Department of
MECHANICAL ENGINEERING
THE UNIVERSITY OF UTAH

Hoverbike Airfoil

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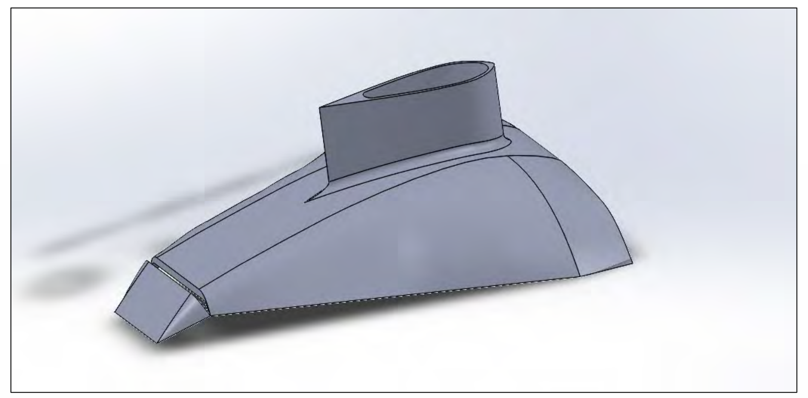
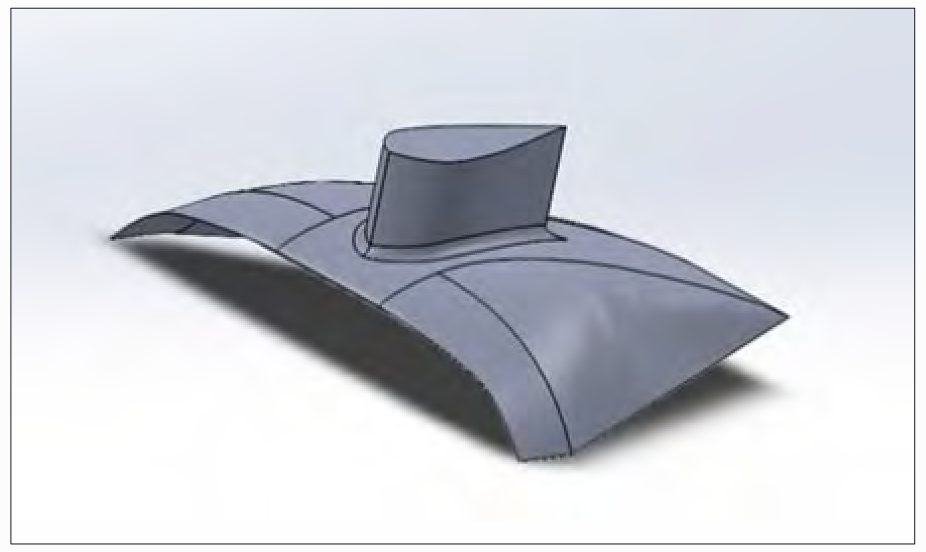


Introduction

Goal: Design, develop, and test an air foil that will be used to generate a cushion of air that provides lift for a hoverbike design. This air foil effectively replaces the wheels of a conventional 3 wheeled vehicle. The air foil will be accompanied by a nozzle in which compressed air is blown through in order to generate a cushion of air for the vehicle to ride on. Lift must also be generated from forward motion, in addition to moving air through the nozzle.



Base design of the Echols Foil

Wind Tunnel Testing

A 1/7th scale model was 3D printed and tested in the TFES wind tunnel at the 3 highest speeds the wind tunnel could perform for angles of attack between 0—20 degrees. Ground effect was unable to be tested reliably.

Simulations were also performed to compare real world data to our simulation parameters. Rows shown in red below show the percent error between simulation and wind tunnel data. This shows that our simulations are not only reliable, but slightly conservative.

Angle of Attack				
	Actual Air Speed (m/s)	32.70	29.83	26.88
	Similitude Air Speed (m/s)	4.67	4.26	3.84
0	Lift (N)	3.19	2.60	2.26
	Simulation Lift (N)	3.08	2.56	2.07
	error	3.49%	1.68%	8.17%
4	Lift (N)	4.66	3.83	3.04
	Simulation Lift (N)	4.12	3.42	2.77
	error	11.67%	10.66%	8.91%
8	Lift (N)	5.92	4.91	3.97
	Simulation Lift (N)	5.17	4.29	3.49
	error	12.58%	12.52%	12.28%
12	Lift (N)	6.97	5.89	4.76
	Simulation Lift (N)	6.15	5.11	4.15
	error	11.75%	13.20%	12.86%
16	Lift (N)	8.09	6.82	5.55
	Simulation Lift (N)	7.06	5.87	4.76
	error	12.72%	13.92%	14.34%
20	Lift (N)	8.42	6.92	5.23
	Simulation Lift (N)	7.67	6.37	5.17
	error	8.91%	7.88%	1.05%

Static Hover Testing

A 1/4th scale model was 3D printed for the hover test. The static hover testing apparatus was comprised of two 50mm diameter brushless motors paired with 380mm diameter counter rotational propellers, and a custom drum that was designed and 3D printed to channel air down through the airfoil. This design is calculated to produce a total of 5.6Kg/s of mass flux through the exit nozzle.

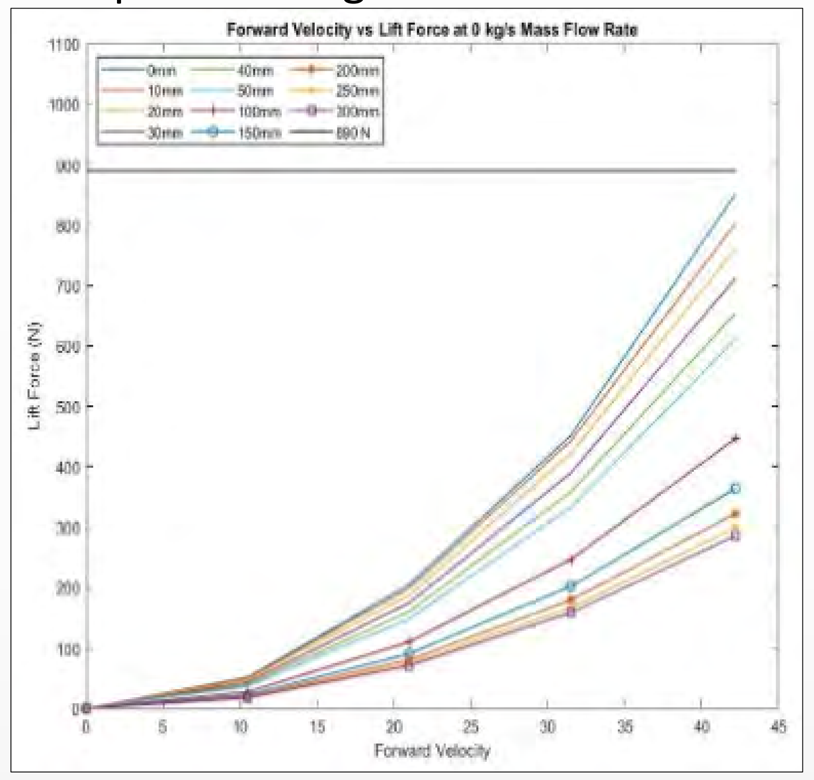
CFD Simulations

The goal for this testing is to show that our design is effective at creating lift, show that forward motion aids in lift, and to point out key issues that would need to be addressed moving forward. Parameters for the flow simulations included: angle of attack, height off the ground, forward velocity, and mass flow of air through the internal nozzle.

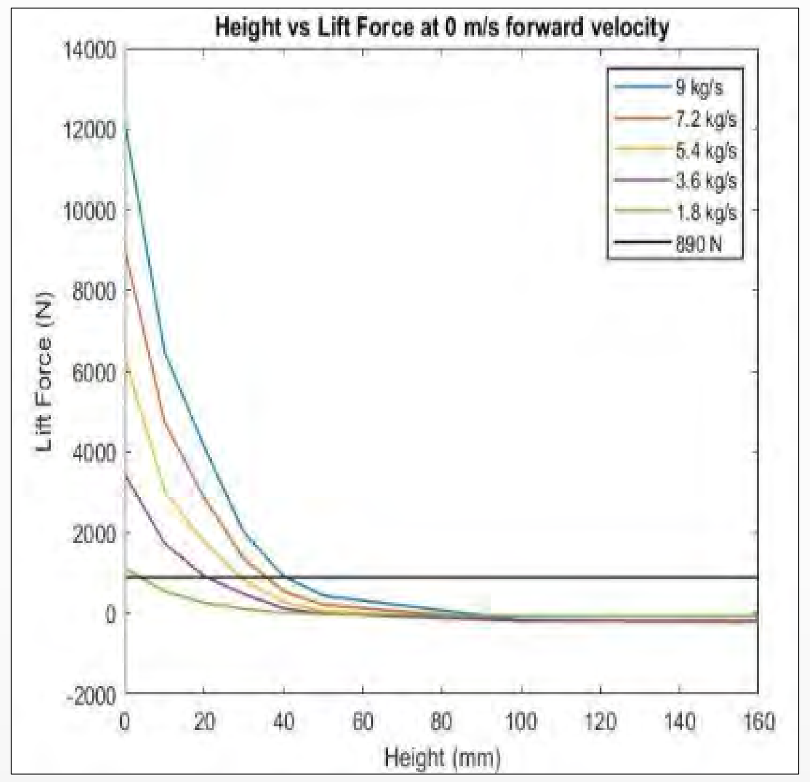
CFD Simulation Results:

The results from this large-scale simulation campaign were largely positive. We achieved sufficient lift at all forward velocities, but still lacked when no air was blown through the nozzle.

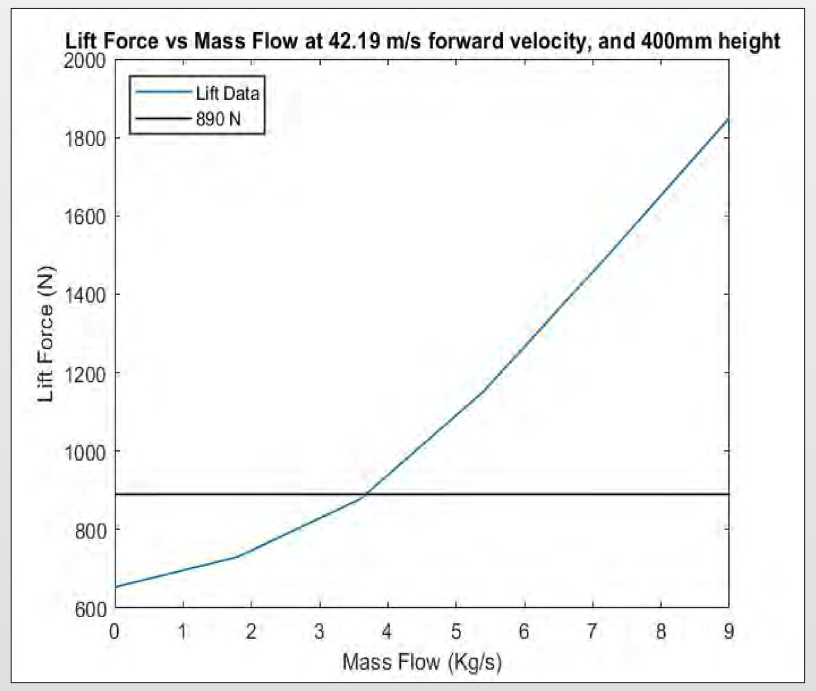
One thing we did notice is that as the foil increased in height out of ground effect, the lift force achieved decreased rapidly and even turned negative. WE believe this is due to air moving faster beneath the foil than above, causing a low-pressure region below the foil.



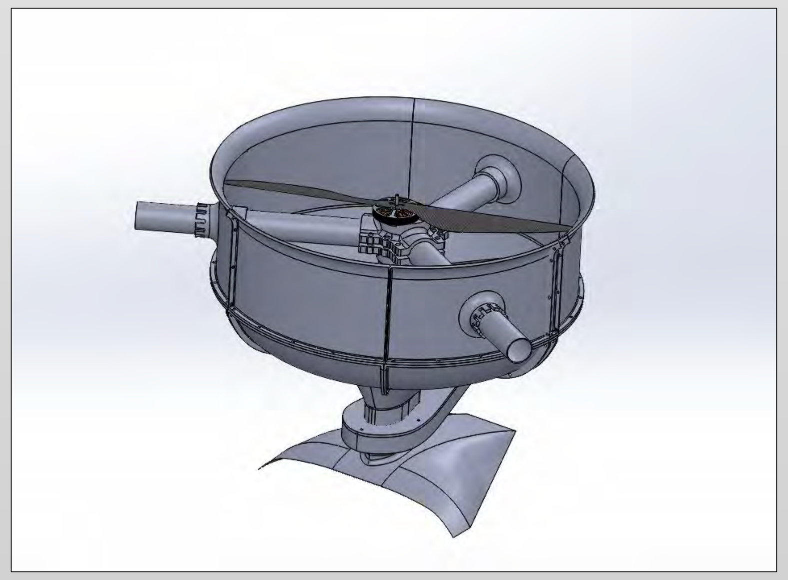
Plot comparing lift generated as forward velocity increases at various heights off the ground with no air pushed through the nozzle. Simulation of static hover test. Black line represents the required 890 N of lift force to achieve hover.

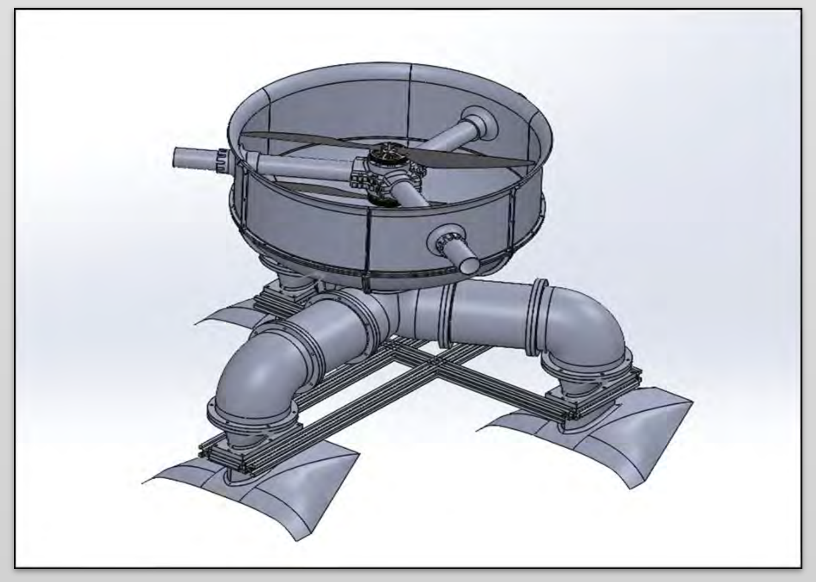


Plot comparing lift generated as height off the ground increases at various mass flow through the nozzle with no forward velocity. Simulation of forward velocity test. Black line represents the required 890 N of lift force required to achieve hover.



Plot showing lift force as a function of Mass Flow at 42.19 m/s and 400 mm height. This plot shows the increase in lift force as the mass flow increases. The black line represents the 890 N of lift force to create hover.

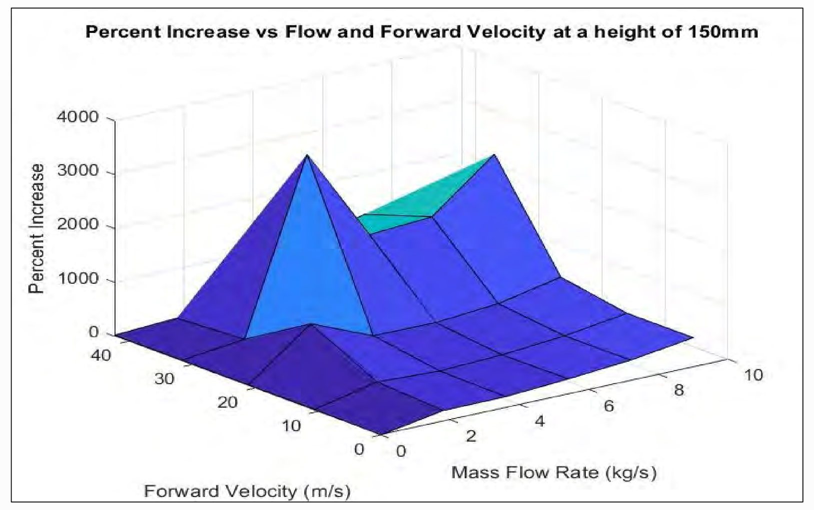




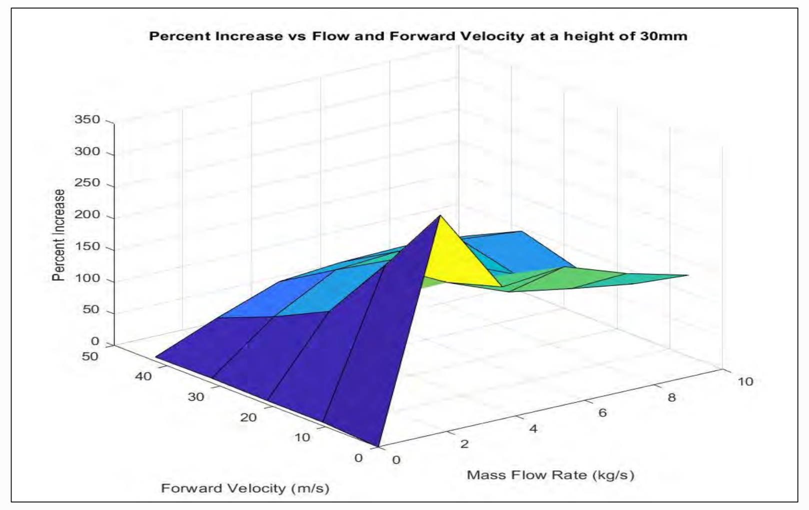
Design Improvements

Flap Design:

One of the reasons we were getting negative lift as we increased height out of ground effect is that the air was moving much faster underneath the foil than above, thus creating a Bernoulli effect that is the opposite of what we want. One possible solution that we tested is to add a flap at the rear of the foil. This will slow down and redirect the air coming through the nozzle to our advantage. Simulation results showed that adding this flap increased lift across all heights, flow speeds, and air speeds. It especially helped when outside of ground effect.



Plot comparing forward velocities and mass flow rates to percent increase of lift at a height of 150mm and the flap at 10 degrees. It shows massive gains in lift outside of ground effect at the higher velocities and flow rates.



Plot comparing forward velocities and mass flow rates to percent increase of lift at a height of 30mm and the flap at 10 degrees. It shows that gains were more consistent across all flow regimes but had a spike at 2 kg/s and 0 forward velocity.

Results

Optimal Hover and Flight Conditions:

Height (mm)	Mass Flow Required to Hover at standstill (Kg/s)
0	1.8
10	3.6
20	3.6
30	7.2
40	7.2
50	N/A
100	N/A
150	N/A
200	N/A
250	N/A
300	N/A

Minimum Flight Requirements		
Height (mm)	Mass Flow (Kg/s)	Forward Velocity (m/s)
0	1.8	0
10	1.8	21
20	1.8	42.19
30	7.2	42.19
40	5.4	42.19
50	9	42.19
100	N/A	N/A
150	N/A	N/A
200	N/A	N/A
250	N/A	N/A
300	N/A	N/A

Minimum Flight Requirements w/ flap at 20 degrees		
Height (mm)	Mass Flow (Kg/s)	Forward Velocity (m/s)
50	1.8	42.19
100	5.4	42.19
150	7.2	42.19
200	7.2	42.19
250	7.2	42.19
300	7.2	42.19

Conclusion:

The results from the wind tunnel testing of the 1/7th scale model showed that our CFD simulations for lift were on the conservative side in terms of lift data collected vs the data collected from the testing. This leads to the conclusion that the airfoil design is adequate in producing the desired lift for the projected combined weight of the rider and vehicle. All attempts of a static hover test have resulted in inconclusive of failed results leading to conclusion that the current set up maybe inadequate to produce the static lift required to bring the vehicle and rider to a static hover state. Moving forward, we plan to continue the final planned modification of the airfoil nozzle and subsequent hover test to present to our sponsor.