AERODYNAMICS CONCEPT

An analysis of RMIT Racing's R15/R16 aerodynamic package

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R15 Benchmarking

R15 was the first year the team took an interest in aerodynamics in regard to adding wings. Over the previous years due to the low mass, low drag concept teams wouldn't justify wings.

Even through R15 did not have wings they were research and wind tunnel tested. The reason R15 didn't have wings is due to not having enough money, time to manufacture and validate. The goal in 2015 was 210N at 40km/hr which was evaluated to win skid pad. Skid pad was chosen because it is a quick test, can be validated at school, replicated multiple times and apart of the FSAE-A competition. A max Cd of 3 is required to become speed limited at 110km/hr calculated through sacrificial break horse power. Engineers selected different profiles and CFD tested them in 2D. An FYP was done on a 1/6 wind tunnel model and a 3D CFD of the car that correlated up to 10%. The wings were not added to CFD due to meshing issues. The wings research in 2015 will be used in 2016 to understand dynamically what is happening. Wind tunnel testing on the wing evaluated they were making the downforce required. The wind tunnel didn't have full scale force balance so suspension patches were used. The patches fluctuated between 1kg a path.

To anyone on the aero team, make sure to budget time appropriately. Don't spend too much time on CFD, make sure to always wind tunnel test as early as possible and get it on the car to validate. Aerodynamics aren't dominating factors on the car, don't spend more time than needed in CFD or wind tunnel. Engineers may be able to gain time out of the car by tweaking parameters but on top of that drivers have time to gain.

R15 side pods were created in R12. The side pods were added because there were 2 papers worth of information about how they worked. They were designed to try and increase air flow to radiators and control the air flow around the car. The flick up diverted air around the rear tire, resulting in less drag by the rear tire, kept it hotter and if understood would be able to decrease pressure and increase grip (need good tire data to validate if its needed). Due to the fan, which is able to pull enough air through, the radiator isn't depended on ram air. The side pod didn't appear to increase the efficient of the radiator.

R16 Concept

Team Goals

Intelligent design

Validation through testing

Vehicle dynamics goals

Understand R15 to create a balanced R16 car

Aerodynamics Goals

Understand how the COP is moving

The aerodynamic goals relate to the vehicle dynamic goals which relate to the team goals. The goals will be important in the decision-making process, always ask the questions will this move me closer to my goal.

The reason understanding COP migration is 2016 goals is if we understand how the COP is moving, VD has that knowledge and it will change the way they set up the suspension/tire/aero. That way we can understand in what situations the package will help and in which it won't.

Aerodynamics is a subsystem that helps suspension and tires because aero forces don't dominate grip levels. Aero helps other subsystems a push over the edge to become a winning car.

2015 Canterbury team reported seeing 2% lap time gain in skid pad using aero. A GFR diffuser paper found it made the car 1% faster. These are some examples that show, aero makes the car faster, but it isn't a game changer.

Why we went for our package –

- Needed to validate 2015's suspension as it was the basis for 2016. Data was taken, but not recorded on the drive
- Needed to understand tires. No avon data
- By making the aero package that could hit the target.
- Wanted a package designed early in order to determined how we could manufacture the package and mounting
- Wanted to put the aero package on the car and start testing as much as we could
- We could test out our assumptions –

    - ground clearance
    - skid pad times according to simulation
    - what speeds aero helps in skid pad and slalon
    - how it effects slaloms
    - how the COP moves
    - how the drivers respond to aero.
- Need to understand how we can use the wings to tune under/oversteer
- How to change the suspension set up accordingly
- Largest limit was human resources – not many people that knew aero/system

Aerodynamic analysis

2015 Results outlined in Table 1. Table 2 outlines the 1st, 3rd and 8th times with respective teams

2015													
Position	Team	Acceleration Time	Acceleration Score	Skid Pad Time	Skid Pad Score	Autocross Time	Autocross Score	Endurance Score	Economy Score	Aero Package	Downforce(N)	Drag(N)	Speed(km/hr)
1	Monash		35.2	4.9	71.6	1min 38 sec	100	308.5	84	Yes	1168	608	80
2	Melbourne		26		54.2		91.6	325	68	Yes			
3	Canterbury		31.8		75		93.6	294.1	65.9	Yes			
4	Auckland		48.8		64.8		91.4	186.6	86.5	No			
5	Queensland Petrol		67.8		55.6		81.3	154.6	64.5	Yes			
	ECU	3.9											
18	RMIT		22.2		28.2					No			

Table 1-2015 results

Event Analysis									
Event	1st Points (pts)	1st Time(s)	Team	3rd Position(pts)	3rd time(s)	Team	8th Position (pts)	8th Time (s)	Team
Acceleration	75	3.9	ECU	52.6	4.363515755	Melbourne	41.3	4.814638609	Waikato
Skid Pad	75	4.89	Cantebury	71.8	4.931526712	ECU	49.2	5.258403349	Missouri
Autocross	100	98	Monash	92.7	100.3941546	Woolongong	84.5	103.2269165	Waikato

Table 2- 1st, 3rd and 8th analysis

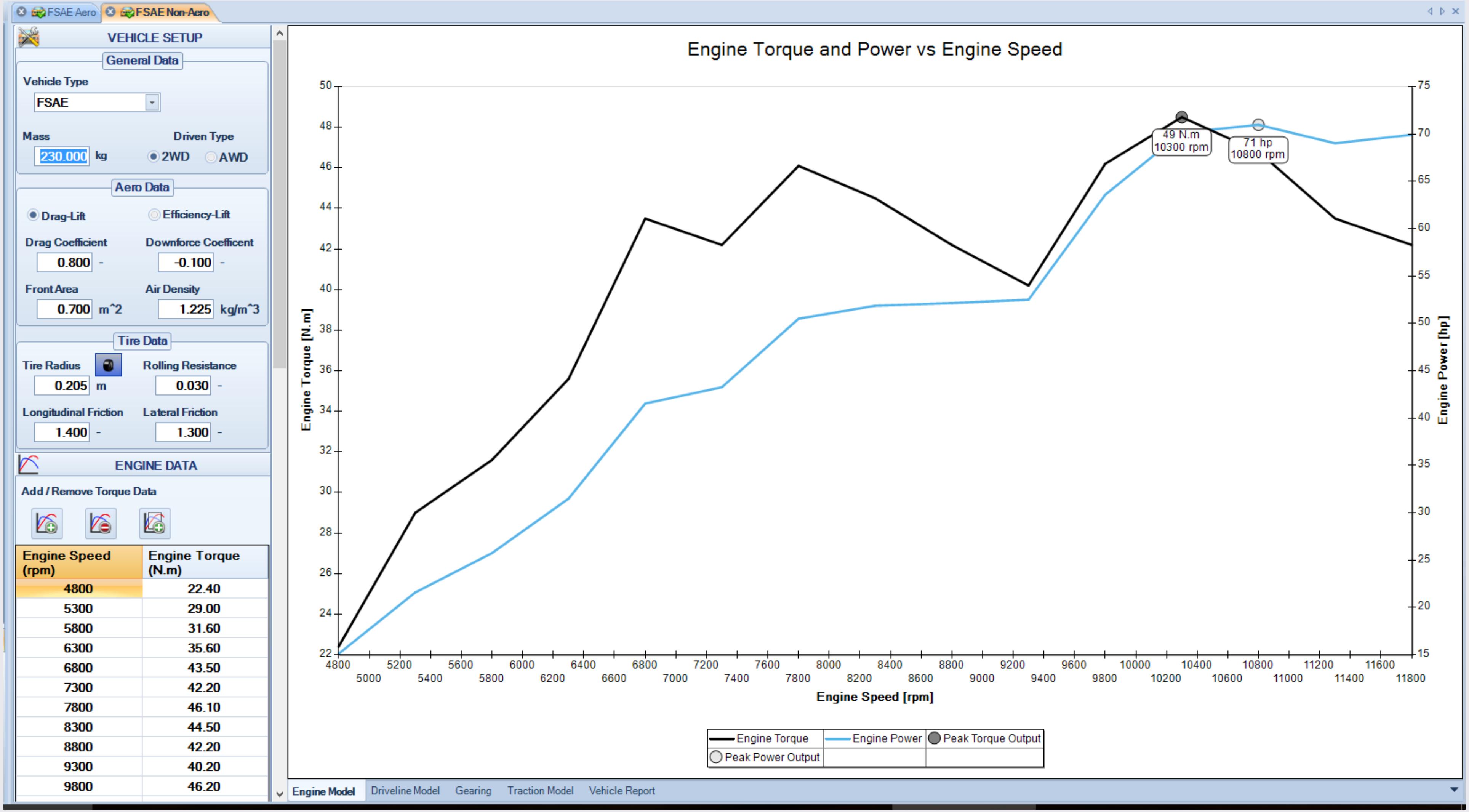
Lap Simulator

Lap simulator used was optimum lap. It is a point mass simulator taking into account aerodynamic loads. It was used because it is free, has ability to input aerodynamic loads and we didn’t have anything better (using resources at our disposal). A point mass simulator doesn’t take into account weight transfer, aerodynamic change due to yaw, and COP/COG change. Due to the errors listed the time will be lower in real life. It was used to ensure that the direction the aero package was heading in is correct and analysis went into defining goals. Maximising downforce is not a goal!

RMIT RACING

2015 RMIT Current Concept Data from Optimum Lap

Figure 1 outlines the RMIT 2015 Concept Car. Data was taken from transmission and engine to make the graphs needed.



RMIT RACING

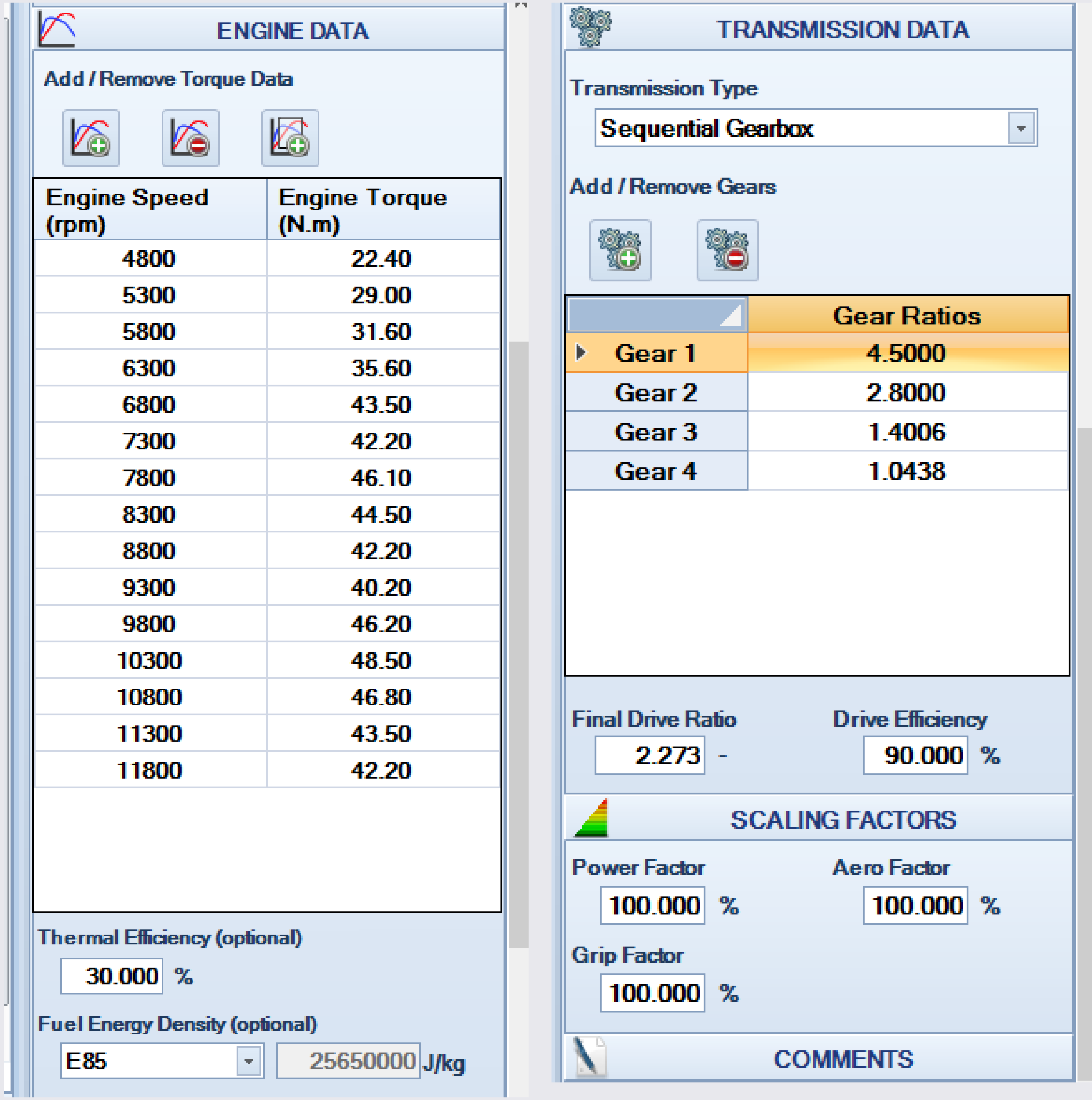


Figure 1- RMIT 2015 Concept

In order to try calibrating the skid pan model, Canterbury was used. Downforce and lap time is known. No engine or transmission data is present, shouldn't affect skid pan. Figure 2 on the right shows downforce and drag coefficients. Data is on the Canterbury motorsport page.

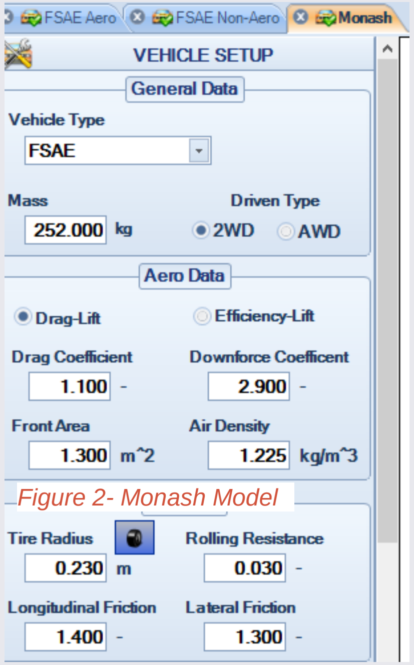


Figure 2- Monash Model

Winning times

Table 3 outlines the winning times of the competition. The times were found through Facebook posts and FSAE-A app.

Skid Pad	**4.9**

Table 3-Winning times

Benchmarked R15 Times from Optimum Lap

Table 4 outlines the benchmarked R15 times from Optimum Lap. Appendix A outlines all data from the Optimum Lap.

Acceleration	**3.68**
Skid Pad	5.1
Autocross	123
Economy (Autocross kJ)	1033

Table 4-Benchmarked times

Benchmarked Canterbury Times from Optimum Lap

Table 5 outlines the benchmarked times of Canterbury.

Acceleration	**3.81**
Skid Pad	4.83
Autocross	122 sec
Economy (Autocross kJ)	1097kJ

Table 5-Monash Times

Centerbury times were used to calibrate the model. In order to get their times similar to their comp time Lat. Friction had to drop to 1.4.

R16 Aerodynamics

Using the 2015 benchmark and Centerbury times, downforce coefficients were increased until the skid pan times reached a winning number. Figure 3 shows the data used.

Aero Concept Times

Table 6 outlines the R16 times.

Acceleration	**3.75**
Skid Pad	4.9
Autocross	120
Economy (Autocross kJ)	1269

Table 6 -R16 Times

With the result, the Cl was increased by 20% to represent the teams getting faster, ending up needing Cl-1.7. This does not take into account what is lost in yaw. This will need to be validated; this approach can then be refined for the future.

Difference

Event	Winning Times	Canterbury	Benchmark	Aero Concept	Difference
Acceleration	3.9	3.81	3.68	3.75	-0.07
Skid Pad	4.9	4.87	5.1	4.9	0.2
Autocross	98	122 sec	123 sec	120	3
Economy (Autocross kJ)	Not listed	1120	1033	1269	236

The acceleration times are too low compared to the winning times. The time difference is very small. This will need to be validated.

Skid Pad is the main focus of this exercise. It shows that with a Cl of 1.7 the team will be in a competitive position.

The Autocross times shows us that there is a 3 second increase per lap in just adding.

The economy shows that 236kJ of energy needed to overcome aero drag.

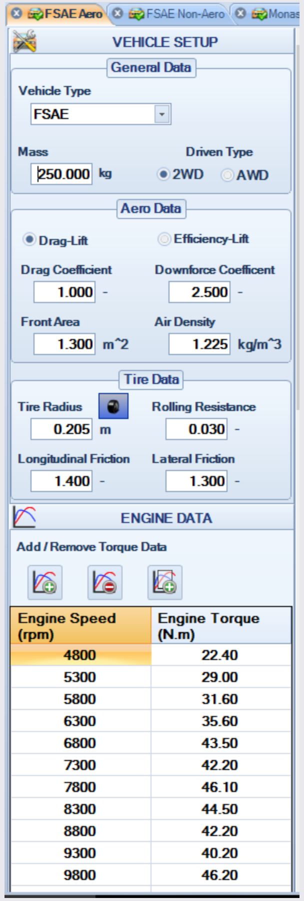


Figure 3-R16

Using the benchmarked times points analysis was conducted in Table 7. Points scoring system outlined in rules

Event	Concept 1 Points	Concept 2 Points	Points Difference
Acceleration	68.1	63.7	-4.4
Skid Pad	59.6	74.2	14.6
Autocross	87.6	94.9	7.3
Endurance	289.0	310.2	21.3
			38.8

Table 6-Points analysis

Event Analysis

Use of Aero

Created a table below to understand where aero can help. Need to focus on CFD mid corner.

	Speed Range		
Situations	Low Speed (20km/hr)	Medium Speed (30km/hr to 40km/hr)	High Speed
Braking into a corner	Not effective - Drag of aero package will help reduce braking distance, low speeds aero doesn't no dominate, mechanical assistance needed	Effective – Want max drag to reduce braking distance Car will be pitching due to brakes, want max drag	Effective – Want max drag to reduce braking distance Car will be pitching due to brakes
Mid Corner	Not effective - At low speeds car won't be traction limited, want aero to produce grip however low speeds aero doesn't dominate. At low speeds the yaw angle will decrease due to wings and will adversely affect the car	Effective – Want max downforce as car may be traction limited Max downforce when car is in roll Also want high yaw acceleration allowing the car to turn into the corner	Effective – Want max downforce as car may be traction limited Max downforce when car is in roll
Accelerating out of a corner	Not effective - Aero won't help	Effective – Low drag to help the car accelerate out of a corner	Effective – Low drag to help the car accelerate out of a corner

Skid Pad

Evaluate the cars cornering ability while making a constant radius turn

Course lay out-

- Couse is two circles of 15.25m with 3m track radius
- The driver enters the course, does two laps in left circle and then two in right circle.
- The second lap time is recorded for each circle and the average is taken as their time

Through optimum lap

- R15 can pull 1.2 G's
- R16 can pull 1.4 G's
- Centerbury is pulling 1.43G's

Able to validate these figures with G sensors. If they aren't available able to measure difference in time and back calculate to understand if aero is helping.

Want to use linear pots to try and understand the aero distribution and how it changes in yaw.

Pressure tapping the wings using pressure sensors can also be used. (Need to look into this)

Acceleration

Evaluates the cars acceleration

Course lay out-

- straight line for 75m

As drag increased to a Cd of 1, acceleration times increased by 0.07 sec.

In order to validate, need to test with and without the package.

Autocross

Evaluate the cars manoeuvrability and handling qualities, on a tight course. Combines benefits of acceleration, braking, and cornering in one event
From the FSAE rules they try and limit average speed to 40km/hr.
Course layout -

- Straights no longer than 60m with hairpins at each end or 45m straight with wind turn on ends
- Constant turn of 23 to 45 m
- Hairpins at 9m minimum OD
- Slaloms in straight line with 7.6 to 12.2m spacing
- Miscellaneous, chicanes, multiple turns, decreasing radius turns, min track width is 3.5.
- 0.8km track

From Optimum Lap data, the aero car spends .21% less cornering, 7% less accelerating and 7% more braking, 3% more in open throttle with a 2km/hr higher max speed. Average speed increase from 47.4km/hr to 48.3km/hr. Max lat g's increases from 1.3 to 1.6, max long acc increases from 0.63g to 0.60, max long dec increase from 2.3 to 1.4.
Most corners were between 20-45km/hr adding 180-300N of downforce, only 1 corner at 80km/hr.

Appendix B outlines the track map, speeds and downforce.

Endurance

Course lay out

- 22km
- evaluate the overall performance of the car, test durability and reliability
- average speed is 48 to 57km/hr
- top speed of 105km/hr
- straights – no longer than 77 with hair pin or 61m with wind ends
- 30-54m constant turns
- Min9mOD hair pin
- 9-15 slalom spacing
- Miscellaneous, chicanes, multiple turns, decreasing radius turns, min track width is 4.5.

- Autocross is around 27 laps to make endurance

If autocross data is extrapolated, 81 sec saving with aero

Fuel Efficiency

Based on how much fuel is consumed/ lap time on endurance course averaged over the length of the event. Extrapolating autocross data 6372kJ of extra fuel is used.

Decision Matrix

Decision Matrix was used to determined where resources should be spent.

		Devices					
Factors considered	Multiplier	Front Wing	Rear Wing	Diffuser	Side Pod	Side Wings	
Validation on track	1	2	2	2	1	3	
Time needed to understand the device	2	1	2	4	3	5	1-low factor
Time taken to Design and integration	3	2	3	4	1	5	4-high factor
Time needed to Simulation	4	1	2	4	3	4	
Resources to manufacture	5	2	3	4	1	3	
	Total Score	24	38	58	27	59	lower=better

Results show needed to focus on front wing, rear wing, side pods, diffuser and then side wings. Focused on front and rear due to time constraints.

Drag Analysis

From Aero Package 2016 – Table 8 used to determined max drag capable.

Max Cd of the car is 2.2, which is very high.

Calculating 'Sacrificial' Drag Brake Engine Power	
Brake kW absorbed	Cd*A*v^3/(1633)
A of car(m^2)	0.7
Cd of chassis	0.8
Cl of chassis	-0.2
kW avaliable	60
Solving for v(max speed)	55.93064178
Assuming v(max) around track(m/s)	30.55555556
Brake kW absorbed(chassis only)	9.783007702
kW remaining for drag of rear wing	50.2169923
Max Cd of Car	
Area of the Car with Wing(m^2)	1.3
Max Cd Allowed	2.211174293
Speed(m/s)	11.11111111

Table 7-Calc max drag

Determining COP

The COP is very important to the car. In order to tune understeer, the COP needs to be pushed to the front Figure 4. By understanding where the COG is, COP migration (estimate), COP position can be determined. Knowing the COP of the wings, distance to the COP can be determined and downforce for each wing can be determined as seen in Table 9. Figure 5 outlines FBD.

Designing for COP				
COG Position from the front of the car	56%			
COP Migration	10%			
COP Position from the front of the car	46%			
Length of Car	2600			
COP Position from the front of the car	1196			
Downforce required at 40km/hr	173.3333333			
Distance from Front Wing to COP(m) (Double Element COP at 0.4c from CFD)	1.07			
Distance from Rear Wing to COP(m) (Triple Element COP at 0.6c from CFD)	1.28			
Front downforce(N)	Cl of Front Wing	Rear downforce(N)	Cl of Rear Wing	Total Downforce
93	1.56	77.74	1.58	170.74

Table 8-Determining COP

We need a Cl front wing of 1.5, Cl rear of 1.5.

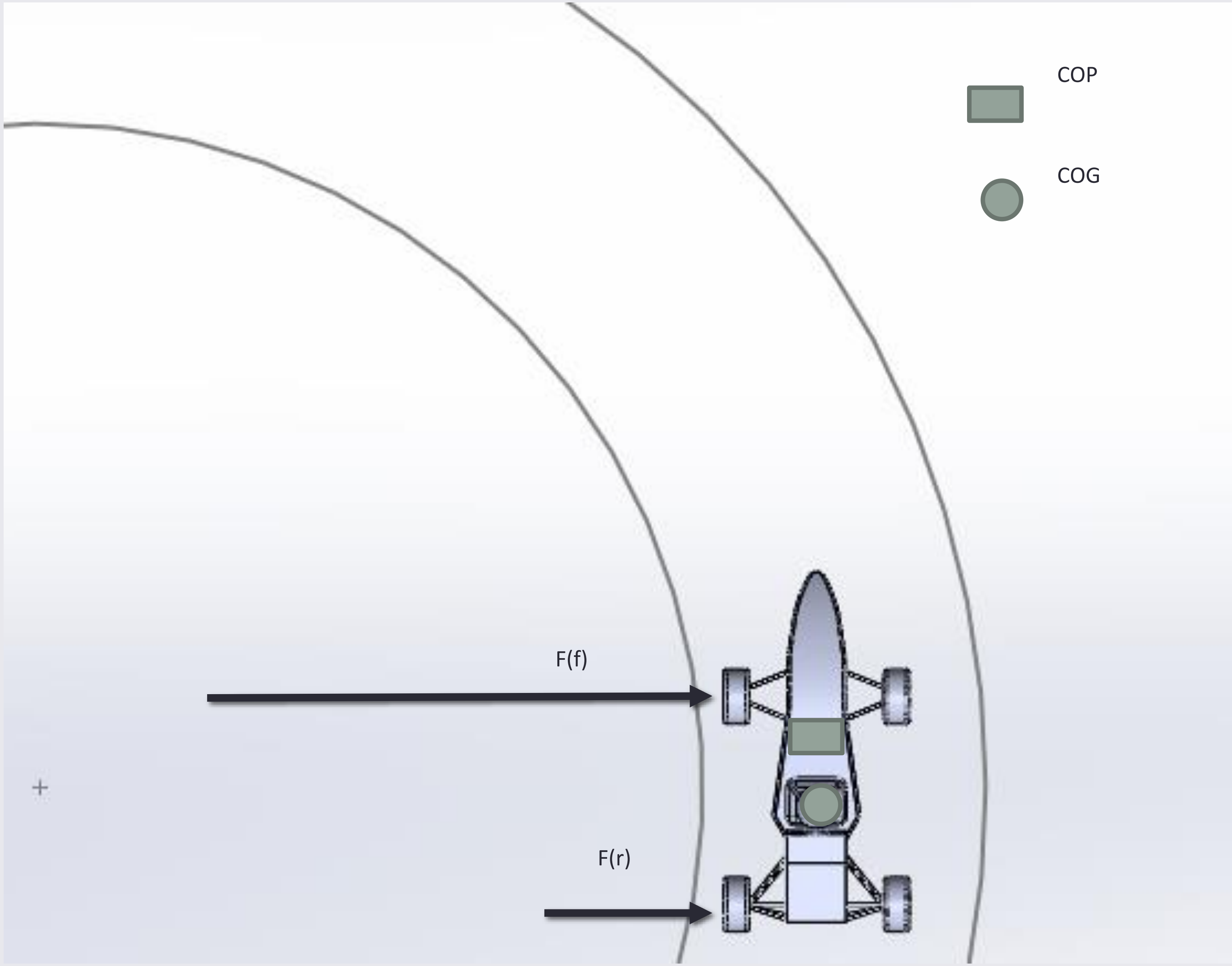


Figure 4-COP Calc

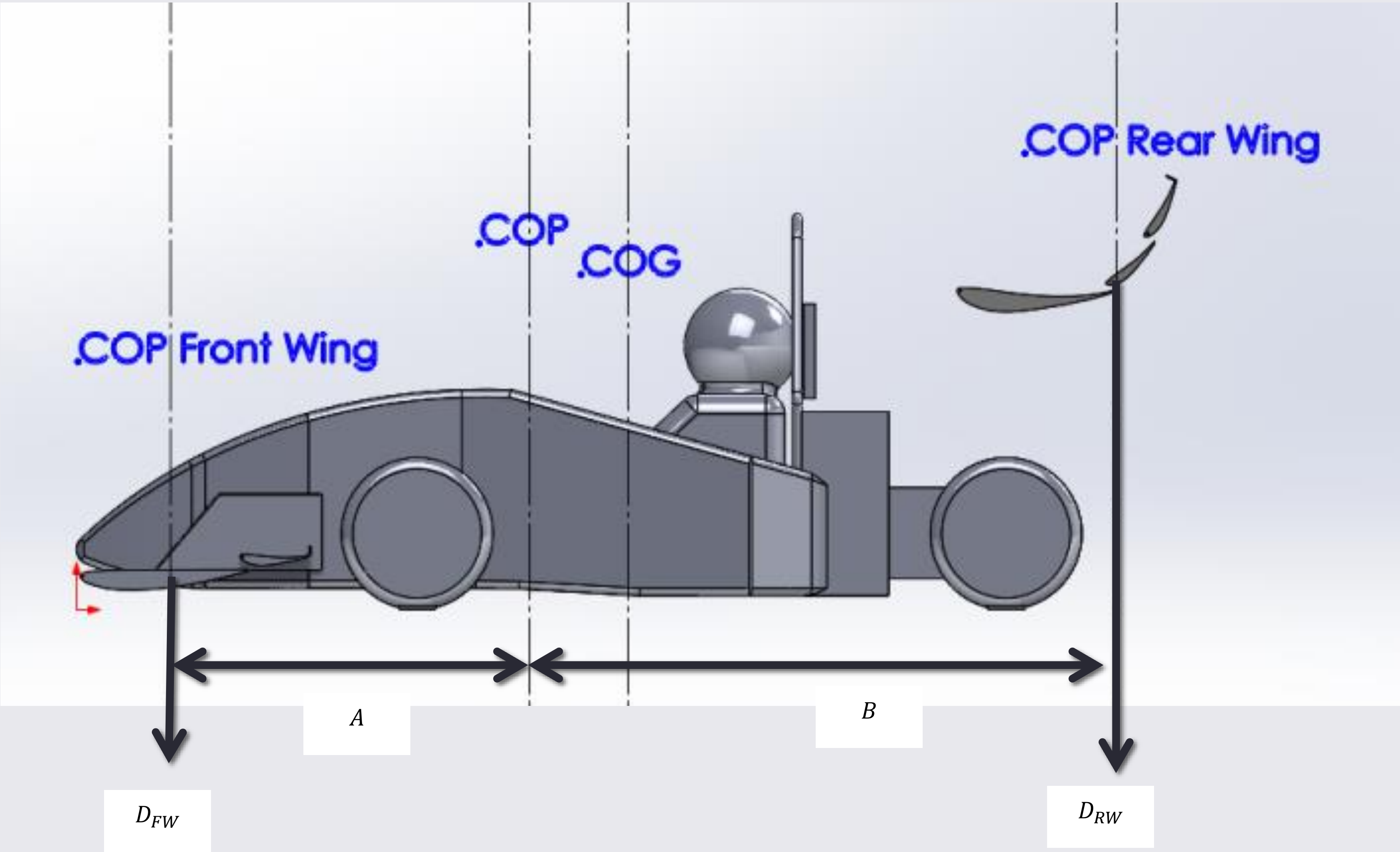


Figure 5-COP CALC

RMIT RACING

Determining front wing ground clearance

Table 10 was used to determine ground clearance. Knowing weight of the front during roll and braking, spring rate, tire spring rate and shock angle, max deflection can be determined.

Calculating ground Clearance (data from Suspension)	Front(N/mm)				
Spring Rate(N/mm)	43.76				
Tire Spring Rate(N/mm)	165.00				
Shock Angle	11.00				
	Front weight(kg)	Front Force(N)	Deflection due to Suspension(mm)	Deflection due to Tire(mm)	Deflection due to Downforce at 80km/hr (mm)
Braking at 1.6G	76.00	745.56	16.72	4.52	15.55
Weight transfer at 1.6G	86.00	843.66	18.93	5.11	
Ground Clearance Due to Braking (mm)	36.80				
Degrees due to Braking	1.45				
Ground Clearance Due to Roll(mm)	39.59				
Degrees due to Roll	3.36				
Deflection of the wing(mm)	10.00				
Max ground Clearance (mm)	49.59				

Table 9-Max deflection of the wing

R16 CAD Concept

Figure 6 - Aero package with front wing, rear wing and side pods.

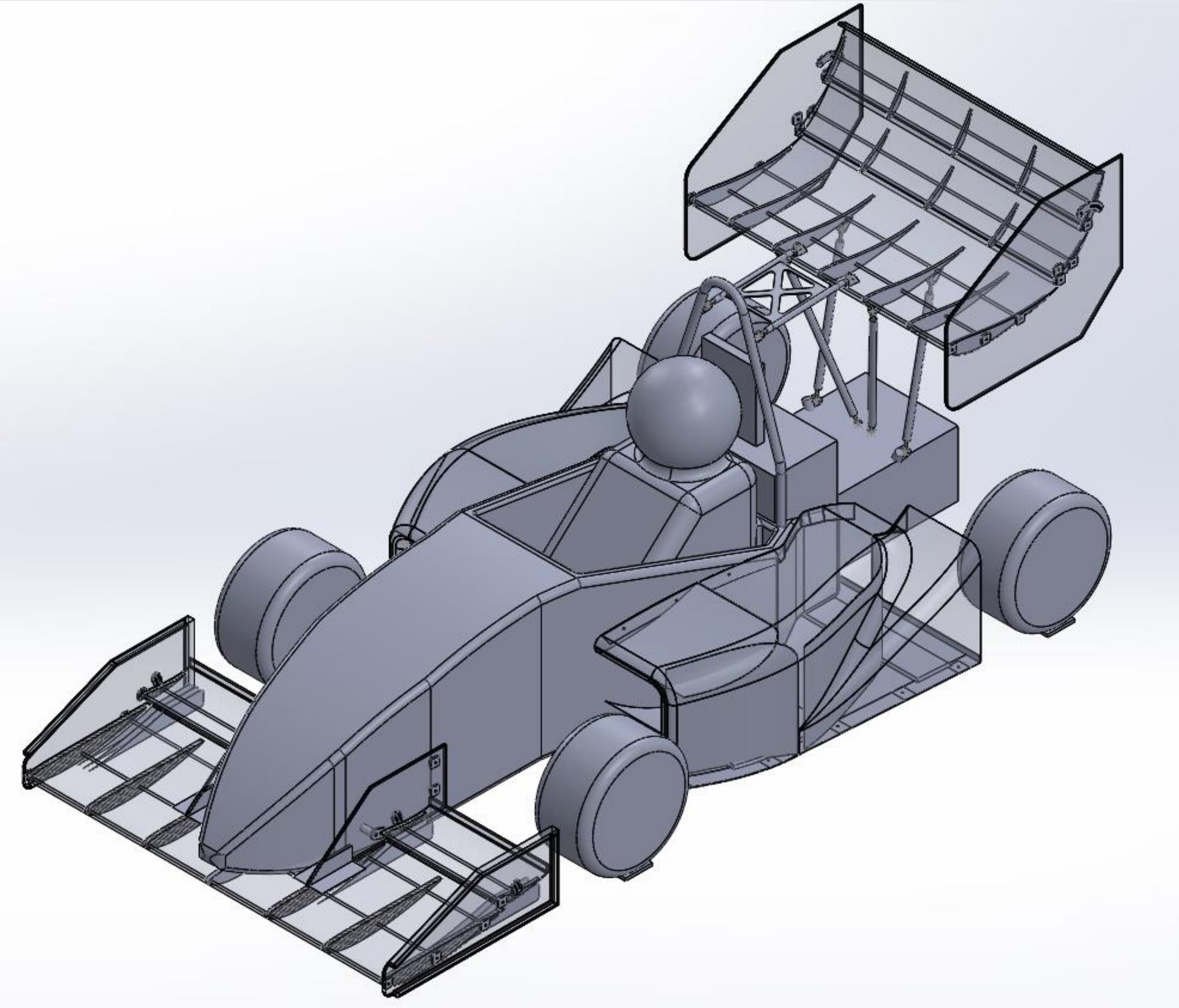


Figure 6-Concept CAD

Front Wing

Due to clean air on the front wing it makes more downforce. A rear wing is needed to bring balance. After profiles are understood, end plates and strakes seal air and control flow. CFD used to optimise profiles, strakes and end plates. Figure 7 outlines

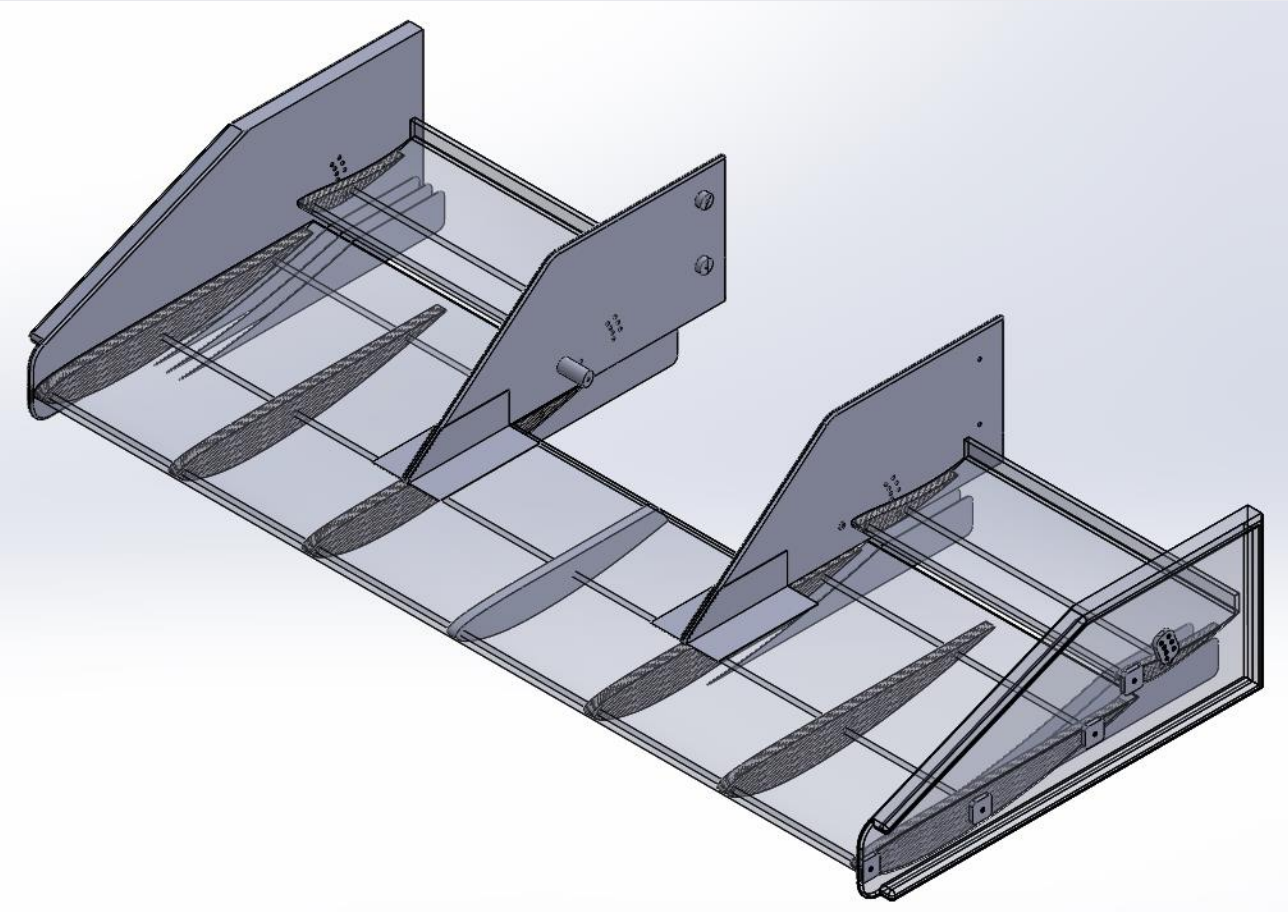


Figure 7- front wing testing CAD

Profile

Clarky Y – S1223

Dimensions outlined in Figure 8

- 30% flap chord
- 2% gap
- 4% overlap
- 4% gurney
- Due to suspension, wing ground clearance is set to 50 mm, need to test sensitivity on track.

Do more testing in 3D to validate the 2D CFD.

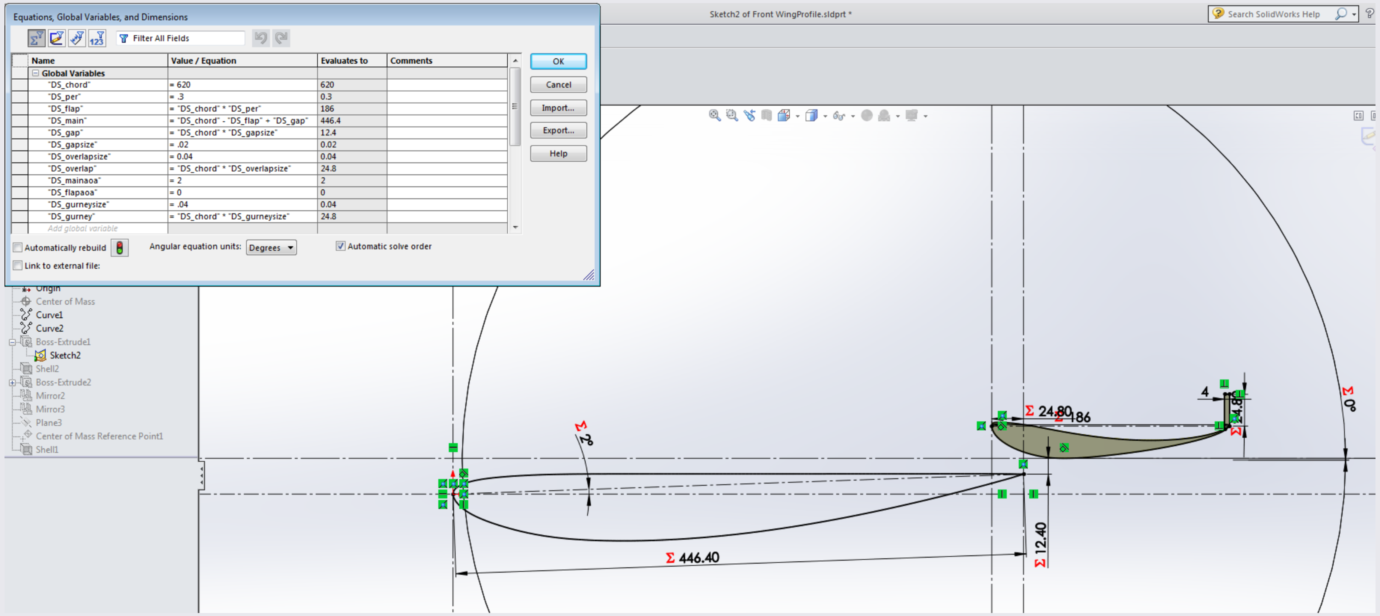


Figure 8-Profile Dimensions

Ribs

Using hollow wings ribs were used to give strength in torsion, close the ends and bolt to. The ribs were, 3 layers of 0-901, 14 mm core and 2 layers 0-90. They were spaced 200 mm apart, just because. The ribs were 2 mm offset for the profiles to take into account the skins, seen in figure 9. Not CAD'ed but spars were added running span wise. They held the skins up and added strength in bending.

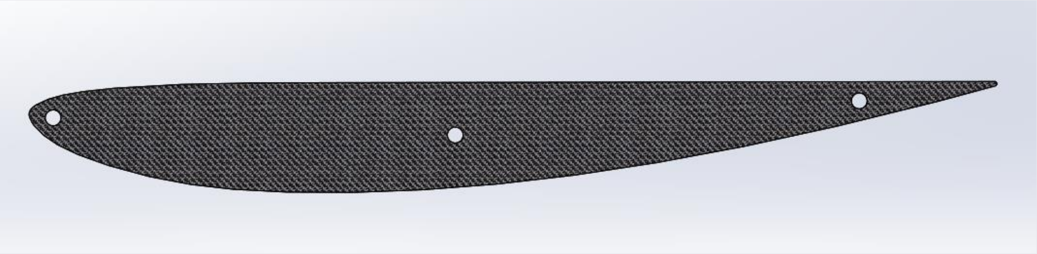


Figure 9-End Caps

End Plates

End Plates were 10 mm below the lowest point of the wing, go as far back as possible and as high as the wing at max angle. Do more testing to determine the trade off between a higher wing but more end plate coverage.The section taken out is to be more efficient in yaw but more testing needs to be done to determined how effective it is. The side plates were added to delay and reduce the intensity of vortices on the pressure distribution of the wing. Testing needs to be done to determine the size and trade off. Figure 9 shows end plates.

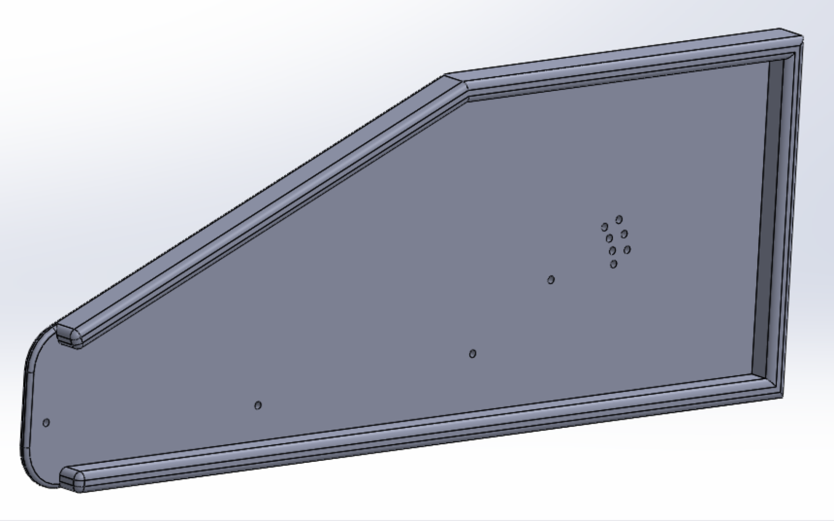
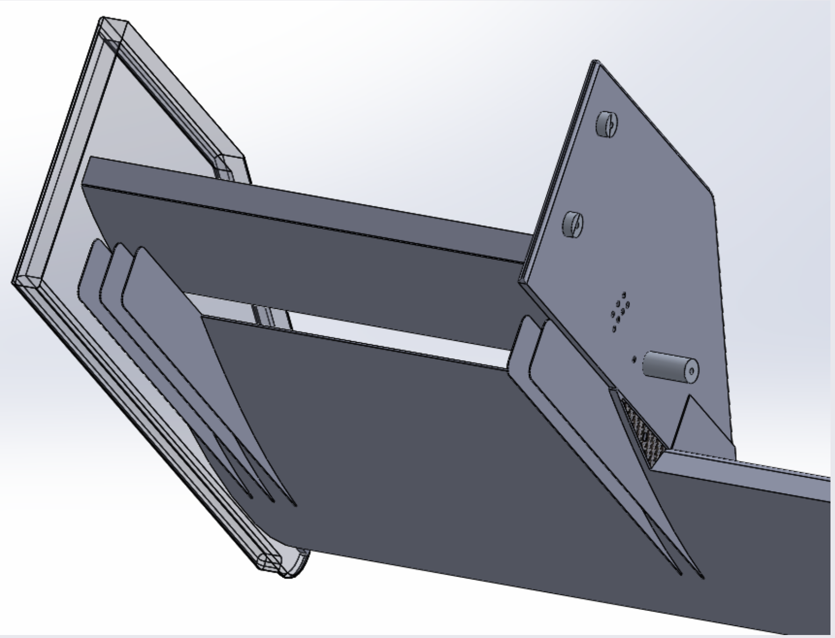


Figure 10-end plates

Strakes

Strakes were used to control the air flow. The vortex created from the underside of the end plate interact with the pressure of the wing and reduce downforce. The strakes aimed to control the air flow and confine it to the corner of the wing. More research can be added to optimise the design and understand how it affects downstream.



Mounting System

Mounting plate runs half way to the front of the wing. Right angle sections were added to increase the bonding area. The mounting plates were attached to the chassis using the spacers below. The mounting plate was 6 mm core with 2 layers of 0-90 each side. Hard points added at mounting sites.

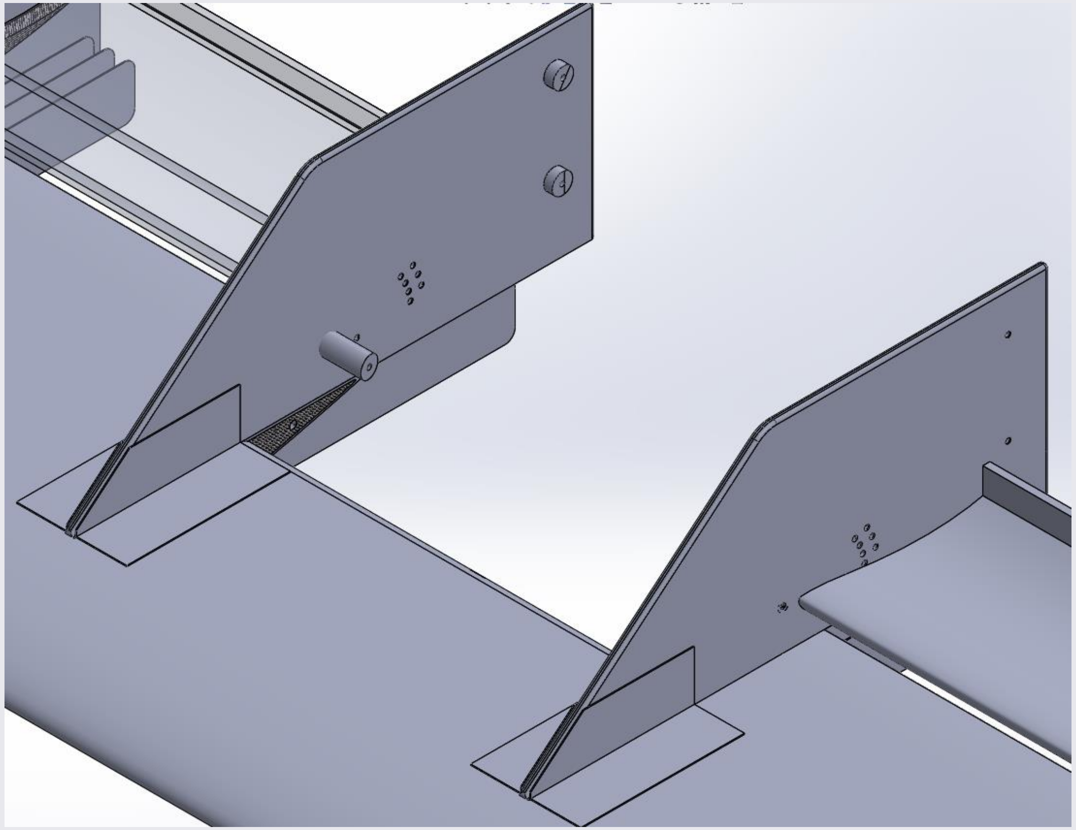


Figure 9-Dimensions of mounting

Manufacturing

Went with manufacturing hollow wings. Time consuming but good surface finish. Try foam wings next year due to ease. Spend time figuring out how to make them look good.

Rear Wing

Rear wing was used to balance out the car. Triple was used this year but next year focus on a 2 doubles with a diffuser down low.

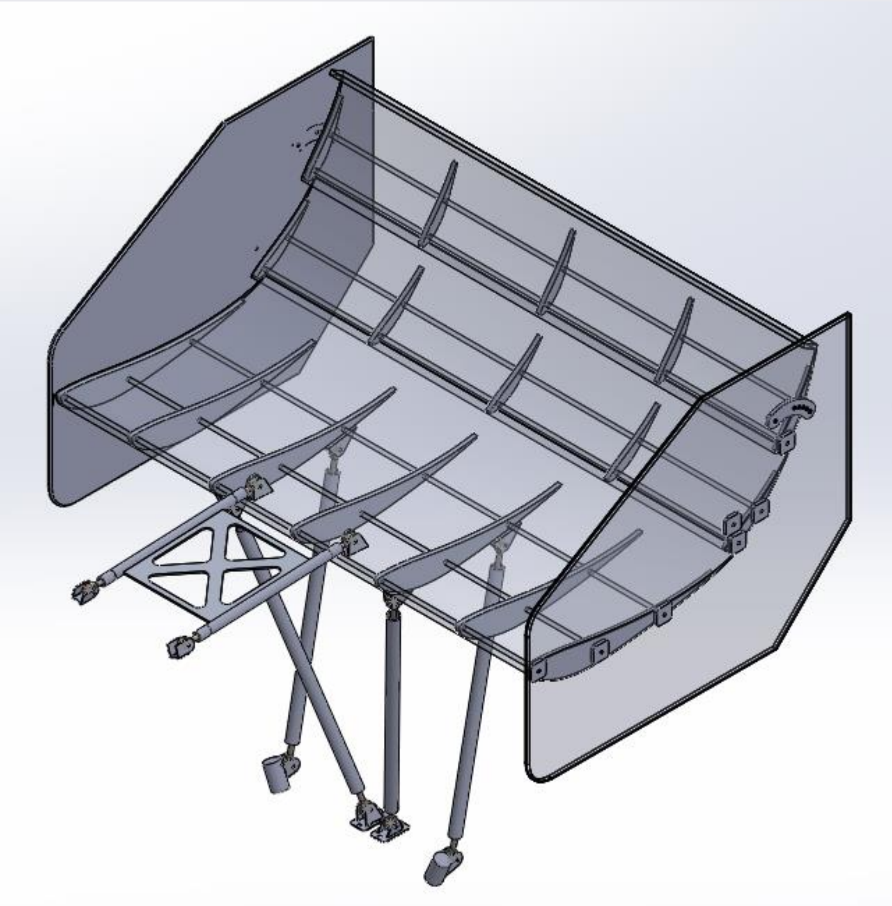


Figure 10-Rear Wing Package

Profile

S1223-1223

Dimensions Figure 15 outlines dimensions and how equations were used:

- 700mm chord
- 20% flap chord
- 1% gap
- 4% overlap
- 4% gurney

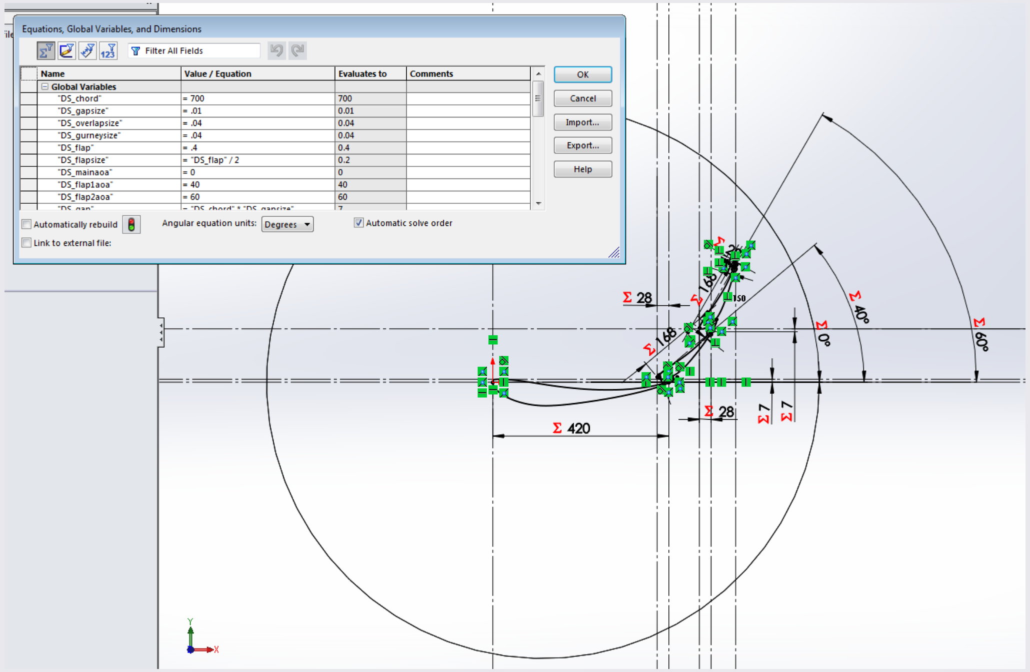


Figure 11-Profile dimensions

Figure 12-End Caps Rear

End plates

Used to seal air flow of the rear wing. Extra holes added for low drag position of the rear wing. The section taken out at the top was for yaw, do CFD to better understand. The section taken out at the bottom was for style, chief wanted it to look a bit better. The section reduced downforce but not by a huge amount. The end plate is 3x the thickness of the bottom of the wing. Plates and vortex channels should be added to improve downforce. Hard points added to the end plates as well.

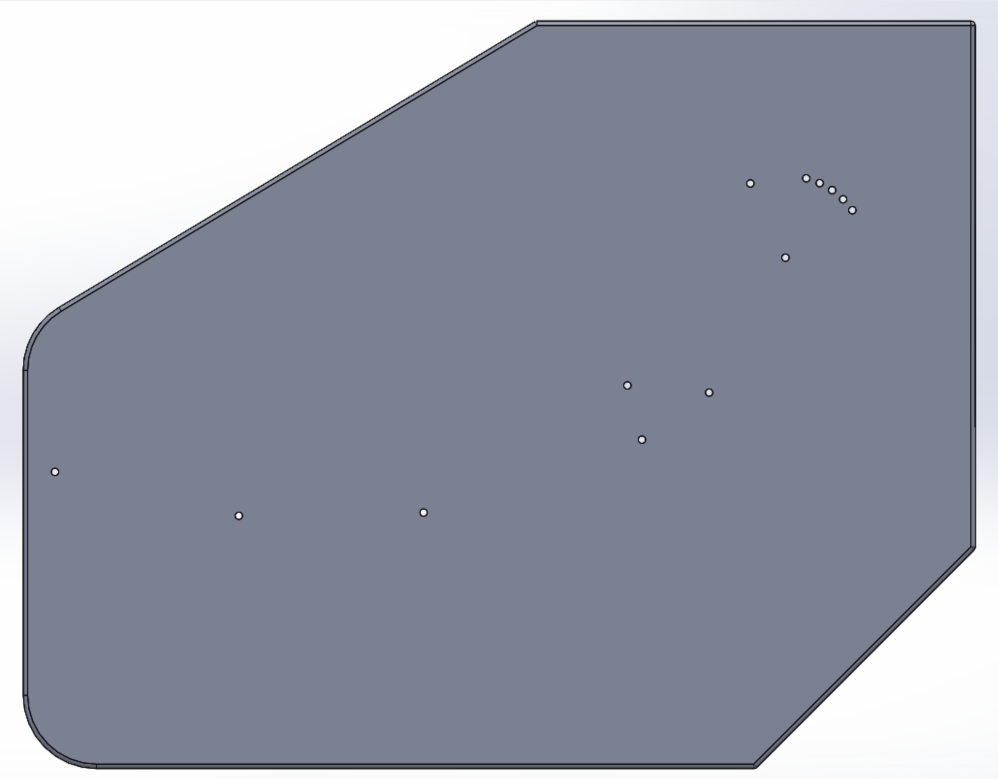


Figure 13- Rear End Plates

Rear Wing Mounting

Mounting was to the middle of the wing. The air flow will be disturbed there already due to the driver. Ribs were placed at the mounting rods so the force would be transferred to the top skins. 6 rods to constrain the 6 DOF, the cross brace was used from bath university.

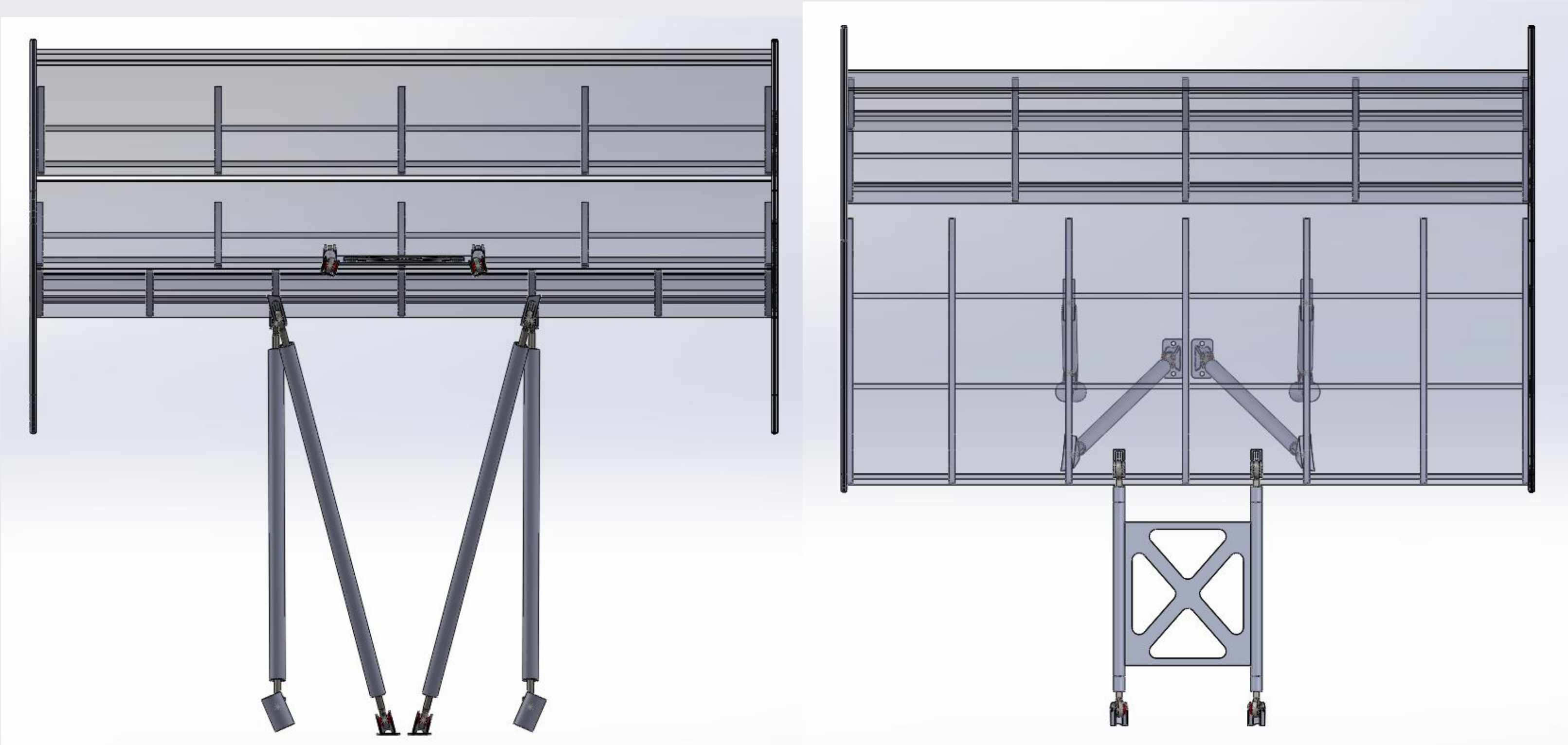


Figure 14- Rear Mounting System

Side Pods

Side pods are used to increase the efficiency of the radiator. Side pods are also used to control air flow around the car, reduce drag around the tire and can be designed to feed air to rear. Figure 20 – side pods. There are internal channels to create a high pressure a high pressure before the radiator and a low pressure behind it. It will create a favourable pressure gradient to help cool the radiator.

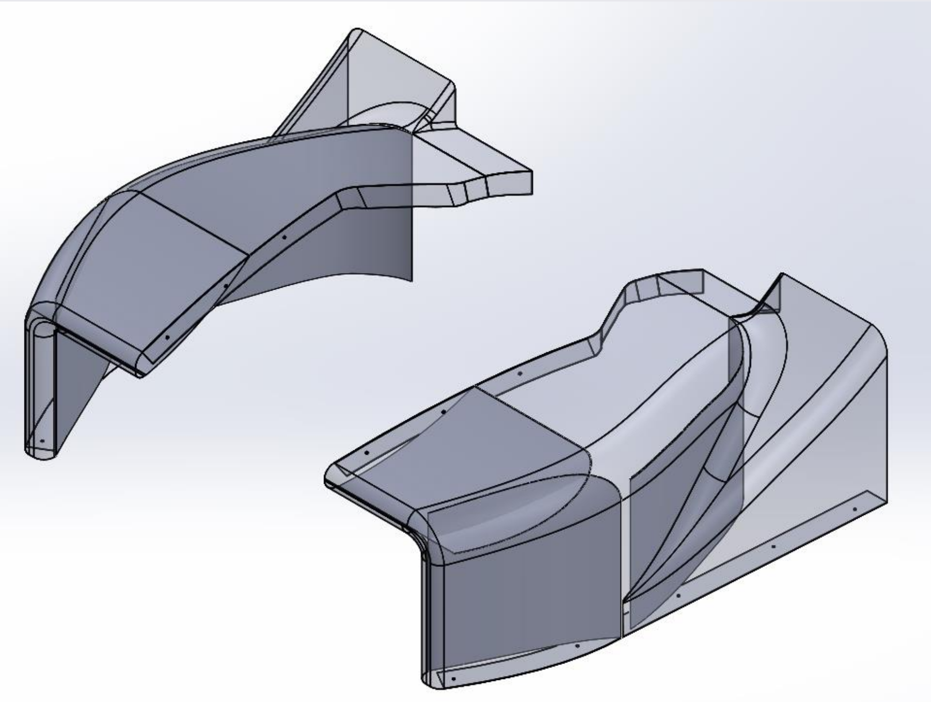


Figure 15-R15 Side pods

Testing Concept

Test 1 – Wind Tunnel Testing

Purpose: Understand and calibrate shock pots, basic understanding of COP, how it changes with yaw.

Add the car with no wings into the wind tunnel on the suspension patches and linear shock pots. First calibrate the shock pots by adding known weights and observing the response, make sure Motec software is working, any corrections to that data and work out any bugs. Turn the wind speed up and should see the suspensions patches get light (car makes lift) and measure changes in the shocks.

Add the wings to the package and measure the results. Change the angle on the wings to ensure the suspension paths and shock pots are changing as anticipated.

Yaw the car in the wind tunnel try get a baseline of how yawing the car changes the front to rear balance.

Can use the smoke wand to understand flow and wool tuffs to see separation. This is a very basic test but able to iron out any bugs and understand if linear shock pots can be used or not.

Errors involved – no rolling road, ground effect, no rotating wheels so won't understand the full extent of the front wing and how tire flow effects the rear.

Test 2 – No Wings Benchmark

Purpose: Establish a benchmark

Need to find a straight strip, pump tire pressure and get the car running in second gear at constant speed recording shock pot data. Should be able to understand how much noise is on the shock pots and what can be done to reduce it.

Make sure to run the car up and down to average effects due to wind direction and speed.

Do a coast down test to determined drag and braking distance.

Test 3 – With wings

Purpose: Understand and calibrate shock pots on the road, determine COP

Run the same test with wings set at an angle from the wind tunnel. Start off at low speeds and build up to as much is possible. Use the recorded data and compare to No Wing benchmark. By averaging the data and playing around with Motec should be able to see a difference in spring deflection which can be correlated to aerodynamic load.

Do coast down test and compare to Test 2. Understand how much extra drag is added and how braking distance decreases.

Test 4 – Skid Pan Benchmark

Purpose: Benchmark

Without the aero package run the car in a constant radius. Add speed limiters through Motec and steering stop to keep that car at a constant angle. Take a lap and up the speed until the driver breaks traction.

If there are G-sensors available should be able to use them to understand how many we are pulling with no aero.

Test 5 – Skid Pan Wings

Purpose: Understand how downforce affect traction, steady state cornering.

With the aero package on do the test as above. Traction should break later and able to back calculate how much downforce is being created.

Review data to test 3. Should be able to understand how much downforce is lost in yaw.

Will need to ensure the suspension is set up that it doesn't affect the test.

Then change the angle of the front and rear wing to change the COP to try and understand how it affects the car.

Using G sensors should be able to see a difference in the lateral G's.

Test 6 – Left and Right Turn Benchmark

Purpose: Benchmark

Using skid pad radius and a car with no wings, run the car at a constant speed and steering angle. Understand at what speeds it breaks traction and if the car is under and over steering.

Use G sensors to determine how many we are pulling.

Test 7 – Left and Right Turn Wings

Purpose: Can the COP be used as a stunning tool for understeer and oversteer.

Using same set up as above understand at what speeds it breaks traction. Shift the COP to try and compensate for the under/over steer.

Use G sensors to determine how many we are pulling.

Test 8 – Slalom Benchmark

Purpose: Benchmark

Benchmark with no wings using rules grade slaloms. Understand at what speeds that can be take, is the car over/under steering.

Test 9 – Slaloms with Wing

Purpose: How does downforce effect the car dynamically, how is the yaw rate effected.

Add the wings to ensure they can take the slaloms at higher speeds. It will show the effect of moving the COG up and if aero can be used to compensate over/under steering.

Weight Analysis

Aero Package 2016 has a weight analysis spread sheet to estimate package weigh. Option for pre-preg and wet lam package. Document will help in understanding weight and required carbon.

Table 8 outlines the method used to determined weight and carbon needed for wings.

Front Wing		
Surface Area	1.6411839	m^2
Density(4 layers, 0/90 UD UD 0/90)	1264.222503	kg/m^3
Layer Thickness	0.0005	m^2
Layers	4	
Weight	4.149643236	kg
Carbon Required	6.5647356	m^2

Front Mounting		
Surface Area	0.075893	m^2
Layers	4	
Layer Thickness	0.00025	m
Density of carbon	1200	kg/m^3
Thickness of core	0.006	m
Area of core	0.075893	m^2
Density of core	32	kg/m^3
Weight	0.105643056	kg
Carbon Required	0.303572	m^2

Table 10- Sample weight analysis

Bill of Materials/Weight Target/COG analysis

Table 9 outlines the BOM.

Sub-Assembly	Sub-Assembly Description	Quantity	Material	Mass (Kg)	Total Mass (Kg)	Distance from ground to COG (mm)	COG Moment (kgmm)
Front Wing Assembly	Main Element	1	Wet Lam Carbon	5.34	5.34	126.00	672.64
	Slat	2	Wet Lam Carbon				0.00
	End Plate	2	Wet lam + core	0.27	0.54	180.00	97.72
	Mounting Plates	2	Wet lam + core	0.05	0.11	226.00	23.88
	End Cap	6	Aluminium	0.25	0.25	126.00	31.21
	Aluminium Insertes	12	Aluminium	0.01	0.12	180.00	21.60
	M5 Bolts	12	Steel	0.01	0.06	180.00	10.80
	M5 Nuts	12	Steel	0.01	0.06	180.00	10.80
	M5 Washer	24	Steel	0.00	0.05	180.00	8.64
	Wing Jig		Ply				
	End Plate Jig		Ply				
	Mounting Jig		Ply				
Rear Wing	Main Element	1	Wet Lam Carbon	5.22	5.22	900.00	4697.70
	Slat	1	Wet Lam Carbon				
	End Cap	2352	Water jet Cut Pre-Preg Carbon	10.00	0.24	900.00	211.68
	End Plate	2	Wet lam + core	0.45	0.90	920.00	920.00
	Aluminium Insertes	8	Aluminium	0.01	0.08	900.00	72.00
	Rod	6	Carbon	0.50	3.00	620.00	1860.00
	A-Arm Insert	12	Steel	0.01	0.12	620.00	74.40
	Clevis	12	Steel	0.02	0.24	620.00	148.80
	Rod End	12	Steel	0.03	0.36	620.00	223.20
	M5 Bolts	36	Steel	0.01	0.18	620.00	111.60
	M5 Nuts	36	Steel	0.01	0.18	620.00	111.60

	M5 Washer	72	Steel	0.00	0.14	620.00	89.28
	Wing Jig		Ply				
	End Plate Jig		Ply				
Side Pod	Side Pod		Pre-Preg	0.00	0.00		0.00
	Bracket		Carbon	0.01	0.00		0.00
	Guide Wire		steel	0.01	0.00		0.00
	Turb Buckel		aluminium	0.01	0.00		0.00
	M5 Bolt		Steel	0.01	0.00		0.00
	M5 Nut		Steel	0.01	0.00		0.00
	M5 Washer		Steel	0.00	0.00		0.00
Floor	Floor		Carbon	2.61	0.00		0.00
	M5 Bolt		Steel	0.01	0.00		0.00
	M5 Nut		Steel	0.01	0.00		0.00
	M5 Washer		Steel	0.00	0.00		0.00
	Cutting Template		Paper				
Covers	Engine Cover	1	Carbon	1.30	1.30	800.00	1041.39
	Engine Cover Jig		Ply				
					18.49		564.64

Table 11-BOM

RMIT RACING

APPENDIX A - Data from Lap Sim

FSAE Aero | FSAE Non-Aero | Monash | **Table** | Acceleration | Figure of 8 | Endurance FSAE-A 2015

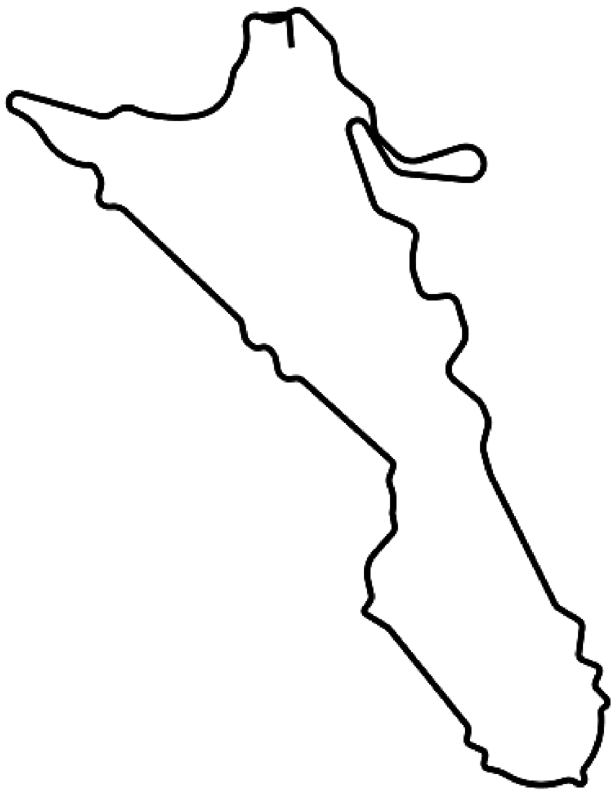
KPI Description	Acceleration			Figure of 8			Endurance FSAE-A 2015		
Vehicle	FSAE Non-Aero	FSAE Aero	Monash	FSAE Non-Aero	FSAE Aero	Monash	FSAE Non-Aero	FSAE Aero	Monash
Lap time [s]	3.68	3.75	3.79	10.27	9.82	9.74	123.09	120.32	123.59
Percent in Corners [%]	0.00	0.00	0.00	100.00	100.00	100.00	51.79	51.46	50.81
Percent Accelerating [%]	100.00	100.00	100.00	99.90	99.90	0.09	63.01	65.03	69.51
Percent Braking [%]	0.00	0.00	0.00	0.10	0.10	99.81	35.42	33.48	29.07
Percent Coasting [%]	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.09	0.13
Percent 100% Throttle [%]	100.00	100.00	100.00	0.00	0.00	0.00	35.03	37.30	39.70
Percent TCS Enabled [%]	53.06	0.00	0.00	99.91	99.91	99.81	63.97	40.84	33.71
Lowest Speed [km/h]	36.27	36.27	40.69	36.25	36.24	39.17	18.12	18.30	18.33
Highest Speed [km/h]	105.68	99.46	100.69	37.18	38.90	40.69	98.91	98.11	99.12
Average Speed [km/h]	79.34	77.80	76.19	37.17	38.85	39.18	47.44	48.73	46.58
Energy Spent [kJ]	111.92	124.74	126.23	5.09	13.17	0.12	1033.64	1269.63	1120.79
Fuel Consumption [kg]	0.01	0.02	0.02	0.00	0.00	0.00	0.13	0.16	0.15
Gear Shifts [-]	1.00	1.00	1.00	0.00	0.00	0.00	4.00	6.00	0.00
Maximum Lateral Acceleration [m/s^2]	0.00	0.00	0.00	12.73	13.97	14.17	-12.75	15.93	16.55
Maximum Longitudinal Acceleration [m/s^2]	6.29	7.06	5.76	4.37	4.02	3.56	6.30	7.07	5.76
Maximum Longitudinal Deceleration [m/s^2]	3.61	2.11	1.01	-0.35	-0.64	-0.74	-14.94	-24.61	-26.38
Time in Sector 1 [s]	3.68	3.75	3.79	5.13	4.92	4.87	123.09	120.32	123.59
Maximum Speed in Sector 1 [km/h]	105.68	99.46	100.69	37.18	38.90	40.69	98.91	98.11	99.12
Minimum Speed in Sector 1 [km/h]	36.27	36.27	40.69	36.25	36.24	39.17	18.12	18.30	18.33
Percent in Gear 1 [%]	58.53	57.60	93.47	100.00	100.00	100.00	97.08	95.86	100.00
Percent in Gear 2 [%]	41.47	42.40	6.53	0.00	0.00	0.00	2.92	4.14	0.00
Percent in Gear 3 [%]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Percent in Gear 4 [%]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Time in Sector 2 [s]	-	-	-	5.13	4.90	4.87	-	-	-
Maximum Speed in Sector 2 [km/h]	-	-	-	37.18	38.90	39.17	-	-	-
Minimum Speed in Sector 2 [km/h]	-	-	-	37.18	38.90	39.17	-	-	-
-	-	-	-	-	-	-	-	-	-
Vehicle Mass [kg]	230.00	250.00	252.00	230.00	250.00	252.00	230.00	250.00	252.00
Drag Coefficient [-]	0.80	1.00	1.10	0.80	1.00	1.10	0.80	1.00	1.10
Downforce Coefficient [-]	-0.10	2.50	2.90	-0.10	2.50	2.90	-0.10	2.50	2.90
Frontal Area [m^2]	0.70	1.30	1.30	0.70	1.30	1.30	0.70	1.30	1.30
Drivetrain Efficiency [%]	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00
Tire Rolling Radius [m]	0.21	0.21	0.23	0.21	0.21	0.23	0.21	0.21	0.23
Air Density [kg/m^3]	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23
Final Drive Ratio [-]	2.27	2.27	2.27	2.27	2.27	2.27	2.27	2.27	2.27
Longitudinal Friction [-]	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40
Lateral Friction [-]	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30

FSAE Aero | FSAE Non-Aero | Monash | Table | Acceleration | Figure of 8 | Endurance FSAE-A 2015

KPI Description	Acceleration			Figure of 8			Endurance FSAE-A 2015		
Drag Coefficient [-]	0.80	1.00	1.10	0.80	1.00	1.10	0.80	1.00	1.10
Downforce Coefficient [-]	-0.10	2.50	2.90	-0.10	2.50	2.90	-0.10	2.50	2.90
Frontal Area [m^2]	0.70	1.30	1.30	0.70	1.30	1.30	0.70	1.30	1.30
Drivetrain Efficiency [%]	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00
Tire Rolling Radius [m]	0.21	0.21	0.23	0.21	0.21	0.23	0.21	0.21	0.23
Air Density [kg/m^3]	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23
Final Drive Ratio [-]	2.27	2.27	2.27	2.27	2.27	2.27	2.27	2.27	2.27
Longitudinal Friction [-]	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40
Lateral Friction [-]	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30
Fuel Energy Density [J/kg]	25650000.00	25650000.00	25650000.00	25650000.00	25650000.00	25650000.00	25650000.00	25650000.00	25650000.00
Engine Thermal Efficiency [%]	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00
Tire Rolling Drag [-]	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Power Scaling Factor [%]	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Aero Scaling Factor [%]	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Grip Scaling Factor [%]	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Mass Lateral Friction [kg]	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
Load Sensitivity Lateral Friction [-]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mass Longitudinal Friction [kg]	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
Load Sensitivity Longitudinal Friction [-]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aero Efficiency [-]	0.13	2.50	2.64	0.13	2.50	2.64	0.13	2.50	2.64
Rev Limit [rpm]	11800.00	11800.00	11800.00	11800.00	11800.00	11800.00	11800.00	11800.00	11800.00
Torque Data [N.m]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RPM Data [rpm]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gear Ratio Data [-]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gear Shift Points [rpm]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-	-	-	-	-	-	-	-	-	-
Shift Point [1 to 2] [rpm]	11800.00	11800.00	11800.00	11800.00	11800.00	11800.00	11800.00	11800.00	11800.00
Shift Point [2 to 3] [rpm]	11800.00	11800.00	11800.00	11800.00	11800.00	11800.00	11800.00	11800.00	11800.00
Shift Point [3 to 4] [rpm]	11800.00	11800.00	11800.00	11800.00	11800.00	11800.00	11800.00	11800.00	11800.00
Shift Speed [1 to 2] [km/h]	89.16	89.16	100.03	89.16	89.16	100.03	89.16	89.16	100.03
Shift Speed [2 to 3] [km/h]	143.29	143.29	160.76	143.29	143.29	160.76	143.29	143.29	160.76
Shift Speed [3 to 4] [km/h]	286.45	286.45	321.39	286.45	286.45	321.39	286.45	286.45	321.39
Top Speed [km/h]	143.29	134.14	117.11	143.29	134.14	117.11	143.29	134.14	117.11
Acceleration Time To Speed [27.778 km/h] [s]	3.27	4.47	3.62	3.27	4.47	3.62	3.27	4.47	3.62
Acceleration Time For Distance [100 m] [s]	4.50	4.72	4.68	4.50	4.72	4.68	4.50	4.72	4.68
Deceleration Time For Speed [27.778 km/h] [s]	2.43	2.87	1.64	2.43	2.87	1.64	2.43	2.87	1.64
Deceleration Distance For Speed [27.778 km/h] [m]	26.90	20.10	19.70	26.90	20.10	19.70	26.90	20.10	19.70
-	-	-	-	-	-	-	-	-	-

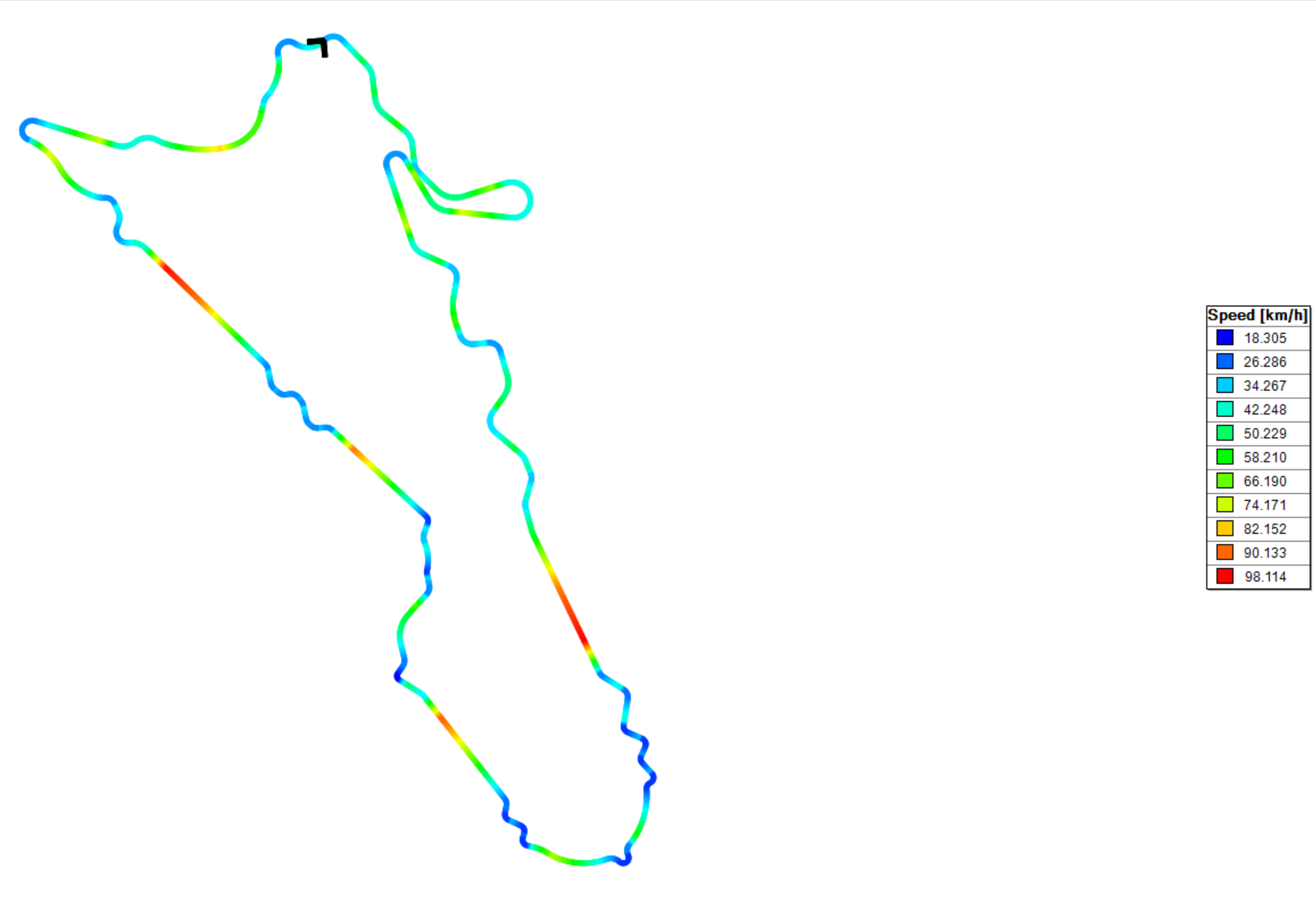
APPENDIX B - Endurance track

Endurance FSAE-A 2015, Melbourne, Australia



Autocross speed map of R15

Endurance speed map of R16



Endurance downforce map R16 RMIT aero