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# Aerial Coanda High Efficiency Orienting-jet Nozzle

## D.1.4 – Publishable summary

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## EXECUTIVE SUMMARY

ACHEON PROJECT has been a great success. It has reached an ample set of high level results:

- It has demonstrated the feasibility of the system in subsonic conditions;
- It has overcome initial problems derived by swirl components;
- It has allowed effective modeling of the Coanda Effect;
- It has allowed modeling of the Coanda effect in a nozzle with two streams;
- It has produced a clear and successful simulation of applicability on aircrafts, relating to commuter class and UAS scale.

The preliminary analysis has been performed, and the terms defining modeling and simulation aspects have become more concrete, and their influence for defining the experimental setup and the related equipment has been successful. The Technology Evaluation has produced a detailed verification of ACHEON's technology against both traditional and innovative future aircraft configurations. The key objective has been the demonstration of the advantages that the ACHEON advanced propulsive concept in all aspects of the aircrafts operations and its environmental impact. It has been also verified how ACHEON performs under the various operating regimes that current and future aircraft will encounter.

This will include environmental issues such as operation in snow, rain, sand and dust as well as FOD. Safety is also a consideration, current twin aircraft have exceptional safety records that can be met or bettered by ACHEON.

Up to 45 deg of deflection has been obtained in subsonic condition even in presence of swirl (using simplified testing conditions). This encouraging results has allowed a certain degree of confidence through applications on different aircraft types.

# PUBLISHABLE SUMMARY

ACHEON Coanda effect based nozzle allows producing a thrust and vector propulsion system by the adhesion of a synthetic jet to a Coanda surface. This propulsion system is based on a nozzle concept developed and patented at Università di Modena e Reggio Emilia [1, 2] coupled with Dielectric Barrier Discharge equipment studied at Universidade da Beira Interior [3, 4]. The nozzle initially studied by Trancossi [5] that has produced a reasoned review on Coanda effect. Dragan [6] has later used the conclusions by Trancossi in for his mathematical model for Coanda effect velocity approximation.  Trancossi and Dumas has presented the concept describing the potential of the Coanda effect nozzle [7] and presented a preliminary CFD 3D simulation about the ACHEON system with encouraging result [8]. The analysis of feasibility of the ACHEON vector and thrust propulsion system has been financed by European Commission [9]. The ACHEON Project has produced an effective analysis on Coanda effect, which has produced different models. Preliminary guidelines for modeling the ACHEON have been defined by Dumas et al [10].

A preliminary model has presented by Trancossi, Subhash and Angeli [11] with the aim of describing the Coanda effect adhesion by integral equations using inviscid fluid flow hypothesis. Another model has presented by Dumas and Subhash [12] who has realized a very large CFD activity on a 2D model. Dumas et al [13] has also evidenced the effects of temperature gradients between fluid and Coanda surface. They have defined that a positive temperature gradient favors adhesion, while a negative one produces a negative buoyant effects, which reduce the attachment.

Trancossi, Subhash et al. [14] have analyzed the ACHEON Coanda effect based propulsion nozzle for aircraft propulsion considering the dynamic equilibrium of two jet streams and explain how the Constructal optimization process allowed the preliminary definition of the nozzle. The model has developed by using inviscid flow theory. A mathematical model of a 2D case of the system has presented by Trancossi et al. [15], focusing on the combined effect of the mixing effect of the two streams and the Coanda Effect Adhesion over a convex surface. Trancossi et al. [16], who have produced a more effective model of the ACHEON Coanda effect two streams nozzle, have also verified the preliminary results. This paper presents a preliminary design guideline. This model defines macroscopic governing laws for this innovative two-stream synthetic jet nozzle. The uncertainness levels of the model are discussed and novel aircraft architectures based on it are presented. A CFD campaign is produced for validating the model and the designs produced. This model has referenced by Dragan [17]. Pascoa et al. [18] have produced a bibliographic analysis on thrust deflection systems producing an effective comparison with other thrust and vector system.

The Dielectric barrier concept and architecture used in ACHEON nozzle has defined by Pascoa et al. [19] in 2009.  The concept by Pascoa is presented in Fig. 2. Abdollahzadeh and Pascoa (2014) [20] have introduced a generic analytical approach that can be used to predict analytically the momentum transfer in DBDs. In further development steps of the ACHEON project, it will allow a better analytical analysis of the dynamic behavior of the ACHEON nozzle. Abdollahzadeh et al. [21] have explored the use of thermal DBDs. Until the moment, only non-thermal DBDs have been adopted in ACHEON, due to the lower flow speeds involved. This is a general paper dealing with the numerical modeling of nanosecond pulse micro-shock wave plasma actuators.

Although ACHEON can be utilized with current aircraft technologies its true advantage will be realized as an enabling technology for the All Electric Aircraft as originally foreseen by Cronin et al. As a purely electric technology there is no need for high temperature materials allowing the exploitation of lighter materials with improved performance and tolerance to future environmental effects such as volcanic ash and high altitude ice ingestion.

Work has focused on novel twin spool electrically powered axial compressors and the necessary control systems to regulate the two mass flow rates into the nozzle. Consideration is also being given to the arrangement of any intermediate plenum stage and particle separation. Simulations has been performed on twin spool aircraft has considered. Old fashioned architectures has been considered as a means of providing important reference data through future development. This will provide the basis for the future work where various configurations, both traditional and novel, are evaluated to determine the economic and technical advantages. Obtained results has clearly demonstrated the feasibility of the system and its potential integration.

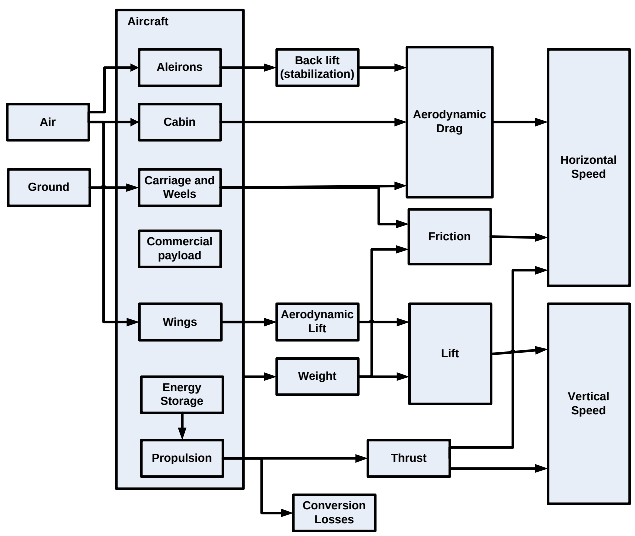


Figure 1. Functional schema of an aircraft propelled by ACHEON system.

Different models has been studied.

One of the best airplanes ever realized by the European Aircraft industry was the Dornier Do 28D Skyservant, an extraordinary STOL light utility aircraft with the capability to carry up to 13 passengers. It has been a simple and rugged aircraft capable also of operating under arduous conditions and very easy and simple maintenance.

The preliminary definition of an increased performance cogeneration system for optimizing the energy efficiency and maximizing the thrust of ducted fan propeller has produced. It then produces an effective design of the ACHEON nozzle for such an aircraft, the definition of the optimal positioning for stability and efficiency. In conclusion, it analyses the expected performances of the resulting aircraft architecture.

Outstanding results allows verifying an effective possibility of implementing the ACHEON Coanda effect thrust and vector propulsion system on real aircraft.

## HIGH WING STOL AIRCRAFT CONFIGURATION

The paper has evaluated summarily the possibility of applying the ACHEON propulsion system to a Dornier Do 28 D2. The outstanding results in terms of landing space and the verification of compatibility in terms of produced thrust allows reducing of more than 50% the needs in terms of landing and takeoff space.

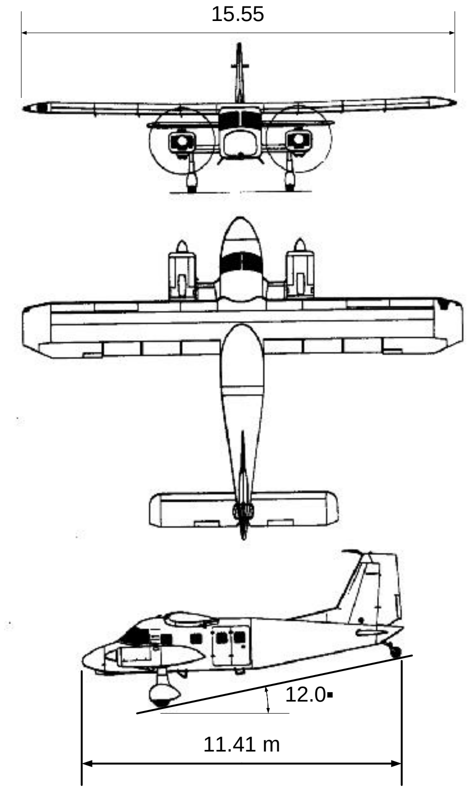


Figure 2. Dornier Do 28D "Skyservant"

The architecture of this airplane, which has operated actively for more than 20 years, is very interesting analyzing the implementation of a new propulsion system because of the unusual incorporation of two engines, as well as the two main landing gear shock struts of the faired main landing gear attached to short pylons on either side of the forward fuselage. This unconventional design allows an easy implementation of different propulsion units, such as the history of different experimental versions allowed.

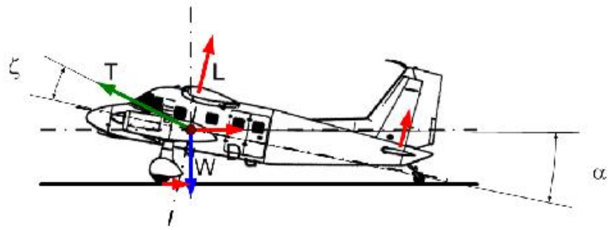


Figure 3. Equilibrium of forces at takeoff

A max thrust to take off weight factor of 0.32 is considered. Max thrust can be then evaluated about 13500 N. Preliminary data for comparison have been calculated for a traditional aircraft with no thrust inclination ( $\zeta$=0° ). The angle of attack during take off operation can be defined by the aircraft drawing and is assumed about 12°.

Assuming a max lift coefficient of 4 for the specified wing with leading edge slat, it can be calculated a CL at take off about 4 both considering the angle of attach and wing characteristics. Consequently, the stall speed VS in take off configuration can be calculated about 22.5 m/s. This value seems in line with the aircraft data table and allow defining a takeoff safety speed VTO = 1.2 VS = 27 m/s. The average take off speed is then VTO,av = 19.2 m/s. Velocity of minimum control is then VMC ≅ VTO / 1.1 = 24.54 m/s. Assuming the minimum take off length of 310 m it results a takeoff time tTO= 16.2 s and an acceleration of aTO ≅ 2.37 m/s2.

Assuming an angle of the ACHEON jet propeller at 15°, the angle of the thrust is estimated about 27°. The thrust generates two components Tx ≅ 36500 N and Ty ≅ 6125 N. Stall speed reduces then at about VS = 18.6 m/s and safe take off speed is about VTO = 22.6 m/s. The average takeoff velocity becomes VTO,av = 15.8 m/s. Velocity of minimum control is then VMC ≅ VTO / 1.1 = 20.25 m/s. Reducing the acceleration proportionally to the new direction of the thrust (aTO ≅ 2.22 m/s2 ) it results a take off time tTO= 9.72 s and a much reduce take off space of 154.7 m.

The obtained results show clearly the benefits during takeoff of the new direction of the thrust. Values that are more effective can be obtained with higher angles of inclination of the jets.

Climb

Assuming to use the aircraft reference system, the equilibrium of forces (Figure 4) during climb can be evaluated.

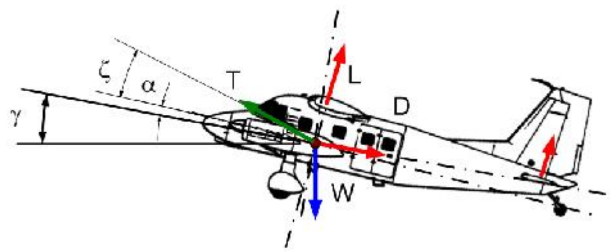


Figure 4. Equilibrium of forces during climbing

Preliminary climb

During the preliminary accelerated climbing phase, it is evident that it is possible to perform this phase with a higher climbing angle and acceleration respect the original. Considering in fact a traditional aircraft ( ζ = 0 ) and one equipped by ACHEON and making the comparison between the two configurations, assuming to climb with the same aerodynamic configuration:

- traditional aircraft

$$m_{TO} \cdot a_{c,x} = T\cos\alpha - L\sin\alpha - D - W\sin\gamma_0 \qquad (13)$$

$$m_{TO} \cdot a_{c,y} = T\sin(\alpha) + L\cos\alpha - W\cos\gamma_0 \qquad (14)$$

- ACHEON propelled aircraft

$$m_{TO} \cdot a_{c,x} = T\cos(\alpha + \zeta) - L\sin\alpha - D - W\sin\gamma \qquad (15)$$

$$m_{TO} \cdot a_{c,y} = T\sin(\alpha + \zeta) + L\cos\alpha - W\cos\gamma \qquad (16)$$

Assuming to climb at constant angle, In diagram the vehicle is assumed to be climbing at a constant angle ( γ0 in case of the traditional aircraft and γ in the case of the ACHEON propelled aircraft. It can be then written:

$$\frac{\Delta a_{c,x}}{g} = \frac{T}{W}\left[\cos(\alpha + \zeta) - \cos\alpha\right] - \sin\gamma + \sin\gamma_0 \qquad (17)$$

$$\frac{\Delta a_{c,y}}{g} = \frac{T}{W}\left[\sin(\alpha + \zeta) - \sin\alpha\right] - \cos\gamma + \cos\gamma_0 \qquad (18)$$

Equations (17) and (18) allow demonstrating that a higher climb angle is obtained with the same thrust because of vertical acceleration are higher and horizontal one is lower. The second consequence is that the thrust to have the same vertical acceleration, which must not overcome the max admissible load factor n = L / W, the required thrust and x velocity are lower.

Cruise speed climb

After cruise speed is reached, it can be possible to express the equilibrium of the velocity in horizontal and vertical direction:

- traditional aircraft
  $\cos\gamma_0 = \frac{T}{W}\sin(\alpha) + \frac{L}{W}\cos\alpha$ (19)
- ACHEON propelled aircraft
  $\cos\gamma = \frac{T}{W}\sin(\alpha + \zeta) + \frac{L}{W}\cos\alpha$ (20)

That shows that using the same thrust for $\zeta > 0$ it results $\gamma > \gamma 0$.

Horizontal flight

The conditions during horizontal flight can be defined easily by Figure 5.

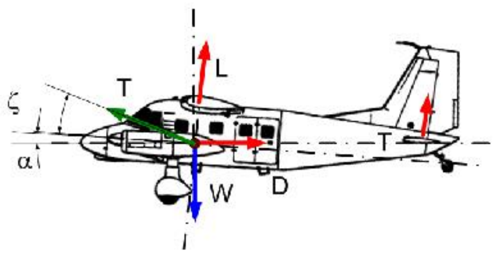


Figure 5. equilibrium during horizontal flight

Equations becomes

- traditional aircraft
  $T\cos\alpha - L\sin\alpha - D - W\sin\alpha = 0$ (21)
  $T\sin(\alpha) + L\cos\alpha - W = 0$ (14)
- ACHEON propelled aircraft
  $T\cos(\alpha + \zeta) - L\sin\alpha - D - W\sin\alpha = 0$ (22)
  $T\sin(\alpha + \zeta) + L\cos\alpha - W\cos\alpha = 0$ (16)

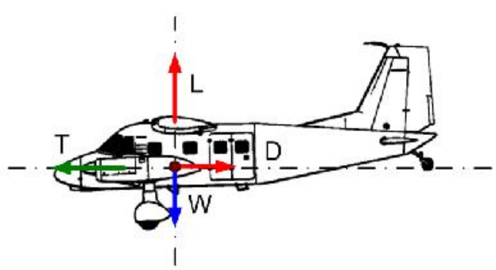


Figure 6. Horizontal flight configurations with low or null angle of attack.

If $\alpha$ is less than 6° or null (Figure 6) it can be obtained:

- $T - D \cong 0$ (23)
  $L - W \cong 0$ (24)

- ACHEON propelled aircraft

  $T\cos(\alpha+\zeta)-D=0$ (25)

  $T\sin(\alpha+\zeta)+L-W=0$ (26)

It shows clearly that the airplane can flight at very low speed. It allows explaining how the stall speed is much lower.

When the thrust is directed along the direction of flight above equation becomes equal.

Descending

The descent before landing can be described by Figure 7.

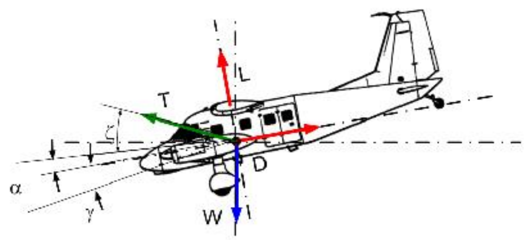


Figure 7. Airplane descent forces.

The equilibrium of forces is:

- traditional aircraft

  $m_{TO}\cdot a_{c,x}=T\cos\alpha+L\sin\alpha-D+W\sin\gamma_0$ (27)

  $m_{TO}\cdot a_{c,y}=T\sin\alpha+L\cos\alpha-W\cos\gamma_0$ (28)

- ACHEON propelled aircraft

  $m_{TO}\cdot a_{c,x}=T\cos(\alpha+\zeta)+L\sin\alpha-D+W\sin\gamma$ (29)

  $m_{TO}\cdot a_{c,y}=T\sin(\alpha+\zeta)+L\cos\alpha-W\cos\gamma$ (30)

It can be then easily verified that reducing thrust and increasing the angle is important to allow ACHEON propelled airplane higher angles of descent than any other airplane.

Landing

Landing operations are facilitated by very low stall velocity, which can be obtained. Assuming stall velocity of VS = 22.5 m/s in traditional configuration a landing length about 300 m is assumed. With the ACHEON propelled version the stall velocity is about VS = 18.6 m/s in the ACHEON propelled version it can be calculated a landing length of about 200 m, assuming the same acceleration on the ground of the conventional airplane. Landing run after touchdown results 110 m in the first case and 90 m in the second.

Some final consideration about design are necessary.

To give a max power in line with the one of the original engines (Lycoming IGSO-540-A1E) at least 140 kW per propulsive motor must be ensured. Looking at most interesting products  very good electric motor has found. It is the Plettemberg NOVA 150 motor, who has an extraordinary Power/ weight ratio. Main data have been provided by the manufacturer (Table 2).

Table 1. Plettemberg NOVA 150 Datasheet (courtesy of Plettemberg Electromotoren, http://www.plettenberg-motoren.net)

| | |
|---|---|
| Max. Power: | 150 kW |
| Weight: | 11,5 kg |
| Max. Speed of rotation: | 6.000  1/min |
| Max Torque: | 250 Nm |
| Voltage: | 350 V |
| Eta: | 95% |

Two NOVA150 per ACHEON unit can be considered.  Assuming to use an axial fan to produce the necessary thrust, the specific design of the axial fan is not one of the objectives of this paper but some considerations can be done. Acceptable a pressure jump for an axial compressor are between 0.1 Patm and 0.3 Patm.

Being

$$T = 0.5 \cdot {}^\circ \cdot A \cdot [V_{p,out}^2 - V_{p,in}^2] = \Delta p \cdot A \qquad (31)$$

We can assume a value about 0.1 Patm. The necessary area for the actuator disk of any system results about 0.35 m2. It is increased up to 0.4 to consider pressure losses. It can be defined also the difference of speed that ensures this pressure jump in operating conditions.

$$V_{p,out}^2 - V_{p,in}^2 = 2\Delta p / \rho \qquad (32)$$

Assuming to use a single stage axial ducted fan unit an effective design can be produced. An accurate preliminary design has bee realized for this configuration. In particular, it can be observed that this configuration is not very efficient and have too large front imprint. Better design of a multistage compressor will be produced for the specific objective. The characteristic of the preliminary single stage design that can fulfill propulsion needs are reported in Table 3. Behavior of the propeller with speed is reported in Table 4. The above-formulated model for any ACHEON nozzle can evaluate pressure losses. In particular, effective thrust with direction results are expressed in Table 5.

Table 2. Evaluation of each ducted fan unit.

| | | |
|---|---|---|
| Power | 150 | kW |
| Fan Diameter | 1100 | Mm |
| Hub Diameter | 120 | Mm |
| Max Fan Speed | 6000 | RPM |
| FOM | 0.9 | |
| Blade Angle Delta | 0.36 | Rad |
| | 20.75 | Deg |
| Fan Swept Area | 0.94 | m2 |
| Fan Blade Tip Speed | 348.10 | m/s |
| Fan Blade Tip Mach | 1.02 | M |
| Disk Power Loading | 159.74 | kW/m^2 |

Table 3. Characteristics at max power of any ducted fan unit

| Aircraft Airspeed (Vf) | mass flow induced | mass flow total | Velocity Induced (Vi) | Velocity @ Disk (Vd) | Velocity Exit (Ve) | Efficiency | Thrust |
|---|---|---|---|---|---|---|---|
| m/s | Kg/s | kg/s | m/s | m/s | m/s | - | N |
| 0 | 48.03 | 48.15 | 41.75 | 41.85 | 83.60 | 0.00 | 3474.27 |
| 20 | 18.99 | 42.00 | 16.51 | 36.51 | 53.02 | 0.49 | 3697.67 |
| 40 | 13.84 | 59.86 | 12.03 | 52.03 | 64.06 | 0.69 | 2594.66 |
| 60 | 8.67 | 77.70 | 7.54 | 67.54 | 75.08 | 0.80 | 1998.76 |
| 80 | 6.26 | 98.30 | 5.45 | 85.45 | 90.89 | 0.84 | 1579.90 |
| 100 | 4.69 | 119.74 | 4.08 | 104.08 | 108.15 | 0.86 | 1297.09 |
| 120 | 3.61 | 141.67 | 3.14 | 123.14 | 126.28 | 0.88 | 1096.29 |
| 140 | 2.85 | 163.91 | 2.47 | 142.47 | 144.95 | 0.88 | 947.51 |
| 160 | 2.29 | 186.36 | 1.99 | 161.99 | 163.98 | 0.89 | 833.36 |
| 180 | 1.25 | 208.34 | 1.09 | 181.09 | 182.18 | 0.89 | 497.00 |

Table 4. Different values of thrust and angle at different propeller regimes.

| N2/n1 | Ttot | | Angle | Teff | Tx | Ty |
|---|---|---|---|---|---|---|
| (-) | (kg) | (N) | (deg) | (N) | (N) | (N) |
| 1 | 708.31 | 6948.54 | 0.00 | 6601.11 | 6601.11 | 0.00 |
| 0.866769 | 710.82 | 6973.17 | 3.20 | 7036.54 | 7025.57 | 392.79 |
| 0.74928 | 717.98 | 7043.37 | 6.40 | 4960.77 | 4929.85 | 552.97 |
| 0.642565 | 729.90 | 7160.33 | 10.60 | 3863.57 | 3797.64 | 710.71 |
| 0.545337 | 746.49 | 7323.10 | 15.00 | 3107.70 | 3001.81 | 804.33 |
| 0 | 804.86 | 7895.64 | 15.00 | 2551.41 | 2464.47 | 660.35 |

The regimes below 50% of difference in regime are avoided to avoid possible phenomena, which can affect fan couple in parallel. This is particularly important in the case of axial fans because of their pronounced stall characteristic. In practice, before this condition is reached, the fans may exhibit a noticeable "hunting" effect.

It has been possible to verify the possibility of applying the ACHEON propulsion system to a Dornier Do 28 D2. The outstanding results in terms of landing space and the verification of compatibility in terms of produced thrust allows reducing of more than 50% the needs in terms of landing an takeoff space.

After these results, a preliminary redesign activity has started in order to define a more actual aircraft design and use of composite in substitution of at least 30% of the aircraft structure with a reduction in terms of weight of about 20%.

The loss of weight by ACHEON propulsion units and reduction of weight will be estimated in about 300 kg, The composite elements substitution will give a reduction about 350 kg . It is then possible to evaluate max combustible mass in 710 kg. It means that a mass about 1360 kg could be disposable.

An effective evaluation about installing a cogeneration unit can be possible. Assuming to use a Rolls Royce RR500 Turboprop based cogeneration unit, which ensures good performances (Dry weight: 102 kg, Maximum continuous Power 300 kW; Normal power 260 kW, Fuel consumption: Max continuous 117.8 kg/hour; Normal: 107.48 kg/hour).

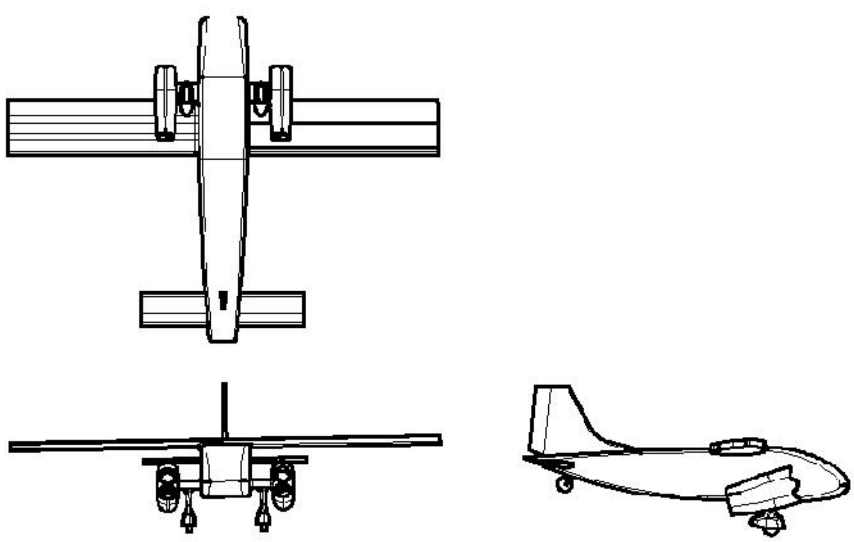

Figure 8. Preliminary aircraft redesign activity.

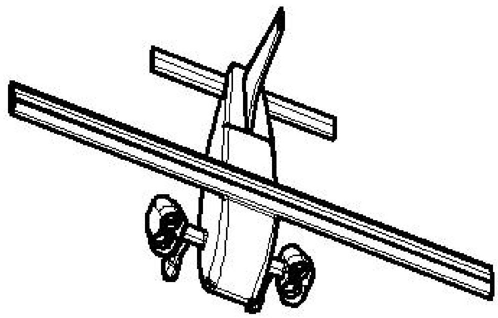

Figure 9. Preliminary aircraft redesign activity

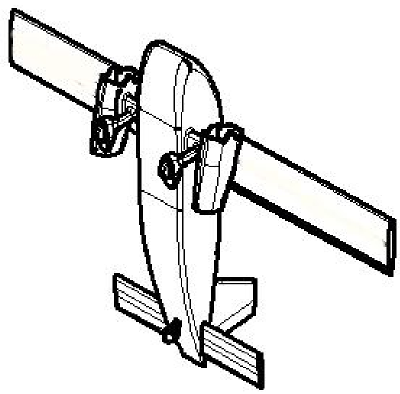

Figure 10. Preliminary aircraft redesign activity

This turbine has a fuel efficiency about 38% and then 62% of the thermal energy is dissipated. Assuming an exhaust heat recovery unit it can be recovered about 80% of the heat by a cross flow heat exchanger. The heat recovered by a solution of water and glycol can be used for heating the honeycomb section of the ACHEON Nozzle.

Considering the thermal exchange model of honeycomb it is possible to make a reasonable hypothesis of ceasing to the air almost the same amount of energy that generates electric production. It means about 260 kWt. at a temperature of about 120 °C. Calculating the efficiency of the system by considering the following heat exchange model (Figure 23) an average efficiency of the exchanger can be assumed about 50%. It is characterized by an external chamber, in which hot water flows and exchanges with the internal metallic honeycomb structure, which is used for reducing the swirl component of the flow.

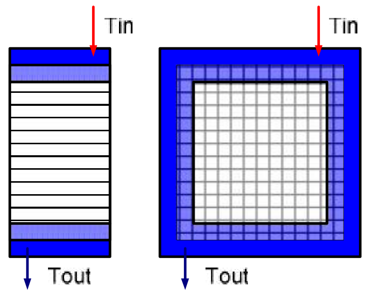


Figure 11. Heat exchanger concept.

In conclusion, the actual even if preliminary stage of design demonstrate that the possibility of equipping a Dornier Do-28D2 by ACHEON propulsion with large benefits in terms of takeoff space, landing space, climbing rate and descent rate In addition a study on the Architecture of CESSNA 402 has been realized.

## LOW WING COMMUTER

It clearly demonstrates the benefits of the ACHEON nozzle applied to the propulsion of a commuter class transport twin-engine aircraft. The choice has been focused on the Cessna 402 aircraft because its geometric conformation, which could easily allow a positioning of the ACHEON nozzle with centre of thrust almost coincident with centre of mass. The basic control equations of an aircraft has produced with this singularity showing the benefits of variable direction thrust applied in this position.

For simplicity three only positions has been considered, because they seems the state that can be easily produced at this level of research activity. They are full thrust (two fans on) with an angle t of inclination (with t comprised between 0° and 15 °. A nozzle with opening equal to t so that two extreme positions could be stabile:

- 0° for horizontal flight, with higher jet near 100% ant the other below 50%.
- 2t for takeoff operations to sustain the airplane during operations with lower jet about 100% and lower below 50%.

The aircraft configuration has been studied reflecting on the aircraft performances and required powers for different operations. A complete analysis of the performances of the modified Cessna 402 plane will be performed against the traditional plane with propellers. In particular, Fig. 16 shows the airplane configuration with a section on the ACHEON propeller and allows understanding the main positioning of the system.

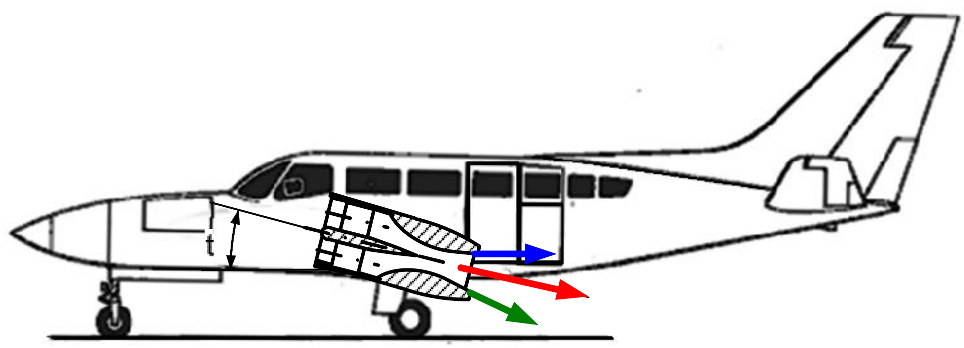


Figure 12 - ACHEON configuration on a longitudinal plane section and main directions of thrust.

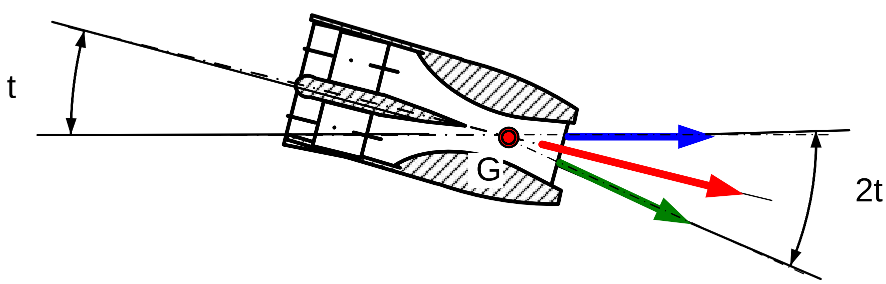


Figure 13 - Nozzle positioning and limiting thrust  vector directions

Fig 13 shows the detail of the ACHEON nozzle section and its configuration so to allow a better comprehension of its behaviour. In particular, the proposed model presents a limitation in angular terms of the jet, so to allow an effective prediction of the maximum angle, which could be reached.

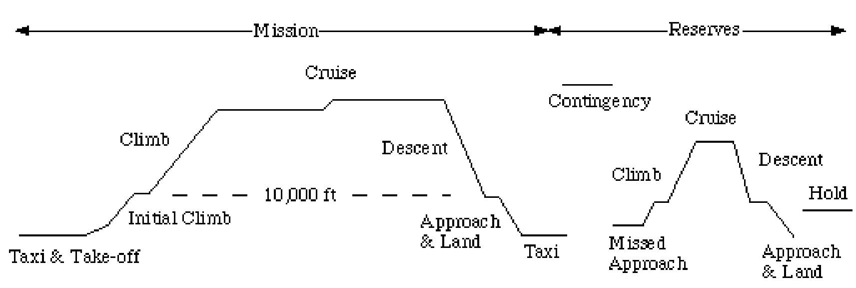


Figure 14 - Typical mission profile divided in mission and reserves

To simplify the model controls and to ensure a better integration with the airplane configuration a positioning of the geometric centre of thrust coincident with the centre of gravity will be considered. Otherwise, it is evident that torque components could be introduced with negative consequences on the aircraft behaviour. The application of the centre of thrust rotation in the centre of gravity could is also considered to increase the safety of the system and allowing an adequate system behaviour in case of technical problems.

In particular, there will be assumed three limiting positions:

– an angle = *0* ensured by top jet (horizontal flight);

– an angle = *t* ensured by both jets (take off);

– an angle = *2t* ensured by bottom jet (landing).

Different angles t could apply, as demonstrated by the project activities. they space in a range *12* ö *25°* . The effects will be evaluated for some specific angles, while jet velocity and regimes will be defined according to specific conditions.


Figure 15 - Cessna 402 during takeoff

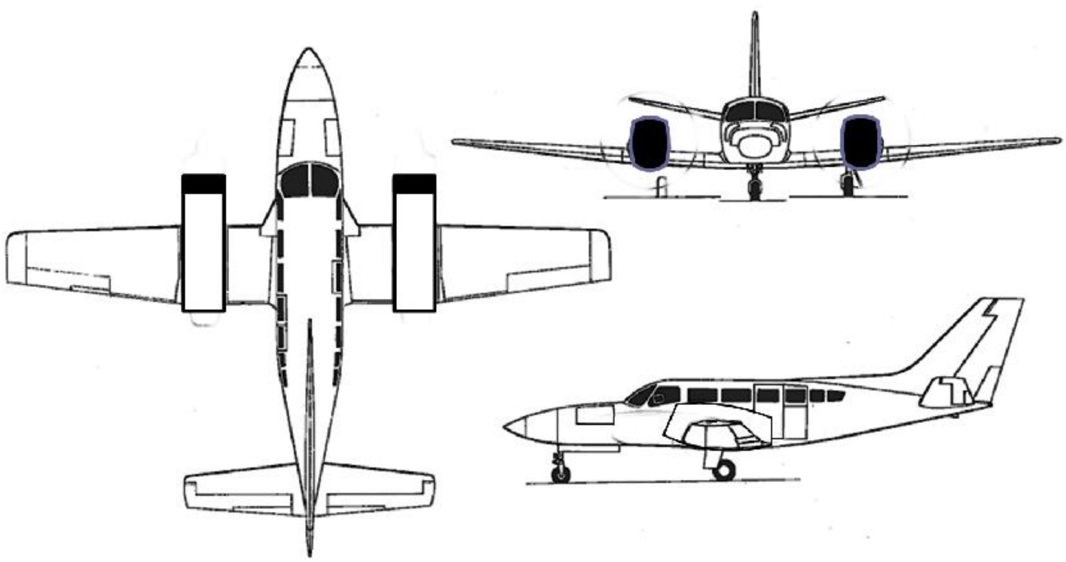

Figure 16 - Cessna 402 modified for installing acheon.

Energetic and environmental evaluations will be also performed.

To describe the results a specific mission will be considered. The typical mission profile is defined according to the FAR standards for commercial vehicles.

In some operations, different operative methods will be taken into account and will be compared. The analysis will also consider FAR standards to verify the suitability of the system for future application into aviation. Further considerations will regard the possible modifications, which could be necessary to the FAR to allow ACHEON integration. ACHEON will be also preliminarily evaluated against EC Reg. No. 216/2008, identifying future certification needs for flying in Europe. A typical mission profile is illustrated in Fig. 14.

The results will be compared to the effective performances of Cessna 402 analyzing improved one and reduced ones. Energy and performance related considerations would be performed focusing on the specific effects of the all-electric ACHEON propulsion system.

Further consideration will regard the necessity of further improvements, which could be necessary for implementing in ACHEON. It is assumed to use the same aerodynamic configuration, which is used for traditional version and equal thrust condition.

The main parameters of the aircraft have been preliminarily calculated. The propulsion model is shown in Fig. 17 The lift and drag data are calculated and reported in Table 5 and the engine data in Annex 1, will be used as models of the aircraft and engine.

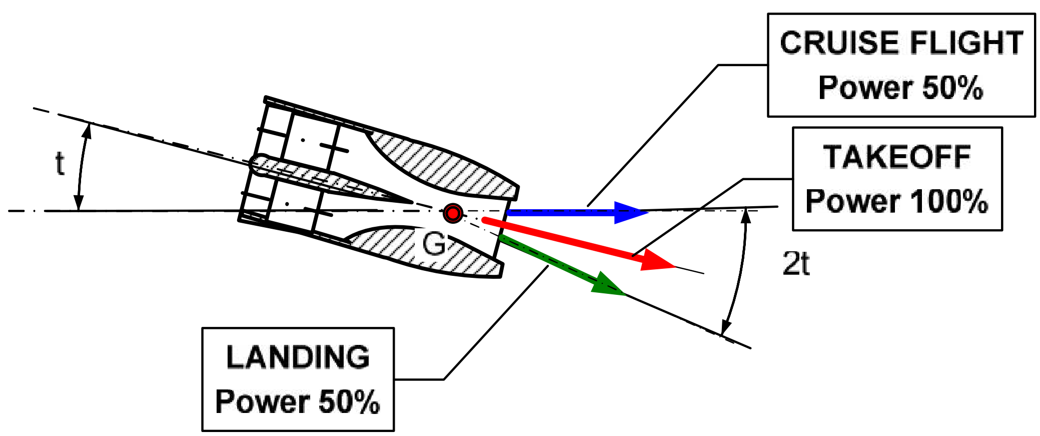


Figure 17 - Preferential use of different configurations during different flight operations

A concrete/asphalt runoff is supposed with friction coefficient *0.02* for takeoff and landing operations.

Table 5 - Aerodynamic parameters

| | |
|---|---|
| $C_{D0}$ | 0.027 |
| E | 7.7 |
| K | 0.00617 |
| $C_{L0}$ | 0.167 |
| $C_{Dmax}$ | 0.0338 |
| $C_{Lmax}$ | 1.104 |
| $C_{Lmax,carriage}$ | 0.0415 |
| $C_{Lmax\ carriage}$ | 2.35 |
| $W_{TOmax} / S$ | 185.86 |
| $T_{SL}/ W_{TOmax}$ | 1.67 |

The following data can be assumed by FAR Part 25 (Table 6).

Table 6 - FAR Part 25 optimal takeoff and landing parameters.

| | Number of Engines | | |
|---|---|---|---|
| Flight Condition: | 4 | 3 | 2 |
| First Take-Off Segment | 0.5% | 0.3% | 0.0% |
| Second Take-Off Segment | 3.0% | 2.7% | 2.4% |
| Final Take-Off Segment | 1.7% | 1.5% | 1.2% |
| Enroute Climb | 1.6% | 1.4% | 1.1% |
| Approach Segment | 2.7% | 2.4% | 2.1% |
| Landing Segment | 3.2% | 3.2% | 3.2% |

Simplified takeoff profile is assumed Main data have been reported in Table 4.

Table 7 - Flight behaviour

| | Angle of Attack | Angle of Climb | Pitch Attitude | Incidence | Airspeed |
|---|---|---|---|---|---|
| Initial roll | 4.5° | 0° | 0.0° | 4.5° | Small, incr. |
| After rotation | 12.0° | 0° | 7.5° | 4.5° | increasing |
| At liftoff | 12.0° | 0° | 7.5° | 4.5° | 6% below $V_Y$ |
| Initial climb | Decr. | incr. | 7.5° | 4.5° | increasing |
| Steady climb | 7.0° | 5° | 7.5° | 4.5° | 10% above $V$ |

The values in Table 7 have been calculated during takeoff, considering that the average speeds during these operations has been evaluated at $0.71\ u_{takeoff}$. It is the first part of the takeoff it relates to the following phases transition a screen up to *35 feet* (*10m*) has been considered, as specified by FAR Part 25. Maximum initial vertical speed of *7.6 m/s* is assumed for the CESSNA 402 and it results after take off. It means that the initial average horizontal speed is 52.7 m.

Table 8 - **Take off parameters**

| | Propellers | ACHEON | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Angle of deflection | | | 15° | | 10° | | 5° | 0° | |
| Direction of | | Tx | Ty | Tx | Ty | Tx | Ty | Tx | Kg |
| Thrust | 5185.2 | 5009 | 1342 | 5106 | 900.4 | 5166 | 451.9 | 5185 | kW |
| Max Power | 280 | | | | | | | 280 | m/s |
| $u_{stall}$ | 46.3 | | 26.3 | | 32.9 | | 39.5 | 46.3 | m/s |
| $u_{stall,carriage, down}$ | 31.74 | | 18 | | 22.6 | | 27.1 | 31.7 | Kg |
| Take off mass | 3105 | | | | | | | 3105 | m/s |
| Lift Off Speed | 50.93 | | 28.93 | | 36.19 | | 43.45 | 50.93 | m/s |
| Take off Speed | 55.56 | | 31.56 | | 39.48 | | 47.4 | 55.56 | m |
| Liftoff Length | 641.5 | | 206.8 | | 323.4 | | 468.4 | 690 | m |
| Takeoff Length (calculated) | 690 | | 222.4 | | 347.8 | | 503.8 | 690 | m |
| Take off length declared | 670 | | | | | | | | m/s |
| Lift Off Time | 16.5 | | 9.48 | | 11.9 | | 14.32 | 16.5 | S |
| Take Off Time | 17.74 | | 10.2 | | 12.8 | | 15.4 | 17.74 | kJ |
| Energy needs | 132012 | | 27468 | | 31068 | | 34668 | 44280 | kJ |
| Energy saving | 0 | | 104544 | | 100944 | | 97344 | 87732 | - |
| Energy saving | 0 | | 79.19% | | 76.47% | | 73.74% | 66.46% | |

Energy needs for take off includes also taxi time wait ant run, according to FAR Part 25. Ten minutes operations has been estimated. .

Advantages in terms of energy saving are evident at each angle of the takeoff length. It can be verified that if it has been assumed a well defined load factor during operations that could not exceed 1, to ensure an adequate comfort of the passengers,

*n=L/W,*

which becomes for ACHEON propelled airplanes

*n = (L + T sin t ) / W* á *1,*

that constitutes a precise limit to aerodynamic loading in function of the thrust.

*L* á *W - T sin t (45).*

It shows clearly that the flight asset can be ensured in two ways:

1. by changing lift maintaining directional thrust;

2. by changing thrust direction maintaining aerodynamic lift.

The other evident result is that the same take off performance could be also obtained with a much-reduced aerodynamic lift and then a lower drag.

It is assumed that the plane at the end of takeoff segments up to 10,000 ft (3048 m) reaches the cruise speed (109 m/s).

After the transition phase it is expected a slow transition from the dual jet configuration to allow the jet to adhere to the upper surface, as shown in figure 19, but also a climb with inclined Thrust can be performed. An angle of attach of 7* has been considered.

The difference in terms of accelerations between the two solutions is evident by subtracting the system of equations (13) and (15).

$$\begin{cases} m \cdot \left(a_{x,t} - a_x\right) = T \cdot \cos t \cdot \cos c - T \cdot \sin t \cdot \sin c - T \cdot \cos c = T \cdot \cos(c+t) - T \cdot \cos c < 0 \\ m \cdot \left(a_{y,t} - a_y\right) = T \cdot \cos t \cdot \sin c + T \cdot \sin t \cdot \cos c - T \cdot \sin c = T \cdot \sin(c+t) - T \cdot \sin c > 0 \end{cases}$$

It is clear the difference of accelerations along x-axis is reduced, while the one along y-axis is increased.

Average speed during climb can be evaluated in different configurations:

An average climb rate of *6.7 m/s* has been assumed. About *40 kWh* (*144000 kJ*) are necessary in all the configurations. Expected energy consumption is about *140 kWh* (*504000 kJ*) for traditionally propelled aircraft and about *53 kWh* (*191000 kJ*) for electric ones.

## Horizontal Flight

Flight will is estimated considering the above model and standard atmosphere data at 1000m. an average angle of attach of 3° has been assumed, even if a twin engine aircraft in cruise could also fly with horizontal axis. Consumption for 1 hour flight at *1000 m* and cruise velocity is expected to be *1060 kWh* (3816000 kJ) for traditional propulsion and about *360 kWh* (1296000 kJ) for electrical one only because of increased efficiency of electric propulsion. In the case of horizontal flight electric propelled airplane there is no mass reduction and this aspect must be considered during landing operations.

Landing energy needs can be evaluated according to usual twin-engine general aviation aircrafts. Typical angle and airspeed during landing are presented in Table 9.

Table 9- **Landing, Airspeeds and Angles**

| | Airspeed (KCAS) | Pitch Attitude | Incidence | Angle of Climb | Angle of Attack |
|---|---|---|---|---|---|
| cruise (clean) | 100 ÷ 120 | 0.0° | 4.5° | 0.0° | 4.5° |
| level VY (clean) | 70 | 4.0° | 4.5° | 0.0° | 8.5° |
| level (flaps) | 70 | 0.0° | 8.5° | 0.0° | 8.5° |
| slower (flaps) | 65 | 2.0° | 8.5° | 0.0° | 10.5° |
| descent (flaps) | 65 | -2.0° | 8.5° | -4.0° ÷ -6.0° | 10.5° |
| flare (flaps) | decr. | incr. | 8.5° | incr. | incr. |
| stall (flaps) | 46.3 | 12.0° | 8.5° | 0.0° | 20.5° |

Landing modes have been presented in Fig 20 assuming a traditional 3° glideslope. Figure 21 shows instead the complete landing manoeuvre considered. It is clear that gliding takeoff requires low energy needs. A 3° degree glideslope for a traditional Cessna 402 will require a landing space, which can be calculated and against the value of 757 m (declared by the producer). Calculations give a worst result of about *763 m*, which is acceptable because of the necessary approximations in calculations.

Data between the descent phase and landing using ACHEON can be assumed adopting a different profile (Table 10).

Table 10 - Landing, Airspeeds and Angles with ACHEON

| | | | Airspeed (KCAS) | Pitch Attitude | Incidence | Angle of Climb | Angle of Attack |
|---|---|---|---|---|---|---|---|
| cruise (clean) | | | 100 ÷ 120 | 0.0° | 4.5° | 0.0° | 4.5° |
| level VY (clean) | | | 70 | 4.0° | 4.5° | 0.0° | 8.5° |
| level (flaps) | | | 70 | 0.0° | 8.5° | 0.0° | 8.5° |
| slower (flaps) | | | 40÷65 | 2.0° | 8.5° | 0.0° | 10.5° |
| descent (flaps) | | | 40÷65 | -2.0° | 8.5° | -3.0°÷-12.0° | 10.5° |
| flare (flaps) | | | decr. | Incr. | 8.5° | Incr. | incr. |
| stall (flaps) for different angles of thrust (half power angle) | 0° | 0° | 46.3 | 12.0° | 8.5° | 0.0° | 20.5° |
| | 5° | 10° | 39.5 | 12.0° | 8.5° | 0.0° | 20.5° |
| | 10° | 20° | 32.9 | 12.0° | 8.5° | 0.0° | 20.5° |
| | 15° | 30° | *26.3* | 12.0° | 8.5° | 0.0° | 20.5° |

Different profiles of climbing has been considered for ACHEON propelled aircraft. they can be ensured by hybrid combination of vertical component of the thrust, when adhering to the lower surface and aerodynamic lift. In this case the thrust in vertical direction could be almost equal to the one during takeoff, while the horizontal one is much reduced. Angle of attack is considered the same as above. Considering different stall speeds ad maximum deceleration about 3 m/s both spaces and times for landing operations have been calculated. Results are presented in Table 8.

Table 11 - Landing performances in different configurations

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Inclination of the nozzle | 15 | | 10 | | 5 | | 0° | |
| Nozzle angle | 15 | | 10 | | 5 | | 0° | deg |
| Direction of thrust | 30 | | 20 | | 10 | | 0 | deg |
| | Tx | Ty | Tx | Ty | Tx | Ty | Tx | |
| Thrust | 2245.17 | 1296.25 | 2436.15 | 886.69 | 2553.11 | 450.18 | 2592.50 | kg |
| Max Power | | | | | | | 140 | kW |
| $u_{stall}$ | 26.3 | | 32.9 | | 39.5 | | 46.3 | m/s |
| $u_{stall,carriage, down}$ | 18 | | 22.6 | | 27.1 | | 31.7 | ù |
| Landing mass | | | | | | | 3105 | kg |
| Gliding Speed | 32.875 | | 41.125 | | 49.375 | | 55.56 | m/s |
| Touch down Speed | 28.93 | | 36.19 | | 43.45 | | 50.93 | m/s |
| Landing Space (calculated) | 431.71 | | 540.04 | | 648.38 | | 760 | m |
| Average landing acceleration | 2.03 | | 2.03 | | 2.03 | | 2.03 | m/s2 |
| Landing Time | 14.25 | | 20.26 | | 24.32 | | 2.00 | s |
| Ground roll Time | 14.25 | | 17.83 | | 21.40 | | 25.09 | s |
| Braking Energy | 2598.71 | | 4066.67 | | 5861.94 | | 8053.95 | kJ |
| Braking energy | 1559.23 | | 2440.00 | | 3517.16 | | 4832.37 | kJ |
| Braking Energy saving | 3273.14 | | 2392.37 | | 1315.21 | | 0 | kJ |
| Energy saving | 40.64% | | 29.70% | | 16.33% | | 0 | % |

It is now evident that ACHEON can also perform better performances in case of landing.

The ACHEON propulsion system can be improved by optimizing the inlet by an effective improvement of the inlet section, as verified by Trancossi and Madonia. By optimizing the air intake design it can be possible to increase the propulsive efficiency especially at high altitude. But this level of optimization it is not performed at this level because it requires a more effective design activity.

This analysis focus on the energy analysis of the electrical ACHEON propelled Cessna 402 against the model on the market. This analysis produces some interesting results.

In particular, the energy comparison are presented in Table 12. An emergency reserve higher than 15% is assumed to ensure some minutes flight for the electric ACHEON Propelled aircraft then the time for flight at cruise condition could not exceed 20 min for electric ACHEON propelled plane.

Table 12 - **Energy performances**

| | Configuration | | | | | |
|---|---|---|---|---|---|---|
| | Cessna 402 | Cessna 402 ACEON | | | | |
| Flight Condition: | traditional | 15° | 10° | 5° | 0° | |
| Take-Off | *132012* | *27468* | *31068* | *34668* | *44280* | *kJ* |
| Second Take-Off Segment | *504000* | *139100* | | | | *kJ* |
| Enroute (30min) | *1908000* | *636000* | | | | *kJ* |
| Approach Segment | *267120* | *53000* | | | | *kJ* |
| Landing Segment | *396036* | *8240* | *9320* | *10400* | *13284* | *kJ* |
| Energy consumption | *3207168* | *863808* | *868488* | *873168* | *885664* | *kJ* |
| Max on board energy | *0* | *1229580* | | | | *kJ* |
| Reserve | *-3207168* | *365772* | *361092* | *356412* | *343916* | *kJ* |

It can be verified that the original configuration is not adequately performing in terms of autonomy and energy storage. A better energy efficiency and cruise performance of the ACHEON propelled aircraft can be obtained by decreasing cruise speed about 324 km/h (90 m/s). data in this case increase to 40 min cruise speed.

Assuming average European electric production efficiency [*49*], which has been estimated about 50% in 2010, the effective energy demand will be about double than declared consumptions, but much lower than the one for the conventional engine.

More improved performances can be ensured by equipping the plane by an electric lightweight cogeneration system coupled by heat recovery system. Assuming a Rolls Royce-Allison Model 250 C20R turboprop [49] with a max nominal power of about *190 kW* and continuous power about *170 kW* (*602.5 MJ*) is considered. It has a weight of *62 kg* dry (*0.32 kg/kW*). Considering all the necessary accessories a weight about *1.2 kg/kW* can be conservatively assumed, including the heat recovery system. Assuming the hypothesis of recovering heat from the turboprop and recovering it by heating the fluid flow, preliminarily conceived by Trancossi, patented by Dumas et al and studied by Trancossi et al. Using the same calculation methodology used by Trancossi et al., thermal emission can be calculated by considering consumption about *0.48 kg/kWh* and a conservative global thermal exchange efficiency about *0.4*. The amount of recovered heat per hour is then *338.65 kWh* (*1220 MJ*).

It means an increase in terms of thrust about 30% that means a reduction of required electric power about *54 kW*.

This new condition allows ensuring flight with a partial system redefinition and general improve, with overall energy efficiency about three times the one of the traditional airplane.

In this case, it can be considered the following configuration *250 kg* of fuel, *250 kg* cogeneration system and *1050 kg* batteries.

This configuration could allow flight endurance about 6 hours with a sufficient reserve, This result is also interesting because the heat exchanger produces some losses but can be also used as a stator for straightening the jet as demonstrated by Shyam and Trancossi, which increases the adhesion, but also a positive thermal difference is a benefit because of an increased adhesion capability as demonstrated by Subhash in his thermal analysis.

The resulting configurations is summarized in Table 10.

Table 13 - Modified Cessna 402 Cogeneration Architecture for high energy performances

| | | |
|---|---|---|
| Empty weight | Lb | 4,069 |
| Useful load | Kg | 662 |
| Max takeoff weight | Kg | 3107 |
| Max on board fuel | **Batteries (Boston Power Swing® 5300 Rechargeable Lithium-ion Cell)** | |
| | Kg | 1050 |
| | Wh/kg | 207 |
| | Ah | 4,420 |
| | | **Fuel** |
| | Kg | 640 |
| **Propulsion** | | |
| Cogen | Rolls Royce Model 250 | |
| Power | kW | 250 |
| Mass | Kg | 250 |
| Motor | Four Plettemberg Nova 150 mounted in two ACHEON Nozzle | |
| Power | kW | 150 |
| Mass | Kg | 11.5 |
| **Performances** | | |
| Max speed | m/s | 118.9 |
| Max cruising speed | m/s | 109.4 |
| Stall Speed | m/s | 46.3 |
| Stall Speed Carriage | m/s | 25.1 |
| Initial rate of climb | m/s | 7.366 |
| Service ceiling | M | 8200 |
| Long range cruising speed | m/s | 84.4 |
| Range with reserves at economical cruising speed | km | 2000 |

The operated reduction of payload, which has been assumed in previous all electric architecture is maintained.

It has been clearly demonstrated the benefits of the ACHEON nozzle applied to the propulsion of a commuter class transport twin-engine aircraft. The choice has been focused on the Cessna 402 aircraft because its geometric conformation, which could easily allow a positioning of the ACHEON nozzle with centre of thrust almost coincident with centre of mass. The paper produces the basic control equations of an aircraft with this singularity showing the benefits of variable direction thrust applied in this position.

For simplicity three only positions has been considered, because they seems the state that can be easily produced at this level of research activity. They are full thrust (two fans on) with an angle t of inclination (with *t* comprised between *0°* and *15 °*. A nozzle with opening equal to t so that two extreme positions could be stabile:

- 0° for horizontal flight, with higher jet near 100% ant the other below 50%.
- 2t for takeoff operations to sustain the airplane during operations with lower jet about 100% and lower below 50%.

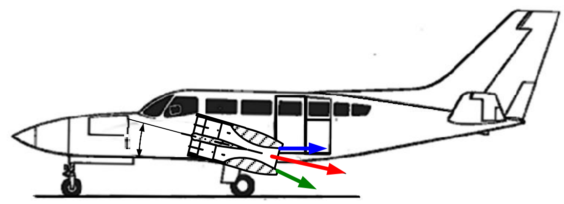

Figure 18 - ACHEON configuration on a longitudinal plane section and main directions of Jets

Kinematic and dynamic main parameters has been estimated during critical operations such as take off and landing verifying the benefits produced by the ACHEON nozzle in different flight condition. It appears fundamental, even if not directly presented in the paper, the importance of DBD to ensure an effective governable transition between the positions to avoid both too fast modifications of the airplane behaviour with potential stability problems and the actual considered capacity of producing thrust in three well-defined directions.

In particular, further application could benefit of the preliminary definition of a possible single jet architecture, which aims to reduce the problems derived from high frontal section required by the dual jet configuration.

A preliminary airplane configuration equipped by high performance batteries is presented.

Energetic evaluations has been performed demonstrating clearly the advantages of the proposed all electric system because of much higher energy conversion efficiency and because of the possibility, which has been presented to define a cogeneration airplane architecture equipped by a Rolls-Royce Model 250 turboprop based cogeneration unit. The large disposability in terms of heat to be dispersed could ensure the possibility of  producing a more effective propulsion effect by using them to heat the jets produced by the ducted fans.

The clear advantages of the cogeneration based solution against the battery only one is evident demonstrating the possibility of an effective applicability of ACHEON all electric propulsion in the future, with a cogeneration based propulsion architecture.

In conclusion, demonstrates the benefits of ACHEON based architecture to civil aircrafts ensuring adequate performances. Even if it is not still sufficient for future ACHEON equipped aircrafts it is a preliminary basis for continuing the studies on ACHEON thought a novel class of all electrical high performance aircrafts, which could not been thought before this revolutionary project.

## UAS IMPLEMENTATION

The implementation on a UAS architecture, based on the Nimbus original configuration has aloso allowed producing an effective result of a UAS that can takeoff and land in about 12 m with a mass of 4.5 kg and cruise as low as 8-12 m/s (but even lower) opening novel frontiers for low speed UAS.

This UAS concept has been named MURALS (acronym of Multifunctional Unmanned Reconnaissance Aircraft for Low-speed and STOL operation) which has been studied by joint activity of the member of the project.

This aerial vehicle concept envisages and develops a previous concept of an innovative single seat jet developed by Aeritalia and Alfredo Capuani, making it suitable for ACHEON based propulsion. In a first embodiment, the aircraft according to the invention has a conventional form with a single fuselage and its primary objective is to minimize the variation of the pitching moment allowing low speed operations.

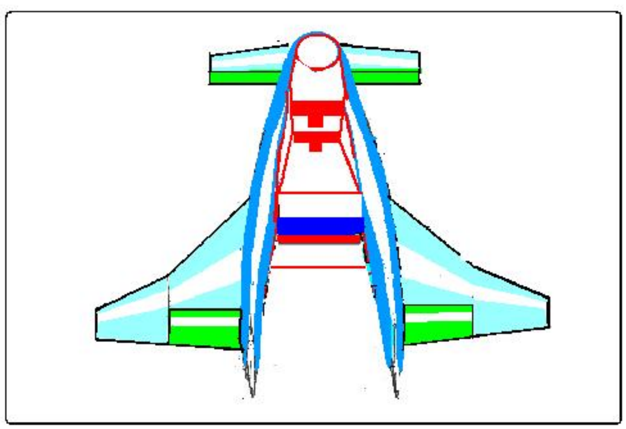

Figure 19. ACHEON integration scheme in Light UAS novel prototype (Original Design)

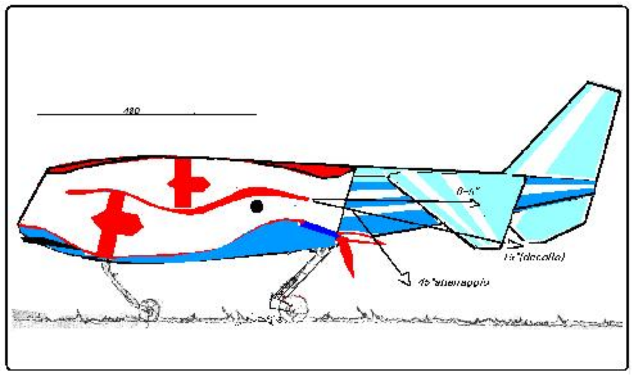

Figure 20. ACHEON integration and lateral view of the previous three analysed cases (15° take-off, 45° landing, 0-5° cruise condition)

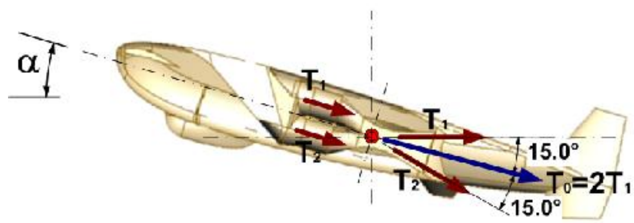


Figure 21. A section view of the airplane concept.

Main objective of the airplane is to allow control by mobile surfaces in the front canard and in the large wing. This plane has been specifically designed to flight at low velocities with a very high angle of attach without loosing in terms of agility.

The resulting airplane concept is specifically designed for road monitoring, and police support and is characterized. The results define an optimal sizing of the aircraft together with an effective performance analysis, which allows identifying the strong points and the potential problems of the project. An effective energy analysis has been performed also.

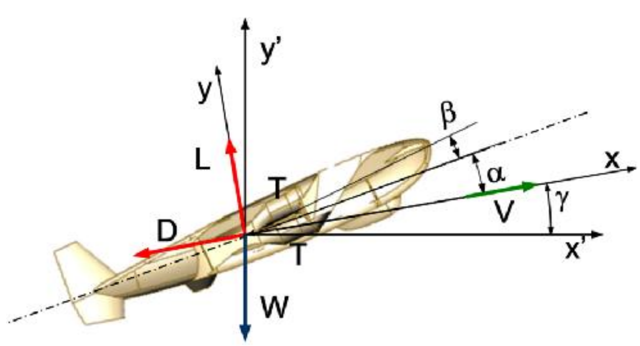

Figure 22 - Lift and Drag analysis

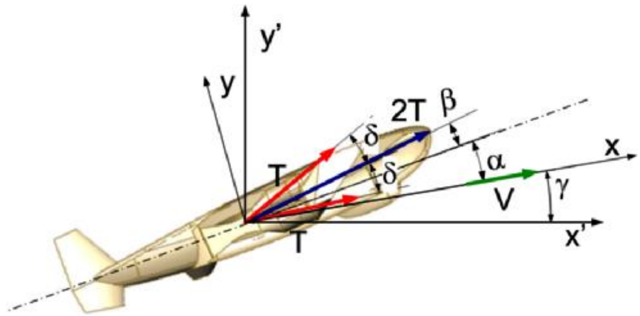


Figure 23. Thrust directions and aircraft angles

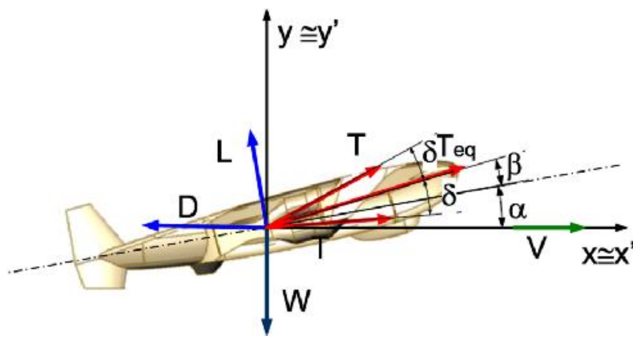


Figure 24. Airplane configuration in steady flight

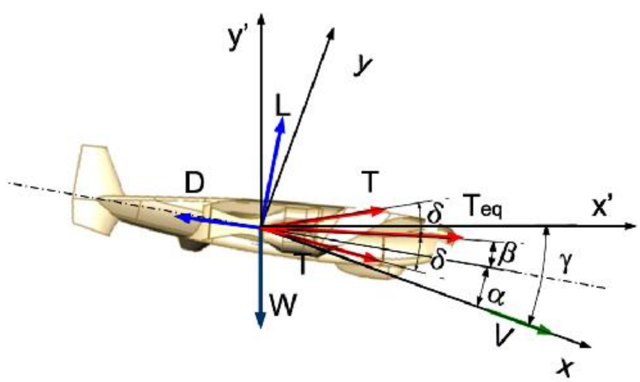


Figure 25. Forces on airplane during descent

Table 14. Aircraft data

| | | |
|---|---|---|
| External volume | $m^3$ | 0.025÷0.03 |
| Main front area | $m^2$ | 0.07-0.85 |
| Main aircraft planform area | $m^2$ | 0.4-0.5 |
| Main rear wing planform area | $m^2$ | |

| | | |
|---|---|---|
| Total mass (kg) | Kg | 5.5÷6.5 |
| Maximum Load factor | - | 4-5 |
| Wing span (m) | M | 0.9-1.1 |
| Length | M | 0.95÷1.1 |
| Max takeoff thrust | kg | 3.1 |
| Max takeoff Power | W | 2400 |
| CL,max | - | -2.0 ÷ 2.5 |
| CL,cruise | - | 1 ÷ 1.5 |
| $\beta$ | deg | 7 ÷ 9 |
| $\delta$ | deg | 15 |

According to the above defined models and components it is possible to start an effective evaluation of the performances. The main coefficients have been defined by Capuani and Sunol and Vucinic: CDmax = 0.1 (at takeoff), CDmin 0.035, CLmax=3.0, CLmin=1, AR=5, L/D = 10, and friction c0efficient with ground 0.05.

Table 15. Main Components

| Component | Unitary mass | Number | Total mass |
|---|---|---|---|
| | G | - | g |
| Propellers | 37 | 4 | 148 |
| Motors | 72 | 3 | 216 |
| Speed control | 26 | 4 | 104 |
| Servo | 85 | 4 | 340 |
| Receiver | 50 | 1 | 50 |
| Battery | 786.2 | 2 | 1572.4 |
| Cabling and accessories | 200 | 1 | 200 |
| | | Total mass | 2630.4 |

Takeoff performances are acceptable. Assuming an angle of attack of 7.5° and an angle of the fuselage and thrust 7.5°, making the hypothesis of max thrust, Vstall is about 9 m/s and assuming a speed Vtakeoff = 10.65, a complete takeoff length about 12 m, and a run of less than an acceleration of 3 m/s.

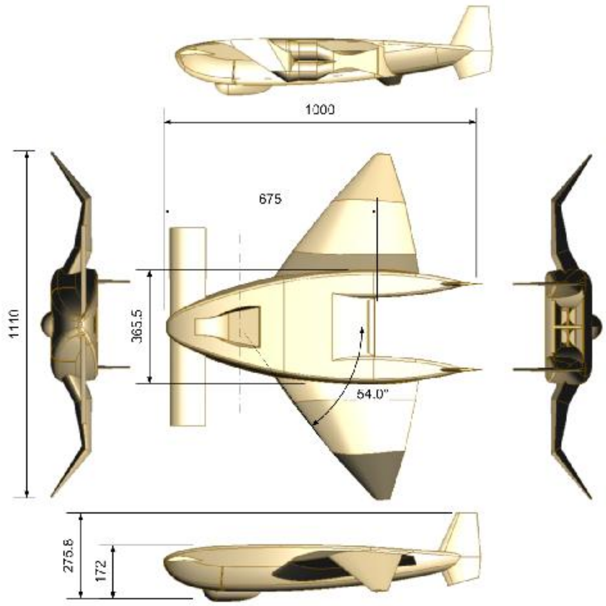


Figure 26. Aircraft preliminary dimensions

Climbing it can be effectuated a climb with an angle of 20° about and a speed about 14 m/s with angle of attack 7.5. Thrust is oriented upward wit an angle of 15°. It requires 2 ducted fan units with thrust oriented up and an angle of attach about 7.5°.

Cruise can be ensured also at low speed about 10÷12 m/s with opportune lift. Assuming a cruise speed of 25 m /s at min drag (about 1), it can be possible to estimate energy consumption.

Landing space results less than 12 m.

Assuming a reserve about 30%, it is possible to estimate more than 1-hour flight with selected batteries.

A precise design methodology for an innovative airplane based on the ACHEON propulsion system and based on the innovative MURALS configuration has been defined. .

Starting from methodological results an effective design activity will be produced taking into account the preliminary statements. After considering results from conceptual design, some important conclusions were drawn.

The proposed airplane architecture is very interesting for low speed operations and short take off and landing. The results show clearly that the designed aircraft meets the predefined objectives.

The weight of the overall structure of about 3 kg is acceptable however. It can be reduced by improving the design. This reduction will produce a further increase of the performances.

The airplane could be also improved considering a carbon fibre structure instead of the considered foam, both in terms of structural loads and in terms of better performances and accuracy of components, with a consequent reduction of weights.

The best wing loading can be achieved by carefully consider the aspect ratio of the main wing. A better wing loading can be achieved by carefully designing the fuselage profile.

Jet deflection studies performed in ACHEON project can affect dramatically novel concepts of aircraft vehicle design (both manned and unmanned) with enhanced manoeuvrability without moving parts resulting in energy savings and maintenance advantages.

Radical new concept of aircrafts can be joined to jet vectoring study to improve comfort, manoeuvrability and energy efficiency. Flight control without mobile parts and tails for light UAV segment cannot be reached without a full comprehension of directional control of propulsive jets.

From a market point of view, the ACHEON project applied to the UAS sector can make available novel platforms in terms of size, architecture and control system. This feasibility study of propulsive thrust vectoring can be integrated in the pre-design phase of new UAV concepts to enhance maneuverability and open up radical new product families.

With some further improvements, it can safely take off and land over a 40 ft container making it ideal for escort missions, civil protection and police fast intervention on roads, but also for many military missions.

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