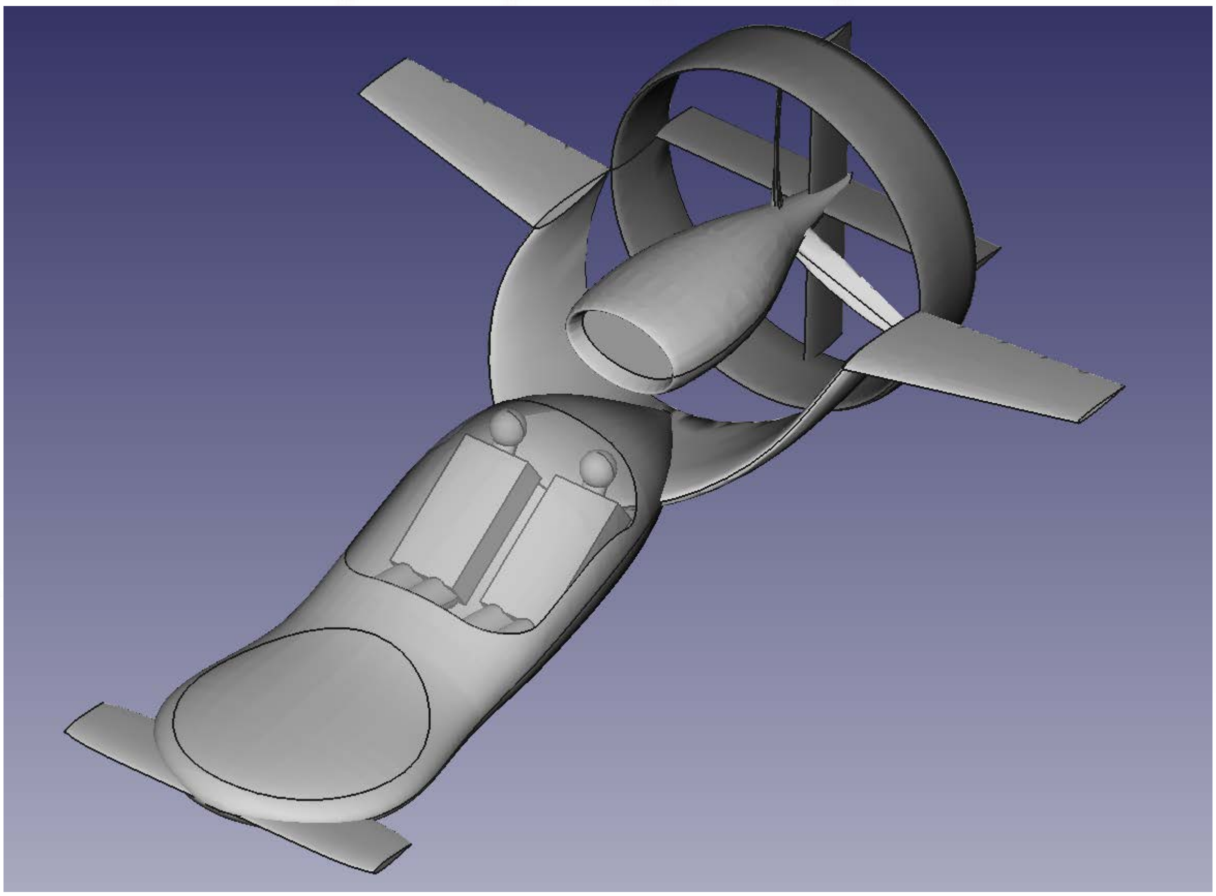
Lip wing
Lift at zero speed

Dusan Stan, July 2014
http://hypertriangle.com/lipwing.php
dusan.stan@hypertriangle.com



1. Introduction

There are a lot of devices that enhances the lift at slow speeds as slats, slots, flaps, but they do not provide any lift at zero speed. In order to design a VTOL vehicle, a device that provides lift at zero speed and low drag at higher speeds must be invented.

2. Known zero speed lift devices

2.1. Propeller/Helicopter rotor

Most efficient VTOL to date is the helicopter; it uses an open rotor, in order to achieve that high efficiency low disc loading is required and that means a really big rotor. The big rotor invariably means problems/low efficiency as speed increases making the helicopters quite inefficient and slow at moving stuff from A to B.
Tilted rotor: Compromise between efficiency at hovering (higher disk loading than most helicopters) and horizontal flight (not really efficient at horizontal flight either: more propeller disk that they need)

2.2. Ducted fan/Shrouded propeller

In order to make the propeller more efficient it can be enclosed into a shroud: eliminates tip loses, intake creates thrust – it seems ideal solution. Reality: Although shrouded propellers create more static thrust, they become less efficient as speed increases. They can be designed to provide high static thrust (bell shaped inlet) or designed for higher speeds, but not do both well. General consensus: above ~200kts open propellers are more efficient (Ref [3]). Current turbofan airliners uses ducted fan at high speeds – its duct is designed to lower intake airspeed to avoid hypersonic flow, making it more efficient than turboprops and not least important quieter too. This design point makes current turbofans inefficient at slow speeds.

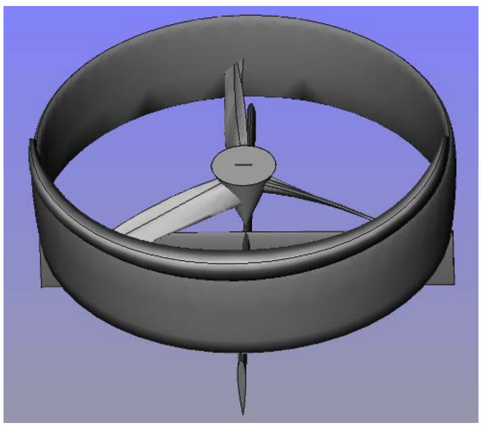
2.3. Channel (Custer) wing

It creates some lift at zero speed. Ref [1]: 340lb lift at 800lb horizontal thrust created by propeller. Although 340 lb seems almost 50% more, compounding vectors gives 870 lb of total thrust or actual 8.75% increase. This small thrust increase, wing weight and structural complications made channel wing only a history lesson.

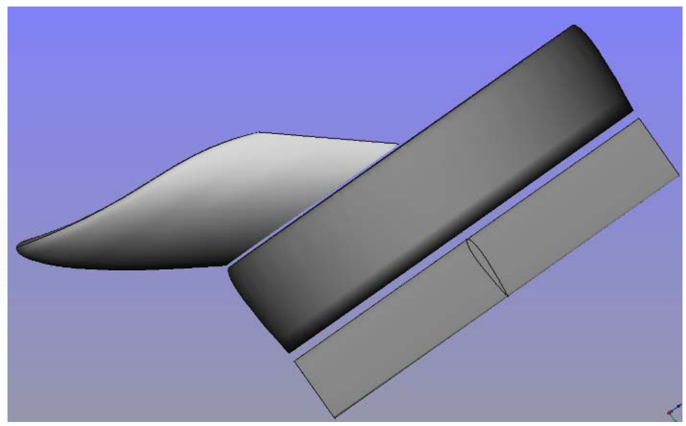
3. Design of the lip wing

Lip wing system consists of a shrouded propeller and an elliptical curved wing that aerodynamically matches the intake of the shroud basically increasing the effective area of the shroud's lip, hence the name - lip wing. Lift is created by forcing airflow over the top of the wing decreasing its dynamic pressure.

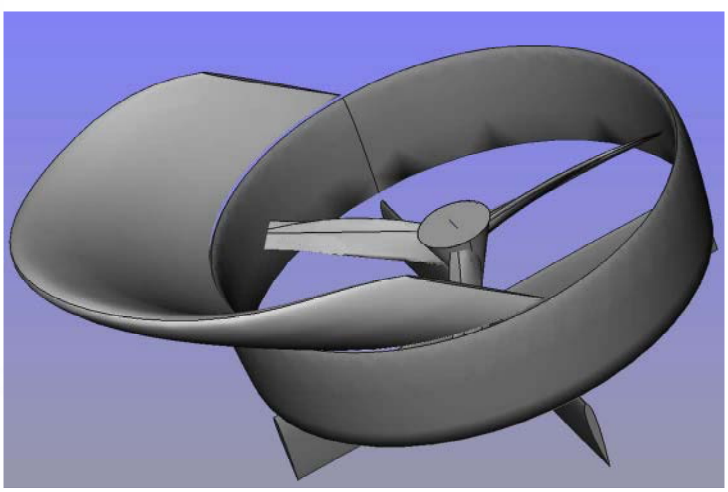
Lip wing system shown in VTOL configuration



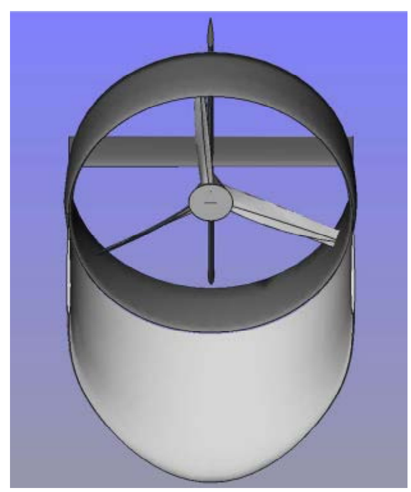
Front view



Side view

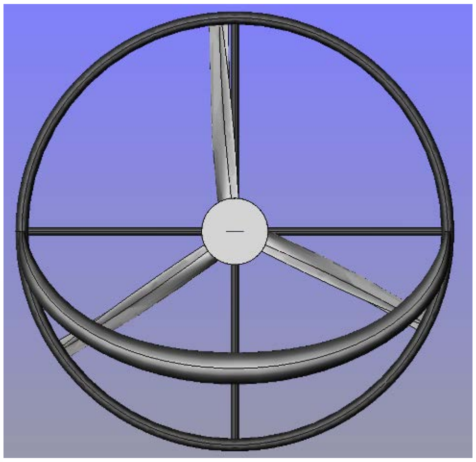


Axometric view

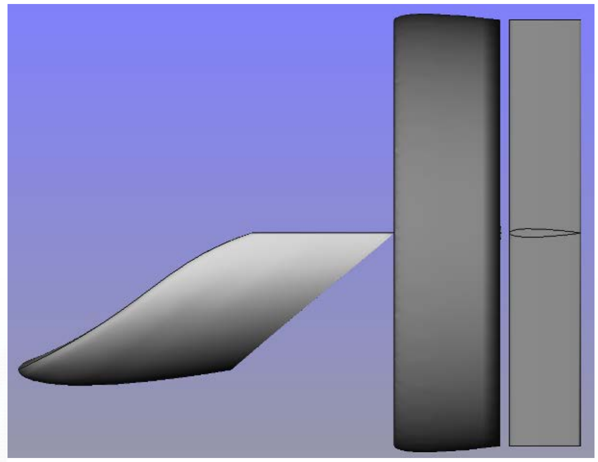


Top view

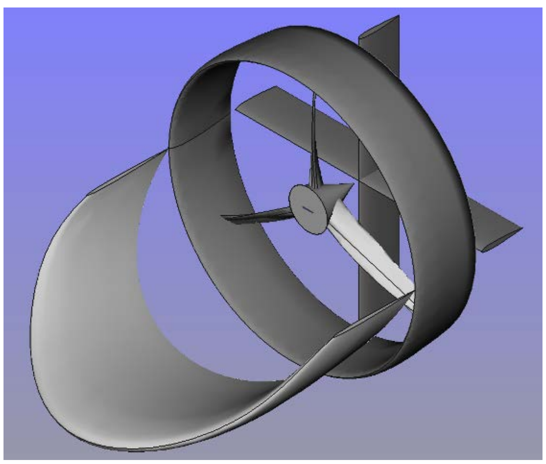
Lip wing system shown in horizontal flight configuration



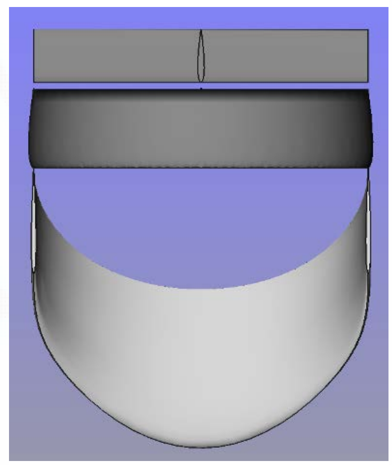
Front view



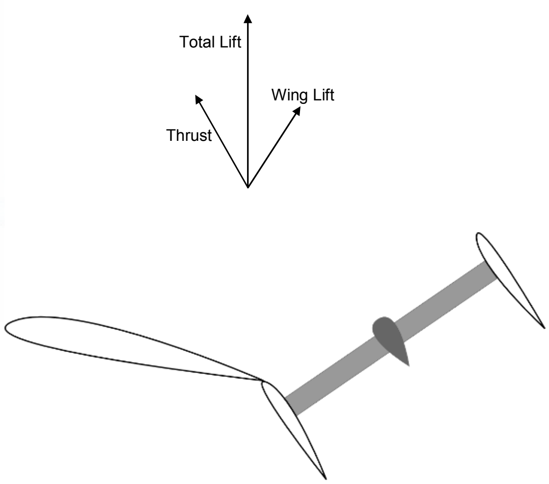
Side view



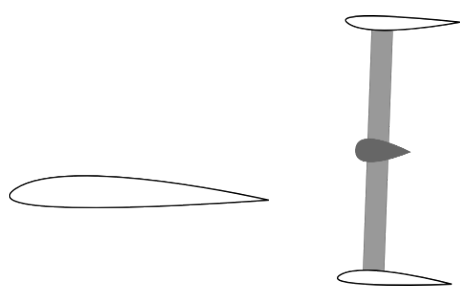
Axometric view



Top view



VTOL configuration, high total lift

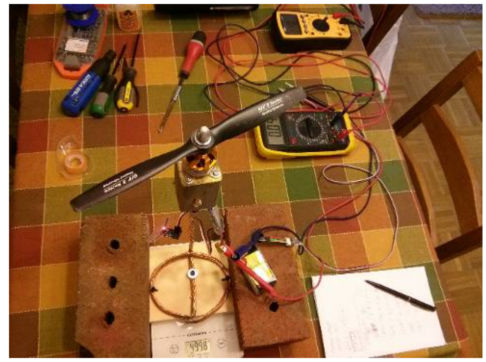


Horizontal flight configuration, low drag

4. Preliminary model tests

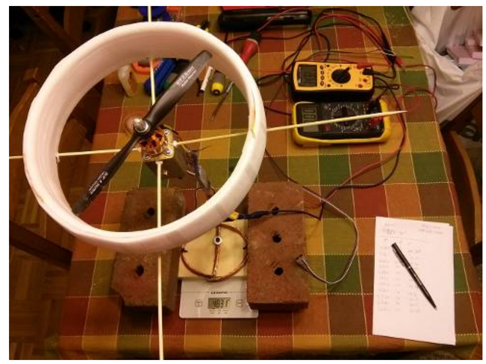
Using a 2208 outrunner electric motor and an 8” propeller, 3 configurations were tested.

4.1. Open air propeller



Pwr [W]	107.7	131.4	109.7	108.0	107.6	107.0	104.8
Thrust [g]	118	148	123	120	115	121	124
T/P [g/W]	1.10	1.13	1.12	1.11	1.07	1.13	1.18

4.2. Shrouded propeller

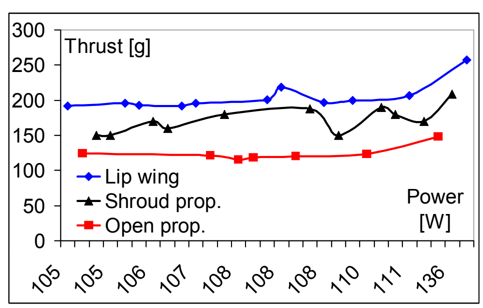


Pwr [W]	110.4	136.4	111.5	110.4	108.7	108.3	107.5	106.0	106.0	105.0	104.8
Thrust [g]	190	209	170	180	150	188	180	170	160	150	150
T/P [g/W]	1.72	1.53	1.52	1.63	1.38	1.74	1.67	1.60	1.51	1.43	1.43

4.3. Lip wing system

Pwr [W]	108.0	138.7	110.7	109.0	108.3	107.8	106.1	106.6	105.9	105.1	104.6
Thrust [g]	219	257	207	200	197	201	192	196	193	196	192
T/P [g/W]	2.03	1.85	1.87	1.83	1.82	1.86	1.81	1.84	1.82	1.86	1.84

4.4. Conclusions



	Avg. thrust @100W grams [oz]	Total %
Open air propeller	111.96 [3.95]	100.00%
Shrouded propeller	156.11 [5.51]	139.43%
Lip wing system	185.83 [6.55]	165.97%

Lip wing has an increase of 19.04% over shrouded propeller and 65.97% over open air propeller. These tests were done with a shroud and lip wing having not even a vague resemblance to an airfoil so I think performance is only to be increased by a proper aerodynamically designed shape for a particular application.

5. First draw aerial vehicle

Personal aerial vehicle wish list:

- VTOL;
- carry 2 persons + luggage;
- amphibious;
- Trailer without permit or even better: make it roadable;

Considering efficiency point of view, a vehicle should have a rotor as big as possible, but for our exercise let's have it at 2.4m (95inches) diameter. A balancing front rotor seems logical so let's have one of 1.6m (63inch) diameter. Preliminary calculations (Ref [9]) show that open rotors would have almost 1200 lbs thrust with an 180hp motor. Considering only 30% increase for shrouded propellers and 55% for lip wing gives a thrust over 1720lbs; considering vehicle weight 1400lbs, thrust/weight ratio is 1.20

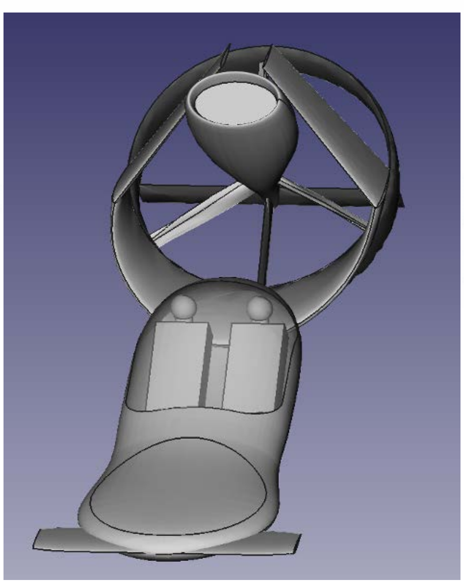
From the airplane point of view, (Ref [5]) calculation shows a really bad rate of climb. Some kind of foldable wings are needed; a span of 18 feet insures a ROC of 2100ft/min. Center of gravity being towards the back, a canard configuration makes sense.

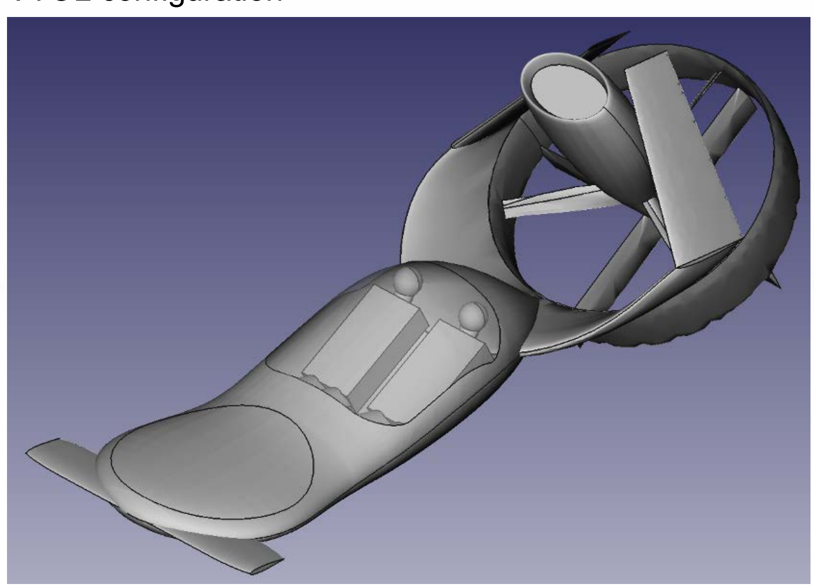
Rest of the calculated specs:

- Stall 63kts (116km/h);
- Cruise speed 170kts (315km/h);
- Max range 480nmi (890km) @ 125kts (231km/h) and 30.2mpg (7.8l/100km);
- Max speed 210kts (389km/h);

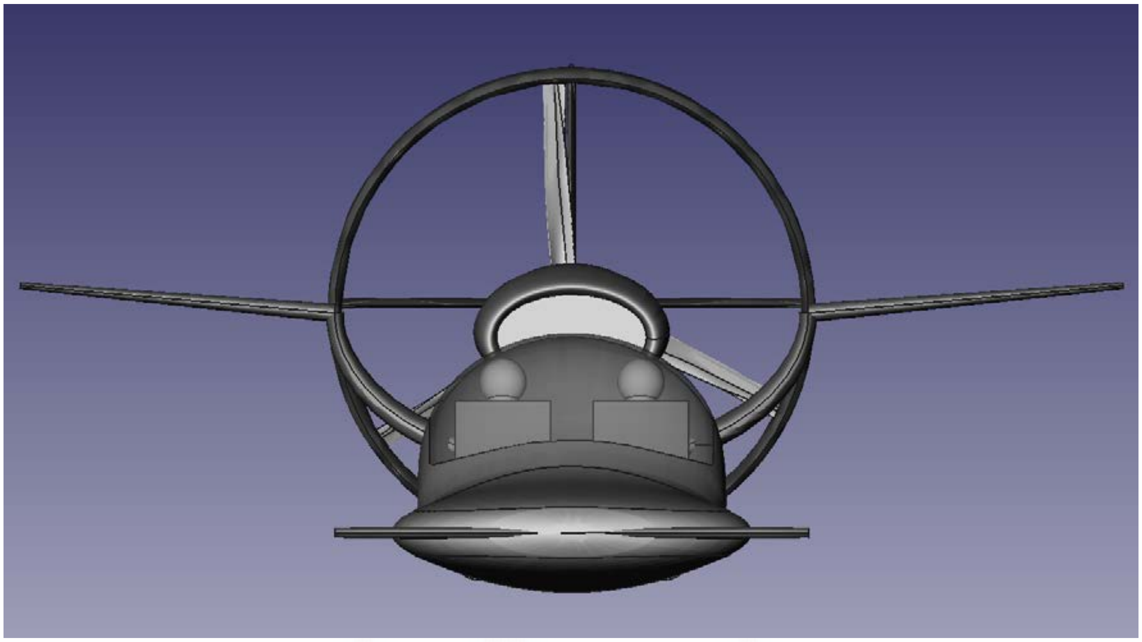
These calculations for sure are a bit off; Raymer's spreadsheet is not for weird aircraft like this.

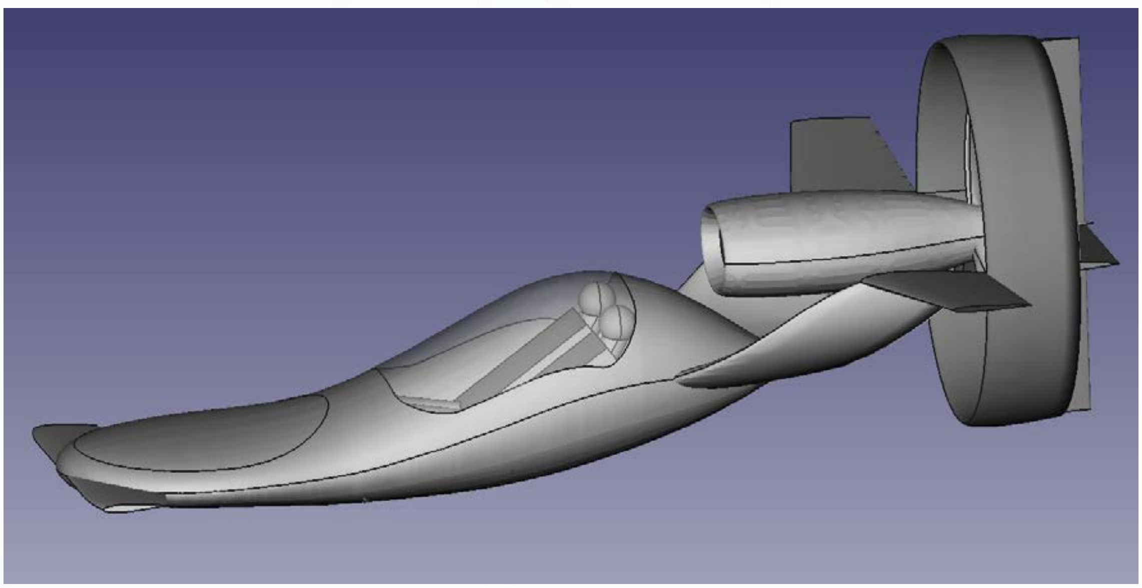
VTOL configuration





Horizontal flight configuration





6. References

[1] – Full scale tunnel tests of the custer channel wing airplane – Jerome Pasamanick 1953;
[2] – The ducted propeller for STOL airplanes – August Raspet 1960;
[3] – Ducted fan design Volume 1– F. Marc de Piolenc & George E. Wright Jr. 2002;
[4] – A wind tunnel investigation of a 7 feet diameter ducted propeller – Kenneth IV. Mort 1967;
[5] – Aircraft Design-A Conceptual Approach – Raymer 2002;
[6] – Airplane Aerodynamics and Performance – Roskam 1997;
[7] – Aerodynamic Analysis of Non-conventional Wing Configurations – Demasi 2004;
[8] – Modern helicopter aerodynamics – Conlinsk 1997;
[9] – http://www.heli-chair.com/aerodynamics_101.html