PORSCHE CAYMAN - 987

AERODYNAMIC DEVELOPMENT

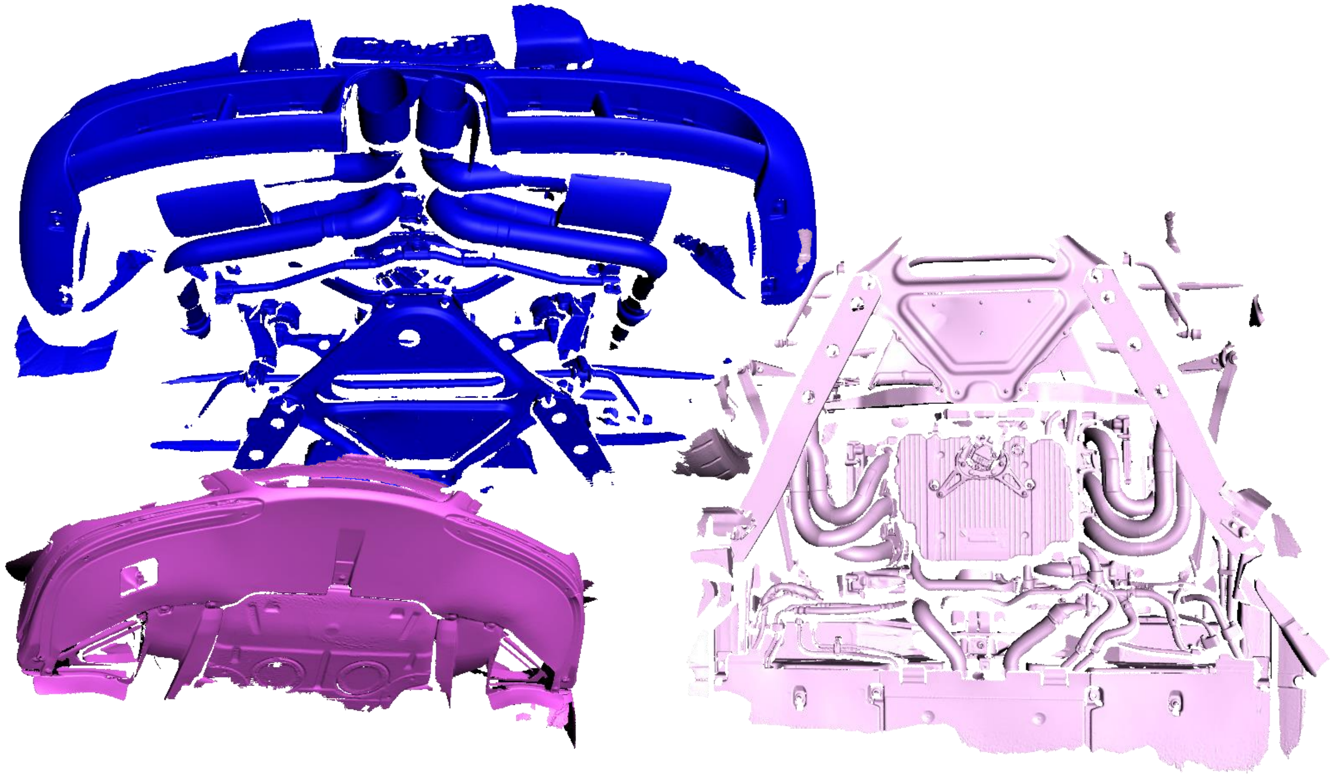
OVERVIEW

This is an informative packet on the Verus Engineering aerodynamic development of the Porsche 987 Cayman.

SCANNING THE CAR

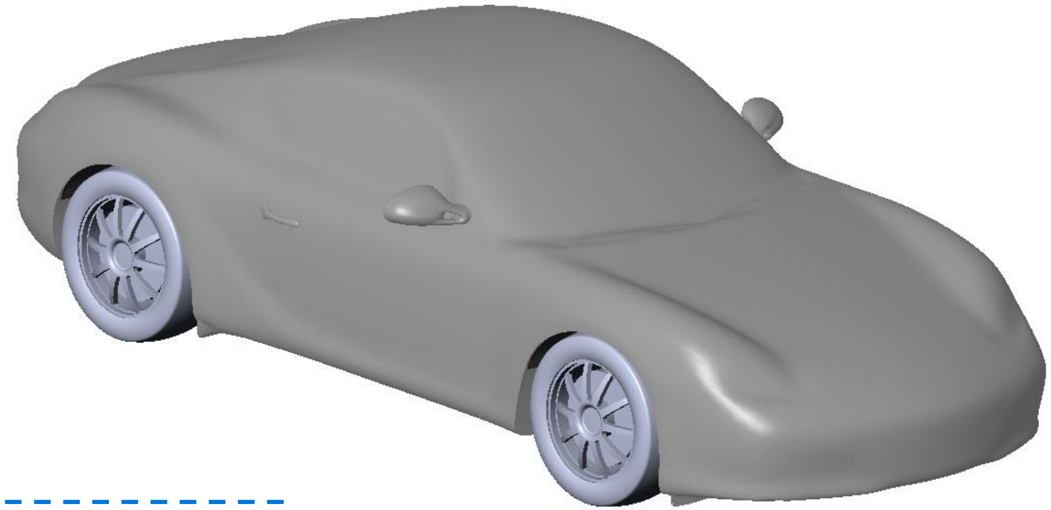
Scanning the car is used for 2 main purposes during development

1. Creating CFD Model
2. Using the scans for proper fitment of the manufactured components

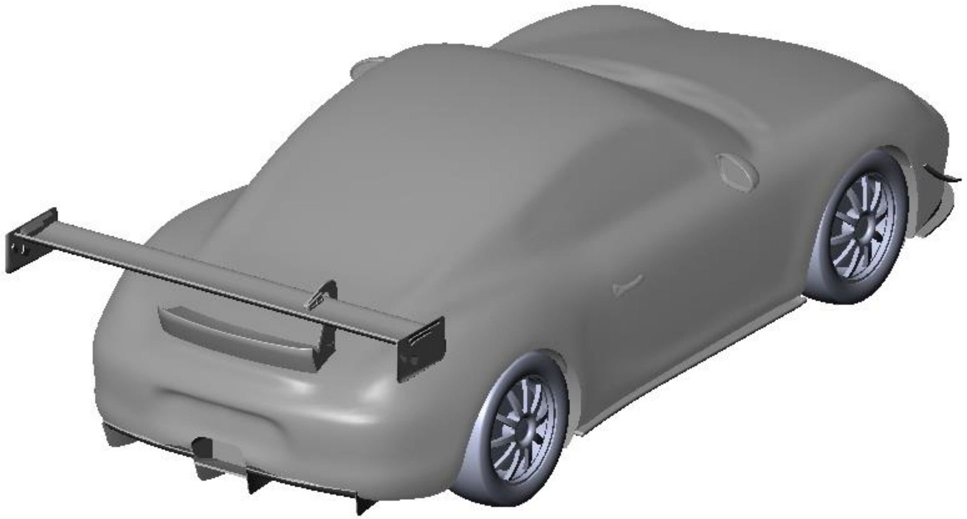


CFD MODEL

Creating a CFD model from a scan is a long and tedious process. This is done with the combination of scanning software and CAD. This is the real bottleneck of developing an aerodynamic package for a scanned vehicle.

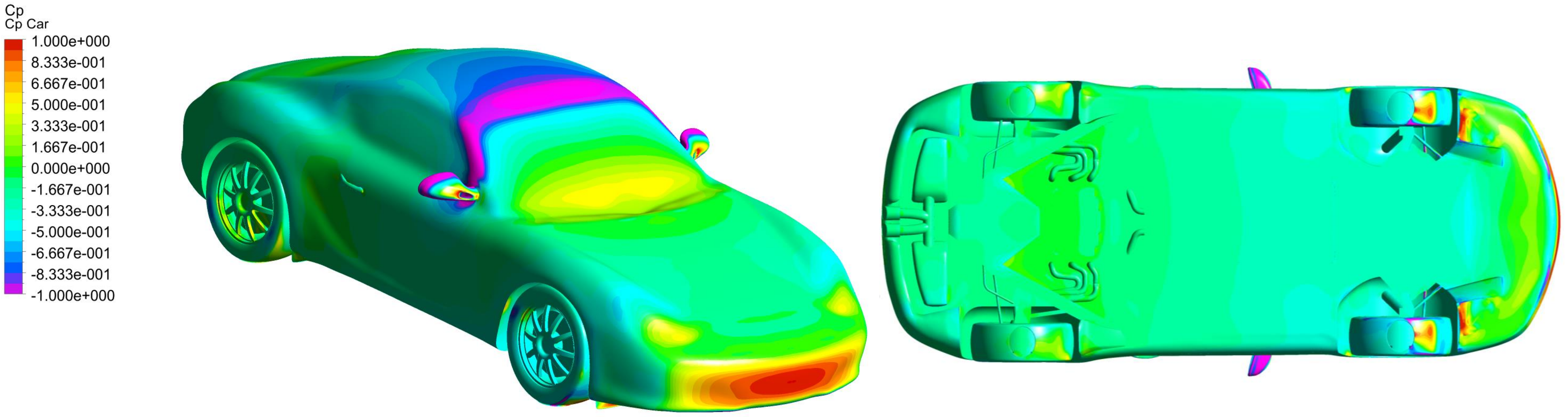


INITIAL MODEL



MODEL DURING DEVELOPMENT

BASELINE



Analyzing the vehicle's baseline is the first step in the development. This gives our team the starting point and locations where improvement can be developed. From there, we can make incremental changes while watching how these changes impact drag, downforce, and aerodynamic balance.

DEVELOPMENT GOALS

The goal that we set out to achieve was an aerodynamic package that had good downforce for heavily tracked Caymans but was also very street-able. Vehicles that are street-able need to watch ride height and all underbody aerodynamic components. The main concerns for street-ability were the front splitter and diffuser strakes.

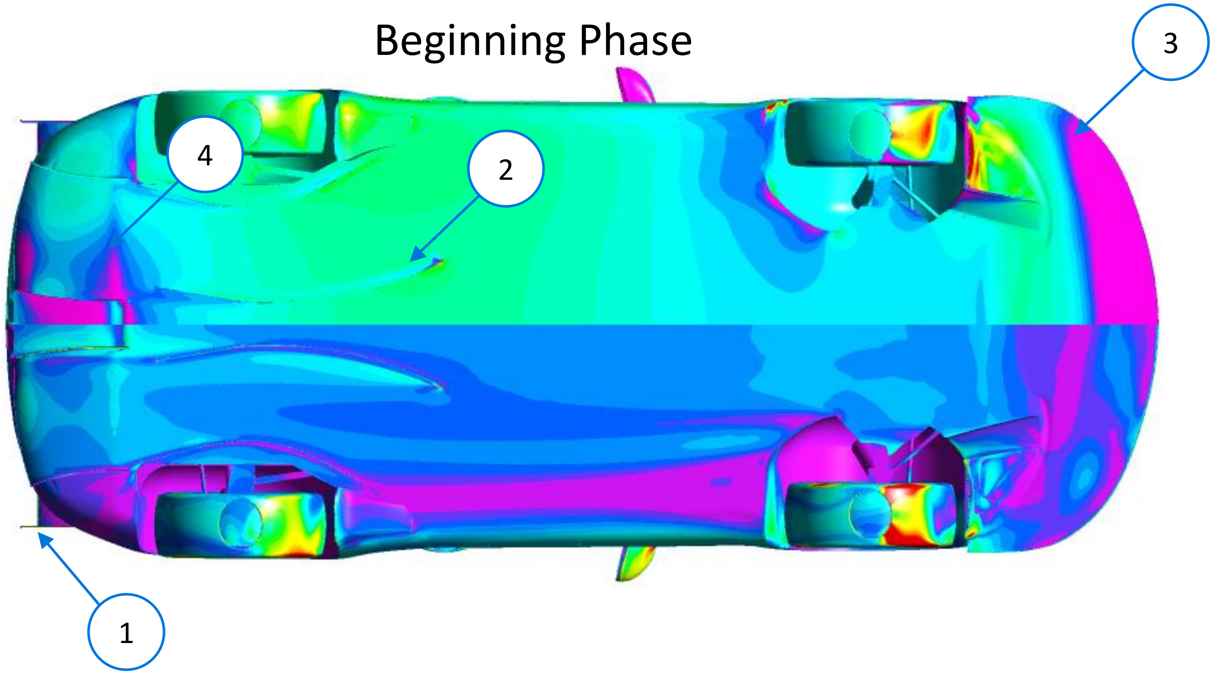
Front Splitter:
The front splitter needs to be as short as possible while still creating enough downforce to balance out the rear wing. Having a short splitter means it is less likely to hit objects on the street and the vehicle can be setup with a lower static front ride height.

Diffuser Strakes:
Diffuser strakes can add a substantial amount of performance gain to the rear diffuser. However, they hang low on the rear of the car. To ensure this will not be an issue on the street, we made them out of a hard durable plastic. This will ensure proper function of a strake while not being concerned with damage by road obstacles.

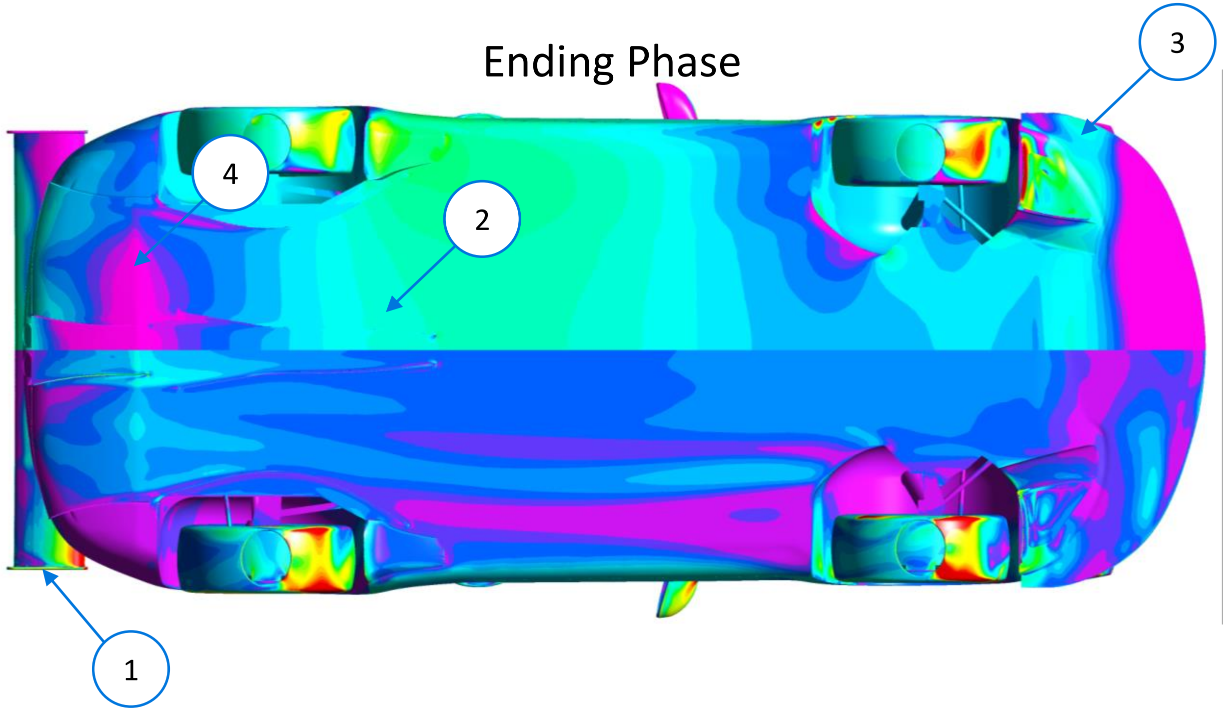
DEVELOPMENT PHASE

From the stock analysis, we went through 25 major design changes not including some minor changes in between.

Beginning Phase

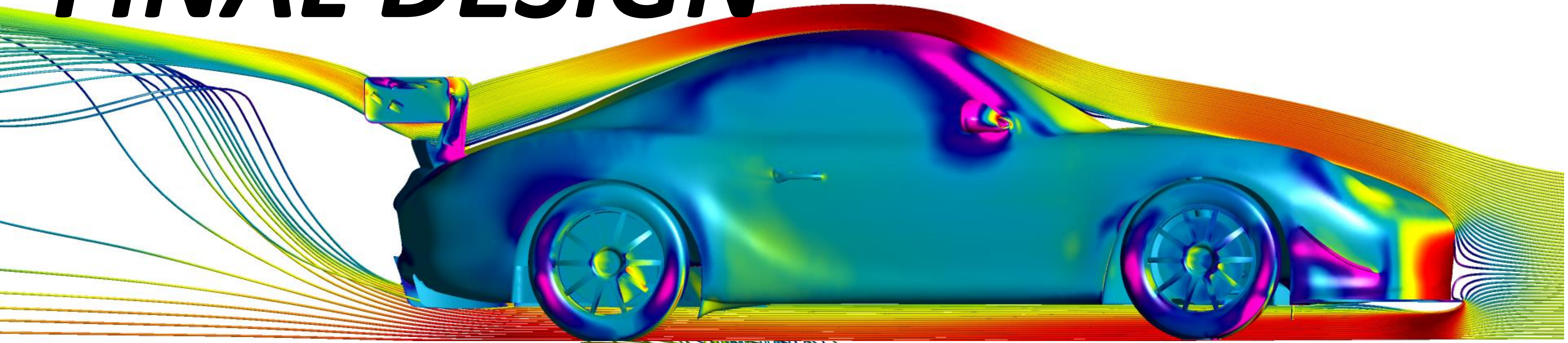


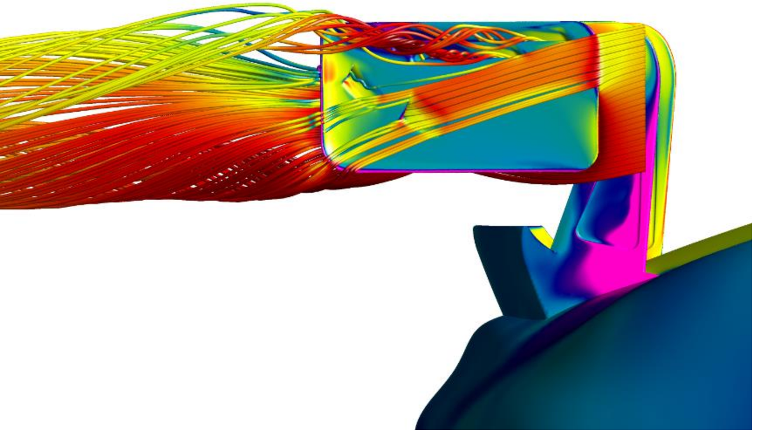
Ending Phase

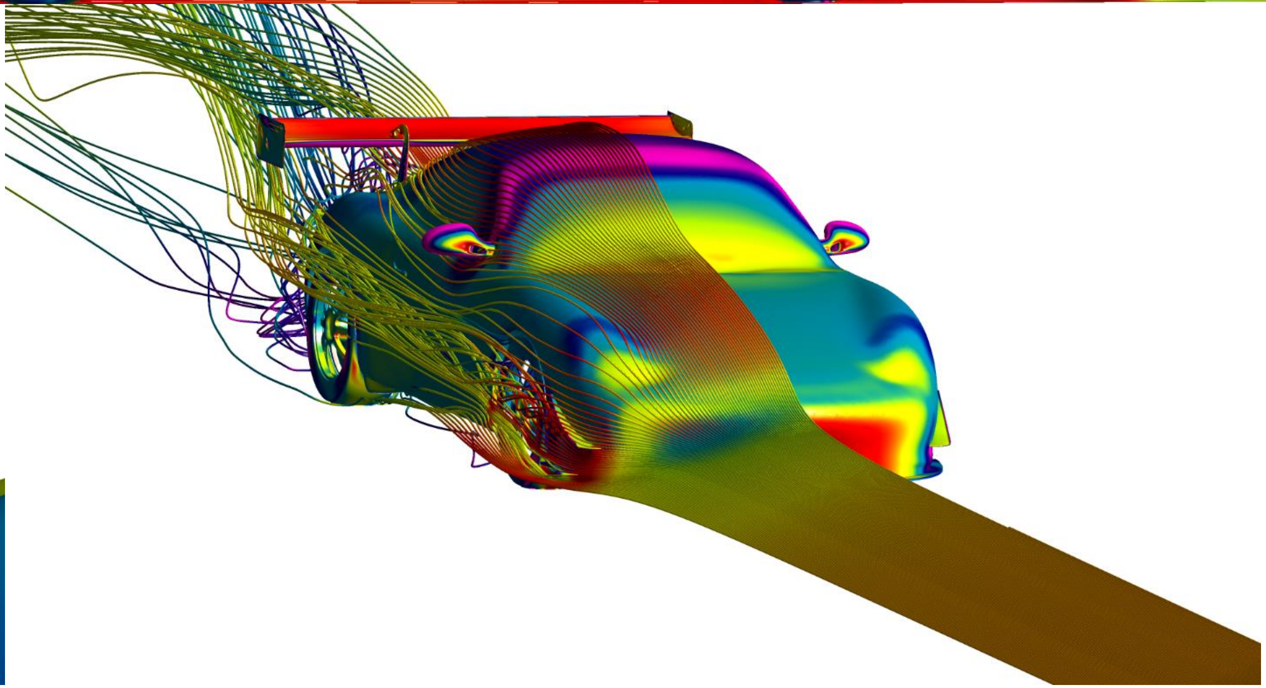


1. Rear wing changes were both major and minor. A major change would be endplate design change while minor would be location change.
2. The entry to the diffuser went through a few major changes and a few minor changes.
3. The front splitter sizing changed a few times to dial in the aerodynamic balance. The overall design of the splitter stayed fairly constant during the development.
4. The rear diffuser went through multiple major changes to get the performance we demanded.

FINAL DESIGN



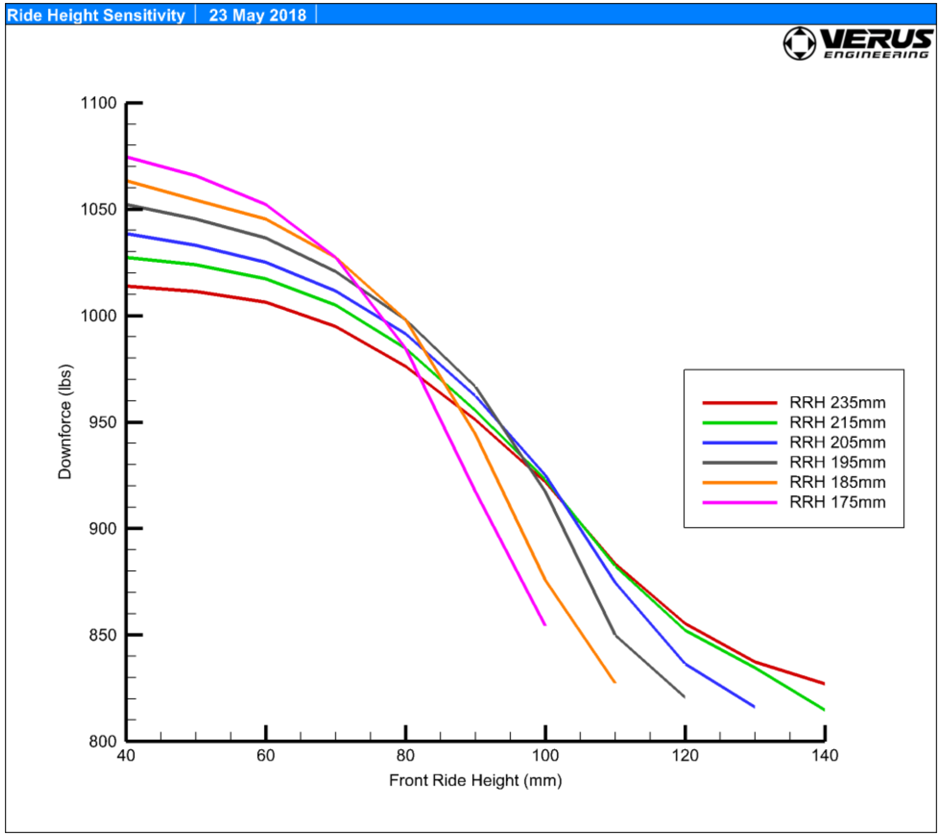


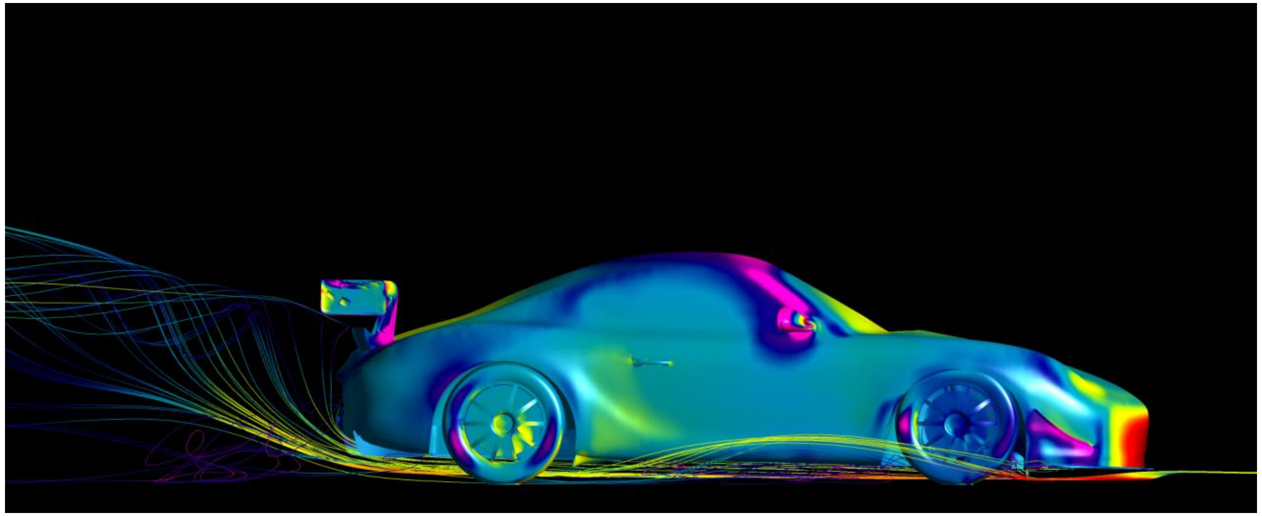


The whole system met our development goals, especially for a street-able, high downforce setup. The front splitter was kept to a minimum length with help from the dive planes. The rear diffuser strakes are designed to flex when impacted and also kept them as high as possible to the chassis without negatively impacting performance. The rear wing airfoil and endplates were optimized for maximum performance with a low drag penalty. Each and every component was developed to work with each other in harmony for the best aerodynamic performance available in such a package.

RIDE HEIGHT SENSITIVITY

One major issue with vehicles that create large amounts of downforce using the underside of the vehicle is ride height sensitivity. We studied this during development and a final ride height sensitivity map was developed before moving to prototyping phase.





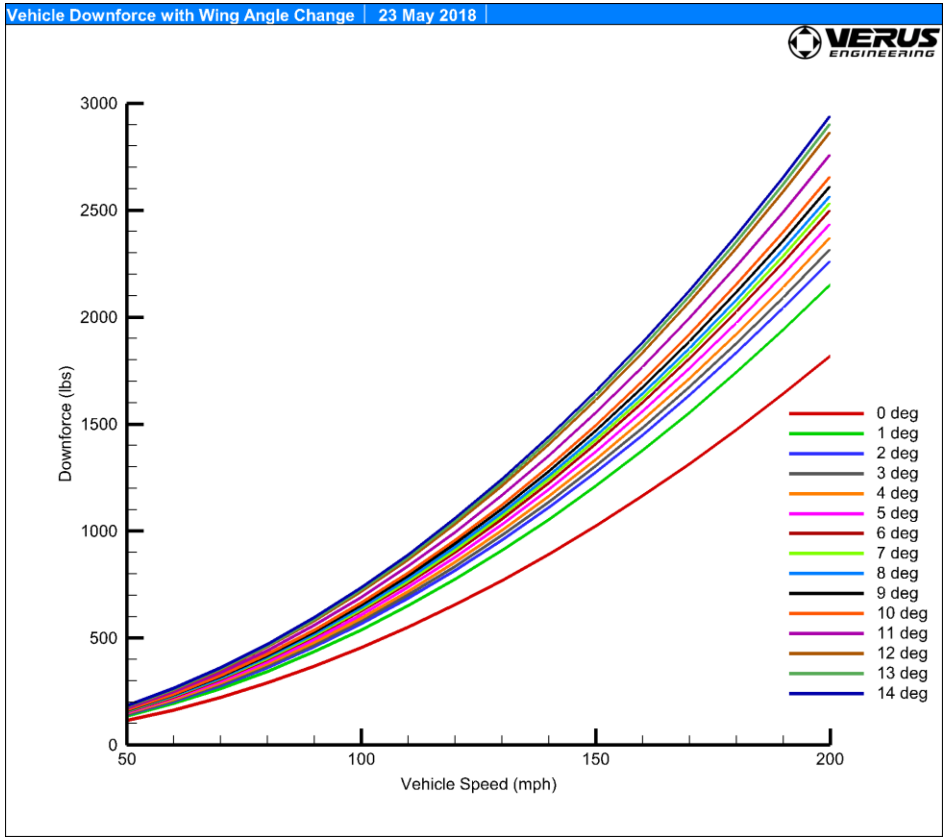
Note the much lower ride height in the front during this testing procedure

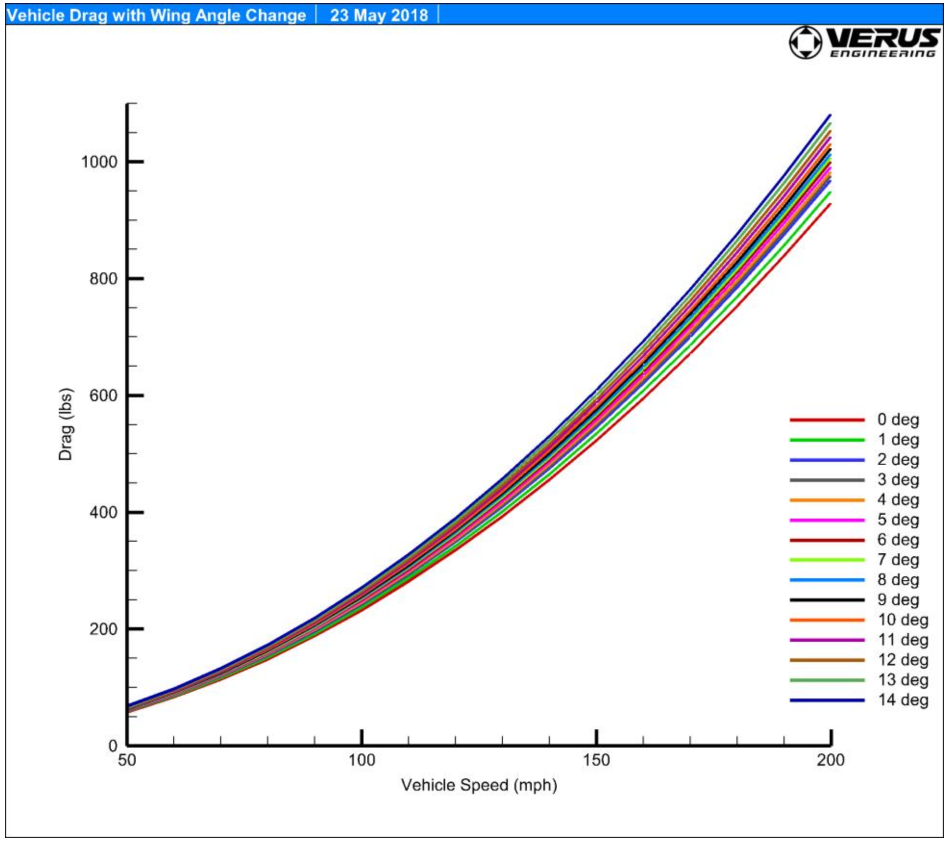
RRH = Rear ride height

The ride height map is fairly standard looking with nothing abnormal to throw any red flags at the design. This map will also help setup the car at the track.

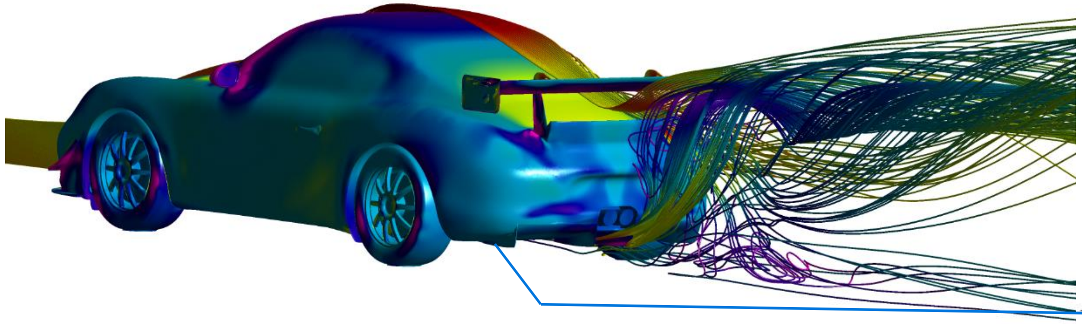
PERFORMANCE

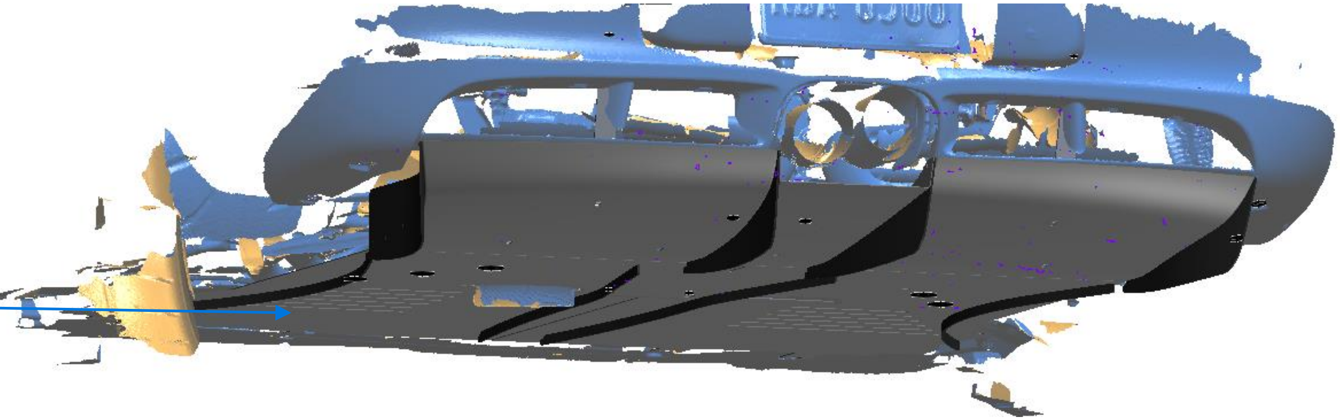
The downforce and drag of the total car is in the maps below. Each color plots a different wing angle, but at a fixed ride height of 90mm FRH and 205mm RRH measured from the front splitter to the ground in the front and from the rear diffuser to the ground in the rear. Also note the factory car made 140 lbs of lift, which meant we had to overcome that lift to just start to make downforce.

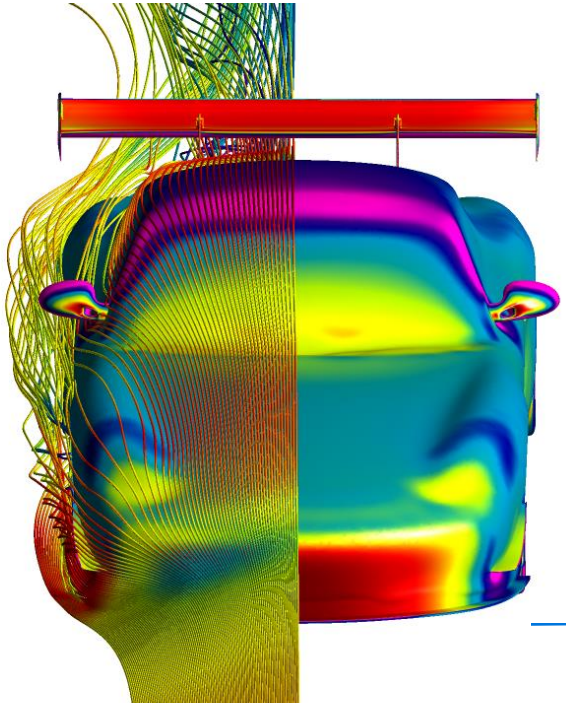


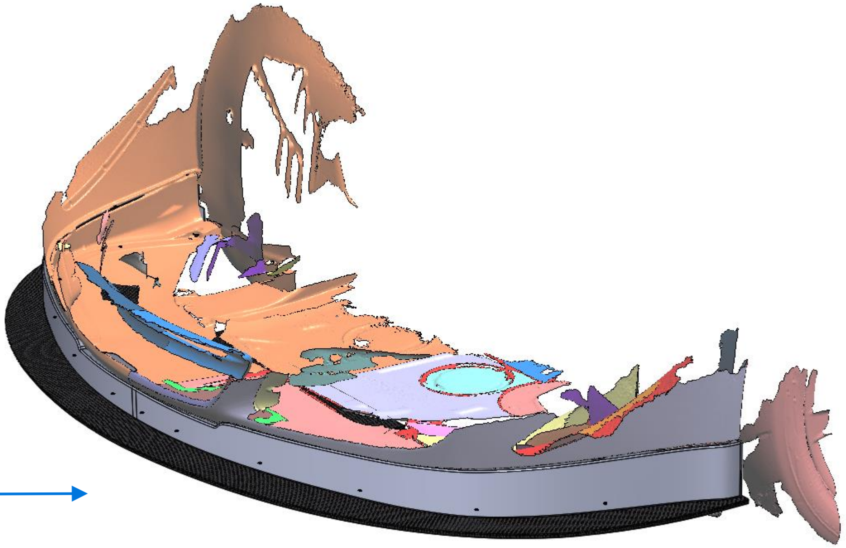


FROM CFD TO MANUFACTURING CAD

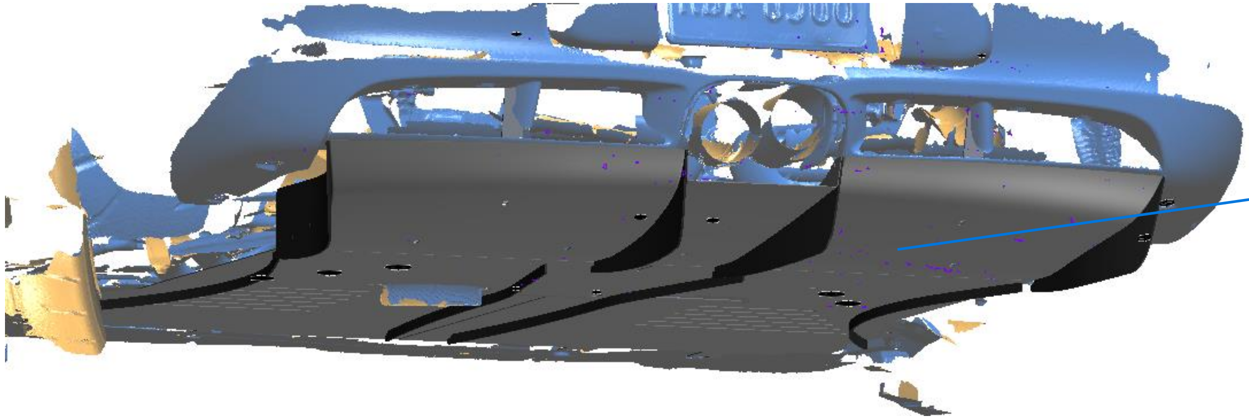


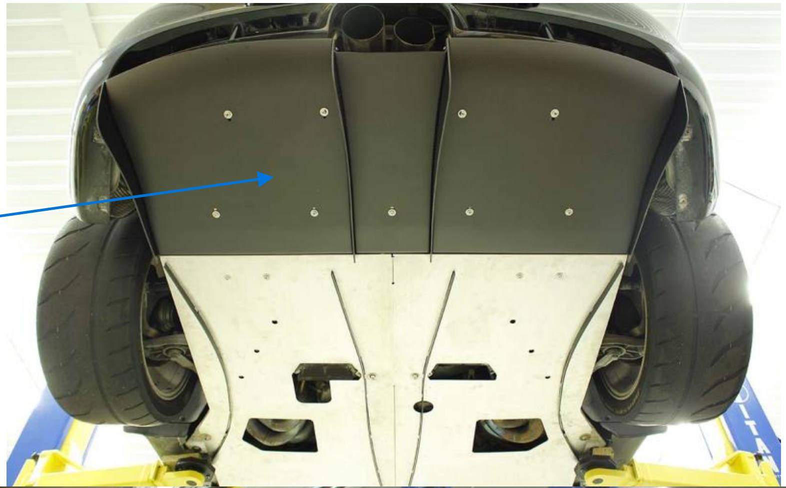






FROM MANUFACTURING CAD TO PROTOTYPES





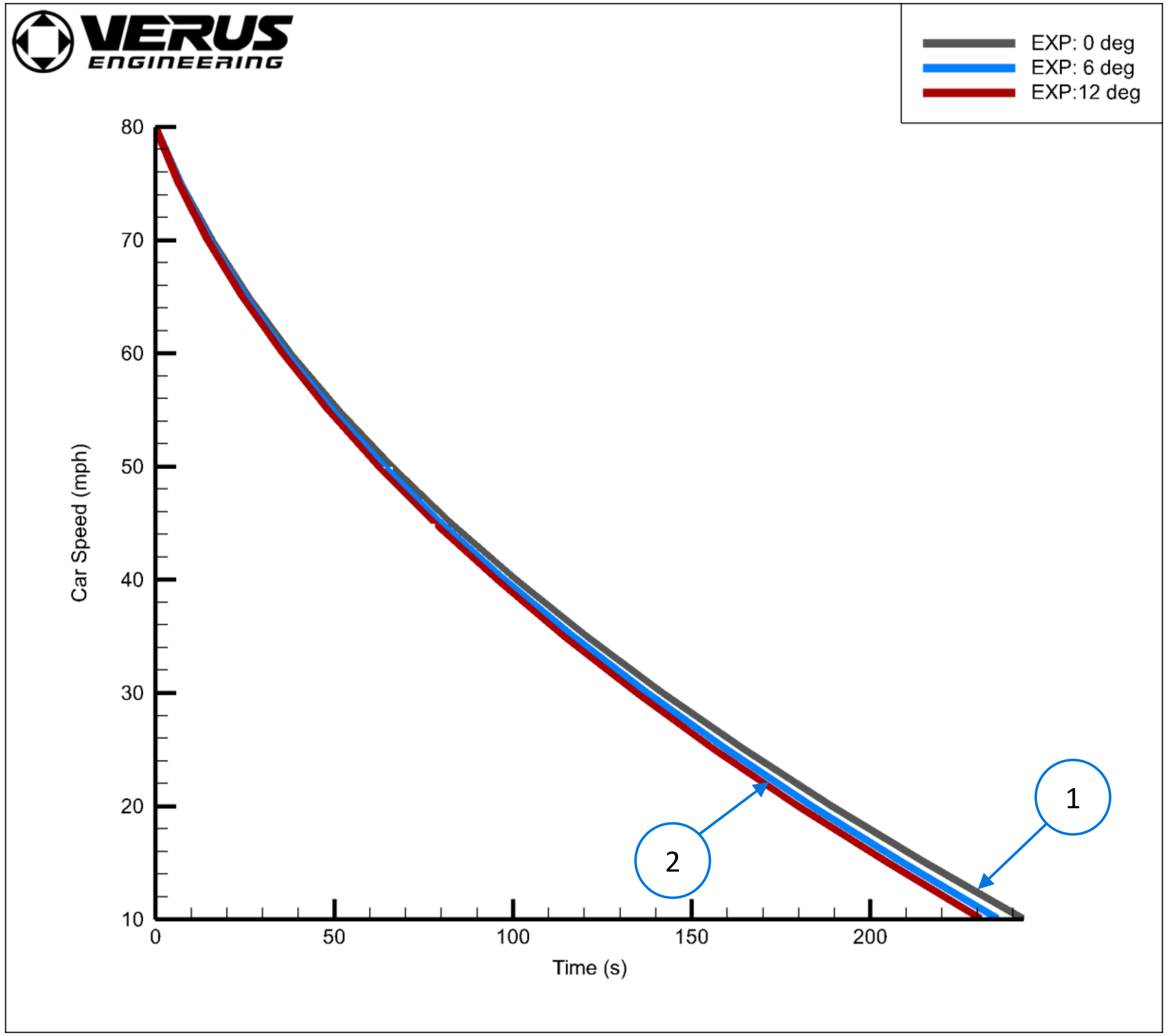
PROTOTYPE QUALITY

FRONT SPLITTER/AIR DAM AND DIVE PLANES:
The front splitter is made out of a special carbon fiber that does not shatter which makes it perfect to takes hits on the track and street. The air dam and dive planes are normal 2x2 twill weave carbon fiber to finish off the front end. The front splitter is easily strong enough for a person to stand on if so preferred.

REAR DIFFUSER:
The rear diffuser is 2x2 twill 3k carbon, pre-preg carbon (dry carbon) that is finished with a matte clear. The strakes are a hard durable plastic to handle abuse from road debris and curbs.

REAR WING ASSEMBLY:
The rear wing is carbon fiber with carbon rib down the center for strength while keeping weight to a minimum. The billet machined mounts are knife edged in the rear and are mounted to the carbon fiber duckbill. All the downforce is transmitted into the chassis via the trunk lid and factory wing chassis location.

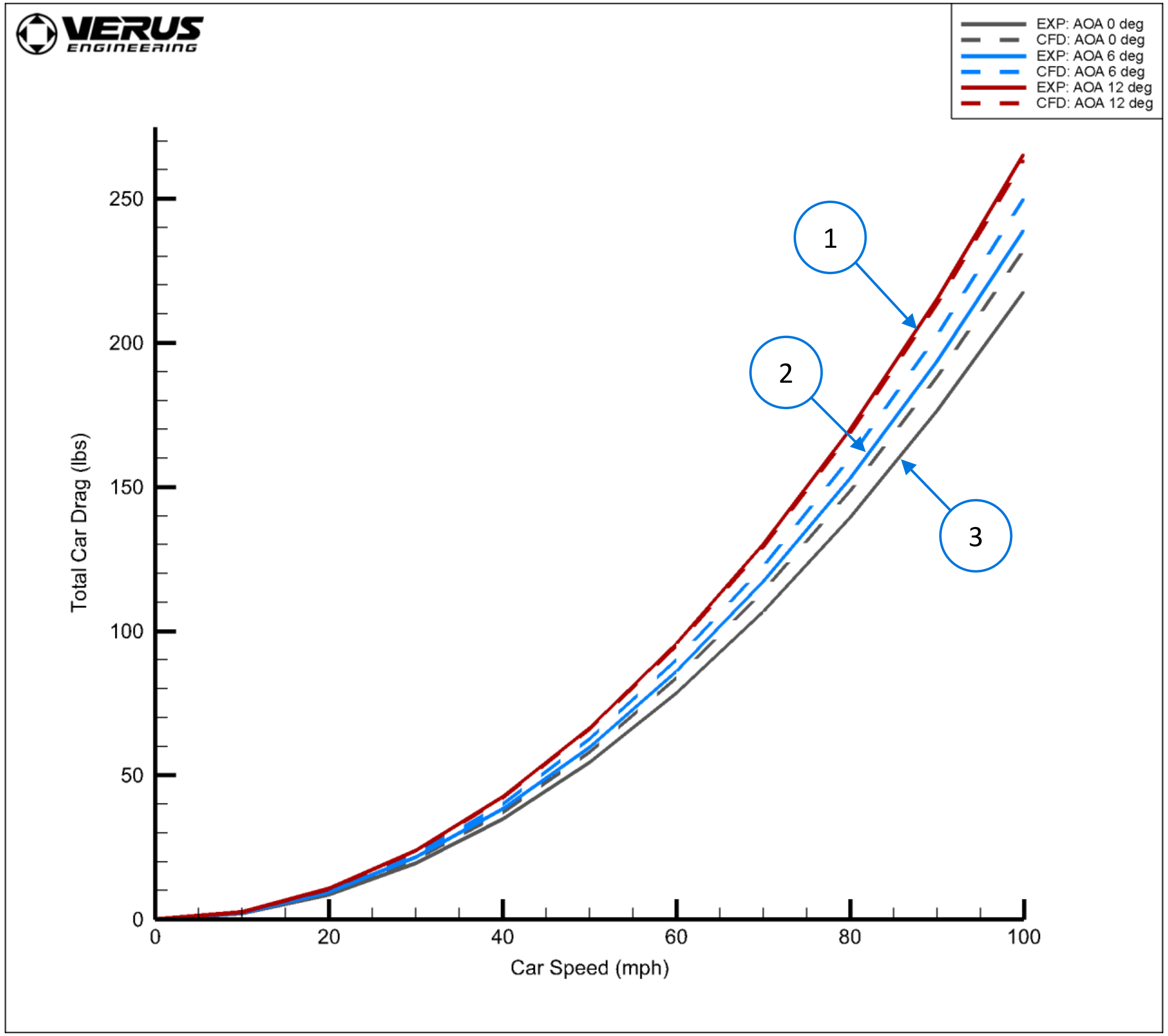
COAST DOWN TESTING



We followed the SAE standard of coast down testing as close as we could. We coasted down from 80mph to around 10mph with 3 different cases; wing at 0 deg, wing at 6 deg ,and wing at 12 deg. The data was recorded using an AIM data logger and 4 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 0 degree angle of attack took the longest to coast down. This logically makes sense because it has the least amount of drag slowing it down.
2. The 12 and 6 degree angle of attack slow down quicker but they are close together. This also makes logical sense because the drag from 12-6 degrees is less overall than the drag from 0-6 degrees.

COAST DOWN TESTING

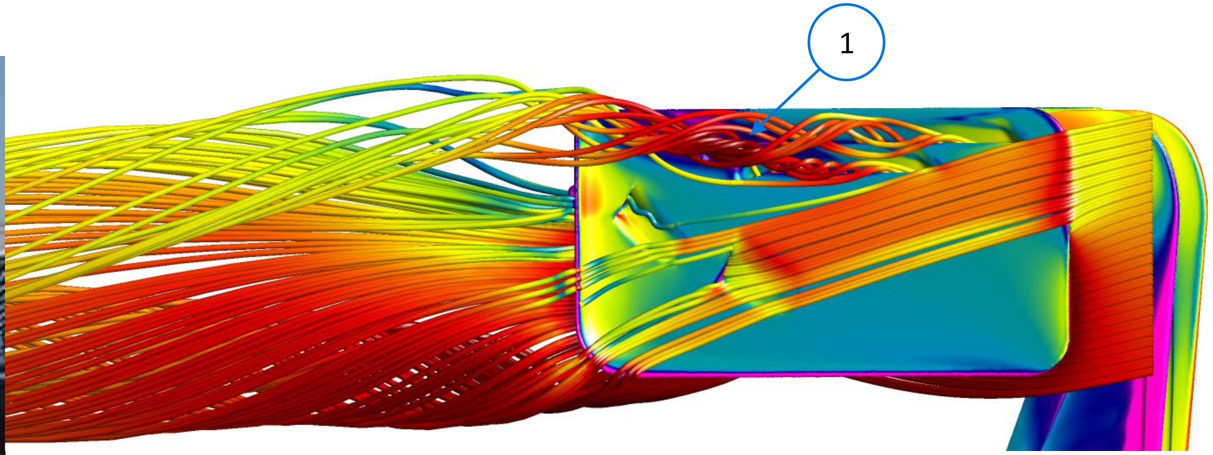


From the coast down testing data, calculation of the coefficient of drag (cd) was completed. From this, the ability to compare simulated CFD drag to coast down testing drag was possible.

1. The real world (experiment) and CFD on the 12 degree angle of attack correlated extremely well.
2. At 6 degrees angle of attack, the real world experiment showed less overall drag than we calculated in CFD.
3. At 0 degree angle of attack, the real world experiment also showed less overall drag than calculated in CFD. However, with both 6 and 0 have similar trends, this most likely was early separation on part of the CFD model.
4. Overall, the real world results correlate well to CFD estimated data. The drag numbers are still very close even though 6 and 0 degree angle of attack are not as close as 12 degree angle of attack. It could also be a change in wind during the coast down test that caused the slight skew.

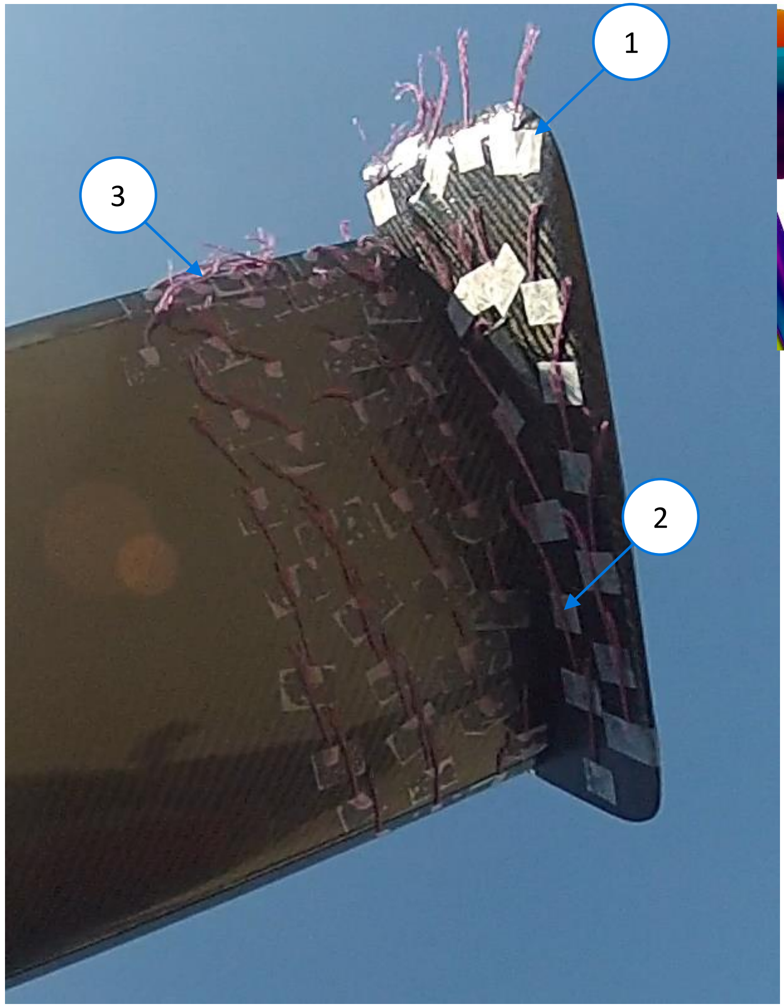
TUFT TESTING

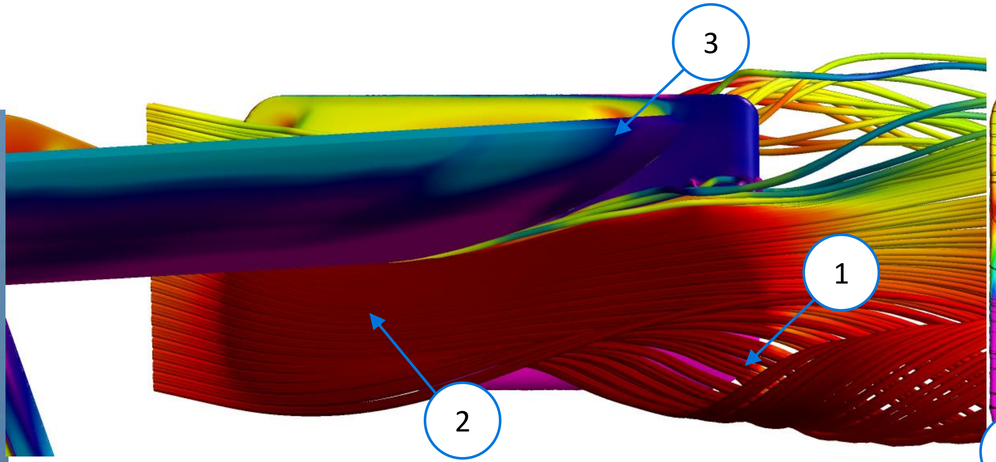
Tuft testing is when yarn is taped to the surface of parts to see how the airflow is behaving. This is used throughout motorsports in wind tunnels to visualize the flow field which could not otherwise be seen. We specifically used the tufts to compare CFD visuals to actual visuals.

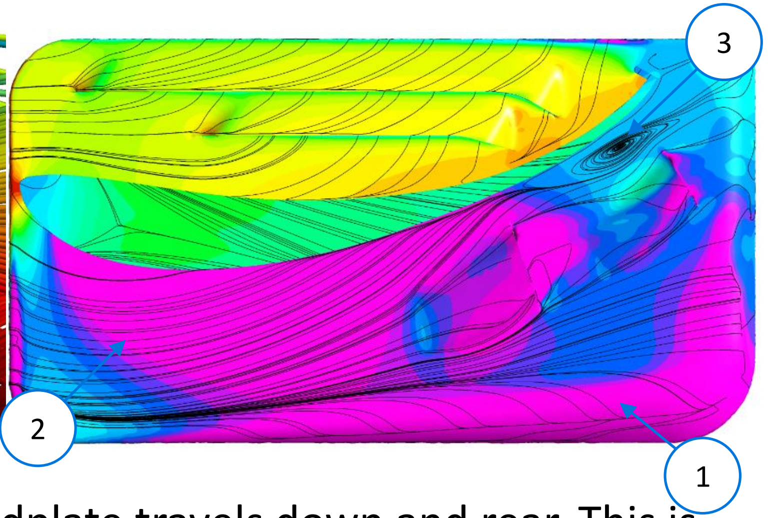


1. The tufts can be seen flowing from the high pressure side (top inside) to the outside. This is also seen in CFD and the vents were specifically designed to operate this way. The geometry is very critical for this to work right and is also dependent on the airfoil shape.

TUFT TESTING



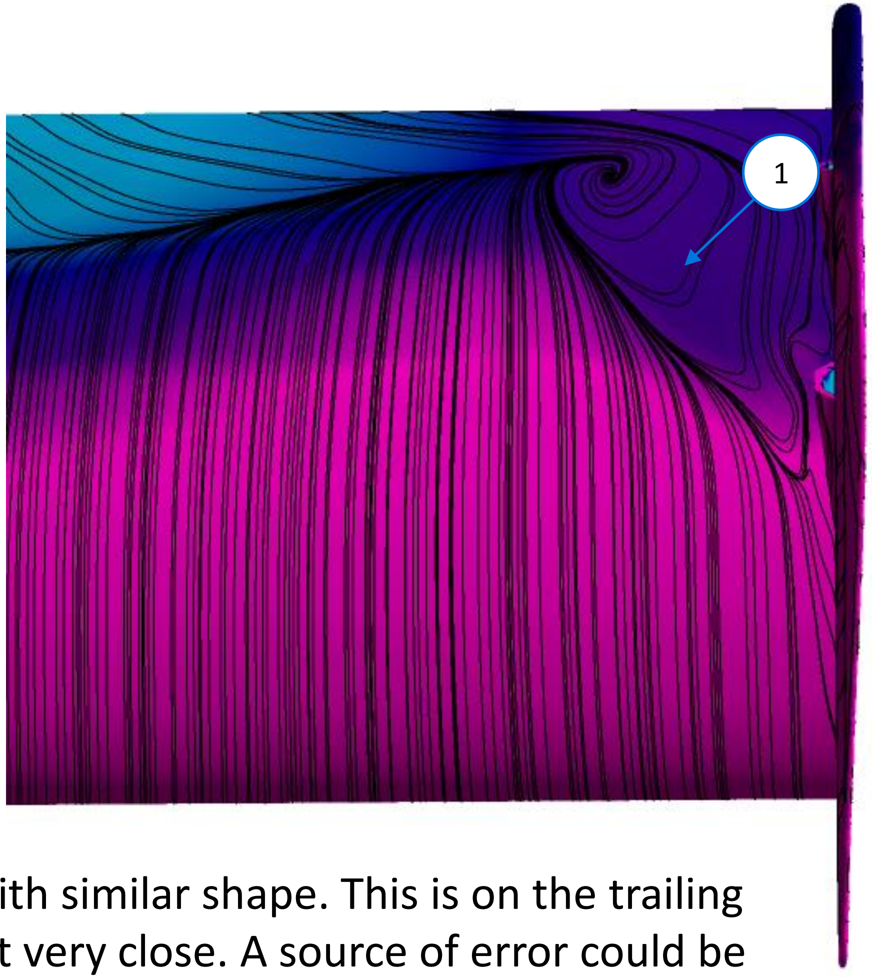




1. The airflow around the rear bottom of the endplate travels down and rear. This is because the air is trying to go under the end plate to the other side which creates a vortex. This design decreases the strength of this vortex.
2. The air flow towards the front/middle bottom of the endplate travels up with the shape of the wing.
3. The airflow is actually separating a little in this section. This was as expected and airflow is designed to be separated in this area towards the wing's maximum angle of attack. It is better to separate at the trailing edge (soft stall) than the leading edge (hard stall). A soft stall will not have a large loss in downforce when separation occurs unlike leading edge stall. A trailing edge stall will also continue making more downforce for a few more angle of attack from this location before decreasing.

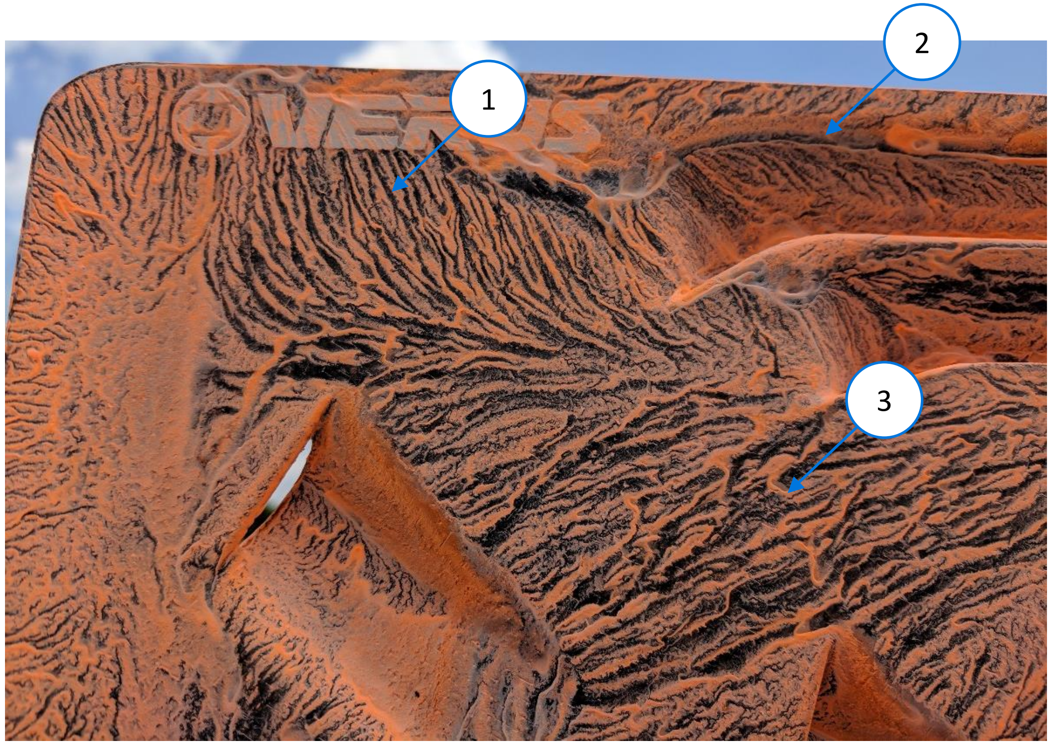
FLOW VIZ TESTING

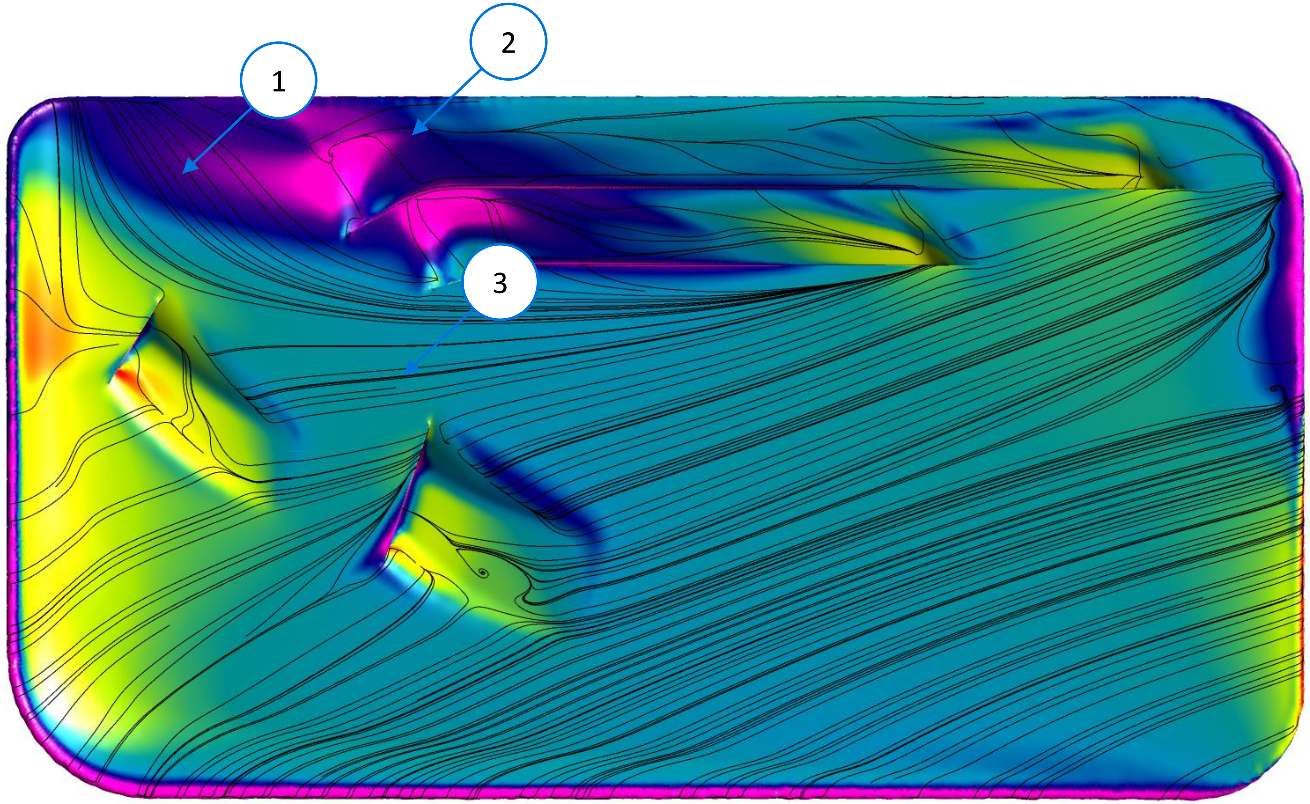
Flow Viz is a type of testing where a special paint is applied to the surface of different parts of the vehicle to compare surface streamlines from CFD to wind tunnel or track testing.



1. Separation can be seen in the flow viz and CFD in the same location with similar shape. This is on the trailing edge of the wing and close to the endplate. The shape is a little off but very close. A source of error could be cross winds during testing.

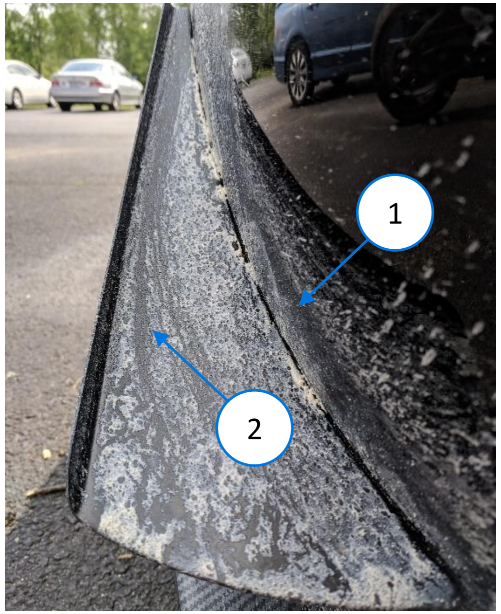
FLOW VIZ TESTING

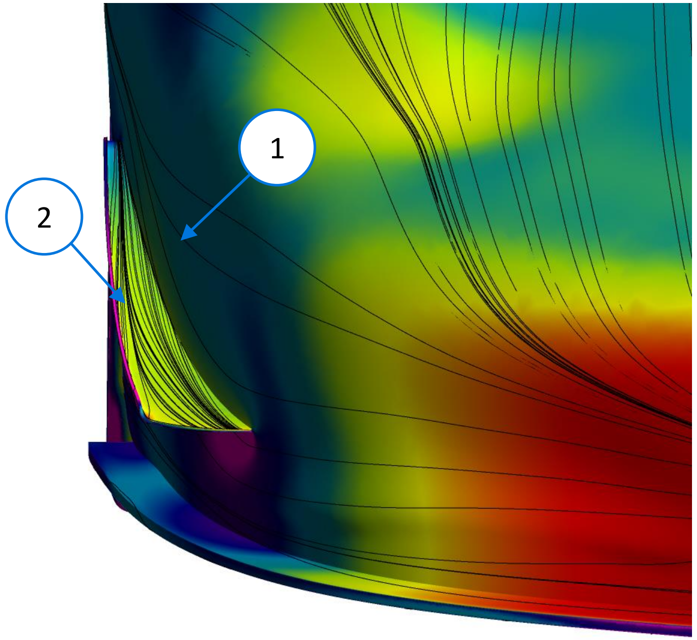




1. The flow viz and CFD flow line up very close on the endplates. The flow can be seen on both curving up and rearward on the endplate.
2. The flow viz shows substantial flow out of the slots at the top. The flow can be seen flowing upwards and then rearward at the top edge where the arrow is located and this exact same phenomenon can be seen on the CFD image.
3. The flow in both the flow viz and CFD show the flow field going rearward and down. The endplates show impressive correlation between the CFD and flow viz.

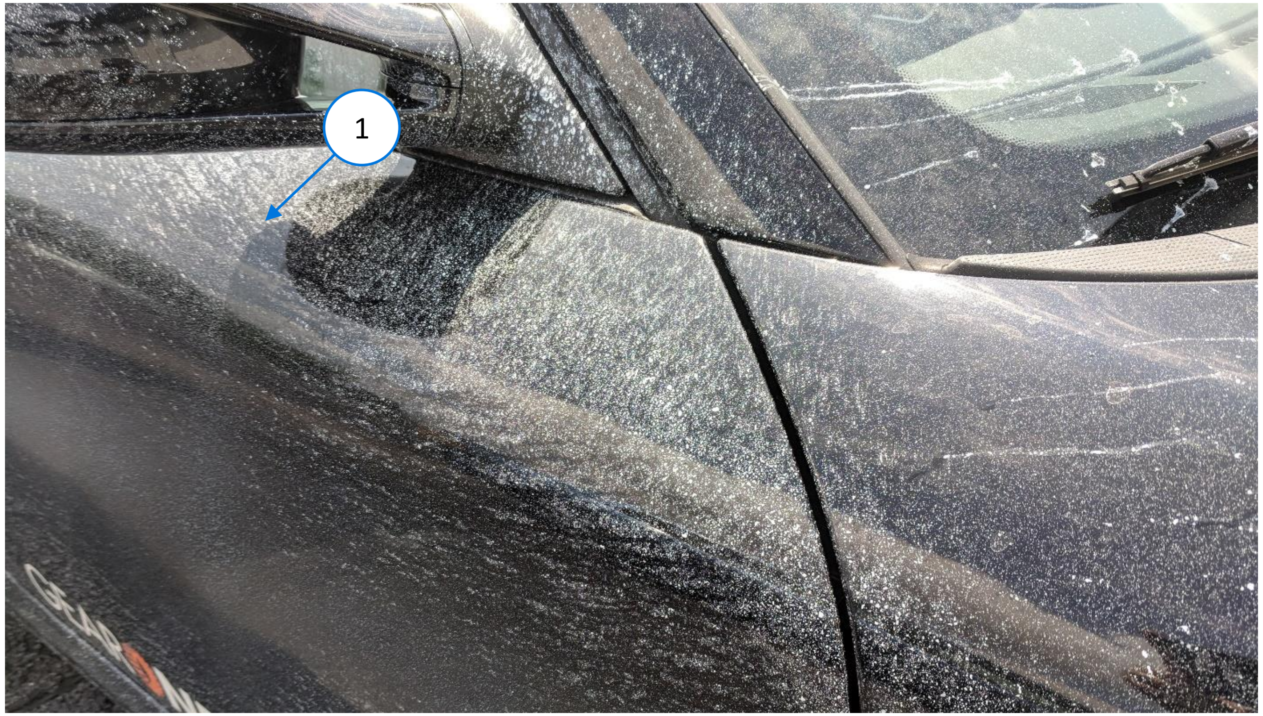
FLOW VIZ TESTING

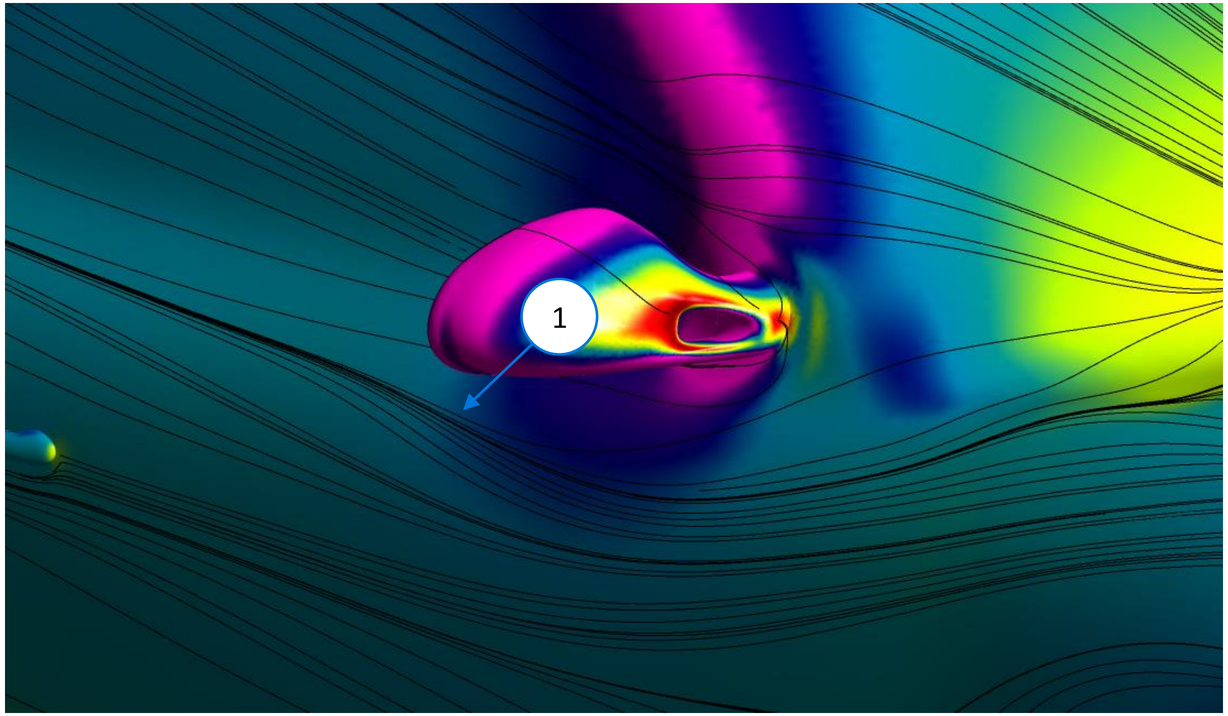




1. The flow field on the bumper can be seen traveling up along the dive plane and rearward. This is also evident in the CFD image and can be seen very easily. This is from the interaction of the high velocity field around the bumper and its interaction with the dive plane.
2. The flow on the actual dive plane is identical to the flow on the CFD image. The curve in the flow field on the top side is evident in both images in the same location and the streamline move towards the body on the rear most of the dive plane.

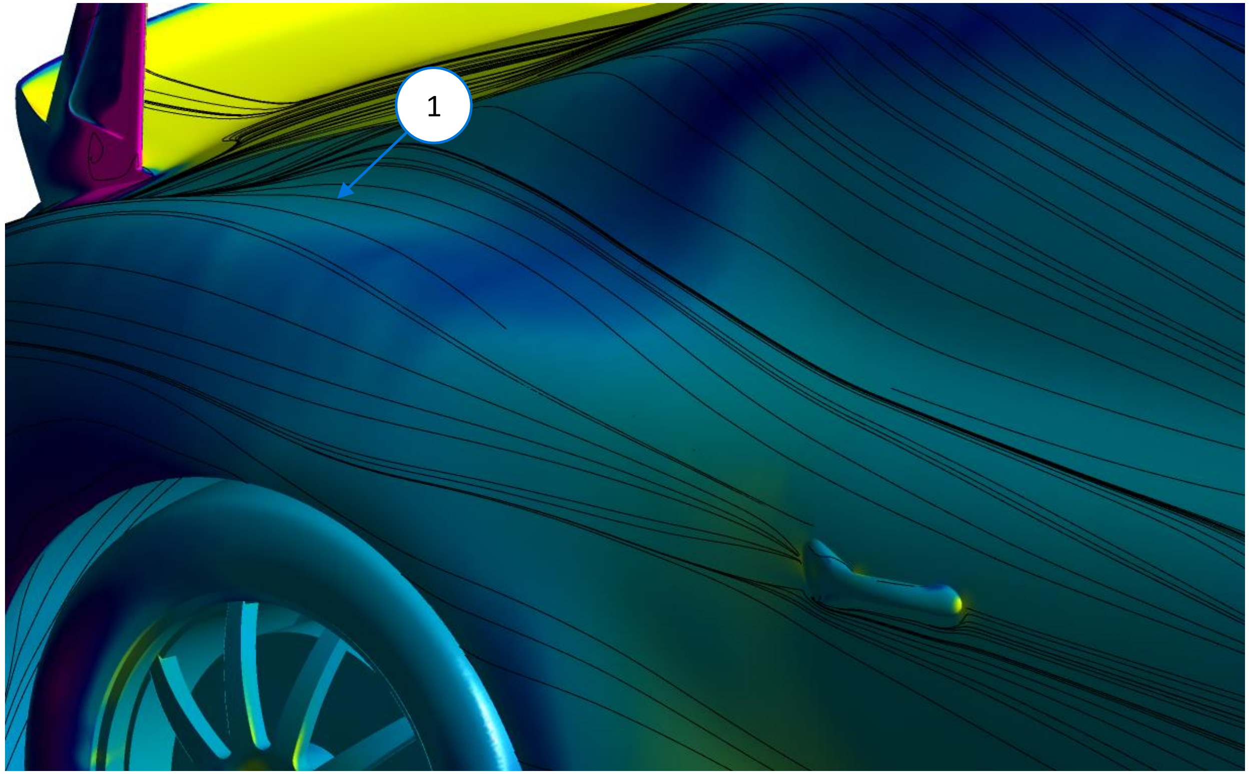
FLOW VIZ TESTING





1. The flow structure around the mirror is the same in CFD and flow viz. The streamlines can be seen coming from the top of the fender/hood, down the door, under the side mirror, and then curving up before straightening out . This flow field is caused by the shape of the car and the mirror. The low pressure on the bottom side of the mirror causes the flow field to curve back up while the high pressure on the front side causes the air to flow down in the front of the mirror.

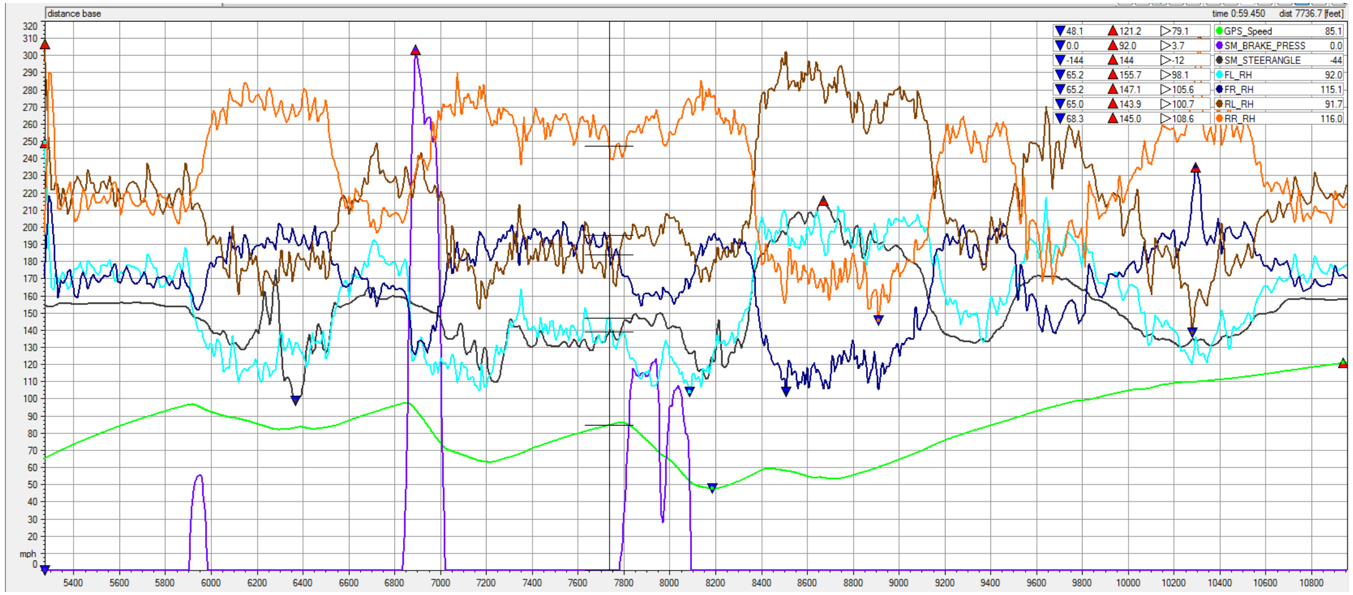
FLOW VIZ TESTING



1. The flow structure towards the rear of the car can be seen in both images. The streamlines flow up the rear quarter panel and towards the center of the car. This can be seen in both the flow viz and CFD. The flow field is a litter stronger on the flow viz and this indicates the door handle has less interaction to the flow than in CFD. This is very minor but can be noted by careful examination on the flow viz.

TRACK TESTING

The aerodynamic kit was then fully tested on the track during the summer of 2018. The car was fashioned with data acquisition system to collect data which included 3 laser ride height sensors.



Ride heights correlated with downforce numbers when corrected for weight transfer and roll. We are still working on optimizing suspension setup to go with the added downforce.