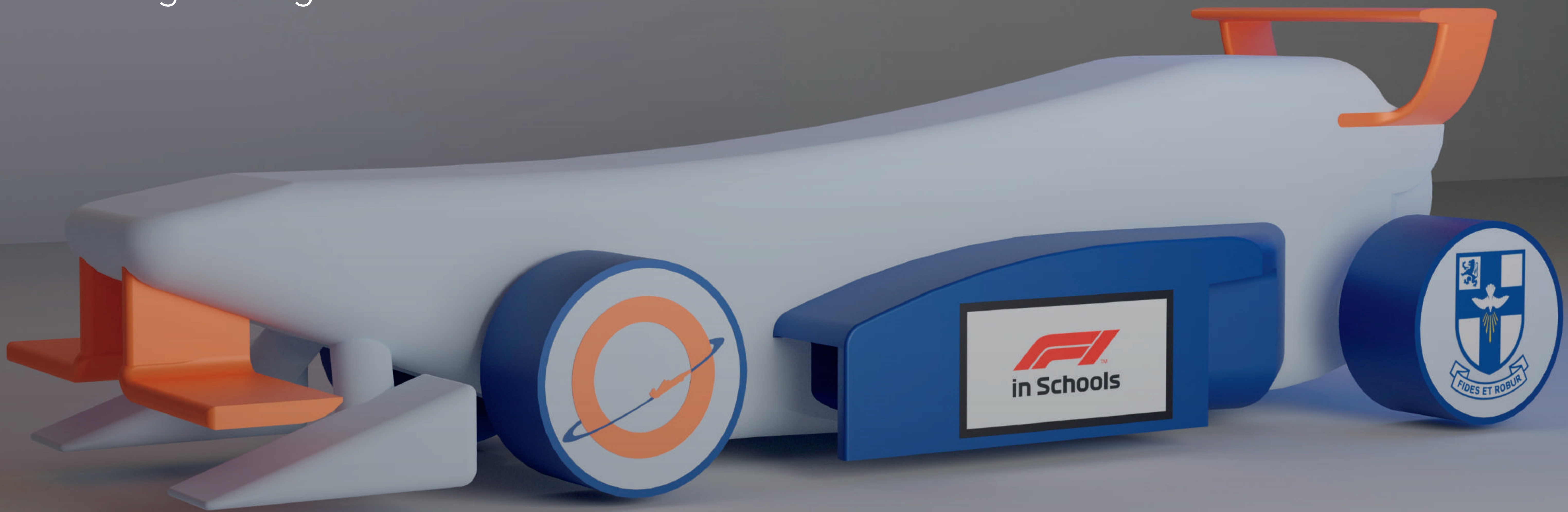
ORBIT RACING

F1 in Schools Ireland

Ireland National Finals

Engineering Portfolio



ENGINEERING

May 2023

INTRODUCTION & RESEARCH

Introduction

Welcome to our F1 in Schools engineering portfolio. This is a comprehensive presentation of our journey as a team in the international STEM competition, F1 in Schools. We are a group of highly motivated students with a deep passion for science, technology, engineering, and mathematics. Our engineering team has dedicated countless hours to design and build our model. We have not only applied our STEM knowledge and skills form online to real life but also developed our teamwork, communication, and creativity. Throughout this competition, we have faced various engineering challenges, from designing aerodynamically while keeping weight low, to optimizing the performance of our car on the track. These challenges have allowed us to apply our theoretical knowledge to practical, real-world problems, developing our engineering skills and expertise. This portfolio aims to highlight our achievements, challenges, and learnings throughout the competition, while also demonstrating our commitment to pursuing careers in STEM-related fields. We believe that this engineering portfolio will provide an in-depth understanding of our journey and passion for F1 in Schools.

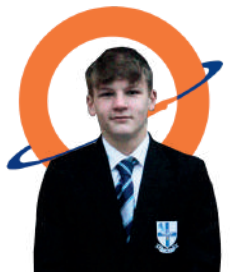
OUR TEAM

The **Engineering Team**

Oliver Lee

Role: Design Engineer
Skills: Canva, Fusion 360, Solidworks, Creative Design
Knowledge: Aerodynamics, Computational Fluid Dynamics, Computer Aided Design.

Conor Blackburn



Role: Manufacturing Engineer
Skills: Canva, Fusion 360, Simscale, Solidworks,
Knowledge: Aerodynamics, Computer Aided Design, Computational Fluid Dynamics.

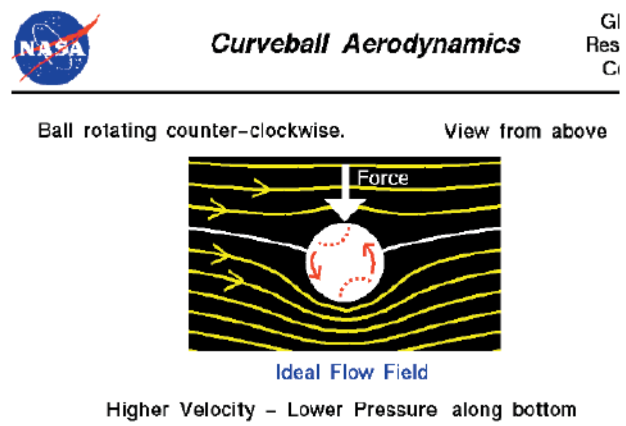
Aerodynamics & Air-Flow Research

Aerodynamic efficiency can be researched by using computational fluid dynamics (CFD) software. This software can simulate how air travels around a body, showing areas of pressure and turbulence. The CFD software we chose to use was SimScale. This allowed us to apply and analyse different concepts and effects that are prevalent in the automotive industry today, and use them to improve out F1 in Schools Car. This let us study how different parts of the car experienced the oncoming air and how pressure and turbulence was created on the car. It allowed us to identify these flaws in the design, and make changes to benefit the aerodynamic performance of the car by smoothing edges or even completely remodelling parts of the car. We used this software to predict the performance of the car under conditions that the car will experience during of the race.

Research

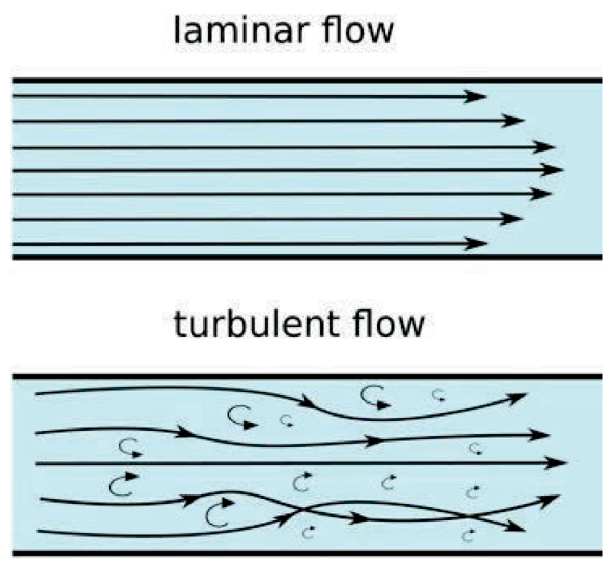
The **Magnus Effect**

The Magnus effect is the force exerted on a rapidly spinning cylinder or sphere moving through a fluid. As the wheels of our car are rotating in a forward direction, this createstop-spin. This essentially sucks the car onto the track, as a result of downforce. This effect can be minimised by either reducing the overall surface area of the wheels, or creating a smoother wheel surface. A great example of the magnus effect in the real word can be seen as breaking pitches, in baseball, as pitchers can manipulate the spin axis of the ball to alter the trajectory of the ball towards home plate, making it harder to hit, as the seams create friction between the ball and the air as it spins.



Laminar & Turbulent Air Flow

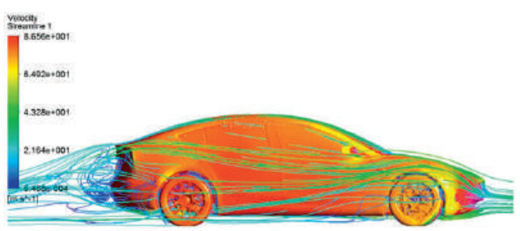
Laminar flow is the movement of air particles travelling in uniform, smooth and consistent straight lines. Laminar flow allows for predictability, in how oncoming air will act on a surface and will be assumed in many of our calculations. Turbulent flow is the opposite of laminar flow as it is disorderly, hard to predict and doesn't move in uniform to the surrounding air. Turbulent air flow presents many challenges to the aerodynamics of the car as it leads to areas of high or low pressure, slowing down the movement of the car. An example of turbulent air in the real world, can be seen on aeroplanes. When the plane travels through a turbulent airspace, the cabin will shake causing possible discomfort amongst the passengers.



RESEARCH & DEVELOPMENT CONT'D

Drag Coefficient

Drag Coefficient (expressed as Cd in formulae) is a figure that is used to measure resistance of an object moving through a fluid in relation to the frontal surface area. This formula will give an accurate representation of how aerodynamically efficient the car is. The lower the drag coefficient, the more aerodynamically sound the car will be. We used CFD to calculate the drag coefficient on our F1 in Schools car. SimScale was able to show what parts of the car were causing the drag coefficient to increase.
Drag coefficient is a very popular statistic in modern day electric road cars such as, the Mercedes-Benz EQS (Cd=0.20), Porsche Taycan (Cd=0.22) and the Tesla Model 3 (Cd=0.23). Features from cars, such as the ones listed, can inspire design features that may be used on an F1 in Schools car. One thing all of these cars have in common is a smooth path for the air to travel around the car, the streamlinming effect contributes to this factor.



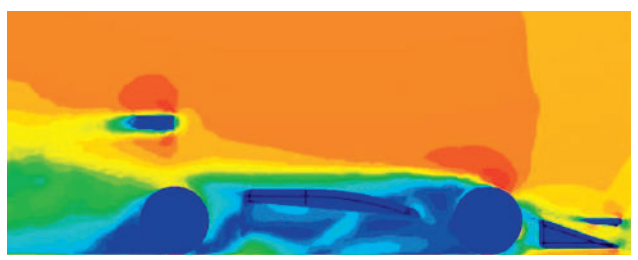
$$c_d = \frac{2F_d}{\rho u^2 A}$$

Weight

The weight of our car is an important factor that heavily affects its performance on the track. The lighter the car, the faster it can accelerate to top speed. To get as close to the minimum weight as possible, we designed the main body with minimising volume as a key in mind we removed weight from the car by adjusting the design. We removed material from the underside of the car to remove as much weight as possible. Other design features involve weight saving, without compromising performance, such as the front wheel guards.

CFD Analysis

During our use of SimScale, we noticed an area of low pressure, behind the body of our car. Instead of trying to remove this area of low pressure, we thought of how it could be used to our own advantage. Diffusion is a naturally occurring phenomenon that is described as 'The net flow of molecules occurring from regions of higher concentration to regions of low concern under the influence of concentration gradient.' The car accelerates because of this effect, as high pressure inside the gas canister, moves to an area of lower pressure, which is the surrounding air. We noticed that the area of low pressure would increase the rate of diffusion and increasing the cars acceleration.

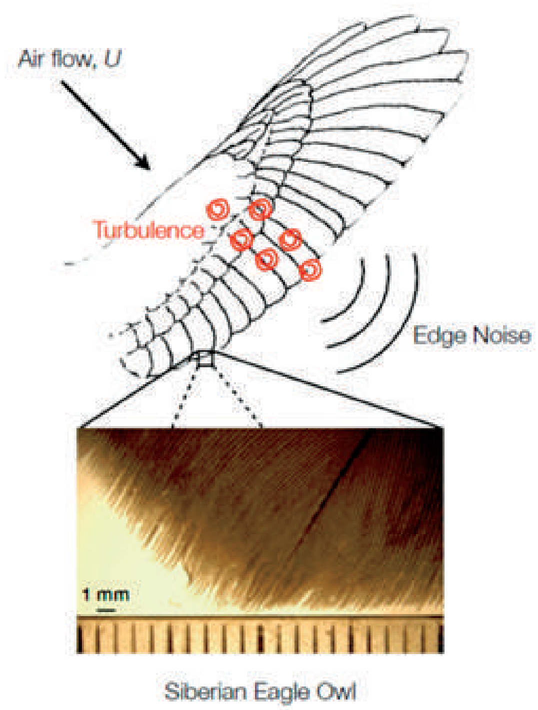


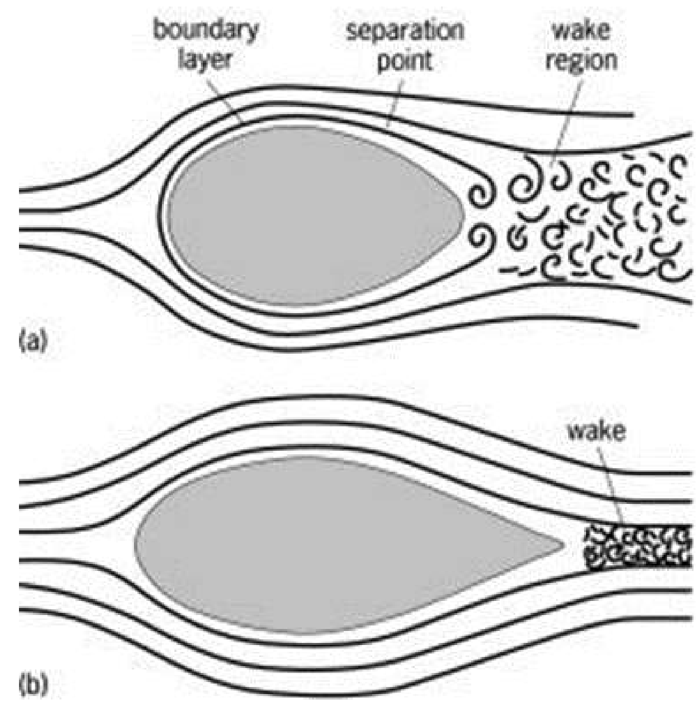
Centre of Mass

We also took the centre of gravity into consideration as is a critical aspect of any vehicle's design, including an F1 in Schools car. It refers to the point at which an object's weight is evenly distributed, and it is essential to maintain a centre of gravity in the middle of the car to achieve optimal performance and stability. If the Centre of gravity is too far forward it will cause the car to crash before the end of the race, but alternatively, if the centre of gravity is too far back the car will have too much lift. The centre of gravity will always be towards the back due to the air canister, but we have also taken that into consideration and added more weight to the front wing.

Streamlining

Streamlining is a design feature that improves efficiency of a body moving through a fluid. This feature involves an object having a smooth body with a gradual taper towards the end of the object, reducing the wake formed behind the object while moving through the fluid. A blunt object would be the opposite of a streamlined object. It would have a large wake due to a sudden drop off, of the width in the rear of an object. Great examples of the streamlining effect can be found in nature. If you compare the wings of a chicken, and the wings of an owl, you will notice that the shape of the wings and feathers are optimised to be energy efficient while flying. This is how owls catch many of their prey. The prey cannot hear the owl coming, as very little of the energy used to flap their wings is converted into sound energy showing aerodynamic efficiency. A chicken on the other hand has quite the opposite effect, as they make a large amount of noise due to the inefficient nature and shape of their wings. We used this concept to improve the efficiency of our front and rear wings.





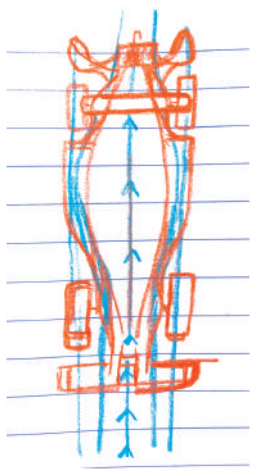
RESEARCH & DEVELOPMENT CONT'D

Introduction

To design our team's F1 in Schools car, we used Autodesk's CAD (computer assisted design) software, Fusion 360. The design process involves various stages, starting with an idea, that becomes a sketch, which is then modelled on CAD software and finally tested for stress patterns and aerodynamics, using, computational fluid dynamics, before being created into a physical model.

Sketching

Sketching is the initial stage of the design process. The base idea is usually sketched on a piece of paper, as a rough sketch. These sketches are used as concepts, which will be experimented with during modelling and aerodynamic testing, to make changes that will benefit the performance of the car. Many different sketches come together to create an overall improvement to the car. An idea can come into mind at any time so we always make sure to photograph any sketches we do.



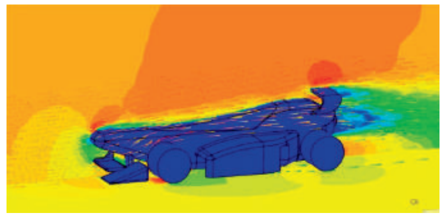
We used Fusion 360's sketching tools to develop the car's basic shape and form. The sketching process enabled us to explore different design concepts and experiment with different geometries and design features, and develop a clear understanding of the car's overall form. These sketches can then become bodies within a project. The bodies can be manipulated and formed to the designers liking.

Modelling

After finalizing sketches, we moved on to the modelling stage, where we used Fusion 360's parametric modelling tools to create a 3D model of the car. We tecperimented with using forms, extrusions and a variety of other modelling techniques. The modelling process involved creating the car's various components, including the chassis, wheels, and aerodynamic components. We used Fusion 360's advanced modelling tools to ensure that each component was precise, accurate, and met the competition's technical regulations.

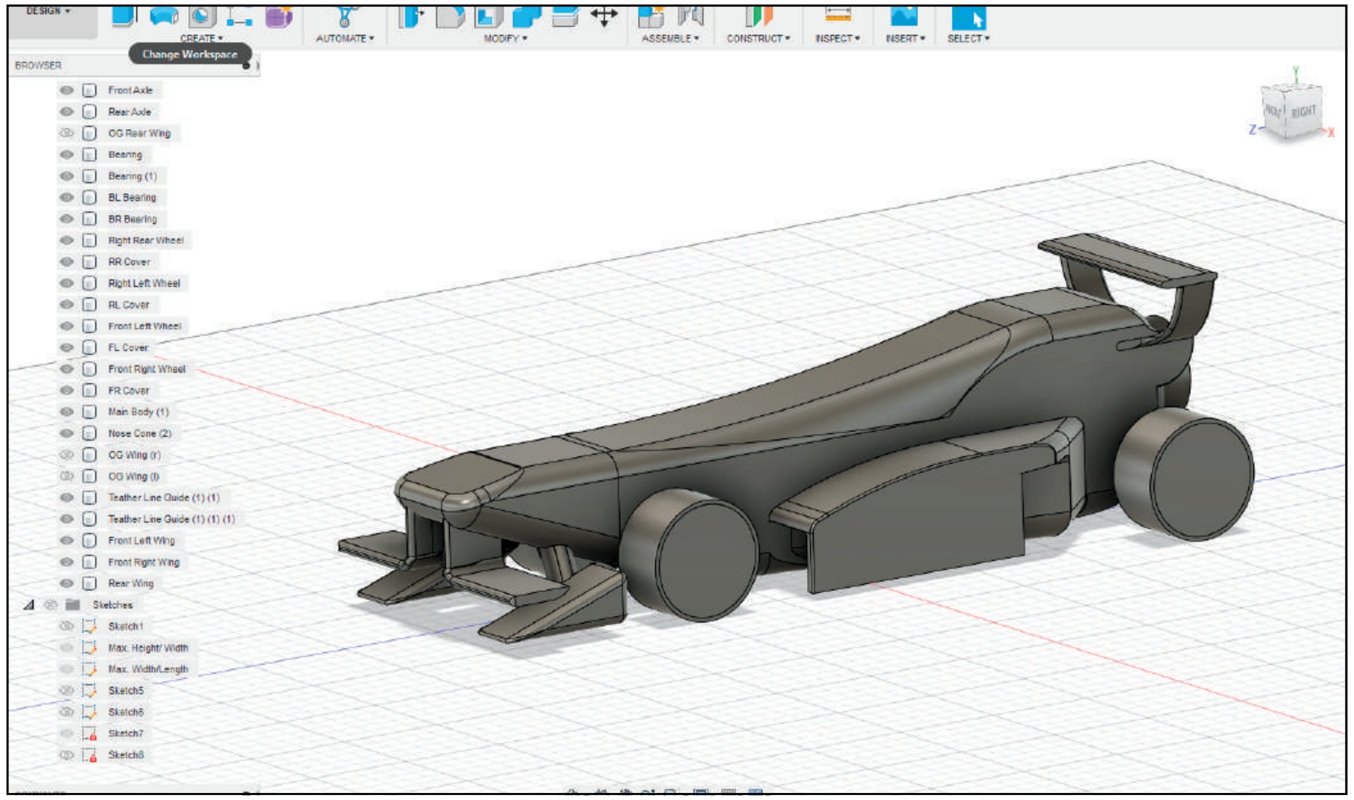
Simulation

Once the 3D model was complete, we used Fusion 360's simulation tools to analyse the car's performance. The simulation process involved analysing the car's stability, and structural integrity. Using these simulation tools, we were able to identify potential design flaws and make necessary changes to ensure that the car would perform optimally. We also used SimScale for running CFD tests on the car to find statistics such as drag coefficient. Our goal was to lower our Drag coefficient as much as we could, while keeping the weight of our car as close to our 50g goal. On every new design model we had, we would run a new simulation on to visualise our improvement.



Conclusion

In conclusion, our experience using Fusion 360 to design and develop our team's car was very rewarding. The ease of use allowed for an overall enjoyable and interesting experience. Fusion 360's powerful CAD, modelling, and simulation tools enabled us to create a precise, accurate, and innovative design that showcased our team's technical skills. I believe that using modelling software such as Fusion 360 can give a good insight to the creative process of engineering. We look forward to utilizing these skills in the future.

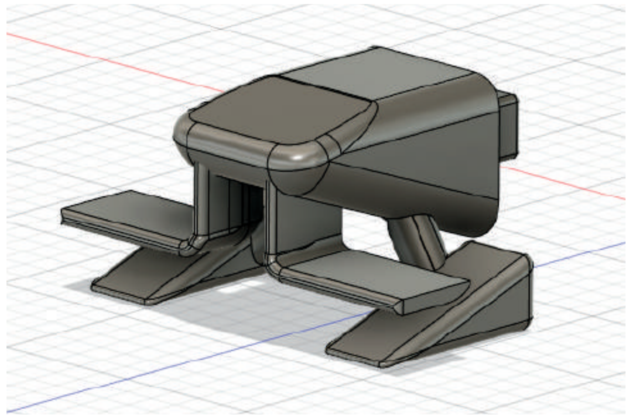


Research Evaluation

We wanted to use our initial research, in the design of our car and applying it when we could. We used every aspect of our aerodynamics and air flow research in the car body, front wing and rear wing to make sure it was as efficient as possible. We used our SimScale simulations to find areas we could improve on and adjusted the car accordingly.

Nose Cone & Front Wing

The nosecone was the first component to be designed on the car, the reason being that it is simply the first object that will be affected aerodynamically. This means that the rest of the car can be built to accompany the airflow from the front of the car. There are three main components to the nose cone: the main nose cone structure, the wheel guards and the front wing(s). The goal is to get air to flow smoothly over the front components, wile minimising surface area. This will mean that there is minimal friction between the air and the car, leading to less turbulent air and drag.

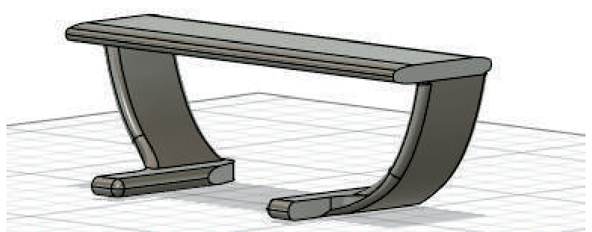


The wheel guards create a ramp, so that air can smoothly travel up and over the front wheels, reducing the frontal surface area and minimising air getting stuck under the wheel, to prevent creating an area of high pressure, reducing lift underneath the wheels.

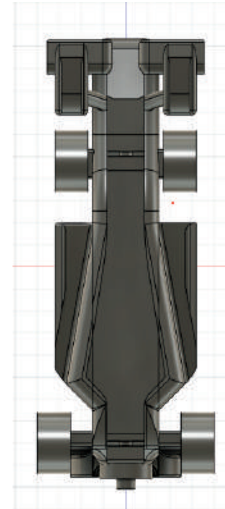
Our design engineer decided that having two front wings would be a beneficial feature to include in the cars design. It allows for smooth airflow underneath the car as it provides a gap for air to flow straight to the cars underside without a wing disrupting the airflow. The goal for the front wings is, to exist while creating minimal disruption to the surrounding air, this means that a simple design with a tapered end is ideal. Our front wings taper slightly upward to continue the smooth flow of air over the front wheels, as they are located above the wheel guards.

Rear Wing

The main goal of the rear wing is to make sure that the surrounding air is disturbed a little as possible. Ideally the car would not include a rear wing, so it needs to have a minimal impact on the car's aerodynamic performance. The first sketches of the rear wing were very basic and elliptical, creating a smooth object which contains both the support structure and the wing itself. We took inspiration from many other teams as elliptical seemed to be the normal across F1 in Schools Cars. The leading and trailing edge of the wing are the most important features of the rear wing, as they will dictate the overall aerodynamic efficiency of the structure. The chamfer and fillet tools were used to create a smooth leading and trailing edge on the wing and its support structure. It is also important to keep the overall surface area of the rear wing minimal to reduce the friction of the air travelling around it. The wing attaches to the car by sliding into a slot cut out of the chassis to fit the support structure and wing.



Side Pods

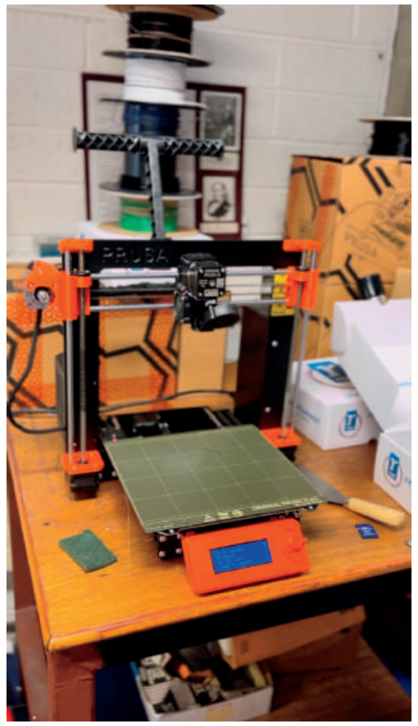


The sidepods of our car act as a feature to streamline the air, over the space in between the front and rear wheels of the car. The sidepods begin with the front, being lower than the middle and end of the sidepods. This catches the wake created by the front wheels and smooths the air, to flow towards and over the rear wheels. A design feature that helps the flow of air around the rear wheels of the car, is vent or an 'air curtain' that collects air from behind the front wheels and moves it around the rear wheels. The 'air curtain' concept and can be seen as a feature of many modern-day cars. Air curtains a are relatively new aerodynamic concept. The flow of air coming out of the vent pushes turbulent air from in front of the wheel, away so it doesn't affect the car near as much as before.

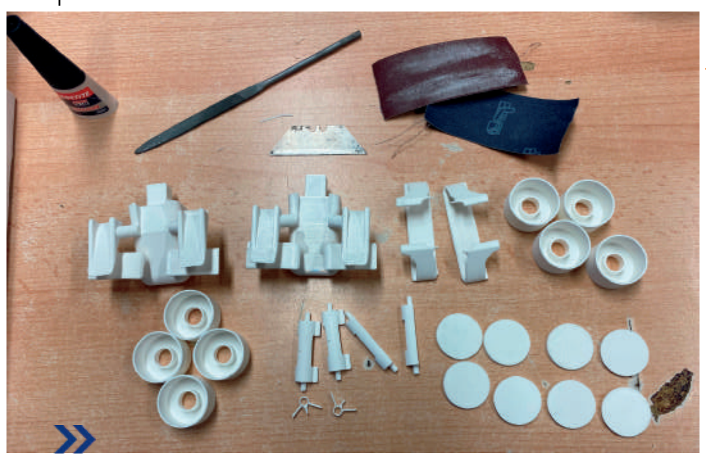
3D Printing

From early on in the competition we had access to a 3D printer in the school. It was not the most precise but allowed us to see our car in real life motivating and inspiring us to keep going. Our first print was the whole car in one full piece which made it easier to see where we had flaws and helped us get a sense of what the finished car would look like. We used the 3D printer numerous times after this to print out smaller parts such as the front wing, rear wing and wheels. We found printing out pieces brought the car to life and helped us identify strengths and weaknesses in the cars design.

3D printing was a slightly different process from milling. Instead of starting with a block and cutting away the excess material, it is formed from filament which is extruded onto the printer platform to produce the desired car component. While it may be cheaper and have more room for experimentation than the milling, it does have its downfalls. One of these downfalls is precision. Due to the heat used to melt the filament, it causes expansion. To overcome this challenge, we sanded and filed down required components that were not to our desired precision so that they could be fitted seamlessly the rest of our car. As previously mentioned, we had an Ultimaker S3, 3D printer located in our school, and there are a number of Pursa MK4 3D printers in the engineering workshop in Trinity College Dublin that were used for the construction of the car. This meant we could find the perfect proportions to print at that accounted for the expansion. This meant we were ready and confident with our design when it came to getting it professionally printed and meant we required minimum sanding leading to a better overall finish both visually and performance wise.

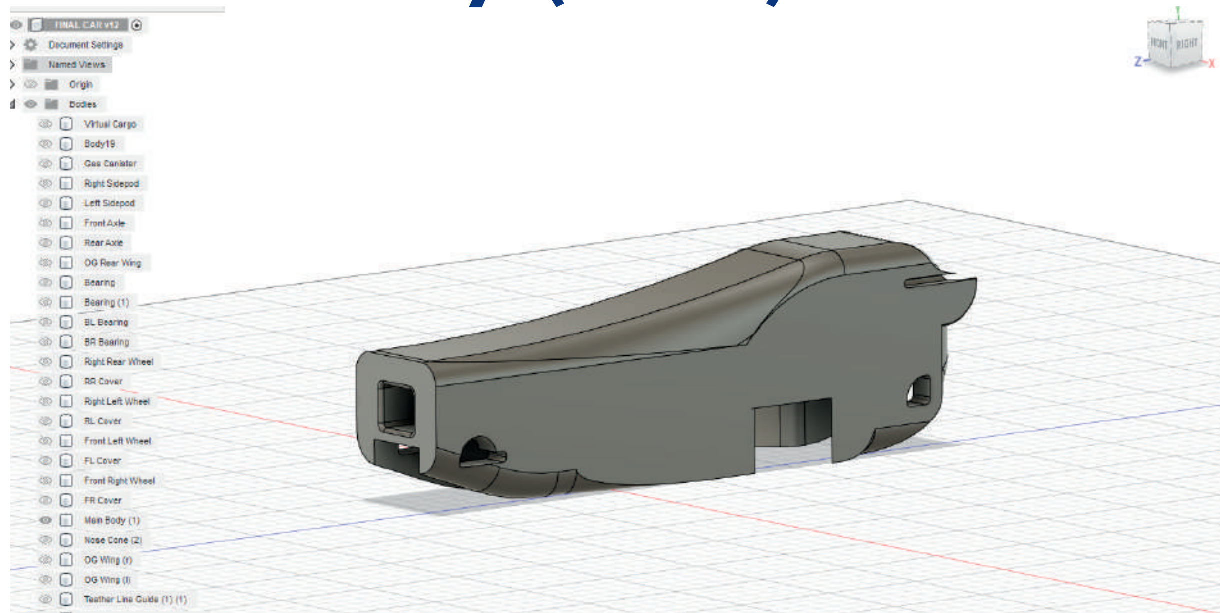


Prusa MK4



3D Printed Parts

Milled Body (CAD)



Construction

When it came to car assembly, we wanted to get everything perfect as we had seen other teams fall down in some areas so therefore had no excuse to make these mistakes. A common mistake talked about when it came to car assembly, that we had heard from multiple teams, was time management when it came to painting the car. We had heard stories of teams not leaving enough time between using primer on their car and using the actual colour causing mixing and leaving an overall worse finish. To avoid this, we made sure to leave the required amount of time for the primer to dry and used multiple coats for a smooth finish.

We had mentioned how the car pieces were previously tested with our school printer, allowing us to determine the exact dimensions to use while taking all inconsistencies into account, meaning when it came to creating our final car, we had minimal sanding to do. We used our last coat over the paint once the main car body was fully assembled, closing any small seams that were left.

In terms of constructing the car, it was a simple process. To start, all the support structures left over from 3D printing had to be removed. This was done mostly by hand, and any bits that couldn't be done by hand, were done by sanding down the material to the desired shape. As we made sure to fabricate our parts with precision in our measurements, the pieces fit together like a LEGO set. Any parts that we had concern of possibly slipping or falling out of place, were superglued to make sure there was no unwanted movement of parts. Our tether line guides were attached with superglue, as the axles had to slot through a custom fitted hole in the side of the main car body, which the tether line guides wouldn't be able to fit through if they were connected to the axles. A set of four ceramic bearings, from Boca, were placed on the end of each axle and secured with superglue. The wheels could then fit over the bearings and the wheel covers on the wheels, both being secured with superglue

Materials

For the manufacturing of the car itself we wanted to find the lightest material possible while keeping it strong. Weight is a lead contributing factor to the competition, but we also focused on durability because if we were to use light weak material, we wouldn't be able to keep the car from breaking through transport and racing. When it came to the body of the car, we did not have any choice in material as it had to be the provided model blocks, whereas for the rest of the car, (rear wing, front wing and wheels), we had freedom to pick what we desired. While we wanted the material to be light and durable, we also wanted it to be solid and not flex. Another contributing factor was that we wanted to be certain all of our parts would fit into each other with perfection and have minimal seam lines. We needed a material that was precise, durable, light and rigid.

We decided the best material that suited all of these factors was 3D printer filament. We looked at a range of filament types, including ABS, Polypropylene and PLA and decided to use PLA. As it fit our requirements best. We had also looked into some hybrid metal and plastic filaments but decided against it due to the excessive weight. PLA was the strongest and lightest material while being solid and rigid. We used this for our nosecone, wheels, front and rear wings, wheel supports and tethers.

Name	Density (cm^3)	Tensile Strength	Minimum Print Thickness
PLA	1.24g	37 Mpa	1.2mm
Polypropylene	0.84g	21Mpa	1mm
ABS	1.04g	22Mpa	1mm

Manufacturing Process

When it came to getting the model blocks CNC'd we decided to use Trinity College Dublin. TCD have a Hurco VM-2, 3 axis milling machine. It is called a 3 axis machine as it operates on 3 axes, the X,Y&Z. 5 axis machines have two rotational axes, which makes it so that there is a minimal amount of cycles that a block has to go through when milling, making the process much faster. Because of our Enterprise team we had a lot of sponsorship funding to work with, giving us a wide range of choice with the assembly and manufacturing of the car.

Hurco VM2 3 Axis Milling Machine

There were numerous things we had to consider while designing the car in terms of manufacturing. As previously mentioned, we had to design our cars components to fit seamlessly into each other. We also had to design these components (front wings and nose cone especially) to be durable enough to survive the impact of deceleration and transportation.

We also took the thickness of the paint into account as we had seen other teams suffer a loss of points due to this. We looked into multiple forms of paint, but none compared weight wise to spray paint. We wanted to be certain that the weight of the paint would not affect our overall result because, after research, we discovered every gram added to the minimum of 50g equated to a few milliseconds extra in race time no matter the aerodynamics of the car. We concluded to using spray paint because it is both a thin and consistent layer of paint. It left us with a nice finish that was clean and light.

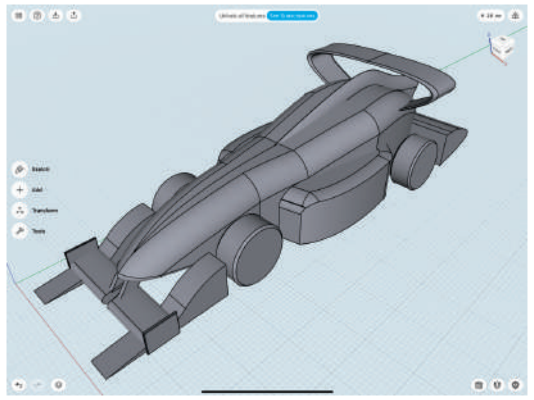
For the decals on the car, we used waterslide paper. To apply the decals, you print whatever you like onto the sheet of paper. You then submerge the paper into water for around thirty seconds, while keeping the edges held down to make sure they don't curl up. Once the sheet is taken out of the water, slide the film off the paper, directly onto the object you want to place the decal on. Once the water has evaporated, the adhesive will be active and the decal is done.

TCD Engineering Workshop

Car Development

Car design began as a number of sketches, done around September, 2021, when our design engineer first showed interest in the competition.
One design idea that was prevalent in these sketches was a dorsal fin, along the top of the car, which was supposed to improve the stability of the car. The inspiration behind this idea was to make sure the car would stay in a straight line, as video footage from national finals, in 2021, showed that cars moved from side-to-side, hitting the barriers and losing time as a result. We decided to stray away from this idea as although it could theoretically help the car travel in a straight line, if the car
was to move from its original path, it would also keep the car off its desired path.

To start our journey into the world of computer aided design, we used the free trial version of Shapr3D; an application run on an iPad Pro. The software of Shapr3D was much harder to use than fusion 360, as we quickly moved to Autodesk's Fusion 360 software, which was free as it was for educational purposes.



MK.1

Once the team had transitioned to using Fusion360, we experimented with the different types of objects we could create. We began using forms, which are objects that you can warp and form by pulling and pushing, edges and faces until you have an object you are happy with. This is how Orbit Racings Mk.1 Car was made. It was more of an experiment to learn how to use the software than an attempt at a competitive car.

MK.2

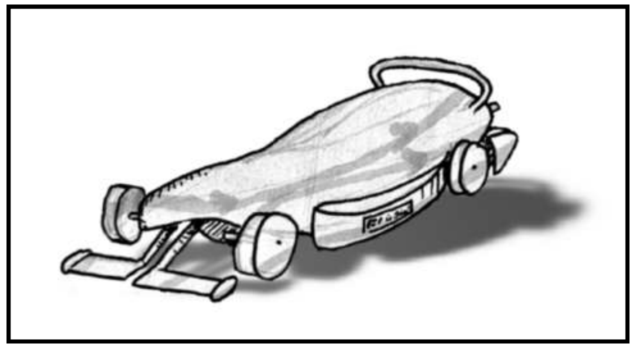
Orbit Racing's Mk. 2 car was our first attempt at creating an aerodynamic car that actually resembled an F1 in Schools Car. The design was very simple yet it used aerodynamic concepts such as streamlining. The finished product looked clean and presentable. This car started to take on basic technical regulations, but still didn't meet the all of the requirements.

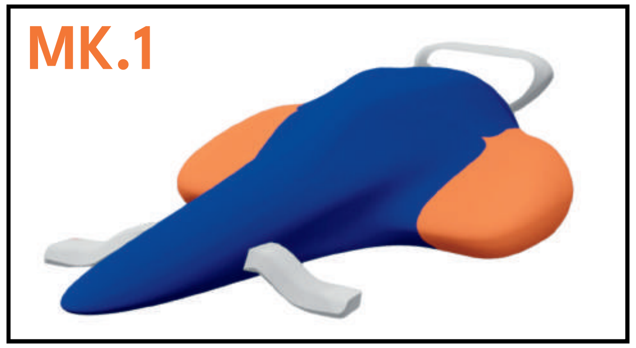
MK.3

Orbit Racings Mk. 3 car was supposed to be a starting ground for a car, in F1 in Schools Ireland's regional competition. Unfortunately regionals never took place, but as an upside, this gave us more time to research and perfect out car. This car stayed with the construction of using a form as the main body. Mk. 3 was vital in the teams engineering development, as we experimented with what was in regulations and how we could optimise the body within those regulations.

Per Aspera

Mk. 4.1 also known as, 'Per Aspera' translating into 'through diversity' into English from Latin is Orbit Racings final model for the F1 in Schools Ireland competition. It began as Mk.4 and is an amalgamation of all the knowledge gained over the previous three draft models. Our design engineer worked hard to make the car as efficient as possible through both aerodynamics and weight. This model was by far the most time consuming project on the engineering department. The car is fully in regulations, but with some close calls that almost slipped past our design engineer, however he has spent hours scruteneering snd making sure the car is in regulations and ready to compete against the other teams. This car has been modified from originally having a drag coefficient of 0.55 to under 0.42. We have compared this drag coefficient with other teams that have been successful in nationals and we have found that we have good enough numbers to win races, making reaching world finals is a realistic outcome for the team. The name, 'Per Aspera' shows how the car was made by going through adversity and achieving a goal.



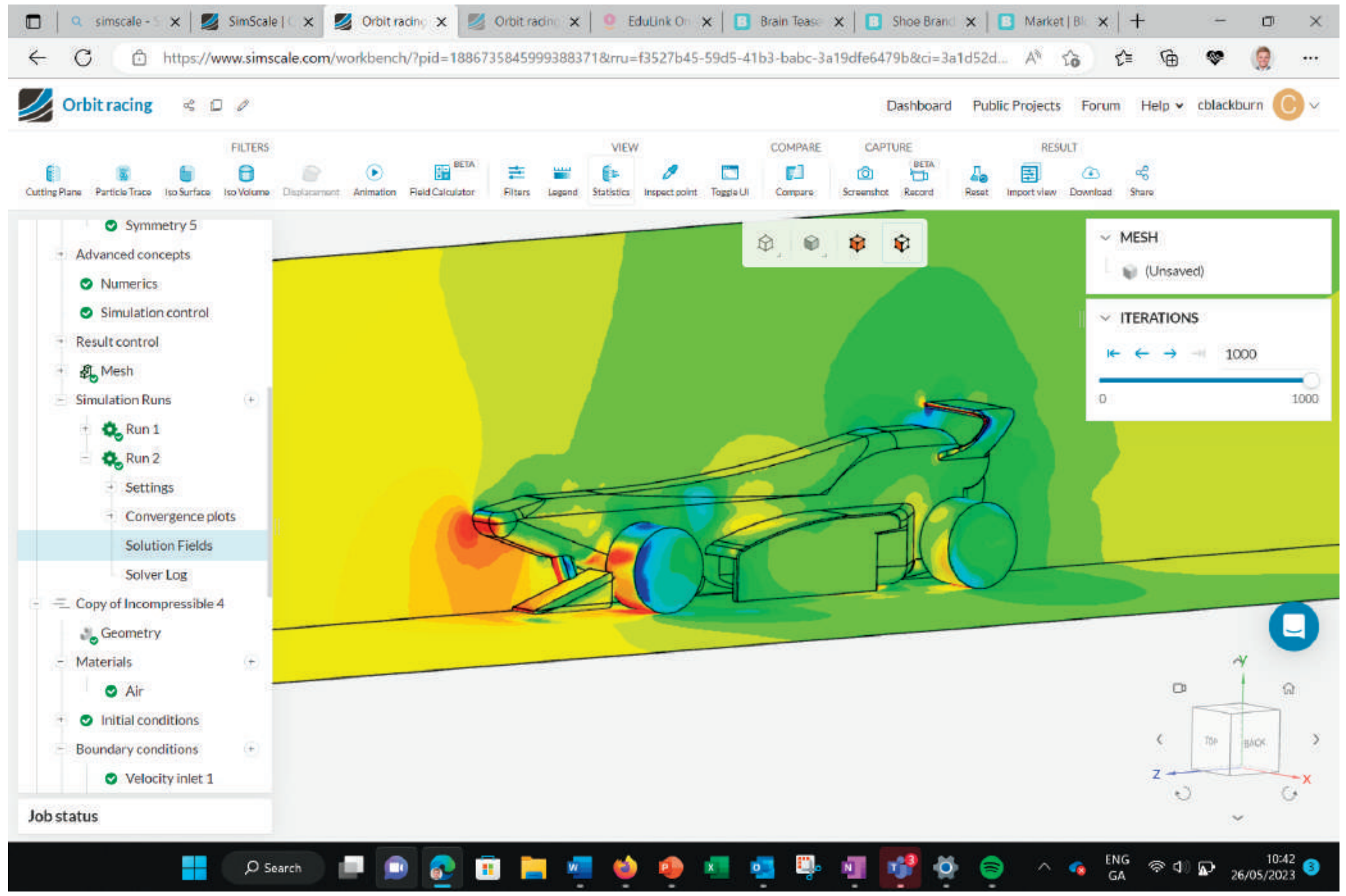


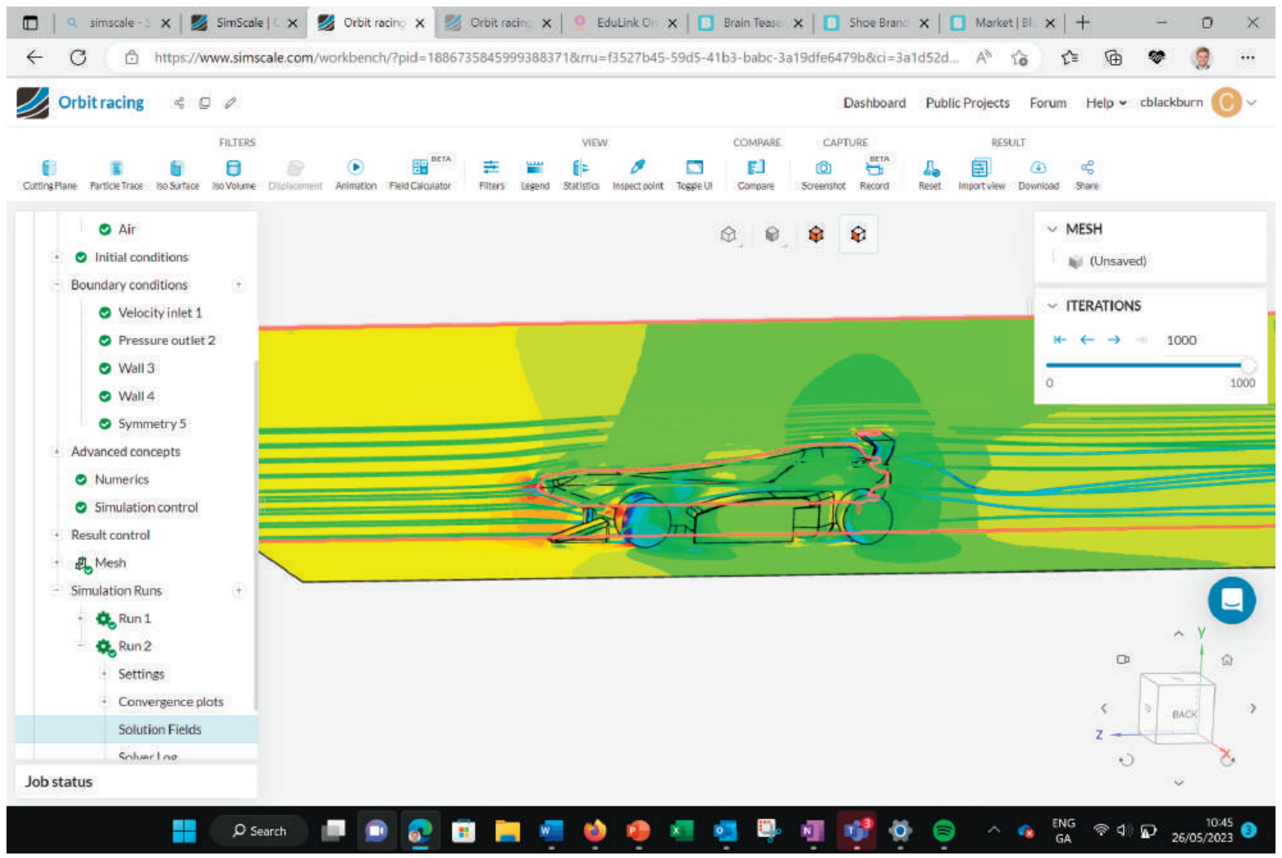
CFD Research

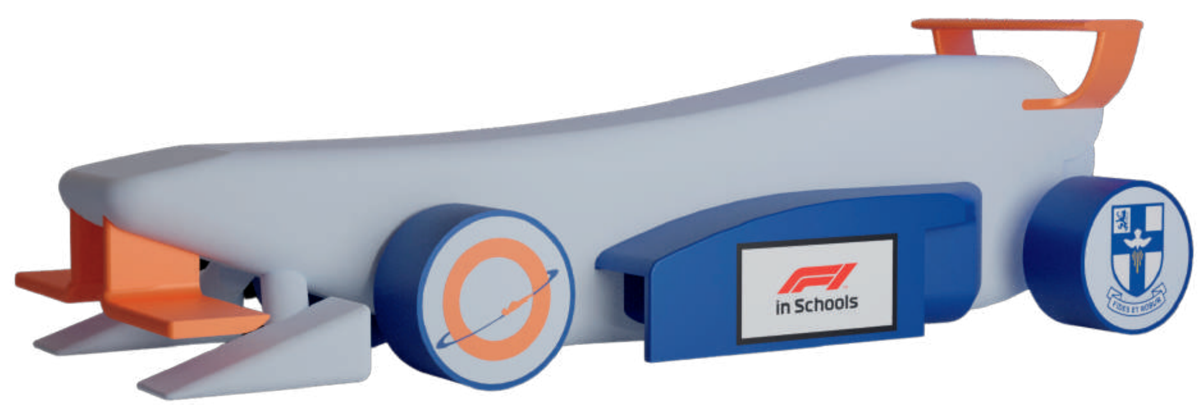
When it came to running simulations on the car, we decided to use Simscale. Simscale is a website that allows you to see how your design handles different conditions. For example, we were able to see how the air would flow over and around the car using their CFD (Computational Fluid Dynamics) software.

With this software we were able to set the conditions our car would be facing to as close as they would be on the track, making for an accurate result. Some of these adjustable factors included where the air would be coming from (which was front on from the car), how fast the air would be travelling (this simulated the speed the car would be travelling which is roughly 20m/s) and the centre of gravity (this is where the cars centre of mass is located). Using these simulations, we were able to identify faults in our car and redesign and fix areas before testing again.

Another statistic Simscale offered was the drag coefficient of our car. Drag coefficient is how aerodynamically efficient your car is. For example, a flat surface moving through the air would catch much more air than a pointed tip. We aimed to lower our drag coefficient with each simulation and eventually achieved our goal of below 0.42.







Engineering Evaluation

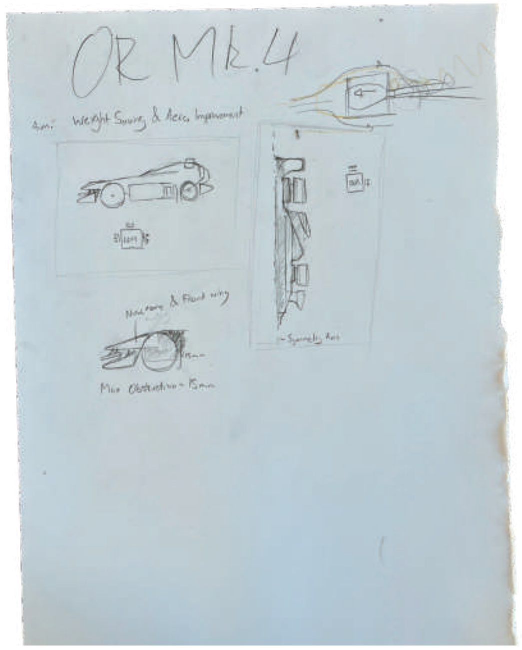
After many months and hundreds of hours of hard work and dedication, Orbit Racing's Engineering department have created our national finals car, OR Mk.4.1, or Per Aspera as the team has officially named it. A massive amount of effort and commitment has gone into the physics behind the car, as well as the manufacturing process and materials that we could make the car out of. We partnered with organisations with major connection to the engineering world such as Boca Bearings, being a big supplier for bearings across F1 in Schools and Roe Autocraft, having large a connection the Andretti IndyCar team. The team carried out many aero tests and conducted real world tests, to know the strength of the car, so it doesn't break on track. Each iteration of our car has gone through hours of simulation to optimise aerodynamics and efficiency on the track. We purchased the lowest fiction bearings possible to allow our chars wheels to spin as freely as possible. The team met in person and online four to five times a week for the course of roughly ten months. The final car was assembled with the upmost care and scrutineered to precision by the engineers. We have found interest and developed skills in CAD, CNC, CFD, improved creativity, communication skills and teamwork through this project. So much has been learnt about physical laws principles and effects of engineering The team has transformed from a group of students with a passion for STEM into a group of friends working together to achieve a goal. The whole team is very proud of getting as far as we have trough the quality of our work and how we have met our high expectations. The only thing left to do now is push even further as we aim for the World Finals.

Manufacturing Evaluation

After many hours of the car being milled and printed with precise machines and after all the hours of designing, finally the car is in physical form. It is very interesting and rewarding to see an object that has been designed on a computer for hours and hours, to becoming an object that you can hold in your hand. The smooth finish on the objects produces a satisfying feeling in the hand. The team is extremely grateful for the top of the line facilities we had access to, in Trinity College Dublin. Our manufacturing and design engineers, did a great job reaching out to, Professor Reilly, who was very kind to us throughout the manufacturing process. We were lucky to have a budget to pay for the services that were supplied to us. Once all the machined pieces were finished, the assembly was quite straight forward as we expected. We have access to top-of-the-line bearings, due to the help of our financial team, which excellently executed their job. Our engineers then primed and painted the car, giving it the same amazing look as the renders/ Waterslide paper was used to apply F1 in Schools decals and sponsorship logos. Looking back at the manufacturing process, we are very happy as to how the process was executed and it gave us a great amount of knowledge as to how parts can be created and machined. We are very proud of our work and hope to have just as good of an experience, should we advance past Irish National Finals.

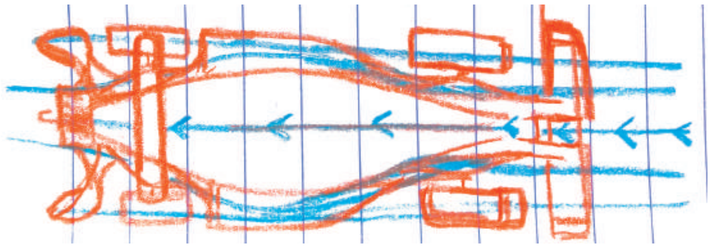
RENDERS, DRAWINGS & PHOTOS

Original MK.4 Sketch

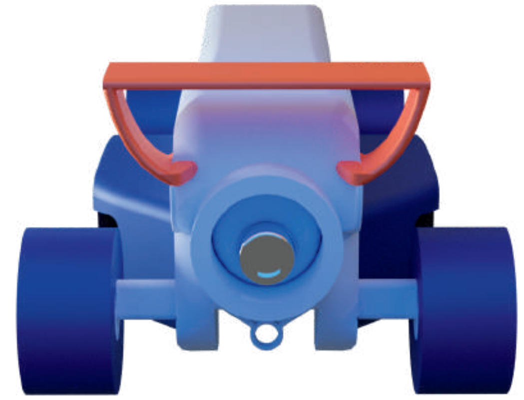


MK.4.1 Render

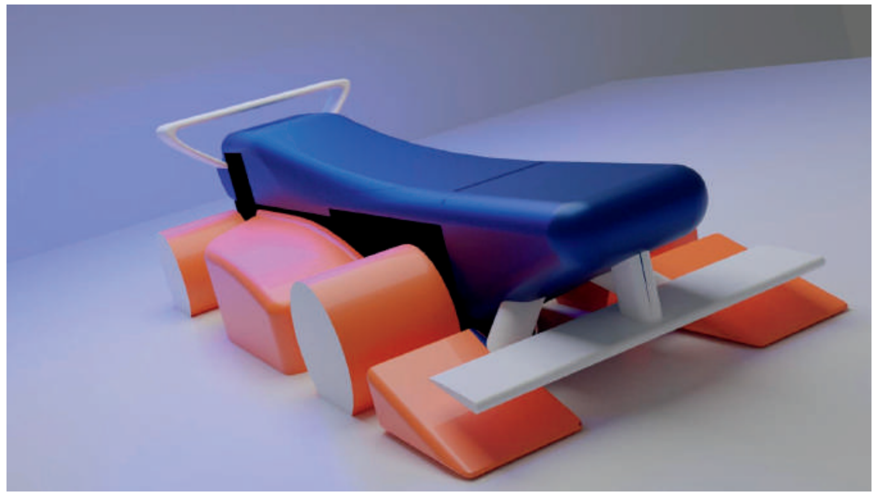
MK.4 Sketch



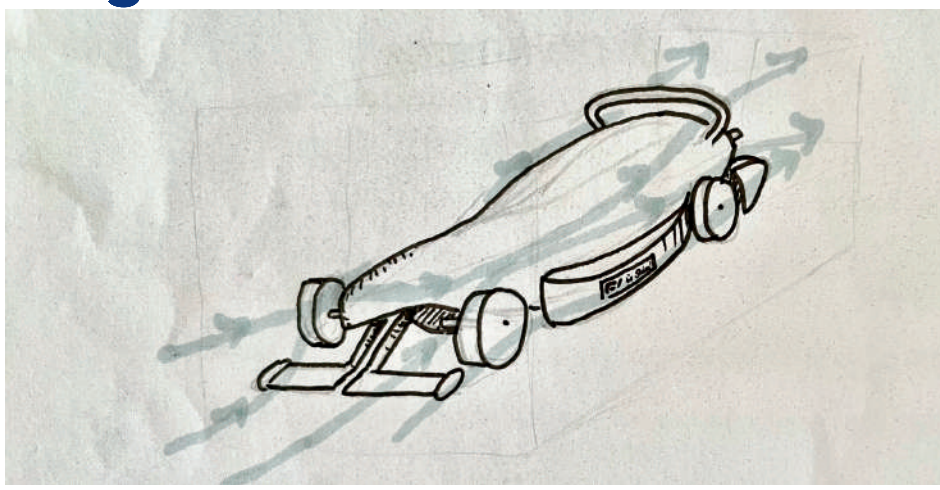
MK.4 Prototype

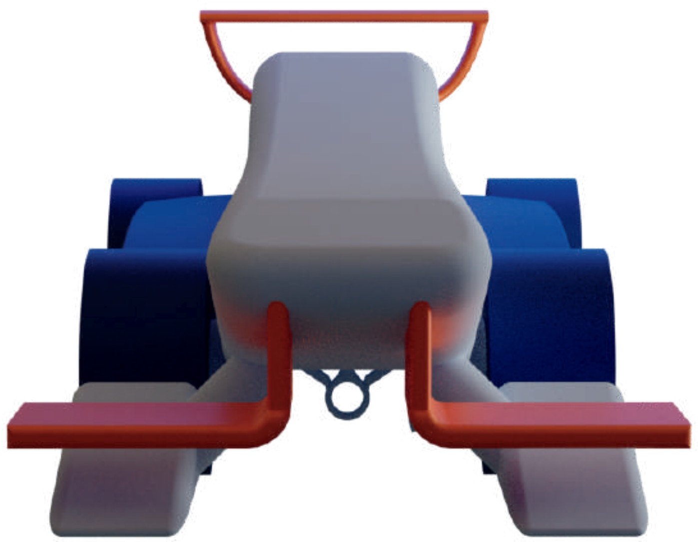


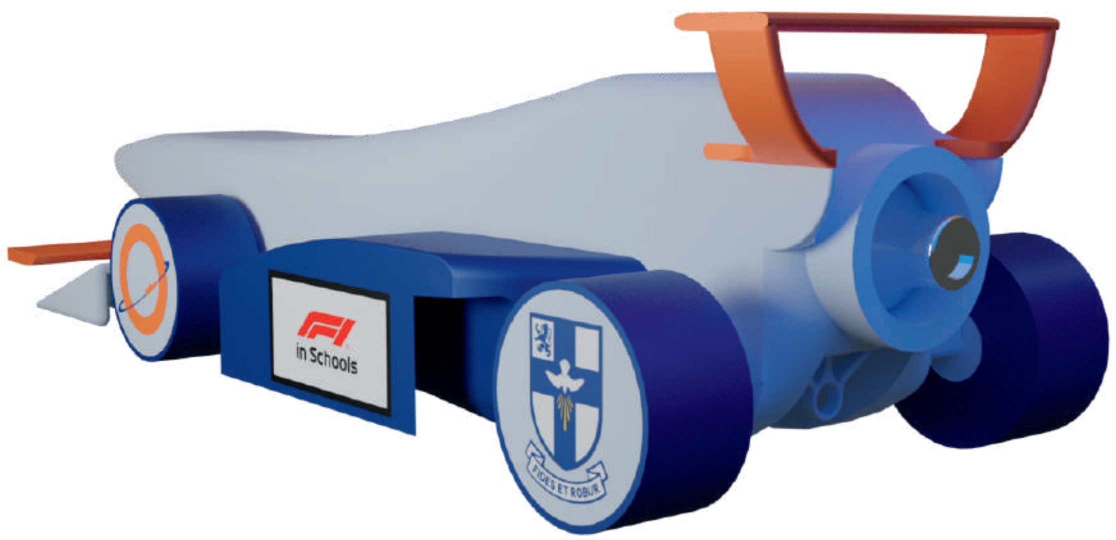
MK.4 Render

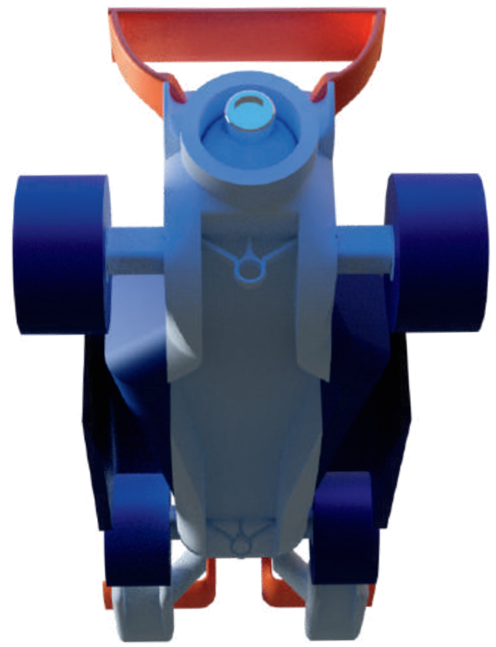


Original MK.3 Sketch









ORBIT RACING

F1 in Schools Ireland

Ireland National Finals

Engineering Portfolio

ENGINEERING

May 2023