TEAM AIB RACING

CONTENTS AND INTRODUCTION

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INTRODUCING TEAM AIB

Team AIB Racing is an F1 in Schools team from St. Muredach's College. We are the first team from our school to enter the competition and are competing as a newcomer team and school this year. Our team consists of four students aged 16 and 17 from the West of Ireland. Our aim is to showcase the best Ireland has to offer in terms of science, technology and innovation.

DESIGN TEAM

As part of their critical contributions to the team and their role interactions, Aaron (Team Manager) and Enda (Manufacturing and Resources) took the lead on the engineering aspect of the project. Aaron's role focused towards the design process, whereas Enda was responsible for the manufacturing, sourcing of materials and final assembly of the car. Aaron and Enda collaborated closely during the testing process, as this was a key area where their roles interacted. Although Robert (Sponsorship and PR) and Paul (Graphic Design) did not have roles directly related to the Design and Engineering area, they remained informed on each stage of the process, and gave input for new design ideas or improvements.

PORTFOLIO STRUCTURE

This portfolio has been organised in the structure of our design process (Design Process is outlined in more detail on our Pit Display) which has four stages:

Define: Research the brief and gain an understanding of the work involved. Conduct research on possible designs and on testing and manufacture.
Ideate: Create a number of technically inspired concepts from the research conducted using new techniques learned.
Prototype: Develop designs into worthwhile prototypes using virtual analysis and CAD modelling. Build new prototypes for test.
Test: Carry out purposeful testing and record results. Analyse and refine models.

We have then outlined our manufacturing preparation and processes, which brought the product of our design process to life. Finally, we conclude the portfolio with a summary of the engineering behind our fastest car yet.

PROGRAMS

Our 3D modelling work was carried out using Autodesk Inventor, which we chose over SolidWorks due to its ease of use and better compatibility with programs such as Autodesk Showcase and FlowDesign. We used Showcase to produce all of our rendered images while we chose to retain FlowDesign as our chosen CFD package over Symscape's Caedium, as FlowDesign proved much less time consuming, more user friendly and it gave exact figures for the drag force and drag co-efficient. Other programs used in the engineering process were PowerMill Pro (see page 9) and MiniTab D.O.E.

AUTODESK® INVENTOR®

Delcam PowerMILL

AUTODESK FLOW DESIGN

Symscape CFD for All

ENGINEERING BOOKLET

As part of our preparation for the World Finals, we have decided to prepare a short engineering booklet. The booklet contains further detail and background on the design of the car, as well as more depth on the innovations and collaborations which we utilised to develop our car. The booklet was developed to cover areas which we felt we could not include here due to the restriction on the number of pages in the Design and Engineering portfolio and the Key Performance Indicators which were outlined in the Competition Regulations. Also featured is the design and development of concepts which didn't make it to the final car. Copies of the booklet are available to take from our Pit Display.

COMPETITION REVIEW

After the National Finals we held a post-competition evaluation of our performance in the design and engineering area for the season. The purpose of this review was to identify weak points in our project which needed to be addressed. Here we have listed some of the observations made and the associated improvement action:

- We received our lowest mark in the area of testing. To improve, we spent time researching (Page 2) and carrying out (Page 6) far more purposeful tests linked to improvement (Page 7).
- Paul's reaction times in the National Final were below the standard he had set at the Regional Finals. We analysed his technique and worked on how to eliminate outside influences (Page 6).
- Our team had only a brief experience of working with CNC machines and CAM programs before the National Finals. We sourced facilities and training (Page 8) for our team to practice and improve.
- Our safety considerations for the National Finals were not of a high enough standard. This prompted a stronger emphasis on safety (Page 8) and following procedure during manufacture.

RESEARCH AND DEVELOPMENT

R & D CYCLE

Research and Development forms the basis for any successful design process. Our team has endeavoured to use relevant Research and Development processes throughout our entire car design and development cycle. We have identified a number of key research areas on this page, and have used these along with our virtual (Pages 3 and 4) and physical testing (Page 5) findings, to develop our final car design (Page 9).

DRAG

Drag can be broken down into two categories - parasitic and lift induced. Parasitic drag can be broken down into a further three categories - skin friction, form drag and interference drag.

SKIN FRICTION

Skin friction is a product of particles of air being dragged along the surface of the car.

Outcome: Reduced “wetted” surface area for lower drag force.

FORM DRAG

Form drag is created by the areas of turbulent flow (as opposed to laminar flow) made by the car as it travels. These areas of low pressure oppose the motion of the car.

Outcome: Developed long canister housing “shroud” and tapered rear pods to reduce form drag.

INTERFERENCE DRAG

This is caused when the flow of air around a shape in the body is disrupted by the flow around a different shape in the body.

Outcome: Used fillets at joints to reduce flow interference.

LIFT INDUCED DRAG

Lift induced drag occurs when a wing or lifting body is present. The amount of lift induced drag increases with the angle of attack, and when the spanwise and chordwise flows meet.

Outcome: Incorporated tapered elliptical wings at angle of attack of 0 degrees which reduced lift induced drag.

FLOW TYPES

Through our work with the Aeronautical Engineering Department at the University of Limerick, we were able to discover that due to the speed and size of the car, the boundary layer around it would be Laminar. We calculated this with an average velocity of 20 m/s, a characteristic length of 200mm, the density of air and the viscosity. A Reynolds number of less than 400,000 is used as an indicator of Laminar flow.

Outcome: Pursued a very smooth finish for maximum efficiency.

UNIVERSITY of LIMERICK
OLLSCOIL LUIMNIGH

$$R_e = \frac{\rho V L}{\mu}$$

WHEEL RESEARCH

ROTATIONAL KINETIC ENERGY

Rotational kinetic energy takes the same form as linear kinetic energy. Rotational kinetic energy is defined as half the rotational inertia (moment of inertia) by the velocity (angular torque) squared.

MOMENT OF INERTIA

The moment of inertia of a wheel is defined in maths as half of the mass by the radius squared. A high moment of inertia means the car will have more momentum, at the cost of less acceleration.

This research led to our wheel development - see next page.

TEMPERATURE

The temperature of air and the pressure of that air are directly proportional. This is set out in Guy Lussac’s Law which makes up part of the ideal gas law. If a canister’s environment was to become colder, it would produce less thrust. This research was important in the research and development of our HERS concept, which didn’t make the final car after the R&D cycle was complete.

TESTING METHODOLOGY

We felt it was extremely important to research and develop our testing processes, methodology and strategy. Without having a solid, meaningful process which would be linked to design improvements, our test data would be worthless. We conducted research into several different methods of testing and analysis, and made a decision on whether to progress with each.

COMPUTATIONAL FLUID DYNAMICS

A virtual flow visualisation tool which allows us to benchmark progress through analysing the drag co-efficient and drag force values for each model.

WIND TUNNEL

A wind tunnel has two potential uses - flow visualisation and recording the drag force on an object. We decided against recording the drag forces as they wouldn’t be large enough to register on the analysis machines. We progressed with the flow visualisation, however.

HIGH SPEED CAMERA

Analysing the start of our races would enable us to see if our LERS systems works as intended. Analysis of video would allow us to rule out ideas which didn’t have the desired effect.

TRACK TESTING

We invested in an F1 in Schools track for our school which we used to accurately analyse the performance of prototype cars.

THERMAL IMAGING CAMERA

Using this equipment we were able to analyse the temperature range which the car experiences after a number of races and how to best solve the problem of the loss of heat energy.

STRENGTH TESTING

For testing our tether line guides until they fail to see if they can withstand the 200 gram force.

TEAM AIB RACING

INSPIRED CONCEPTS

TECHNICAL INSPIRATION

Our design team worked to develop design concepts from the large range of research conducted, which is summarised on Page 1. We took into account a number of scientific and mathematical principles and calculations and previous test findings to develop the following ideas which were then applied to our car.

WHEELS

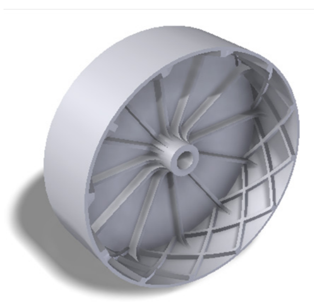
When developing our wheel systems we took into account the research conducted into the Moment of Inertia and Rotational Kinetic Energy. We also encountered friction, which opposes the rotational motion of the wheels over the surface of the track.

With this in mind, we experimented with a number of design concepts:

Prior to the National Finals we had experimented with Delrin Acetal wheels and PLA wheels 3D printed at 10% infill.

The outer shell of our initial concept was made from carbon fibre which has a hard surface thus decreasing friction. The carbon fibre tubing was then cut using a CNC lathe to a thickness of 1mm. SLS manufactured rims made from PLA decreased mass and inertia.

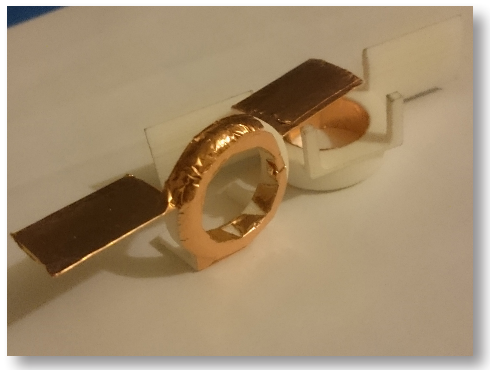
Our final wheel design was manufactured using precision SLS printing for maximum accuracy. Our innovative “criss-cross” support structure designed in CAD software allows us to minimise the mass of the wheel (to 1.1 grams) without affecting structural stability, giving the wheel an extremely low moment of inertia. The wheel was primed and painted to give a smooth finish.

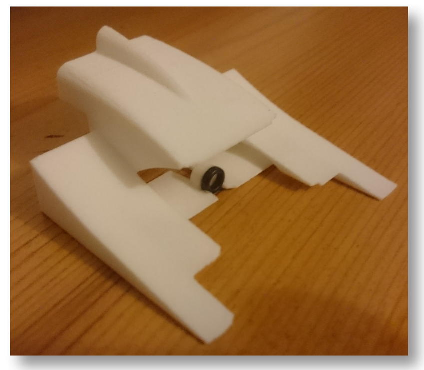


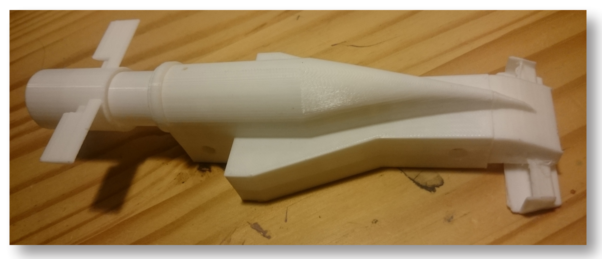
WHEEL SUPPORT

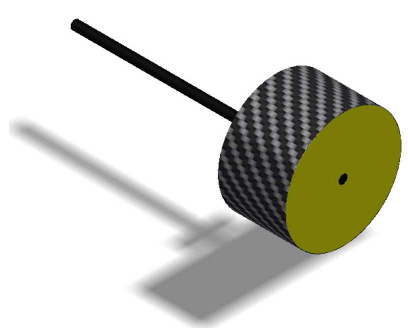
As with the wheels, it is important to reduce the moment of inertia and friction encountered in the support system to minimise the loss of kinetic energy and increase angular torque. The number of rotating parts in the wheel system can affect the moment of inertia, however having wheels rotating independently can increase the amount of axes of rotation which affects alignment and stability. We chose carbon fibre axles over steel for less inertia.

We chose to build a support system which features an axle rotating on the inner race of our ceramic bearings. To improve this further, we built our own bearing cases which stopped bearings popping out of place during races - a common occurrence with this type of wheel system.









Top Left: H.E.R.S. system implemented using Copper on rear wings. Top Right: Ceramic inserts used for tether line. Above Left: Carbon fibre wheel shell. Above Right: “Piston” design on the rear of prototype car. Left: 3D Printed and Acetal wheels, followed by our innovative World Finals wheel design and our carbon fibre shell concept.

TETHER LINE GUIDES

Friction, the force which opposes the motion of two surfaces in contact, generates a loss in kinetic energy. This applies to our tether line guides as the tether line will inevitably be pulled on during racing. To maximise efficiency, a material with a low friction co-efficient is needed.

Inspired by our local fishing industry, we sourced a number of ceramic inserts for fishing rod guides. We then incorporated these inserts into our front and rear wing systems as our tether line guides.

OTHER CONCEPTS

In any research and development process, there are a number of concepts which are well researched and developed which do not make it into the final design of the product. To that end, our car design was no different. There were two systems in particular which we developed strongly - our “piston” system to add to our LERS and our Heat Energy Recovery System.

Our Heat Energy Recovery System was designed to transfer heat energy from the ambient air to the canister chamber area which is radically cooled due to the liquid CO_2 becoming a gas. This then creates a cold environment for the next canister, reducing thrust. We developed systems using thermally conductive materials such as graphene and copper. More detail can be found in our booklet.

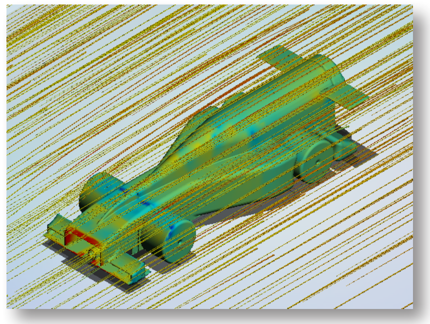
ONGOING EVALUATION

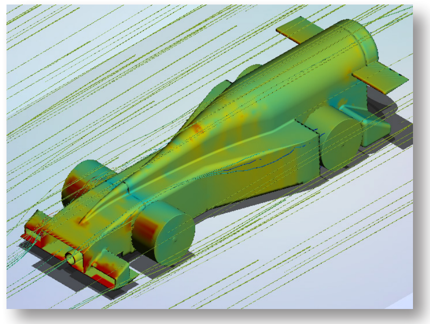
Our research stage, which led onto our technically inspired ideas stage, was a big learning curve for us. When we moved on to CFD, testing and manufacture we became accustomed to the high level of detail and innovative thinking that was required. The experience we gained here allowed us to create even further innovations and inspired concepts over the course of the project.

TEAM AIB RACING

FEA AND CFD ANALYSIS

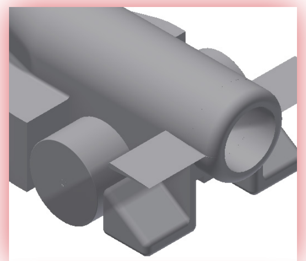
CAR BODY CFD





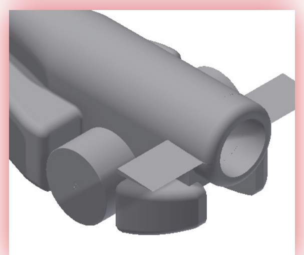
We began our World Finals Computer Aided Analysis process by virtually testing our National Finals car. From there we worked to reduce the car's surface area to the minimum allowed dimensions and to make it sleeker and less bulky. This reduced our drag force by 0.01. We then moved on to analysing each of our design concepts for different areas of the car.

REAR PODS CFD



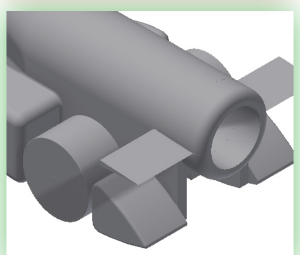
NATIONAL FINALS DESIGN

DRAG FORCE: 0.160N



WORLD FINALS CONCEPT 1

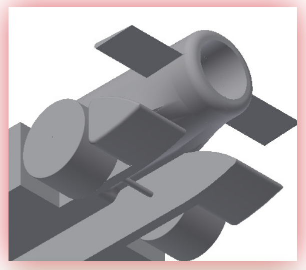
DRAG FORCE: 0.164N



WORLD FINALS CONCEPT 2

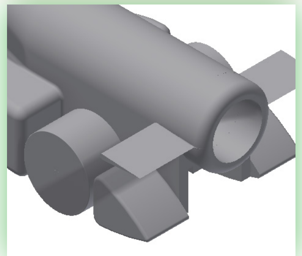
DRAG FORCE: 0.150N

CANISTER CHAMBER



WORLD FINALS CONCEPT 1

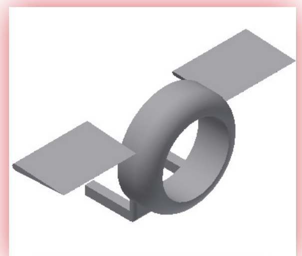
DRAG FORCE: 0.166N



WORLD FINALS CONCEPT 2

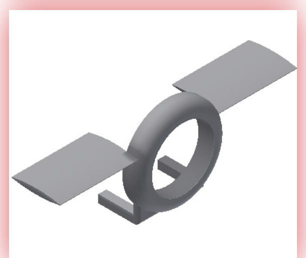
DRAG FORCE: 0.150N

REAR WING CFD



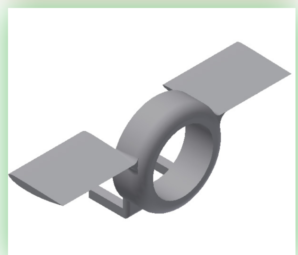
NATIONAL FINALS DESIGN

DRAG FORCE: 0.150N



WORLD FINALS CONCEPT 1

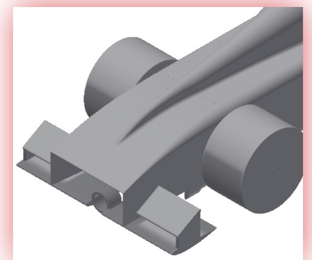
DRAG FORCE: 0.154N



WORLD FINALS CONCEPT 2

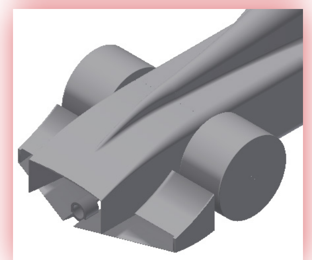
DRAG FORCE: 0.147N

FRONT WING CFD



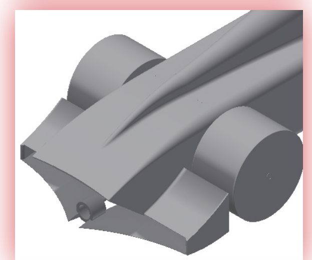
NATIONAL FINALS DESIGN

DRAG FORCE: 0.147N



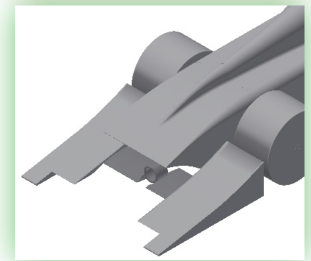
WORLD FINALS CONCEPT 1

DRAG FORCE: 0.131N



WORLD FINALS CONCEPT 2

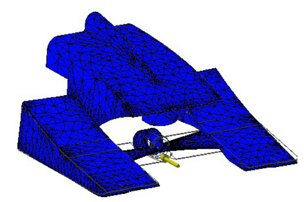
DRAG FORCE: 0.123N



WORLD FINALS CONCEPT 3

DRAG FORCE: 0.121N

FRONT WING FEA



Optimised shape to withstand a number of different potential forces which could be applied during manufacture, transport and racing.

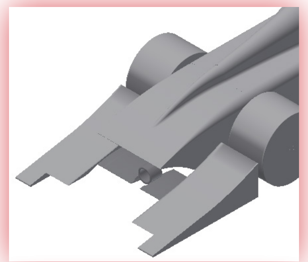
TEAM AIB RACING

FEA AND CFD DEVELOPMENT

DEVELOPMENT

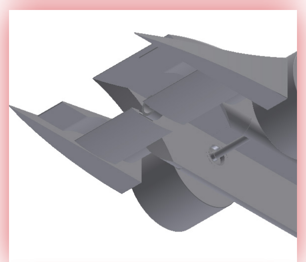
After choosing the initial design concepts as seen on the page before, we began to work on developing these concepts into fully working parts. We used CFD to lower the drag co-efficient and FEA to ensure the parts created would withstand the forces applied to them during racing. These design developments were based on research and manufacturing possibilities. Some designs had to be refined due to regulation failures.

FRONT WING CFD



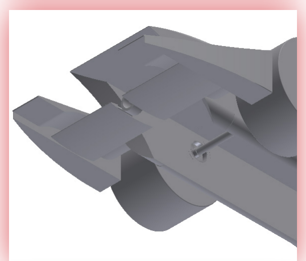
WORLD FINALS CONCEPT 3

DRAG FORCE: 0.121N



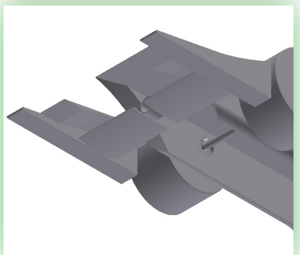
CONCEPT 3 DEVELOPMENT 1

DRAG FORCE: 0.128N



CONCEPT 3 DEVELOPMENT 2

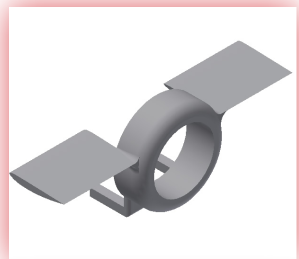
DRAG FORCE: 0.126N



CONCEPT 3 DEVELOPMENT 3

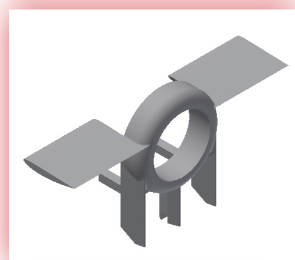
DRAG FORCE: 0.121N

REAR WING CFD



WORLD FINALS CONCEPT 2

DRAG FORCE: 0.121N



WORLD FINALS CONCEPT 2

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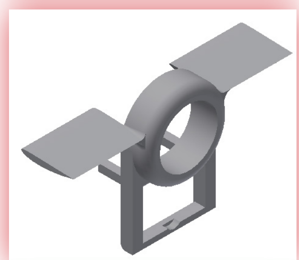
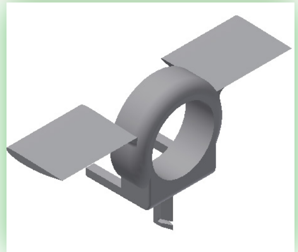


WORLD FINALS CONCEPT 2

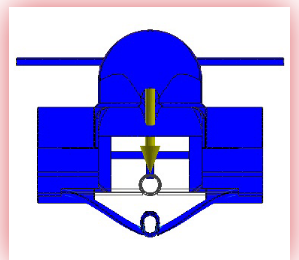
DRAG FORCE: 0.135N



WORLD FINALS CONCEPT 2

DRAG FORCE: 0.125N

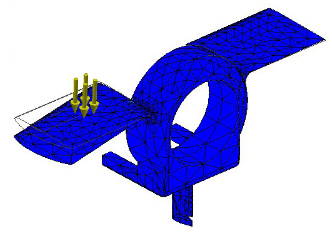
TETHER LINE FEA

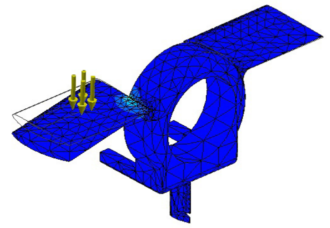


TESTED TO FAILURE

FORCE: 20N

REAR WING FEA





To ensure that our cars were strong enough to withstand the forces applied not only during racing but also during manufacture and transport we did a number of FEA simulations which allowed us to see how the car would perform. These simulations such as the two pictures on the left gave us an indication that additional strength was required. To do this we built a number of fillets around the wing profile to ensure adequate support and bulk. This allowed us to be certain our cars could withstand all the strenous conditions they would face over the course of the competition.

ONGOING EVALUATION

Throughout our initial Computer Aided Analysis stage we feel we have developed a number of new and important skills. In terms of outcomes, we had a number of evaluations which lead to improvements in how we conducted our CFD testing.

- We introduced a new system of recording results, where we recorded every single detail included in the analysis output.
- Then after evaluating our analysis process again, we sought the assistance of Dr. Andrew Niven in the University of Limerick, who informed us that we should run simulations with the wheels slightly off the ground due to their round shape.
- We also trialled numerous other CFD software packages to ensure we got the best quality simulation, however we were satisfied with the performance of Autodesk Flow Design.
- Our original FEA output was not meshing properly. To remedy this we simplified the parts which produced the data far more accurately and easily.

TEAM AIB RACING

TESTING METHODS

WIND TUNNEL

Our wind tunnel testing, as described on Page 1, focused only on flow visualisation, as attempting to read the forces would be difficult and require a lot of time and resources to set up and get access to. We conducted this testing as we felt we needed to get a more realistic and concrete view on how the air interacted with car than CFD could provide to us.

We recorded the wind tunnel testing using wide angle cameras as well as the slow motion feature on our smartphones. After analysing the video, we were able to identify the front wing as a key area for improvement.

HIGH SPEED CAMERA

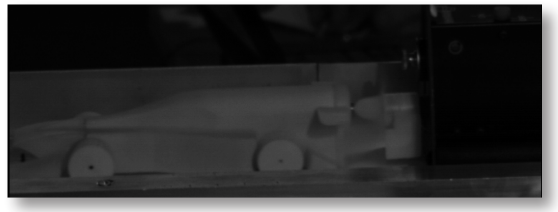
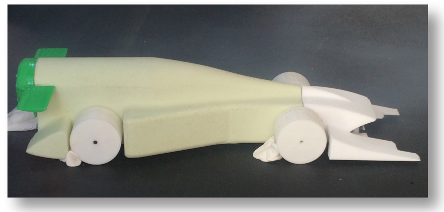
To analyse the performance of a number of high speed issues we used a high speed camera with a frame rate of over 500 FPS. Through conducting this video analysis we could see how the flow from the canister interacted with our different LERS designs, and we were able to identify areas which could be addressed in newer designs. This testing process was also extremely helpful in identifying areas of the manufacturing process which needed to be addressed to ensure the car was stable at joints, due to the large force placed on the object at the start of the race.

Aside from the design and manufacturing analysis, the camera proved useful when analysing Paul's reaction technique. We were able to identify a number of flaws in the technique which when rectified lead to a much faster reaction times.

STRENGTH TESTING

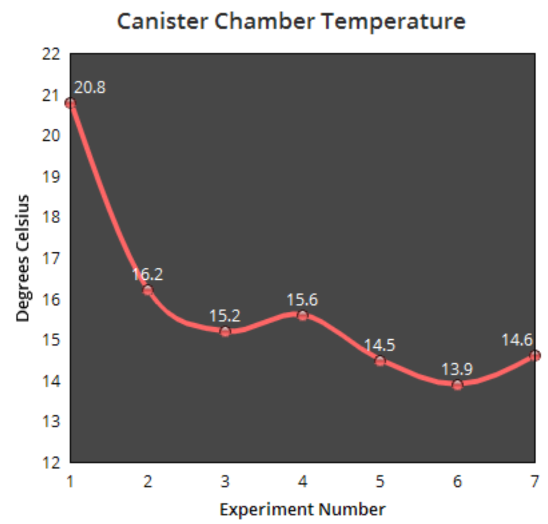
To ensure our cars complied with Technical Regulation T7.4 Tether Line Guide Safety, we tested our front and rear wing support systems, which incorporate our tether line guides, for strength using a test to fail mechanism. In this test, we were able to identify if the guides could support the 200g weight placed on them.

TEST GALLERY

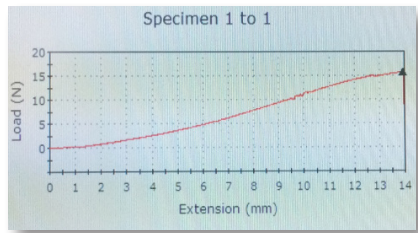



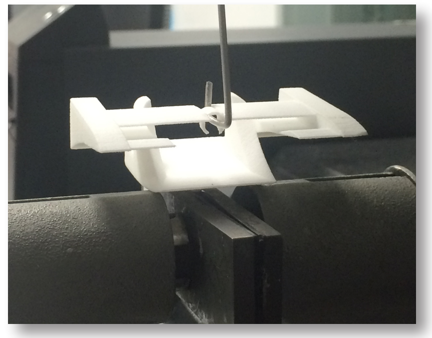
Upper right: High speed camera analysing LERS system. Upper Left: Car setup in wind tunnel. Lower Right: Using thermal imaging camera to analyse heat loss. Lower Left: Laser level used to keep track straight.

TEST DATA



RunOrder	CenterPt	Blocks	Height	Width	Length	Track Time	T1	T2	
1	0	1	4	3	6	1.193	3.656	2.463	17:20
2	1	1	1	2	4	1.172	3.771	2.599	17:25
3	1	1	1	4	4	1.18	5.196	4.016	17:30
4	1	1	7	4	8	1.17	4.793	3.623	17:33
5	1	1	7	2	8	1.194	4.103	2.909	17:35
6	0	1	4	3	6	1.174	4.472	3.298	17:37
7	0	1	4	3	6	1.212	5.425	4.213	17:39
8	1	1	1	2	8	1.185	4.084	2.899	17:41
9	1	1	7	4	4	1.194	4.281	3.087	17:43
10	1	1	1	4	8	1.177	5.588	4.411	17:47
11	1	1	7	2	4	1.208	5.305	4.097	17:50
12	0	2	4	3	6	1.183	5.069	3.886	17:53
13	1	2	1	2	4	1.187	4.489	3.302	17:54
14	1	2	7	2	4	1.195	4.753	3.558	17:56
15	1	2	1	4	4	1.183	4.217	3.034	17:59
16	1	2	1	2	8	1.193	3.955	2.762	18:01
17	1	2	7	2	8	1.206	4.811	3.605	18:03
18	0	2	4	3	6	1.194	4.562	3.368	18:05
19	1	2	7	4	4	1.196	4.964	3.768	18:07
20	0	2	4	3	6	1.175	1.536	0.361	18:09
21	1	2	7	4	8	1.188	4.106	2.918	18:12
22	1	2	1	4	8	1.194	4.044	2.85	18:13



TRACK TESTING

Track testing was the most accurate and useful form of testing as it brings in all the race day conditions. This method of testing was used to test our final prototypes to see which produced the best times. Examples include our wheel systems testing, prototype component testing, LERS testing and innovation testing - examples being our Heat Energy Recovery System and piston device. The results of each experiment (race) were then recorded along with the conditions in which the test was held (temperature, time, date). The outcome of this testing was being able to select which components worked best and which components needed improving. To ensure race day conditions were simulated, we invested a lot of time in ensuring the track was level and straight through the use of a laser level, while also ensuring the official F1 in Schools equipment was used. We were also able to go through race day procedures to ensure we were prepared for the finals.

THERMAL TESTING

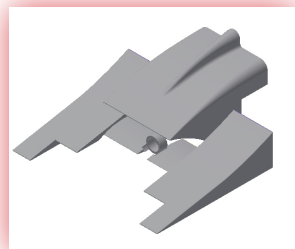
We gained access to a thermal imaging camera and thermal probe for use in our research into the need for a Heat Energy Recovery System, and the effectiveness of such a system. The thermal imaging camera was extremely useful in quickly identifying the drop in temperature and the extent to which the drop in temperature spread throughout the car body and onto the canister. The thermal probe was then used to ensure an accurate reading was recorded from deep inside the canister chamber. We were also able to analyse the effects of our system when we implemented it, and thus were able to identify a number of improvement actions from the data provided by the camera and the probe. Although the thermal testing proved that heat loss is a significant problem, our track testing indicated that even substances created specifically for thermal conductivity purposes were unable to bring the ambient heat energy back into the canister chamber in sufficient time. This is discussed further on the next page.

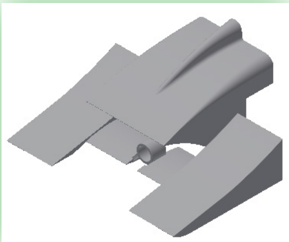
TEAM AIB RACING

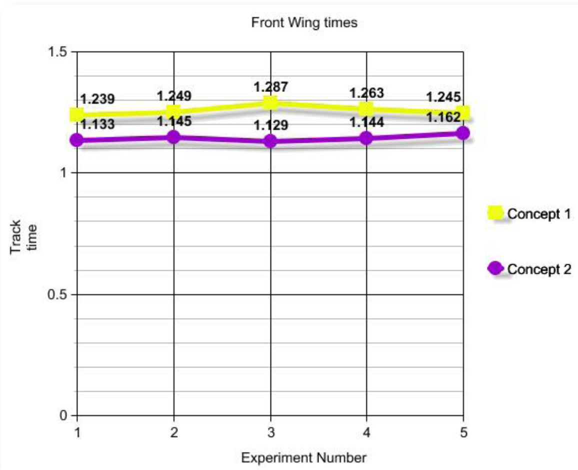
ANALYSE AND REFINE

FRONT WING

The concept which originally performed the best in our CFD analysis failed to work in reality on the track. Therefore we had to refine this design again and develop an alternative wing which was shorter, more mechanically stable and aerodynamic.





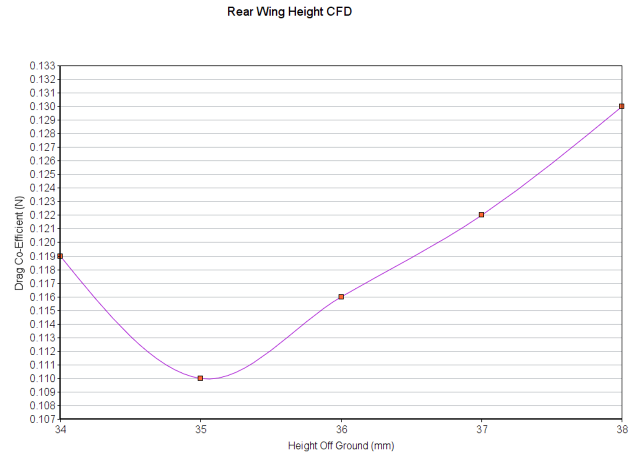


CONCEPT 1 CFD: 0.125N

CONCEPT 2 CFD: 0.122N

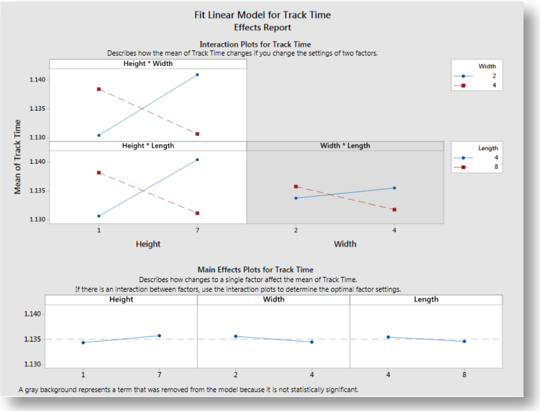
REAR WING

Having developed our best concept and wing profile, we needed to optimise the height at which to place the wing profile. From the graph below we can see that a height of 35mm to the lowest point was the best.



D.O.E.

Design of Experiments is a statistical tool used in the analysis of data. It allows us to get a better insight into which concept combinations work best from less experiments conducted. As our knowledge of Launch Energy Recovery Systems prior to the World Finals was limited, we applied the Design of Experiments testing process to try out a range of different combinations using track testing.



Above: MiniTab D.O.E. software. Above Right: Prototyped LERS design. Right: Final LERS design focused on confining air to a small space.

Using D.O.E. we were able to analyse which of the best combinations from our video analysis phase were the best in terms of track time. Our D.O.E. lead us to confirm that confining the air to a small space was the best system for gaining thrust.

H.E.R.S.

Although we identified that a successful H.E.R.S. would be effective and increase track time, we were unable to implement such a system in the final design. We endeavoured to use the best materials available, including graphene and copper, to ensure the best transfer of the heat from the surrounding air into the car. However the impacts on track performance, as seen in the graph below, were marginal. This was due to the materials not transferring the heat quickly enough to make a sustainable impact. The system proved to be a useful R&D exercise however.

WHEEL SYSTEM

We had a wide range of wheel system concepts which we prototyped:

- Our 12 bearing system, 8 bearing system and 4 bearing system
- 1.1 gram “criss-cross” wheels, 2 gram SLS wheels
- 3 gram 3D printed wheels
- Steel axles, carbon fibre axles
- Carbon fibre shell wheels

Due to manufacturing difficulties and theoretical calculations which we assessed in the prototyping stage, we decided to experiment with two final concepts: Our 12 bearing system and our 8 bearing system using our 1.1 gram SLS wheels. Our final test was a “roll test” which analysed the performance of both sets of wheels using an inclined plane and measuring tape. We established from this test that our 12 bearing system was the more efficient option and thus we chose it for our final car.

ONGOING EVALUATION

Throughout our testing and refining stage we developed a number of skills such as problem solving, ensuring test results were accurate and experience of a real life product development testing process. We constantly evaluated our testing process and came up with a number of improvement actions:

- For our high speed camera testing, we attached a long steel ruler to the side of the track so we could get a more accurate idea of how the LERS systems performed.
- We originally used only the thermal imaging camera for our thermal testing, however the addition of the probe allowed us to get more accurate data for inside the canister chamber.
- After conducting our testing, we evaluated our track times and decided further improvement was need so we continued to optimise car components using CFD.

MANUFACTURING PREPARATION

3D MODELLING

Before sending our cars to manufacture it was important to update all models so they were accurate to the abilities of the machining facilities which were made available to us. We included a 1mm radius around the canister housing and shroud, due to the complexity of the part and the abilities of the tool. We also rounded off the edges of the rear pod so they could be produced accurately. Our wing profiles had to be rounded off due to the resolution of the SLS printer being 0.1mm.

FACILITIES

Our school does not have access to any machining or engineering facilities at present. As a team, we have worked tirelessly to promote engineering in the west of Ireland and in our school. Through the work of our team, our school has found a patron willing to assist with upgrade of engineering facilities in the school in the coming years.

Due to the lack of facilities available we have worked hard to source facilities in local third level institutions and precision engineering companies. Through collaboration with these companies we have been able to gain knowledge of CNC and CAM technologies.

WORKPLACE SAFETY

Safety is of the upmost importance when producing our cars. Our team has developed a safety strategy for use in all manufacturing operations in any of the facilities we use. Team members must:

- Always be accompanied by a trained supervising adult
- Never wear loose or dangerous clothing/items
- Wear appropriate protective gear
- Be briefed on the potential dangers using any equipment has
- Have read the Material Safety Data Sheet for all materials used
- Refer to the MSDS if uncertain about handling a material
- Be equipped with the necessary training to operate machinery

QUALITY CONTROL

Ensuring each product is consistent and of the highest quality is of the upmost importance in any manufacturing process. In any Quality Control and Quality Assurance code there are a number of steps which we made a note of adhering to:

- **Quality of the raw materials:** We checked the F1 Polymer Block for dimensional and weight issues before each CNC manufacture. We examined each of the materials used in the design in the same way.
- **Adhere to manufacturing instructions:** To maintain consistency, each car was manufactured, treated and painted using the same process in the same conditions.
- **Overall end product quality:** Each manufactured car was assessed in a number of areas - most notably to see if it passed critical regulations. This testing was done using calipers and gauges.
- **Production efficiency:** It is impossible to ensure the quality of the product if the manufacturing process is not run efficiently, smoothly and in a professional and planned manner.

OUTSOURCING

Our final car design included a number of parts which were produced using outsourcing. We endeavoured to produce as many parts as possible, especially in the prototyping stage, however without the access to state of the art facilities for producing some of our parts this was not possible.

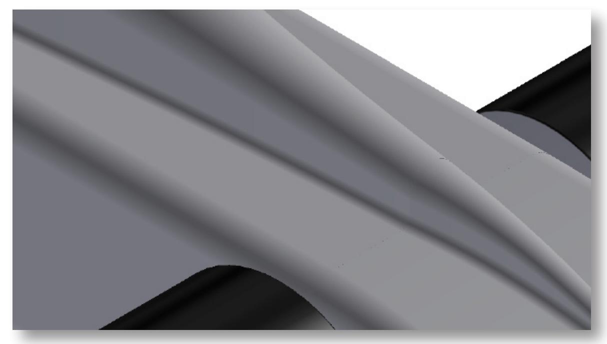
We were able to 3D print wheels for use in the National Finals, and continued to produce our own prototypes using the facilities made available to us. However, for the final car we decided to outsource the printing of our front and rear wings, wheel rims and bearing holders to a Belgian company, Materialise. They were able to produce these parts using Selective Laser Sintering which made the parts far more accurate and lightweight than the parts produced by the team.

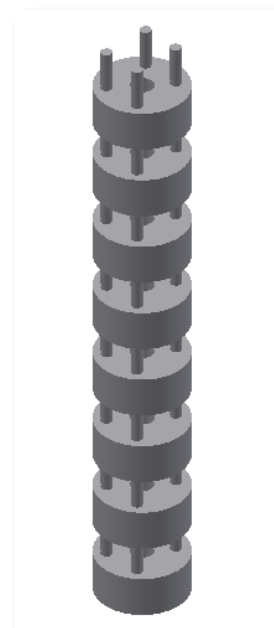
TRAINING

After reviewing our performance at the National Finals, we felt it was important that our team members upskilled in the area of CAM and CNC technologies. Because of this, the team collaborated with experts in a local precision engineering company, Tool and Gauge. Not only did they provide access to extremely accurate CNC Mills and Lathes, but they were able to teach us how to use the software and machinery, and supervised the production of our cars.

COST REDUCTION

To ensure we could get the most from our budget, we implemented a number of cost reduction measures without impacting the quality of the product received. One such method was when buying small SLS parts. We designed support structures for the part in Inventor, and created several copies of this. We were then left with numerous copies of the part in one Inventor file. This meant instead of being charged for every single part by itself, we were only charged for one.





Above: 3D Modelling for Manufacture with fillets. Left: Cost Reduction. Below: Team with manufacturing partners.

TEAM AIB RACING

CAM PROGRAMS

The CAM program used in the manufacture of our car was PowerMILL Pro 2014. Our car models were imported into the software in a .STEP format. The computer on which the software was run was linked up with the Hurco VMX50 CNC mill, which bypassed the need for the machine's software to be used in setting up the model and the sequence of cuts.

PowerMILL Pro allowed us to machine the car to a very high finish - we were able to set the various different toolpaths at the step over (the distance the at which the tool moves horizontally after each revolution of the part) and step down (the distance at which the tool moves vertically after each revolution of the part). PowerMILL Pro was able to predict the size of the "cusp" of material left over between each step over when creating curves. We could also get a visualisation of the process, and an accurate estimation of the time taken by a cut sequence. We were also able to control the speed of the tool.

THE CNC - SETUP

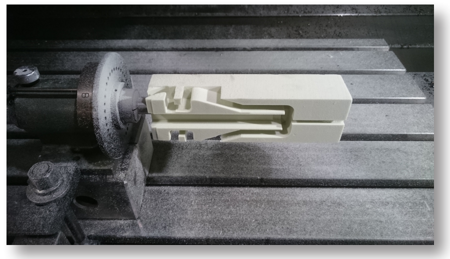
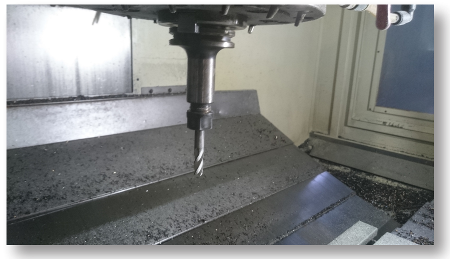
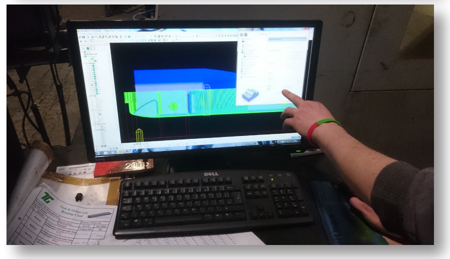
Although we had access to a number of different machining facilities we decided to manufacture the final set of cars at a precision engineering company called Tool and Gauge. We were given access to a Hurco VMX50 3 Axis CNC Mill. Tool and Gauge helped us in our manufacture with an innovative "spinner" system. A custom metal insert was placed into the canister chamber at the rear so it fit snugly and the block was secured. Each time a new cut had to be made, the spinner could be twisted to the exact orientation required, thus removing the human error in repositioning the block. It also removed the need to clamp the car from four cut sequences.

By using the spinner mount, we were able to set the centre of the hole as the 0 X, Y and Z axis reference point. This reduced the error in the centering of the holes on the blocks. This was done using a 2mm probe. We then marked off the sides and ends of the block using the probe to ensure the car would be referenced correctly.

CNC MILLING

To begin the CNC Milling process we chose the correct tools for use for each cut. A 10mm end mill was used for roughing cuts, 6mm ball nose tool was used for the raster toolpath and a 1.5mm end mill was used to cut out small details on the front and rear of the car. To ensure the tools didn't attempt to cut the canister chamber, a plane was created across the area of the hole. We were able to analyse the tool position and path before each cut from the software on the Hurco CNC. We then set out our cut sequence plan and continued to machine the car.

Bottom: Constant Z "roughing cut" toolpath using a 10mm end mill at a step down of 2mm. Raster finish using a 6mm ball tool, at an angle of 45 degrees and a step over of 0.15mm.
Sides 1 and 2: Rotated car 90 degrees to Side 1. Constant Z roughing cut with 10mm end mill and step down of 2mm. Raster finishing using 2mm at 45 degrees, step over of 0.15mm. Rotated 180 degrees to Side 2 and repeat.
Top: Rotate car 90 degrees. Model area clearance roughing cut using 10mm end mill with a step over of 4mm and a step down of 2mm. Raster toolpath finish with 6mm ball cutter and a step over of 0.15mm, leaving a cusp of 0.001876mm.
Front: Car set up on an angle plate and clamped on the side pods. 1.5 mm end mill used to cut simple front attachment feature.
Back: 1.5mm end mill used to cut out small attachment feature at the rear of the car.


Top Left: Car turned 90 degrees on spinner. Top Right: 10mm end mill tool used for roughing cuts. Bottom Left: Preparing toolpaths on PowerMILL Pro. Bottom Right: Drying after painting.

SLS MANUFACTURE

Selective Laser Sintering manufacturing allows CAD models to be rapidly made into 3 dimensional objects. CAD models are first converted into .STL format so the SLS machine can read them. The powdered material (in this case, plastic) is dispersed into a thin layer above the build platform. The laser is then directed down at the platform and it begins tracing cross sections of the desired object onto the powdered plastic. This heats areas under the laser to just below their melting point, causing the tiny powdered particles to fuse together, creating a tiny layer of the part. The platform then drops immediately to allow the next layer to come under the focus of the laser, with this process repeating over and over until the part is complete.

FINISHING PROCESSES

- Check mass of components for irregularities in expected values.
- Sanding: Car body and SLS manufactured parts lightly sanded using 500 and 600 grit sand paper to remove any rough textures. Car weight checked and recorded.
- Coat with PVA glue to seal the car body. Once dried, repeat the process twice more.
- Apply first purple coat of paint and lightly sand using 800 grit sand paper. Repeat this process with second coat. Apply third coat of purple to body. Leave to dry.
- Blast the SLS manufactured parts with air to remove dust. Apply a coat of plastic primer to front and rear wing.
- Apply two coats of yellow colour to front and rear wings. When dry cover the wing profiles with masking tape. Apply two coats of purple paint followed by a lacquer.
- Place decal stickers on car followed by two coats of lacquer.
- Use black primer on wheels and dry with an air drill. Spin on air drill whilst applying 800 grit sand paper to get rid of ridges. Apply two coats of black satin paint.
- Final assembly of car with full wheel system, front and rear wings. Use lead inserts to bring car up to 54.5g.

TEAM AIB RACING

FINAL CAR DESIGN

REAR WING

The rear wing of car features tapered eliptical aerofoils which we found to be the best aerodynamically through our CFD testing. The SLS manufactured part has a hollow centre to allow for lead inserts to be placed into the support structure for mass purposes.

CAR BODY

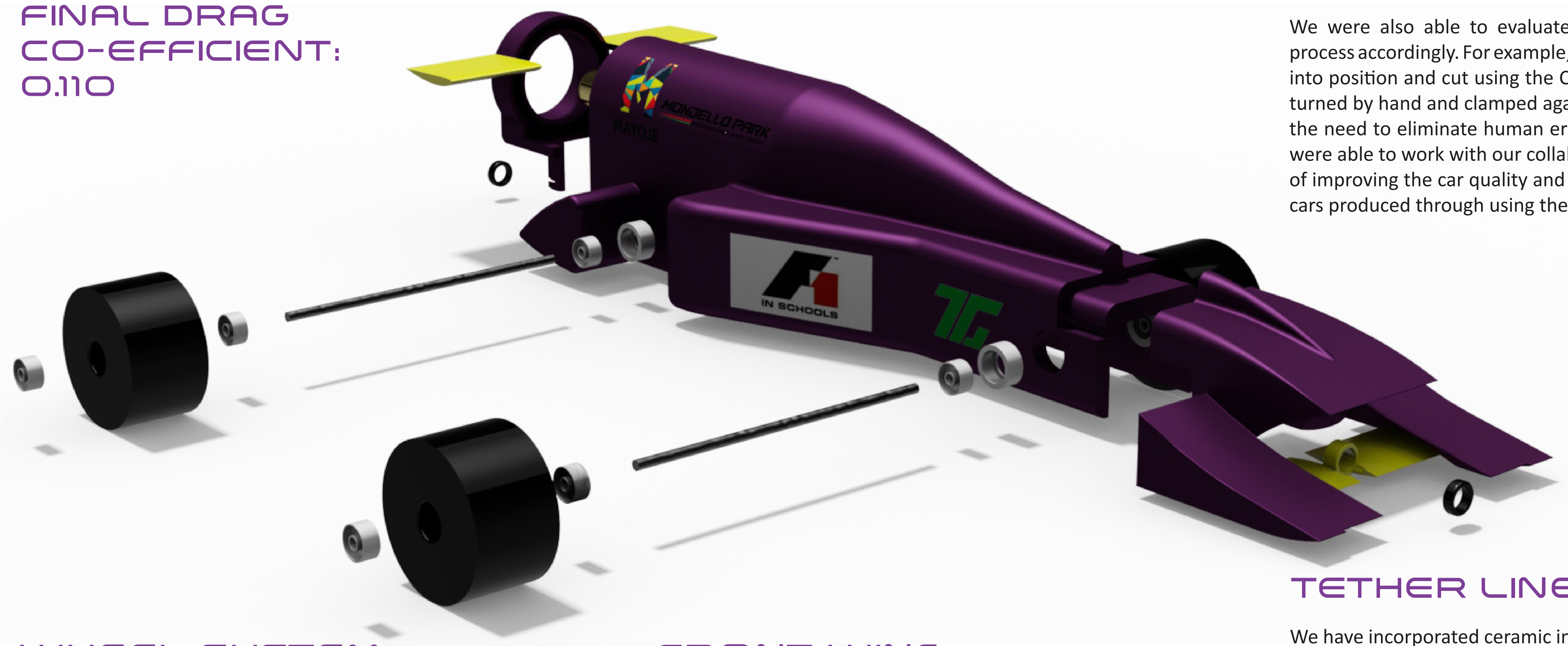
Our car body features our distinctive long canister shroud - a feature which reduces frontal pressure. The body is cut down to minimum dimensions for maximum speed and aerodynamic efficiency.

ONGOING EVALUATION

Throughout the manufacturing stage, from setup to quality assurance to assembly, we strived to bring our best car design yet to life with top class mechanical design and state of the art manufacture. We were able to learn a huge amount of new, practical skills which could be used in our future careers.

We were also able to evaluate and adapt our manufacturing process accordingly. For example, our cars were originally clamped into position and cut using the CNC mill. The cars would then be turned by hand and clamped again. However through identifying the need to eliminate human error and strive for perfection, we were able to work with our collaboration partners and find a way of improving the car quality and decreasing the amount of faulty cars produced through using the spinner mounting system.

FINAL DRAG CO-EFFICIENT: 0.110



TETHER LINE GUIDES

We have incorporated ceramic inserts at the front and rear of the car to minimise kinetic energy losses to friction from the tether line being pulled.

WHEEL SYSTEM

Our innovative wheel system uses 12 bearings so the car can pick the path of least resistance during racing - for example, while it may be more efficient to rotate on the inner race of the bearings in the body at one point in the race, it could be more efficient to rotate on the outer race of the bearings in the wheel at another point.

FRONT WING

The SLS manufactured front wing is designed for maximum aerodynamic efficiency. The wing ensures that air is easily directed over the front wheel. Its sleek, elegant yet innovative design brings a much lower drag co-efficient and an aggressive look to the car. It also has a hollow centre where we have placed lead inserts to bring the car up to optimal mass.