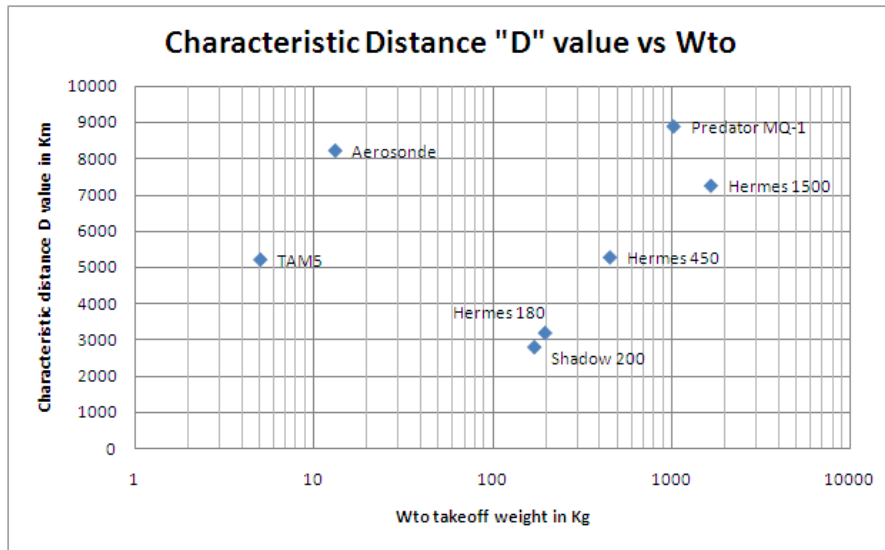
**Weight of fuel**

For a flight at constant speed, we have assumed the power required to keep the plane moving is directly proportional to the total weight of the plane, which decreases in a non-linear manner with time as the fuel is used up.

The weight of the plane at a distance = x is given by  $W(x) = W_{to} * \exp(-x / D)$ , where  $W_{to}$  is the take-off weight of the plane, and D is a figure-of-merit for the plane we call the "characteristic distance". Through a simple integration, it can be shown that:

$$D = R / \ln (W_{to} / W_{nf})$$

where R is the range,  $W_{to}$  is the take off weight and  $W_{nf}$  is the weight of the plane with no fuel on board. For simplicity, it is assumed that at the end of the UAV flying a distance = R, there is no fuel left on the UAV.



Above is a plot of D figure-of-merit values for several well known UAVs. There is quite a spread.

The higher the D value, the more efficient the UAV. The Characteristic Distance "D" figure-of-merit value, or efficiency measure, for the UAV, is the distance the UAV flies per Kg of total, time dependent (since the UAV gets lighter as it uses up the fuel), aircraft weight, per Kg of fuel used.

We made some numerical investigations about this parameter to produce some guidelines for the method, using different Characteristic Distance, to match the actual values of the parameters for different UAVs configuration. This numerical investigation gives us the following guidelines, which should be D for typical UAV configurations (Table 1)

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This parameter is used as input in the sizing method according to the UAV configuration type UAV TYPE	MANUFACTURER	Characteristic Distance – D (Km)
SCAN EAGLE	BOEING (USA)	7500
AEROSONDE	AAI (USA)	8100
LUNA	EZT (GERMANY)	5000
YARARA	NOSTROMO (ARGENTINA)	5300
SILVER FOX	ADVANCED CERAMIC (USA)	5400
MANTA	ADVANCED CERAMIC (USA)	5800

Table 1

Inverting the above relationship, the weight of the fuel = Wf from is calculated as:

$$\text{weight of fuel} = W_f = W_{to} * ( 1 - \exp( - \text{Range} / D ) ) = [\text{Kg}]$$

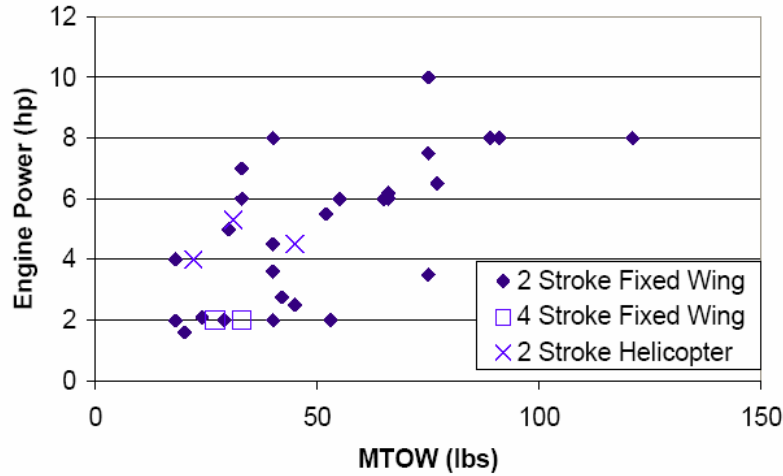
**Engine power**



Maximum engine power =  $P_{eng\ max} = 0.169 * W_{to}^{0.927} = [Watts]$

$W_{to}$  = the takeoff weight in Kg

The correlation of Ref (1) has been updated with data from Ref (2)

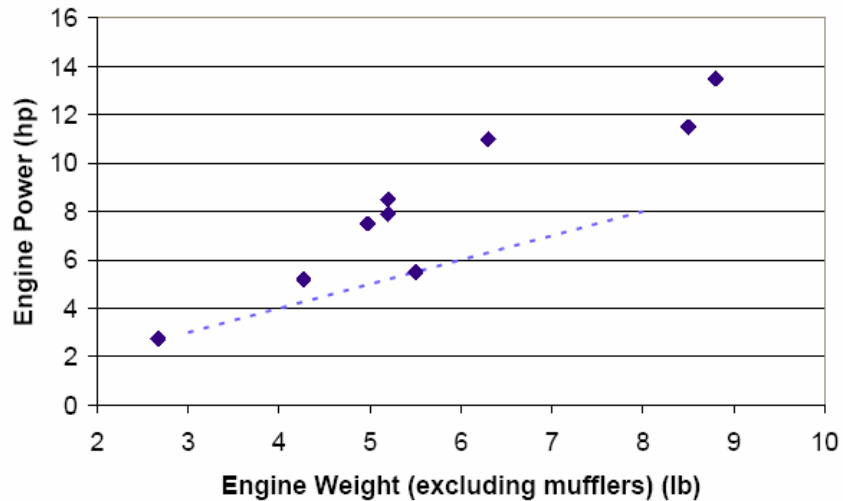


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#### Engine weight

- For a 4 stroke engine, the power-to-weight ratio =  $R_{ptw} = 1.814 \text{ KW / Kg}$
- For a 2 stroke engine, the power-to-weight ratio =  $R_{ptw} = 2.418 \text{ KW / Kg}$

The correlation for 2 strokes has been tested using the following data Ref (2) :



Gasoline 2-stroke Power to Weight  
 Source: www.3w.modelmotors.com

#### Airframe weight

airframe + avionics weight =  $W_{af} = W_{to} - W_{pl} - W_f - W_{eng} = [Kg]$

Note: The airframe weight includes the weight of the avionics.

**3. Testing the Sizing Method**

Many examples have been used to test the sizing method described in this paper, for most of the examples the sizing prediction is very good compared with the real UAV under analysis.

However the sizing method requires some experience in the designer, mainly regarding to the appreciation of the kind of UAV configuration on his mind. The table presented before gave a good idea about this. An aerodynamic clean configuration, with no landing gear and efficient integration of the engine, propeller and low fuel consumption engine will required a large characteristic distance D as input, while a more "rustic" UAV will exhibit a smaller D.

Nevertheless there are many other performances characteristics that are strong linked to the mission to performed which can not well described in the sizing method , such as the need for high climb rates or high cruise speed . Those factors shall be taken into account by the designer when the sizing method is applied. This sizing method for 2 and 4 strokes gas engine has been also extended to electrical powered UAV, giving similar results regarding prediction quality.

The complete set of correlations is now being integrated in more complex software for quick assessment of small tactical UAVs including more variables as well as with an optimization procedure.

**Some examples using the Sizing Method**



Scan Eagle	Actual Values	Predicted (Sizing Method)
Wto	18 Kg	19.2 Kg
Span	3.22 meters	3.1 meters
Waf	12 Kg	13 Kg



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LUNA	Actual Values	Predicted (Sizing Method)
Wto	30 Kg	29.2 Kg
Span	4.17 meters	3.85 meters
Engine Power (Hp)	6.75	6.2



YARARA	Actual Values	Predicted (Sizing Method)
Wto	25 Kg	26.1 Kg
Span	4.0 meters	3.78 meters
Engine Power (Hp)	5.5	5.1

**References :**

1. BARNARD MICROSYSTEMS LIMITED. UAV Design Guidelines

<http://www.barnardmicrosystems.com/>

2 .Mason Brian "Operation of a Rotating Cylinder Valve 4-stroke Engine on Heavy for UAV Applications. Presentation at AUVERSI 2007 – RCV Engines Ltd. UK