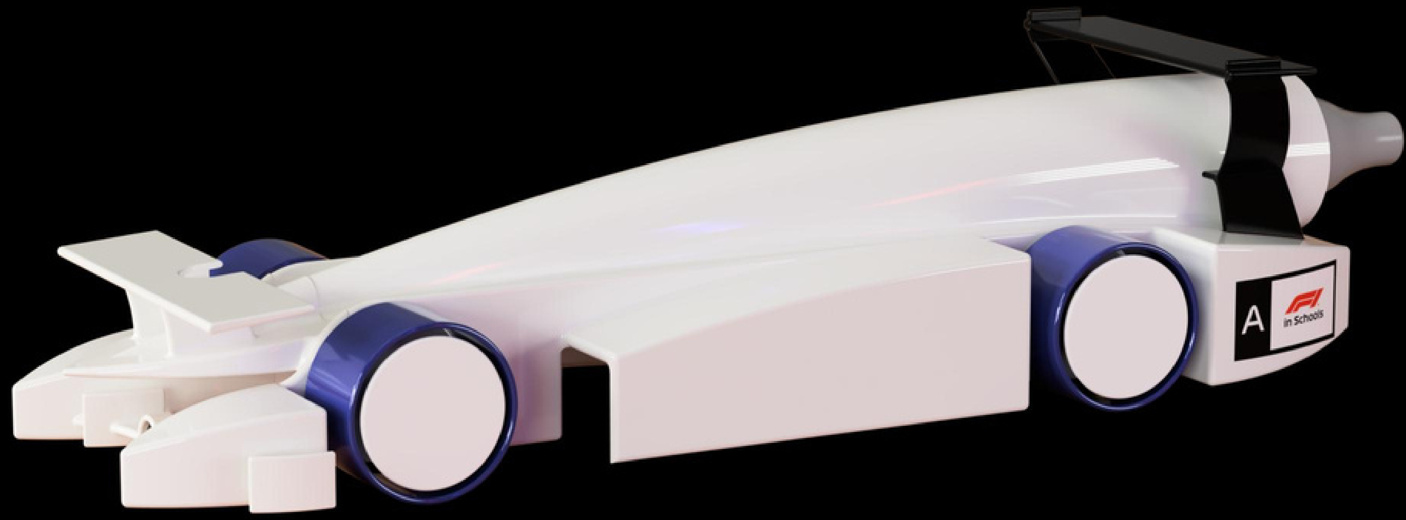
Radtek
MOTORSPORTS

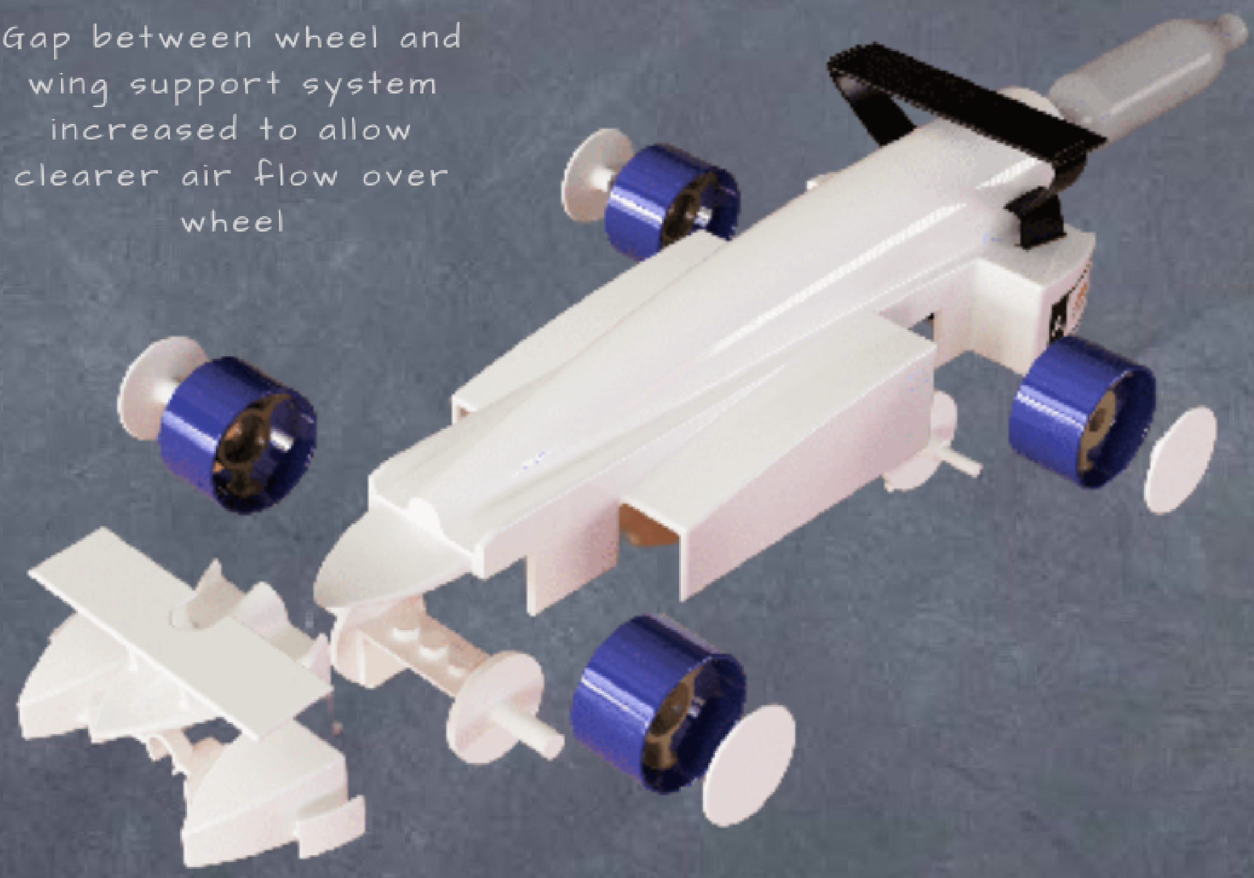


DESIGN
& ENGINEERING
PORTFOLIO

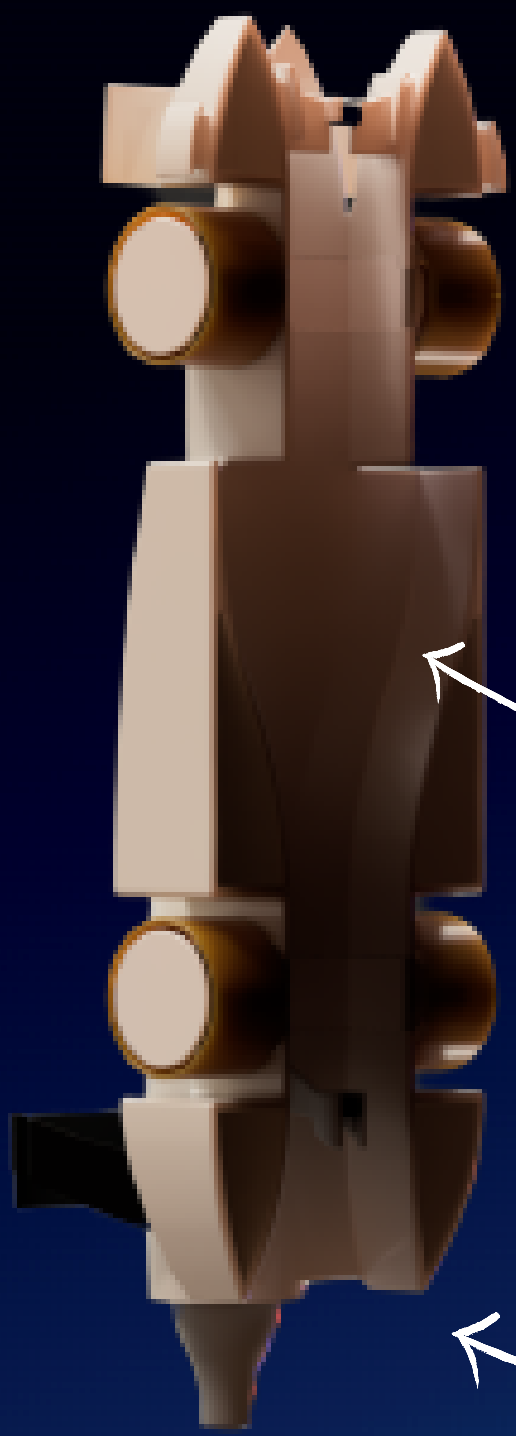
F1 in Schools
STEM Challenge

Design Development

Innovation never stops, and neither do we! Many different concepts and ideas have been tested, analysed and evolved to what we believe to be the best looking and most capable racing machine we could produce!



Car Design



The open design of the front of the car allows oncoming air to channel right underneath the car unopposed, rather than being forced to flow above or around the car.

Maximized Rotation

The wheels have the smallest dimensions allowed in the technical regulations. This enables them to create less drag, and spin faster as surface in contact with the track is closer to the axel

Air flowing within the underside of the car experiences the Venturi effect, moving at a higher speed and lower pressure.

Greater Laminar Flow

Air flowing outside the car sticks to the curvature of the rear side pods.

Air travelling outside and inside the car meet and mix with equal pressure and velocity. The interior and exterior surfaces of the rear side pods converge, leaving no wake or flow separation.

Biomimicry has been used by engineers for hundreds of years. Studying the aspects of nature and incorporating them into their own designs has helped designers create better, faster, stronger and more efficient machines. In the automotive and aerospace industry, aquatic and airborne animals are constantly analysed, as many of them hold the key to the greatest designs possible. We took a similar approach on designing our car.

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Aerofoil or also known as Airfoil is a structure with curved surfaces designed to give the most favorable ratio of lift to drag in flight, which is mainly used as the basic form of the fins, wings, and tailplanes of most aircraft. The shape of our back wings were inspired by the airfoil

The car’s body is designed to be completely curved and smooth, with no interruption, air can flow smoothly above and around all surfaces.

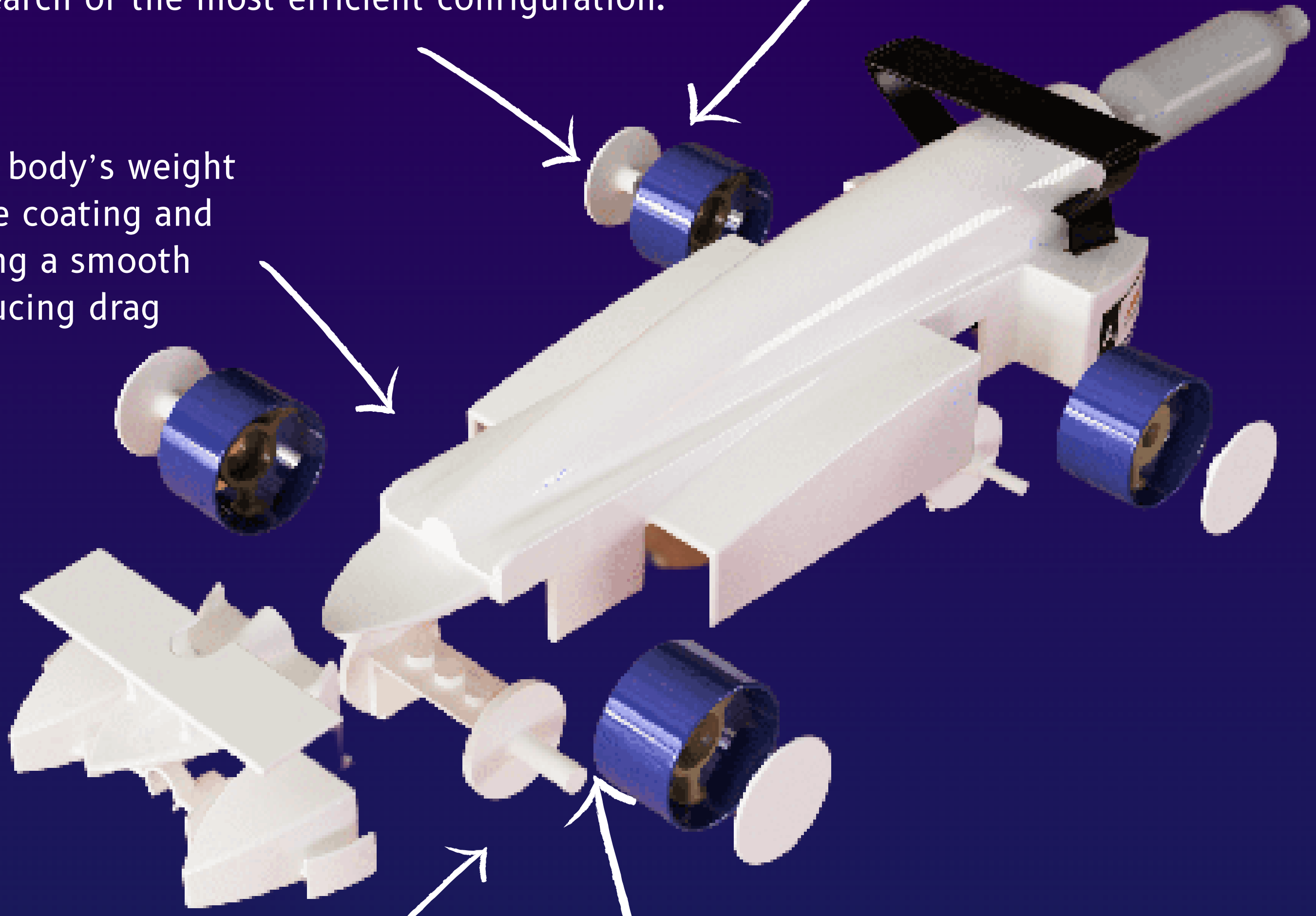
It was necessary for us to deflect the air travelling towards the front wheels over the wheel, eliminating a potential high pressure area. However, too much air can oppose the forward rotation of the wheel due to skin friction, reducing its axial velocity. For this reason, only air flowing above the front wing is deflected over the wheel, and air flowing beneath the wing is deflected around the wheel.

Vehicle Assembly

The rear tether guide has been integrated into the rear wheel support module, making assembly much easier, and reducing drag and weight

Our wheel system has evolved significantly in search of the most efficient configuration.

33% of the car body's weight consists of the coating and paint, creating a smooth finish, reducing drag



Fully printed bearings, for optimal rotation

Machined slots in the car body allow the wheel axel mounts to fit perfectly into the body, to support the wheel system with perfect alignment.

Our Nationals car features 16 individual components, which has been reduced from 29 components for Final car. We reduced our amount of parts in order to produce a more reliable, simple racing machine, while retaining complete functionality.

COMPLETE.
PRECISION.

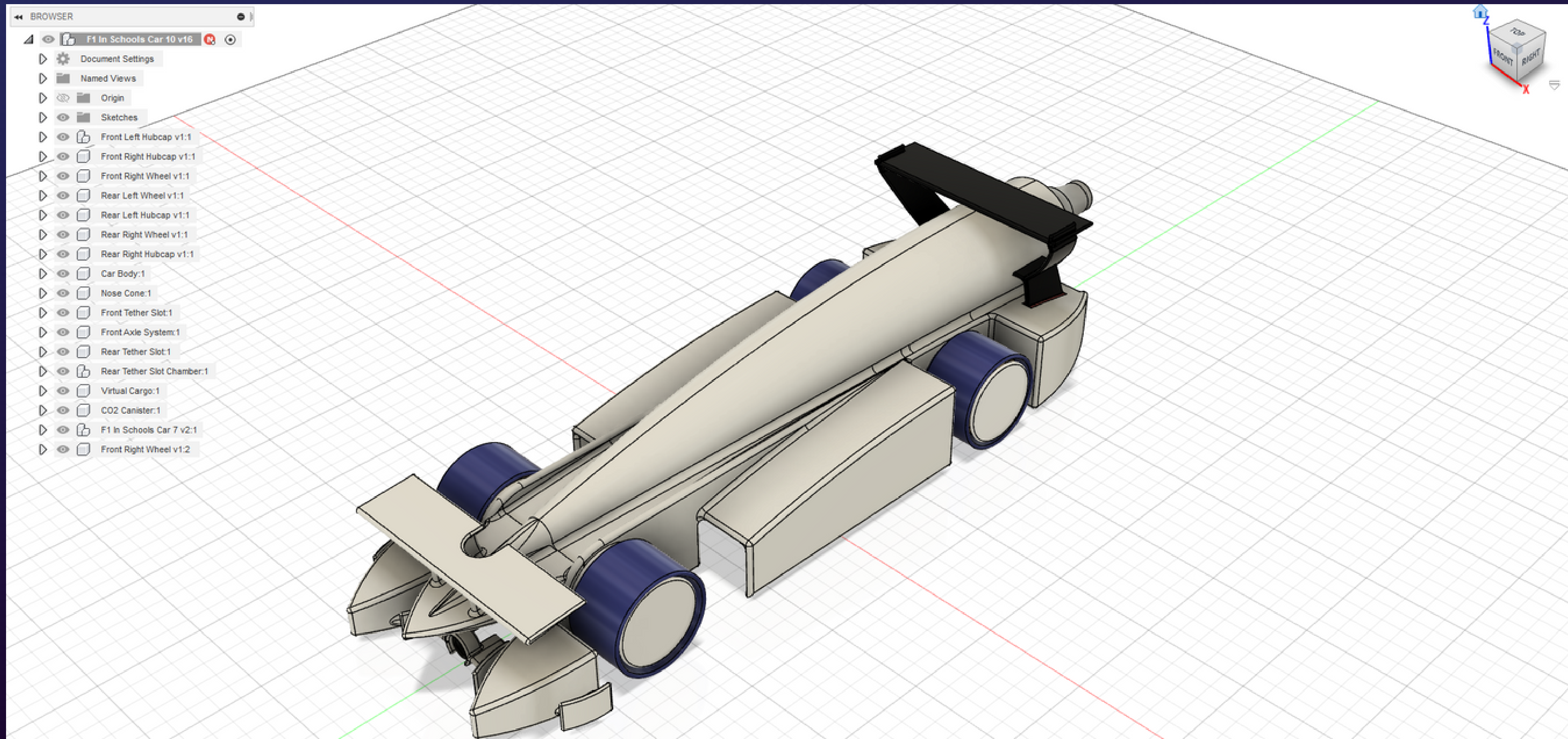
SEAMLESS.
INTEGRATION.

DESIGN EVALUATION

Research; develop. Analyze; improve. Study; enhance.
Our final car is the result of the continuous application of these verbs to our design process. Looking back to our first ever F1 in Schools Car Prototype to our final car shows the impact of a comprehensive design and R&D strategy. All F1 cars are prototypes none of them are perfect, but we firmly believe that this car is as any could be. However, this is not enough for us, If we continue racing in F1 in Schools, we will continue to develop, enhance and improve, to find every hundredth of a second possible.

Computer Aided Design

All components of the car were modelled using Fusion 360 at the facilities of our home. Fusion 360 was used due to our engineer's experience using the software, and its array of advanced modelling features and its seamless integration with ANSYS and SimScale, enabling the car to be transformed from sketches to a 3D model, and from there, a manufactured racing machine.



The entire car, excluding the wheels was produced using the “bottom up” master assembly method. First, the entire car was modelled as one. Then, using the “split” and “combine” features, each individual component could be isolated and saved as a part for manufacturing. This method greatly reduced the time of the modelling. Each part was then reassembled, to study how they interact as separate mated components and to find any potential errors.

The full CAD assembly contains all 16 individual car components mated, a decrease from our first car, which had 29 parts. We decreased the complexity of our car to reduce costs and manufacturing times, while improving performance. This assembly allowed us to visualize exactly how the parts interact with each other and allowed us to find any potential problems that may have arisen with the manufacturing or assembly processes. Shown here is the assembly of the front wheel.

The nose, alongside most of the car was modelled using sketches and extrudes. Solid geometry was preferred over surface geometry, as the aerodynamic cross sections of some of the parts cannot be defined with surfaces, even when they are thickened, for example, aerofoils and other flow structures. Using the sketch feature, the exact desired shape of the car’s components were achieved.

A number of sketches were used to define the geometry of the rear side pods with a Extrude. The rear pods play a critical role in the aerodynamic setup of the car, as they allow air flowing over the wheel to converge, reducing the car’s Reynolds Number. This feature and many others included fillets, to help with the machining process

Manufacturing Considerations

When Modelling the car on Autodesk Fusion 360, every feature was assessed to determine if it could be manufactured effectively, via both additive and subtractive manufacturing.

The car's design was intended to be fully modular, allowing all components to be changed, replaced or improved, with very little time or expense. This meant that all components must be fitted together with minimal glue. We concluded that a transition-fit tolerance would be the most effective at keeping the parts strongly mated together, with friction and a little glue, but they could be removed with reasonable force, and without risk of damage. Any part that inserted to another had at least a 0.1mm gap, so that the tolerance zonespartially overlapped, making sure that our accurately built parts fit together seamlessly.

The axels of our car have experienced the highest amount of change and improvement of any car component. Originally optimised for FFF 3D printing, the axel was long and thin, fitting our bearings, but extremely fragile, and not entirely accurate. We added short support columns to increase the strength of the axel further.

A large radius was added to the front wing support system. This was originally a vertical surface, which still allowed the air to flow around the wheel, however, when 3D printing, there was no surface underneath it for support material to build from. For this reason, the radius was cut into it, eliminating the overhang and the need for support when the nose is printed pointing upwards.

CAD Evaluation

We were very satisfied with the outcome of the iterative method we used to model every component of the car using Autodesk Fusion 360. Over many weeks, every part was modelled to match the concept sketches as closely as possible while keeping functionality and manufacturability.

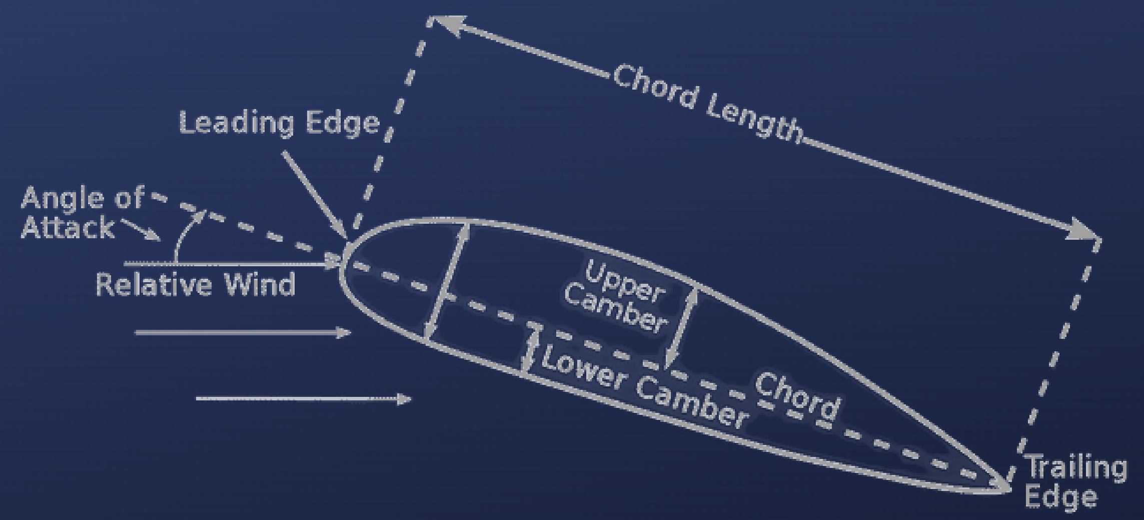
The F1 in schools race can be thought of (like any other CO2 dragster race) as occurring in 2 phases:

1. Acceleration phase (CO2 egress in progress)

To maximise the effects of the propulsive force and garner the greatest acceleration (and achieve the highest speed), you want to have the lightest possible car and minimize the predominant drag forces in that phase. The predominant drag forces at the beginning will be those that occur at lower speeds and include wheel drag and tether line frictional forces. These can be minimized by minimizing rotational frictional forces with bearings and minimising rotational inertia with wheels that are as light as possible. The wheels should be well aligned to avoid inducing yaw tendencies, which would cause the tether line to rub against the guide holes. The wheels should also be as rigid as possible to reduce loss of energy in wheel deformation.

2. Coasting phase (CO2 used up)-car at maximum speed and starting to slow down

In the coasting phase, while wheel related factors are still very important, good aerodynamics now becomes much more important. If you look at slow motion captures of F1 in schools races, you may see that some cars start off slowly then overtake the other car towards the end. This may be a sign of superior aerodynamics, since aerodynamic forces come into play when the car is traveling at high speed, in the coasting phase



Our team expend enormous amounts of resources to gain an advantage over their competitors, and the technical race that takes place behind the scenes is perhaps the sport's defining feature. To accomplish this, our designers and engineers employ a variety of tools to maximize the speed of their vehicles. The Coanda effect, which has been and continues to be an essential part of an F1 car's aerodynamics. It has also been responsible for some interesting scandals in the recent past, is one such tool. The Coanda effect, in essence, describes the tendency of a fluid jet to remain attached to a curved surface. It was discovered by Henri Coanda, a Romanian inventor who is sometimes credited with developing and flying the first jet aircraft.

The phenomenon is essential in the production of lift through the use of aerodynamic devices, and is thus also crucial in the generation of downforce for the purposes of F1.

The basic principles are to minimize frontal area, minimize the effects of pressure drag from flow separation/turbulence, and minimise the effects of overpressure at the front of the car. The drag force on an object is produced by the velocity of a liquid or gas approaching the object. Drag force is dependent upon the drag coefficient of the object and the geometry of the object. Drag depends on the density of the air, the square of the velocity, the air's viscosity and compressibility, the size and shape of the body, and the body's inclination to the flow. Wheel rim covers can decrease significantly wheel drag. Many racing cars have uncovered wheels. Alternative strategies are used in order to decrease wheel drag and wheel-induced drag. Turning plates can be installed to constrain the wake and to direct it away from the car body. Wing Design Airfoil • The mean camber line is a line drawn midway between the upper and lower surfaces. • The leading and trailing edge are the most forward an rearward of the mean camber line. The chord line is a line connecting leading an trailing edge. • The chord length is the distance from the leading to the trailing edge, measured along the chord line. • The camber is the maximum distance between mean camber line and chord line. • The thickness is the distance between the upper and lower surfaces. The front wing on the car produces about 1/3 of the car's downforce and it has experienced more modifications than rear wing. It is the first part of the car to meet the air mass, therefore, besides creating downforce, it's main task is to efficiently guide the air towards the body and rear of the car, as the turbulent flow impacts the efficiency of the rear wing. Modern rear wings produce approximately 30-35 % of the total downforce of the car. The most downforce is provided by the upper airfoil. On tracks with many turns, more downforce is needed, therefore the wing is set at higher angle of attack. Conversely, on tracks with long straights, wing has small angle attack, thus reducing air drag and allowing higher top speeds. Another important part of rear wing are endplates . They provide a convenient way of mounting wings, but also have aerodynamic function. They reduce the 3D effect of the wing by preventing air leakage around the wing tips and thus formation of trailing vortices. An additional goal of the rear endplates is to help reduce the influence of upflow from the rear wheels.

Research

Application of Computer Aided Analysis

Computer simulation is the process of mathematical modelling, performed on a computer, which is designed to predict the behaviour of, or the outcome of, a real-world or physical system. The reliability of some mathematical models can be determined by comparing their results to the real-world outcomes they aim to predict.

Computer-aided analysis (CAA) is the name given to the analysis and optimising parts of the design process which, together with computer- aided design and computer-integrated manufacture, form the complete design package. The benefits of integrating these approaches with computer aids are immense; they include decreased lead time, superior and efficient designs and reduced manufacturing costs.

We used a 2D analysis software made by the previous F1 In Schools participants for the examination of our car. Our car had a lot of trouble being imported to 2D software due to geometry issues but we soon managed to fix that to acquire the graphs and probable outcomes of the race on a 20 M track. We designed the body to be streamlined and took the inspiration from rocket chassis and our hard work had finally paid off. The first chart shows the frontal area of our, the terminal velocity, and the time taken to finish the entire track. The second graph is a Distance over time graph. This chart shows how speed varies over time, you can use this to see how long it takes to reach your terminal velocity. The curved nature of this graph is due to algorithms used to take into account the effect of air resistance on the acceleration of the car. The third chart is a Speed over time graph. This chart shows how the distance varies over time.

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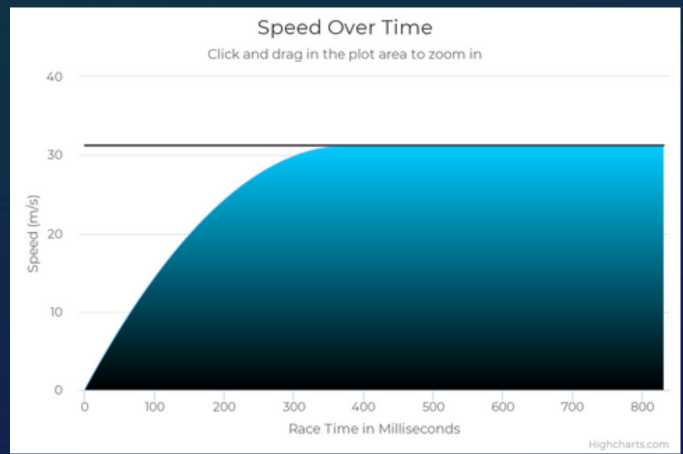
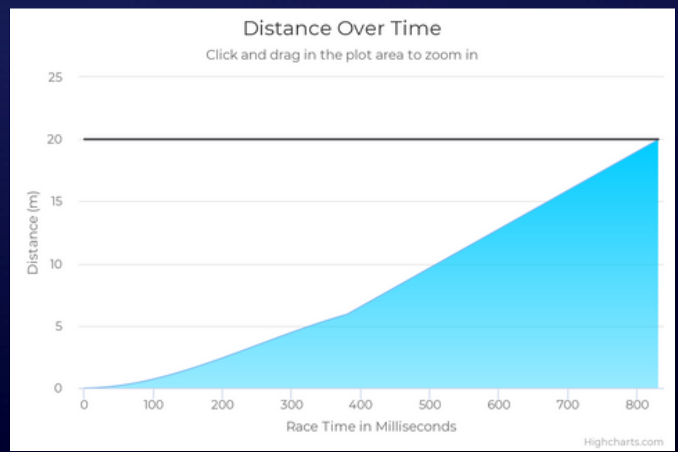




The 3D simulation most likely lacks the resolution to resolve the wakes as the 2D simulation does. 2D will almost always overestimate drag and lift values when flow begins to separate, but it's core value lies in the fact you can resolve fine structures. 3D simulations are inherently more expensive to run, thus you tend to use lower resolution grids and lose fidelity.

Any given 2D simulation will run much faster than it's 3D counterpart, assuming the same mesh density. There are just less points to evaluate and so less equations to run! 2D simulations can provide reasonable approximations in many situations and so is still useful (in airfoil analysis for example), but 3D effects will not be captured. So for example a finite length wing or anything involving out-of-plane geometries, a more time consuming 3D simulation is required.

2D techniques and codes are prevalent and easy to use enough that you typically don't need a CFD group to run something like Xfoil. More importantly even large 2D problems can be solved using your desktop computer. Even modest 3D simulation will at minimum benefit significantly from access to HPC resources. Square-Cube laws means the scale of the problems goes up by L2 for a 2D problem, but for a 3D problem it goes up by L3, so a lot more computational resources is required to solve a problem in 3D.

2D CFD is interesting because it involves way cheaper computational cost as mentioned above, physics itself will sometimes let you reduce the geometrical scale of your problem!

For instance, when one studies a laminar flow in a circular pipe, you can reduce your space of computation down to half a slice of the pipe (in the flow direction) thanks to the axis symmetry of your fluid domain. Thus, you reduce your space from a complete 3D pipe to a single 2D plane with symmetry boundary conditions, and you will still obtain the complete physical solution for your 3D domain!

Sanding
When the car came out of the CNC machine, we sanded the material. This removed the minimal scalloping marks that were remaining, and ensured an overall smooth chassis. We used high grit files and sandpaper to make the body as smooth as possible.

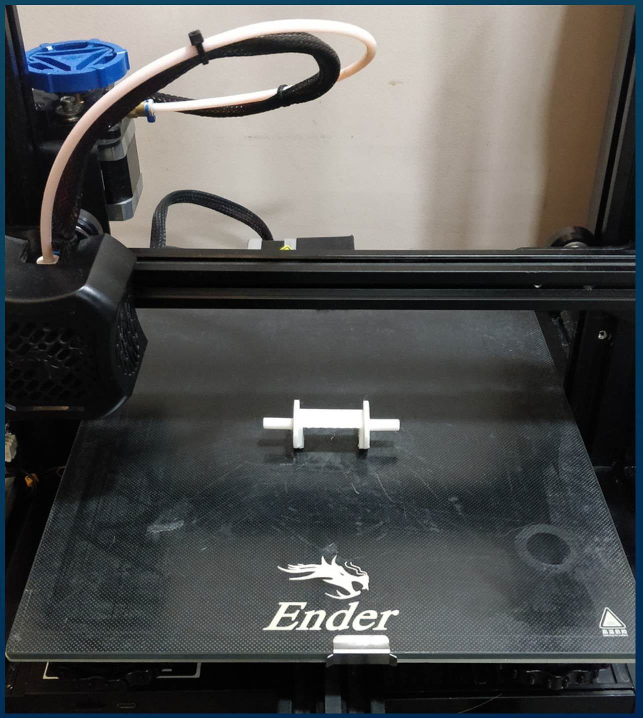
Painting
We used spray paint, intended for use on cars to add colour to our car. This was used for the base layer, while acrylic paint was used for painting a racing stripe. Multiple coats were applied to the model, applying a very light coat each time.

Priming
A primer was used to ensure that the colour of the paint was true to what we wanted. It also helps the paint stick better to the model. Multiple coats were applied.

Polishing
We polished our car using car polish to ensure a smooth finish on the car. This improves speed, as there is less skin-friction drag present. We wanted our car to stand out and shine during race day and polishing it helped us achieve this

Workplace Safety
We had little experience with manufacturing machinery and taking adequate safety precautions was very important. When sanding, we made sure to wear appropriate safety gear, such as ear, eye and hand protection. Finishing our car required an appropriate environment to work in. Paint fume poisoning was the most obvious risk so we did all of our painting outside, or in a well ventilated area. We also wore a face mask when painting our car.

Finishing and Assembly Process
Our finishing process is as follows: Sanding, Priming, Painting, and Polishing. It was important to wear a face mask and gloves during the finishing process, as fumes from paint can be poisonous and harmful to the skin. Painting was done in a well-ventilated, open area

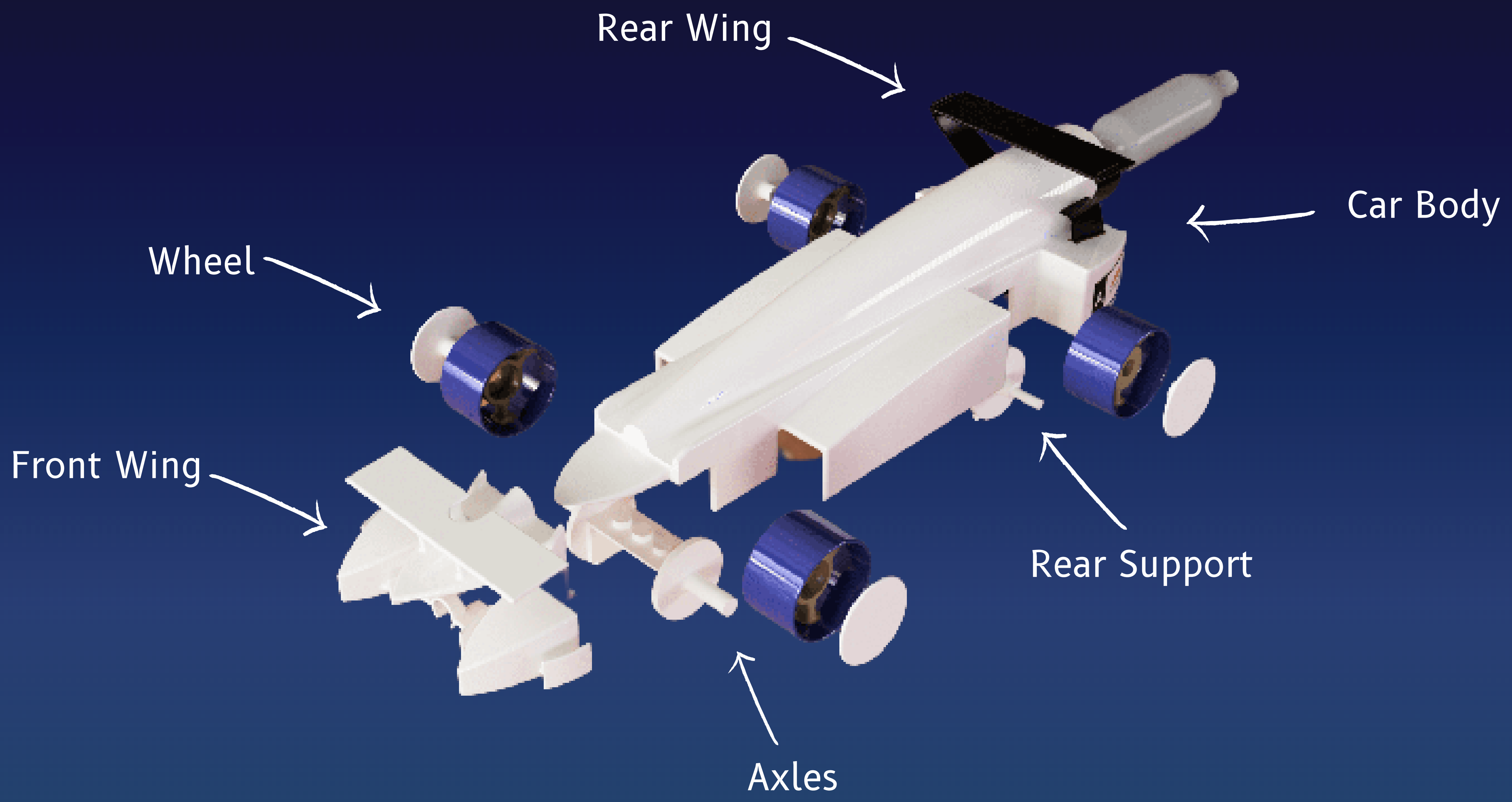


Finishing & Assembly

Wheel Alignment
Making sure that all four wheels are exactly aligned is crucial to ensure a fast car. We made an alignment jig to make sure that our wheels are aligned straight. The car was placed on the jig while the glue was drying. This dramatically improved the alignment.

ASSEMBLY EVALUATION

When assembly was complete we were left with a flawless result. The area of sealing our car was explored. However, we found that brushing a sealant onto our car left a rougher finish and thus was marginally slower in our track tests. We opted to manufacture our car without a sealer. The finishing process was constantly evaluated to see how it could be improved. We found during finishing that our test cars that the parts weren't fully secure in the car. We improved upon this by assembling the wings of our car and then lacquering our car. This essentially sealed the wings into the car body itself.
The team is very satisfied with the finished, assembled car. We used the most advanced, lightest and strongest materials, coupled with the most advanced manufacturing methods made available to us, to ensure that our car quality and speed was second-to-none. Our modular assembly proved very important to the manufacturing and assembly process, as it made the process much more efficient while also allowing for complete guaranteed accuracy and precision in fitting different components together. Despite there being 6 layers of different coatings, it did not change any of the dimensions of the car significantly, ensuring that all the dimensions were the same as intended, and no aerodynamic surfaces were altered.



Exploded Car

Radtek

MOTORSPORTS

NEWGEN

eSPAN

Thank you