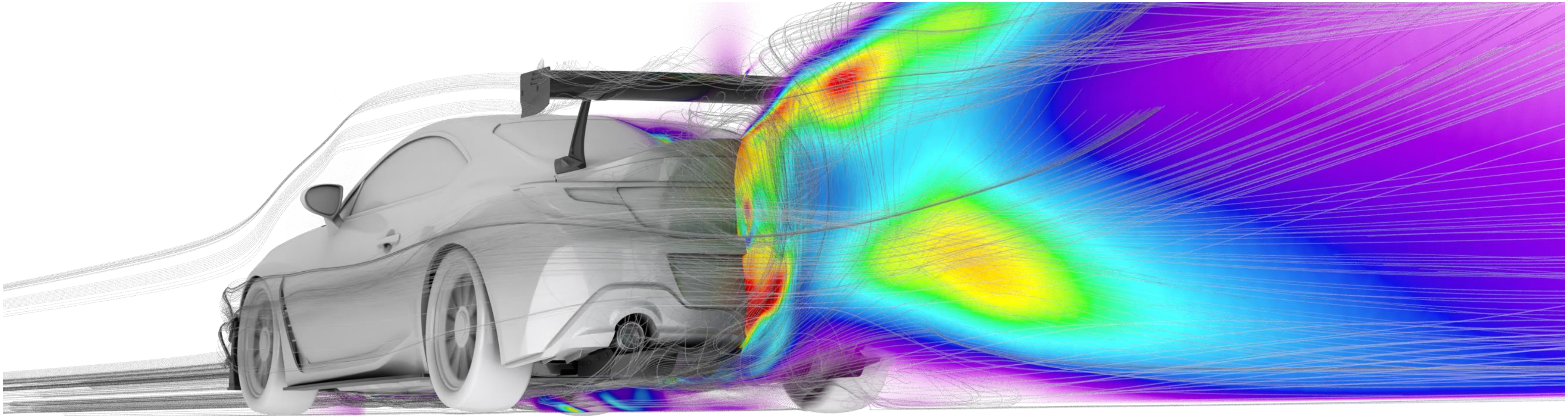


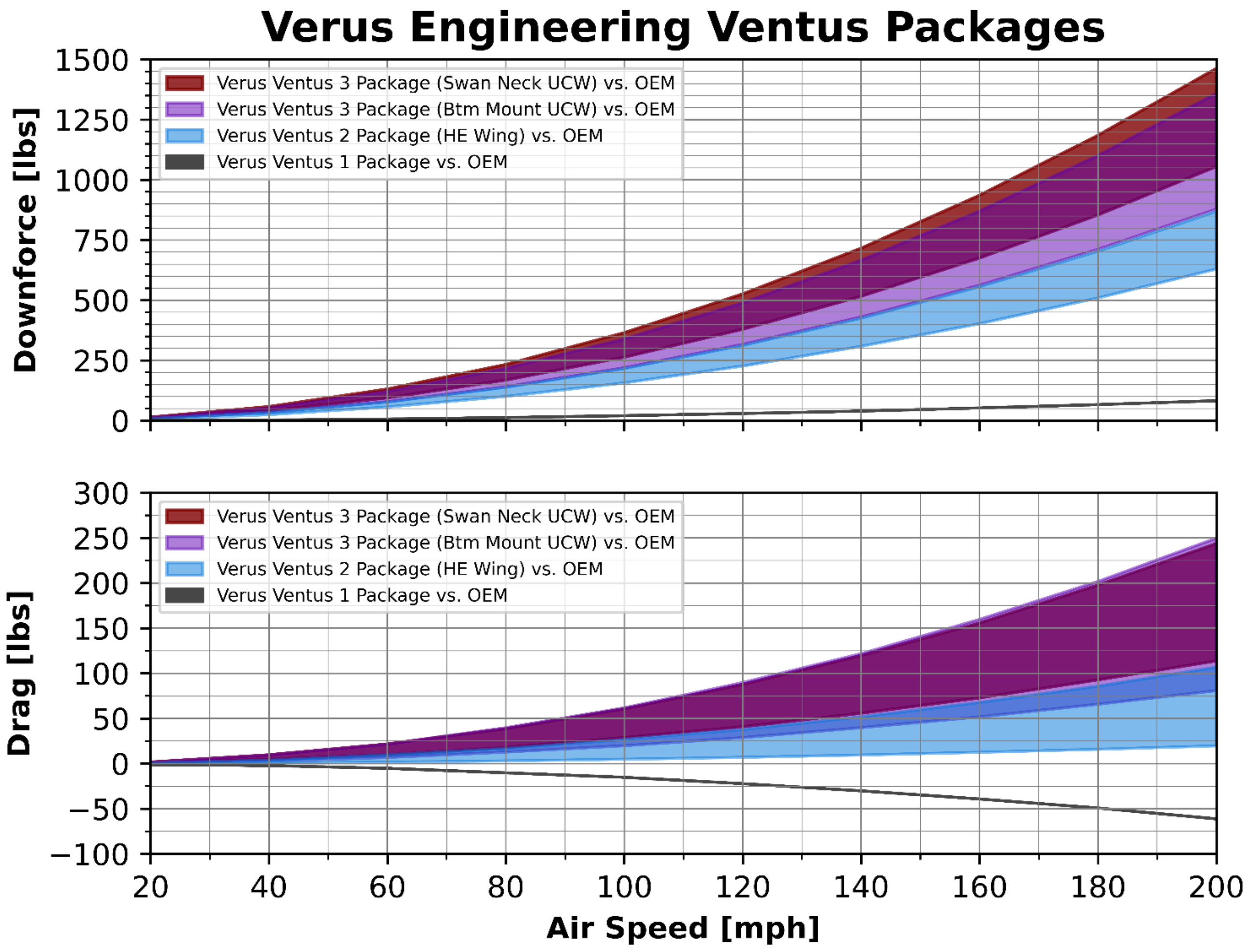
ZN8 GR86 / ZD8 BRZ

PERFORMANCE OF VERUS ENGINEERING VENTUS 1 - 3 PACKAGES

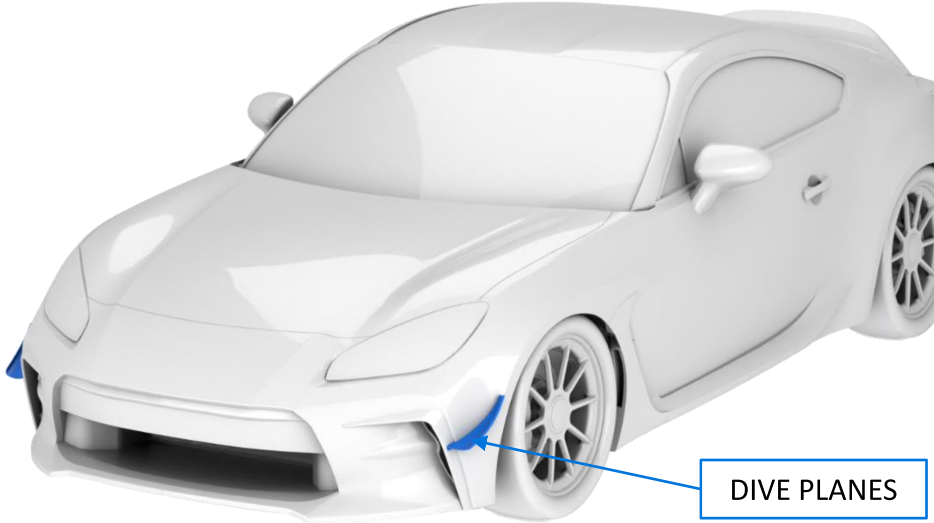
OVERVIEW

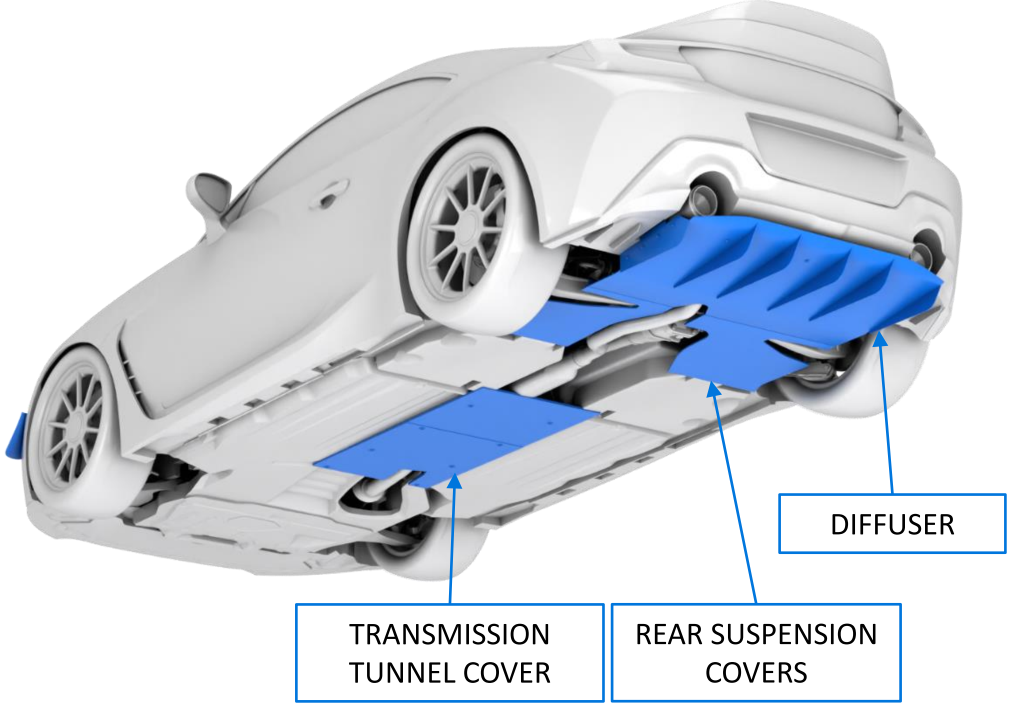
SUMMARY : AERODYNAMIC FORCES

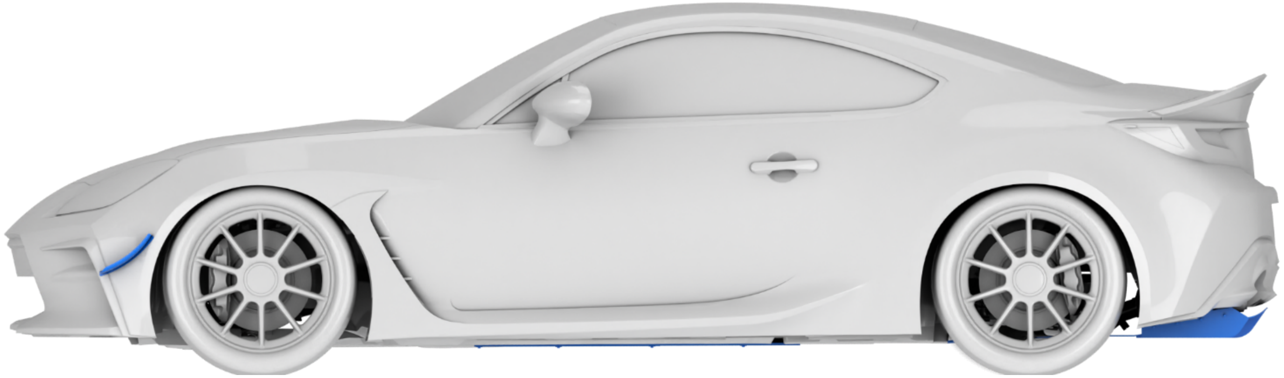
- Aerodynamic forces change with the square of the vehicle speed, which is why we use a graph.
- The Ventus packages significantly increase downforce over stock with a comparatively minimal impact to drag and are a great choice for track enthusiasts and competitive racers alike.
- Packages are analyzed at slightly lower than OEM ride heights that are in line with most aftermarket springs or coilovers.
- The Ventus 1 package uses the Verus Engineering Dive Planes, Transmission Tunnel Cover, Aluminum Rear Diffuser and Rear Suspension Covers. The Ventus 1 package reduces drag compared to OEM.
- The Ventus 2 packages add the, Front Splitter, Rear Spats, and the High Efficiency Rear Wing.
- The Ventus 3 package adds the Front Splitter End Plates, Side Splitters, Hood Louver and your choice of UCW rear wing (Bottom Mount or Swan Neck).
- Angle of Attack (AoA) adjustment allows the driver to fine tune aerodynamic balance to his or her preference.
- The thick diverging lines for Ventus 2, & 3 show downforce/drag variations depending on setup.
  - Ventus 2 is shown from 0° AoA to 12° AoA with the HE Wing
  - Ventus 3 is shown from -1° AoA to 12° AoA with both UCW's



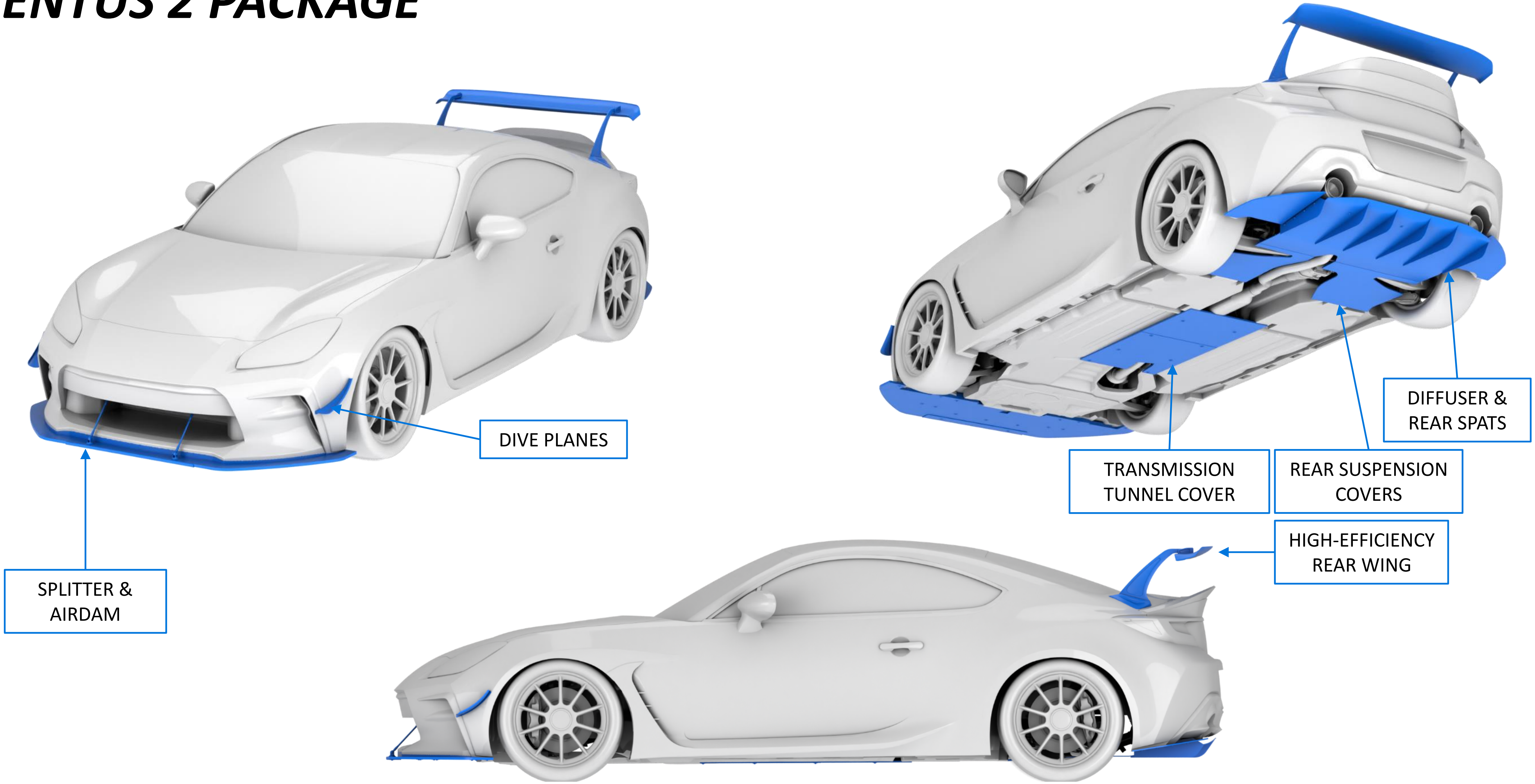
VENTUS 1 PACKAGE



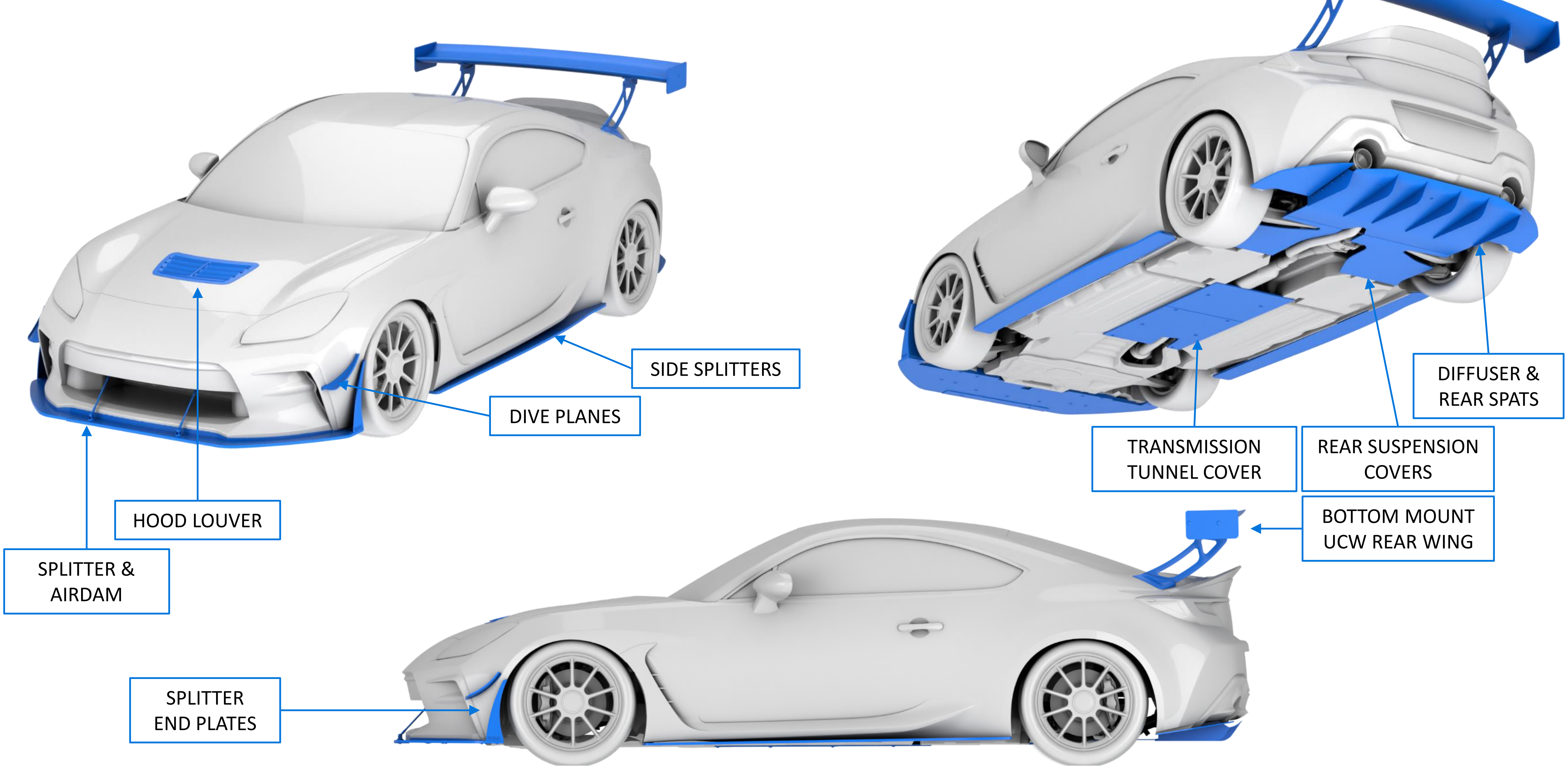




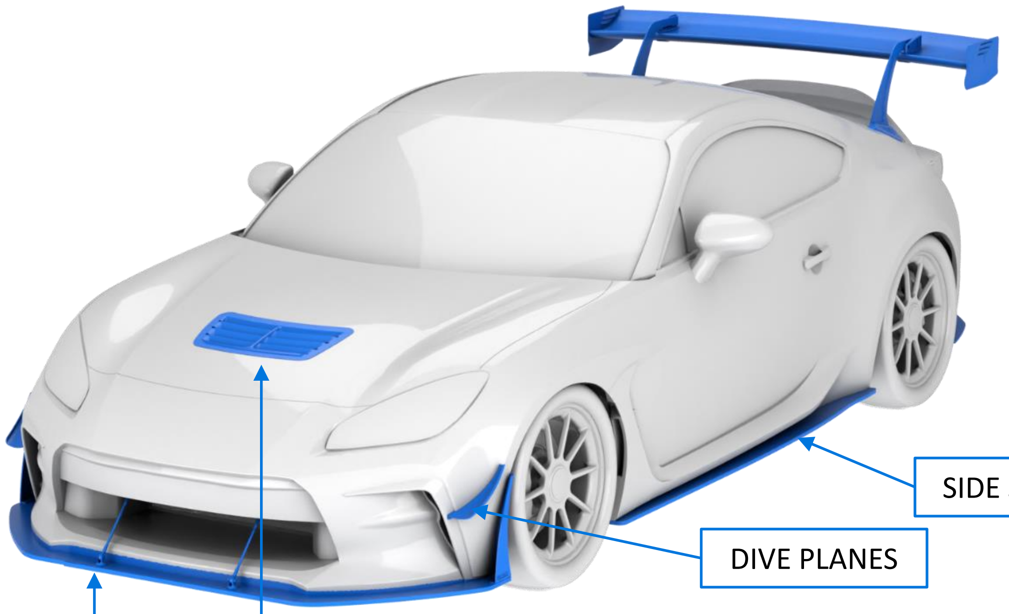
VENTUS 2 PACKAGE

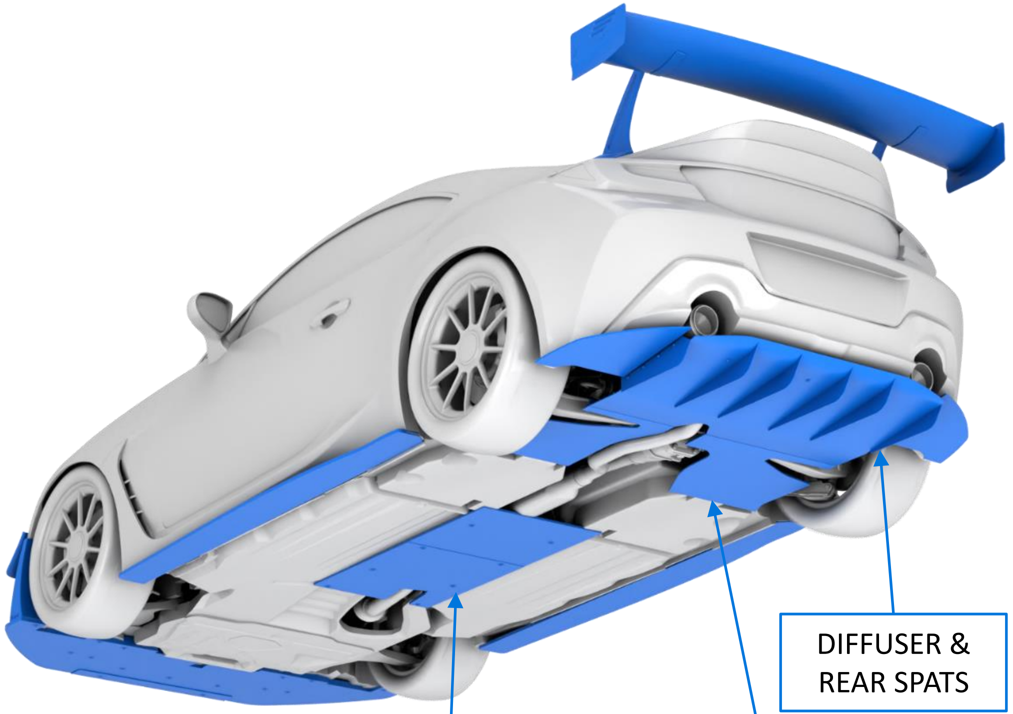


VENTUS 3 PACKAGE (BTM. MOUNT)



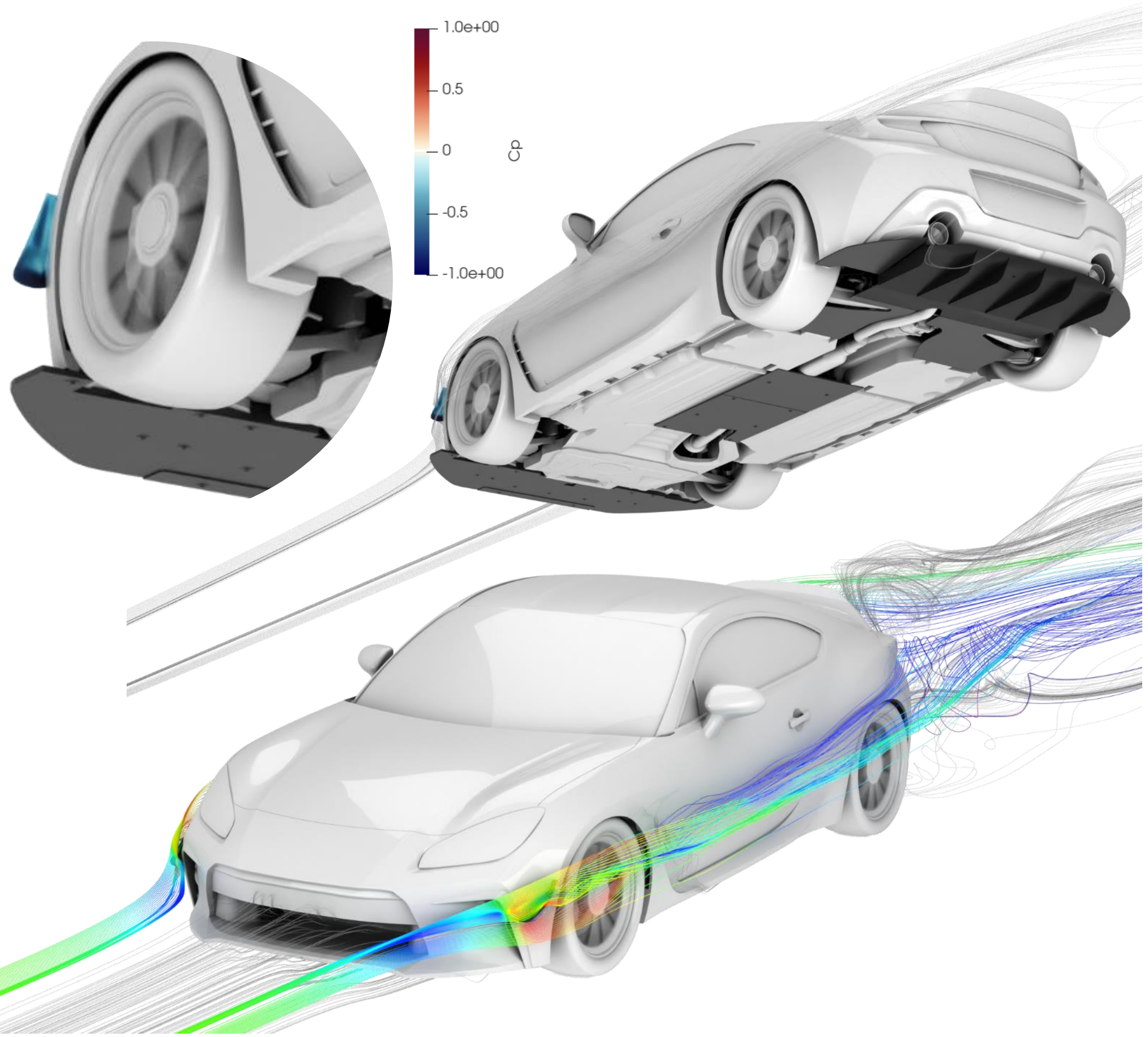
VENTUS 3 PACKAGE (SWAN NECK)





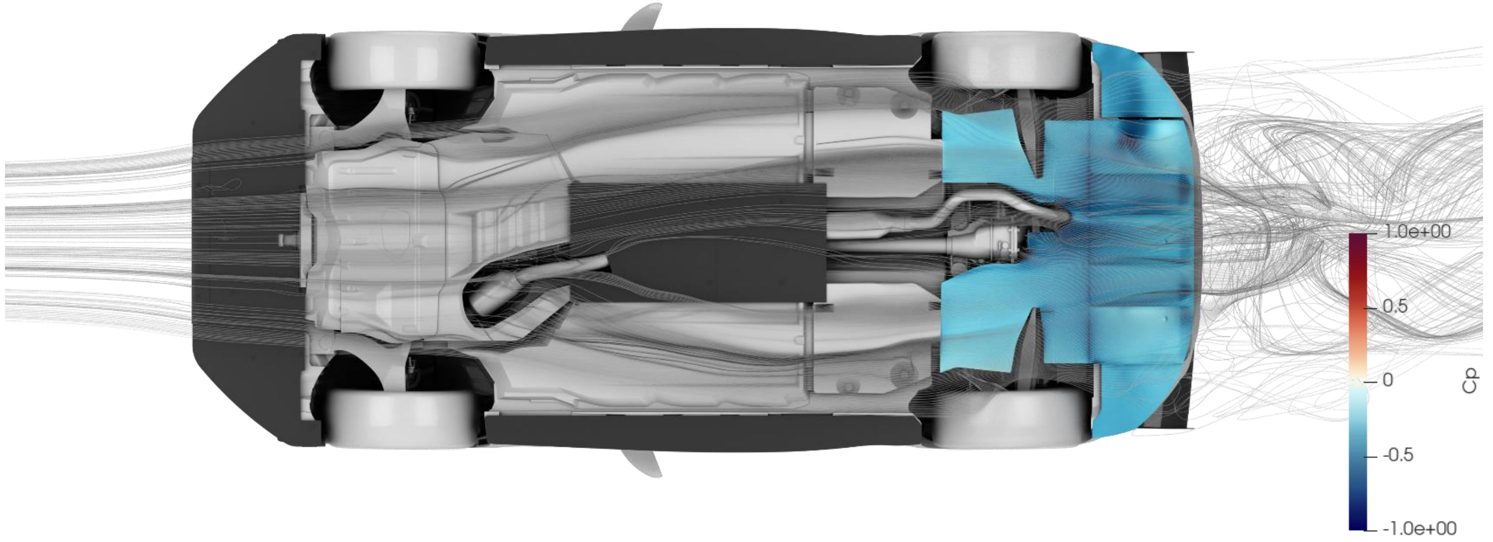
DIVE PLANES / CANARDS

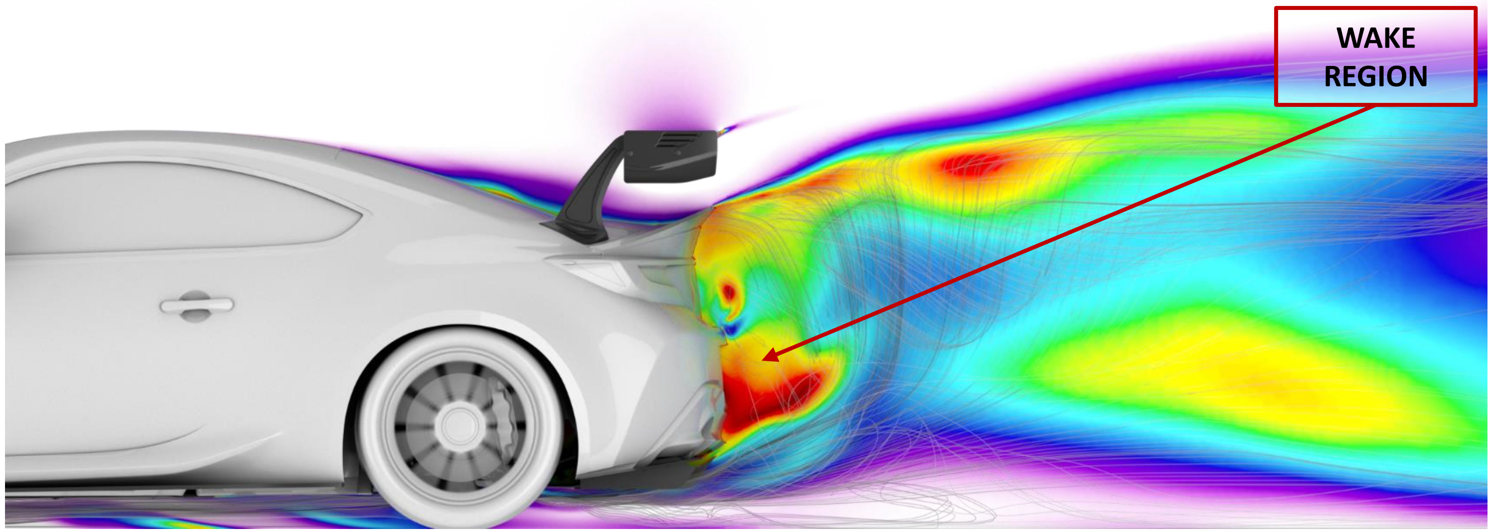
- Dive planes are great for customers looking for a slight bump in front downforce and no reduction in ground clearance.
- Verus Engineering develops dive planes to produce downforce by controlling the flow around the vehicle, not on the units themselves, improving efficiency.
- A small amount of downforce is produced on the units themselves, high pressure on top, low pressure on bottom.
- We develop the dive planes to create a beneficial vortex which helps evacuate the fenders.
- This evacuation reduces lift on the body, improving performance.
- The dive planes are produced from 2x2 twill carbon fiber finished in an automotive clear coat. Templates are supplied to ensure location of the units are correct.



REAR DIFFUSER & SUSPENSION COVERS

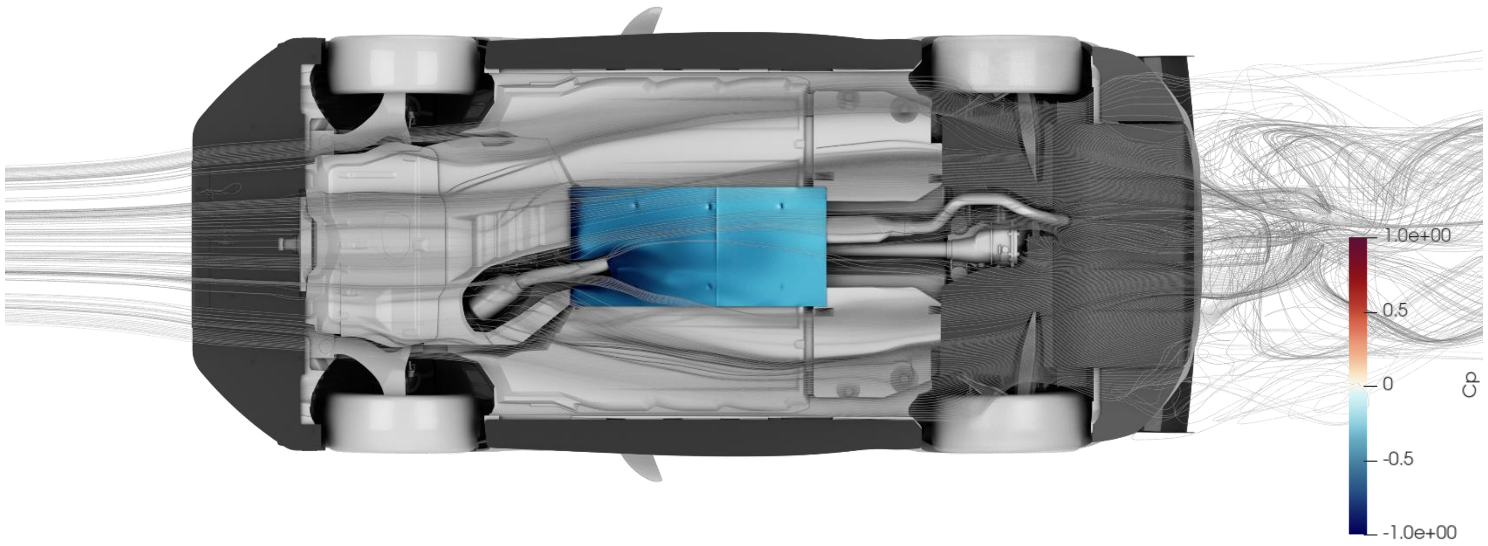
- The rear diffuser is a key component in creating efficient downforce.
- A diffuser is perfect for a street car as it will add stability (downforce) *and* reduce overall drag, when designed properly.
- The diffuser functions by creating low pressure on the bottom surface and reduces drag by filling in the wake region behind the vehicle.
- A large portion of drag on road vehicles is pressure drag, which is the low pressure region behind the car.
- This low pressure region (aka wake region) creates a force that pulls rearward on the car.
- Using CFD and good design practices, we developed a solution that creates downforce and reduces drag.
- This rear diffuser is constructed from sheet aluminum. It attaches to various chassis and bumper locations to ensure for a secure, durable, and low cost unit.





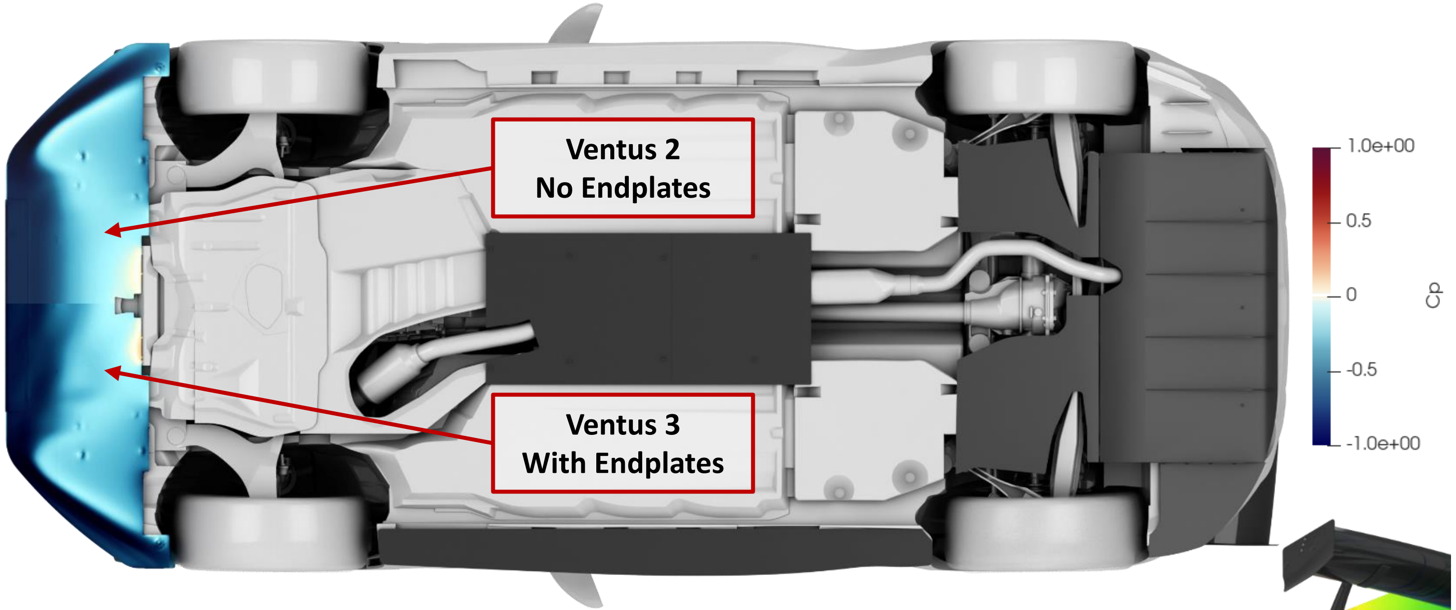
TRANSMISSION COVER

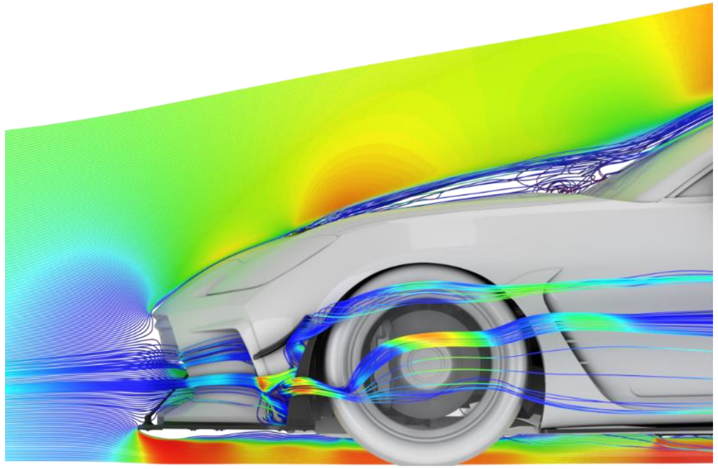
- The transmission covers reduce drag on the factory underbody.
- The two panels decrease dirty airflow under the car and cover up an otherwise large opening.
- In CFD (computational fluid dynamics), we estimate a coefficient of drag (Cd) reduction of 8 points. This is a good reduction in drag.
- The panels increase downforce by utilizing air coming from the engine bay and feeding the airflow out and over the panels.
- The panels clean up airflow from the engine bay as the airflow makes its way to the rear diffuser.
- The transmission tunnel covers are produced from sheet aluminum and bolt to OE locations through customer installed rivet nuts and OE bolt locations.

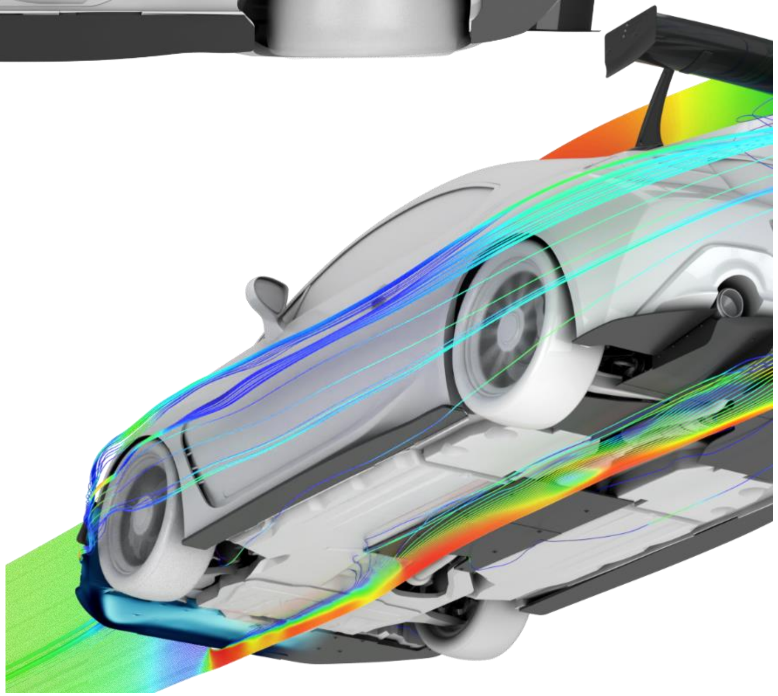


SPLITTER

- The front splitter is ideal for increasing front-end downforce.
- The full splitter assembly is simulated which includes the splitter, air dam, and support rods.
- Splitters are a very efficient aerodynamic device, contributing 36% - 47% of the total vehicle downforce but only ~5% of total drag (depending on wing AOA on a Ventus 2 Package).
- High pressure on the top side helps drive the splitter downward at speed.
- The bottom side, like the rear wing, produces more downforce than the top side.
- The splitter is produced from a hard plastic, which is light, rigid, and cost effective.
- Optional Endplates improve performance of the pressure and suction sides of the splitter. They will shift the aero balance forward, allowing more wing angle to be used to achieve the same balance.

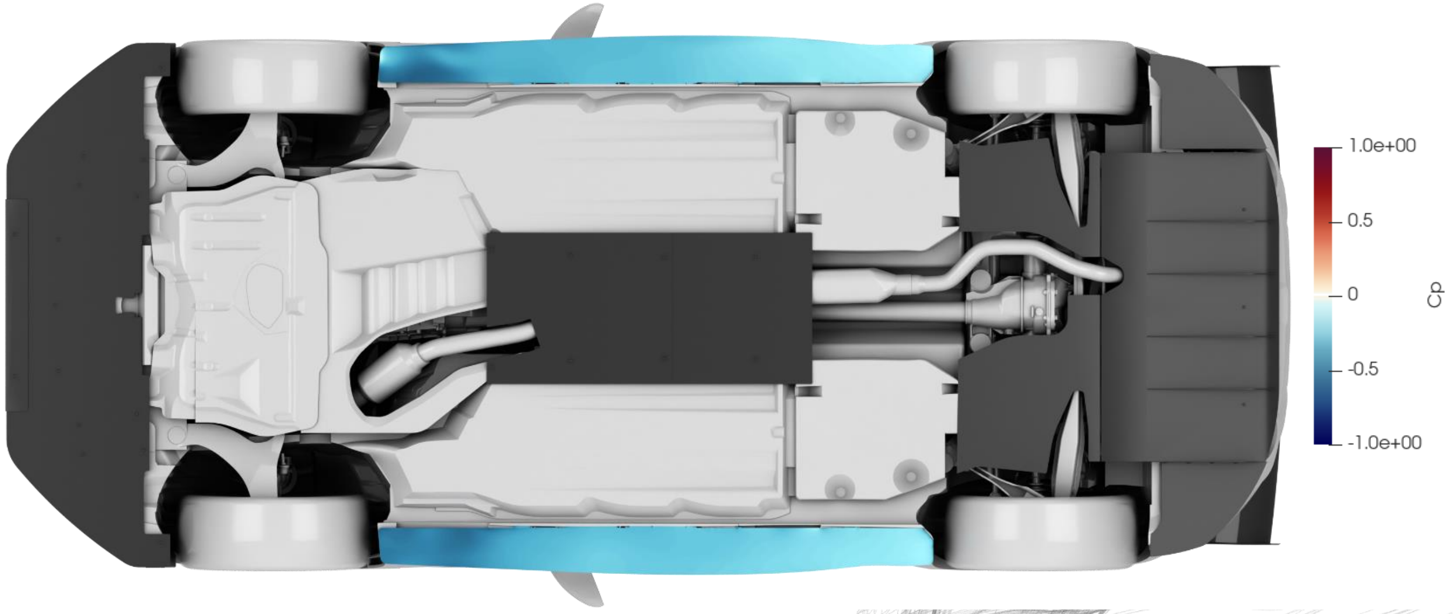


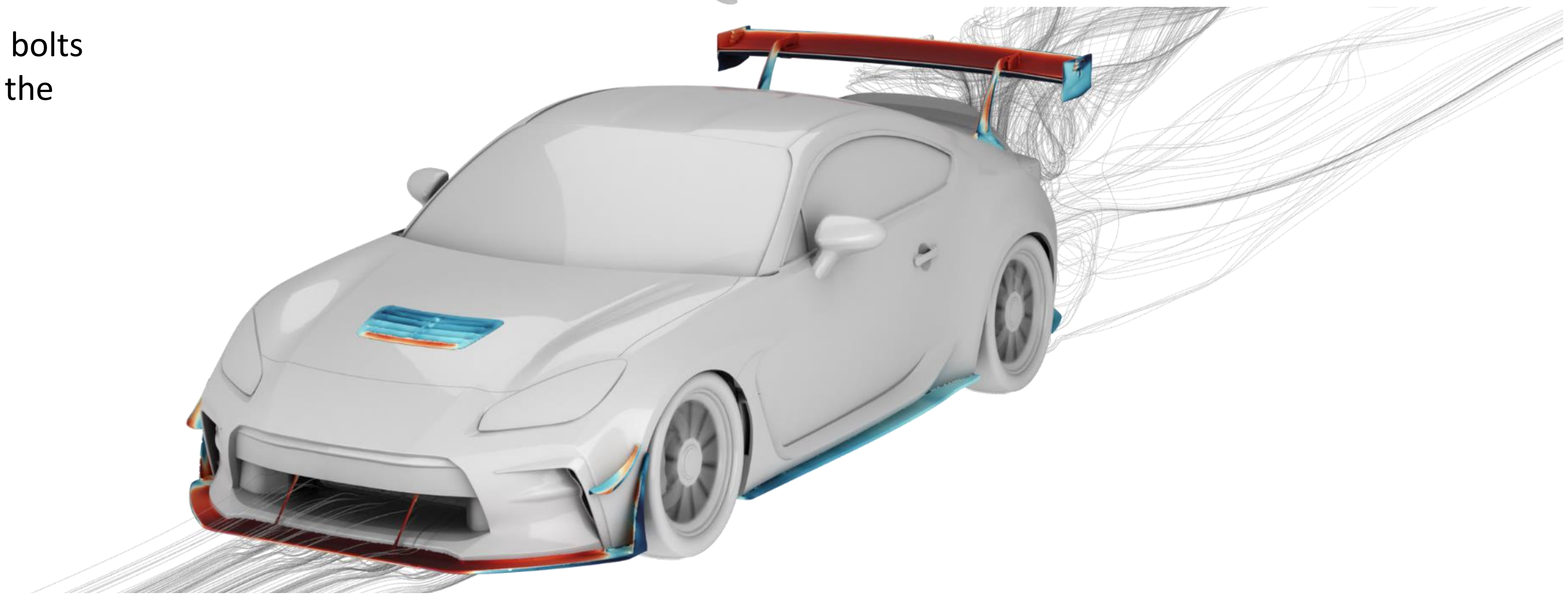




SIDE SPLITTERS

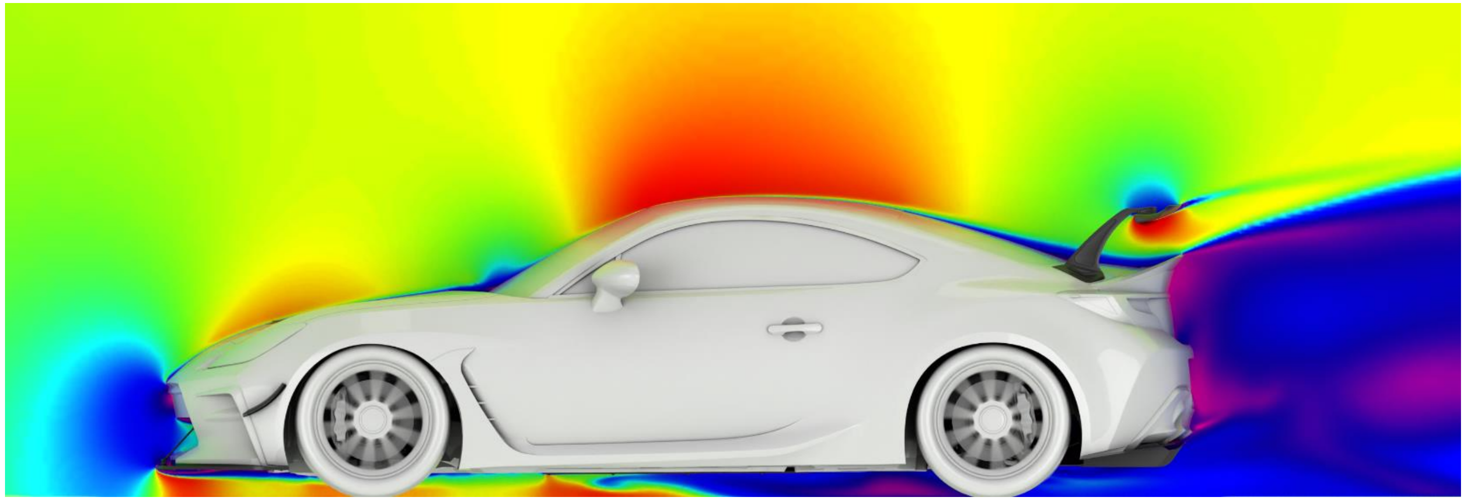
- Side splitters reduce the amount of high pressure air from the top side of the vehicle making it under the vehicle.
- We focused on designing the units to clean up underbody airflow during turning or high yaw conditions.
- In CFD (computational fluid dynamics), we simulated typical ride heights and steering angles from past testing at Putnam Park.
- The increase in downforce is centrally located on the vehicle and the aero balance is minimally affected.
- The side splitters are produced from rigid plastic and bolts to the vehicle through rivet nuts that are installed in the factory plastic side skirt area.





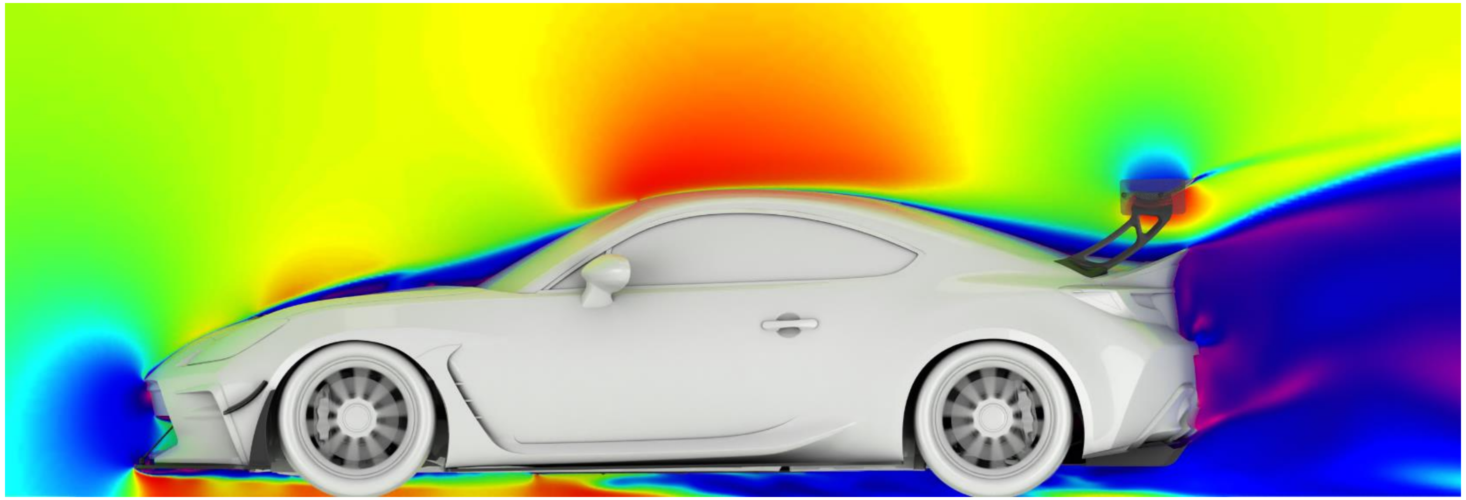
HIGH EFFICIENCY WING

- The High Efficiency wing was developed through many iterations of CFD optimization.
- The goal was to create a wing element perfect for mixed street and track use.
- The low drag suits a lower power chassis with a smaller street friendly splitter.
- The airfoil produces efficient downforce on the GR86 and was positioned to work well in combination with the factory ducktail spoiler.
- This wing is only available in a swan neck mount as the focus was the lowest drag possible.
- The bottom surface is where the majority of the downforce is generated. This low pressure pulls the car downward.
- The top surface still produces downforce, but not like the bottom surface.
- The wing is produced from 2x2 twill, pre-preg carbon fiber, and bolts to a structural part of the trunk.



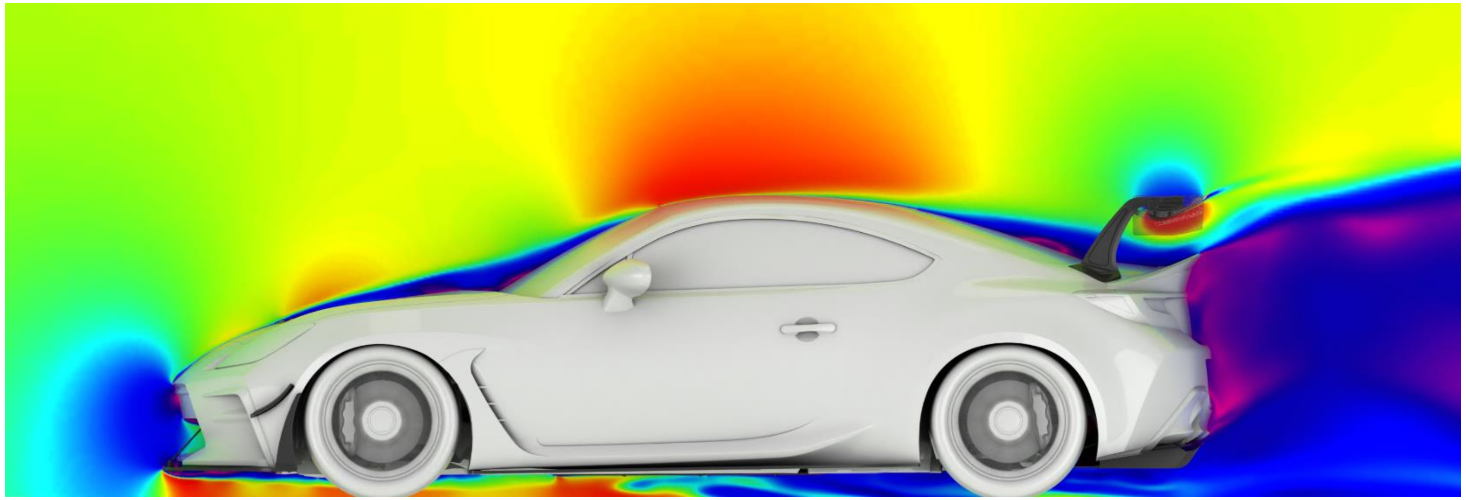
UCW REAR WING (BTM. MOUNT)

- The rear wing is great for customers looking for a large bump in rear downforce.
- The UCW wing profile was developed in CFD and refined in the wind tunnel.
- The airfoil produces efficient downforce on the GR86 in combination with the factory ducktail spoiler.
- The bottom surface is where the majority of the downforce is generated. This low pressure pulls the car downward.
- The top surface still produces downforce, but not like the bottom surface.
- The kit was designed in conjunction with the OE rear spoiler.
- The wing is produced from 2x2 twill, pre-preg carbon fiber, and bolts to a structural part of the trunk.



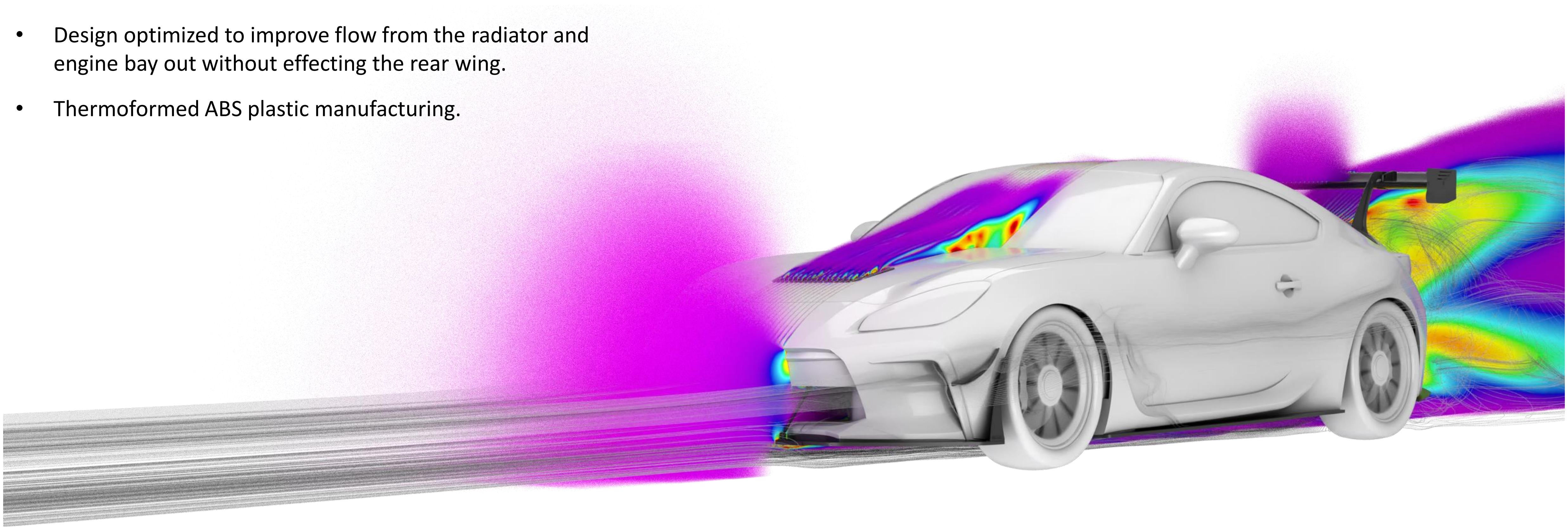
UCW REAR WING (SWAN NECK)

- This rear wing offers a significant performance improvement over the bottom mount UCW. Total downforce and L/D are improved.
- Switching from the bottom mount to swan neck UCW has the following impact on total car drag and downforce (Ventus 3 @ 80 mph).
  - At -1° AOA:
    - Drag + 2.9%
    - Downforce + 16.8%
  - At 12° AOA:
    - Drag - 0.4%
    - Downforce + 6.8%
- This wing uses the same CFD developed and wind tunnel refined wing element as the bottom mount wing.
- The bottom surface is where the majority of the downforce is generated. This low pressure pulls the car downward.
- The top surface still produces downforce, but not like the bottom surface.



HOOD LOUVER

- Increased downforce and decreased drag.
- Overall GR86 efficiency increased by 20 points.
- Aerodynamic balance shifted towards the front by around 5%.
- Design optimized to improve flow from the radiator and engine bay out without effecting the rear wing.
- Thermoformed ABS plastic manufacturing.

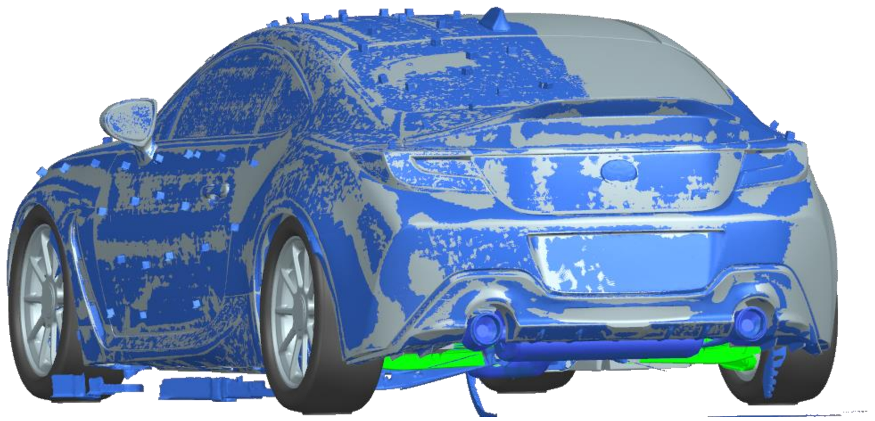


SUMMARY : GENERAL

- The Ventus kits are designed to decrease lap times utilizing well developed and functional aerodynamic components.
- The products feature an OEM like fit and finish, with easy to follow install videos and manuals.
- The components increase vehicle performance on and off the track.
- No engine modifications means you retain the factory drivetrain warranty!
- The R&D was done using cutting edge technology in CFD, wind tunnel testing, track testing with a professional driver, and proven designs from past work.
- Individual components can be installed without the full package, though to ensure a safe balance, we recommend the packages.

QUALITY OF CAD MODEL

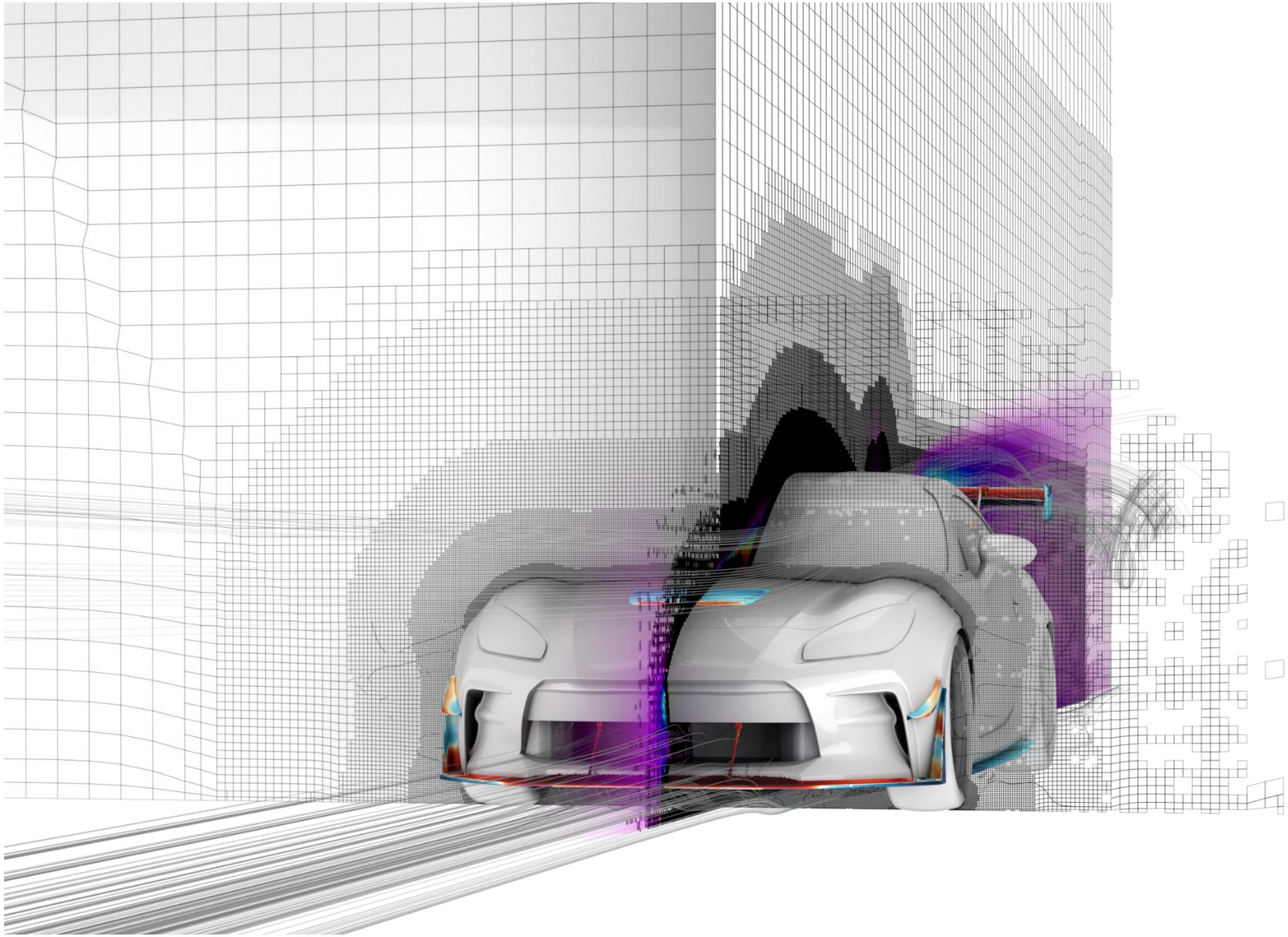
- The CAD model is a crucial aspect of accuracy.
- Bad inputs result in bad outputs.
- The CFD simulation is only as good as the geometry and setup of the CFD analysis.
- The Toyota GR86 was scanned in house and a 3D CAD model was created from this scan.
- The image to the right shows the overlay of the CAD model (gray) and the scan (blue).
- The surfaces are less than 1mm off from the actual scan model in the “worst” locations, with most of the car being significantly less than this.
- Through ducts and radiator ducting were modeled for improved analysis accuracy.
- The engine bay was simplified but includes the main components, including the engine and transmission.



THE SCIENCE

The development was done using OpenFOAM v2106 which is a finite volume CFD software. The solver was SIMPLE and the turbulence model was K-Omega SST using standard wall conditions. We use standard automotive arrangement when setting up boundary conditions and running a full-car. Most of the cases simulated used a slight yawed airflow of 0.5 degrees. This yawed airflow is to ensure we are not analyzing a condition the car will almost never see which is perfectly straight airflow down the length of the car. Other ride heights and yaw rates were also used to simulate cornering.

The use of porous flow was used for all the cooling stacks on the car. The darcy-forchheimer values used were based on past work of similar radiators/heat exchangers.



DEFINITIONS

1. **Coefficient of Pressure (Cp)** = This is a dimensionless number which describes relative pressure to atmospheric pressure. A Cp of 0 equates to atmospheric pressure while a number below 0 represents low pressure and a number above 0 represents high pressure.
2. **CpX** = This is a dimensionless number which describes Cp normal to the x-direction. This helps us visualize locations which create drag. Red represents locations which are creating drag, while blue represents locations where thrust is created.
3. **CpZ** = This is a dimensionless number which describes Cp normal to the z-direction. This helps us visualize location which create downforce or lift. Red represents locations which are creating lift, while blue represents locations where downforce is created.
4. **Total Pressure Coefficient (CpT)** = This is a dimensionless number which describes total energy of the airstream. It is the sum of static pressure and dynamic pressure.
5. **Wall Shear** = This is a force per unit area due to fluid friction on the wall. This is used to visualize areas of separation and rapid changes on the surface.
6. **LIC Plot** = Line integral convolution (LIC) is used to visualize “oil” flow on the surface. It is a great way to correlate to flow vis testing and to study the flow on the surface of the vehicle.
7. **Streamline** = These are fluid tracers which are used to visualize where the air is going or coming from. These are normally colored as velocity where red is high-velocity and blue is low-velocity.
8. **Points** = One point is considered 0.001 of a coefficient. This is used in coefficient of drag (Cd) and coefficient of lift (Cl).