CT18 Inverted Wing

invertedwing.cas.h5 1 GiB

Members: Vivyn B.R.

Resources

FSAE 2025 Rules Draft

www.fsaeonline.com
https://www.fsaeonline.com/cdsweb/gen/DownloadDocument.aspx?DocumentID=349fa543-c65d-467f…

Relevant Rules:

Background

Our current front wing has a steep exit angle for air, sending that air up into the region of our rear wing. The air that comes off of our wings is considered dirty air for other parts of the car, as it travels at a different angle and different speed than normal, straight on air. This dirty air reduces the effectiveness of other aerodynamic devices, as seen in our downforce reduction on the rear wing in the full car sim compared to the rear wing in isolation.

Our goal with the inverted wing/winglet is to redirect the dirty air from the front wing away from the rear wing. Additionally, it would benefit us if the air coming off of the inverted wing also made its way to the radiator, as that would help increase our cooling rate.

Project Outline

The goal of this project is to research about inverted wings and then apply that knowledge to designing an inverted wing setup for the CT18. The project tasks are as follows:

1. Conduct research on the following topics:
    a. Use the Airfoil tools website to pick our airfoil to pick an airfoil that's will force/guide the airflow away from the rear wings and into the side pods and making sure it as a very small Drag Coefficient, and a small lift coefficient as well http://airfoiltools.com/airfoil/
    b. Wing element backwash
    c. Interaction with other aero parts - observe streamlines from front wing, to inverted wing, to rest of the car. Document observations on the flow field around the car
    d. Mounting
    e. Material Selection
2. Identify compatibility of an inverted wing with the CT18
    a. Mounting points
    b. Install and removal
    c. Interaction with existing parts (front wing, nood, body panels)
    d. Compatibility of existing wing models with the inverted wing design
3. Fabricate CAD model for aerodynamic purposes. Make sure the model is always manufacturable and structurally stable
4. Test CAD model in Fluent, make changes to model accordingly
5. Using test data, estimate the weight of the inverted wing and run lap time simulations to judge effectiveness of the inverted wing
6. With finalized model, design a mold model for carbon fiber layups

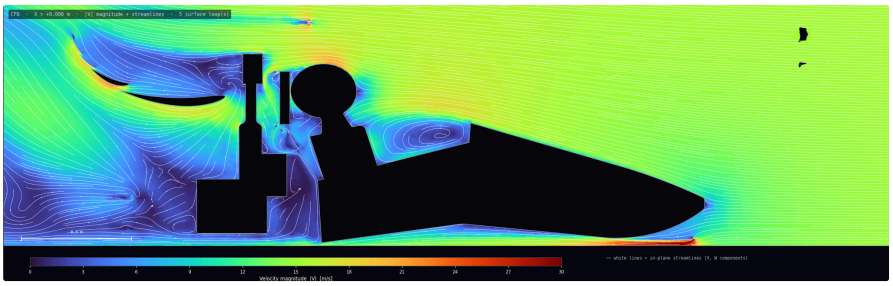


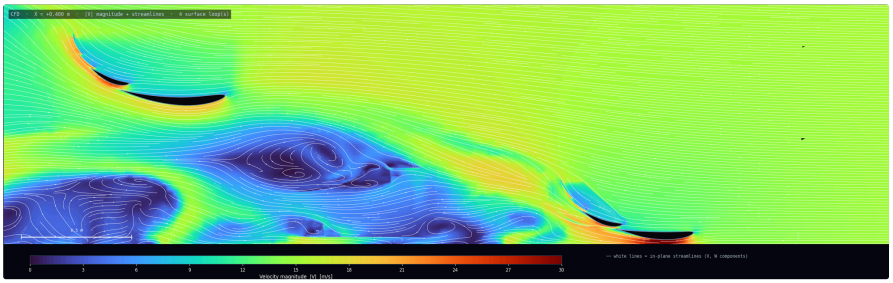


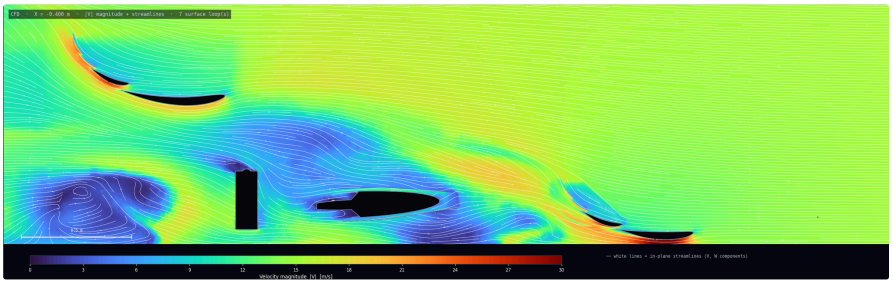
Visualizing the full aero sim:

- For post-processing, I initially tried using ANSYS CFD-Post and then paraview on my own laptop to visualize the airflow around the car. However, because the full aero sim was so massive (around 20 million cells i think), both programs kept crashing and running out of memory, even when i tried them through Uconn Anyware. So I decided to write a custom python script that extracts the data from the simulation data direct from the fluent HDF5 files. This python scripts allowed me to visualize the wake coming off the front wing without relying the heavy GUI software that kept crashing on me. I am planning using like very simplified model. But i decided to work with the simulation file that was already done and using to get a sense of things.

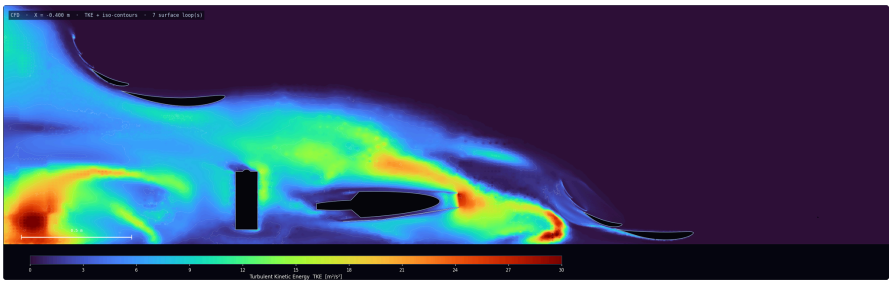
Velocity Magnitude:

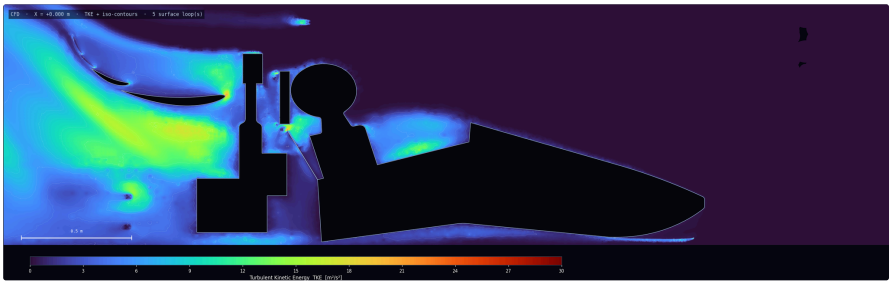


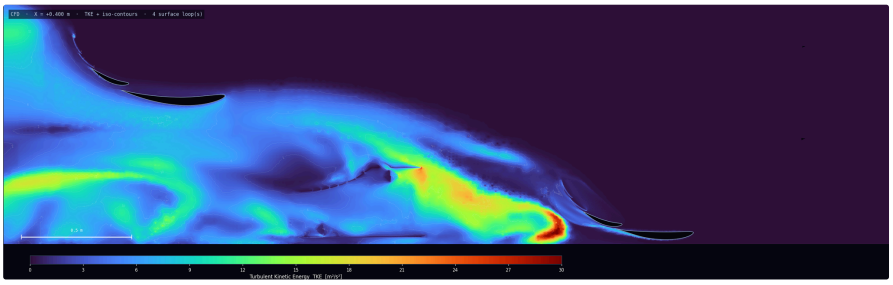




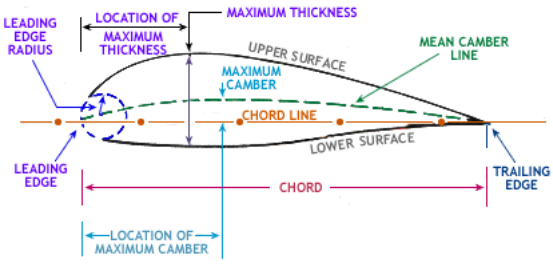
TKE:





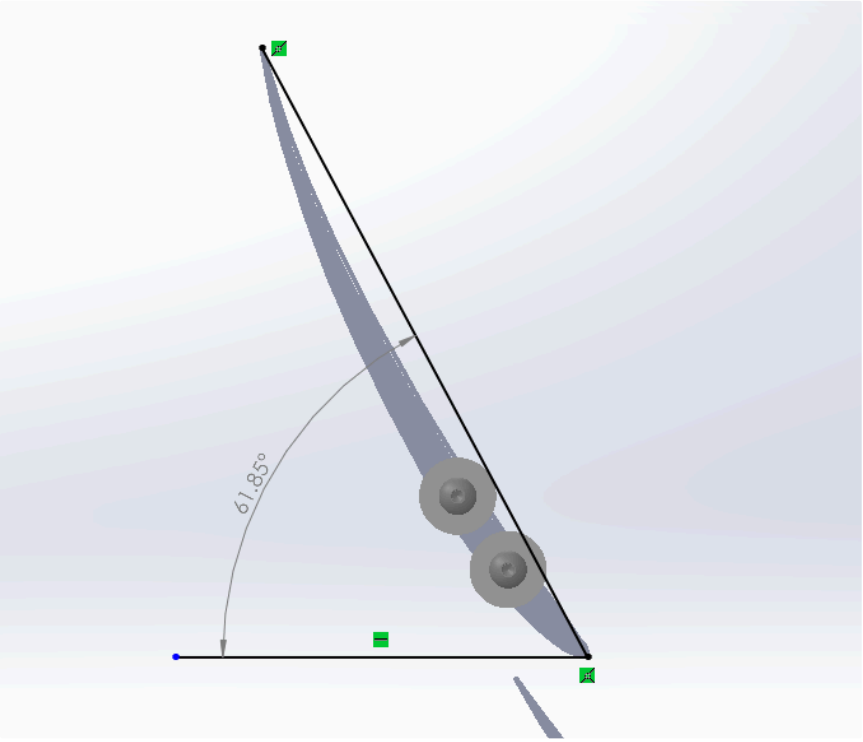


Custom designing the Airfoil:



Numbers needed from the sim:

- Exit angle of the upwash and the velocity magnitude created by the front wing (from the last airfoil)
    - Velocity:
        - 13m/s
    - Exit angle:

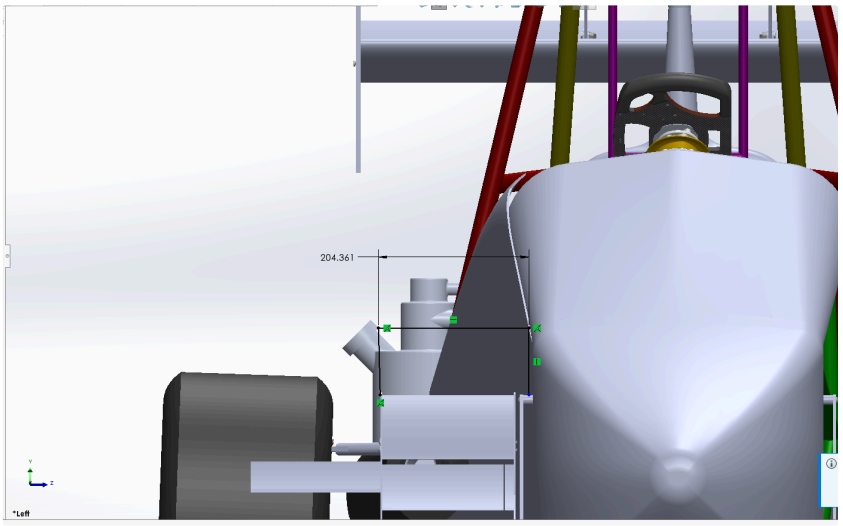


    - AOA = 61.85
- TKE (turbulent Kinetic Energy) of the upwash
    - 10% Turbulent Intensity
- Inlet (for 3d):
    - 0.25m x 0.25m

Variables to do sweep studies on:

- chord length
    - 125mm - 130mm
- Camber
    - We need a decently high cambered airfoil because of the upwash exit angle being at around 62 degrees
- Thickness
    - We can't make it too thick because of drag but also not too thin which might cause premature airflow separation
- AoA
    - 0-20 degrees

- How far the air foil protrudes out the nood
    - 205mm (only needs to end at or go little further after the rear wing endplate)

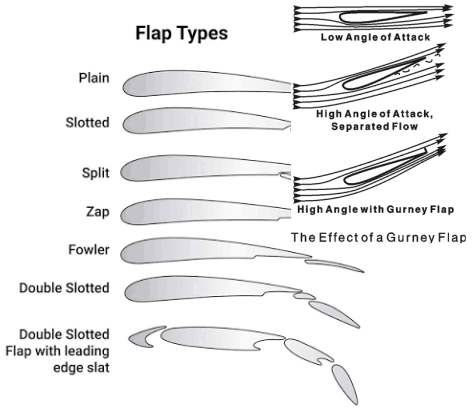


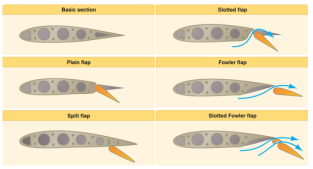
Re = ((1.225*13*0.125)/1.81x10^-5)) = 109,979.28

Output variables

- C_L
- C_D
- Exit angle of airflow
- Mass of airfoil, assume stressed skin (no internals)

Ponder on GURNEY FLAPS, and other Flap types, etc…….







results after pondering: gurney flaps can be helpful

Airfoils:

- NACA 9411
- Cambered plate C=16% T=5% R=0.86 (cp-160-050-gn)
- Cambered plate C=18% T=5% R=0.78 (cp-180-050-gn)
- GOE 531 AIRFOIL (goe531-il)
- GOE 462 AIRFOIL (goe462-il)

- GOE 464 AIRFOIL (goe464-il)

2D SIM:

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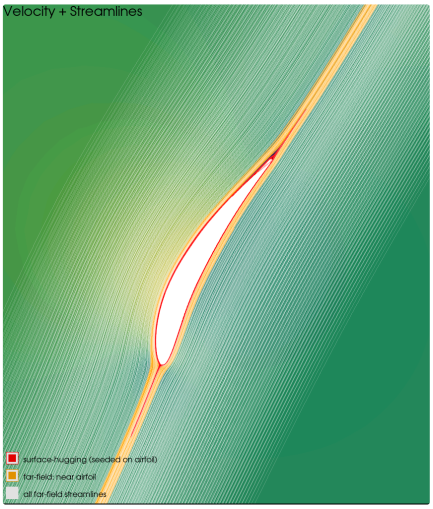
▼ Open Foam:

NACA9411:

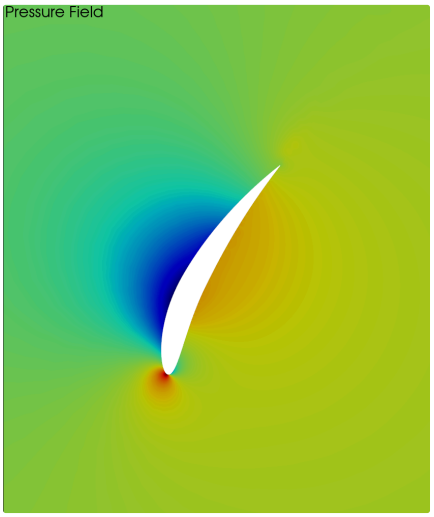
NACA9411 parallel to Upwash (0 AoA):

coefficient.dat 179.3 KiB

- Visualization:







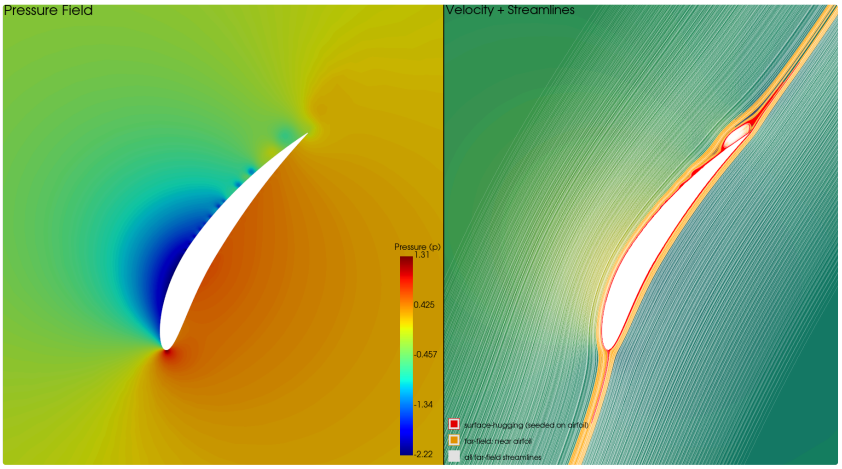
- Numbers:

Metric	Last Iteration (t=16000)	Average (last 2000)
C_L	0.9117	0.9122
C_D	0.0198	0.0199
L/D ratio	46.0	45.8

NACA9411 5 AoA:

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coefficient.dat 178.8 KiB

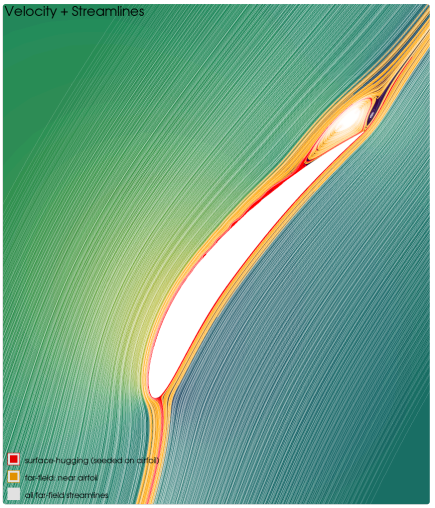


Metric	Last Iteration (t=16000)	Average (last 2000)
CL	1.331820	1.313109
CD	0.036351	0.030391
L/D ratio	36.64	43.21

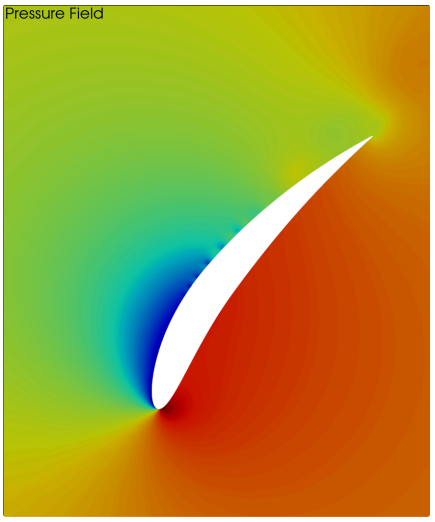
NACA9411 10 AoA:

coefficient.dat 179.5 KiB

- Visualization:







- Numbers:

Metric	Last Iteration (t=16000)	Average (last 2000 iters)
C_L	1.6202	1.5998
C_D	0.0544	0.0519
L/D ratio	29.8	30.8

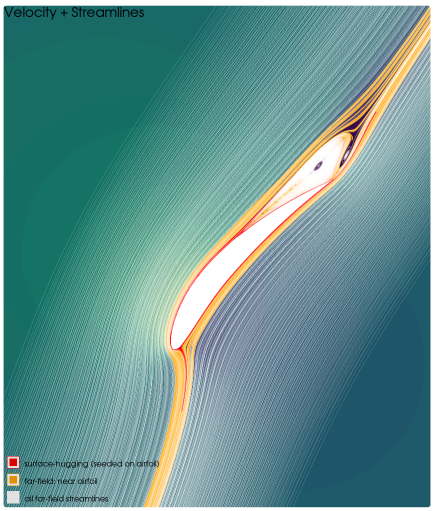
NACA9411 15 AoA:

coefficient.dat 178.8 KiB

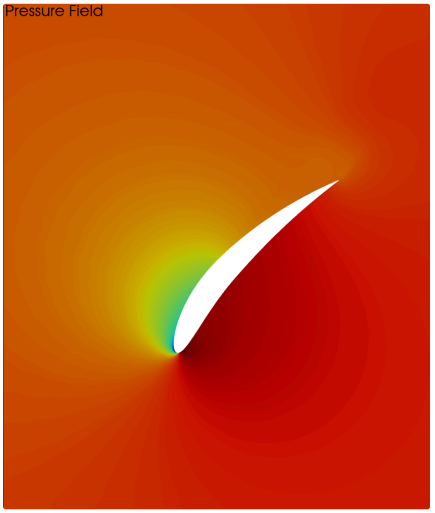
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- Visualization:







- Numbers:

Metric	Last Iteration (t=16000)	Average (last 2000 iters)
C_L	1.8280	1.8280
C_D	0.0894	0.0894
L/D ratio	20.45	20.45

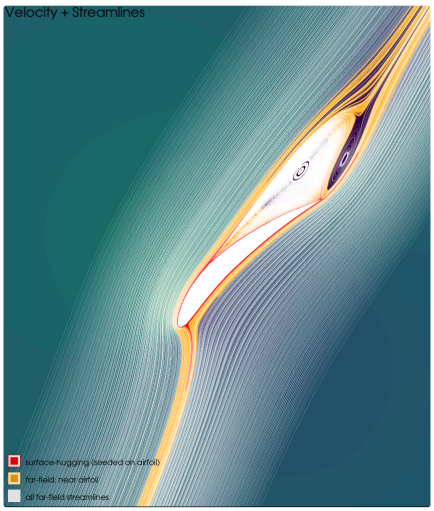
NACA9411 20 AoA:

coefficient.dat 178.3 KiB

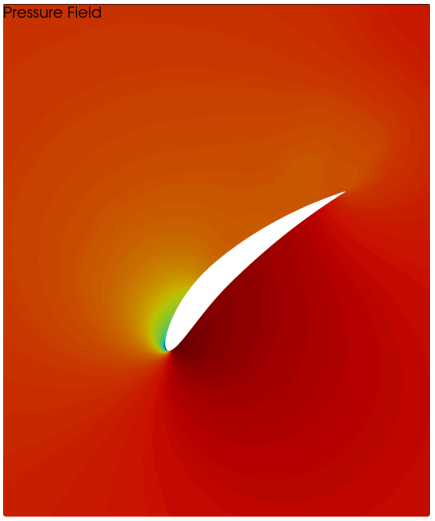
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- Visualization (very close to stalling):







- Numbers:

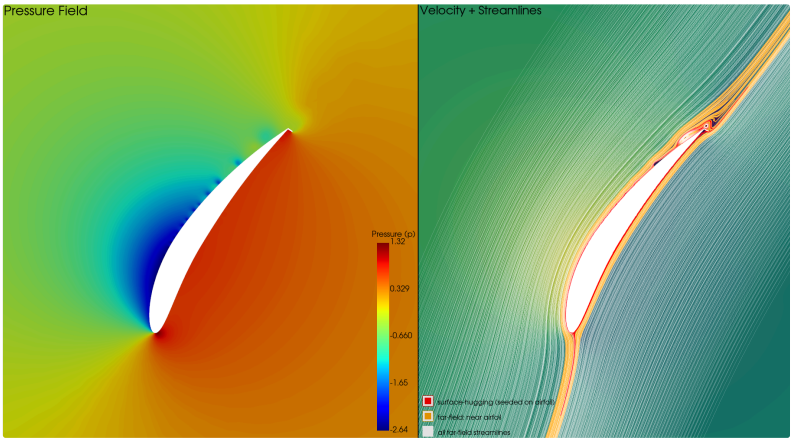
Metric	Last Iteration (t=16000)	Average (last 2000 iters)
C_L	1.6882	1.6820
C_D	0.1848	0.1781
L/D ratio	9.1	9.4

NACA 9411 with gurney flap

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NACA 9411 at 5 degree AoA WITH gurney flap (2% chordlength):

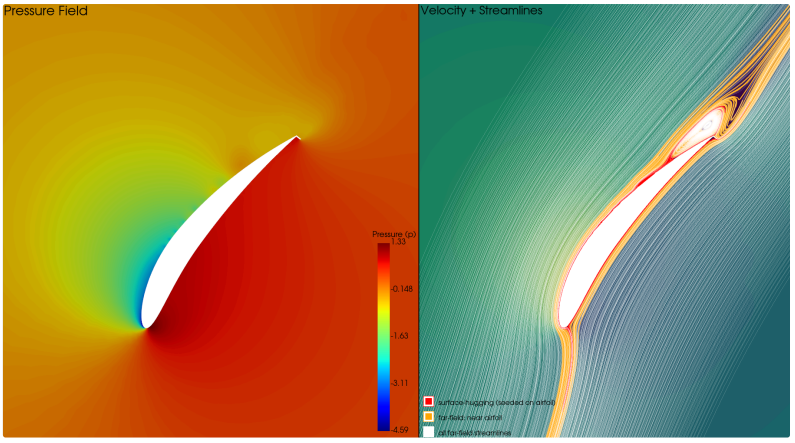
coefficient.dat 179.1 KiB



Metric	Last Iteration (t=16000)	Average (last 2000 iters)
CL	1.789551	1.743270
CD	0.057900	0.042786
L/D ratio	30.91	40.74

NACA 9411 at 10 degree AoA WITH gurney flap (2% chordlength):

coefficient.dat 179.4 KiB



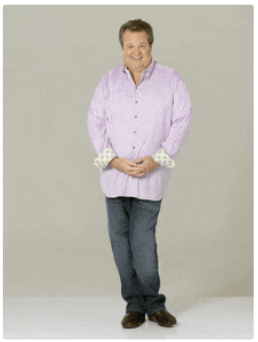
Metric	Last Iteration (t=16000)	Average (last 2000 iters)
C_L	**1.873095**	**1.927653**
C_D	**0.061048**	**0.068269**
L/D ratio	**30.68**	**28.24**

> Won't be moving forward with gurney flap with NACA 9411 since it did not improve with the gurney flap. It probably wont work even if we changed the AoA.

#2 airfoil (130mm chord length) (i forgot what this was. I forgot to label the file when i downloaded it. I'm just going to call it airfoil #2):

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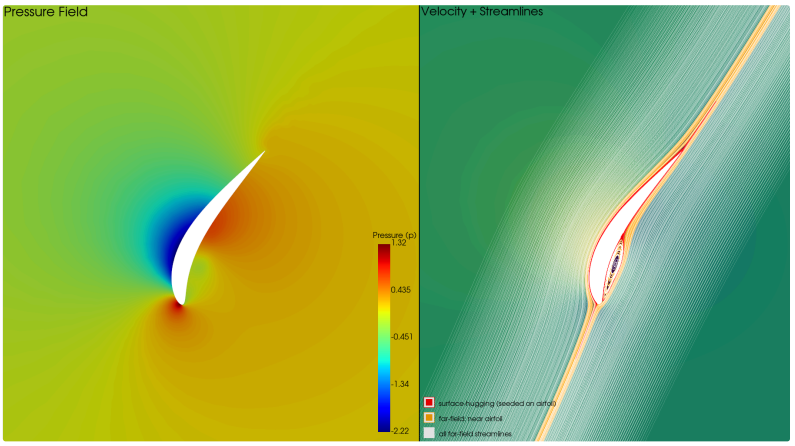
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#2 at 0 degree AoA

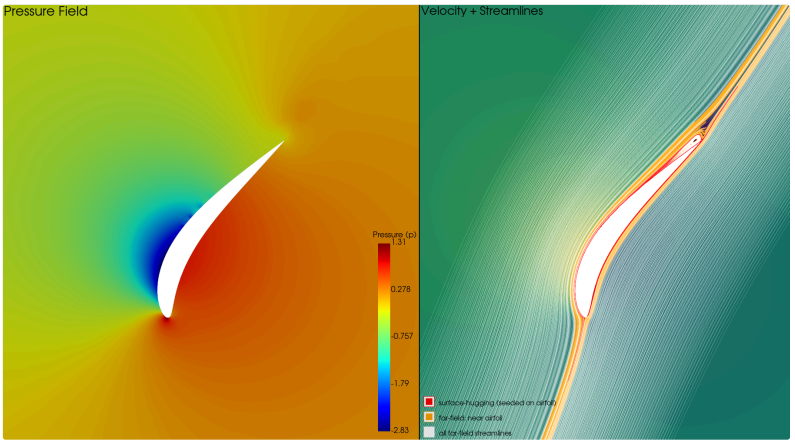
coefficient.dat 179.8 KiB



Metric	Last Iteration (t=16000)	Average (last 2000 iters)
C_L	1.1167	1.1304
C_D	0.0484	0.0485
L/D ratio	23.1	23.3

#2 at 5 degree AoA

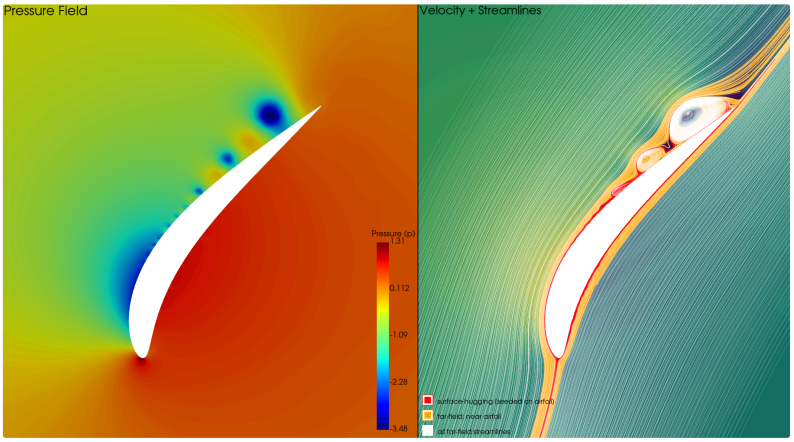
coefficient.dat 179.5 KiB



Metric	Last Iteration (t=16000)	Average (last 2000 iters)
C_L	1.5501	1.5495
C_D	0.0405	0.0402
L/D ratio	38.3	38.5

#2 at 7 degree AoA

coefficient.dat 178.9 KiB

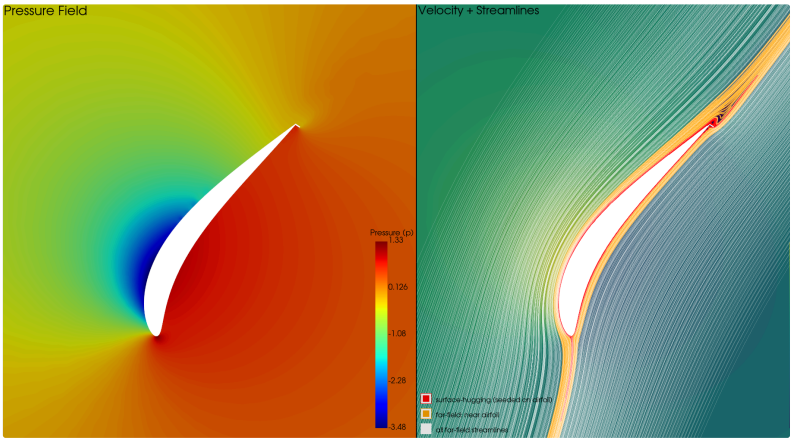


Metric	Last Iteration (t=16000)	Average (last 2000 iters)
C_L	0.88565	0.78525
C_D	0.13292	0.02280
L/D ratio	6.66304	34.43708

#2 with gurney flap:

#2 at 5 degree AoA WITH gurney flap (2% chordlength):

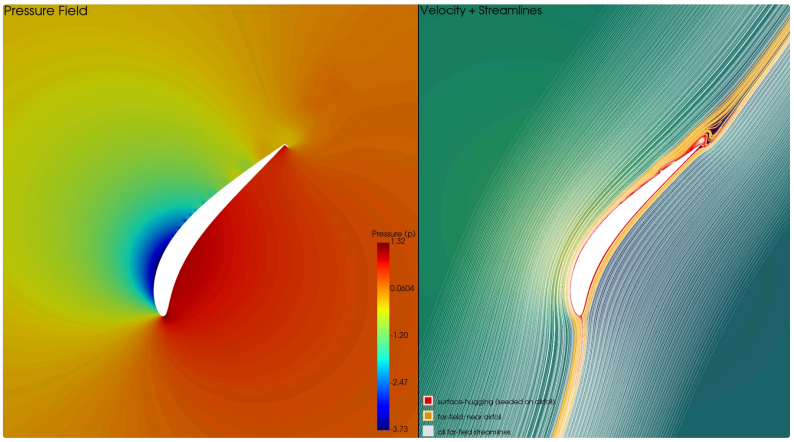
coefficient.dat 179.6 KiB



Metric	Last Iteration (t=16000)	Average (last 2000 iters)
C_L	2.0812	2.0936
C_D	0.0363	0.0407
L/D ratio	57.3	51.4

#2 at 7 degrees AoA with gurney flap (2% chordlength)

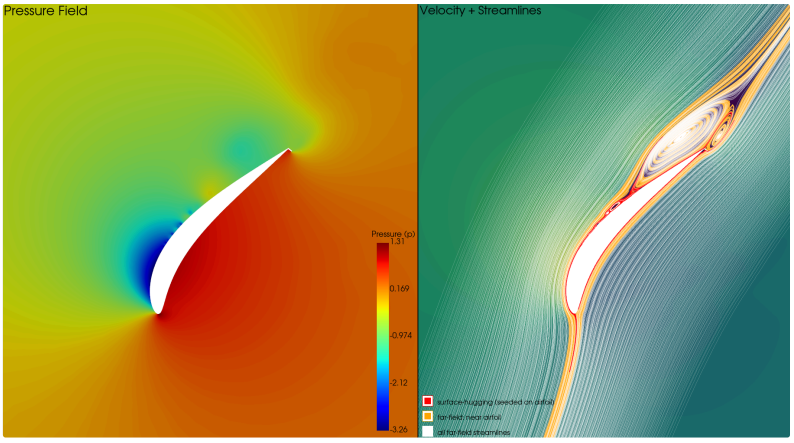
coefficient.dat 178.8 KiB



Metric	Last Iteration (t=16000)	Average (last 2000 iters)
C_L	**2.169594**	**2.179320**
C_D	**0.050442**	**0.053554**
L/D ratio	43.01	40.69

#2 at 10 degrees AoA with gurney flap (2% chord length)

coefficient.dat 179.2 KiB



Metric	Last Iteration (t=16000)	Average (last 2000 iters)
C_L	**1.910643**	**1.744983**
C_D	**0.167959**	**0.138065**
L/D ratio	**11.38**	**12.64**

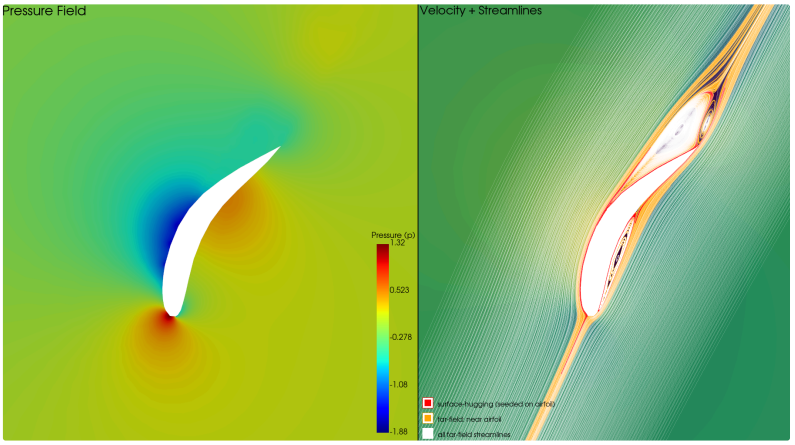
GOE531:

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GOE531 at 5 degrees AoA

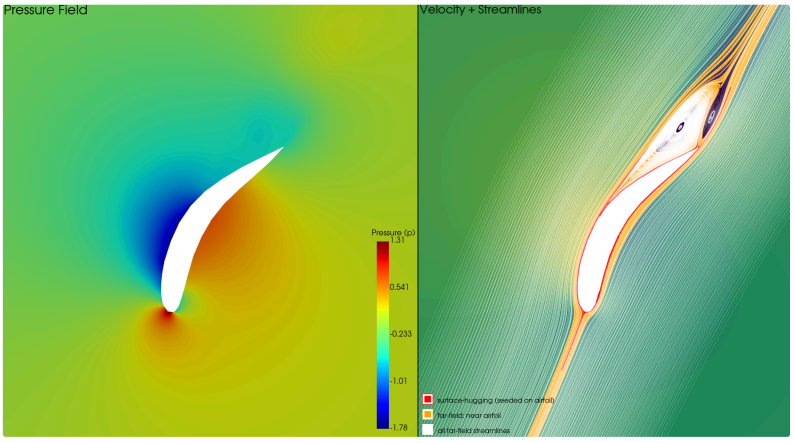
coefficient.dat 178.5 KiB



Metric	Last Iteration (t=16000)	Average (last 2000 iters)
C_L	0.770140	0.777569
C_D	0.120012	0.120371
L/D ratio	6.42	6.46

GOE531 at 7 degrees AoA

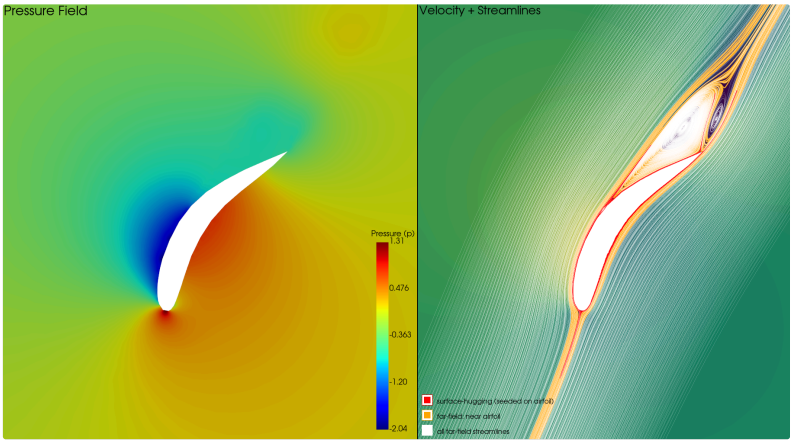
coefficient.dat 178.5 KiB



Metric	Last Iteration (t=16000)	Average (last 2000 iters)
C_L	0.990192	0.990246
C_D	0.119005	0.118999
L/D ratio	8.32	8.32

GOE531 at 10 degrees AoA

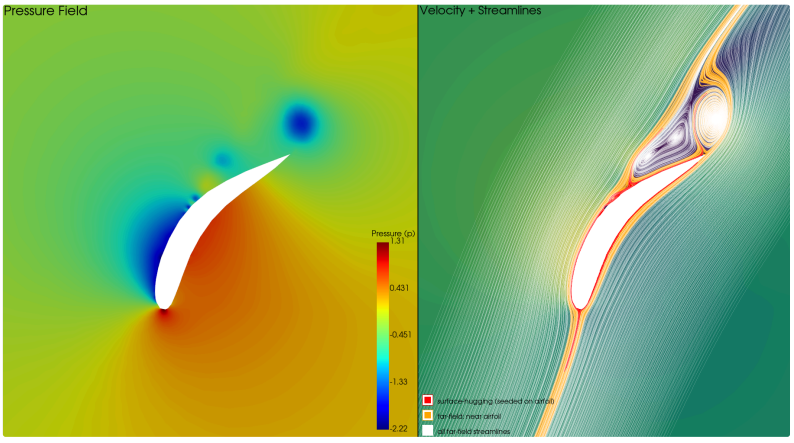
coefficient.dat 179.2 KiB



Metric	Last Iteration (t=16000)	Average (last 2000 iters)
C_L	1.206238	1.204899
C_D	0.134865	0.134245
L/D ratio	8.94	8.98

GOE531 at 12 degrees AoA

coefficient.dat 179.2 KiB



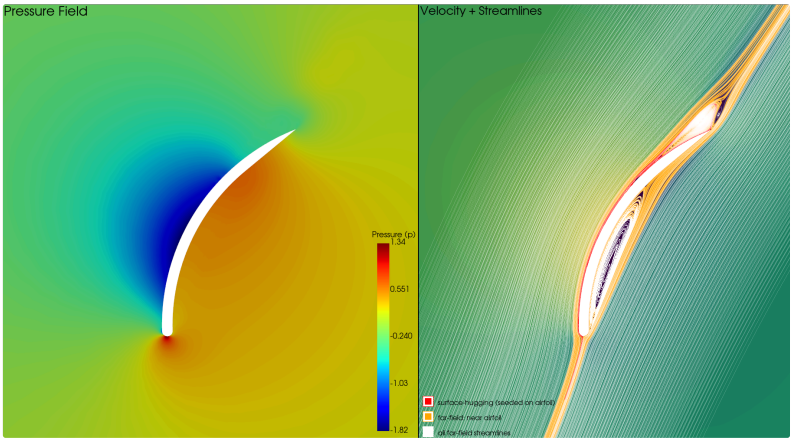
Metric	Last Iteration (t=16000)	Average (last 2000 iters)
C_L	1.196550	1.278476
C_D	0.093200	0.144682
L/D ratio	12.84	8.84

> ts built like a baked bean. Won't be moving forward with GOE531 since it's causing too much drag and isn't worth adding a gurney flap to this airfoil. Since it's going to cause more drag anyway

cp-160-050-gn:

cp 16 at 5 AoA

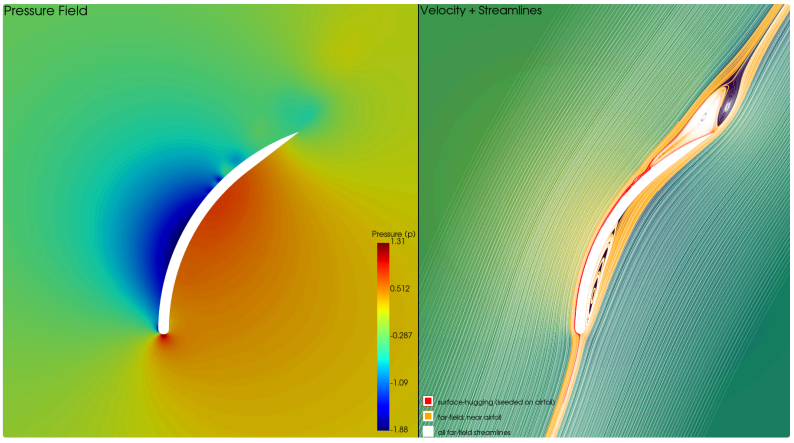
coefficient.dat 179.1 KiB



Metric	Last Iteration (t=16000)	Average (last 2000 iters)
CL	1.236545	1.239238
CD	0.058231	0.058815
L/D ratio	21.24	21.07

cp 16 at 7 AoA

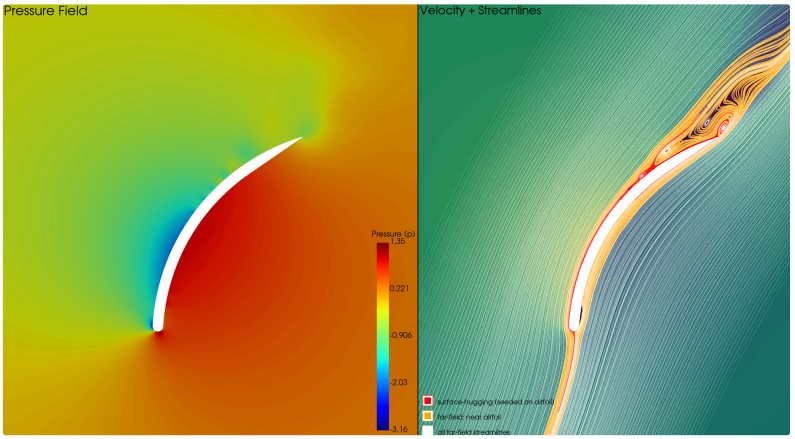
coefficient.dat 178.8 KiB



Metric	Last Iteration (t=16000)	Average (last 2000 iters)
CL	1.335522	1.350646
CD	0.055235	0.074040
L/D ratio	24.18	18.24

cp 16 at 10 AoA

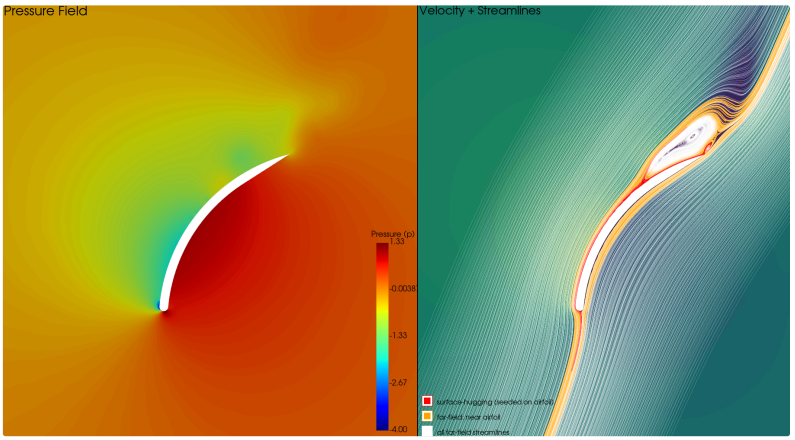
coefficient.dat 179.2 KiB



Metric	Last Iteration (t=16000)	Average (last 2000 iters)
CL	1.563221	1.578432
CD	0.084602	0.084964
L/D ratio	18.48	18.58

cp 16 at 12 AoA

coefficient.dat 178.7 KiB

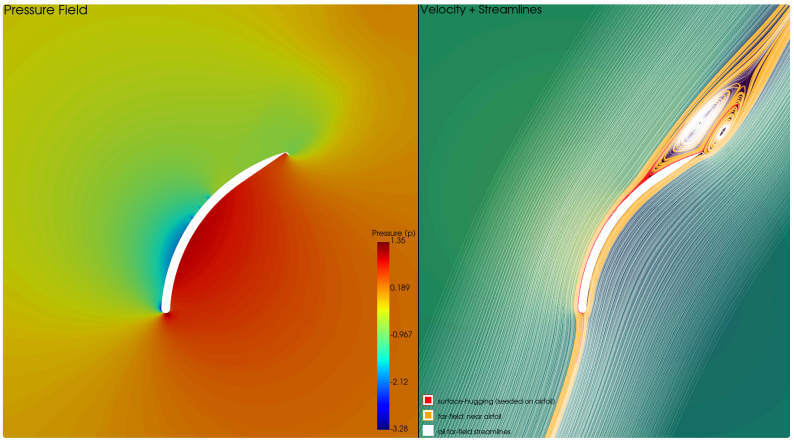


Metric	Last Iteration (t=16000)	Average (last 2000 iters)
CL	1.704678	1.638165
CD	0.151446	0.102627
L/D ratio	11.26	15.96

cp-160-050-gn with gurney flap:

cp 16 at 10 AoA **2% gurney flap**

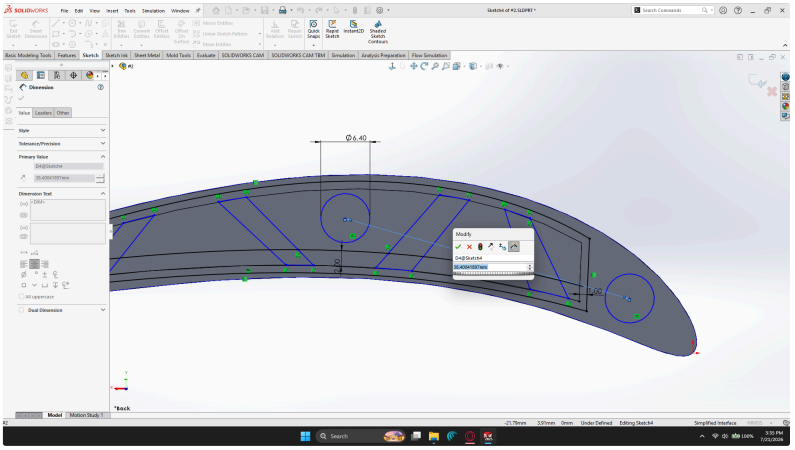
coefficient.dat 179.4 KiB

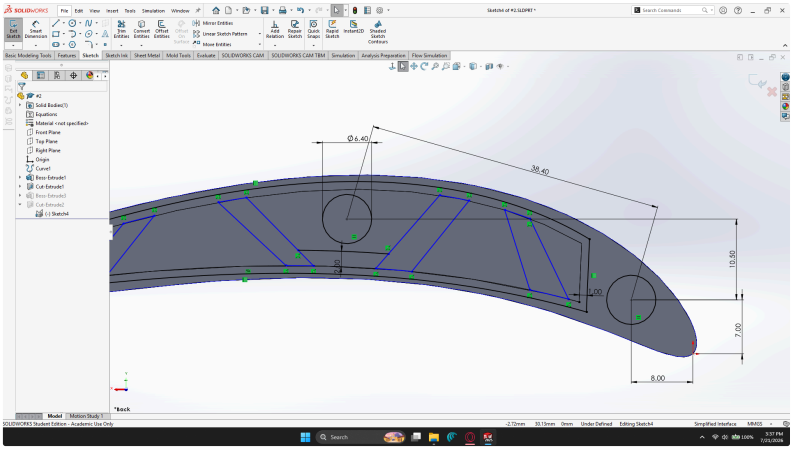


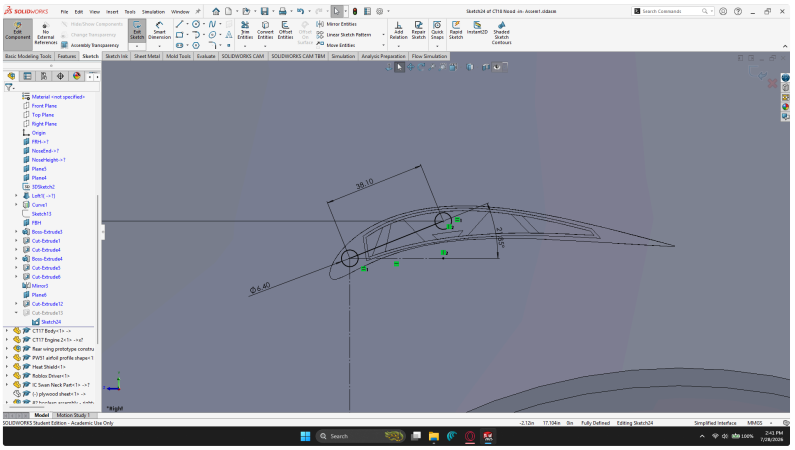
Metric	Last Iteration (t=16000)	Average (last 2000 iters)
C_L	1.616	1.746
C_D	0.1217	0.1241
L/D ratio	13.28	14.07

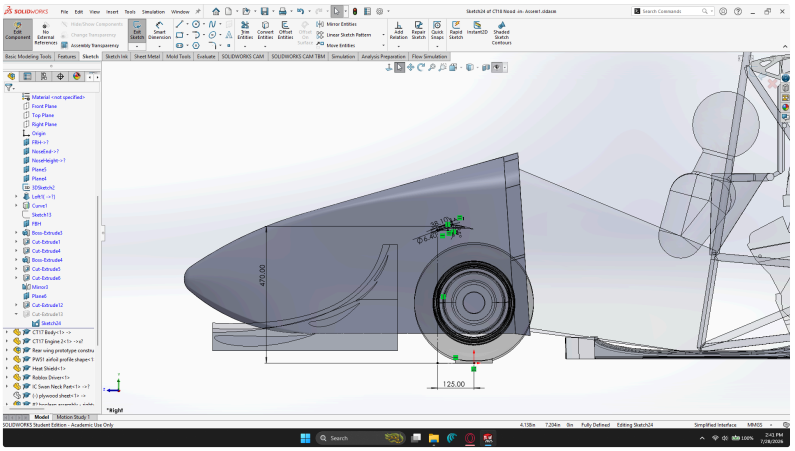
Design 3d:

- Attaching the inverted wing to the nood:



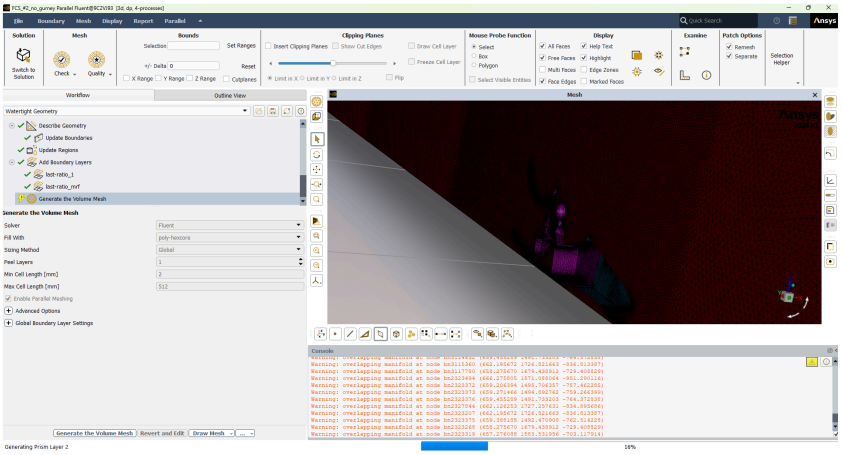


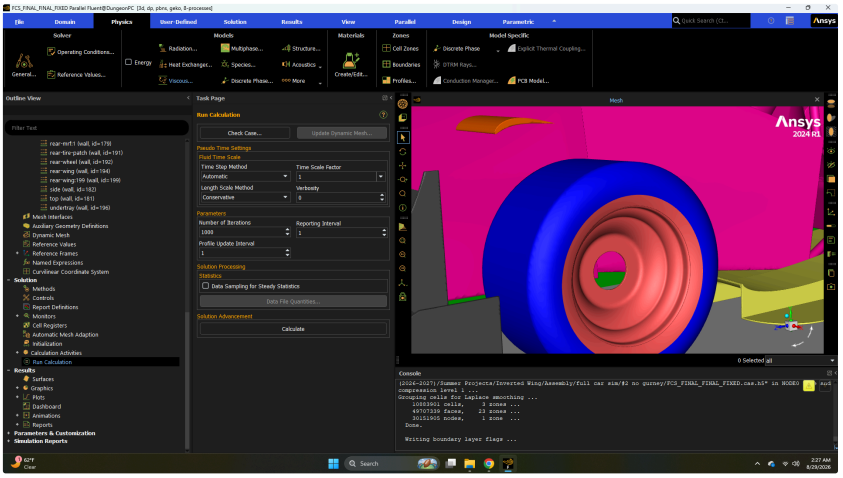




3D SIM:

▼ Ansys:





FCM Files for the HPC to run the sim:

▼ Version #1 case and mesh files

- files:

  invertedwing.dat.h5 1.2 GiB

  invertedwing.cas.h5 1 GiB

▼ Results:

- Y(downforce/lift):

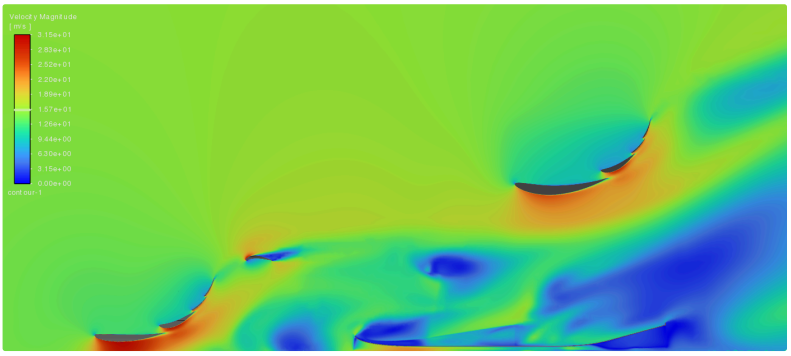
Forces - Direction Vector (0 1 0)

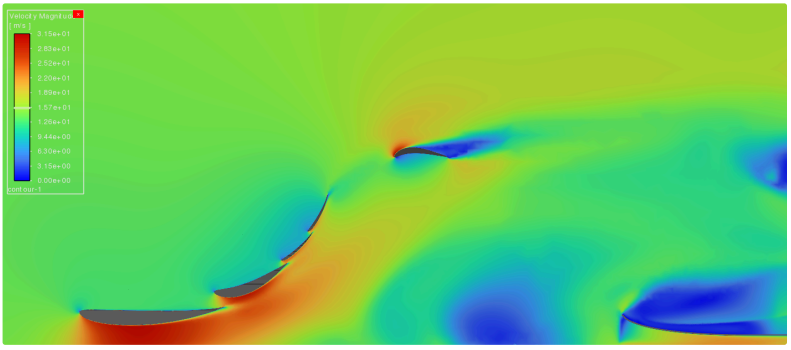
	Forces [N]			Coefficients		
Zone	Pressure	Viscous	Total	Pressure	Viscous	Total
chassis	0.11402096	-0.14473105	-0.03071009	0.0014652105	-0.0018598463	-0.00039463574
front-mrf:1	-0.37501985	0.026070617	-0.34894923	-0.0048191404	0.00033501684	-0.0044841236
front-tire-patch	-0.00019144348	0	-0.00019144348	-2.4601179e-06	0	-2.4601179e-06
front-wheel	6.7087884	0.069808112	6.7785965	0.086210353	0.00089705944	0.087107412
front-wing	-106.68226	0.17001397	-106.51225	-1.3709056	0.0021847409	-1.3687208
inverted-wing	6.4201975	0.011016859	6.4312144	0.082501856	0.00014157062	0.082643427
rear-mrf:1	-0.28231703	0.0046750418	-0.27764199	-0.0036278758	6.0075975e-05	-0.0035677998
rear-tire-patch	-0.0004780249	0	-0.0004780249	-6.1427926e-06	0	-6.1427926e-06
rear-wheel	3.6803849	0.047761933	3.7281468	0.047294274	0.00061375808	0.047908033
rear-wing	-83.822365	0.31983871	-83.502426	-1.0771477	0.004111328	-1.0730363
rear-wing:198	-0.01105123	-0.00076122733	-0.011812457	-0.00014201229	-9.782046e-06	-0.00015179434
undertray	-87.158592	0.050031984	-87.10856	-1.1200194	0.00064292906	-1.1193764
Net	-261.40888	0.55382495	-260.85506	-3.3591985	0.0071168506	-3.3520817

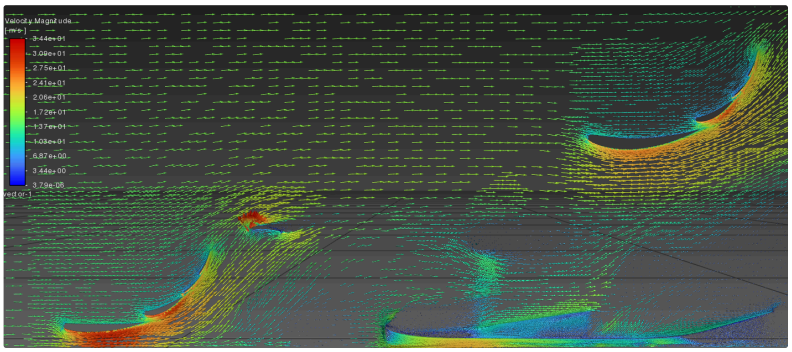
- Z(drag):

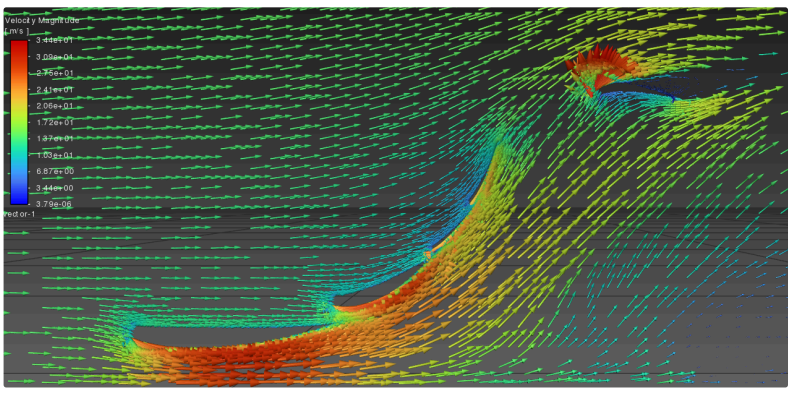
Forces - Direction Vector (0 0 1)

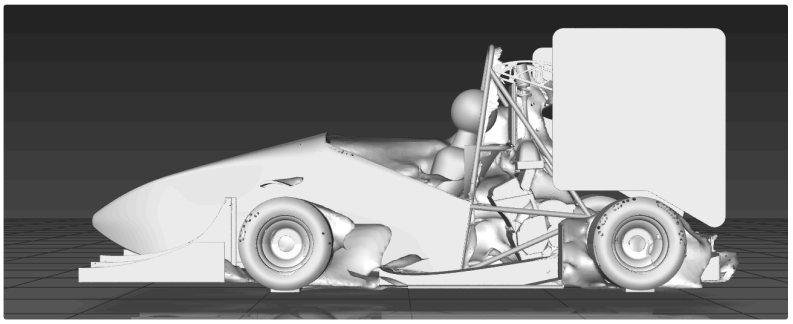
	Forces [N]			Coefficients		
Zone	Pressure	Viscous	Total	Pressure	Viscous	Total
chassis	-25.242608	-1.0848165	-26.327424	-0.32437662	-0.013940283	-0.33831691
front-mrf:1	-1.7621122	0.025931961	-1.7361803	-0.022643778	0.00033323506	-0.022310543
front-tire-patch	-0.2726129	0	-0.2726129	-0.0035031742	0	-0.0035031742
front-wheel	-5.1209228	-0.296960546	-5.4178282	-0.065805706	-0.0038153423	-0.069621049
front-wing	-15.588559	-1.2029986	-16.791558	-0.20031861	-0.01545896?	-0.21577758
inverted-wing	1.0492397	-0.029980275	1.0192594	0.013483109	-0.00038525736	0.013097851
rear-mrf:1	-0.59066647	-0.0010634877	-0.59172996	-0.0075902774	-1.3666201e-05	-0.0076039436
rear-tire-patch	-0.21689379	0	-0.21689379	-0.0027871636	0	-0.0027871636
rear-wheel	-2.2773305	-0.22042519	-2.4977557	-0.029264519	-0.0028325433	-0.032097062
rear-wing	-30.91043	-1.3224711	-32.232901	-0.39721018	-0.016994231	-0.41420441
rear-wing:198	-0.054906074	-0.012795294	-0.067701368	-0.00070556287	-0.00016442414	-0.00086998701
undertray	-11.618491	-1.3080341	-12.926525	-0.1493018	-0.01680871	-0.16611051
Net	-92.606293	-5.453558	-98.059851	-1.1900243	-0.070080189	-1.2601045

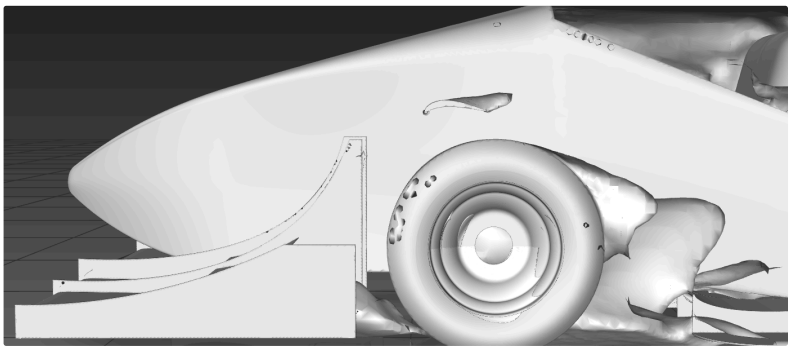


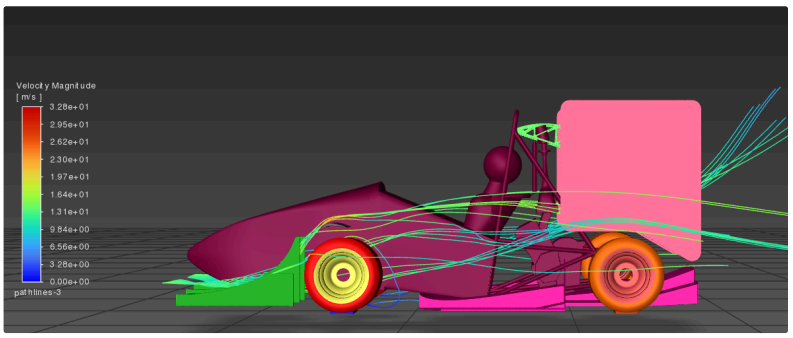


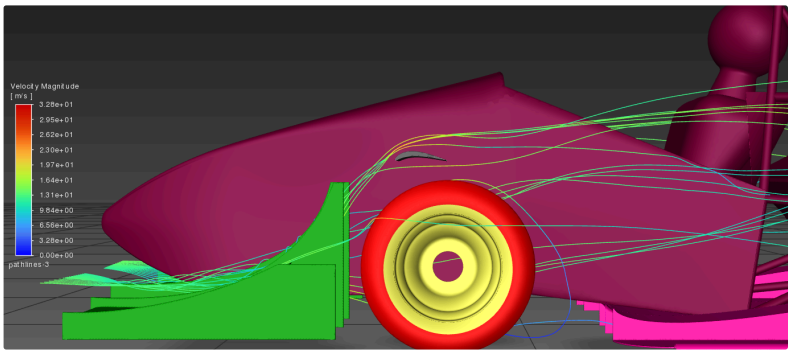


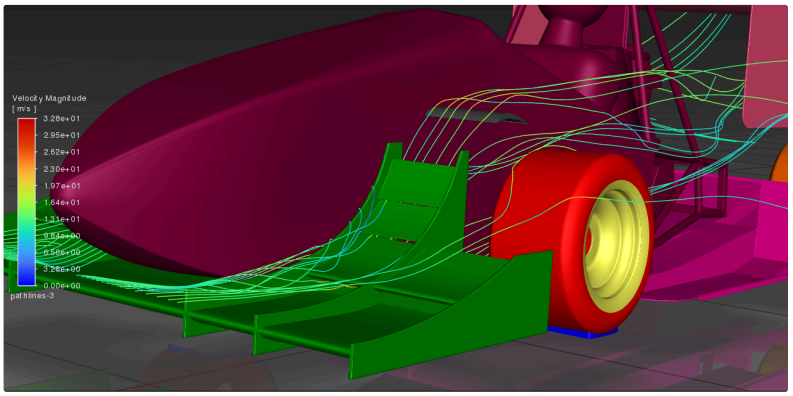


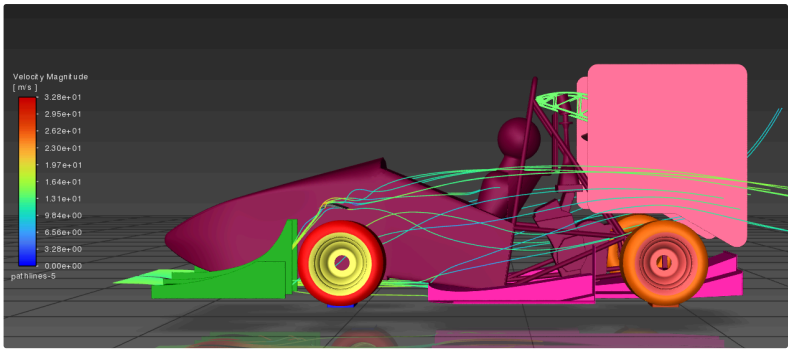


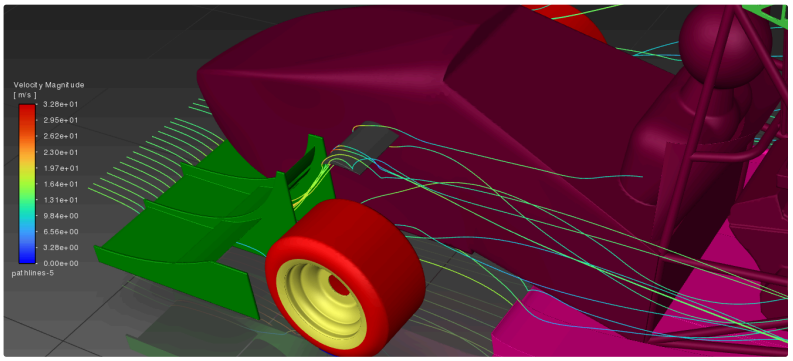


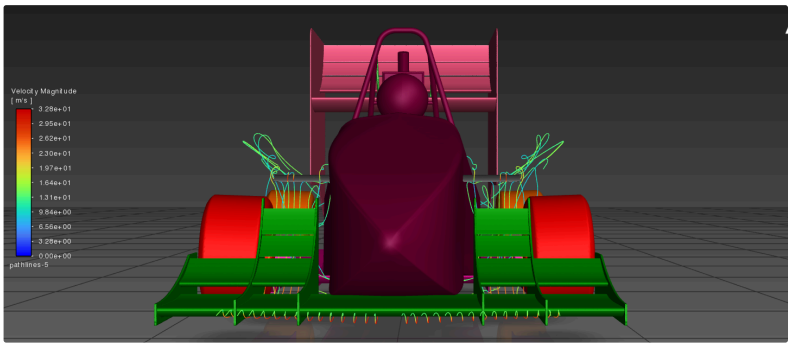

Velocity Magnitude
[m/s]
3.28e+01
2.95e+01
2.62e+01
2.30e+01
1.97e+01
1.64e+01
1.31e+01
9.84e+00
6.56e+00
3.28e+00
0.00e+00
pathlines-3

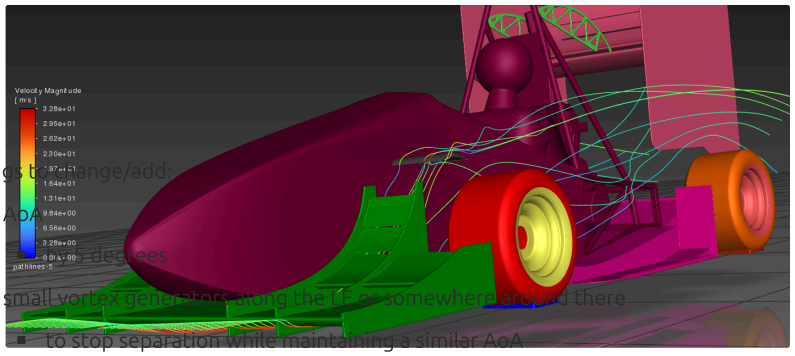

Velocity Magnitude
[m/s]
3.28e+01
2.95e+01
2.62e+01
2.30e+01
1.97e+01
1.64e+01
1.31e+01
9.84e+00
6.56e+00
3.28e+00
0.00e+00
pathlines-3


Velocity Magnitude
[m/s]
3.28e+01
2.95e+01
2.62e+01
2.30e+01
1.97e+01
1.64e+01
1.31e+01
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0.00e+00
pathlines-3

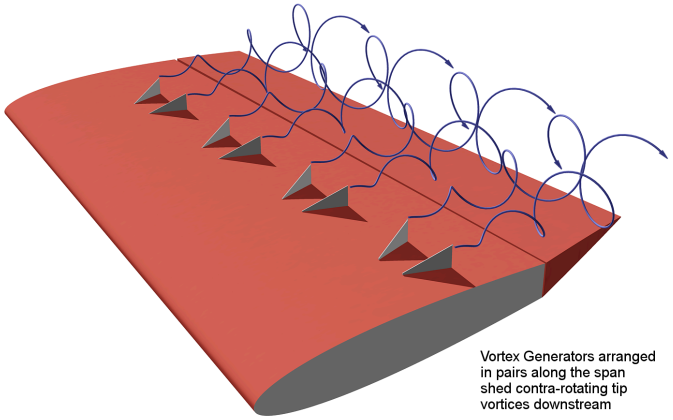

Velocity Magnitude
[m/s]
3.28e+01
2.95e+01
2.62e+01
2.30e+01
1.97e+01
1.64e+01
1.31e+01
9.84e+00
6.56e+00
3.28e+00
0.00e+00
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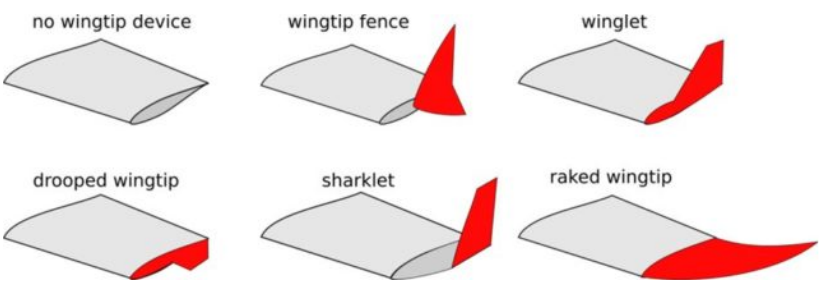


- Things to change/add:
  - AoA
    - [illegible] degrees
  - small vortex generators along the [illegible] or somewhere around there
    - to stop separation while maintaining a similar AoA
      - example:



  - Endplates
    - 65%-75% of the endplate below the airfoil (on the high pressure side)
    - Maybe louvered endplate?

Ideas for the future with wingtips to make the inverted wing better:



Types of Winglets

