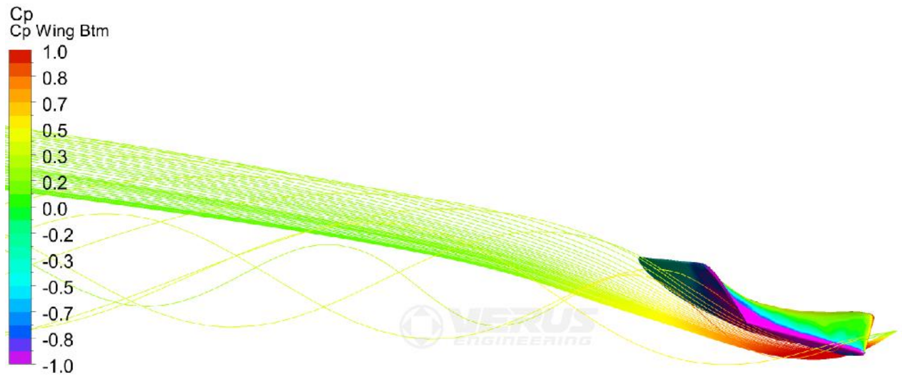
VERUS HIGH-EFFICIENCY WING

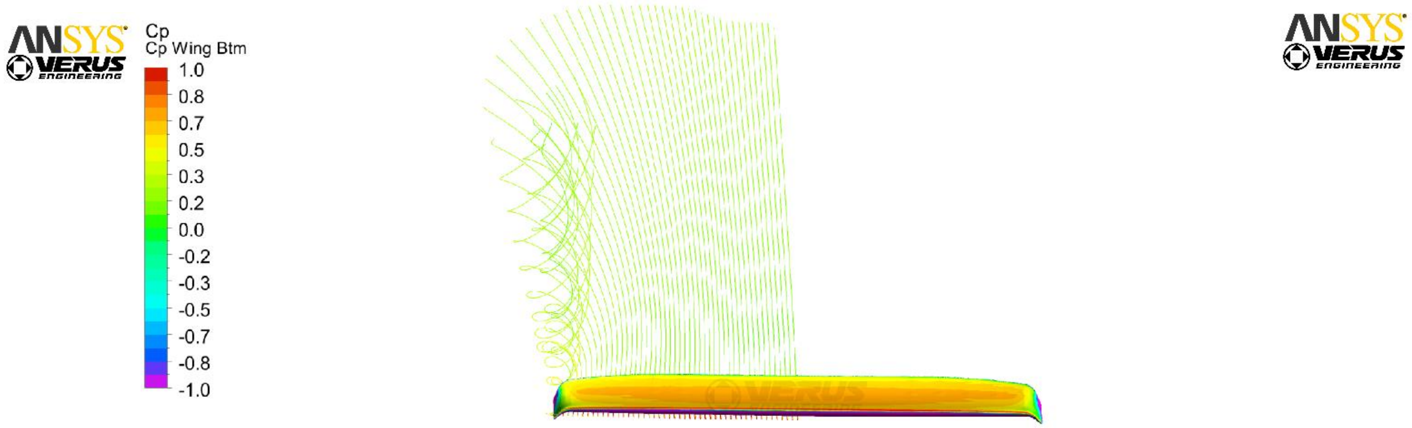
A0020A INFORMATIVE PACKET

OVERVIEW

This is an informative packet on the Verus Engineering High-Efficiency Wing, with information on testing and data gathering.

WING IN FREE STREAM



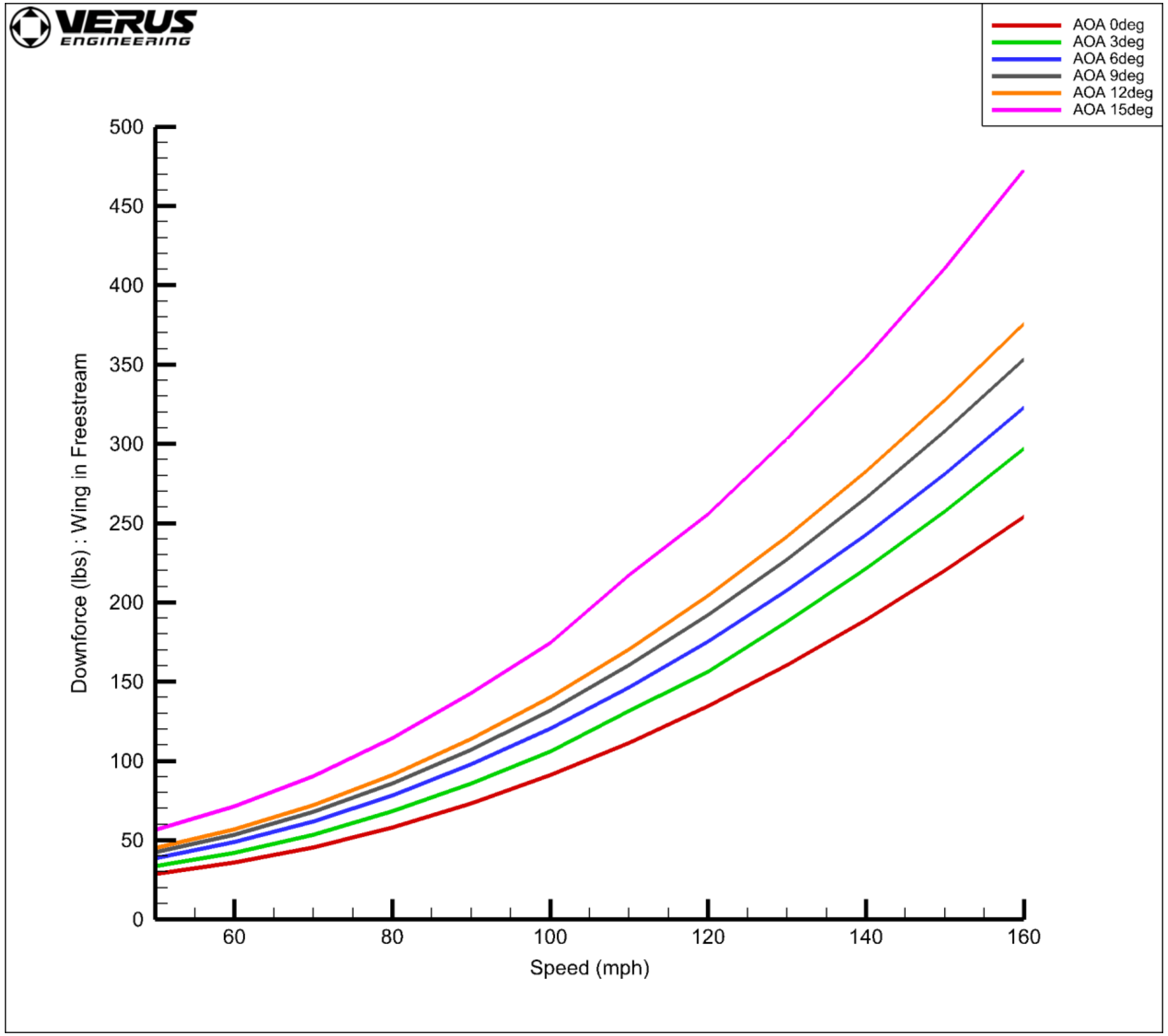


Why do we publish free stream data on the wing when the performance of the wing changes on your FT86?

By publishing this data, you can compare our data directly with other wings on the market who publish data. This will allow direct comparison of drag, downforce, and efficiency for the consumer to make the most informed decision possible. We take every effort to ensure accuracy when performing CFD analysis. Please be sure that competitors are competent and using proper software as well for accurate comparisons.

WING IN FREE STREAM

DOWNFORCE

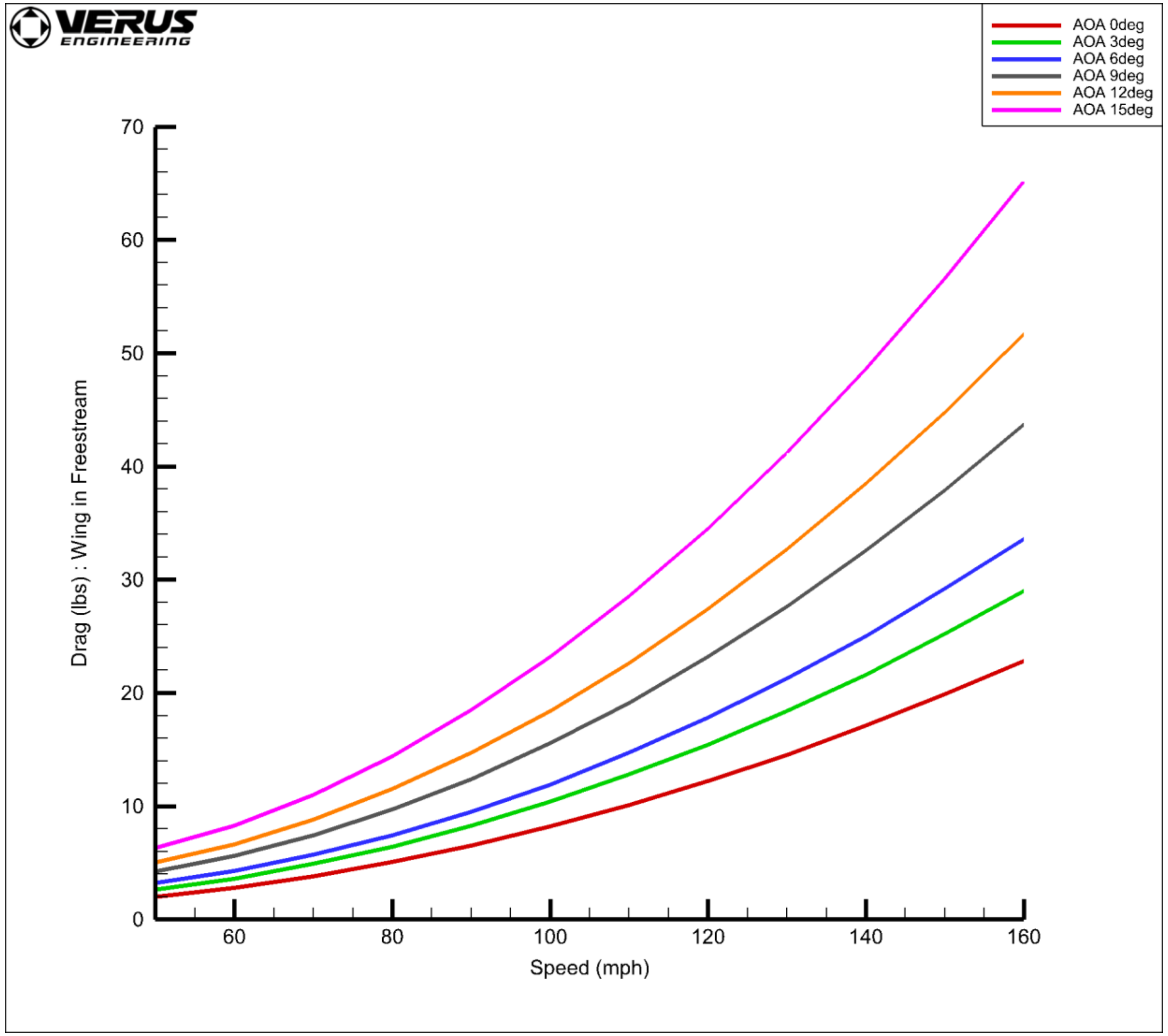


Fz(lbs)	50	60	70	80	90	100	110	120	130	140	150	160
0	28.6	35.7	45.5	58.0	73.1	90.9	111.4	134.6	160.5	189.0	220.2	254.1
3	33.5	41.9	53.4	68.1	85.8	106.0	131.5	156.3	187.6	221.3	257.6	297.0
6	38.7	48.7	61.9	78.3	97.8	120.5	146.3	175.3	207.4	242.7	281.2	322.8
9	42.4	53.4	67.8	85.7	107.1	131.9	160.2	191.9	227.1	265.8	307.9	353.5
12	45.1	56.8	72.1	91.1	113.9	140.3	170.3	204.1	241.5	282.6	327.4	375.9
15	56.6	71.2	90.5	114.3	142.8	174.6	216.9	255.4	303.2	354.5	410.7	472.8

The left column is the angle of attack (AOA) and the top row is velocity of the air in miles per hour (MPH). Units within the chart are in pounds.

WING IN FREE STREAM

DRAG

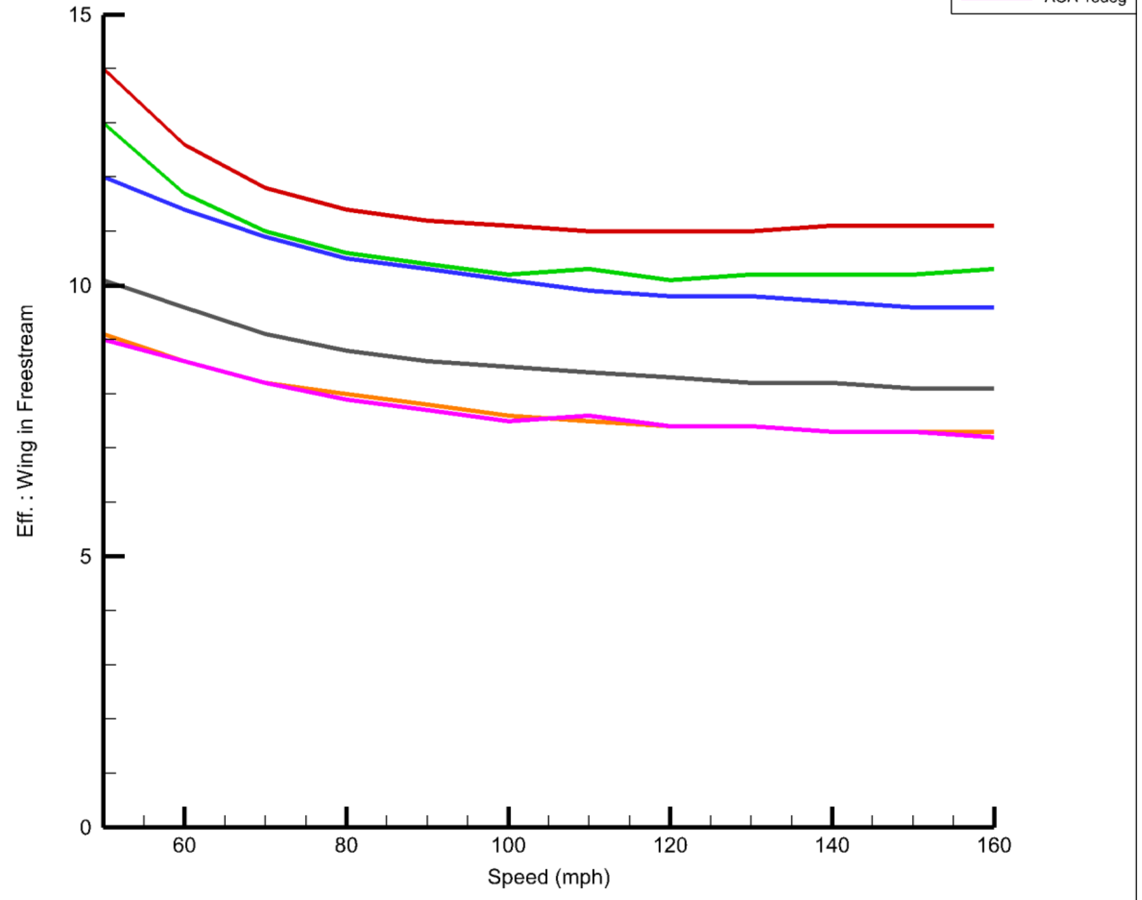


Fx(lbs)	50	60	70	80	90	100	110	120	130	140	150	160
0	2.0	2.8	3.8	5.1	6.5	8.2	10.1	12.2	14.5	17.1	19.9	22.8
3	2.6	3.6	4.9	6.4	8.3	10.4	12.8	15.4	18.4	21.6	25.2	29.0
6	3.2	4.3	5.7	7.4	9.5	11.9	14.7	17.8	21.3	25.0	29.2	33.6
9	4.2	5.6	7.4	9.7	12.4	15.6	19.1	23.2	27.6	32.6	37.9	43.7
12	5.0	6.6	8.8	11.5	14.7	18.4	22.6	27.4	32.7	38.5	44.8	51.7
15	6.3	8.3	11.0	14.4	18.5	23.2	28.5	34.5	41.2	48.6	56.6	65.2

The left column is the angle of attack (AOA) and the top row is velocity of the air in miles per hour (MPH). Units in the chart are in pounds.

WING IN FREE STREAM

EFFICIENCY



Eff.	50	60	70	80	90	100	110	120	130	140	150	160
0	14.0	12.6	11.8	11.4	11.2	11.1	11.0	11.0	11.0	11.1	11.1	11.1
3	13.0	11.7	11.0	10.6	10.4	10.2	10.3	10.1	10.2	10.2	10.2	10.3
6	12.0	11.4	10.9	10.5	10.3	10.1	9.9	9.8	9.8	9.7	9.6	9.6
9	10.1	9.6	9.1	8.8	8.6	8.5	8.4	8.3	8.2	8.2	8.1	8.1
12	9.1	8.6	8.2	8.0	7.8	7.6	7.5	7.4	7.4	7.3	7.3	7.3
15	9.0	8.6	8.2	7.9	7.7	7.5	7.6	7.4	7.4	7.3	7.3	7.2

The left column is the angle of attack (AOA) and the top row is velocity of the air in miles per hour (MPH). Efficiency is a unit less measurement.

- Efficiency is Downforce divided by Drag which is also called L/D (Lift over Drag).

WING IN FREE STREAM

Fz(lbs)	50	60	70	80	90	100	110	120	130	140	150	160
0	28.6	35.7	45.5	58.0	73.1	90.9	111.4	134.6	160.5	189.0	220.2	254.1
3	33.5	41.9	53.4	68.1	85.8	106.0	131.5	156.3	187.6	221.3	257.6	297.0
6	38.7	48.7	61.9	78.3	97.8	120.5	146.3	175.3	207.4	242.7	281.2	322.8
9	42.4	53.4	67.8	85.7	107.1	131.9	160.2	191.9	227.1	265.8	307.9	353.5
12	45.1	56.8	72.1	91.1	113.9	140.3	170.3	204.1	241.5	282.6	327.4	375.9
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3	2.6	3.6	4.9	6.4	8.3	10.4	12.8	15.4	18.4	21.6	25.2	29.0
6	3.2	4.3	5.7	7.4	9.5	11.9	14.7	17.8	21.3	25.0	29.2	33.6
9	4.2	5.6	7.4	9.7	12.4	15.6	19.1	23.2	27.6	32.6	37.9	43.7
12	5.0	6.6	8.8	11.5	14.7	18.4	22.6	27.4	32.7	38.5	44.8	51.7
15	6.3	8.3	11.0	14.4	18.5	23.2	28.5	34.5	41.2	48.6	56.6	65.2

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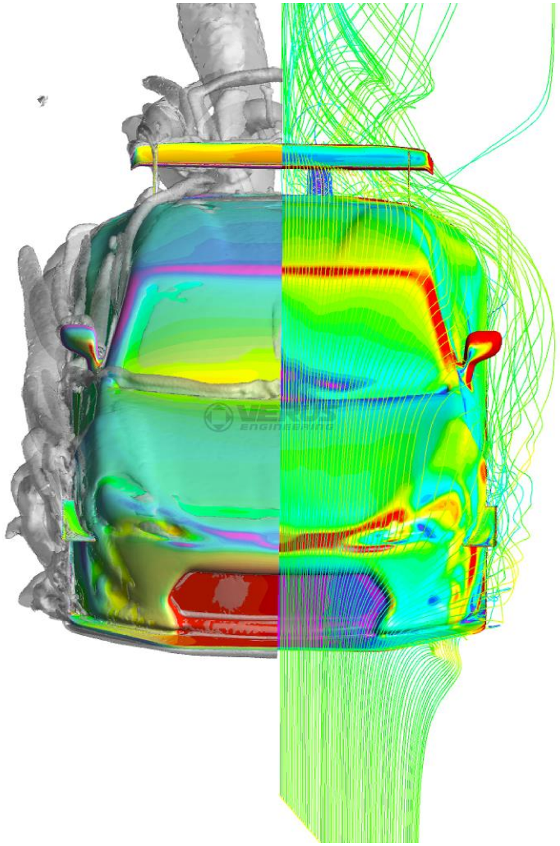
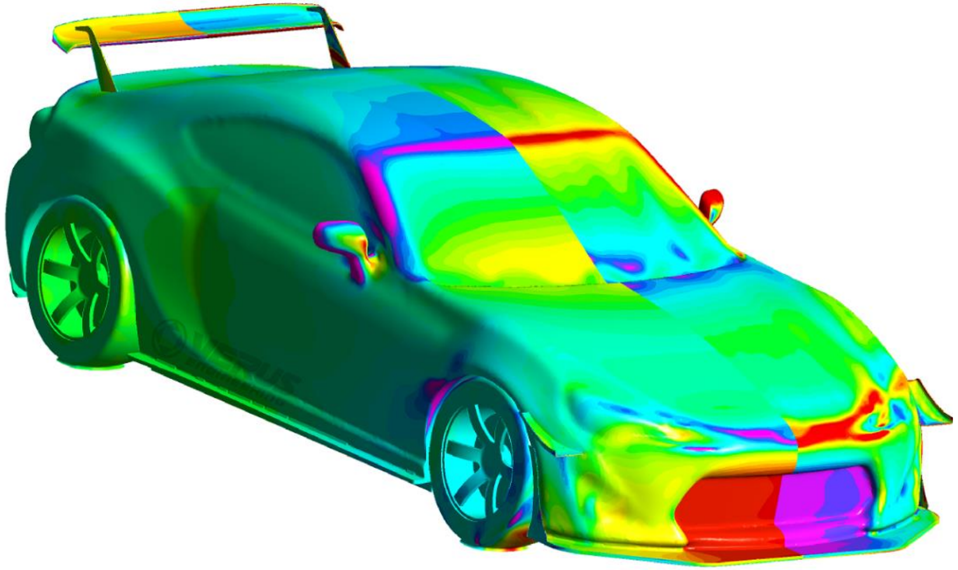
0	14.0	12.6	11.8	11.4	11.2	11.1	11.0	11.0	11.0	11.1	11.1	11.1
3	13.0	11.7	11.0	10.6	10.4	10.2	10.3	10.1	10.2	10.2	10.2	10.3
6	12.0	11.4	10.9	10.5	10.3	10.1	9.9	9.8	9.8	9.7	9.6	9.6
9	10.1	9.6	9.1	8.8	8.6	8.5	8.4	8.3	8.2	8.2	8.1	8.1
12	9.1	8.6	8.2	8.0	7.8	7.6	7.5	7.4	7.4	7.3	7.3	7.3
15	9.0	8.6	8.2	7.9	7.7	7.5	7.6	7.4	7.4	7.3	7.3	7.2

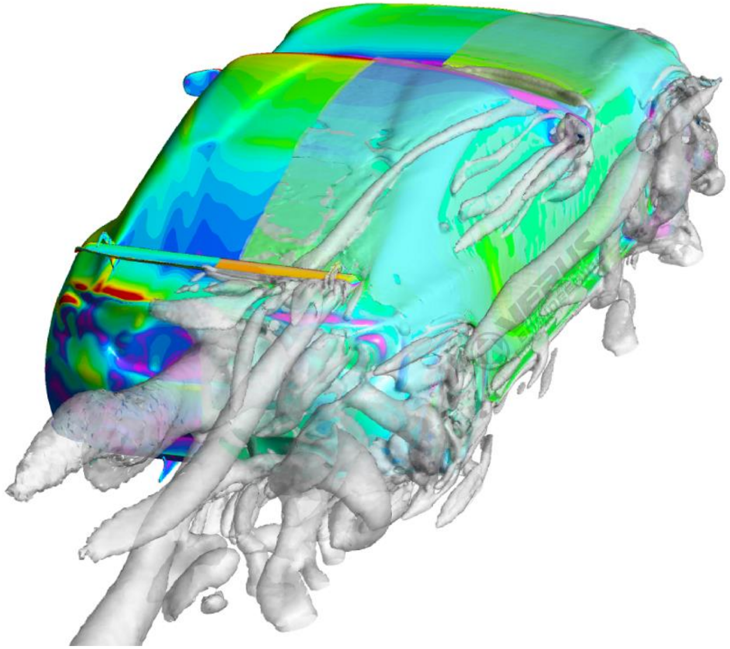
Overview/Summary:

The Verus Engineering High-Efficiency Wing is highly efficient. This was purposeful; as the FRS/BRZ are low powered vehicles, so producing the most downforce for every pound of drag is paramount. The goal was to develop the most efficient wing on the market that could be mounted on the trunk without buckling the trunk from the downforce. To accomplish this, we optimize the wing profile first in 2D and then in 3D. The end of the wing has winglets instead of endplates which limits downforce and decreases cost. The winglets also limit vortices off the wing tip to keep drag to a minimum. We have compiled downforce (Fz), drag (Fx) and efficiency in the graph to the left to allow you to fully understand what the wing is capable of doing in free-stream airflow. This also allows you to compare to other wings on the market.

WING ON FT86





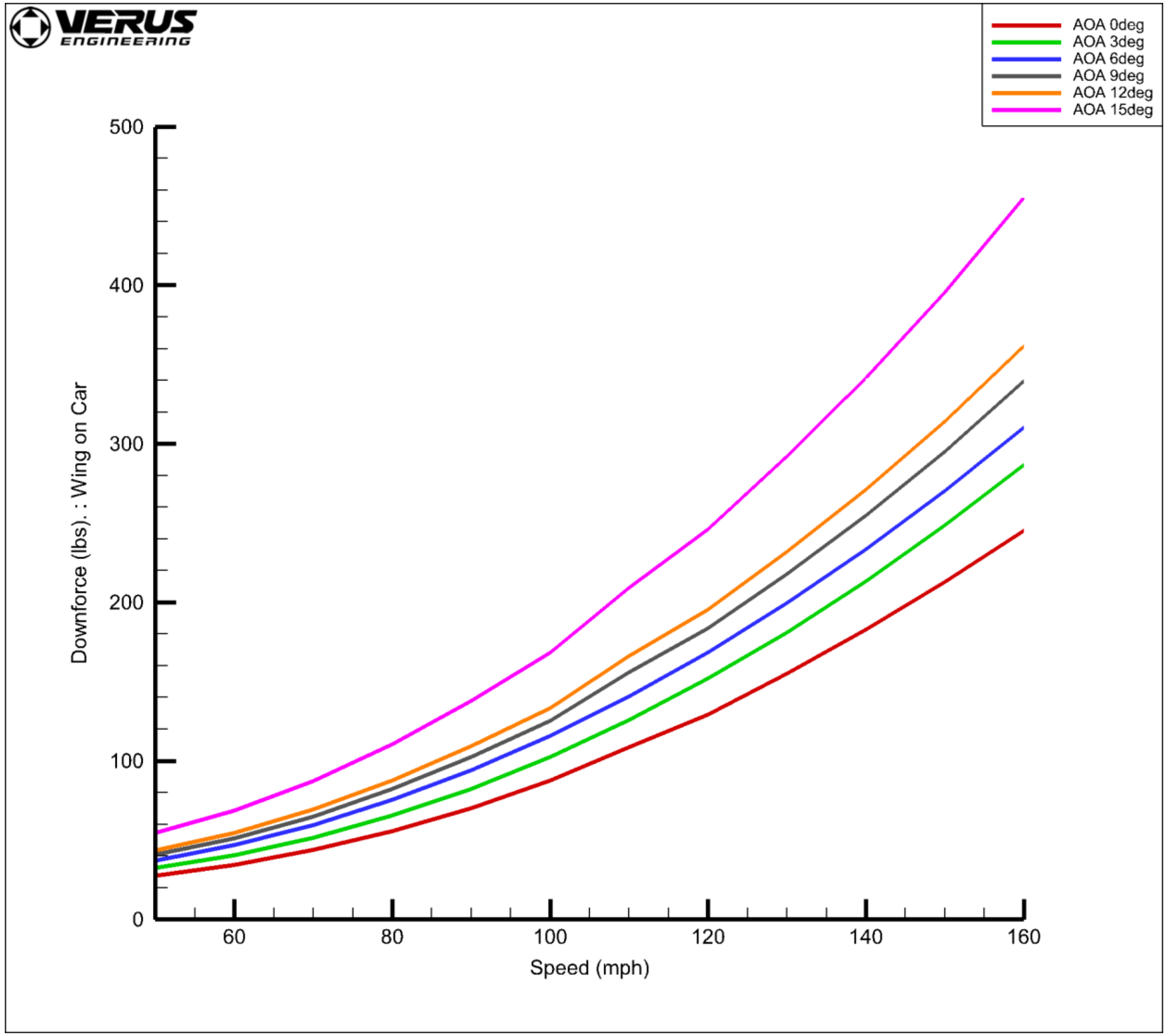


Why do we publish data of the Low Drag Wing on the FT86 when this is not common in the industry?

By publishing the data of the wing on the FT86, the customer will understand exactly how the wing will perform on their car. This is not common in this industry because it is very time consuming and involves a large amount of work. However, we feel it is the best way to present the data as it allows end users to understand what is happening on vehicle.

WING ON FT86

DOWNFORCE

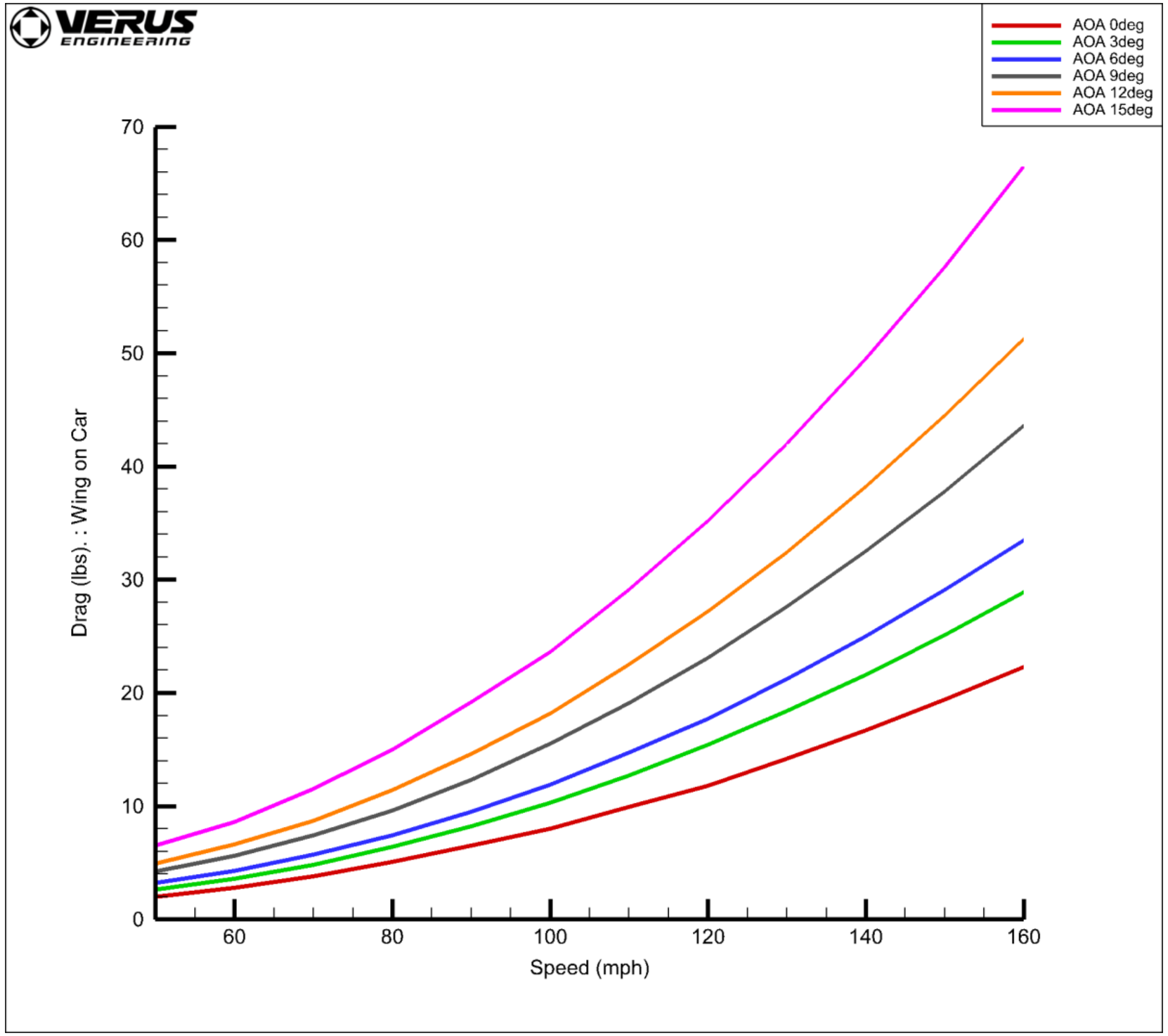


Fz(lbs)	50	60	70	80	90	100	110	120	130	140	150	160
0	27.5	34.4	43.8	55.8	70.3	87.5	108.6	129.1	155.0	182.8	212.8	245.3
3	32.3	40.3	51.3	65.4	82.5	102.6	125.7	151.9	181.1	213.3	248.5	286.7
6	37.2	46.9	59.6	75.3	94.0	115.8	140.7	168.5	199.5	233.4	270.4	310.5
9	40.7	51.2	65.0	82.2	102.6	125.5	155.9	183.6	217.9	254.8	295.2	339.8
12	43.4	54.6	69.3	87.6	109.5	133.5	165.9	195.4	231.9	271.2	314.1	361.6
15	54.6	68.8	87.4	110.4	138.0	168.2	208.9	246.1	292.1	341.5	395.6	455.4

The left column is the angle of attack (AOA) and the top row is velocity of the air in miles per hour (MPH). The units in the chart are in pounds.

WING ON FT86

DRAG



Fx(lbs)	50	60	70	80	90	100	110	120	130	140	150	160
0	2.0	2.8	3.8	5.1	6.5	8.0	9.9	11.8	14.2	16.7	19.4	22.3
3	2.6	3.6	4.8	6.4	8.2	10.3	12.7	15.4	18.4	21.6	25.1	28.9
6	3.2	4.3	5.7	7.4	9.5	11.9	14.7	17.7	21.2	25.0	29.1	33.5
9	4.2	5.6	7.4	9.6	12.3	15.5	19.1	23.1	27.6	32.5	37.8	43.6
12	4.9	6.6	8.7	11.4	14.6	18.2	22.5	27.2	32.4	38.2	44.5	51.3
15	6.5	8.6	11.5	15.0	19.2	23.6	29.1	35.2	42.0	49.5	57.6	66.5

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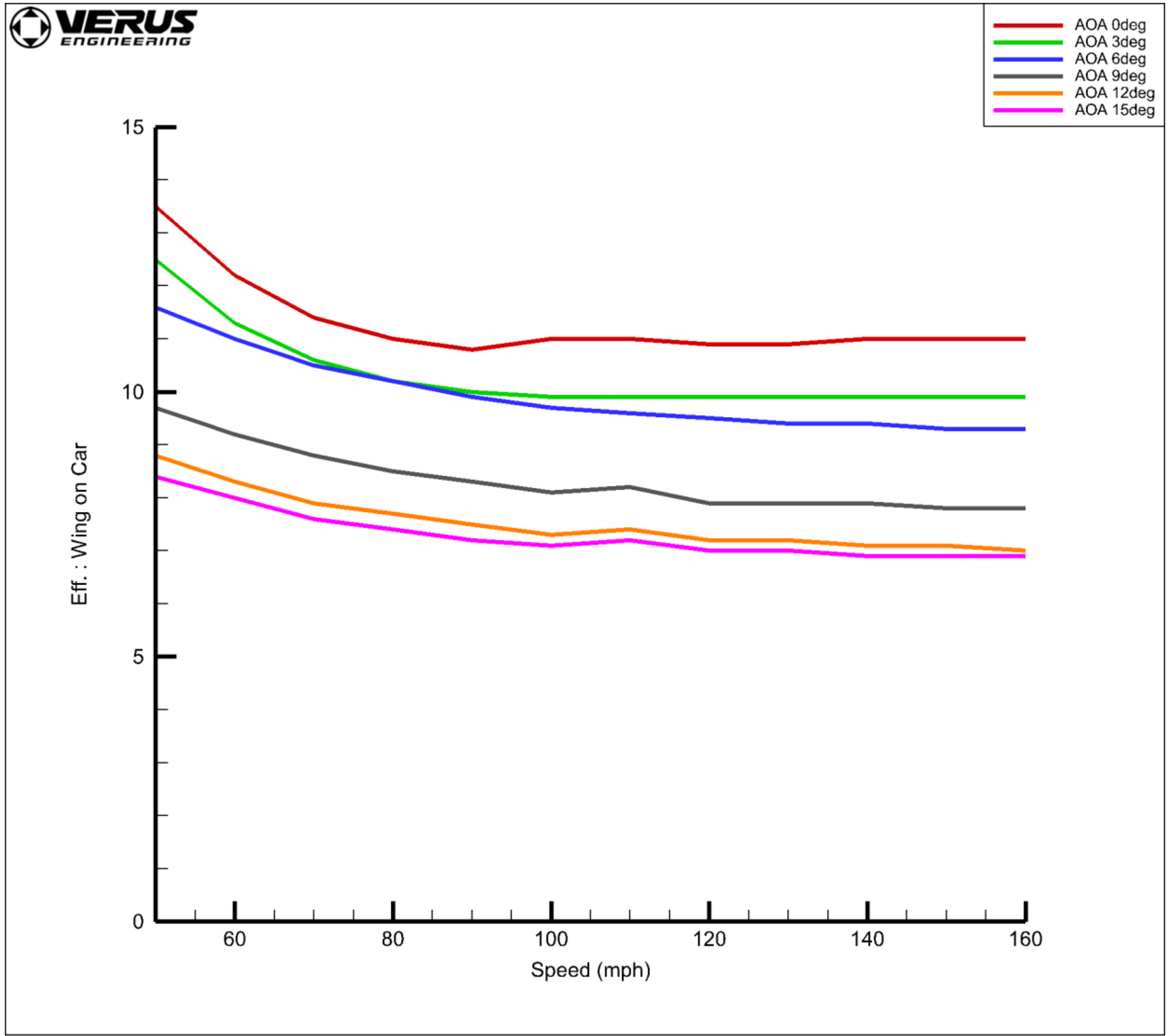
WING ON FT86

EFFICIENCY



Eff.	50	60	70	80	90	100	110	120	130	140	150	160
0	13.5	12.2	11.4	11.0	10.8	11.0	11.0	10.9	10.9	11.0	11.0	11.0
3	12.5	11.3	10.6	10.2	10.0	9.9	9.9	9.9	9.9	9.9	9.9	9.9
6	11.6	11.0	10.5	10.2	9.9	9.7	9.6	9.5	9.4	9.4	9.3	9.3
9	9.7	9.2	8.8	8.5	8.3	8.1	8.2	7.9	7.9	7.9	7.8	7.8
12	8.8	8.3	7.9	7.7	7.5	7.3	7.4	7.2	7.2	7.1	7.1	7.0
15	8.4	8.0	7.6	7.4	7.2	7.1	7.2	7.0	7.0	6.9	6.9	6.9

The left column is the angle of attack (AOA) and the top row is velocity of the air in miles per hour (MPH). Efficiency is a unit less measurement.

- Efficiency is Downforce divided by Drag which is also known as L/D (Lift over Drag).

WING ON FT86

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0	27.5	34.4	43.8	55.8	70.3	87.5	108.6	129.1	155.0	182.8	212.8	245.3
3	32.3	40.3	51.3	65.4	82.5	102.6	125.7	151.9	181.1	213.3	248.5	286.7
6	37.2	46.9	59.6	75.3	94.0	115.8	140.7	168.5	199.5	233.4	270.4	310.5
9	40.7	51.2	65.0	82.2	102.6	125.5	155.9	183.6	217.9	254.8	295.2	339.8
12	43.4	54.6	69.3	87.6	109.5	133.5	165.9	195.4	231.9	271.2	314.1	361.6
15	54.6	68.8	87.4	110.4	138.0	168.2	208.9	246.1	292.1	341.5	395.6	455.4

Fx(lbs)	50	60	70	80	90	100	110	120	130	140	150	160
0	2.0	2.8	3.8	5.1	6.5	8.0	9.9	11.8	14.2	16.7	19.4	22.3
3	2.6	3.6	4.8	6.4	8.2	10.3	12.7	15.4	18.4	21.6	25.1	28.9
6	3.2	4.3	5.7	7.4	9.5	11.9	14.7	17.7	21.2	25.0	29.1	33.5
9	4.2	5.6	7.4	9.6	12.3	15.5	19.1	23.1	27.6	32.5	37.8	43.6
12	4.9	6.6	8.7	11.4	14.6	18.2	22.5	27.2	32.4	38.2	44.5	51.3
15	6.5	8.6	11.5	15.0	19.2	23.6	29.1	35.2	42.0	49.5	57.6	66.5

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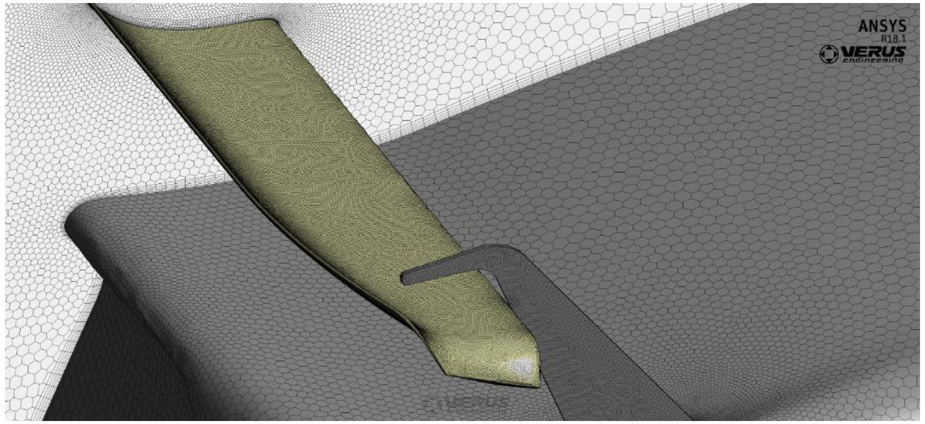
0	13.5	12.2	11.4	11.0	10.8	11.0	11.0	10.9	10.9	11.0	11.0	11.0
3	12.5	11.3	10.6	10.2	10.0	9.9	9.9	9.9	9.9	9.9	9.9	9.9
6	11.6	11.0	10.5	10.2	9.9	9.7	9.6	9.5	9.4	9.4	9.3	9.3
9	9.7	9.2	8.8	8.5	8.3	8.1	8.2	7.9	7.9	7.9	7.8	7.8
12	8.8	8.3	7.9	7.7	7.5	7.3	7.4	7.2	7.2	7.1	7.1	7.0
15	8.4	8.0	7.6	7.4	7.2	7.1	7.2	7.0	7.0	6.9	6.9	6.9

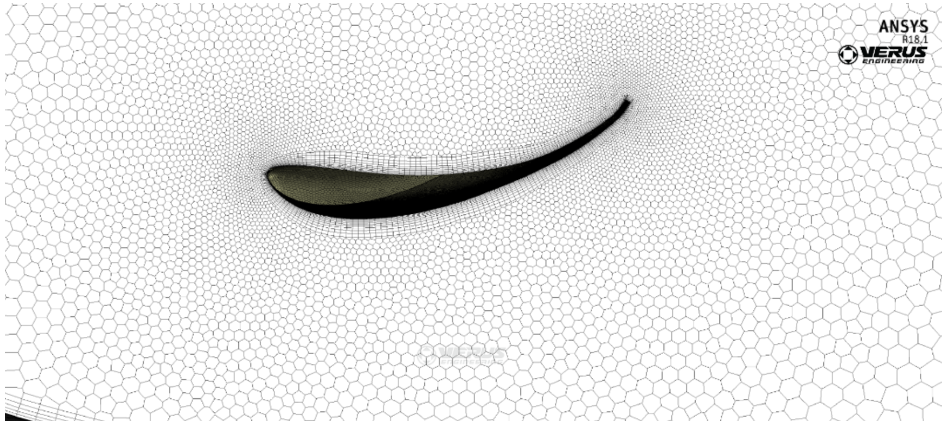
Overview/Summary:

The Verus Engineering High-Efficiency Wing is still highly efficient but less efficient than in free stream. The reason for this is the interaction of the airflow around the car. We optimized the placement of the wing to minimize the negative effect of this airflow. The wing on the car has less downforce, more drag, and efficiency went down. However, the efficiency is very high at a maximum efficiency of 11.0 and a minimum efficiency of 6.9. This is very good. What does this really mean? If you have an efficiency of 11.0, that means you make 11 lbs of downforce per every 1 lb of drag.

CFD VALIDATION

All the computational fluid dynamics used at Verus Engineering is completed using ANSYS Fluent. Fluent is considered to be the best commercial CFD software on the market and is used by many in the top-tier of motorsports including Red Bull F1. On every analysis, we ensure a proper mesh is created for the required results, proper boundary conditions, and proper turbulence models are used.

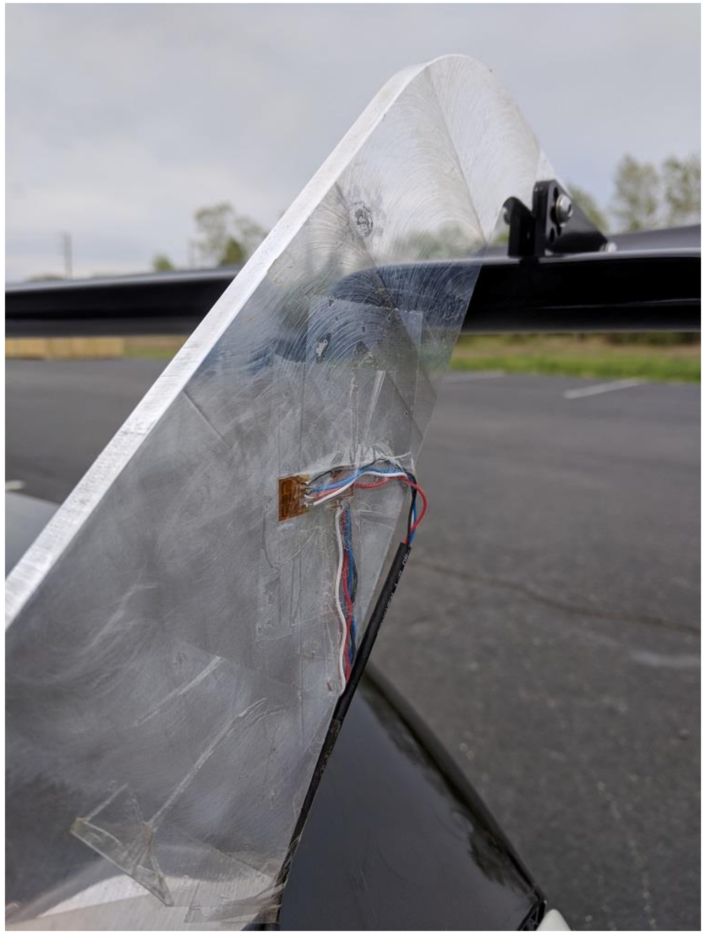


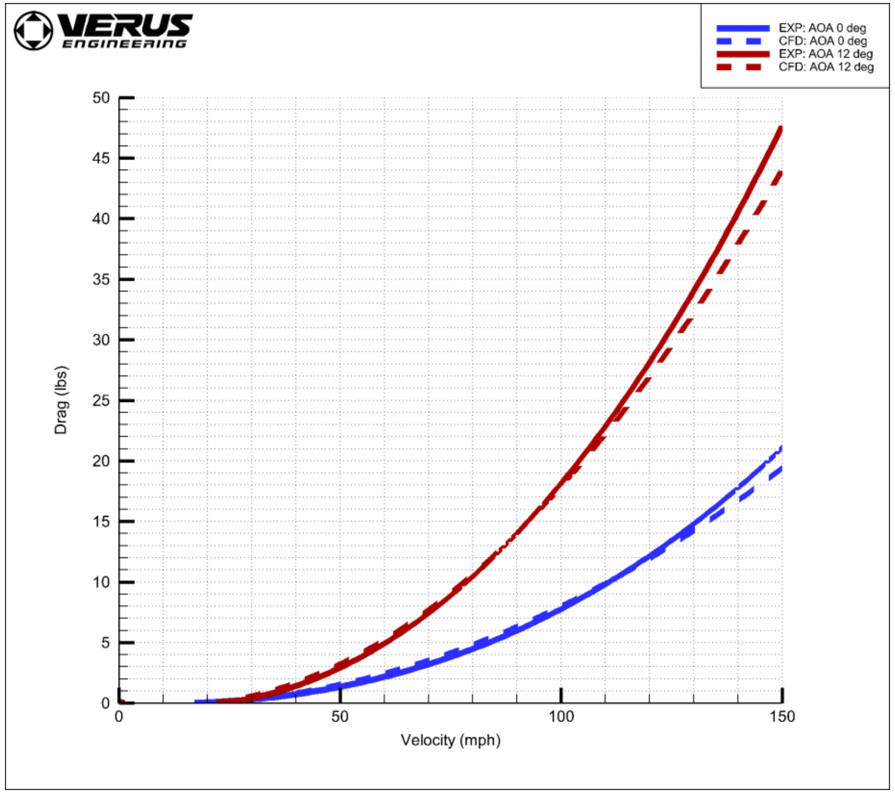


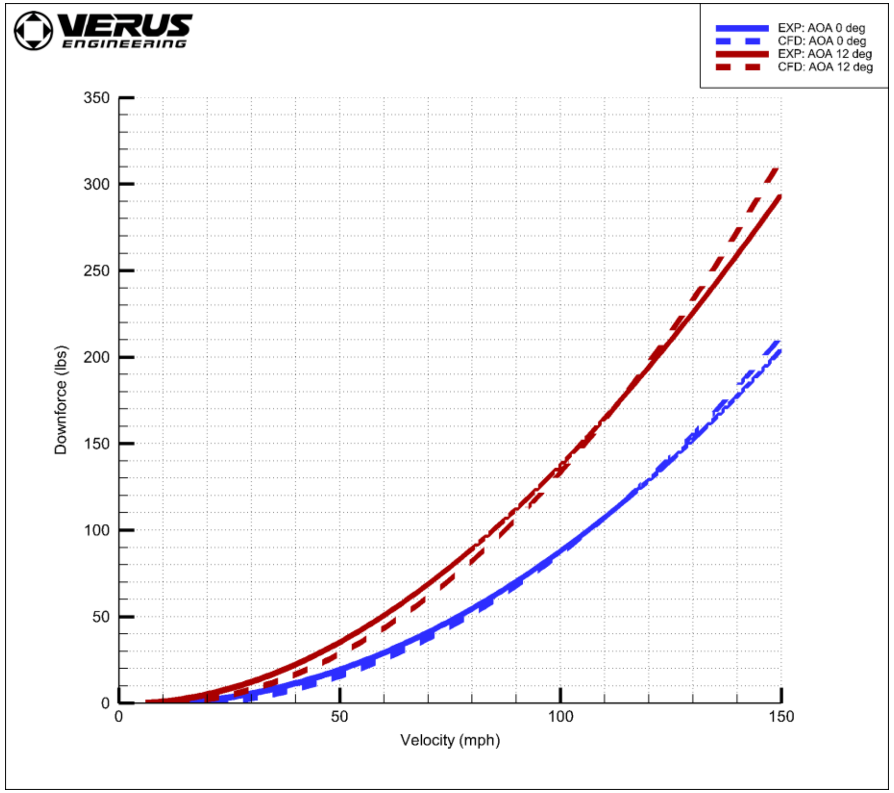
To further validate that our CFD is setup properly, we performed actual part testing on the car as well.

- Strain gauges were placed on the wing uprights to measure downforce and drag forces
- Coast down testing was used to measure changes in drag

STRAIN GAUGES

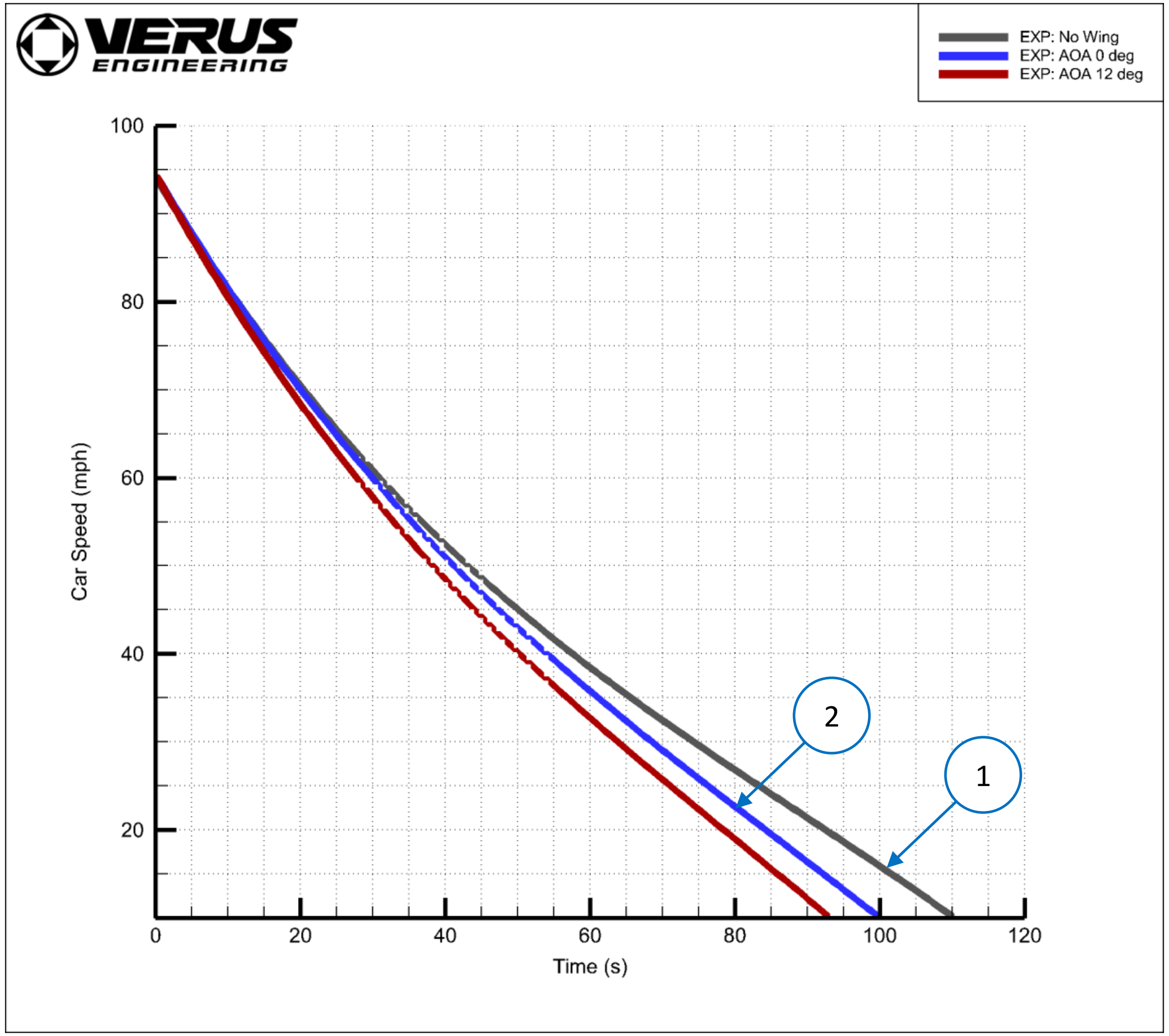






Strain gauges are used to measure the strain of a component, this data can then be calculated into forces. Strain gauges were used to measure the forces of the wing attached to the upright. This data was then compared to the simulation results generated by CFD and FEA. The real world experimental values correlated with the CFD well.

COAST DOWN TESTING

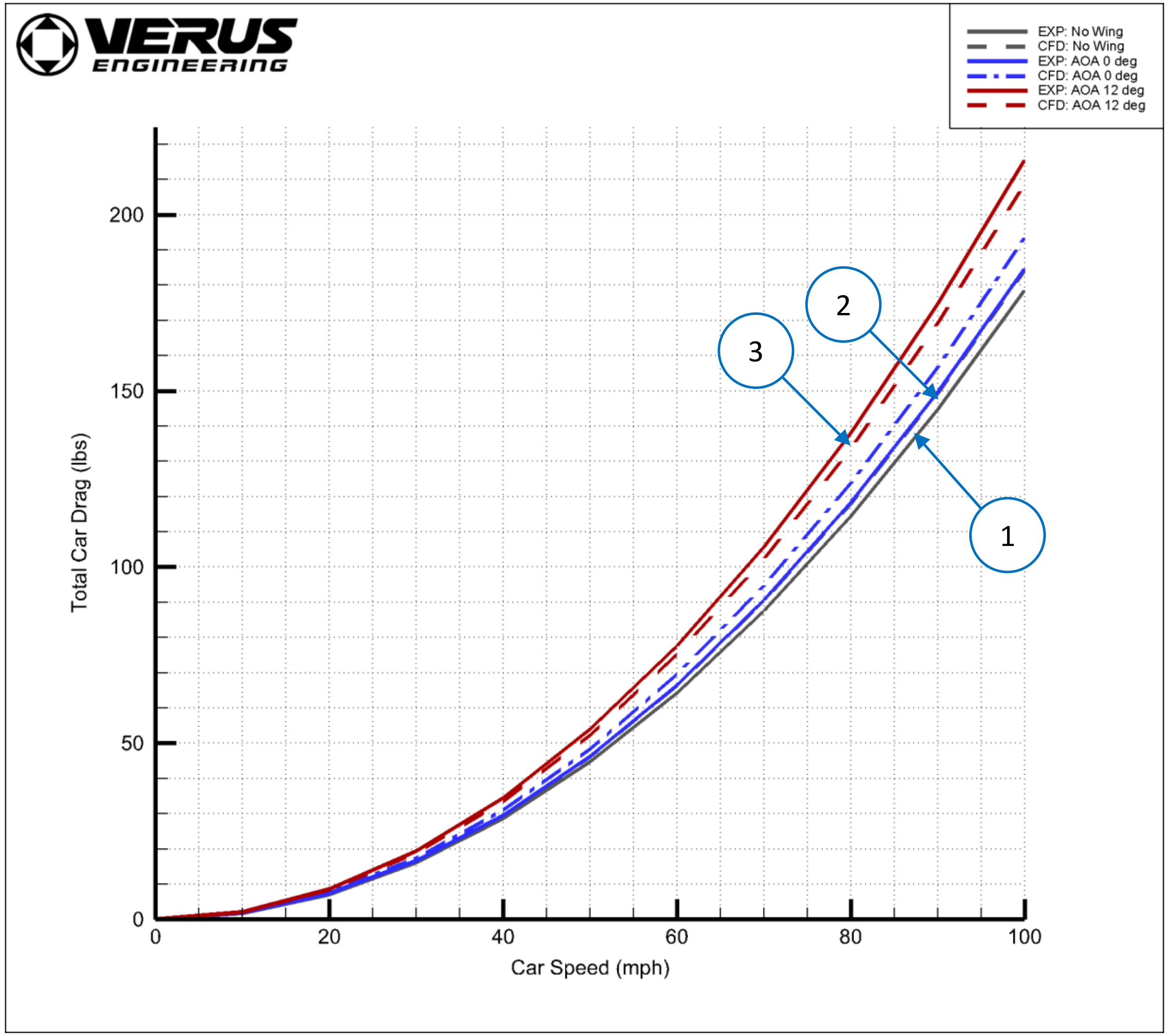


We followed the SAE standard of coast down testing as close as we could. We coasted down from 100mph to around 10mph with 3 different cases; no wing, wing at 0 deg, and wing at 12 deg. The data was recorded using an AIM data logger and 2 runs were done and then averaged. Elevation changes were ignored because it could not be accurately calculated. Runs were made on the same day, at the same location, back to back.

1. The coast down test without the wing took the longest time and this makes sense because it would have the least amount of drag.

2. AOA of 0 & 12 degrees take less overall time to decelerate because of the increased drag of the wing.

COAST DOWN TESTING



From the coast down testing data, calculation of the coefficient of drag (cd) was completed. From this, the ability to compare simulated CFD drag to coast down testing drag was possible.

1. The real world (experiment) and CFD of no wing had the least amount of drag.

2. The CFD drag of the no wing was very close in value to the experimental (real world) 0 degree angle of attack. The lines are very close to overlapping.

3. The 12 degree angle of attack was the only test where the experimented drag was higher than the simulated CFD drag.

4. Overall, the real world results correlate well to CFD estimated data.

SUMMARY

The Verus Engineering High-Efficiency Wing was specifically designed for the FT86 enthusiast who wants more rear end downforce for track days, while not decreasing gas mileage substantially or completely ruining straight line top speeds on track. The wing mounts were specifically placed in the strongest location on the trunk and then reinforced to help prevent trunk damage. The wing uprights were optimized using CFD and FEA to ensure the most efficient airflow in straight line and yaw conditions while being strong enough to handle the loads from the wing.

Our CFD data and our real world experimental data match up quite well. The wing hit all the major goals we set forth to achieve first in our CFD simulations and then with our real world testing. The strong correlation between CFD data and real world testing validates both our CFD analysis approach and the wing's performance.