

# Design of a Three Surfaces R/C Aircraft Model

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*Design of a three lifting surfaces radio-controlled model has been carried out at Dipartimento di Progettazione Aeronautica (DPA) by the authors in the last year. The model is intended to be a UAV prototype and is now under construction. The main goal of this small aircraft's design is to check the influence of the canard surface on the aircraft's aerodynamic characteristics and flight behavior, especially at high angles of attack. The aircraft model is also intended to be a flying platform to test sensors, measurement and acquisition systems for research purposes and a valid and low-cost teaching instrument for flight dynamics and flight maneuvering. The aircraft has been designed to fly with and without canard, and all problems relative to aircraft balance and stability have been carefully analyzed and solved. The innovative configuration and the mixed wooden-composite material structure has been obtained with very simple shapes and all the design is focused on realizing a low-cost model.*

*A complete aerodynamic analysis of the configuration up to high angles of attack and a preliminary aircraft stability and performance prediction will be presented.*

*Keywords: three surfaces, tri-surfaces, canard, R/C model, design, aerodynamic analysis, performance, stability, upwash, downwash, propeller, wind tunnel test.*

## 1 Introduction

In the last twenty years canard configurations have become more and more usual, especially for light and very light aircraft. After the Wrights' first flying machines, the revival of canard configuration on classical "backward-built" airplanes has been pushed by experimental aircraft and by the evolution of the numerical and experimental tools necessary to accomplish the design of this type of configuration. Some aircraft, such as Burt Rutan's famous designs like VariEZ and LongEZ, Boomerang and Defiant, have contributed with their commercial success to the success of canard configuration's. A canard configuration is characterized by positive features (i.e., reduced wing area and aircraft drag), but cannot always comply to the control and stability requirements for all c.g. range and for every flight condition, unless an artificial stability augments system is installed, but this would be a difficult task for small aircraft.

Some authors [1, 2] have shown through detailed analysis advantages and disadvantages of canard configuration on classical aft-tailed configurations.

The best compromise is to add a small horizontal surface behind the wing to compensate the reduction of the aircraft stability due to the presence of the canard surface, and so to adopt a three lifting surfaces (TLS) configuration.

One of the major advantages of the 3LS configuration derives from the added flexibility in selecting the aircraft geometry for what concerns the payload/wing/fuselage relative position, due to the possibility of complying with control & stability requirements for a larger range of c.g. position. Some authors [3] have written papers on theoretical minimum induced drag of TLS airplanes in trim. The other significant advantage of 3LS configuration is the reduction of the total lifting area required to fly, with consequent reduction of total wetted area and aerodynamic drag.

The 3LS configuration has been adopted in the design of some light and commuter aircraft (Eagle 150, Molniya-1, Etruria E-180) and for the well known Piaggio P180 (the only

modern transport aircraft with the 3LS configuration) in recent years and there is growing interest in this innovative configuration.

Design of a three lifting surfaces radio-controlled model has been carried out at Dipartimento di Progettazione Aeronautica (DPA) by the authors in the last year. The model is intended to be a UAV prototype, and is now under construction. A 3-view of the model is shown in Fig. 1, and Table 1 reports all the main dimensions, characteristics and weights. The maximum take-off weight is about 15 kg with a payload of about 4.0 kg and about 1 l of fuel. Smrcek et al [4] and Ostowari et al [5] have investigated, through numerical and wind-tunnel tests, the effect of canard and its position on global aerodynamic coefficients.

Our R/C model has been designed mainly to test the influence of the canard surface on aircraft aerodynamic characteristics, static and dynamic stability and flying qualities at high angles of attack. To this purpose the model has been designed with the goal of flying with and without canard, and so the areas of the lifting surfaces are not optimized. Through the shift of the payload (batteries, acquisition systems and sensors) and fuel it will be possible to modify the c.g. position between 5 and 30 % of the wing chord to fly with the same static stability margin (SSM) with and without canard.

Another very important solid motivation for the project is that the model should be a low-cost flying platform to test all sensors and acquisition and measurement systems (for both flight parameter analysis and external monitoring, i.e., climatic and ground control). As final but not negligible advantage, the small aircraft can be an easy, low-cost system for teaching purposes (in particular useful for flight dynamics and flight maneuver reproduction and analysis).

The model has been built in glass-fiber composite material with a wooden fuselage frame and wing ribs to reduce the empty weight and to have a clean and well finished wetted surface. The fuselage shape and the lifting surfaces planform (see again Fig. 1) have been chosen in order to have very simple and economical constructive solutions. The fuselage has

Table 1

Dimensions		Weights	
wing area	0.95 m <sup>2</sup>	Empty structural weight	8.30 kg
wing span	2.50 m	Payload and fuel weight	4.50 kg
wing chord	0.38 m	Engine (3.5 hp) weight	<u>1.80 kg</u>
canard span	0.90 m		
canard chord	0.14 m	Max TO weight	W <sub>TO</sub> 14.60 kg
canard area	0.13 m <sup>2</sup>		
fuselage length	2.00 m		
fuselage diam.	0.20 m		
horiz. tail area	0.20 m <sup>2</sup>		
horiz. tail chord	0.18 m (movable part 44 % of chord)		
tot vert. tail area	0.13 m <sup>2</sup>		

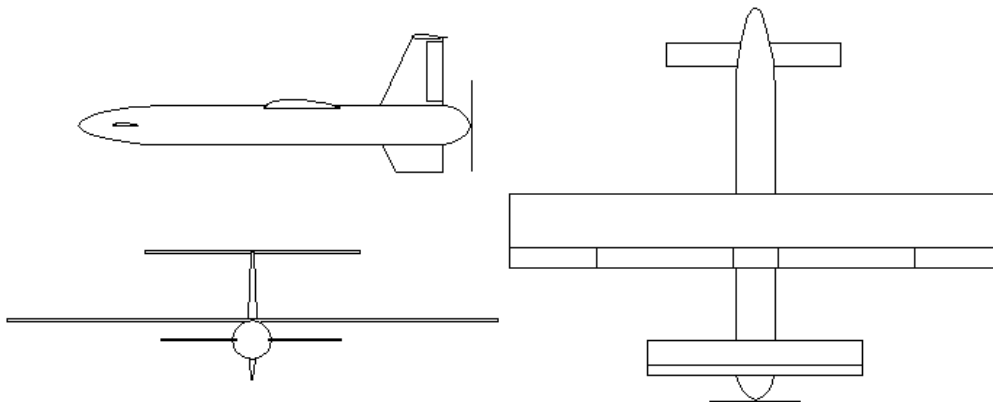


Fig. 1: 3-view of the model

a circular shape and have been molded through a cheap 0.2 meter diameter PVC tube. The 3.5 hp engine and the pushing propeller has been put in the fuselage rear part to have an undisturbed flow for canard and wing surfaces. The propeller effectiveness (behind the fuselage) will be tested in DPA wind tunnel before flight to verify that the necessary thrust is guaranteed.

The wing and canard airfoils have been chosen to have high lift at low flight Reynolds numbers together with a contained viscous drag and a reasonable pitching moment.

The wing has been designed with effective ailerons (to ensure lateral control at low speed) and with flap, although the equilibrated maximum lift with full flap (1.96) is not so high as the lift without a flap (1.68) due to the strong increment in pitching moment that the tail is not able to compensate with reasonable elevator deflections. The predicted stall speed with flap is about 40 km/h and without flap about 44 km/h, so the model should not have any take-off and landing problem.

Due to the short distance between c.g. and the vertical tail a second vertical fin has been added below the fuselage to

ensure good directional stability. This is also necessary to protect the rear propeller from contact with the ground. The design has been accomplished using a code named *AEREO*, which has been developed in recent years at DPA to predict all aerodynamic characteristics in linear and non-linear conditions (high angles of attack) and all flight performances and flying qualities of propeller driven aircraft, and has recently been extended to deal with canard and 3LSC configurations.

## 2 Configuration and structural design

As already pointed out in the introduction, the main goal of this aircraft is to allow flight parameter measurement and estimation of canard influence (especially at high angles of attack) on aircraft aerodynamics and flight characteristics. The first step considered in the design phase was the choice of general dimensions and a weight estimation. The following design specifications were considered:

- 1) PAY-LOAD (instrumentation, battery, record facilities, sensors, etc.) about 4 kg.
- 2) FUEL for about 1 h flight (about 1 kg).

- 3) Cruise speed around 80 km/h.
- 4) 3LS configuration with significant canard surface to allow for the evaluation of canard influence.
- 5) Rear pushing propeller to make the canard work in "clean" conditions.
- 6) Very low stall speed in clean and full flap configuration to ensure good low-speed flight characteristics, short take-off and landing with consequent safer ground approach; i.e.,

$$\begin{aligned} V_{S_{\text{clean}}} &\text{ about 45 km/h} \\ V_{S_L} &\text{ about 35 km/h.} \end{aligned}$$

- 7) Enough control power to allow flight at high angles of attack (to check canard effectiveness and to reach canard stall).
- 8) Engine compatible with aircraft dimensions and weight (engine weight around 2 kg max).
- 9) Significant wing span to have good climb characteristics and wing span dimensions much higher than canard span.

To accomplish task n. 1 and to ensure a good and easy disposition of the instrumentation on board needed in order to measure, record and eventually transmit all flight parameters, a fuselage diameter of about 0.20 m was chosen.

Specification n. 1 and 2 leads to a useful load, around 5 kg. The structural weight can then be estimated to be around 8 kg. In particular, choosing a fuselage that can allow a good working distance for canard and horizontal tail and a fuselage fineness ratio higher than 8 to ensure good propeller efficiency, a 2 m total length fuselage comes out. The fuselage weight can be estimated around 2 and 3 kg. Assuming a weight of about 5 kg for wing, tailplanes and canard, canard an empty structural weight between 8 and 9 kg is expected. With the engine total weight around 2 kg the maximum take-off weight will be around 15 kg.

Stall speed requirements (n. 6), assuming a maximum lift coefficient around 1.7 in clean condition and around 2.0 in full-flap condition, a maximum wing load of about 15 kg/m<sup>2</sup> can easily be evaluated. This gives a wing surface of about 1 m<sup>2</sup>.

Design requirement n. 8 indicates, after a preliminary engine market analysis, an engine with about 3 hp maximum power. The "Thunder Tiger PRO-120" engine was chosen. The engine is characterized by a displacement of about 21 cc and a maximum power of 3.5 hp at 15000 rpm. With a propeller 0.50 m in diameter, a practical working condition around 10000 rpm (then 2.5 hp maximum power) is expected.

The maximum rate of climb at S/L can be estimated through a simple formula :

$$RC_{\text{max}} = 76\eta_P \frac{\Pi_a}{W} - 2.97\sqrt{W} \frac{f^{1/4}}{b_e^{3/2}} \quad [\text{m/s}]$$

$$\text{(with } W \text{ in [kg], } \Pi \text{ in [hp], } f \text{ in [m}^2\text{]} \text{ and } b \text{ in [m])}$$

with the following assumptions:

$$\eta_P = 0.4 \quad \text{Propulsive efficiency at fastest climb speed}$$

$$\Pi_a = 2.5 \text{ hp} \quad \text{Maximum engine power at working rpm (10000 rpm)}$$

$$W = 15 \text{ kg} \quad \text{Maximum take-off weight}$$

$$f = CD_0 S = 0.032 \text{ m}^2 \text{ (with } CD_0 = 0.032 \text{ and } S = 1 \text{ m}^2\text{)}$$

$$b_e = b\sqrt{e} \quad \text{(with } e = 0.80, \text{ Oswald efficiency factor)}$$

and imposing a maximum climb rate at S/L around 3.5 m/s (req. n. 9), leads to a necessary wing span  $b$  of about 2.5 m. It also seems reasonable to have a wing span higher than the canard span (around 0.90 m).

The horizontal tailplane dimensions were chosen to give good stability and control power to fly with and without canard. A movable part (equilibrator) extended over 44 % of the total horizontal plane chord was chosen to ensure good longitudinal control.

The final configuration that was considered is then shown in Fig. 1, with all main dimensions reported in Table 1. The configuration has the following relevant features:

The simple fuselage shape allows a low-cost molding with a consequent economic advantage. In fact the fuselage skin structure in glass-fiber with some added carbon-fiber was simply molded with a 0.20 m PVC tube. Some carbon stringers were added to increase longitudinal stiffness. The fuselage is thus characterized by two high quality wood main spar frames allowing wing and undercarriage connections.

The wing, canard and tailplane structures are made by wooden ribs numerically controlled machine milled (which assure perfect airfoil reproduction) and with a mixed glass-carbon fiber composite skin.

A thickness of about 2 mm was chosen for almost all model surfaces. A very accurate structural analysis (i.e., finite element) has not performed to optimize thickness, dimensions and weight, but the chosen structure ensure a very good safety margin without leading to excessive weight. Considering the experimental task and a possible future fully automatic flight, this design philosophy seems reasonable and efficient.

The weight of the complete structure with exact dimensions and thickness was then estimated and is shown in Table 2 together with the weight obtained after construction. The maximum take-off weight  $W_{TO}$ , adding engine weight and useful load (see Table 1) is then 14.6 kg.  $W_{TO}$  of model without canard is 14.2 kg.

Aircraft c.g. position depends the location of on instrumentation on board. The main goal will be to guarantee a longitudinal static stability margin (SSM) in cruise condition of about 10 % for configuration both with and without canard, taking into account that the neutral point can be estimated to be around 15 % of the chord with canard and 40 % without, the useful load has been located in the fuselage forward part at 23 cm from the nose with canard and 44 cm without. **The full weight c.g. position is imposed to be around 5 % of wing chord with canard and 29 % without.** For the wing and canard the high-lift low-Reynolds number airfoil SD7062 [6] was chosen, and the shape is reported in Fig. 2. A picture of the fuselage in construction is shown in Fig. 3. Fig. 4 shows the wing internal structure before molding. Fig. 5 and 6 show the lift and drag experimental [6] aerodynamic characteristics of the SD7062 airfoil.

Table 2: Weight

	Estimated	Real
Wing	4.00 kg	4.16 kg
Fuselage	2.40 kg	2.31 kg
Hor. Tailplane	0.85 kg	0.80 kg
Canard	0.42 kg	0.38 kg
2 Vert. Tailplanes	0.55 kg	0.65 kg
TOT structure	8.22 kg	8.30 kg

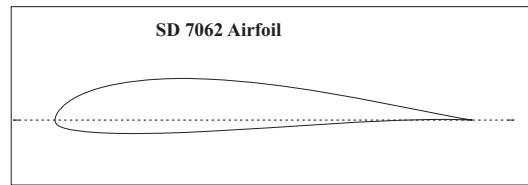


Fig. 2: SD7062 wing and canard airfoil

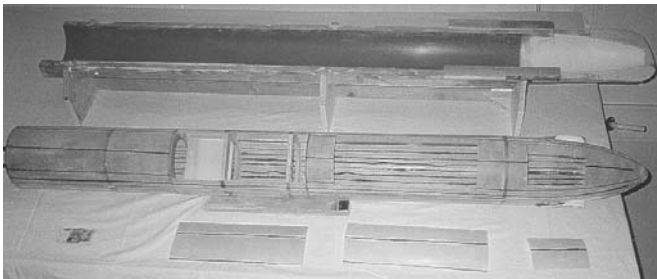


Fig. 3: Fuselage in construction

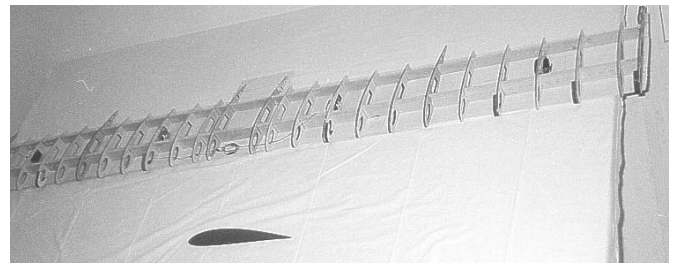


Fig. 4: Wing internal structure and airfoil

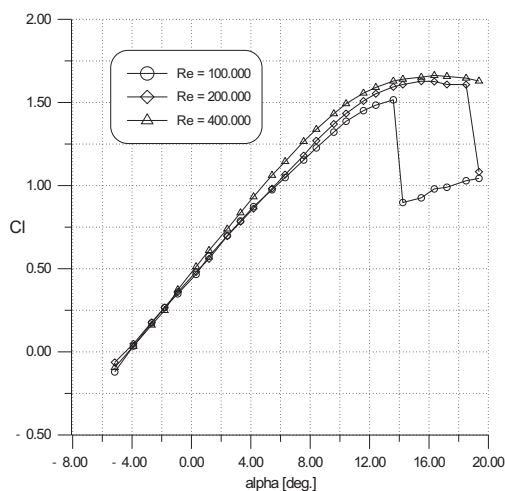


Fig. 5: SD7062 airfoil – lift curve [6]

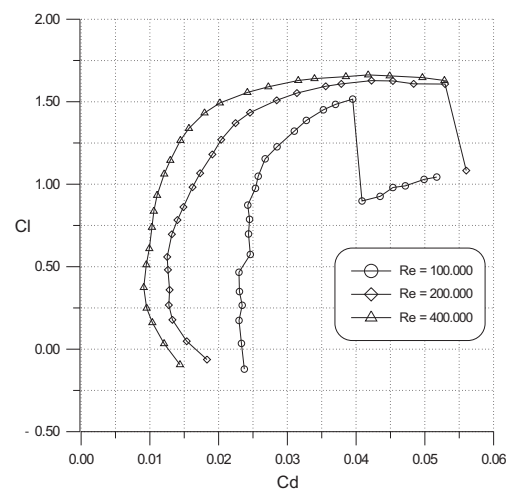


Fig. 6: SD7062 airfoil – drag polar [6]

### 3 Aerodynamic analysis

#### 3.1 AEREO code and extension to canard and 3LS configuration

A code named *AEREO* has been developed by the authors in recent years to predict all aerodynamic characteristics in linear and non-linear conditions of propeller driven aircraft.

The code is based on longitudinal [7] and lateral-directional [8] semi-empirical methods, like those proposed by J. Roskam [9] mixed with more sophisticated calculations, such as wing lift and drag predictions up to stall, are performed using an in-house built code based on non-linear Prandtl lifting-line theory. The code also predicts all performances, static and dynamic stability characteristics, and is

similar to the well known AAA software [10]. The code was originally written to deal with the classical aft-tailed configuration, especially for light aircraft and sailplanes [11]. The code has recently been expanded and improved to deal with canard or TLS configurations. With the simple horse-shoe vortex theory the calculation of mutual influence of wing and canard (downwash of canard on wing, and upwash of wing on canard) has been implemented. Maturing experiences and tools integration [12] has been one of the main goals of the author's activity at DPA in recent years, and the aerodynamic and flight behavior analysis of this configuration certainly goes in that direction.

The authors also have good experience of wind-tunnel tests for analysis and optimization of light aircraft [13] and integration and comparison of numerical calculations with experimental results [14].

The next section presents the results of aerodynamic characteristics evaluation for the aircraft model with and without canard will be presented. The **c.g. position** (for moment coefficient and stability considerations) follows the values indicated in part 2.

### 3.2 Results – lift

Mutual induction of canard on wing (downwash angle  $\epsilon_w$ ) and wing on canard (upwash angle  $\epsilon_c$ ) have been estimated in *AEREO* code through a simple horse-shoe vortex theory and global value is obtained through an average value along the span. Evaluated values of mutual induced angles and downwash at horizontal tail ( $\epsilon_H$ ) derivatives are reported in Table 3, together with the wing-body and global lift curve slope in the presence and absence of a canard surface. Comparison with values of  $d\epsilon/d\alpha$  obtained with panel method calculations shows good agreement.

Table 3: Mutual induced angles and lift curve slopes

	with canard	without canard	panel method
$d\epsilon_c/d\alpha$ (upwash on canard)	0.08	–	0.09
$d\epsilon_w/d\alpha$ (downwash on wing)	0.06	–	0.07
$d\epsilon_H/d\alpha$ (downwash on hor. tail)	0.31	0.36	
$CL_{\alpha}$ wing-body	0.078	0.081	
$CL_{\alpha}$ global	0.10	0.091	

Fig. 7 shows the lift contribution of wing, wing-body, canard and horizontal tail versus  $\alpha$  (with respect to the fuselage center line). It can be observed that canard stalls around  $\alpha = 16^\circ$  and this reflects on global lift and especially the global

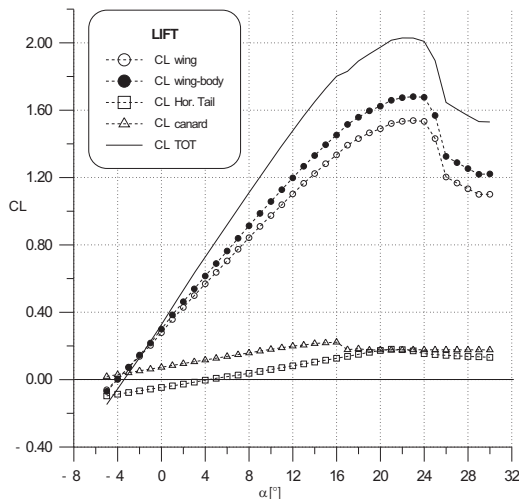


Fig. 7: Lift contributions

moment coefficient curve. An equilibrated lift curve has been obtained for the configuration with and without canard, and for the configuration with canard with  $30^\circ$  flap deflected. The results are shown in Fig. 8.

It can be seen that a maximum equilibrated lift coefficient of 1.66 is obtained for the configuration with canard (and c.g. at 5 % of c), a value of 1.61 for the configuration without canard and a value of 1.97 for the  $30^\circ$  flapped configuration with canard. The resulting stall speeds for the configuration with canard, as stated in the introduction, are about 40 km/h and 44 km/h, respectively, for the clean and flapped conditions.

### 3.3 Results – drag

The equilibrated (trimmed) drag polar for the configuration with and without canard are shown in Fig. 9. It can be observed that the configuration with canard leads to a higher drag than the configuration without canard at high speed conditions, but lower drag (lower global induced drag) at low speed conditions. The global Oswald efficiency factor “e” for the configuration with canard (TLS) in trimmed conditions is about 0.85, showing a good value for an aircraft that should operate at low speed. Moreover, as stated before, the TLS is not optimized because the horizontal tail surface has been designed to fly with and without canard.

### 3.4 Results – moment coefficient and equilibrators deflections

Fig. 10 shows all contributions to moment coefficient (evaluated respect to cg, 5 % of chord) of configuration with canard with equilibrators in neutral position ( $\delta_e = 0^\circ$ ). It can be observed that the global (TOT) moment curve strongly “feels” the canard stall at  $\alpha = 16^\circ$  and a high negative pitching tendency results. The aircraft stall is thus connected to canard stall and this seems to work like an efficient and safe stall warning device.

The estimated necessary elevator deflections to equilibrate the aircraft are shown in Fig. 11 for configuration without canard and with canard (in clean and flapped condi-

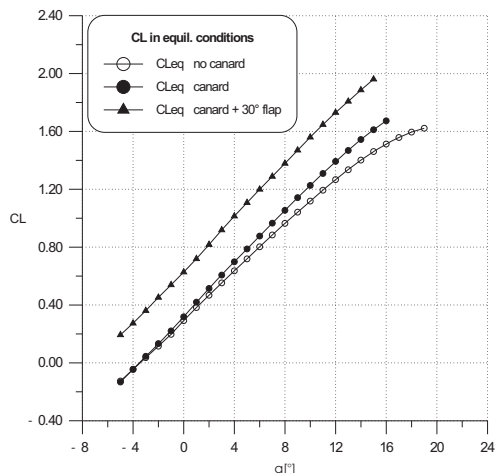


Fig. 8: Equilibrated lift coefficient

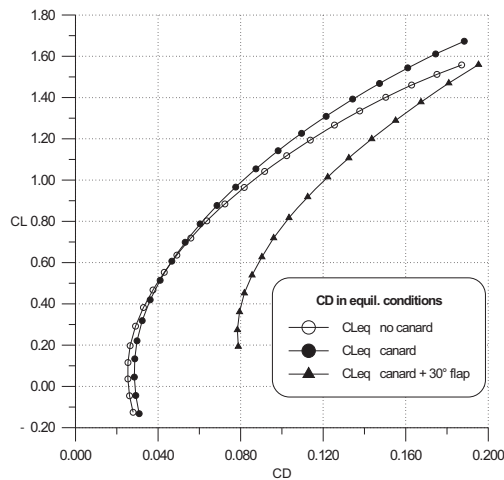


Fig. 9: Trimmed Drag polar

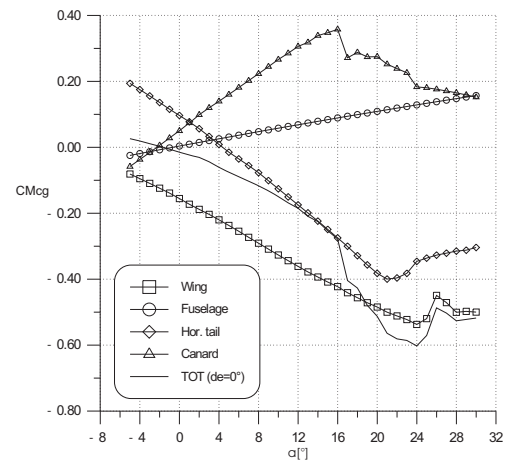


Fig. 10: Moment coeff. contributions

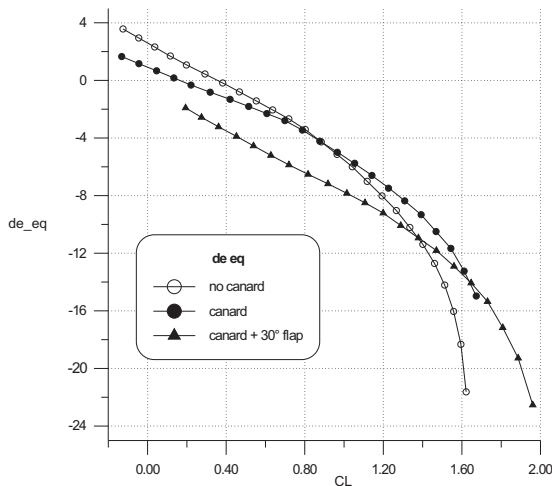


Fig. 11: Necessary equilibrators deflections

tions). The required deflections at stall are always acceptable (for the configuration with canard  $-15^\circ$  in clean and  $-22^\circ$  in flapped conditions).

### 3.5 Results – neutral point – static and dynamic stability

The neutral point versus trimmed lift coefficient for configuration with and without canard are shown in Fig. 12. The SSM is about 13 % at cruise conditions ( $CL=0.50$ ) for both configurations. High stability at low speed can be highlighted.

Longitudinal and lateral-directional stability derivatives have been evaluated for configuration with canard and without canard. Table 4 shows the most significant stability derivatives at cruise conditions for configuration with canard and for configuration without canards ( $\alpha'$  is  $d\alpha/dt$ ). The most significant different values are reported in bold characters. Note that the configuration with canard leads to a higher lift curve slope and higher aerodynamic damping (unsteady  $CM_{\alpha'}$  and  $CM_q$  derivatives).

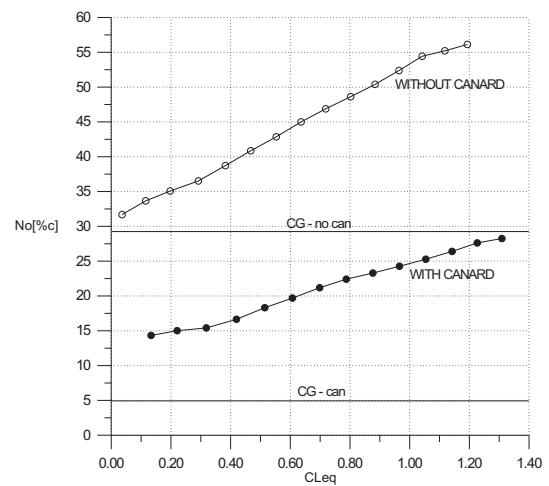


Fig. 12: Neutral stability point

Table 5 shows the dynamic stability characteristics. The long and short period characteristics show that the configuration with canard leads to a slightly lower frequency for long

Table 4: Static stability derivatives

	with canard	without canard
Longitudinal		
$CL_\alpha$	<b>5.60</b> (1/rad)	5.20 (1/rad)
$CM_\alpha$	-0.48 (1/rad)	-0.59 (1/rad)
$CM_{\alpha'}$	<b>-1.94</b>	-1.18
$CM_q$	<b>-8.02</b>	-4.41
Lateral-directional		
$Cl_\beta$	-0.059 (1/rad)	-0.064 (1/rad)
$Cl_p$	-0.52	-0.51
$Cn_\beta$	0.090 (1/rad)	0.079 (1/rad)

period motion and a higher frequency for short period motion. The dumping is always higher with the canard.

Table 5: Dynamic longitudinal stability

	with canard	without canard
Short Period		
Freq. [Hz]	0.710	0.66
Dumping	0.817	0.70
Long Period		
Freq. [Hz]	0.070	0.087
Dumping	0.026	-0.016

## 4 Performance

The necessary power curves at S/L for configuration with canard and without canard were evaluated and are presented in Fig. 13, together with the available power curve, which was evaluated with two possible propellers, 18–6 ( $D=0.46$  m, blade angle  $\beta_{75}=8^\circ$ ) and 18–10 ( $D=0.46$  m,  $\beta_{75}=13.3^\circ$ ). Maximum power of 2.5 hp and maximum propeller efficiency  $\eta_{P\text{-max}} = 0.50$  (the propeller works behind the fuselage) were assumed. It can be seen that a low blade angle (18–6)

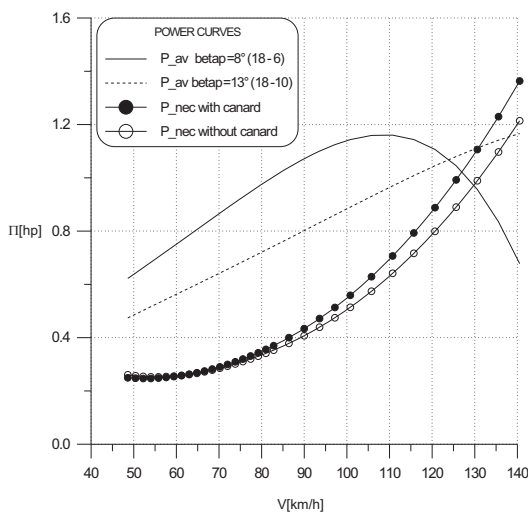


Fig. 13: Power curves

Table 6: Performance at S/L (propeller 18–6)

	with canard	without canard
Max level speed	127 km/h	130 km/h
Max cruise speed (75 % of power)	118 km/h	122 km/h
Max R/C	3.28 m/s	3.5 m/s
Max cruise range	20 km	21 km
Max aer. efficiency	13.1	13
Take-off run	60 m	56 m
Landing run	54 m	50 m

is needed in order to have acceptable propeller efficiency and then a good rate of climb R/C, which occurs at about 80 km/h. There is almost no difference in maximum level speed between the two propellers. Table 6 shows all the main performances with propeller 18–6.

## 5 Wind tunnel tests on engine and propeller

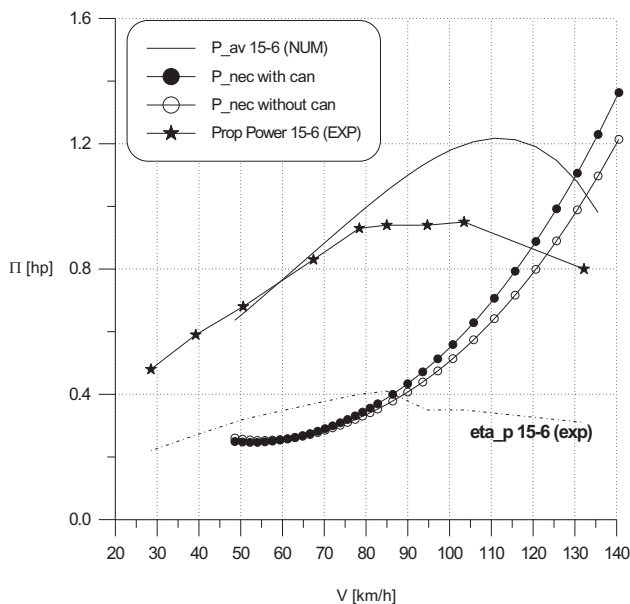
To verify the behavior of the engine coupled to different pushing propellers, the model fuselage with rear mounted engine was set up in the wind tunnel as shown in Fig. 14. Fig. 15 shows a detail of the engine. Drag, lift and moment was measured with an internal 3-component strain gage balance, and they were recorded with the use of an A/D acquisition system. Engine rpm was also measured. Unfortunately due to the lack of model aircraft employing pushing propellers, these are available only in certain diameter/pitch combinations. We tried 18/10, 18/6, 15/8, 15/6, 14/6, of which only the last was available in PVC, while the others were all made of wood. The tests were performed, for each wind speed, setting three throttle levels and recording rpm, forces and moments. Some other angles of attack were also investigated. It can easily be recognized that there were many possible combinations of the free parameters, and while writing this paper we are still analyzing the recorded data. Since the engine needed high rpm to develop its maximum power, when a propeller 18 inches in diameter was tested, it was impossible to get the maximum power from the engine. On the other hand, when using a propeller 14 inches in diameter, the swept area was too small to get high thrust. In summary the best results were obtained with 15/6 pushing propeller. The measured propeller delivered power is compared to the numerical values in figure 16, along with required power. Note that there are some discrepancies between the predicted and measured power: these are mainly due to the unknown geometry of the blades, especially regarding airfoil shape. We made an attempt to measure all the geometrical characteristics of the blades, but due to their small size, the results are not reliable. The maximum measured propeller efficiency was 4: this is valid supposing that the maximum engine power is equal to that declared by the company. No significant reduction in propeller efficiency was measured at high angles of attack, indicating that the position of the propeller and the shape of the rear part of fuselage were fine. We also performed some tests turning the model 180 degrees to test the differences between the pushing and tracting propellers, but we are still analysing the data. During the tests, as already stated, the main problem was the engine, which was not reliable at all: the tuning was very difficult and unstable. At the end of this test campaign, we decided to use a 4 stroke – 2 cylinder – 4 hp engine delivering maximum power at much lower rpm (7000 rpm versus 13500 of the first engine). This engine was tested with 18 in (0.46 m diameter) propellers with two different blade pitch angles,  $9^\circ$  (propeller 18/6) and  $13^\circ$  (propeller 18/10). Fig. 17 shows the experimentally measured power curves of the 4 stroke – 4 hp engine with propeller 18/6 and 18/10. Note that the 18/6 propeller does not give good efficiency (around 0.25), which leads to very low available power. The 18/10 propeller gives good propulsive power with an efficiency around 0.5. In Fig. 17 the necessary



Fig. 14: Fuselage installed in the tunnel



Fig. 15: Particular of rear mounted engine

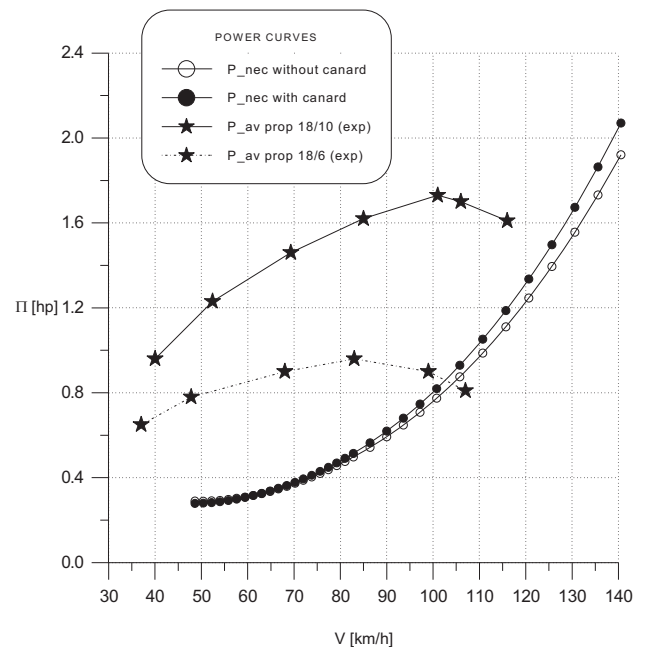
Fig. 16: Required and available power  
2 stroke – 3.5 hp engine, 15/6 prop. (num/exp)

power curves are slightly different from those ones reported in Fig. 13 and 16, because the measured drag in the wind tunnel

Table 7: Performance at S/L

4 stroke – 2 cylinder – 4 hp engine with propeller 18–6

	with canard	without canard
Max level speed	125 km/h	127 km/h
Max cruise speed (75% of power)	118 km/h	122 km/h
Max R/C	5.2 m/s	5.3 m/s
Max cruise range	17 km	19 km
Max aer. efficiency	12.8	12.9
Take-off run	45 m	40 m
Landing run	54 m	50 m

Fig. 17: Required and available power  
4 stroke – 4 hp engine, 18/10 and 18/6 prop (exp)

of the fuselage + undercarriage was also taken into account. The measured drag was found to be higher than the predicted drag, and it can be seen that the necessary power of Fig. 17 is higher than that reported in Figs. 13 and 16.

It can be seen that the predicted maximum level speed with 4 stroke – 2 cylinder – 4 hp engine and 18/10 propeller is around 125 km/h. Performances with the a 4 stroke – 4 hp engine and 18/10 propeller are reported in Table 7. The values show very good flight and take-off characteristics with the new engine.

## 6 Conclusion

Design, aerodynamic and preliminary performance estimation of a three surfaces R/C aircraft have been performed. The aircraft has been designed to test canard influence on aircraft aerodynamics, dynamics and flying qualities. The model will be instrumented to measure all flight parameters during flight. Canard influence on lift, drag and moment



coefficients have been carefully evaluated and shown. The influence of the canard on aircraft static and dynamic stability has been shown. Available power curves versus speed have been measured in the wind-tunnel through a balance. Body drag has been also measured. Estimated performances are in good agreement with aircraft design and desired flight characteristics, especially with the more reliable 4 stroke – 4 hp engine, which was tested with different propellers to set the right one and to obtain the best performance. Flight tests will take place in January 2002.

## References

- [1] McGeer, T., Kroo, I.: *A Fundamental Comparison of Canard and Conventional Configurations*. Journal of Aircraft, Vol. 20, November 1983
- [2] Selberg, B. P., Rokhsaz, K.: *Aerodynamic Tradeoff Study of Conventional, Canard, and Trisurface Aircraft Systems*. Journal of Aircraft, Vol. 23, October 1986
- [3] Kendall, E. R.: *The Theoretical Minimum Induced Drag of Three-Surface Airplanes in Trim*. Journal of Aircraft, Vol. 22, October 1985
- [4] Ostowari, C., Naik, D.: *Experimental Study of Three-Lifting-Surface Configuration*. Journal of Aircraft, Vol. 25, February 1988
- [5] Patek, Z., Smrcek, L.: *Aerodynamic characteristics of multi-surface aircraft configurations*. Aircraft Design, Vol. 2, 1999, pp. 191–206
- [6] Lyon, C. A., Selig, S. et al: *Summary of Low-Speed Airfoil Data*, Vol. 3, SoarTech Publications, Virginia, ISBN 0-9646747-3-4, 1997, pp. 256–263
- [7] Wolowicz, H. C., Yancey, B. R.: *Longitudinal Aerodynamic Characteristics of Light, Twin-Engine, Propeller-Driven Airplanes*. NASA TN D-6800, 1972
- [8] Wolowicz, H. C., Yancey, B. R.: *Lateral-Directional Aerodynamic Characteristics of Light, Twin-Engine, Propeller-Driven Airplanes*. NASA TN D-6946, 1972
- [9] Roskam, J.: *Preliminary Calculation of Aerodynamic, Thrust and Power Characteristic*. Airplane Design. Part VI: Ed. Roskam Aviation, 1987
- [10] Roskam, J.: *AAA, Advanced Aircraft Analysis software*. DARcorporation, Lawrence, Kansas
- [11] Coiro, D. P., Nicolosi, F.: *Aerodynamics Dynamics and Performance Prediction of Sailplanes and Light Aircraft*. Technical Soaring, Vol. 24, No. 2, April 2000
- [12] Coiro, D. P., Nicolosi, F.: *Aircraft Design through Numerical and Experimental Techniques Developed at DPA*. Aircraft Design, Vol. 4, No. 1, ISSN 1369-8869, March 2001
- [13] Giordano, V., Nicolosi, F., Coiro, D. P., Di Leo, L.: *Design and Aerodynamic Optimization of a New Reconnaissance Very Light Aircraft Through Wind Tunnel Tests*. RTA/AVT Symposium on “Aerodynamic Design and Optimization of Flight Vehicles in a Concurrent Multi-disciplinary environment”, Ottawa (CANADA), October 1999
- [14] Giordano, V., Coiro, D. P., Nicolosi, F.: *Reconnaissance Very Light Aircraft Design. Wind-Tunnel and Numerical Investigation*. Engineering Mechanics, Vol. 7, No. 2, 2000, pp. 93–107

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