



DESIGN & ENGINEERING PORTFOLIO

VELOCE DYNAMICS



Smiling
International School

PHYSICS AND PRIOR KNOWLEDGE

Intro

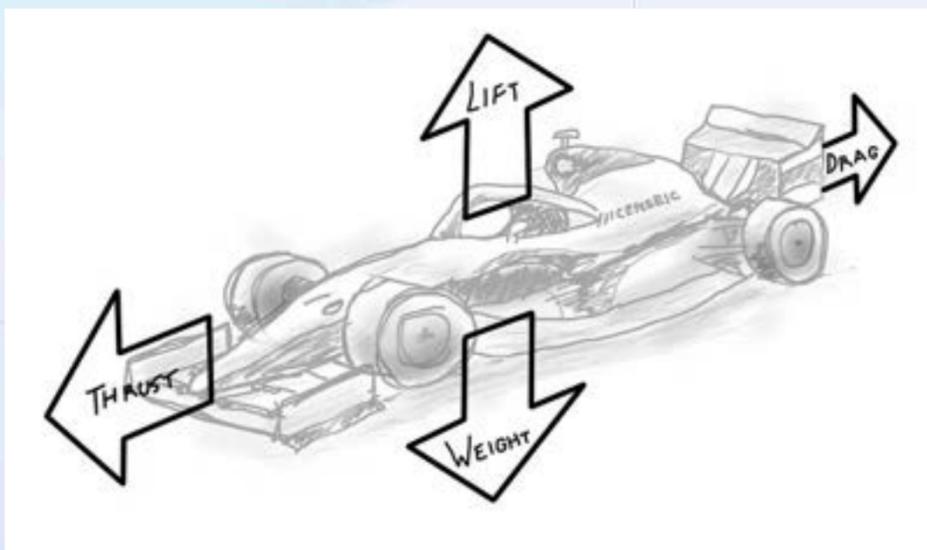
Before working on the CAD program to create our car, we had to study all the physics phenomena that we had encountered during the design phase. Fortunately we had the opportunity to visit the Ferrari museum with our class where we attended an F1 workshop and got some crucial points about aerodynamics explained. We also had two team members specialized in the physical interpretation requirements of the car. This gave us a big advantage during the starting phase.

Lift

In the early stages of the project, we thought that lift, an aerodynamic force generated by a fluid acting on a solid object, perpendicular to the direction of the fluid flow, could help us reduce the friction generated by the wheels. After consulting our physics experts, we found that it was not going to improve the performance of the car, because of drag.

Thrust

Thrust is the reaction force that propels an object forward by expelling mass backward, based on Newton's first law, for this reason it is essential to be able to make the most out of it. This force is produced by a cylinder of compressed CO2 which is perforated at the beginning of the race allowing it to release the gas with a high pressure that makes the car accelerate. To maximize the force we placed the cylinder parallel to the ground so the force is only forward and it isn't dispersed.



Down Force

F1 cars rely on downforce for more grip to keep faster cornering speeds, but this has a significant impact on the drag. Since there are no corners and inertia is low, dragforce is almost useless as we found that the fastest cars have almost no wings at all. It could be said that to manufacture a faster car we needed to have as little forces acting perpendicular to the airstream as possible.

Drag

Drag is an aerodynamic force that acts opposite to the relative motion of any object moving with respect to the surrounding fluid, it can be divided in two types. In our case it is important to minimize this force to get the best results possible.

Form Drag

Form Drag is one of the two types of Drag Force, it depends on the shape of the moving object and we consider it vital to properly constructing the car. The larger the longitudinal section of the body is, the bigger the form drag force will be; this is due to the air pressure behind the object being smaller than it is in the front. So when we talk about an aerodynamic shape, we are speculating on the Form Drag.

Coanda Effect

The Coandă effect is a fluid dynamics phenomenon where a fluid jet (liquid or gas) tends to stay attached to a nearby surface, following its curve instead of flowing straight, due to the creation of a low-pressure zone that "pulls" the fluid towards the surface.

Magnus Effect

The Magnus effect is a phenomenon where a spinning object moving through a fluid experiences a net force perpendicular to its motion, causing a curved trajectory. By utilizing spinning cylinders instead of conventional, drag-heavy wings, racecars can generate significant downforce with less aerodynamic resistance.

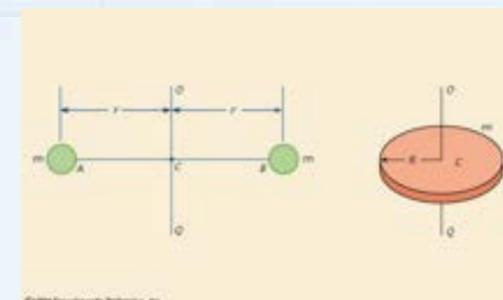
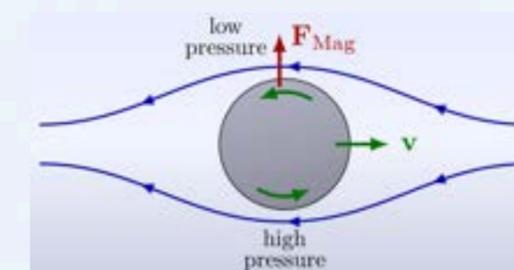
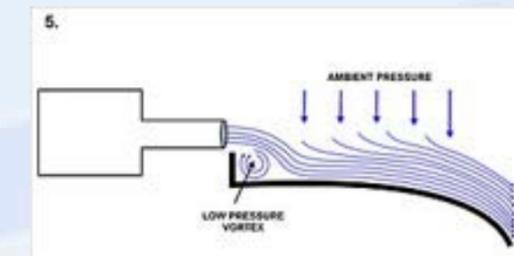
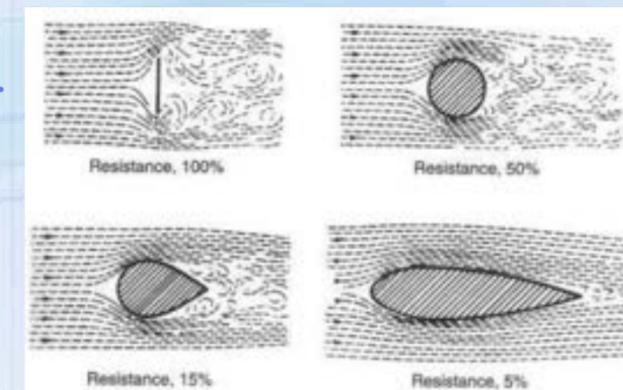
Moment of Inertia

In racing, the moment of inertia, specifically the polar moment of inertia, is a crucial measure of a race car's resistance to rotational acceleration. It determines how quickly a vehicle can change direction, with lower inertia allowing for faster, sharper handling, especially in corners. This however, is not a huge factor to us as the race is a straight line.

Skin Friction

Skin friction drag is caused by air coming into contact with the car. The finish of the surface which the air is passing over is the determining factor of this type of drag. We can greatly reduce skin friction drag by ensuring a smooth, polished finish on our car.

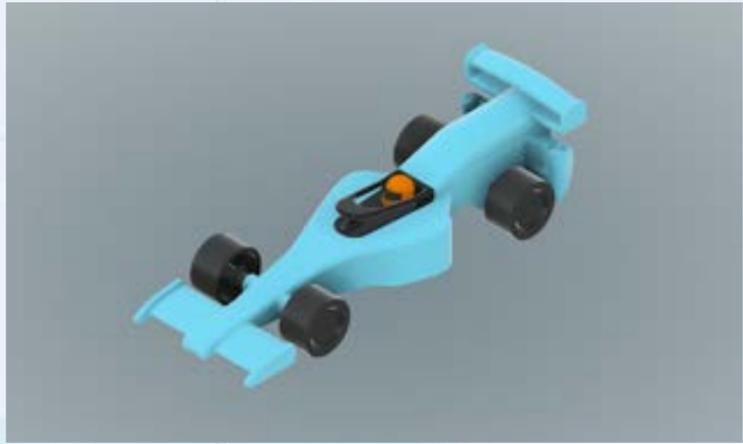
The lower the resistance the better. The teardrop with 5% resistance is the best shape however it is impossible to bypass the 50% due to the wheels of the car



DESIGN CONCEPTS

The Main Goal

Our main goal was to reduce the car weight as much as possible to guarantee the best acceleration possible and the least friction with the ground. For this reason, we designed a car model while continuing to improve it using the aerodynamic analysis to better understand the physics behind our ideas. In different concepts of the car looking for the best compromise between weight and aerodynamics, since a lower weight would involve less material to the aerodynamic components, but a lower moment of inertia would have guaranteed better acceleration to the car. Because we needed to keep the halo's circular notch center at 34mm from the ground, we could not remove a lot of material from the top of the car, so we removed it from the rear wing, creating a channel of air.

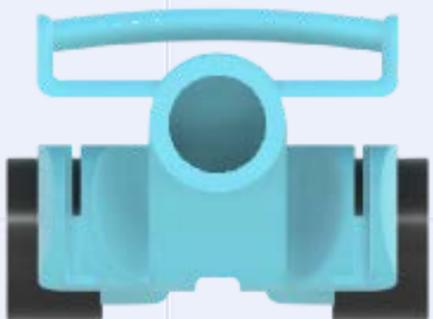


Innovation Point

Our innovation lies in the application of scale-appropriate aerodynamics and optimization. By adopting a low-drag wing philosophy and iterating on wing geometry to reduce airflow disturbance, we focused on maximizing performance within the constraints of the rules. This approach reflects real engineering practice, where innovation often comes from optimization and refinement rather than the introduction of complex new components.

Rear Wing

The rear wing was designed with a slightly higher angle of attack of approximately 6° . This configuration provides a small stabilizing downforce to improve rear-end stability under rapid acceleration, while still maintaining a low drag profile. The rear wing angle was intentionally kept small to avoid excessive airflow separation and turbulence, which would increase drag and reduce overall speed.



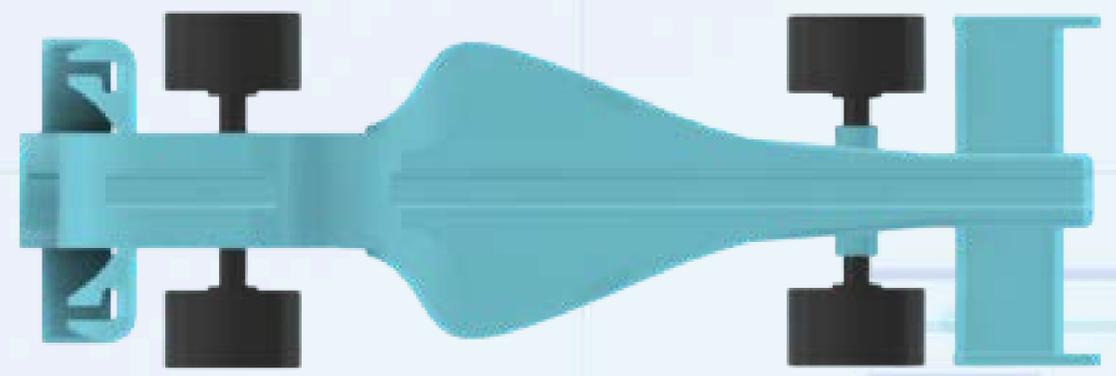
The difference between the front and rear wing angles reflects their functional roles: the front wing prioritizes drag reduction and airflow smoothness, while the rear wing contributes to stability without compromising straight-line efficiency. This balanced approach ensures that the aerodynamic elements support performance rather than hinder it.

Car Bottom

The underbody of the car was deliberately designed to be flat and smooth in order to minimize aerodynamic drag and ensure consistent airflow beneath the vehicle. Given the small scale of the STEM Racing car and its CO₂-powered, straight-line performance focus, complex underbody features were avoided as they could introduce unnecessary turbulence and manufacturing challenges. A simplified underside helps reduce airflow separation and pressure fluctuations, contributing to stable and predictable motion along the track. This design approach also allowed for efficient integration of the CO₂ cartridge while maintaining balanced mass distribution and compliance with competition regulations.

Front Wing

The front wing was set at an angle of attack of approximately 3° . This low angle minimizes aerodynamic drag while preventing front-end lift at high speed. Maintaining front-end stability ensures that the vehicle remains aligned with the track and reduces unwanted aerodynamic disturbances that could affect performance.



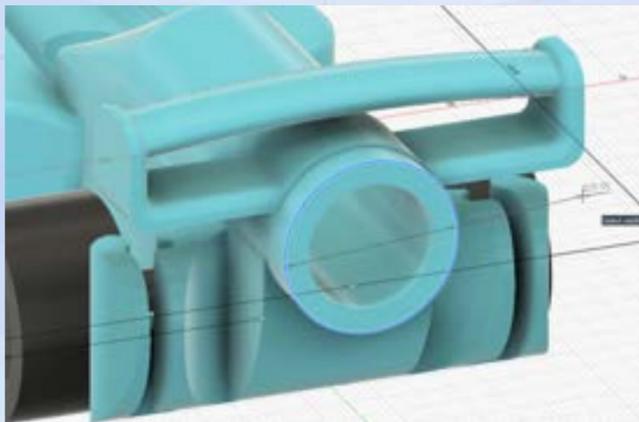
3D MODELING

Evaluating The Modeling Process

Since it was our first time using a CAD software for 3D modeling, we used fusion 360, but we also needed practice before producing a proper design. After we became comfortable with the modeling software, we became more efficient and better organized. Especially after the Christmas holidays, our designs were well organized, with different files for every single component. This way, we were able to refine every piece of the car without risking modifying the others.

Assembly consideration

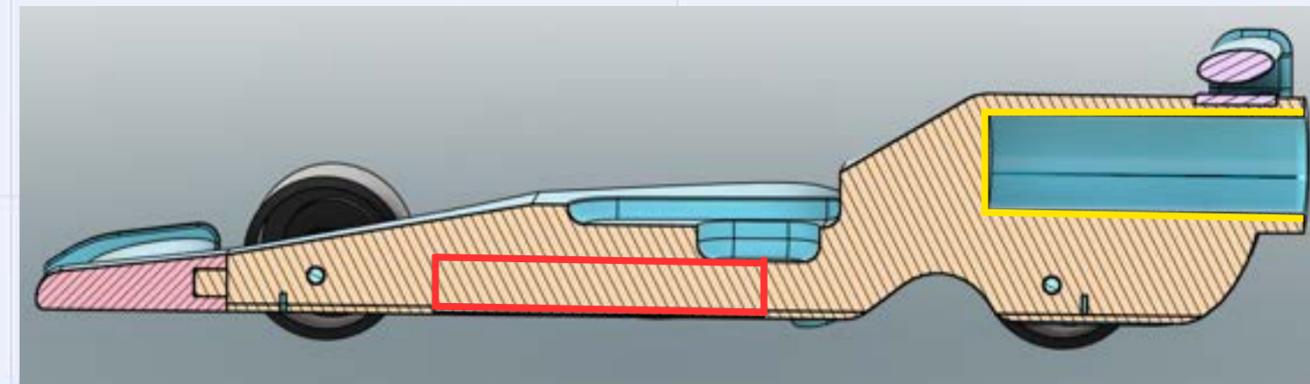
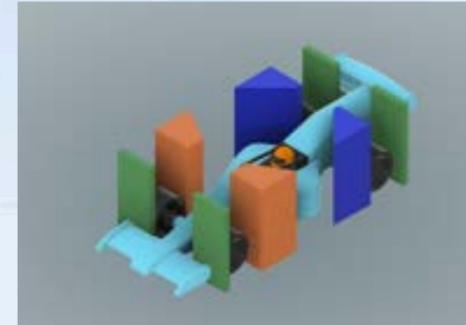
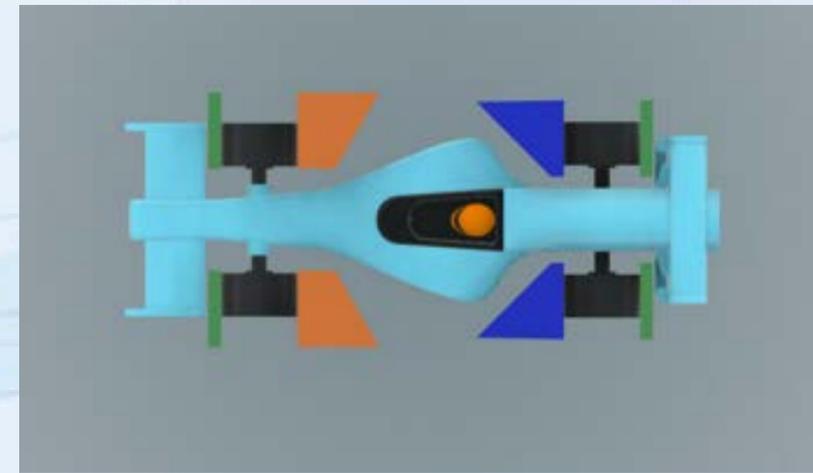
Since our car is made of components, we had to design the housings for them so that they could fit and, to avoid any type of troubles while fitting them, we added a $\pm 0.25\text{mm}$ tolerance everywhere.



3D Modeling Process

To be sure to respect the dimensions given by the rules, we created sketches on the CAD software with areas where car model should have fit to respect the dimensions. We started by creating a general concept of the car body and the wings and modeled them after analyzing them on the CFD software. After completing each part of the car we created the housings and made the last adjustments

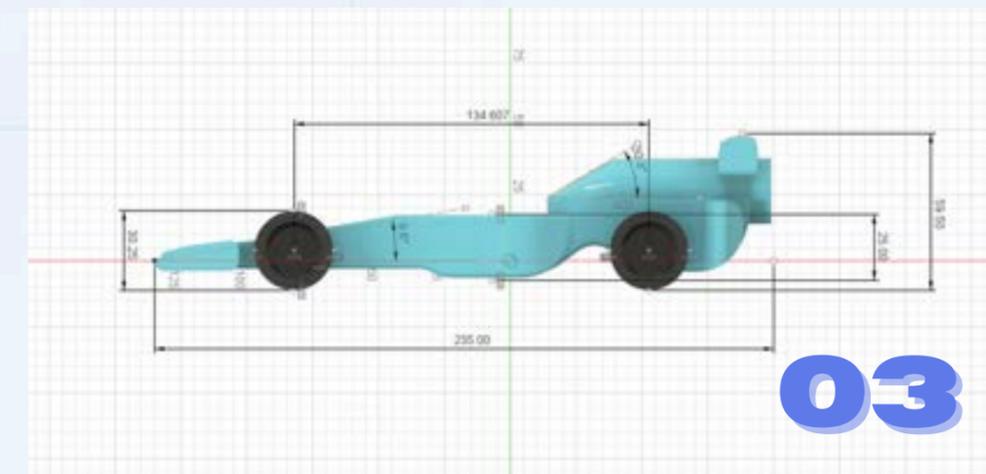
We also designed some other objects to verify that our car respected the technical regulations. We checked the spaces between the components, the virtual cargo and the spaces for the wings



Virtual cargo
3.0mm safety zone

Measurements

- Weight: 0.101
- Front wing: 2mm
- Rear wing: 2.2mm
- Wheel thickness: 3.25



CAR DEVELOPMENT

The Concept

The primary design goal of our STEM Racing car was to maximize straight-line acceleration and top speed while remaining fully compliant with the competition regulations. Because the vehicle is powered by a limited-energy CO₂ cartridge and operates on a short, straight track, minimizing aerodynamic drag was identified as the most important performance factor.

Prototype Rears



The first prototype consisted of a solid, block-style rear wing. This initial design served as a baseline configuration, allowing us to understand how a simple rear aerodynamic element affected airflow and vehicle stability. While structurally simple and easy to manufacture, this design created a large frontal area and likely generated significant aerodynamic drag due to flow separation and wake formation behind the wing.

The second and final prototype introduced a reduced-size rear wing with integrated side channels. These channels were designed to guide airflow more smoothly around and through the wing structure. By funneling air along the sides of the wing, the design aimed to reduce pressure buildup at the front surface and minimize turbulent wake formation behind the wing.



Prototype Front



In the first prototype, the wheel hub holder was too thick, therefore we took this into consideration when designing the following prototypes.

The surface of our first car was too rough, this is why we modified the surface in order for it to be much smoother.

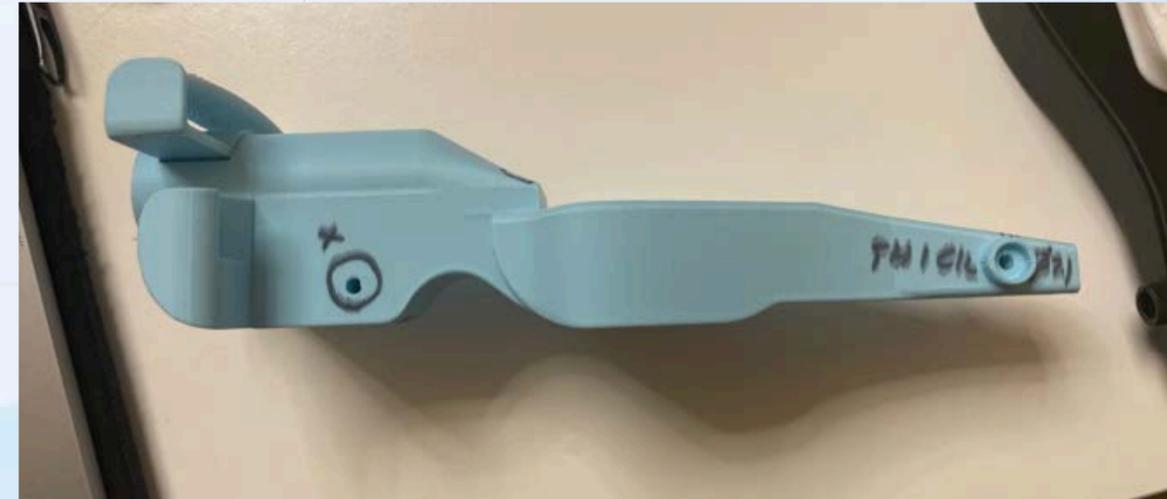
The front wing was embedded with a protruding attachment. This solution wasn't the best, since the front wing kept falling off. In the future prototypes we prevented this by thickening the attachment and using glue.

This iteration represented a significant improvement over the original design. The smaller profile reduced frontal area, while the side channels promoted more controlled airflow, potentially lowering drag force and improving aerodynamic stability. The final rear wing design reflects an iterative engineering approach, where performance is enhanced through incremental refinement and aerodynamic reasoning rather than major structural changes.

Second Prototype



The second prototype was basically identical to the first if not for one small particular: the wing stays didn't perform well in the aerodynamic tests. We changed the design so that the airflow would be smoother and the stays wouldn't block the car.



Third Prototype



Our third prototype was used as our canvas, highlighting all the missing or malfunctioning parts. As an example, the cartridge housing's diameter was too narrow, blocking the cartridge and not allowing it to go in smoothly. This problem was solved by enlarging the diameter by 0.15 millimeters.

Final Prototype



The last prototype is the last finalized version sent to the judges. All the dimensions are in rule according to the booklet. The car has been weighed 101 grams, which is slightly more than what we would have hoped for, therefore we will take this into consideration for future designs.

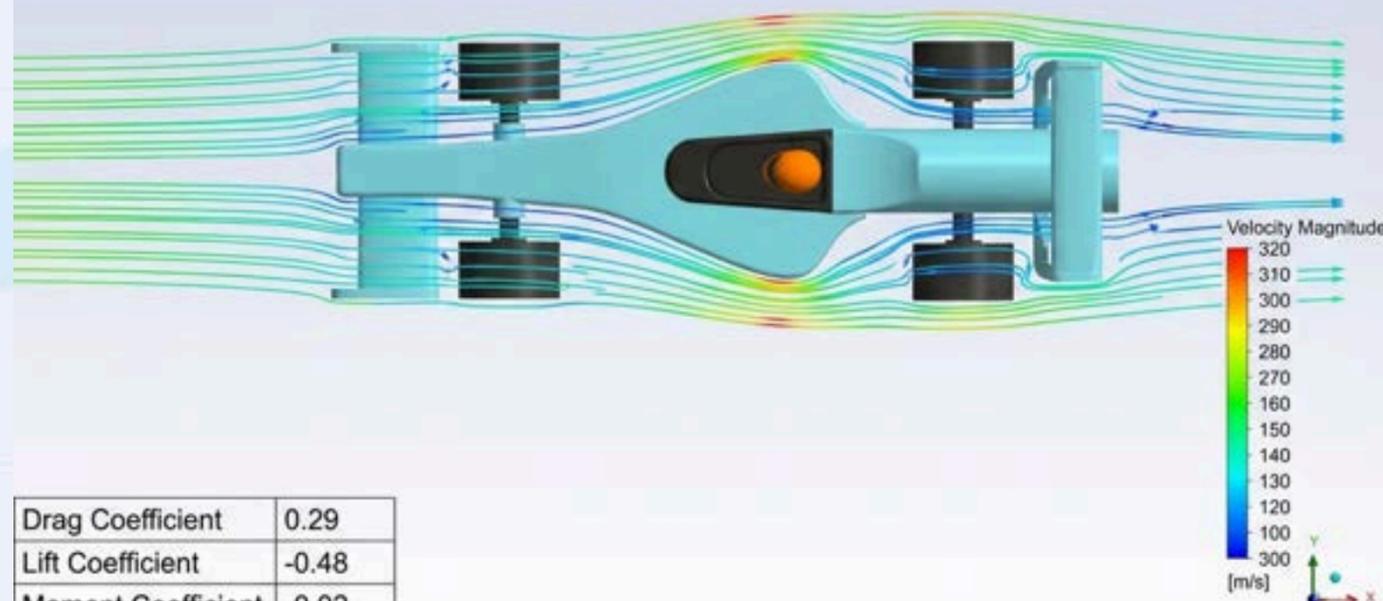
All the others minor inconveniences from the previous prototypes have been improved, leaving us with the best design we have ever made.



CFD results

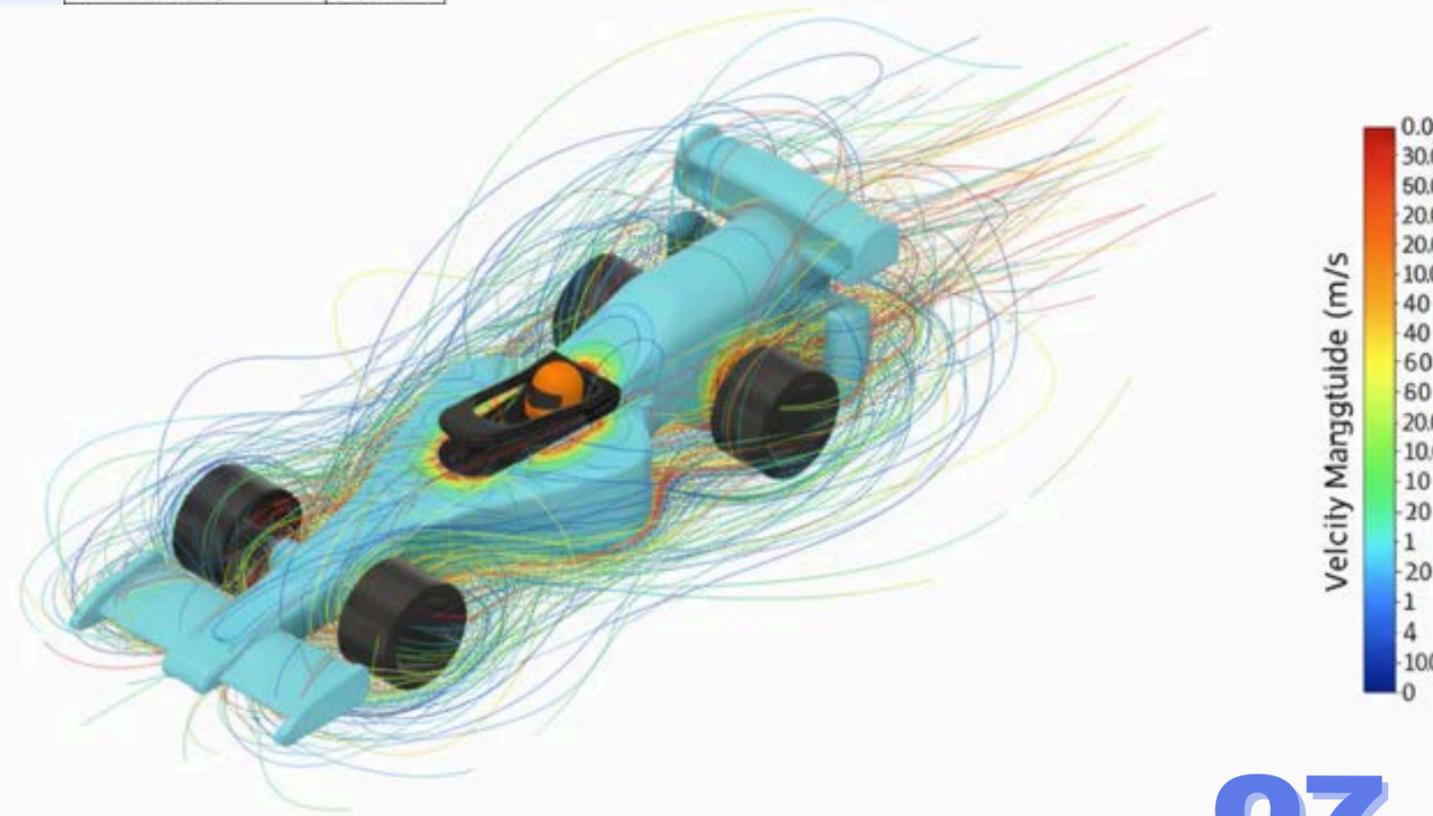
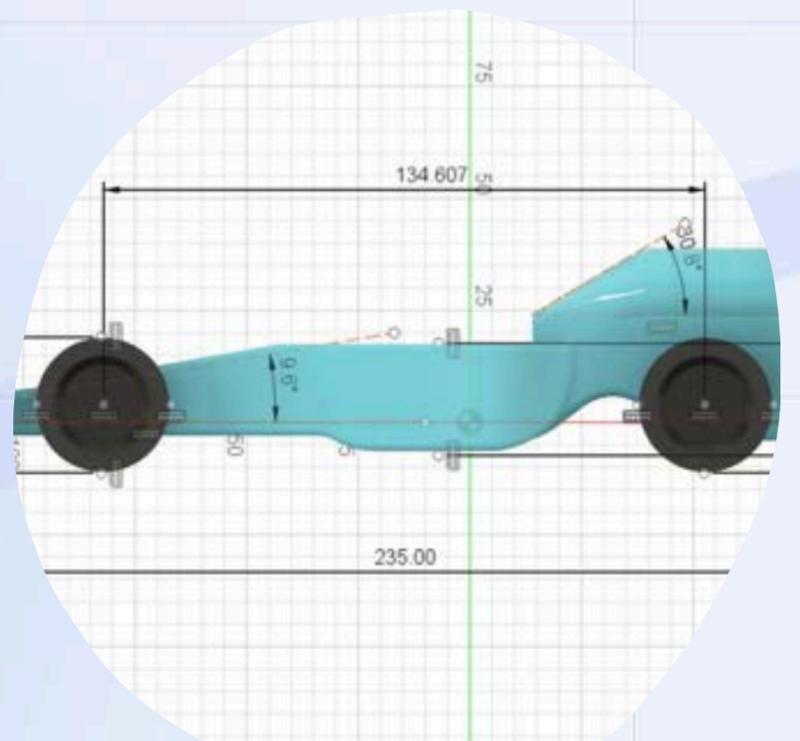
- Top view CAD model with measurements
- Symmetrical layout for balanced handling
- Narrow front section to reduce air resistance
- Wider rear for improved stability
- Wheel positioning optimized for control

- Drag coefficient (Cd): 0.29
- Lift coefficient (Cl): -0.48
- Moment coefficient (Cm): -0.02
- Top view airflow streamlines
- Smooth flow along central body
- Flow disturbance around exposed wheels
- Drag coefficient ≈ 0.29
- Negative lift improves stability

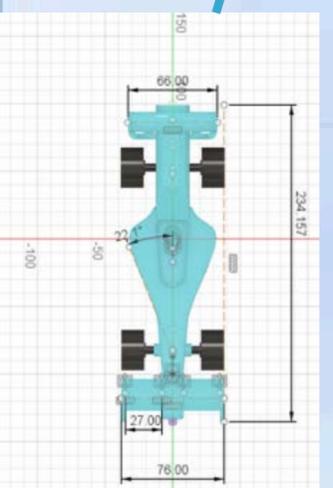
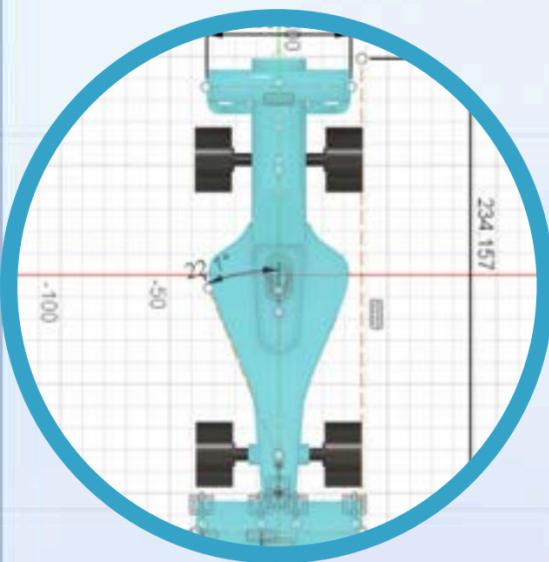


Drag Coefficient	0.29
Lift Coefficient	-0.48
Moment Coefficient	-0.02
Max Velocity	310 m/s

- Side view CAD model with full dimensions
- Optimized wheelbase and ride height
- Low frontal area to reduce drag
- Smooth body profile for efficient airflow
- Proportions designed for stability

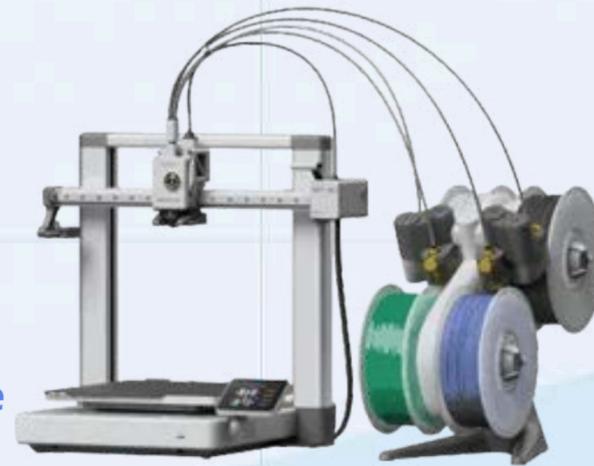


Simulation Results
Drag Coefficient: 0.28
Lift Coefficient: -0.5
Max Velocity: 300 m/s



3D Printer

Thanks to the support of Smiling International School, we had access to one Bambu Lab A1 3D printer. It performs full-auto calibration, including z-offset, bed leveling, vibration resonance, and nozzle pressure, eliminating the need for manual "paper method" leveling. It is also relatively fast. These were useful in saving time and materials.



Car weight

One of our main goals was to manufacture a light car, so we needed to limit the usage of 3D printing, because the material had a certain density. To achieve this goal we decided to print some parts of the body, which could be empty, using less filament. We kept a solid center part which matches with the virtual cargo to be sure that the car respects the regulation.

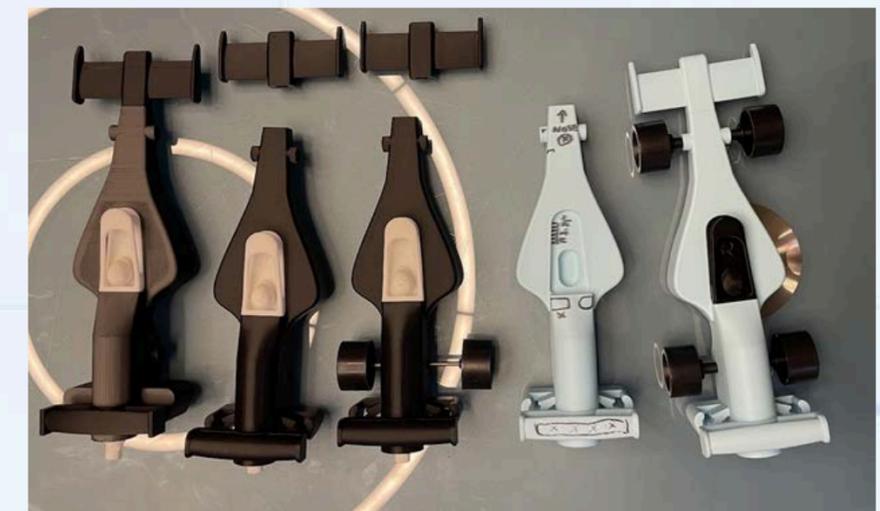


Materials

We analyzed the different types of materials that we could use for the car. We decided to use PLA mate ice blue because it has the best specs for our case, it has great thermodynamic and chemical resistance and also it is the most high quality one to choose from the three allowed ones.

Printing

We printed it horizontally instead of vertically because it increases part strength by aligning layers with the direction of applied force, reduces total print time for many shapes by minimizing the number of layers, and improves accuracy for certain geometries.



FINAL ADJUSTMENTS AND DESIGN EVALUATION

Stickers

For the stickers that we applied on our car, we worked with another sponsor. we sent them a PDF in which we prepared all the stickers we had to use on our car. They printed them and gave them to us, then we applied them with the maximum attention to be sure that they were in the right position.



