NOVA RACING

ENGINEERING PORTFOLIO

Project Framework and Research

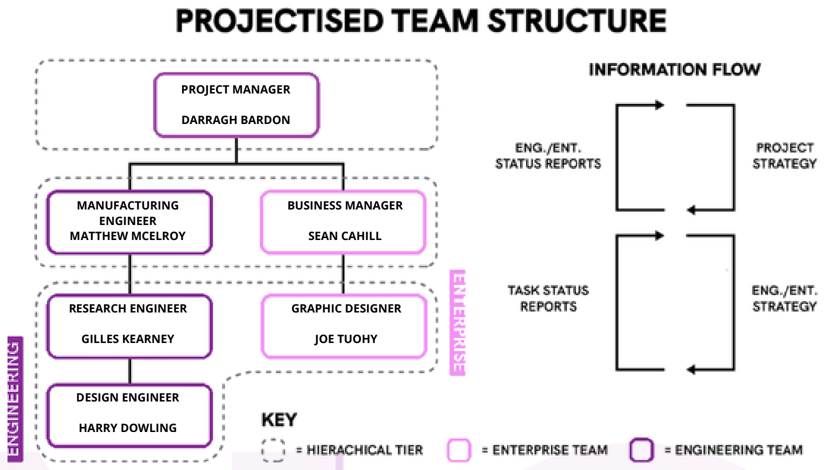
Introduction

In this portfolio we will explain the thought process and execution that went into designing our car and how we believe that our car is the optimal car for a straight line drag race. our aim in this project is to design a **high performing** car optimized for **speed** and efficiency.

In this project we have optimised our car with research, manufacturing and lots of testing. Alongside engineering and performance we aimed to develop a strong **team identity** and presentation. Ultimately our goal as a team is to make the fastest car on the track alongside maintaining our **team brand and innovation** also.

Project Structure

Our project was structured around a clear, engineering plan consisting of **research and development**, design, testing, manufacturing, and evaluation. Each phase was connected, allowing us to constantly be able to refine the car using analysis and research. We also assigned **roles** for each team member to ensure our work was completed on time

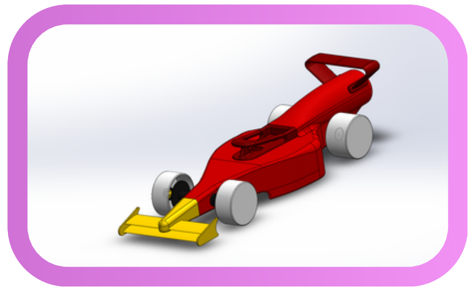


Initial research allowed us to make our first design decisions, which were then developed using **CAD** and assessed through **testing** methods. Insights gained from testing allowed us to make further design changes, ensuring performance was **optimised** and stayed within competition regulations.

This structure allowed us to use our time and resources more efficiently while maintaining our focus on performance and speed of the car

Process Overview

Our project stuck to a structured **engineering process** that we took time to develop before we started. We began with in-depth research into **aerodynamics**, **materials**, and **regulations** set by the STEM Racing competition. Using this knowledge, we developed initial design concepts and refined them through **CAD modelling and simulation to optimise speed and efficiency**.



The selected design was then manufactured using precision machining, followed by even more testing and evaluation. Feedback from testing was used to further refine the car, ensuring we improved it. Alongside this, we managed sponsorship, branding, and team organisation to deliver the best possible final product

Risk Management

Effective **risk management** was very important and responsible for the success of our project, ensuring that any challenges were identified, assessed, and solved quickly at every stage of development. Common risks included **manufacturing inaccuracies**, **time**, and limited **sponsorship funding**, each of which was planned for based on likelihood and the impact it could potentially have on the project.

Regular team reviews and **progress tracking** allowed us to respond as soon as possible to emerging issues, making sure the project remained **on schedule** and in line with our objectives. This strategy enhanced our reliability, **reduced any worry or uncertainty**, and supported the delivery of our final car **on time** and accurately.

Initial Research

Our research focuses on investigating the **key engineering factors** that influence the performance on our car. We studied aerodynamic principles to understand how **airflow affects drag** and downforce, including principles such as Bernoulli's principle, and how these can be applied to improve speed and stability.

In addition, we examine **wheel and axle** design and material to reduce friction and improve efficiency and most importantly save weight.

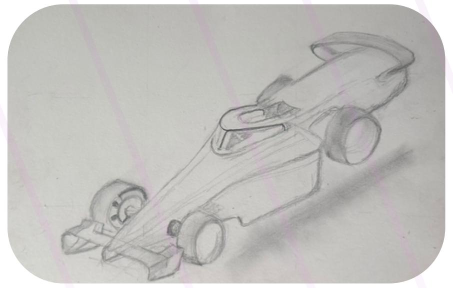
This research has allowed us to make **informed design decisions** and optimise the overall performance of our final model.

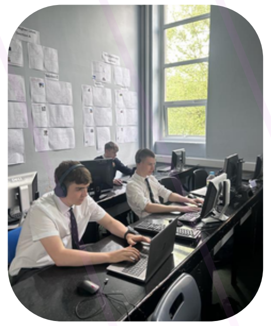
Engineering Timeline

Early in the year we made a timeline to ensure we could **finish the car and the portfolios on time**. This in combination with **assigning roles** to each person allowed us to finish the project on schedule

Ideas

Any ideas we had for the car we made sure to take down and bring up in any **weekly team meetings.** We also made **sketched down** any ideas we have and made sure to take them to discuss at meetings too





Key Findings

- **Structured engineering process** improved the car because of our detailed step by step process
- **Research into aerodynamics, materials, bearings**, and STEM Racing regulations helped us optimise our car
- **CAD modelling and simulation** were used to keep out speed and efficiency
- **Testing using CFD** allowed us to identify errors in our models
- **Reducing drag, friction**, and especially **weight** were our main focuses
- **Team roles and organisation** helped us get stuff in
- **Weekly meetings** helped us keep up to date on the project
- We implemented a **progress tracker** so we knew everybody was putting up an equal workload

Sustainability

Sustainability played an increasingly large role in our design process. We decided that we wanted to use a **renewable approach** to the project by minimising waste. We did this by only creating physical prototype models when we were sure they had a potential role in the future of the project. It also played a role in our manufacturing process by **choosing a supplier** for parts that **needed to be machined** that promotes **the sustainability movement**

Impact of Reaction Time

As part of our research we looked into the impact that **reaction time** really has on the performance of our car in such a short race. Although the CO_2 launch system of course gives **rapid acceleration**, the final outcome of the race can be heavily influenced by the reaction time of the **racer**. To fix this issue, we conducted several reaction time tests to see who is the **quickest**. This investigation helped our team understand our performance isnt solely determined by the car, but **also** by reaction speed of the **people controlling it**

Research & Development

Objectives

- ***Minimise inertia*** *and moment of inertia by concentrating mass towards the centre to improve acceleration and stability*
- ***Maximise aerodynamic*** *efficiency by reducing drag and promoting smooth airflow over the body*
- *Minimise friction in the wheel and axle system through precise alignment and smooth finishes and right materials*
- ***Reduce turbulence*** *(wake effects) around wheels and rear surfaces to lower air resistance*
- ***Optimise weight distribution*** *to keep balanced straight-line tracking and stability*
- ***Minimise frontal area*** *to reduce the amount of air the car must push through*
- ***Maximise laminar airflow*** *over the body to delay airflow separation and reduce drag*
- ***Ensure the car is strong and rigid*** *to prevent flexing or breaking at high speeds*
- ***Stay within regulations*** *and make the car as fast as possible while complying*

Inertia

Inertia is the property of a body that **resists change** to its state of rest or uniform motion. **High Inertia=slow acceleration** as more energy is used to accelerate the car from a stationary position. Inertia=Mass, so the mass of the car is directly proportional to inertia meaning if we lower the mass of the car we lower the inertia.
Moment of inertia is the resistance of an object to **changes in its rotational motion**, depending on its mass and how said mass is distributed around the axis. **Inertia=(mass)(Radius)squared).**

$$I = mr^2 \qquad \text{Inertia} = m$$

Aerodynamic Efficiency

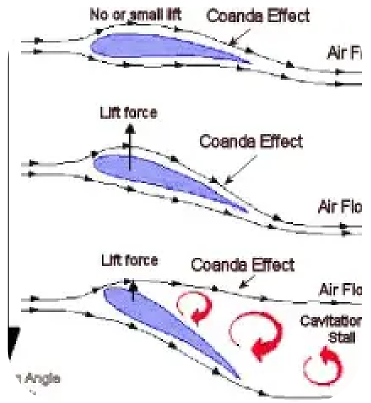
When planning our we researched every aerodynamic concept that is relevant to our car and then we decided which concepts are the most relevant and have the biggest impact on the speed and aerodynamics of the car.

- Magnus Effect and wheel wake
- Coanda effect
- Drag/Downforce
- Bernoulli's Principle

Coanda Effect

This effect is a phenomenon in fluid dynamics where gasses such as air or fluids will have the tendency to **follow the contour of a curved surface** instead of flowing straight off.

By applying this concept we cause high speed air flowing off our car to **"stick"** to the cars body this will then accelerate the airflow which will create a **low pressure** area which will pull the car down creating downforce increasing our grip and stability.



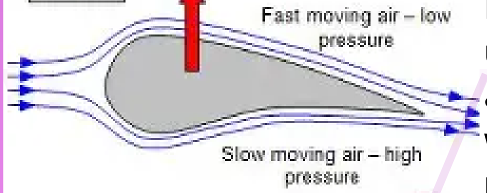
Magnus Effect

This effect occurs when spinning objects travel through the air causing **differences in pressure** on opposite sides of the surfaces. The spinning motion can cause air to move at different speeds at different sides of the the surfaces, this causes a lift force pepidicular to the direction the car is travelling in. we want to **minimise** as it can destabilize the car causing it to go of route and slow the car down.

Bernoulli's Principle

Bernouli's principle state that as the velocity of airflow increases, the pressure exerted by the air decreases.

Figure 1



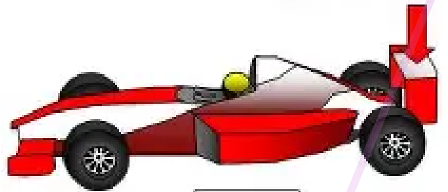


Figure 2

Bernoullli's principle helped us understand how air moves around our car. It shows that when **air moves faster, the pressure becomes lower.** We used this idea when thinking about aerodynamics, helping us design parts of the car to **reduce drag** and allow **air to flow more smoothly** around the body.

Bearings

Bearings are one of the most crucial parts of our car the bearings can **effect the inertia** of the car and how freely the cars wheels can rotate directly impacting the speed of the car.
We made a shortlist of three potential bearing for our car.

1. Silicon carbide ball bearings with a steel outer ring (Hybrid)
2. Full silicon carbide
3. Full silicone nitride

In the end we decided to go with the full silicone carbide bearings reducing our **net friction**. Although we had to redesign the wheel bore we found that the impacts where strong enough to **justify a redesign**. As these bearings are fully ceramic they allow us to reduce weight and decrease inertia.

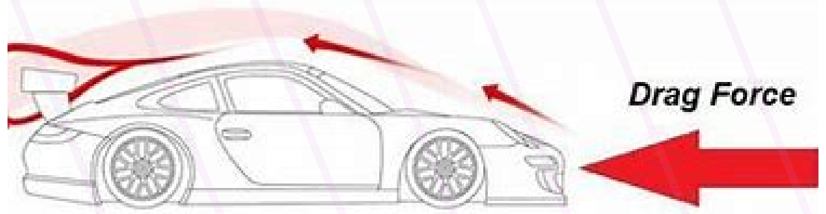
	Silicon carbide	Hybrid
Friction (Less)	★	
Weight (Less)	★	
Strenght		★
Thermal expansion	★	

Research Conclusion

As you can see on the table on the right the benefits of full-ceramic bearings **outweigh the strength** benefit of hybrid bearings as we will only be racing the car for three races they will not be put under significant stress.

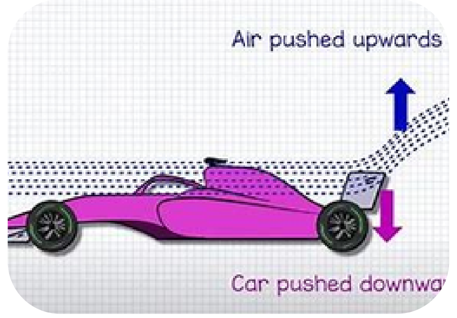
Drag

Aerodynamic drag is one of the key factors taken to mind when designing our car. This is because it is one of the main forces which **opposes motion** and decreasing speed. It is caused due to **air resistance** acting against the car as it travels across the race track.



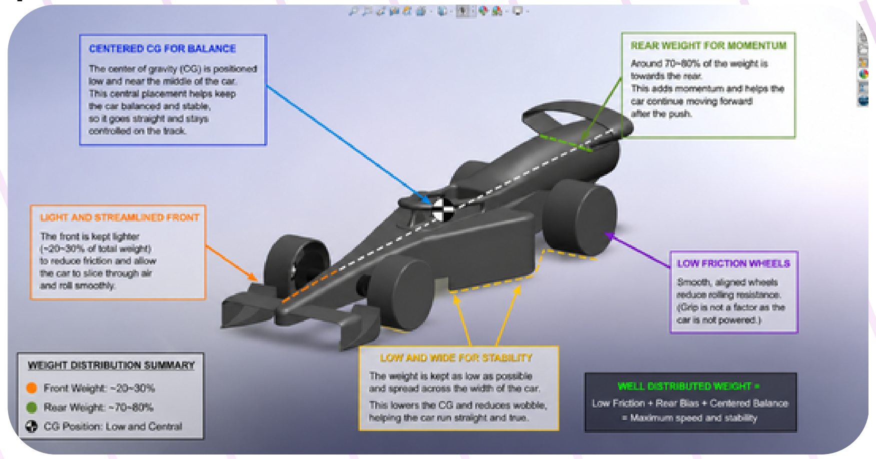
To minimize drag in the car we will need to create a **streamlined** body with **smooth curving corners** and transitions to allow air to flow cleanly around the car.
Formula for drag is: $F_d = \frac{1}{2}\rho v^2 C_d A$

Drag can also be used to our advantage by utilising it to **keep the car stable when racing.** Downforce is a force acting down on the car which means it pushes it down into the ground. While downforce is necessary it needs to be **controlled as it can create significant amounts of drag slowing down the car**



Weight distribution

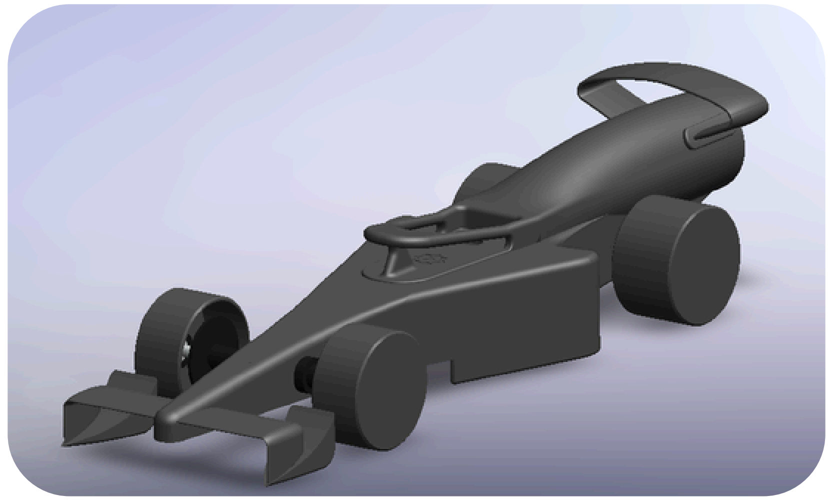
Our car's weight distribution is designed so that most of the mass is concentrated **around the centre/rear of the chassis**, with the front section kept as light as possible. This layout reduces the moment of inertia, meaning our car can accelerate more efficiently because **less energy** is wasted overcoming rotational resistance. It also improves **straight-line stability**, as the car is less affected by uneven forces at either end, helping it maintain **a consistent direction down the track.**
By minimising weight at the extremities, our car achieves better balance and more consistent wheel contact with the track surface, which reduces the risk of instability and **improves overall control at high speeds.**



Testing

Testing Process

The car was made while following our **design plan** and we focused on maximising **aerodynamic efficiency**, and **saving weight**. All testing was conducted using methods we could follow in school to ensure we had **full control over variables and repeatability of tests**. Each stage of testing directly informed design modifications, resulting in measurable improvements in performance across all key metrics.



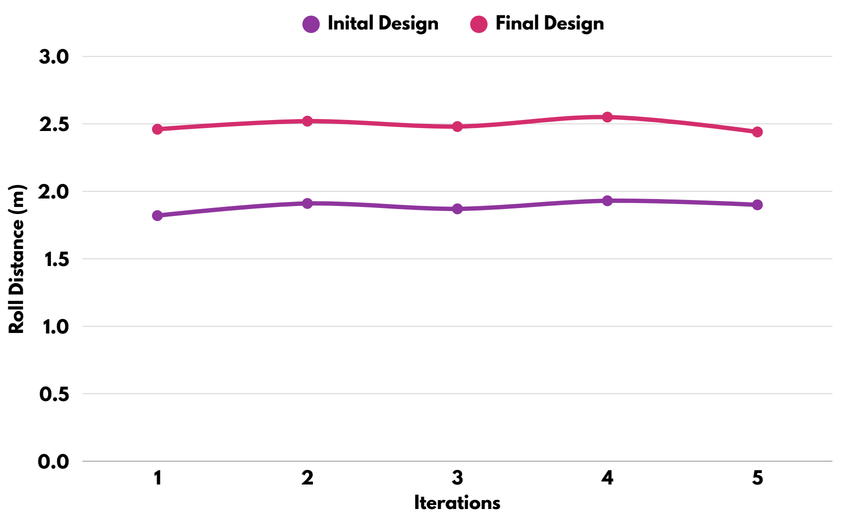
Final Model

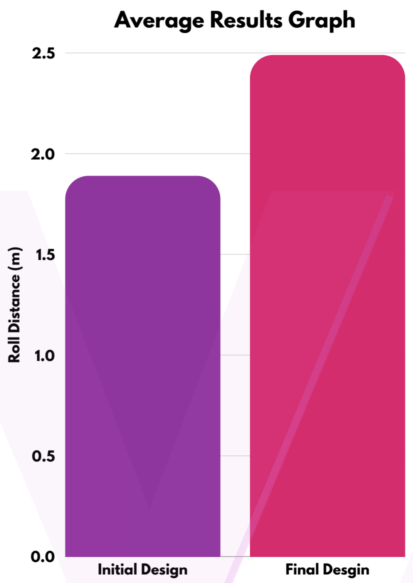
Evaluation

The final design demonstrates **clear** improvements across **all tested performance** areas, validating the importance of testing for the development of the final car. Aerodynamic refinement **reduced drag**, friction optimisation **improved our speed**, and stability enhancements increased consistency. The strong correlation between design changes and performance gains highlights a well-executed engineering approach. Overall, the car evolved from a **functional prototype** into a highly optimised, race-ready design supported by **reliable and repeatable data.**

Rolling Distance

Rolling resistance was assessed through ramp-based distance testing and wheel spin analysis. The initial configuration showed **significant** energy loss due to **axle friction and minor wheel-body contact**. Refinements including axle polishing, improved alignment, and increased wheel clearance led to a substantial improvement in performance. Rolling distance increased from **1.8 m** to **2.6 m**, while wheel spin duration doubled from **3 seconds** to **6 seconds**. These results indicate a significant reduction in frictional losses, allowing more efficient energy transfer during runs.



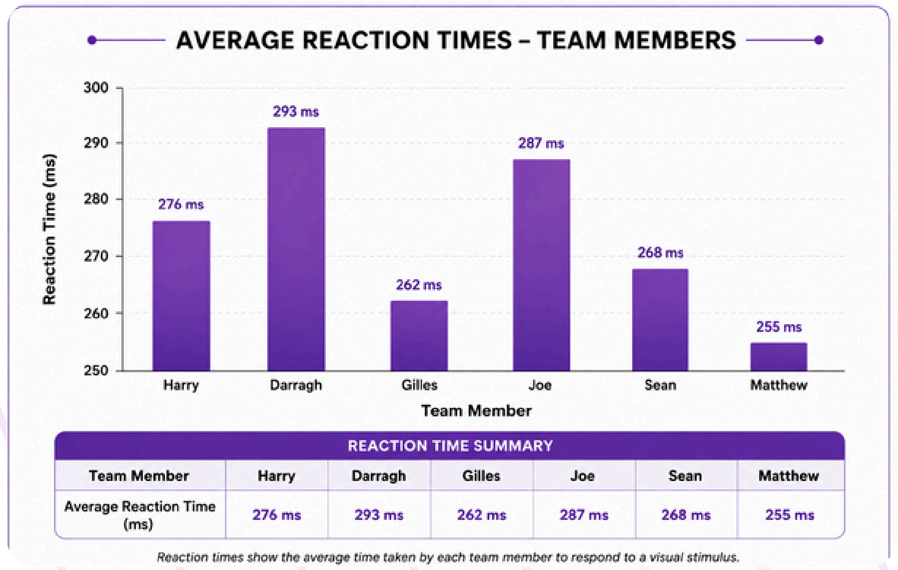


Test Run	Initial Design	Final Design
1	1.82	2.46
2	1.91	2.52
3	1.87	2.48
4	1.93	2.55
5	1.90	2.44
Average	1.89	2.49
Improvement (%)		31.7

Reaction Speed

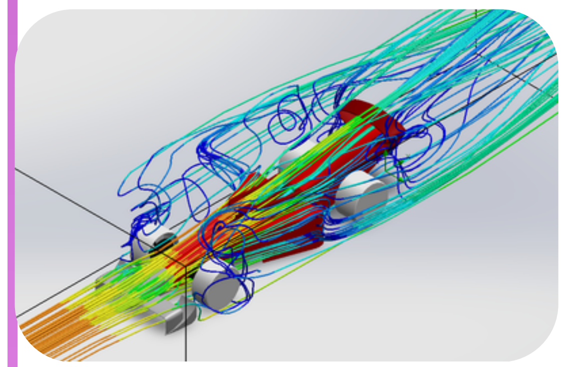
Reaction speed was one of the most important performance factors considered during testing, as STEM Racing cars complete the track in an **extremely short amount of time** where even **hundredths** of a second can determine the final race result. Since the cars are powered by compressed gas and accelerate almost instantly, the initial launch phase plays a major role in overall performance. Any delay in acceleration, instability or **unnecessary resistance** during the first moments of movement, almost always caused by **slow reaction times,** can have a huge impact on the final race time.

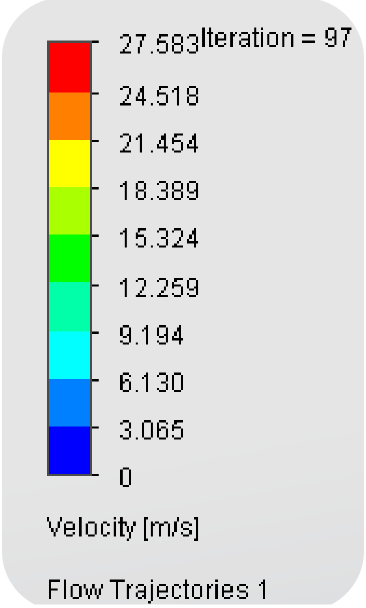
Testing our reaction speed was done by doing an online test where you tap a screen when the colour changes on our phones 3 times each. We then used the results to obtain an **average** for each operator and based on that average we decided who the **optimal race-starter was**.

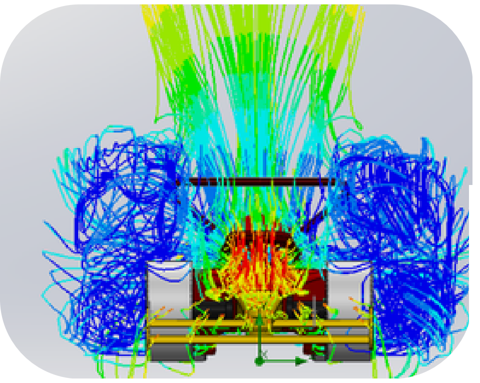


Use of CFD

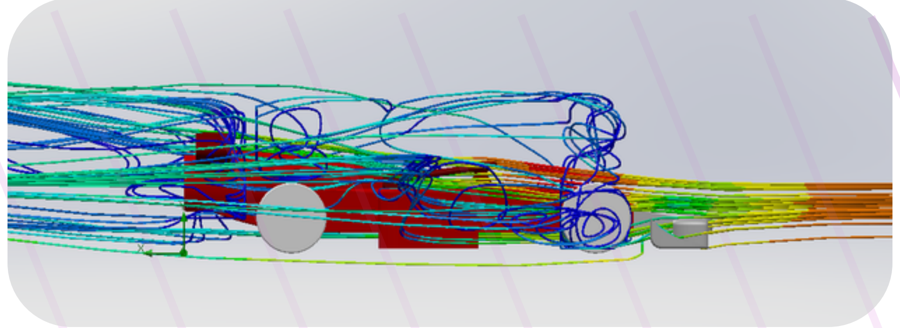
Our main virtual testing was with **CFD**. CFD helped our team of engineers understand how the **moving air** will behave around the car when its racing. By setting **race parametres** we were able to see an accurate simulation of the race on the car. We analyzed it using the images and **data** we were given by **solidworks**, which allowed us to make refinements to better help our performance on the track. This allowed us to make sure our **small sacrifice to our drag coefficient** for weight reduction and aerodynamics **weren't detrimental** to our performance







SOLIDWORKS FLOW SIMULATION



Manufacturing

Manufacturing Process

To ensure we developed a final car optimal for performance a step by step process for manufacturing was followed. We started with basic **sketches** and ideas applying our recently obtained knowledge on key aerodynamic concepts.

Following this, we worked with our design engineer and used some CAD models of the prototype to create 3D printed **concept models** of different parts of the car. We **tested them** to find the best one and then used those in our final model.

We worked with our kind sponsors Boston Scientific, a global medical technology company that develops and manufactures devices used to diagnose and treat a wide range of health conditions, to make SLA prototypes of our car.

Using **CNC** and the most optimal parts we designed our final car using the F1 Block, **silicon carbide** bearings and **PA 2200** for the wings and **Delrin** for the wheels.

Using our structure and plan we ensured that the **manufacturing process** was done on time and accurate

Materials and Why?

Wheels: for our wheels we chose Delrin. **Delrin is an engineering plastic**, also known as **acetal**. We found this material was perfect for our car as it directly targets **keeping our friction as low as possible** while also being strong enough for us not to worry about them breaking on raceday.

Wings: For the wings of the cr we decided to go with a SLS printed PA 2200. **PA 2200** is a type of **Nylon** which performs very well aerodynamically. We chose this material due to both its **reliability** in the field of aerodynamics and for its strength

Bearings: For our bearings we decided to go with fully **silicon carbide by BOCA**. We chose these because of their known ability to **minimize friction and importantly sparing us weight.**

Axels: for our axels we decided to go with **cold worked 7075- T6 Aluminium alloy**. We chose these axels to save us **weight** that would be lost to stainless steel axels. They are also very reliable and we can trust that they wont fault on raceday

art	Part 1	Part 2	Part 3	Part 4
ont wheel	2.8	2.8	2.8	2.8
Rear wheel	3.4	3.3	3.3	3.3
Front wing	4.7	4.8	4.7	4.7
Rear wing	1.8	1.8	1.8	1.7
Halo	5.1	5	5	5
Bearings	0.225	0.225	0.225	0.225

Assembly

During the assembly stage, we carefully combined all manufactured components to complete the final car. The wheels and axles were aligned and fitted to ensure **minimal friction** and **smooth rotation**, which is very important for achieving **maximum speed**. We checked that the main body was straight and balanced to maintain stability. All parts were assembled precisely to avoid unnecessary bad **weight distribution**, as even small errors can affect performance.

Tolerances and Precision

During manufacturing, we had to maintain a level of precision and **tight tolerances** to ensure the car performed as intended. Even small inaccuracies in dimensions or alignment could affect **wheel tracking**, increase friction, or create instability at high speeds. By using **CNC machining**, we were able to keep a consistent accuracy from the **CAD design**, virtually removing human error. We also checked key measurements throughout the process to make sure all parts **fit correctly** during assembly, helping us produce a reliable final design.

Tools and Machinery

For our CAD modelling software we decided to choose **Solidworks 2024** for the final model and **Onshape** for prototypes. We had used Solidworks and Onshape previously for DCG projects. Access to tutorials due to the popularity of the software helped us answer any questions about how to do different things

Fig 1

For our manufacturing tool we chose to use a 5 axis **CNC machine** provided by our sponsor **Boston Scientific**. CNC (Computer Numerical Control) is a manufacturing process where pre-programmed **computer instructions (G-code)** control machine tools to precisely cut, shape, and finish materials into parts directly from a digital CAD file with high accuracy. We learned from using CNC that it is accurate computer controlled machines are **essential for producing quality parts** for the final car (fig 1)

CNC aids us in reducing any **human error**, and also increases the **aerodynamics** of the car with **precise cutting**. We felt that a 5 axis machine would help even better due to its ability to cut shapes at any angle, while also **maintaining a clean finish**. It also allowed us to produce a more **complex shaped wing**, which would have been more difficult without the ability to do so

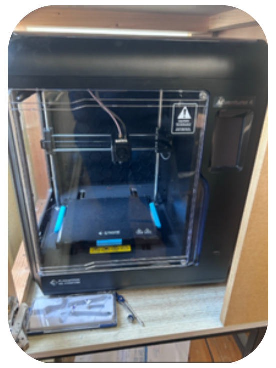
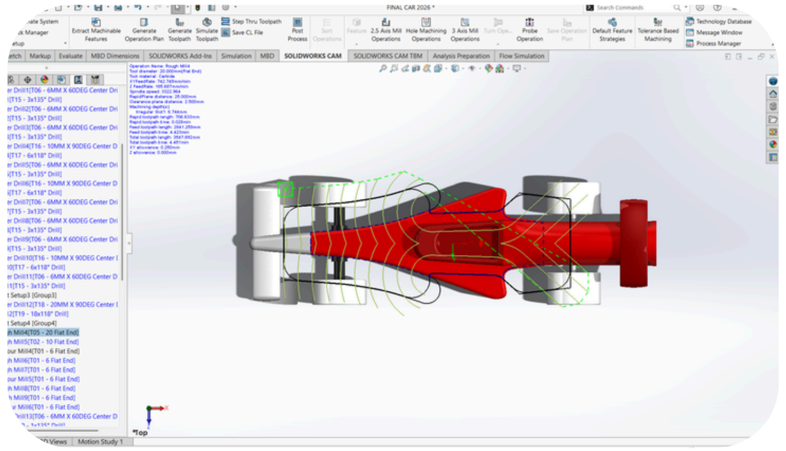


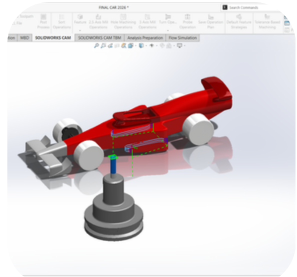
Fig 2

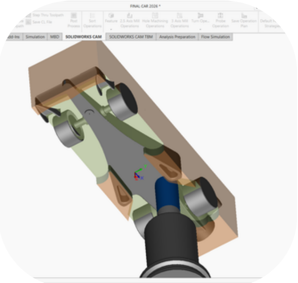
For our prototype models we used a **Flashforge Adventurer 4** (fig 2) using a PLA filament. We used the printer to turn ideas into physical models quickly.

Use of CAM

Using **CAM** helped us ensure the car would be manufactured accurately. By generating the **exact toolpaths** we need to cut the car body reduces any guesswork we would have to do. It improves our **aerodynamic efficiency** by reducing **roughness** in optimising cutting paths







What We Learned Through Manufacturing

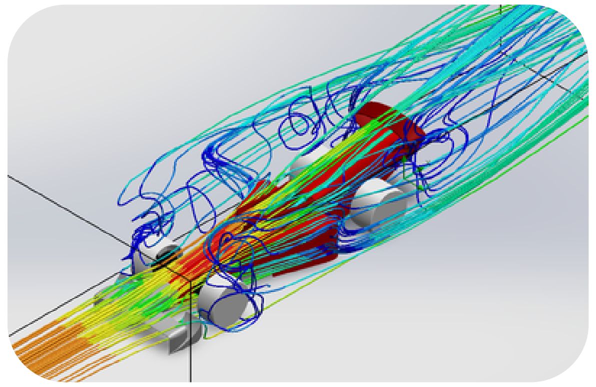
- how to work with **external suppliers**
- how to implement **CAM**
- why material choice is important
- how to make 3D models using a **3D printer**
- why using **CNC** is important for precise cuts
- how different manufacturing methods can affect different factors, such as **aerodynamics** and **ridigity**

CFD Analysis

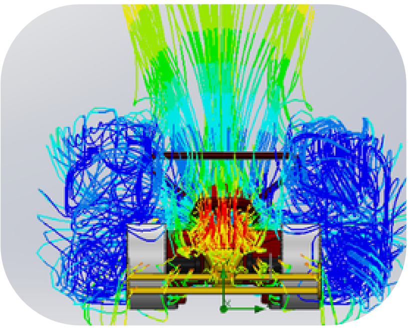
CFD Analysis

Once completeing our car on CAD we were able to use CFD to **conduct testing** on our cars aerodynamics and how the air is flowing around the car. The information we gather will then allow us to make adjustments to our orignal prototype to further increase our cars performance before proceeding to physical testing.

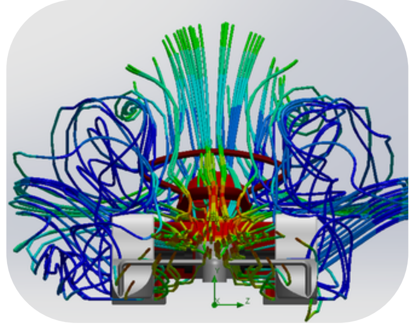
Front View



TR 41



TR 40



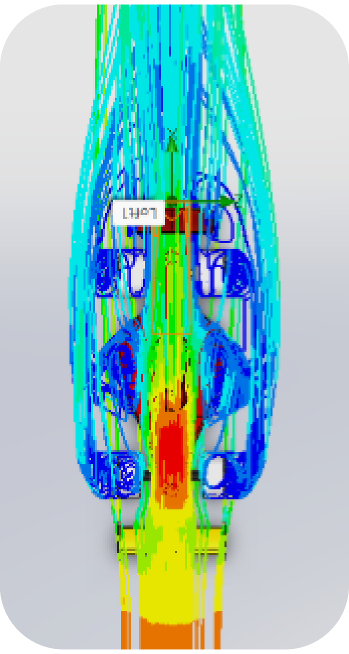
The front view of the car shows us a lot of important information in regards to how the air reacts on initial contyact with the car. it gives us a good insight in how the wing and wheel arrangment effects the aerodynamics.

The TR 40 has a high intensity turbulence with the air creating chaotic **"Bird Nests"** , this will create low pressure vortices which act like vaccums which can pull the car down increasing drag. Taking this into account in the TR 41 we recreated a wing whichs geometry allowed thr air to **"wash"** around the wheels, this allowed us to get more structured streamlines.

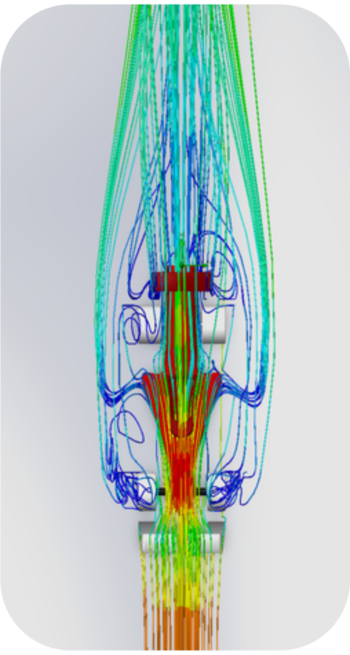
The more structured stream lines mean **less spirals** and less force acting down on the car this will then cause the car to have less drag and will travel better through the air and reach a **higher top speed.**

Plan View

TR 40



TR 41



The plan view of the car provides us with an insight on hgow the air behaves along the sides of the car which can have a significant impact on the drag of STEM racing car.
Through the plan view CFD we are able to see that we have sacrafised some of the **laminar flow** we had around the cars body as we reduced the size of our side pods to **decrease weight**.

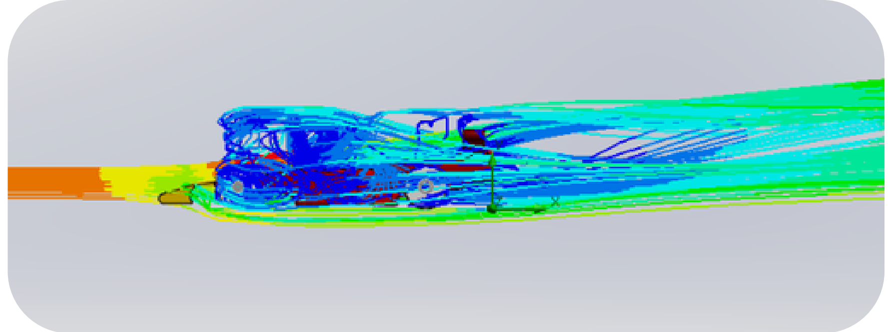
On the TR 40 we can see that the air follows the body of the car much better than the TR 41. The attached airflow on the TR 40 which causes a significant decrease in **pressure drag**.

By narrowing the side pods of the TR 41 we caused the body of the car to have more aggresive curves and cornors which in turn caused the air to **"detatch"** from the car causing low pressure zones. we can see that the more aggresive curves on the sidepod caused the air to push outwards away from the car while this caused significant increase in low pressure zones it also pushed the air around the rear wheels which **decreased the amounts of spirals** created behind the wheels.

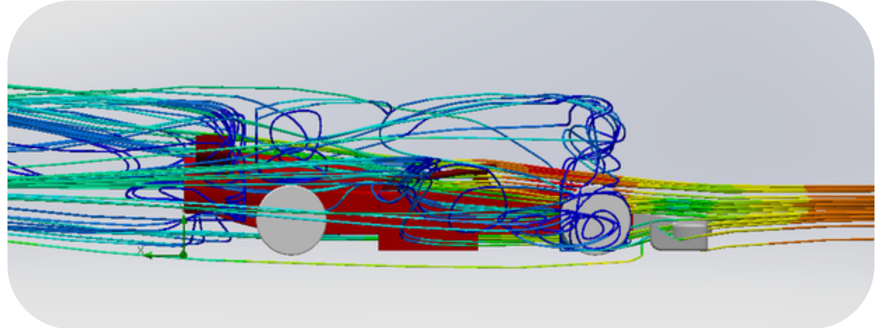
Although the air was being pushed outwards reating more drag it had a positive of pushing the air away from where the CO2 canister will be keeping the airflow away from flat surfaces with aggresive corners keeping the wake **less chaotic** eventually causing the low pressure zone to be smaller decreasing drag.

Side View

TR 40



TR 41



The side view allows us to see the ground effect, lift and downforce of the car. these are some of the most important aspects of the car aerodynamics. The CFD allows us to see how the car is generating downforce, lift and analyze how well the **ground effects are working**. Air being pushed up generates down force and air pushed down creates lift.

We can see on the car TR 41 that the rear wing is causing the air to be pushed up and around the rear of the car creating significant amount of downforce which is important to **keep the car stable** and increse grip but in the STEM racing scenario too much can be detremental as it creates alot of drag. The TR 41 car initiates flow seperation due to a superior front wing design which allows air to reach its designated destination earlier. On the TR 40 has less downforce due to a better implementation of the **Coandă effect** which allowed the air to stay closer to the car but this came at a cost of weight as it requires more volume in the car.

The red lines on the body of the car is showing us that there is **high velocity air hitting the top** of the car this may increase drag but it allows the rear aerodynamics of the car to work **more efficiently.**

Power to weight trade off

Through our CFD analysis we were able to conclude that the TR 40 was the the most aerodynamic car with a drag coefficient of 0.333 compared to the TR 41 which had a drag coefficient of 0.361 this is due to the cars better implementation of the coanda effect. This allowed the car to have a lower drag coefficient. Although it was more aerodynamically efficient it came at the cost of weight which would of put us over the **minimum weight** before application of wings and paint. Due to this we opted for a more weight efficient design which decreased our overall weight to the minimum weight limit which is crucial when it comes to the racing of the car. A lower weight allowed us to accelerate and reach top speed qucker which in the stem racing enviorment is a top priority.

- **Mass Reduction:** by **reducing the sidepods** we were able to drop the weight of the car to below the **minimal weight** before adding wheels and axles
- **Acceleration VS Drag:** the lower weight allows us to reach top speed quicker. The top speed may be lower due to more drag but in a short sprint scenario reaching top speed quicker is more important.
- **Stability:** The front view of the cfd shows us that the TR 41 has more **streamlined airflow** meaning stability on track should be better and less chance of the car shifting or swaying during the race.

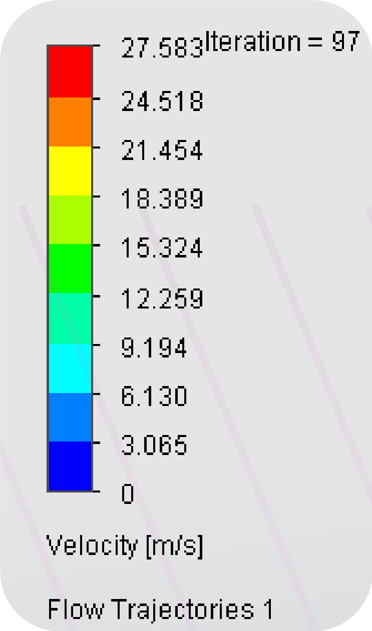
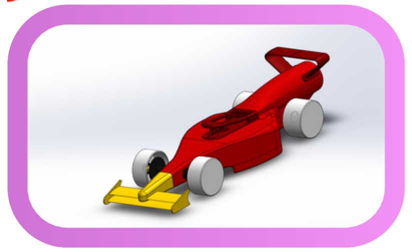


Table showing the speed of air passing around the car

The average speed of a STEM racing car is around "20m/s so to ensure our CFD was as realistic as possible we simulated the air to travel at the average speed of a usual race. This allows us to use the information gathered and implement it into our car as it is relevant to the race performance.

3D Modelling

SOLIDWORKS



KEY MODELLING TECHNIQUES

Extrude Boss/Base
Sweep Features
Lofted Geometry
Fillets & Chamfers
Assembly Modelling
Reference Geometry

3D modelling played a major role in the development of our STEM Racing car. Using SOLIDWORKS, the team was able to create **highly detailed digital models** of individual components before combining them into a complete vehicle assembly. This allowed us to accurately visualise the overall design, understand how each component interacted within the car and identify improvements before manufacturing began.
Creating **digital models** gave the team far greater control over dimensions, proportions and **aerodynamic surfaces** throughout development. Working in a virtual environment made it possible to rapidly test design concepts, **refine geometry** and optimise component placement while **maintaining dimensional precision.**

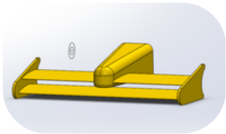
Design developement through CAD

The modelling process was very efficient, with multiple revisions made throughout development to improve aerodynamic efficiency, optimise our part placement and **reduce unnecessary mass**. Working digitally allowed modifications to be implemented quickly while maintaining accuracy and consistency across the entire vehicle assembly.
Accurate 3D modelling also ensured that all components aligned correctly and **complied with STEM Racing regulations** before manufacturing began. By using old dimensions, feature relationships and proptotype modelling, any potential errors that could mess up the machining. This reduced the likelihood of manufacturing problems and improved the overall reliability and quality of the final design.
Creating digital models also improved collaboration within the team. More complicated engineering concepts could be visualised more clearly, making it easier to discuss ideas and refine the final version design

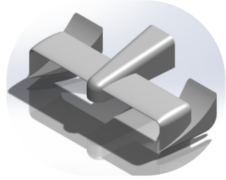
Modelling process

Our individual components were modelled separately before being combined into a complete assembly within **SOLIDWORKS**. This allowed the team to visualise how each part interacted with each other and ensured everybody understood where and what each part does. Features like **extrudes, sweeps, lofts and reference geometry** were used extensively to create smooth aerodynamic surfaces
The modelling process allowed the team to experiment with **multiple design concepts** efficiently while keeping it accurate through the development process. Working digitally also made it easier to **refine the body**, improve aerodynamic flow and optimise the positioning of critical parts of the car within the limited dimensions and regulations of the vehicle.

Wing Iterations



v1

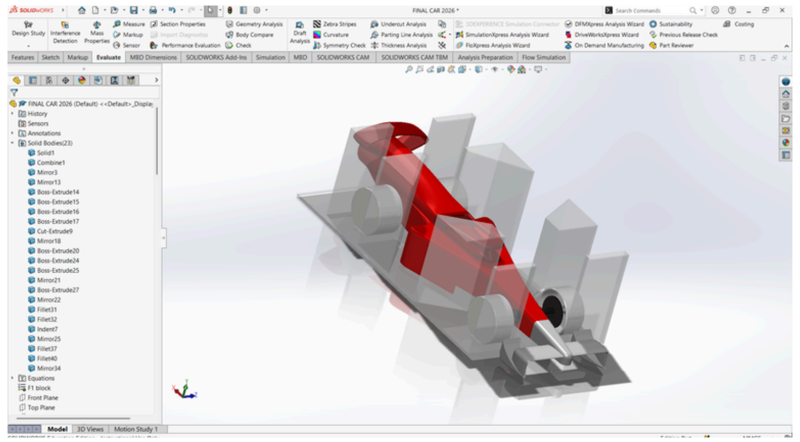


v2

Several front wing concepts were made and evaluated throughout the design process to our aerodynamic efficiency to weight ratio. Early designs featured more **complex geometries** and additional surfaces, however testing showed that a simplified design produced clearer better airflow and reduced unnecessary weight.
Detailed modelling allowed the team to quickly modify wing profiles, also while comparing the effectiveness of each version. This process helped the final design to achieve a good ratio between **aerodynamic performance and mass.**

Tolerances

3D modelling also enabled a high level of dimensional precision throughout the project. Accurate measurements and feature relationships ensured that all components fitted together correctly and complied with STEM Racing regulations before manufacturing began. Applying accurate tolerances throughout the modelling process was essential to **ensure consistency and precision** across all components of the vehicle.

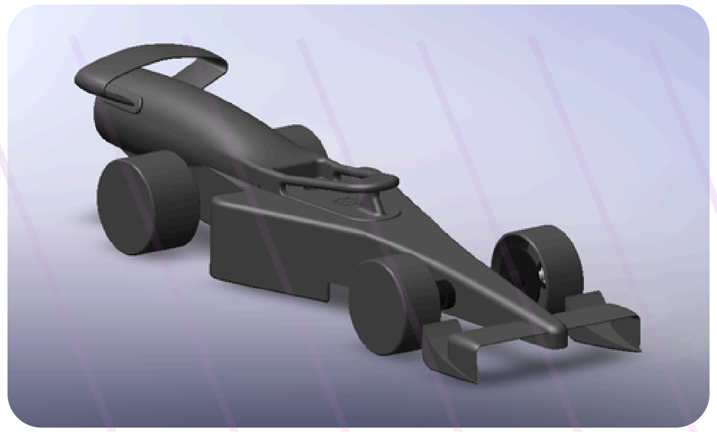


extruded regulatory dimensions to ensure construction of the car did not exceed the regs

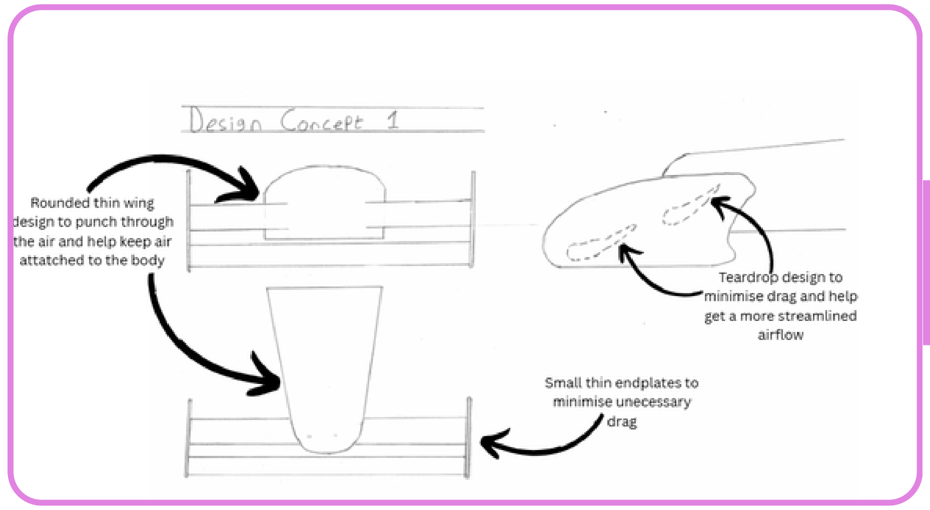
Careful dimensional control allowed the team to account for **manufacturing limitations,** assembly clearances and wheel alignment while ensuring the car remained within STEM Racing regulations. Tolerances were also important in **preventing interference** between parts and maintaining smooth integration between aerodynamic surfaces, helping improve both reliability and overall build quality.
By identifying potential fitment and clearance issues digitally before production, the team reduced the likelihood of manufacturing errors and unnecessary material waste. This improved the efficiency of the development process and helped maintain a high level of quality and repeatability throughout the final build.

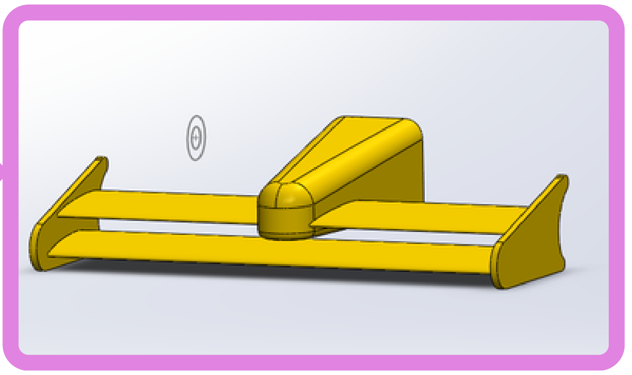
Design for manufacturing

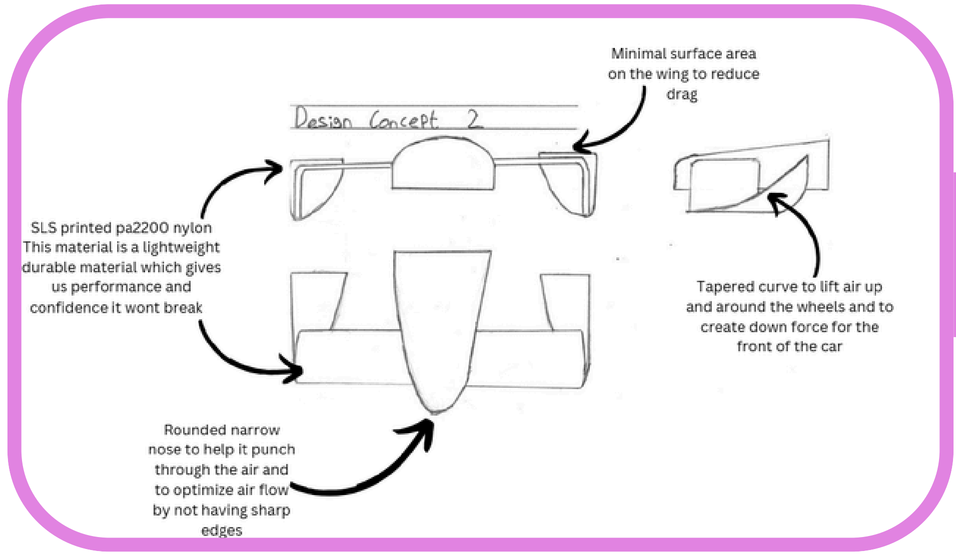
Manufacturing considerations were taken into account throughout the modelling process to ensure the car could be produced **accurately**, efficiently and consistently.
Features such as fillets and chamfers were included across the design to **improve manufacturability**, reduce stress concentrations and create smoother surface transitions during **CNC machining and finishing**.
Minimum wall thicknesses and **simplified geometries** were also maintained to improve **machining reliability** and reduce the likelihood of manufacturing errors or component damage. Throughout development, the team carefully **balanced aerodynamic performance with realistic manufacturing capabilitie**s to ensure the final design could be produced successfully.
Designing the car with manufacturing in mind also **improved assembly accuracy** and overall build **quality**. By considering **machining tolerances** and **structural limitations** during the modelling stage, the team was able to create a final design that was both **highly refined** and practical to manufacture.

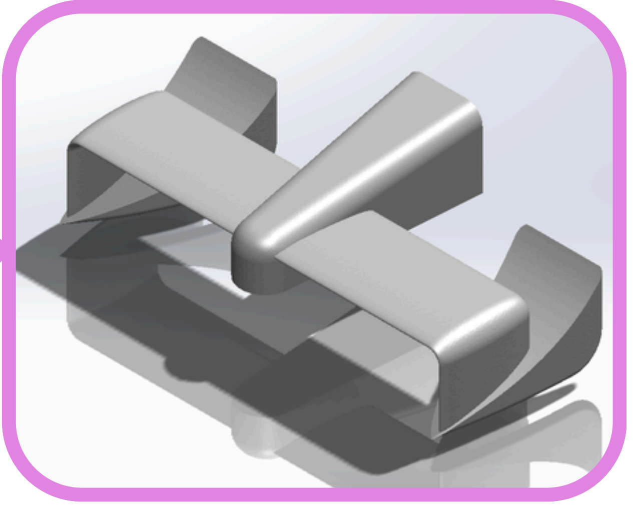


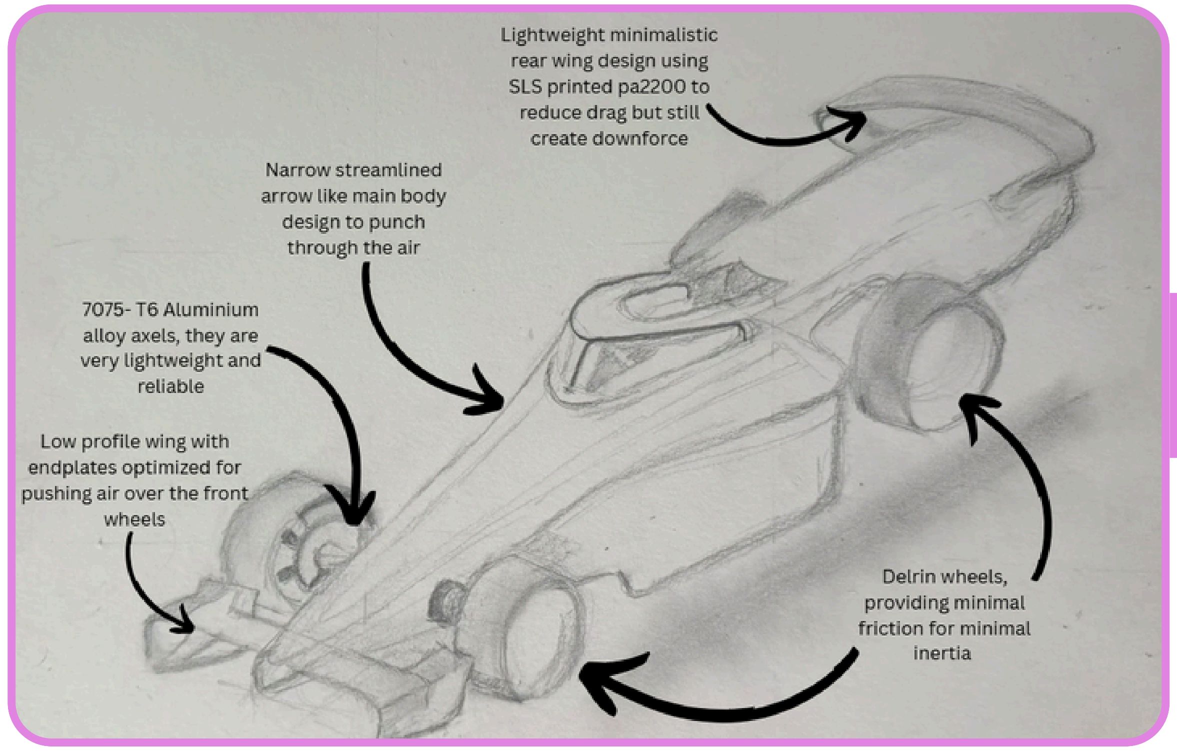
Design Concepts

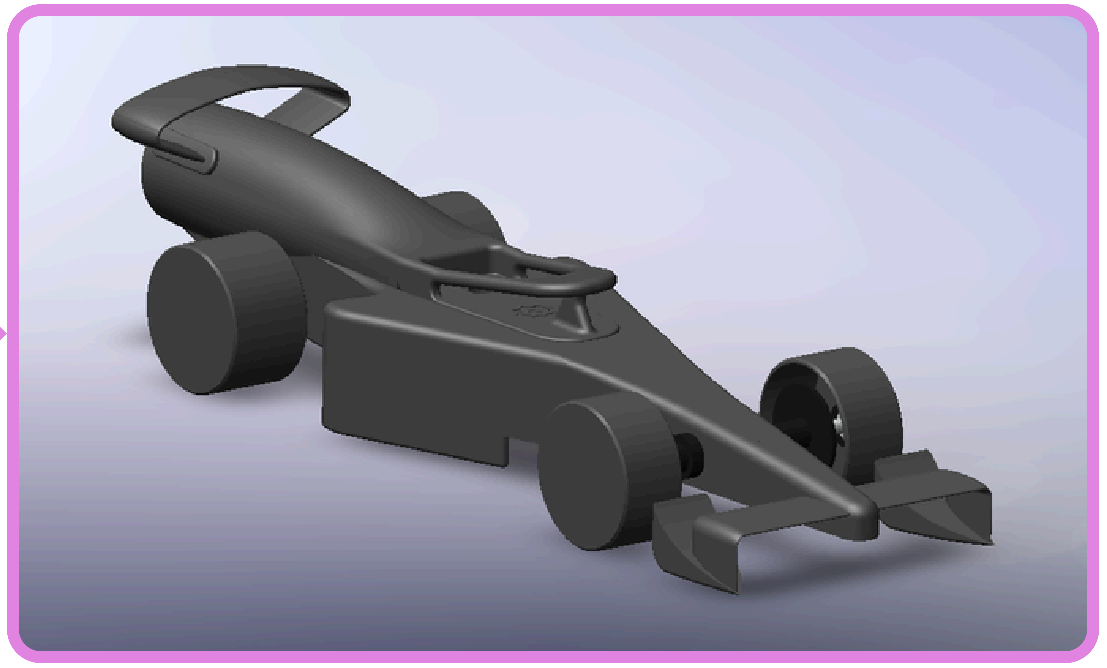


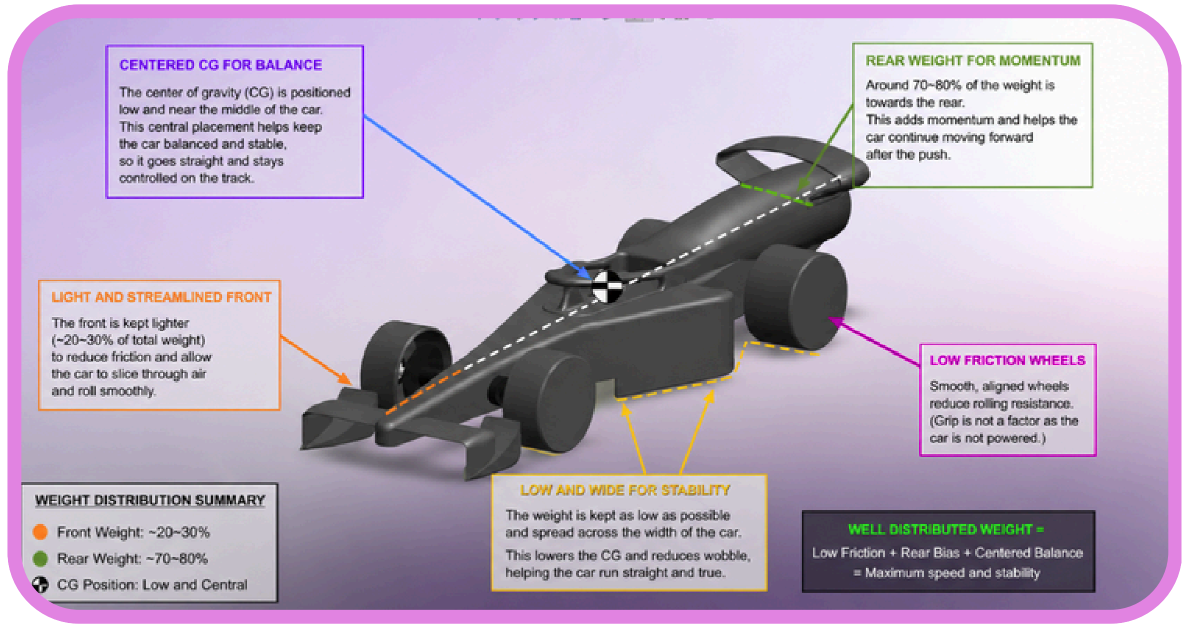


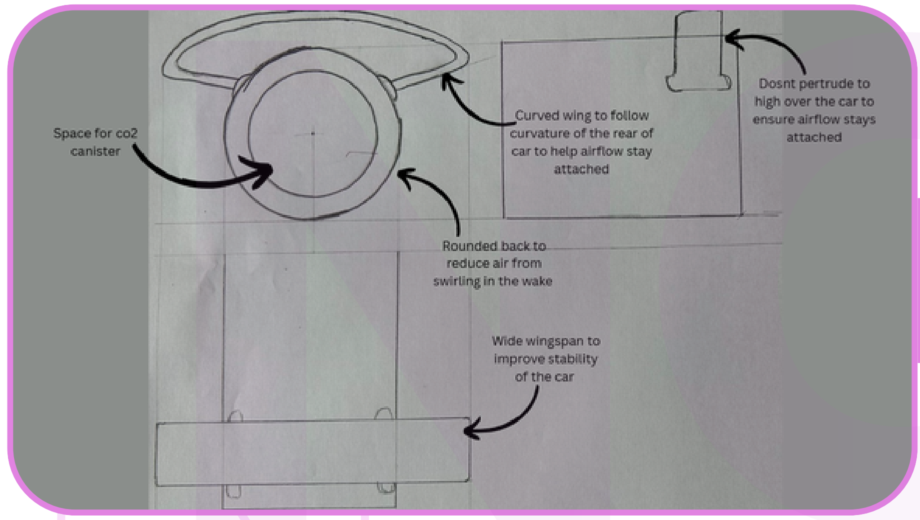


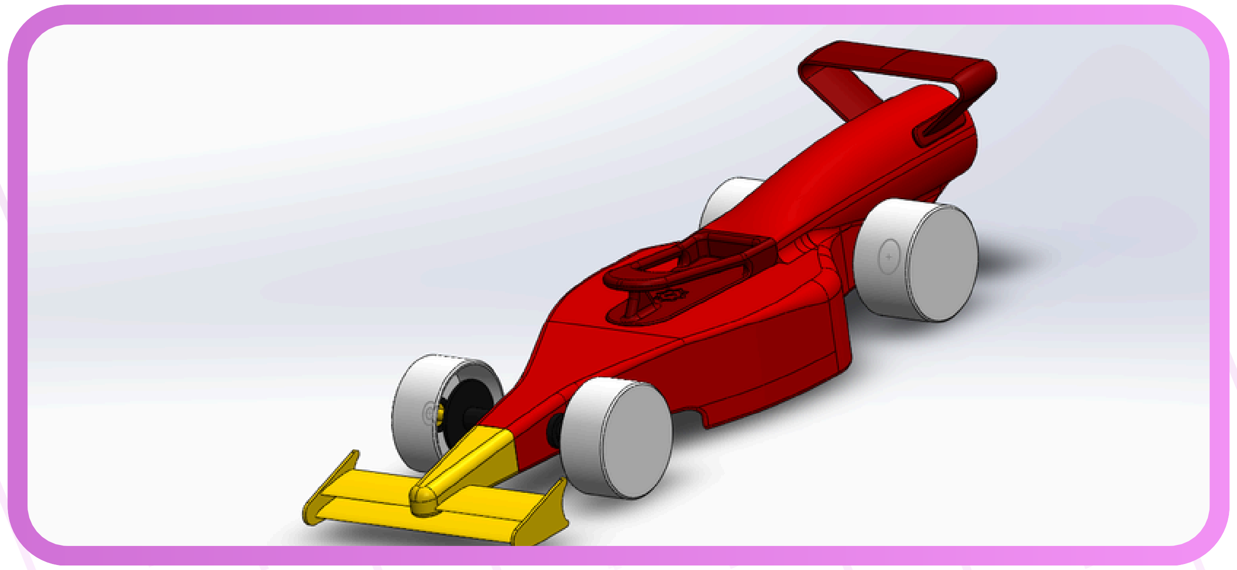






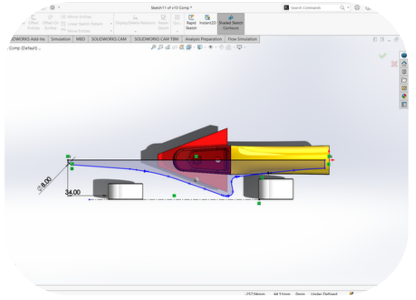






Applications of CAD

KEY CAD TOOLS USED:
Extrude Boss/Base
Revolve Features
Sweep Features
Fillets & Chamfers
Assembly Modelling
Mass Properties
Material Assignment



What is CAD?

Computer Aided Design (CAD) is the use of specialised software to create accurate digital models, technical drawings and engineering assemblies. Software such as **SOLIDWORKS** allows engineers to design, visualise and refine components with a high level of precision before manufacturing begins. CAD is widely used throughout engineering industries due to its ability to improve **accuracy,** efficiency and overall product development.

CAD played a major role in the design and development of our STEM Racing car. Using SOLIDWORKS allowed the team to create, modify and analyse complex components within a fully digital environment. This gave us the ability to **rapidly** test design ideas, **improve aerodynamic** surfaces and optimise component placement while maintaining **dimensional accuracy** throughout development.

Precision & Accuracy

Accurate CAD modelling played a **vital role** in ensuring the car could be manufactured precisely and assembled consistently. By modelling components virtually within SOLIDWORKS, the team was able to **identify potential fitment, clearance and alignment issues before production began**. This reduced the likelihood of manufacturing errors and improved the reliability and quality of the final design.

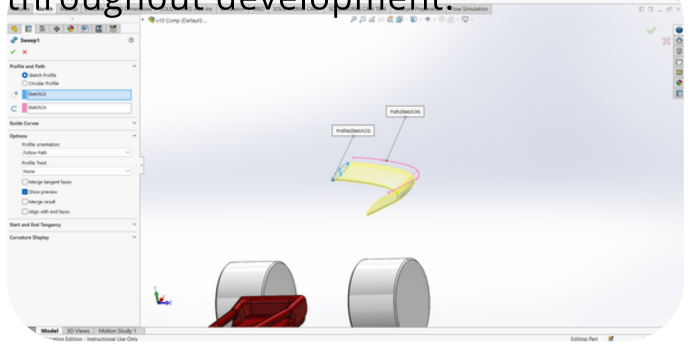
Applying precise dimensions and feature relationships also ensured that all components interacted correctly within the **vehicle assembly** while remaining compliant with STEM Racing regulations. Careful dimensional control allowed the team to account for manufacturing **tolerances,** wheel alignment and assembly **clearances** throughout development.

Parametric Modelling

Using **parametric modelling** in SOLIDWORKS allowed dimensions, constraints and **feature relationships** to update dynamically throughout the design process. This enabled the team to rapidly refine components while maintaining dimensional accuracy and **consistency** across the overall car assembly.

As modifications were made to improve aerodynamics, reduce mass and optimise component placement, related features automatically updated without requiring the model to be rebuilt from scratch. This significantly improved the **efficiency** of the development process and allowed multiple design iterations to be explored quickly and accurately.

Parametric modelling also **improved overall design** flexibility by allowing adjustments to be implemented while maintaining precise relationships between sketches, surfaces and assemblies. This made it easier to refine **geometry**, **optimise aerodynamic** surfaces and ensure all components remained correctly aligned throughout development.



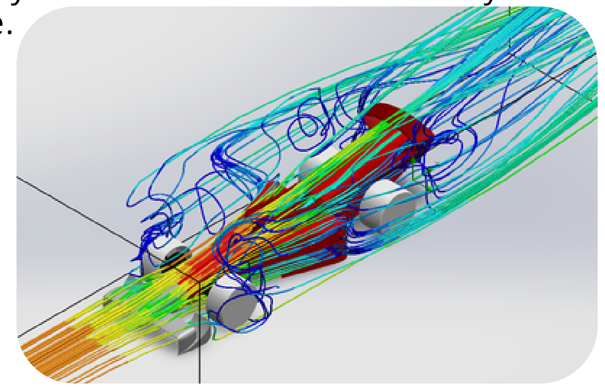
Using the swept boss/base feature to create the profile of the rear wing

Throughout the project, CAD enabled us to **visualise** how each component would fit together and allowed us to make **accurate adjustments** to dimensions, shape and positioning. This reduced manufacturing errors and helped ensure that all parts of the car worked together as a complete system. It also gave our team the opportunity to **experiment** with different design concepts and compare their effectiveness before selecting the **final version.**

CAM & CFD

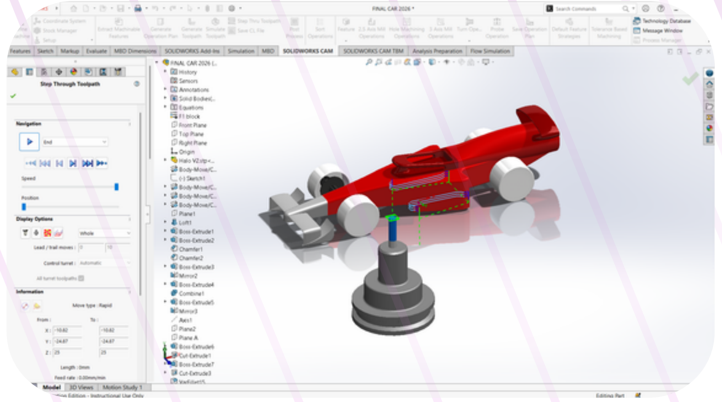
One of the most valuable features of **SOLIDWORKS** was the integration of **Computational Fluid Dynamics** (CFD) and **Computer Aided Manufacturing** (CAM) tools within the design process. CFD analysis allowed the team to **simulate airflow** around the vehicle body and rear wing, helping identify areas of **drag, turbulence** and inefficient airflow before manufacturing began.

By analysing airflow behaviour digitally, the team was able to **refine aerodynamic surfaces** and improve the overall aerodynamic efficiency of the vehicle. Small modifications to body geometry and wing profiles produced measurable improvements in airflow consistency and reduced unnecessary aerodynamic resistance.



testing of our car using solidworks flow simulation

CAM software also played an important role in preparing the vehicle for **manufacturing**. Generating **accurate toolpaths digitally** ensured the car could be machined precisely and consistently while reducing the likelihood of manufacturing inaccuracies. Integrating CAM within the **CAD workflow** improved production efficiency and helped ensure the final vehicle **closely matched** the digital design model.

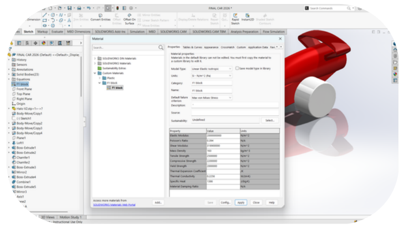


Weight estimation

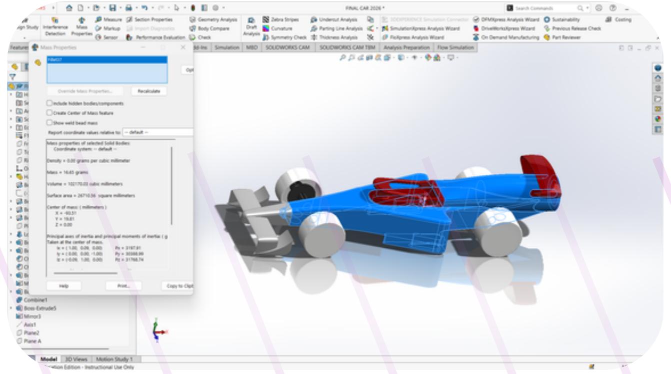
SOLIDWORKS also allowed the team to estimate the **approximate mass** of the vehicle by **assigning material properties** to each component within the assembly. This enabled **accurate calculations** of component mass, **overall vehicle weight** and **weight distribution** throughout the design process.

Monitoring weight digitally was extremely important, as maintaining a **lightweight vehicle** is a major performance advantage within STEM Racing. By analysing mass properties during development, the team was able to identify heavier components, **optimise geometry** and **remove unnecessary material** while still maintaining structural integrity and regulatory compliance.

The use of digital weight estimation also improved the **accuracy** of the final design by allowing engineering decisions to be based on **measurable data** rather than assumptions. Comparing the calculated vehicle mass with the completed physical car demonstrated a high level of accuracy within the modelling process and validated the precision of the CAD assembly.



Input of f1 block density values into the material feature



Using the mass properties feature we calculated the weight of the car body alone, and when we measured the physical car it was accurate to the nearest .1 grams

Design Process Evaluation

Design process strategy

At the beginning of our car development we set out a clear **decisive strategy** that we were going to follow to design and develop our car as efficiently as we could and to create the best possible car.

1. **Brainstorm**

We began the process by brainstorming different parts of the car not just the whole car we seperated the car into 4 different sections front wing, rear wing main body and floor. as a group we **discussed** as many ideas as possible and narrowed down the ideas.

2. **Sketch**

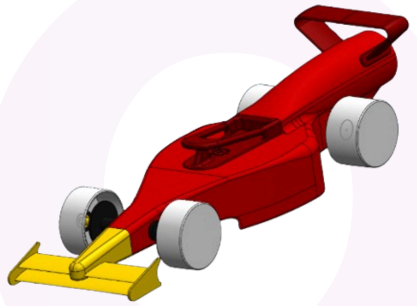
Once we narrowed down our design ideas we sketched them out to refine the idea and get a better understanding of its **characteristics.**

3. **CAD**

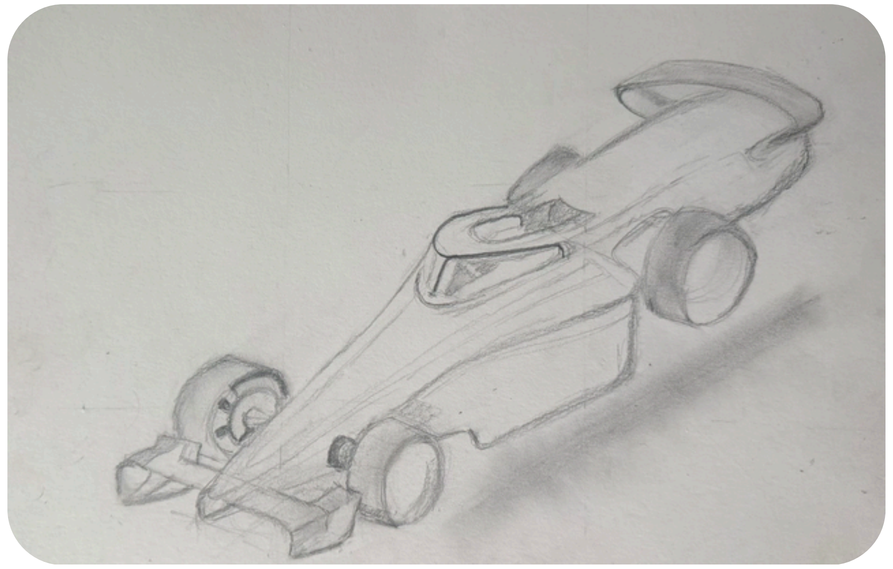
Once we were happy with the sketch of the part we then went onto CAD software to model the design and **combine** all the parts together to get a complete car.

TR 40

Our first concept design was the TR 40. This concept was made with multiple aerodynamic concepts in mind. The coanda effect was the backbone of this concept, we **removed almost all sharp edges** on this car. By applying these aerodynamic concepts we were able to create an **aerodynamically superior** car compared to the cars that we were to design after this one. By applying these aerodynamic concepts we **compromised the weight** of the car which meant that although it would have had a high topspeed it would not have been a competitive car in the race.



TR 41



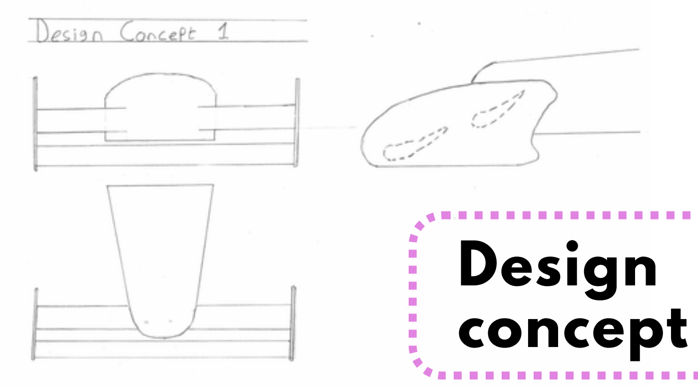
The TR 41 was our last design that we created. We based it on our previous design which had very strong aerodynamics but was overweight. In this design we re-designed the front and rear wing and then adjusted the side pods to be smaller and **thinner in order to save weight.** This came at a cost of aerodynamic performance as we were not able to transition different parts together as best as possible which compromised the excellent application of the coanda effect we had in the TR 40 but the **savings we made on weight were significant enough** for us that we made the decesion to go with it.

Sketching

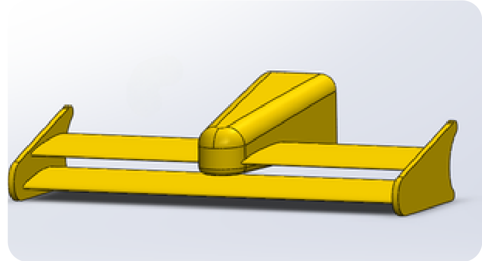
Sketching played a very important role in our design process by allowing us to generate and refine ideas before moving into CAD modelling and **prototyping**. Through sketching we were able to **visualize cars**, experiment with different body profiles and part placements, and show any ideas we had to the rest of the team quickly.

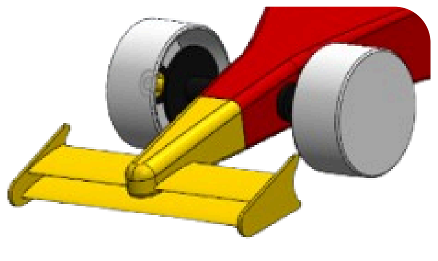
Front Wing Design

The front wing is one of the most important parts of the car it will affect how the air reaches the rest of the car and that can be crucial in order to get certain parts of the car to do what they are intended to do. To design our front wing we used our design process strategy to come up with our best possible ideas.



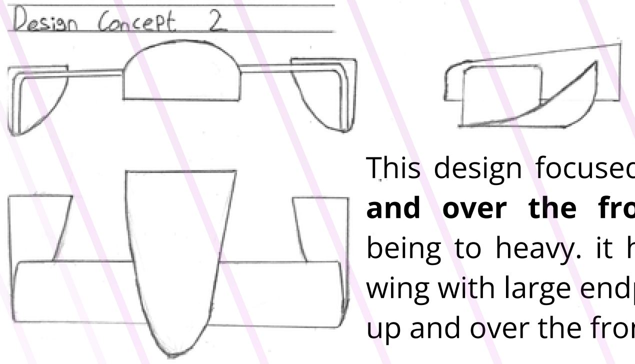
Design concept 1



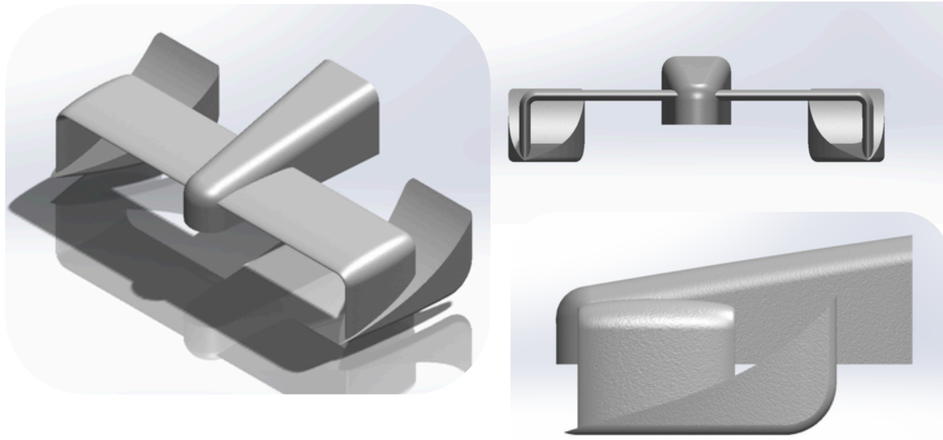


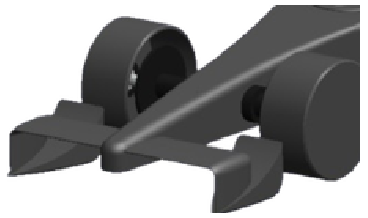
The idea behind this front wing was a **minimilastic design** wich created minimal drag and weight. We began by dicussing an idea first and then we sketched out the wing making adjustments as a team until we came to a unanimous decision. We then made the design on CAD to get a final view and then attached it to the main body of the car.

Design concept 2



This design focused on **pushing air up and over the front wheels** without being to heavy. it has a light minimilist wing with large endplates which push air up and over the front wheels





The reason we went with this design over design concept 1 was because it was **lighter** and offered more of an **aerodynamic advantage** as it pushed the air up and over the wheels more effectivley making it a more suitable choice for the final car

Main Body Design

The main body of the car is the largest part of the car it is where the most of the air in the car is and effect how the air travels from the front to the rear of the car. It can have a large **impact on the wake** of the car. the body needs to be sleek and rounded to ensure that **air moves smoothly** across the suraface and so it does not create too much unecesary weight.

In the TR 40 we focused on making an **aerodynamically efficient** body which ment it was bigger and more rounded to make sure it transferred air effectivley from the front of the car to the rear. This came at the cost of weight which made it unsuitable for the final design.

The TR 41 was based off the TR 40. we kept a similar sha[e but we tightened it to make it as **narrow and thin** as possible to save as much weight as possible. we kept the **edges rounded** to ensure an effective use of the coanda effect. This design was also based on the head of an arrow which punches through the air very effectivley

Conclusion

Our Journey So Far

Our STEM Racing journey so far has been both challenging and rewarding, pushing us to develop new skills in teamwork, engineering, and design. From the early stages of brainstorming and researching to designing, testing, and perfecting our car, all of which has helped us. We have worked hard to overcome any issues we had, alongside developing a high ranking project and racecar. Along the way, we have improved out communication skills being part of a team , learning how important dedication is we want to achieve our goals as a team. As race day approaches, we are really proud of how far we have come as a team and definitely feel that we have improved our standard in comparison to previous years

Engineering Achievements

By far our most valued achievement in STEM Racing so far has been the development of our car. Using our research and development we made sure we developed the most optimal car based on our knowledge. We analysed factors like weight distribution, wheel alignment, and aerodynamics to improve speed on the track. Through testing using software such as CFD we were able to see any flaws that the car had and fix them as soon as possible which we hope will enhance our overall performance. This allowed us to keep our car optimal while also staying in regulations. We also gained experience in manufacturing engineering by working with great sponsors and suppliers for all our machined parts. Our engineering journey has shown us the importance of precision and teamwork in creating a competitive final project

Challenges and Solutions

Throughout our STEM Racing journey, we faced many challenges that tested our abilities. One of the main difficulties was designing a car that stayed quick and light while also complying with the competitions strict regulations. During testing, we discovered big problems such as uneven wheel alignment and excess weight, which affected the car's performance. To solve these problems, we analysed the design, made changes using solidworks and more prototypes and finished with our final car. Time management was another challenge, as we needed to balance work on the project, meetings and school. By staying organised and avoiding procrastination it allowed for us to meet all of our tight deadlines. By improving communication, organisation and teamwork, we were able to overcome all of these obstacles and continue progressing the engineering side of the project toward race day.

Reflection on Skills Gained

Taking part in STEM Racing has allowed us to develop a wide range of valuable skills that will benefit us both inside and outside the classroom. Throughout the project, we strengthened our teamwork and communication skills by helping each other and solving real world problems . We also improved our engineering abilities through designing, testing, and perfecting ourcar using solid works, and CFD. Time management and organisation became essential as we worked together on meeting deadlines. In addition, the experience helped us build our confidence and relationships as teammates due to the amount of time we spent working and improving our project together. Overall, STEM Racing has given us an important experience that we 100% believe will be useful in the future of our education and careers in STEM

Recommendations

Darragh

I would definitely recommend the STEM racing because it helps with social skills and enables you to work towards a big objective like the world finals. The project gave me views on people and their skill sets so i grew closer to the ones with similar interests to me and feel as if a project like this would be beneficial to the youth

Gilles

I felt that the project gave me a real understanding into the engineering and aerodynamic persepctive of F1. As somebody who has followed F1 from a young age i found that being able to look at real F1 cars and compare whjat theyve done to what weve done was really inspiring. Its a great project for future engineers

Matthew

I definitely recommend this project for everyone. It helped me see and understand all the different branches of work that goes into developing a formula 1 team, along with understanding how to work and be apart of an efficient team

Joe

STEM Racing has been resourceful experience. It has taught me many things, about both working in a team and what goes into projects like this. It gave me a look into proffesional engineering, and is something that I will seriously consider in the future.o

Sean

STEM Racing has been a fantastic opportunity to work with others in a team. I got a chance to contribute to a larger project and I really enjoyed the journey. My insight into STEM has grown and I would like do something similar in the future

Harry

I think that STEM racing was an amazing experience and would recommend it to all young engineers and business people so they can really expand and meet people with is similar interests to you

Gallery