INFLUENTIAL CONCEPTS & SOFTWARE

BLACKWING

DRAG

Drag is the *component* of thrust that ***slows the car down***. We optimized our cars to better suit these three main types of aerodynamic drag:

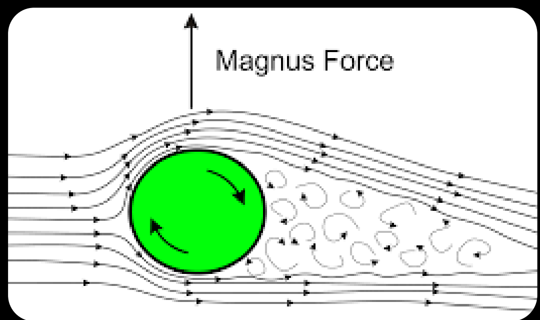
- *Form drag* **:** Caused by pressure differences, which are in turn caused by the shape and design of components.
- *Interference drag* **:** Caused by the turbulence formed when air from high and low pressure zones mix.
- *Skin drag* **:** Caused by the friction between the air and the surface of the car.

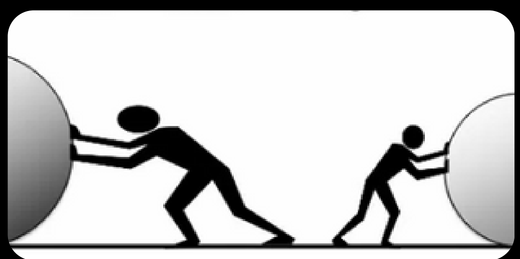
Car Free Body Diagram

OTHER INFLUENTIAL CONCEPTS

Magnus Effect

The Magnus effect occurs when air is deflected by the counter-directional spin of the top half of the front wheel and the directional spin of the bottom half of the front wheel. Reduces performance by a considerable margin.



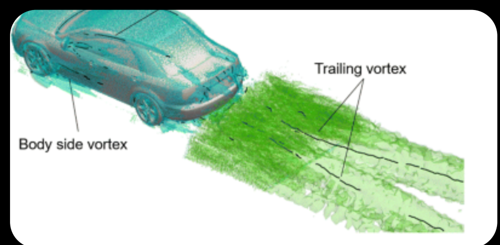


Inertia

Inertia is the inherent property of a body that makes it **oppose any force that would cause a change in its motion**. Inertia *depends on the mass,* so keeping the weight as little as possible is highly essential. (60g)

Vortex

The the *wheel pulling air into a high pressure region,* causing **vortexes.** This *increases turbulence, reducing aerodynamic efficiency* of the objects *behind the wheel.*



SOFTWARE USED

Topsolid CAM/CAD

TopSolid, our gold sponsor, provided us with a copy of their CAD/CAM software. We used their software to simulate machining and verify manufacturability.

Autodesk Fusion 360

Our primary CAD software is Fusion 360. We chose Fusion because (1) two of our members were already experienced with it, and (2) it allowed us to use parametric modelling.

Blender 3D

Blender was used to make all of the renders. It provided a lot of customization options and was free and open source.

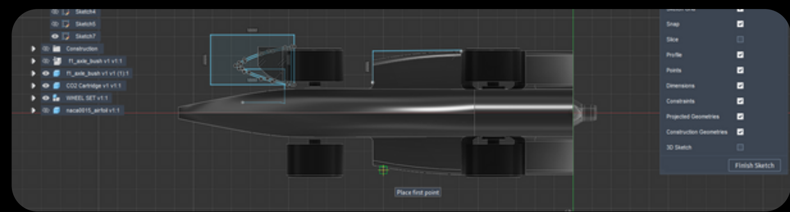
Simscale

Simscale, our sponsor, helped us to perform FEA on our cars. We used it because its highly customisable, provides accurate results, and is browser based.

TOOLS USED

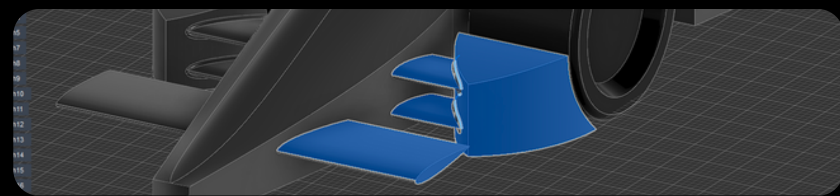
1. Parametric Modelling

Parametric modelling allowed us to create multiple iterations of a components. This allowed us to test multiple component designs without having to redo the shapes.



2. Mass Calculations

The weight of the car is one of the most critical things, when it comes to the track time. We assigned materials for the polyurethane foam, Nylon PA12, and the spray foam inside Fusion 360 so that we could get an accurate mass measurement.



2. Lofts

The main body was lofted (from the canister hole to the front) with guide rails. It helped create an aerodynamic body that could be easilly changed, at will.

4. Seperate Bodies

Keeping all bodies separate and the using the combine tool at the end made changing designs of individual components much more hassle free.

In the beginning of the competition, we made this list to plan all of our tasks in advance.

Speed: • Smooth Wheel System • Aerodynamic Car Body • Low Drag Coefficient • Lower Mass	**Strength:** • Materials Used • Manufacturing Approach • FEA Analysis Done • Stress Simulations Run
Finish: • Even Coats of Paint • Primer and Varnish used as Required • Decals done Neatly • All Components Aligned Perfectly	**Compliance:** • Scrutineering • All Regulations Met • Expenditure • Safety

R&D AND REACTION TIME

BLACKWING

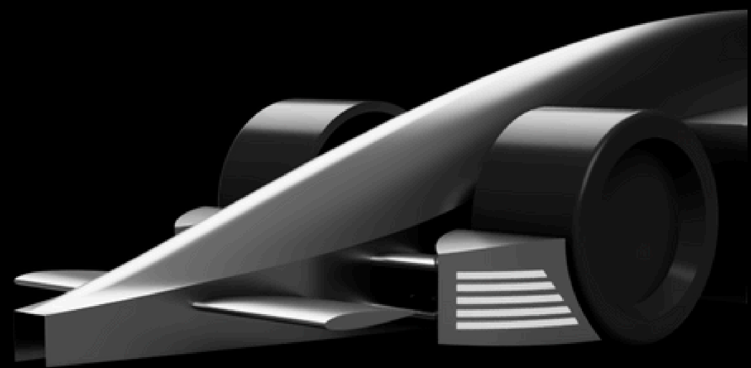
TIPPING MOVEMENT AND **CENTER OF MASS**

- After observing slow-motion F1 in schools races, we noticed the cars ever-so-slightly tip forwards, during the initial few milliseconds of the race.
- This can be attributed to the COM and the Thrust vector of the car not being perfectly aligned, causing torque form. This causes a loss in energy. In order to solve this, we tried our best in order to move the COM as close to the thrust vector as possible.

FRONTAL WHEEL COVERS

Due to the magnus effect, the idea was to cover the front wheel as much as possible to decrease the air going into the front wheel, in turn decreasing wake formation.

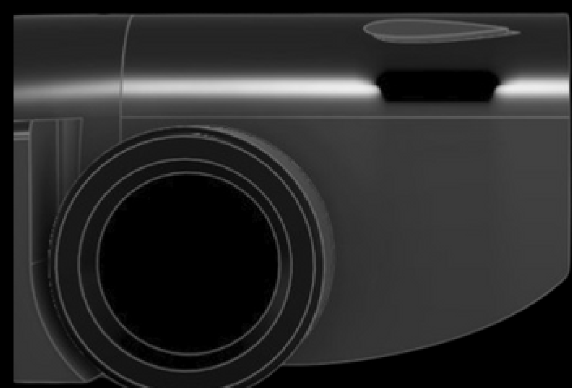
Even early prototypes reduced drag by an average of 7%. After refinement, we landed with this:



KAMM **TAIL**

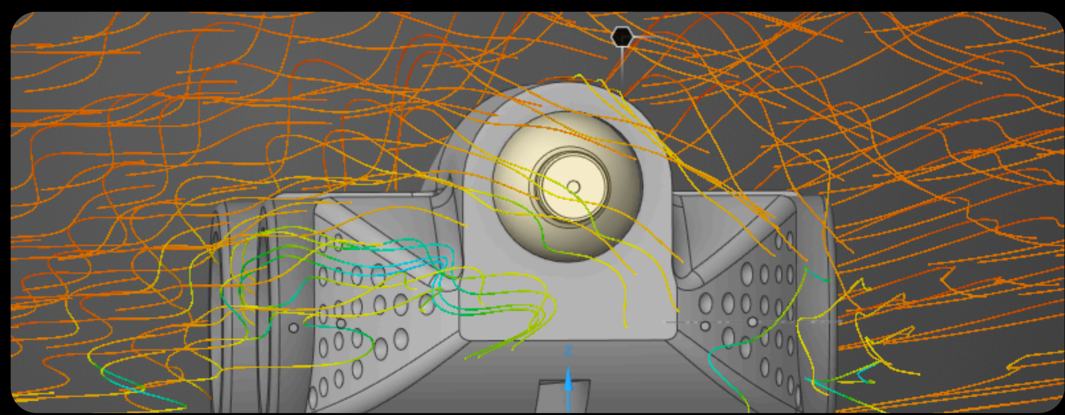
- One of the key principles we applied was the Kammback effect. Discovered by Wunibald Kamm, this concept shows that you can achieve most of the aerodynamic advantages of a teardrop shape without needing a long tail—provided the taper ends at the right point.
- We used this idea to optimize our main body design, ensuring that there were no fillets at critical cutoff points. This design works in two main steps:

- Step 1: Air attaches to the surface smoothly over the body (reducing drag)
- Step 2: Then the air detaches cleanly at the flat cutoff — helping reduce turbulent wake and maintaining aerodynamic efficiency.



GOLF **DIMPLES**

Inspired by a MythBusters episode where dimpling a Ford Taurus improved fuel efficiency by 11%, we set out to recreate and test the concept ourselves.



We tried to replicate the car by attaching dimples over converging rearpods. According to CFD testing, we barely achieved any gains. Moreover, it would be really hard to manufacture and keep the dimples. Therefore, we scrapped it.

REACTION TIME **TRAINING**

You can only do so much with engineering, and the car. The rest, all depends on your reaction times. Therefore, we set out to optimize our reaction times.

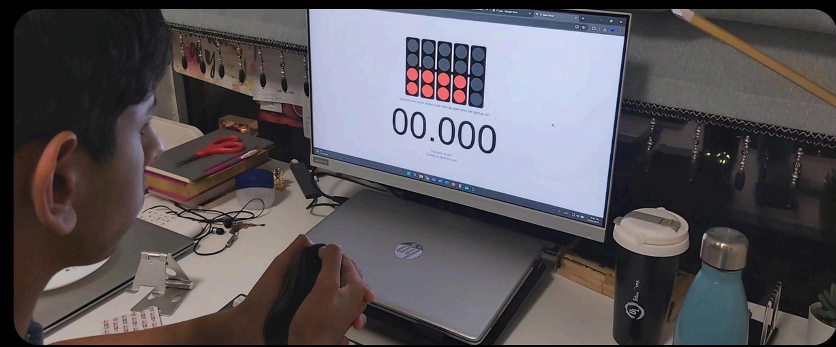
First round: Identify people with naturally low reaction times. All contestants were asked to maintain a good sleep schedule and quality and schedule.

We identified Pallav and Himani to naturally have the best reaction times.

We also supplemented the contestants with a multivitamin/mineral in order to make sure that they did not miss out on their micronutrients.

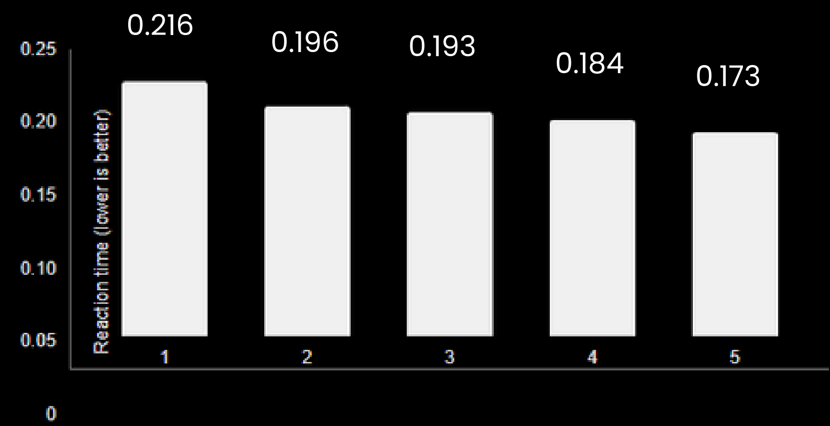
We mainly wanted to investigate the impact of sleep quality, caffeine consumption, training, and nutrition in reaction times.

Subject 1: Himani.
Subject 2: Pallav.



KEY / SCENARIOS

1. Bad sleep
2. Good sleep
3. Good sleep + otrivin
4. Caffeine
5. Good sleep + otrivin + caffeine

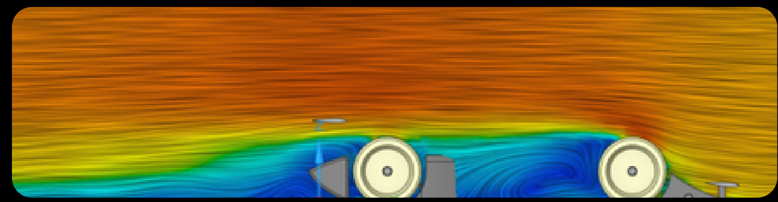


PROTOTYPING, EVALUATION, & TESTING

PROTOTYPING AND DESIGN EVALUATION

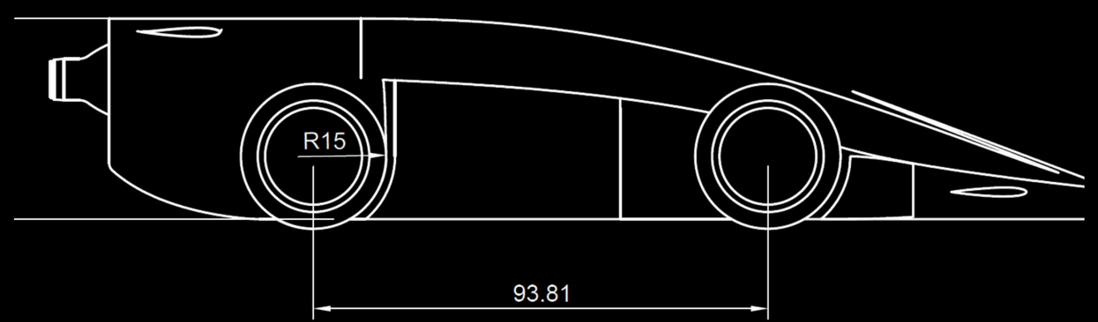
It first started with letting our engineers get familiar with their respective software, by having them design, test, and optimize dummy cars. Some initial work (below).

Once our engineers were well versed with the prototyping process, we focused on isolating variables and component choicing, optimizing efficiency and performance.



Our first step was to list all of the components and factors that could have a reasonable impact the performance of that car. After a long brainstorming session, we got the components, along with how we were going to test them:

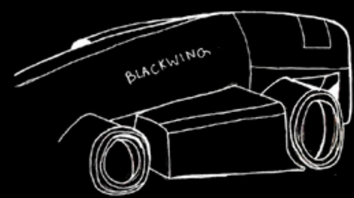
- Wheelbase (track testing)
- Main body (Virtual CFD and virtual crash testing)
- Wings (CFD)
- Wheel covers (CFD and virtual crash testing)
- Sidepods (CFD)
- Rearpods (CFD)
- Tethers (R&D + track testing)

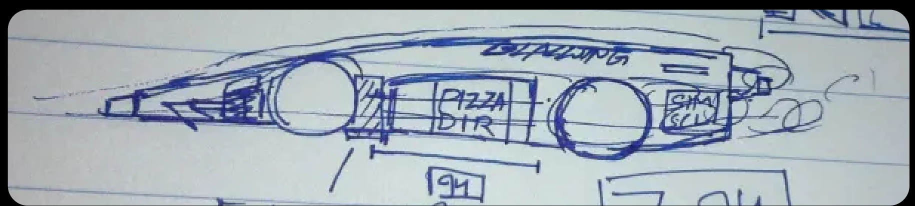


PROTOTYPING PROCESS

1. Sketch component designs, going front to back.

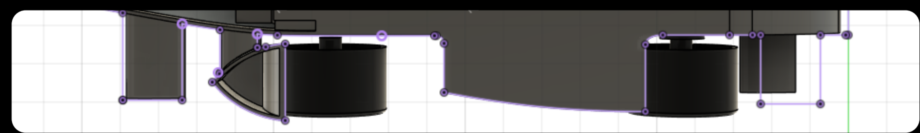
- A majority of this work was done sitting together in groups, since it allowed **quick communication** with less boundaries.

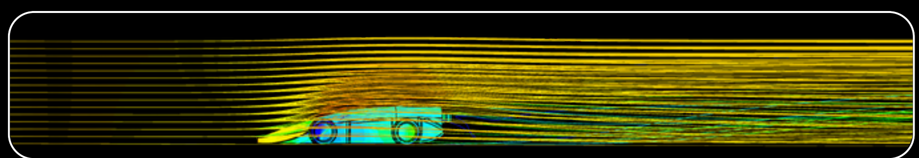




2. Aerodynamicist, design engineer, and cad/cam guy together go over them and disqualify the illegal/unpractical ideas.

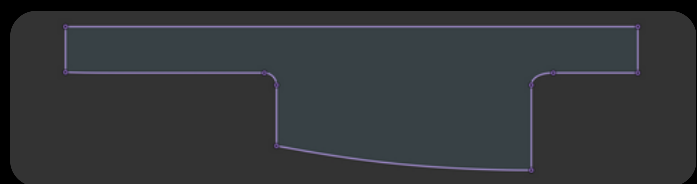
3. Model the ideas and stick them into a basic car template, while keeping all other variables constant.





4. Testing: CFD, Crash simulation, weight management, and even real life testing.

5. Refinement. Test slightly different versions, changing dimensions, curves and shapes of the component at hand. Parametric modelling came in CLUTCH here.



TESTING METHODS

CFD

It was integral to the design and the components of our cars. We aimed for a mesh with a minimum of 10m cells, and a simulation with 1000 iterations.

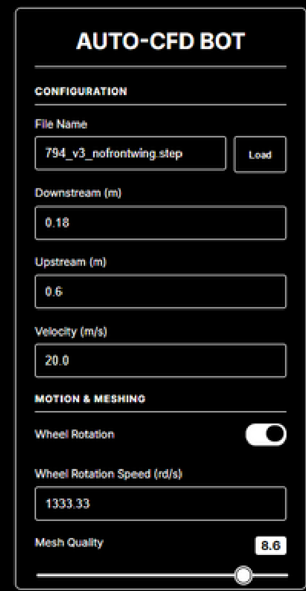
Simulation settings:

- Inlet velocity of 20 m/s
- Symmetry (to save computational costs)
- Rotating wheels (to accurately simulate wake)
- Moving Ground.
- 1800mm downstream (to let wake develop)

AUTO-CFD **BOT**

In order to streamline the process, we made a bot with the help of Google AI Studio, using a mixture of Python and HTML, which automatically sets up the CFD process.

Setting up a CFD simulation manually requires 4 and a half minutes per simulation, and is prone to errors. This bot increased our overall efficiency and saved a lot of time.



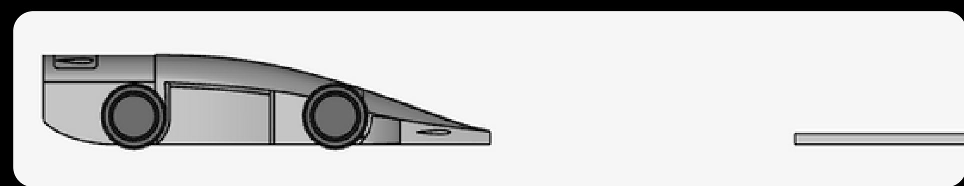
GAS DEVIATION **FORMULA**

Because of the large amount of variations in the Co2 canister, we decided to use Team Sonic Boom's gas deviation formula for calculating the track times of our cars.

$$adjusted\ race\ time = race\ time * \left(\frac{weight\ CO_2}{average\ weight\ CO_2}\right)$$

CRASH **TESTING**

We used a dynamic event simulation. By entering the properties of the Nylon, and guestimating the properties of the deceleration towel and the model block, we could get a somewhat-accurately simulate the car crashing into the towel.



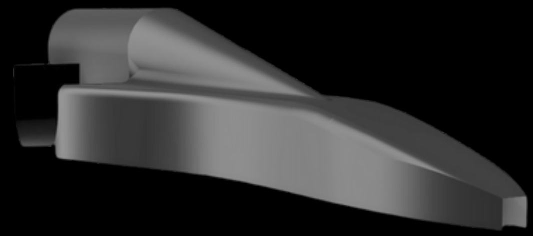
COMPONENT CHOICE & REASONING

FINAL **CAR: 794**

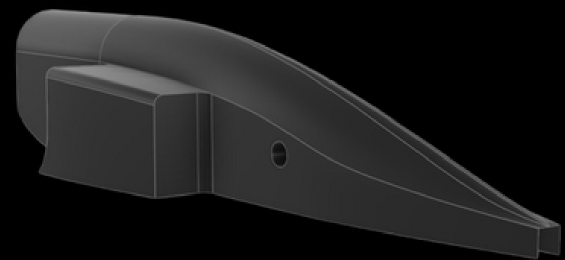
MAIN**BODY**

Our goal was to minimize drag. We tested 2 radically different ideas.

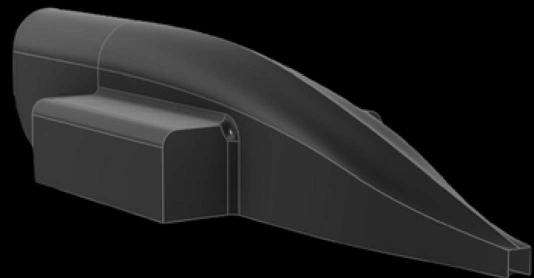
Version 2 was chosen, as it decreased drag by 11%. Further refinements led to this design on the top right.



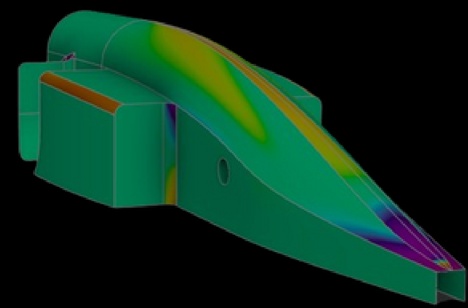
V1



Main Chassis



V2



Curvature Analysis

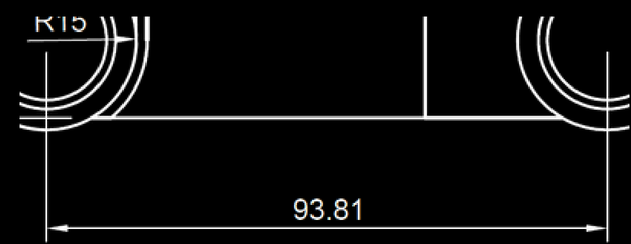
WHEELBASE

Goal: To have the best track times. Choosing the right wheelbase was complicated. A longer wheelbase noticeably increased drag, making it a tough trade-off.

Track times:

- - 85mm: 1.200s
- - 94mm: 1.157s
- - 106mm: 1.236s

Final choice: Wheelbase of 94mm.

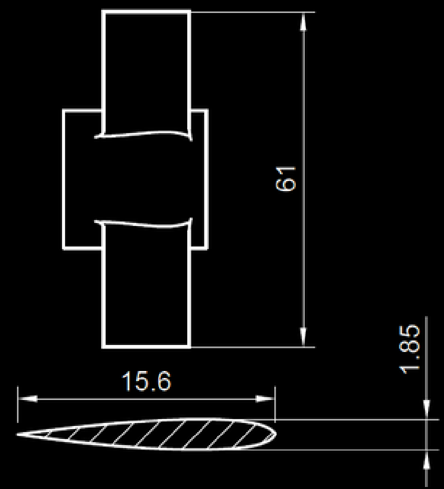


WINGS

Goal: to have a minimum impact on performance while being legal. We opted for the NACA00XX series aerofoils, as:

- They are symmetrical and streamlined, so they generate no lift/downforce and barely contribute to the drag.

Following this, we chose the **NACA0012 aerofoil**, as: It fit the regulations. A 15.6mm chord resulted in a maximum thickness of 1.85mm, which fit the regulations and had a margin for dimensional inaccuracies. It also survived virtual crash testing.

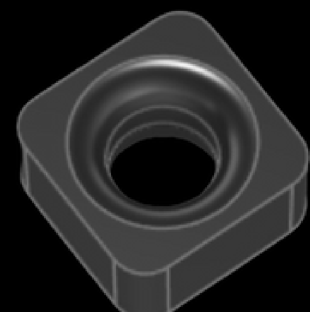


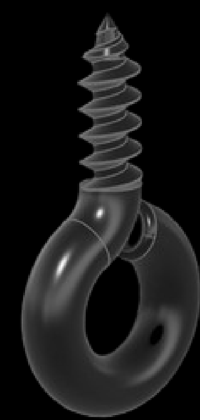
TETHERS

Goal: To have minimum friction, be light, and durable. We tested these materials:

- Default tethers (0.3g), 1.196s.
- PTFE Tube (0.4g), 1.207s.
- Graphite laced steel (0.3g), 1.195s.
- Ceramic (0.2g), 1.203s
- Nylon PA12 (0.2g), 1.207s.

Final Choice: Default tethers.





SIDE**PODS**

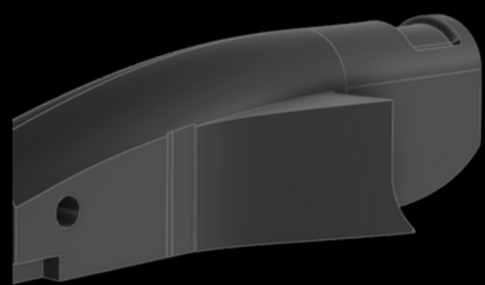
Goal: to prevent the turbulent air from the front wheel from reaching other components of the car, increasing drag

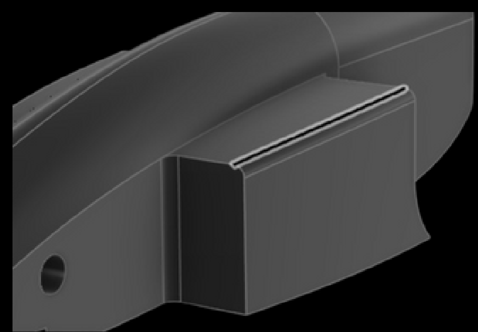
Curved:
- Although they redirected all of the turbulent air from the front wheel away from the car, caused higher rates of skin friction.
- The wake from the front wheels reduced the aerodynamic efficient of the curved sidepods.

Boxed:
- The dirty air from the front wheel gets blocked by the flat face, and decreases the overall drag.
- After optimization, we concluded that a small curve on the boxed sidepods improved drag, and saved weight.

None:
- All of the dirty air from the front wheel was going directly towards the rear wheel, which increased drag by a large margin.

Final choice: Boxed sidepods





REAR**PODS**

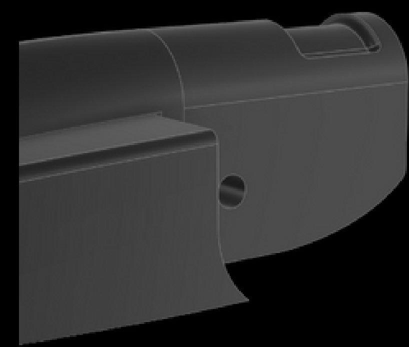
Goal: To handle wake from rear wheels and minimize drag.

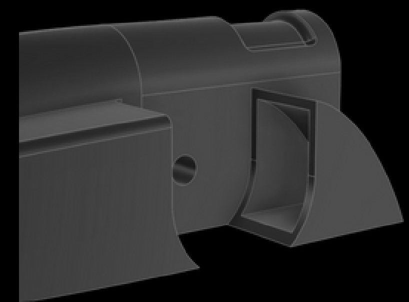
Curved rearpods:
- Effectively handled the wake and reduced vortex formation, and had relatively low drag.

No rearpods:
- with a tapered back did increase drag ever so slightly, but reduced a lot of weight.

Shelled Rearpods:
- contained all of the turbulent wake inside them and performed the best aerodynamically, however they were extremely heavy.

Final choice: No rearpods.





MANUFACTURING AND MATERIAL CHOICE

SANDING

Using a multistepped approach of sanding the car before applying primer. To make sure that there are no scalloping marks there is an even distribution of primer.

400 Grit → 800 Grit → 1500 Grit → 2500 grit (wet sanding)

We also used a vacuum to pick up any residual dust after each sanding process.

With our 3 first test cars, we used different painting processes to see the differences in weight and finish.

Car 1: Filler Primer, then a coat of hand paint. Sand that, and then put another coat of hand paint, and then sand that with 2500 grit wet sanding.

Pros: Moderately light weight.
Cons: Unappealing finish.

Car 2: A coat of spray paintXprimer. Sand that, and then put another coat of spray paint and then sand that with 2500 grit wet sanding.

Pros: Good finish
Cons: Foam absorbed most of the paint, leading to more coats required for attaining the same finish.

Car 3: Filler Primer, then a coat of spray paint. Sand that, and then put another coat of spray paint, and then sand that with 2500 grit wet sanding.

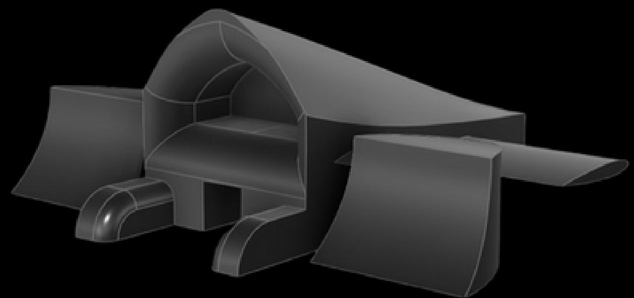
Pros: Amazing finish.
Cons: Moderately heavy.

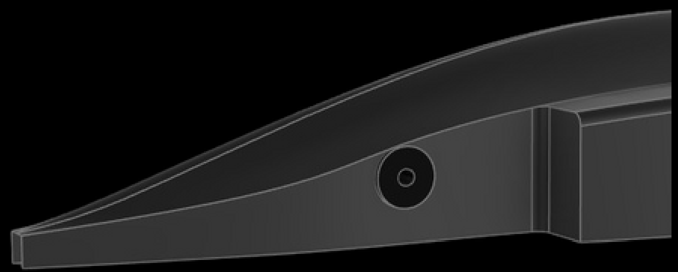
FILLETS

Fillets were an integral part of the design, as we required them to machine our car. We utilised 3mm fillets, as the main bit that was used for machining had a diameter of 6mm.

We filleted the areas where the:

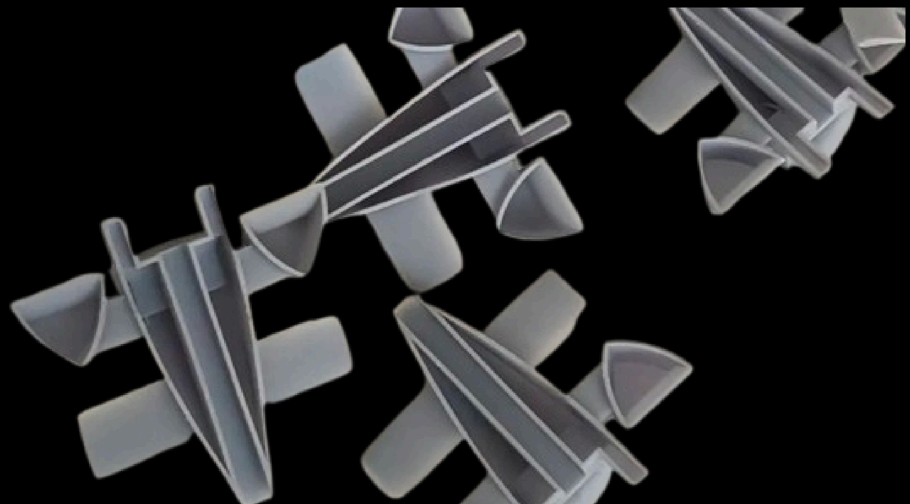
- **Nose cone** and the **rear wing** slotted into the main body. Because of this, we were able to get a perfect fit on our components.
- **Sidepods** attached to the main body (for better load and force distribution),
- **On the top** of our main body for better aerodynamics





NOSE CONE

In order to save weight, we made our nose cone hollow. We planned to then fill it up with spray polyurethane foam, and cover it with wood filler and primer in order to get a smooth, indistinguishable finish.



MATERIAL CHOICE

Main body: Legally only allowed to be with polyurethane foam.

Material needed for nose cone and rear wing:

- Durable and Impact resistant (ASTM D256, higher than 100 J/m)
- Below 1.5 g/cm3 density.
- Able to be manufactured with thin walls (as to be hollow)
- Have a detailed TDS (for impact simulation)

Following this, we crossed out these manufacturing procedures:

- FDM 3d printing
- Resin 3d Printing
- CNC Machining

Our only leftover option was SLS 3d printing. WIthin SLS, we can either use Nylon PA12 or TPU. Due to regulations, all wings must be rigid. Thus, our only option was **Nylon PA12**, with **SLS 3D Printing**.

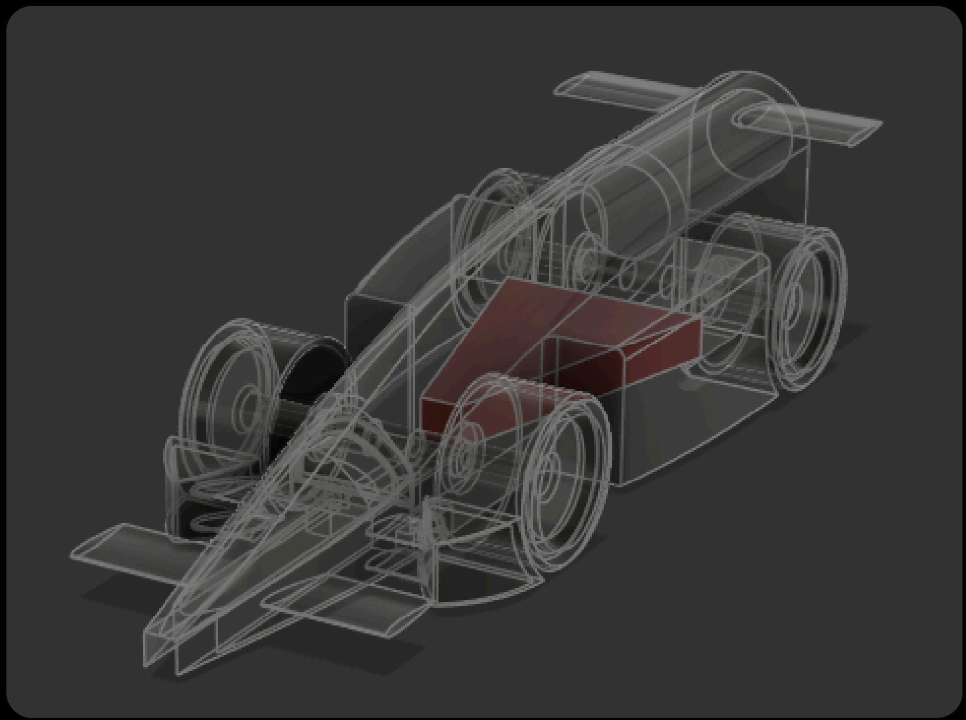
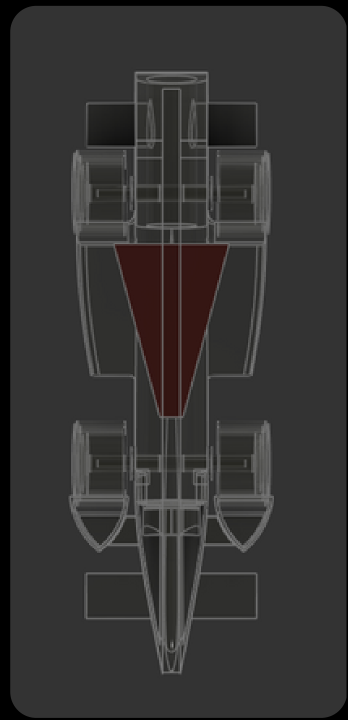
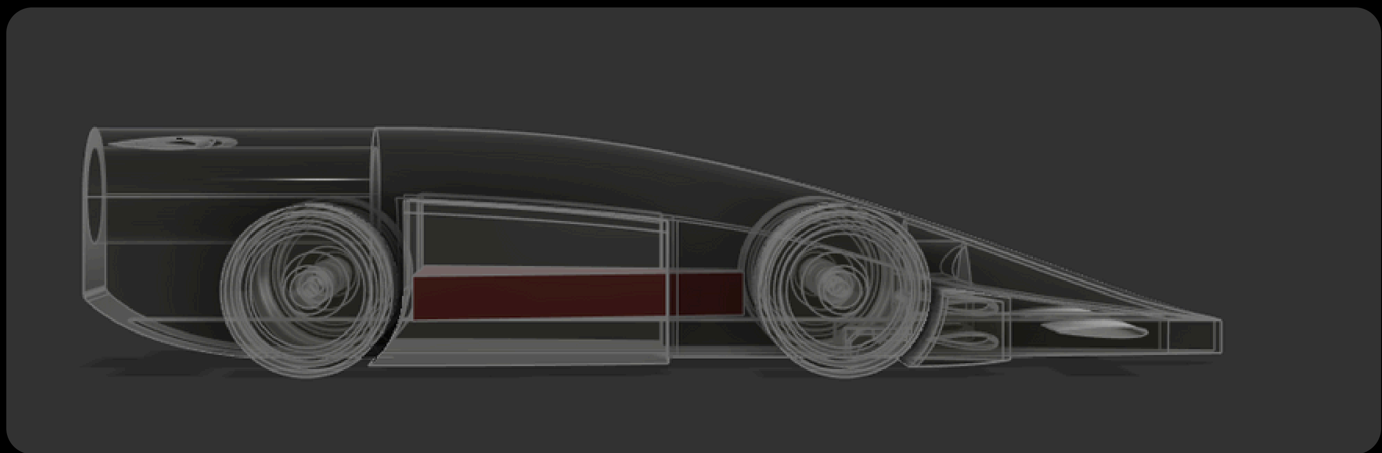
WORKPLACE SAFETY

During the course of this competition, we tried our best to minimize injuries and ailments. Before starting our processes, we made this table so that all of the stakeholders would be well versed with the risks and precautions.

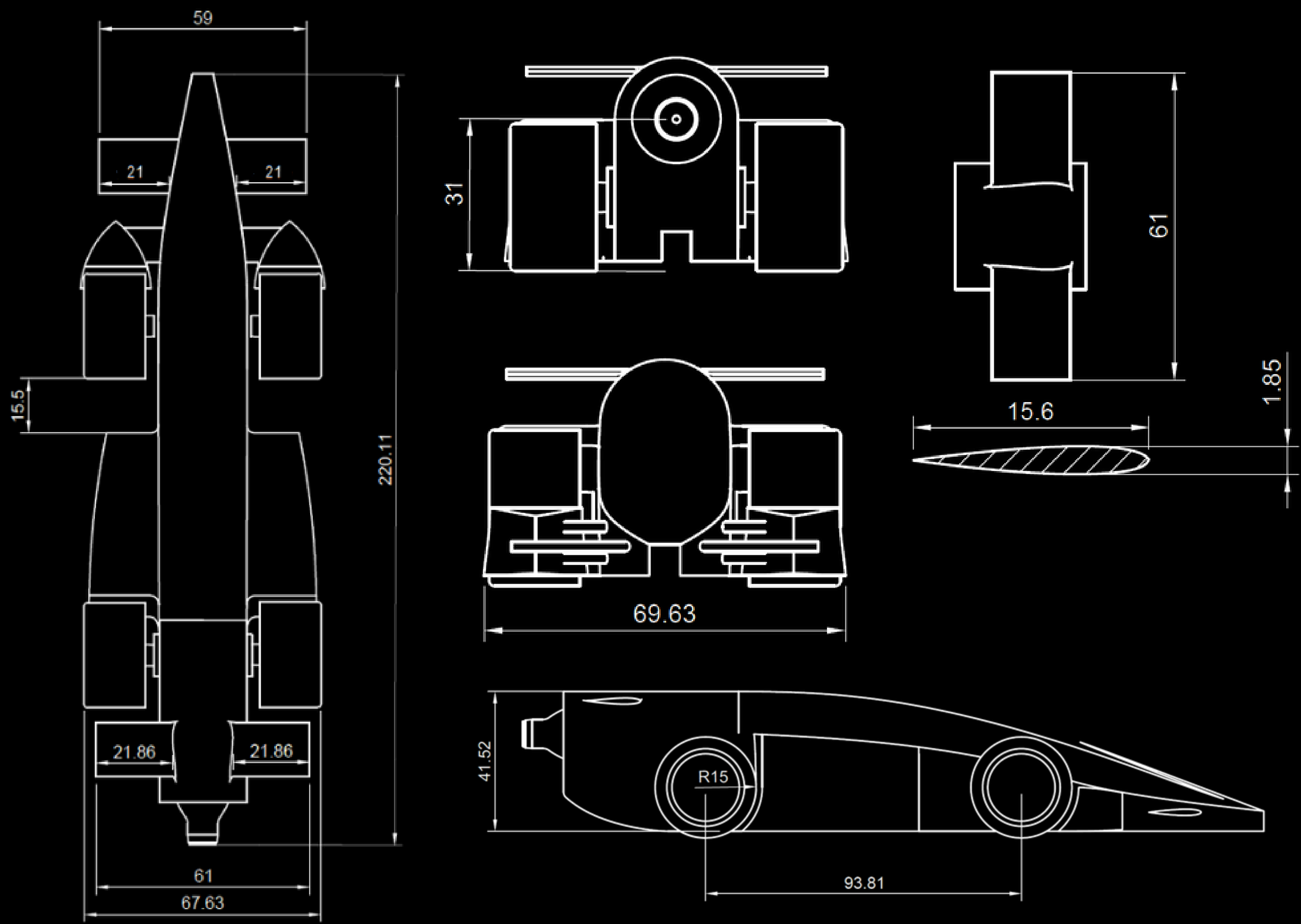
Symptom	Process	Precautions
Skin and eye irritation	Sanding	Usage of gloves and masks, and repeated vacuuming of cars and workplace.
Nausea and light-headedness	Painting	Done in well ventilated areas, with gloves and masks.
Eye irritation and severe injury	Machining	Done by professionals, and using water to minimize dust.
Light-headedness and eye irritation	3D Printing	Fumes ventilated to the outside.
Cuts	Shortening axles	Using a dremel along with cut-proof gloves

ORTHOGRAPHICS & CAM

BLACKWING

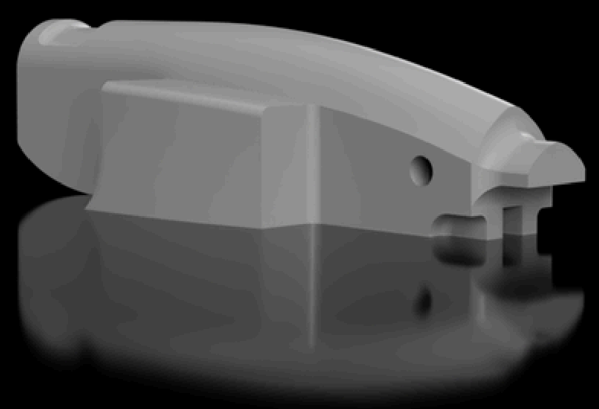




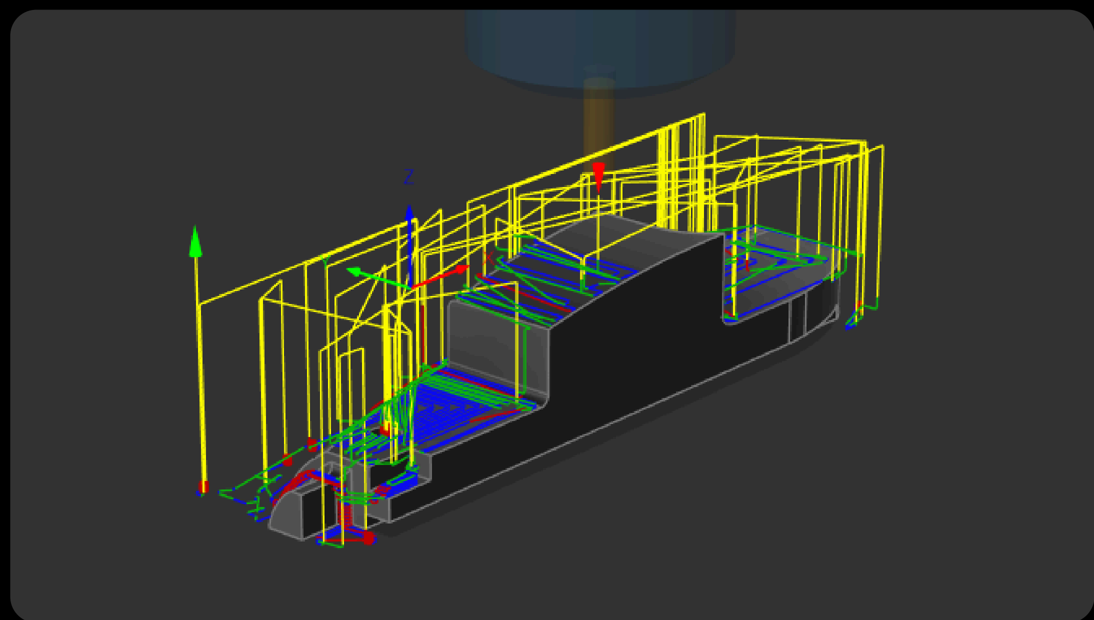
Virtual Cargo Identification



Wing Identification

FINAL CAR BODY:





In order to verify maneuverability, we ran the car through a CNC Milling simulator (CAM).

We used 2 operations for machining our main body, one from the left, and one from the right, as regulations mandated.

We utilised a 6mm ball end bit, as it was plenty accurate for us while being quick and easily sourcable.