

Design of a Cogeneration Hybrid Propulsion System for Commuter Aircrafts With Thermal Recovery

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Citation:

TRANCOSI, Michele (2015). Design of a Cogeneration Hybrid Propulsion System for Commuter Aircrafts With Thermal Recovery. In: EU Aerodays, London, 20-22 October 2015. ASME. (Unpublished) [Conference or Workshop Item]

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YES WE ACHEON!

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Sheffield Hallam University



The present work has been performed as part of ACHEON Project | ACHEON Project - Aerial Coanda High Efficiency Orienting-jet Nozzle project, with ref. 309041 supported by European Union through the 7th Framework Programme (www.acheon.eu).

We have a dream...

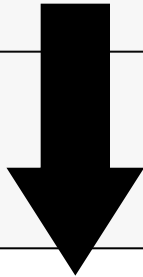


Vrije
Universiteit
Brussel

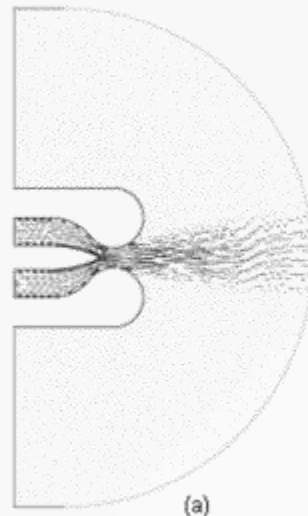


Control of dynamic deflection of a jet without any part in movement:

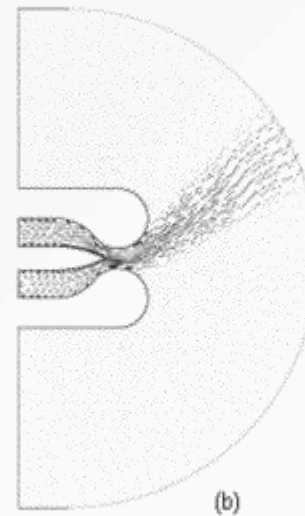
- **Fluiddynamic**
- **Electrostatic**



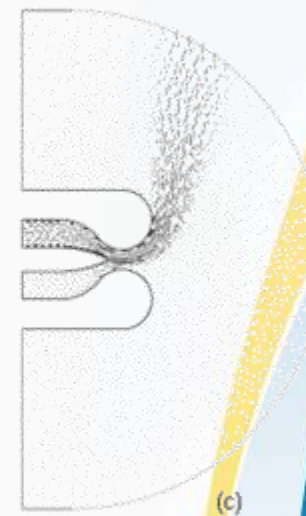
- **Propulsion;**
- **Distribution of chemicals**
- **Acclimatizing**
- **Deicing**
- **Technological Applications**
- **Etc.**



(a)

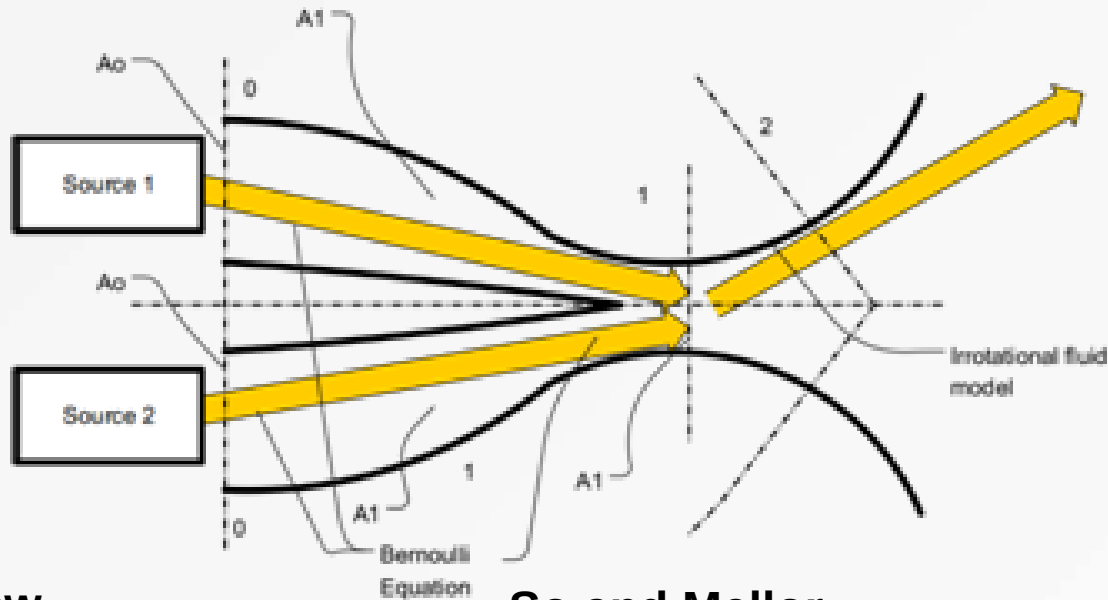


(b)



(c)

Coanda effect: something exoteric...



Bradshaw

$$\theta = f \cdot \sqrt{a \cdot b \cdot \frac{P_{wall} - P_{\infty}}{\rho \cdot u^2}}$$

Newman

$$u_p = \frac{P_s - P_a}{P_0 - P_a} = - \left[2 \frac{b}{a} + \left(\frac{b}{a} \right)^2 \right]$$

So and Mellor

$$u / u_{pw} = \left[(P_t - P_r) / (P_r - P_{sw}) + e^{-2ky} \right]^{1/2}$$

$$u_{pw} = [2P_r - P_{sw}]^{0.5}$$

$$\delta P / \delta y = k \rho u^2$$

Von Karman

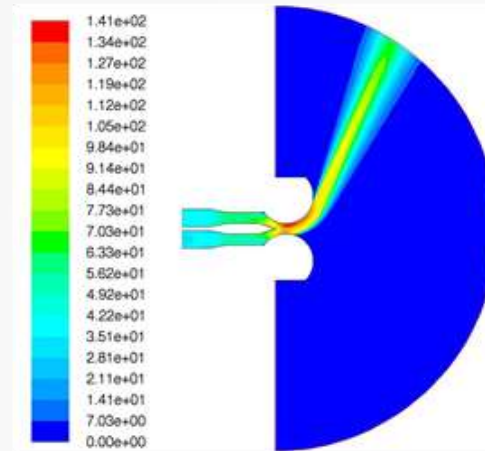
$$\mu \frac{d^2 u}{dy^2} = \frac{dp}{dx}$$

Yes we ACHEON!

45.7-35.3 m/s



40-35 m/s

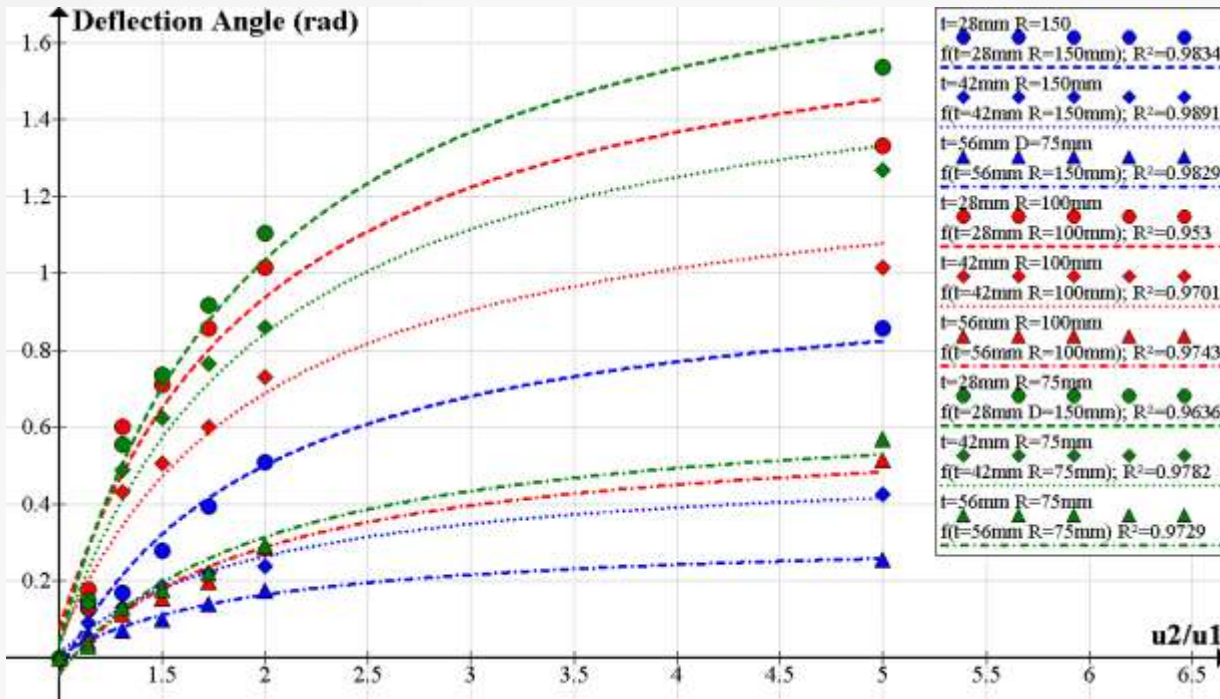


- The fluid stream is subject to a difference of pressure that equilibrates the centrifugal force.
- frictional effects that are depending on the velocity u

$$\frac{\partial P_r}{\partial r} = \rho \cdot \omega^2 \cdot r = \rho \cdot \frac{u^2}{r} \quad \tau = \mu \cdot \frac{\partial u}{\partial r} = c_f \cdot \frac{\rho \cdot u^2}{2}$$

$$u(r) - u_{\min} = \frac{R}{r} \cdot \Delta u_1 \rightarrow u(r) = \frac{R}{r} \cdot \Delta u_1 + u_{\min,1}$$

100% independent validation



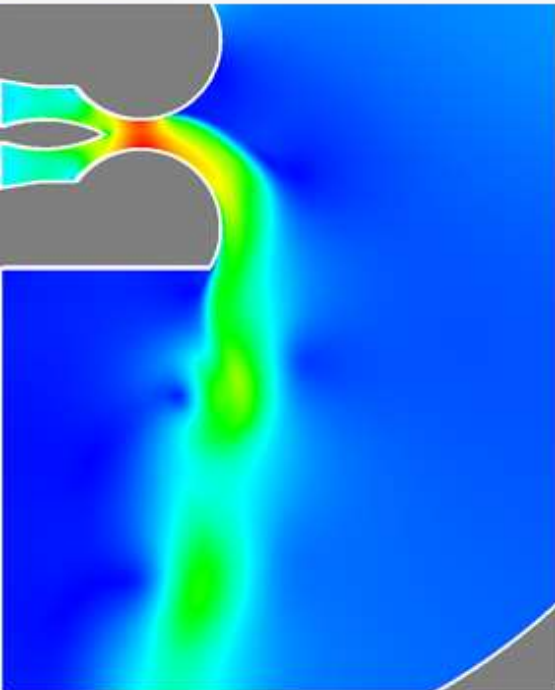
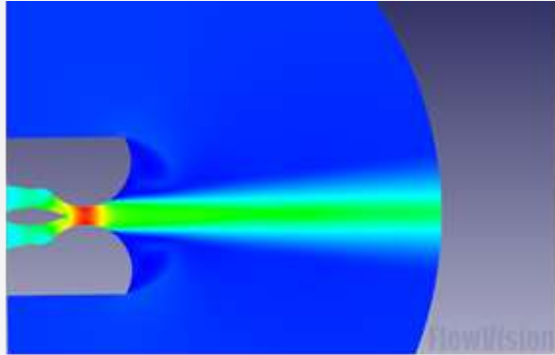
very preliminary model presented by Unimore, from which the project starts, is acceptable

Drăgan V.: A New Mathematical Model for Coandă Effect Velocity Approximation. INCAS Bulletin, vol.4, pp.85–92, 2012.

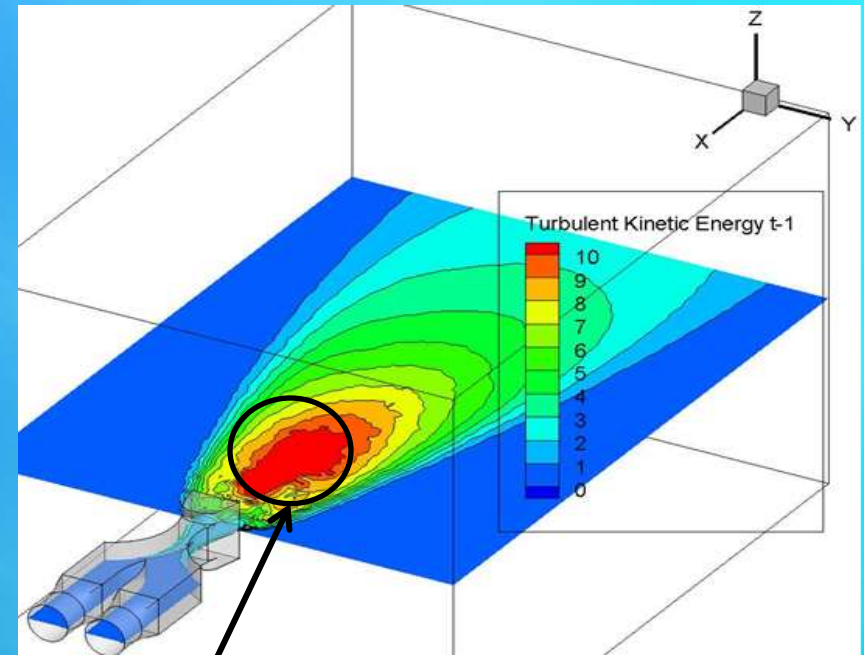
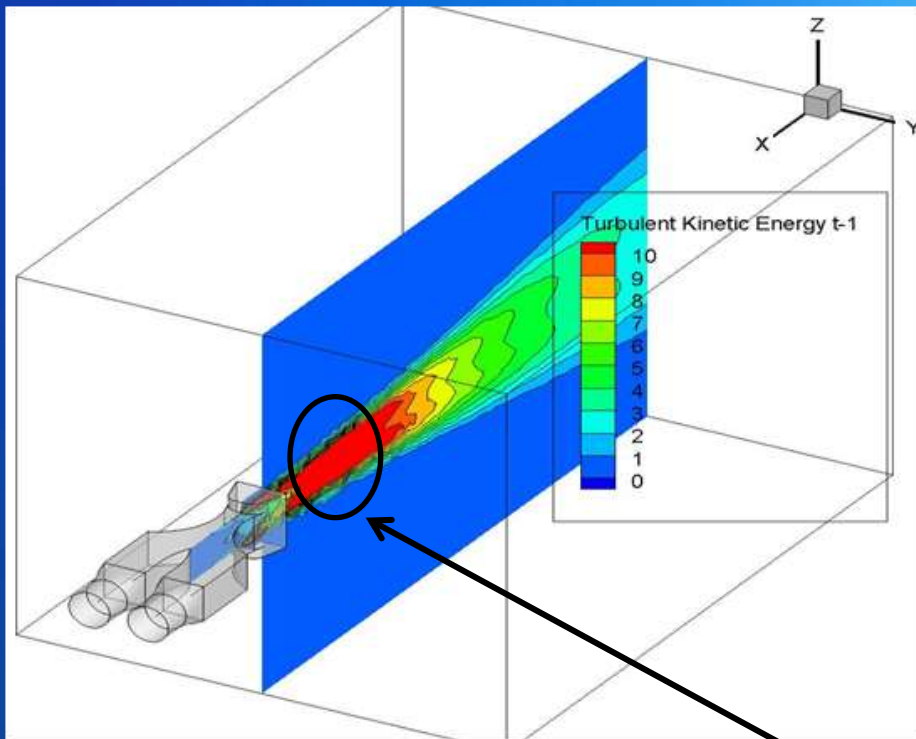
the last presented models works properly even if it needs to be implemented regarding better turbulence models and swirl.

Dragan V., "Reynolds number calculation and applications for curved wall jets", INCAS Bulletin, Volume 6, Issue 3, pp. 35 – 41, (2014).

Computations



Mass velocity [kg/m ² s]	60-60	58-62
F _x [N]	42.15	12.35
F _y [N]	0	41.92
Thrust angle [o]	0	73.35
Efficiency [-]	0.73	0.72

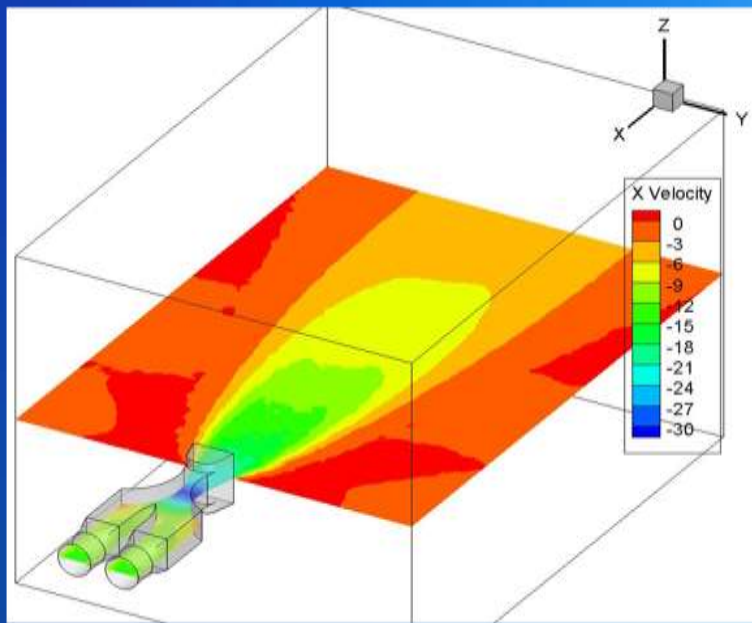


Control zone of interest

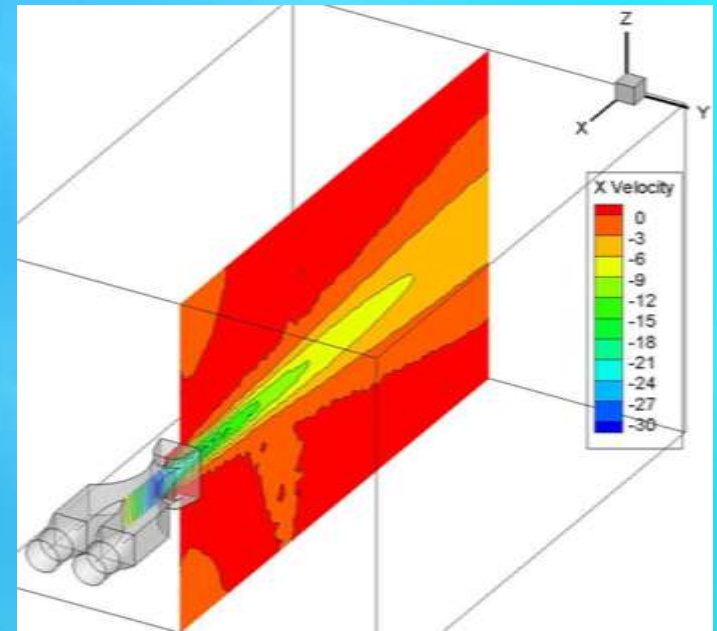
The turbulent kinetic energy shows that the control zone of jet is not just after the exit flow. What was the intuition before computation.

It is located little bit away from the exit.

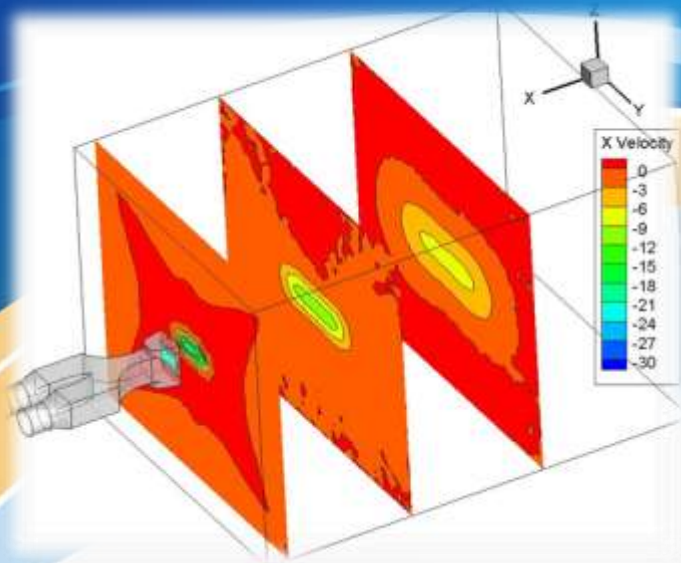
High turbulence zone in z plane indicates the fact.



Flow field for x-velocity for $z = \text{constant}$ for 3D simulation of the nozzle



Flow field for x-velocity for $y = 0$ for 3D simulation of the nozzle

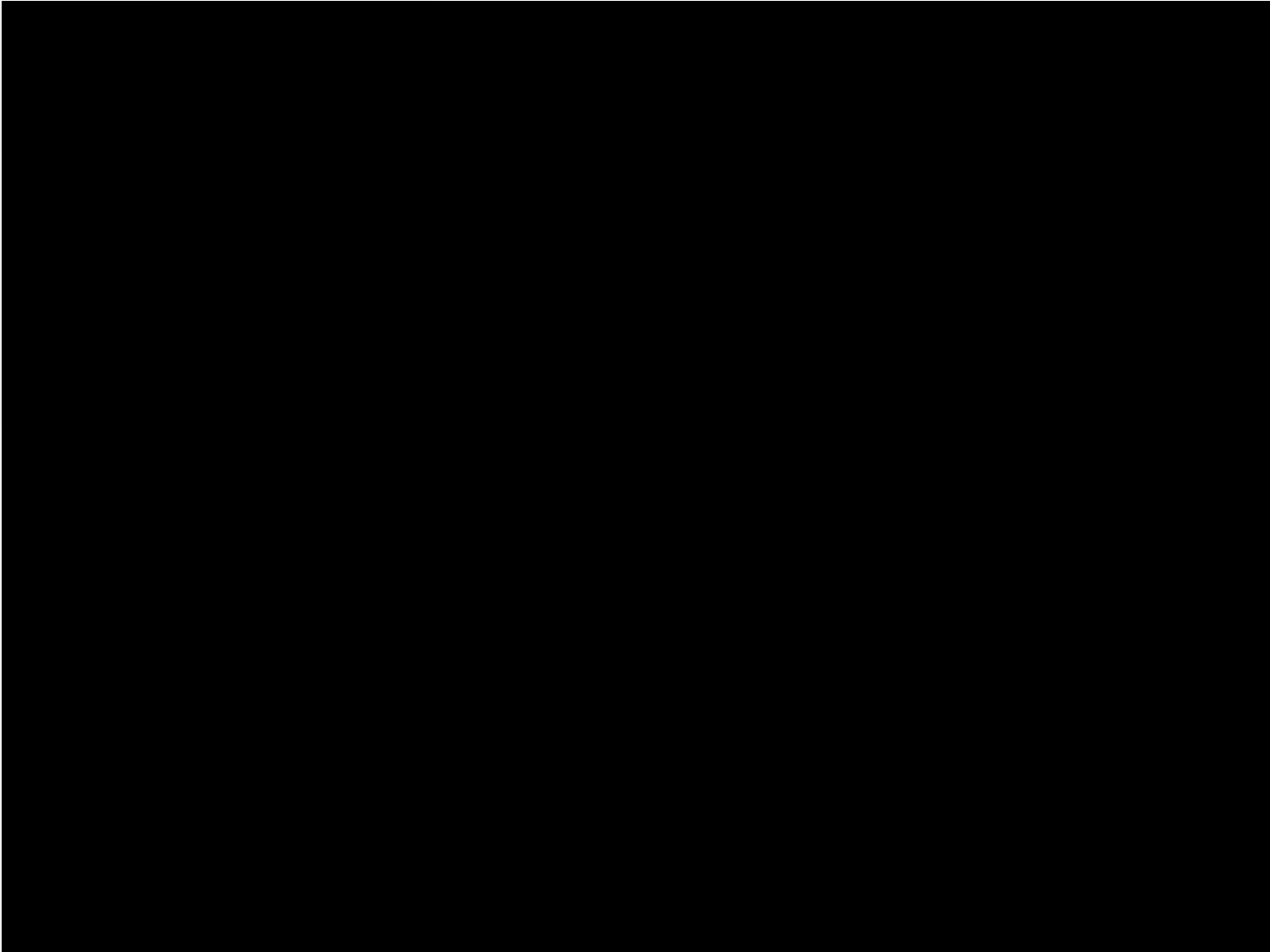


Flow field for x-velocity in x - direction

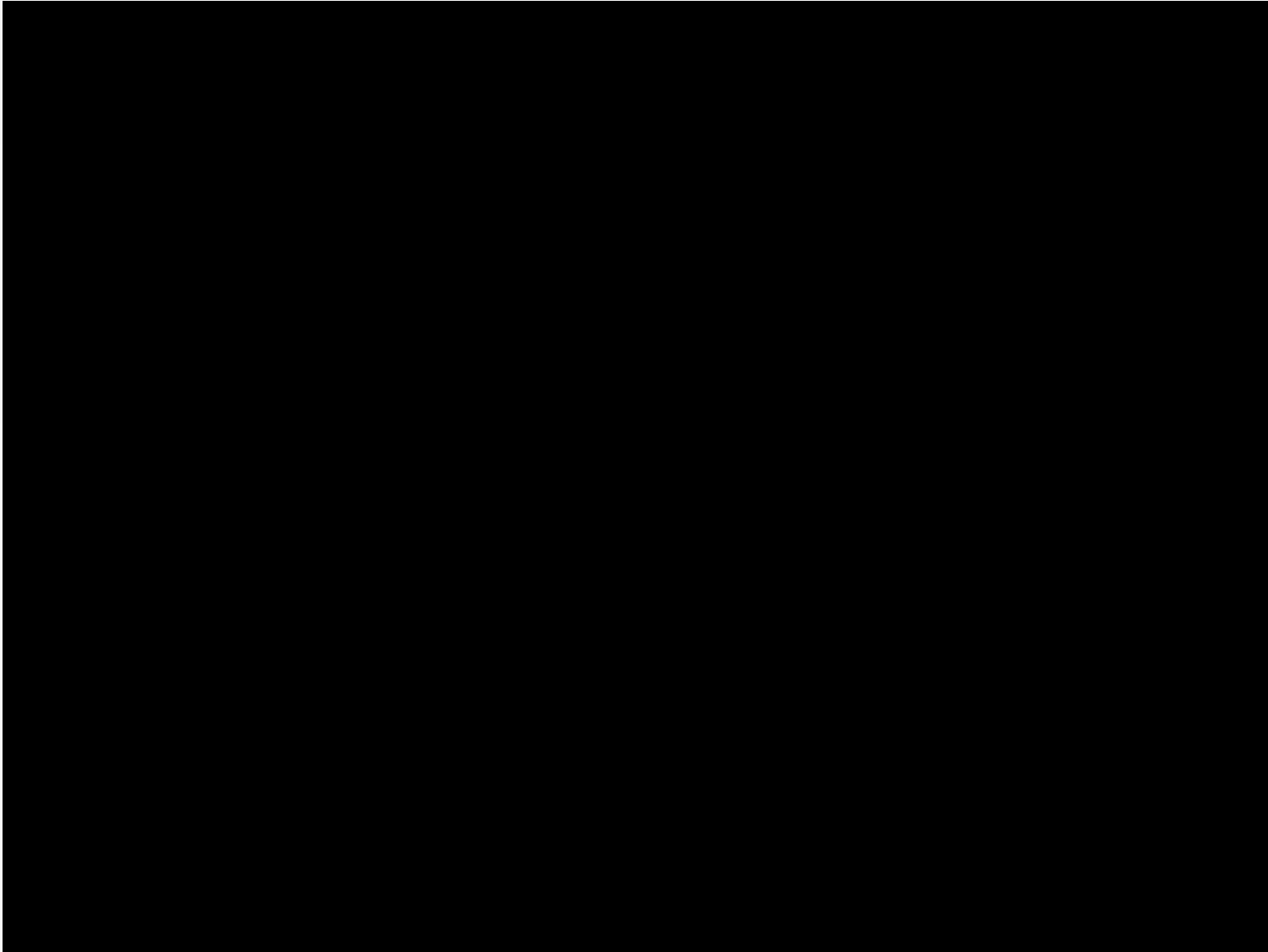
For the inlet velocity 10m/s, at the throat 30 m/s velocity is obtained.

Even slight velocity ratio for 1.5 ($15\text{ms}^{-1}/10\text{ms}^{-1}$) is able to deviate the jet either side.

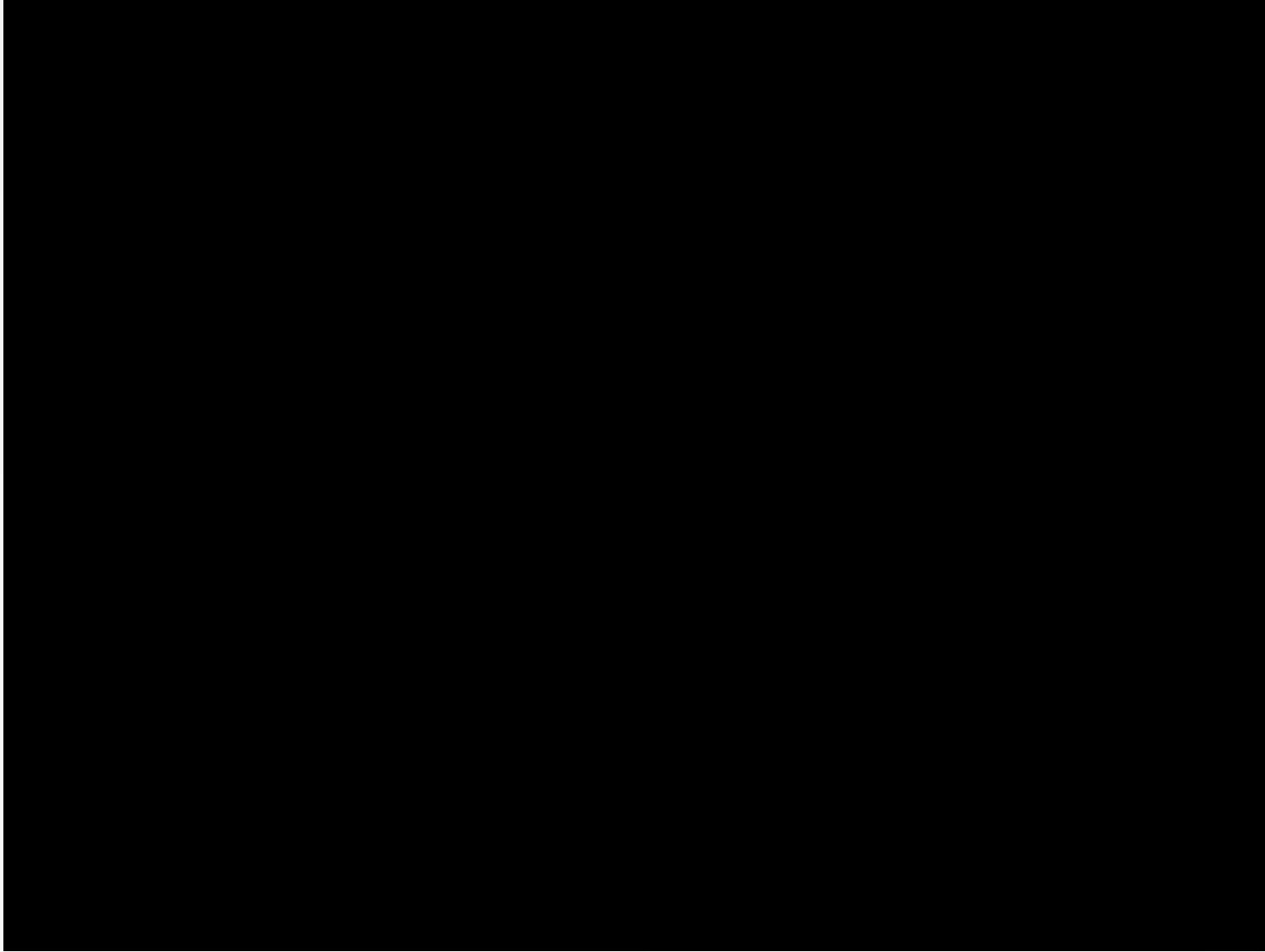
And some experiments...



And some experiments...



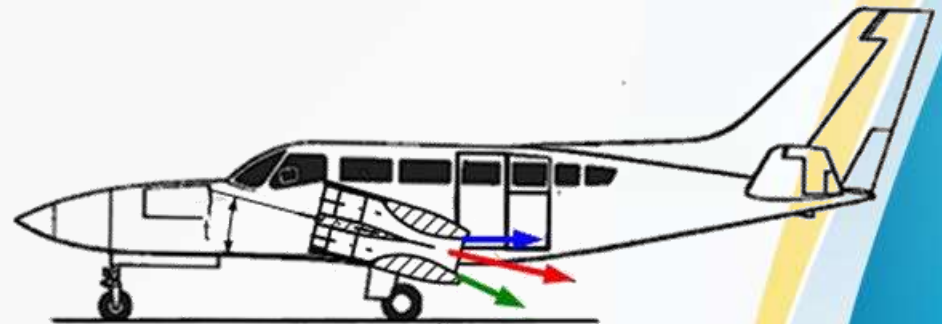
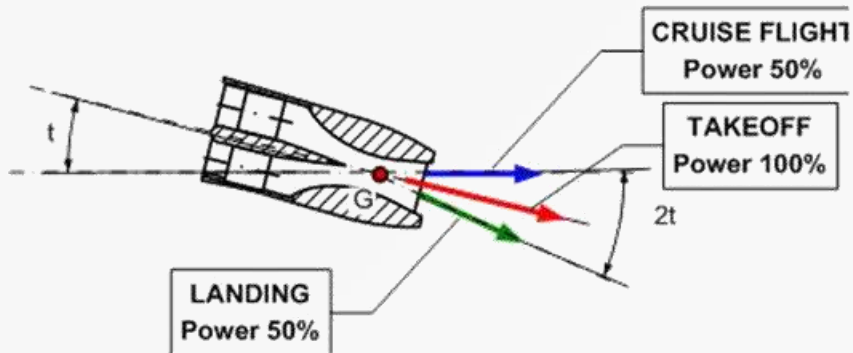
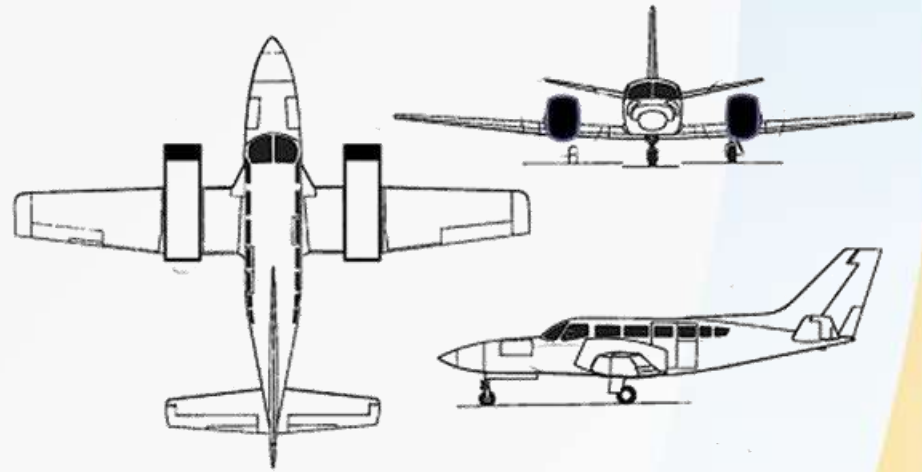
And some experiments...



Can it work on airplanes?

- A wonderful work has produced by UoL
- Cen Z., Smith T., Stewart P., and Stewart J, "Integrated flight/thrust vectoring control for jet-powered unmanned aerial vehicles with ACHEON propulsion", Proceedings of the Institution of Mechanical Engineers, Part G: Journal of Aerospace Engineering, first published on July 29, 2014
- It demonstrates that the nozzle increases the maneuverability of an airplane with surprising results.

Acheonizing an old fashioned plane...



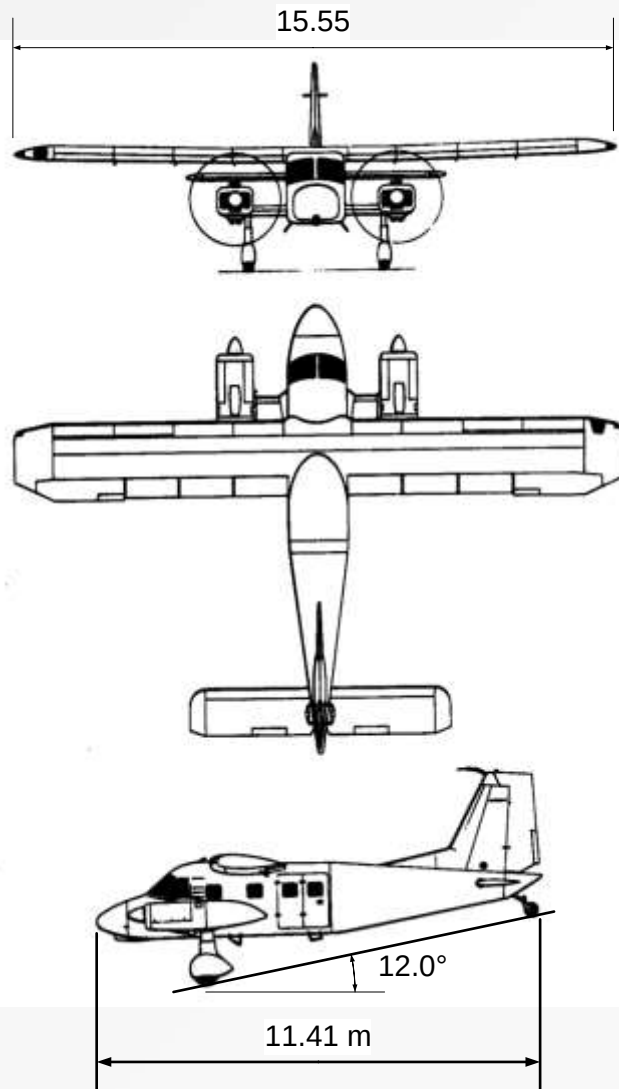
And now some boring numbers!

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

Propellers		ACHEON							
Angle of deflection		15°		10°		5°		0°	
Direction of Thrust	5185.2	Tx 5009	Ty 1342	Tx 5106	Ty 900.4	Tx 5166	Ty 451.9	Tx 5185	Kg 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
Lift off Length	641.5	206.8		323.4		468.4		690	m
Take off 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%	

	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

And now... the best commuter ever built...



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

n2/n1 (-)	Ttot		Angle (deg)	Teff (N)	Tx (N)	Ty (N)
(kg)	(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

Dornier Do 28 D2 can take off from the garden behind my house...

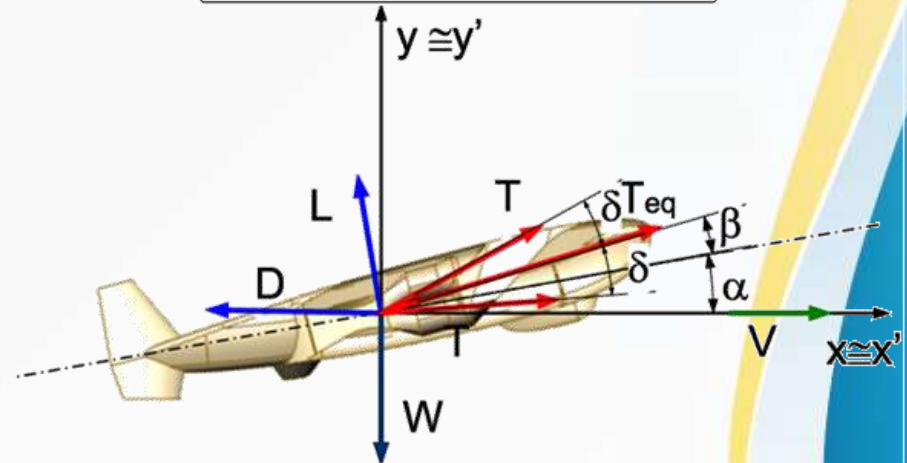
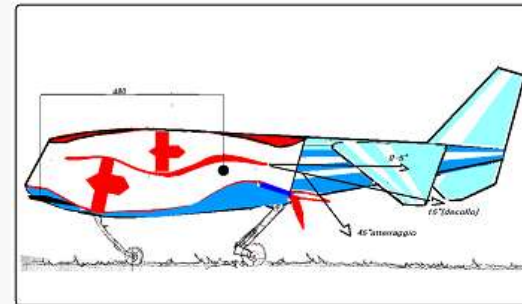
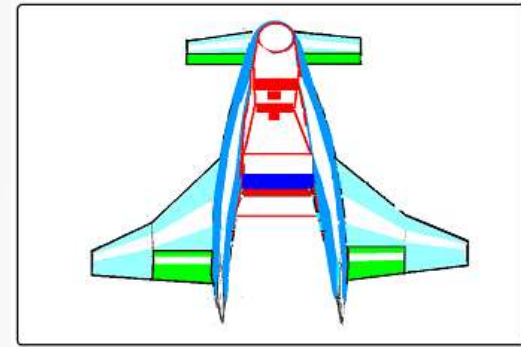
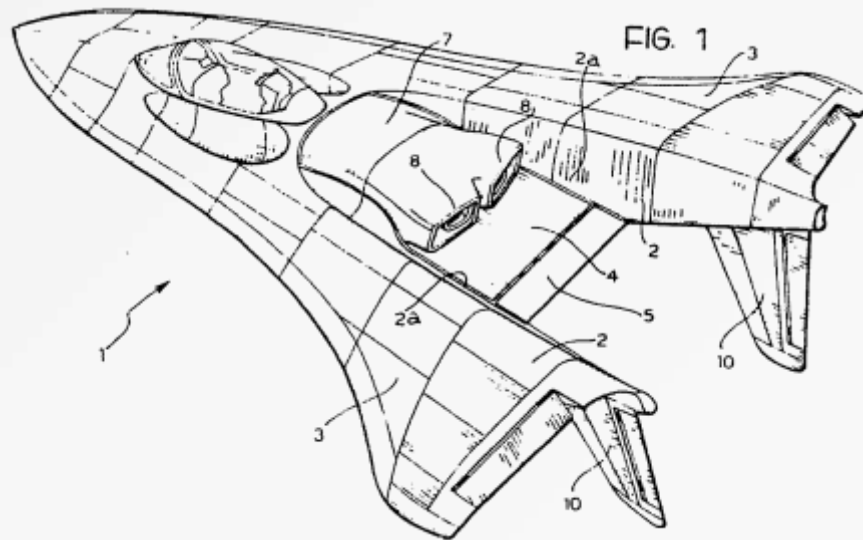
ACHEON allows reducing of more than 50% the needs in terms of landing and takeoff space:

from 170 m to less than 100.

Having some weight and payload

With RR series 250 turbofan cogeneration

...and let's do it strange...



whow... it can work!

Component	Unitary mass G	Number	Total mass 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

- Assuming an angle of attack of 7.5°
- Take off
 - angle of the fuselage and thrust 7.5° ,
 - max thrust takeoff,
 - V_{stall} about 9 m/s
 - $V_{takeoff} = 10.65$,
 - takeoff length about 12 m,
 - acceleration of 3 m/s.
- Climbing
 - angle of 20° about
 - speed about 14 m/s
 - angle of attack 7.5° ,
 - Thrust is oriented upward with an angle of 15°
- Cruise
 - min speed about 10-12 m/s
 - cruise speed of 25 m/s
- Landing
 - landing length less than 12 m.



Less than 4 kg



5 to 45 m/s

About 4.000 €

...and how can we improve it?

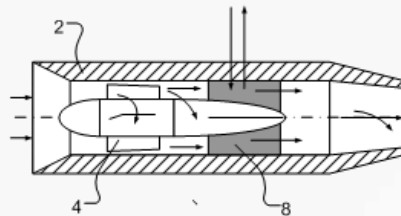
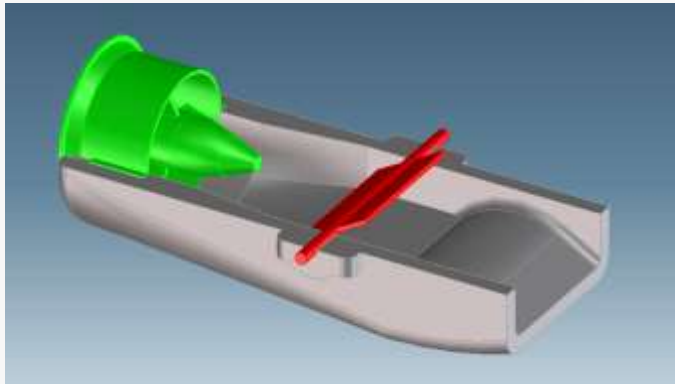
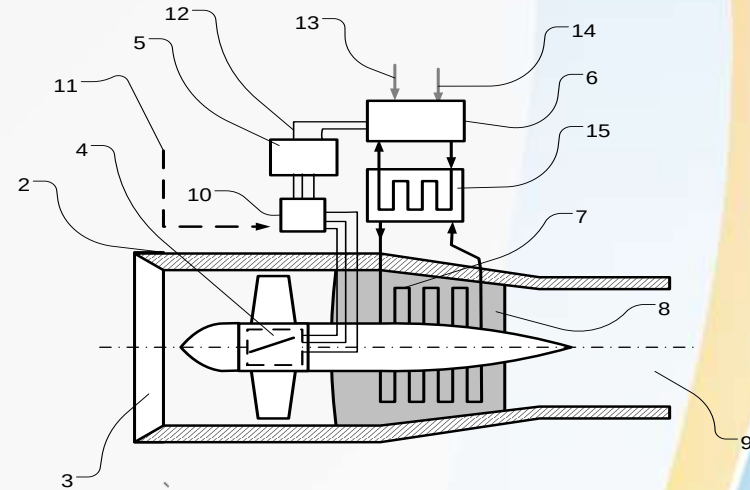
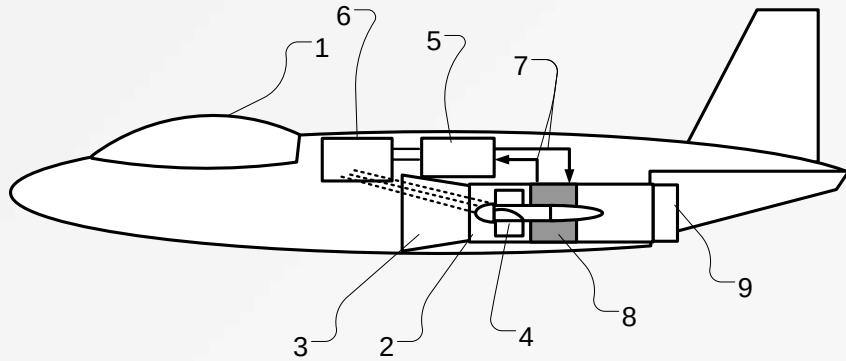


Fig 4/a

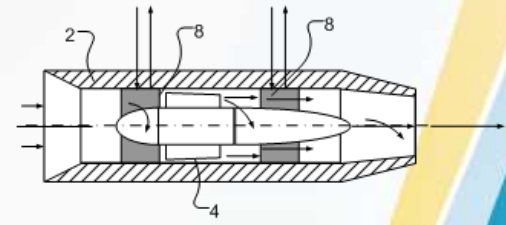


Fig 4/b

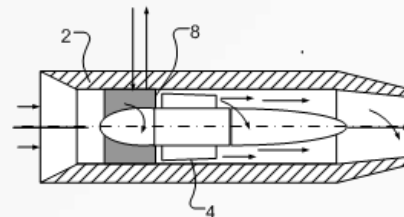


Fig 4/c

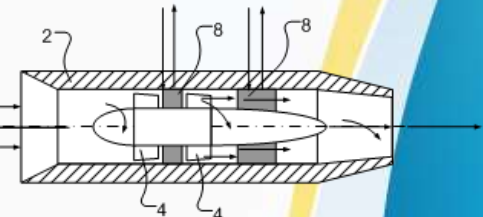


Fig 4/d

ACHEON balance...

- **600.000 Euro demonstrated that, even still embrional ACHEON works!**
- **We have demonstrated that ACHEON could fly...
...actually on subsonic airplanes**
- **it can be helped by thermal effects which needs further studies**
- **A large number of high quality papers produced**
- **Theoretical results reaches fully achieved TRL 2...
... even if they need further studies and further experimental
validations to be exhaustive**
- **... 2 patents... 1 connected patent.**
- **... UOL, UBI, and VUB experimental results have started the road
through TRL 3...**
- **We have encuraged new research direction on Coanda effect**
- **We have met other research groups working on Coanda Effect...
... they have also validated some results free of charge because of
their scientific importance!**
- **ACHEON according to UNIMORE has been a
success!**
- **What do you think about continuing it????**

... and for tomorrow...
I think that ACHEON could work!

Thanks!



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