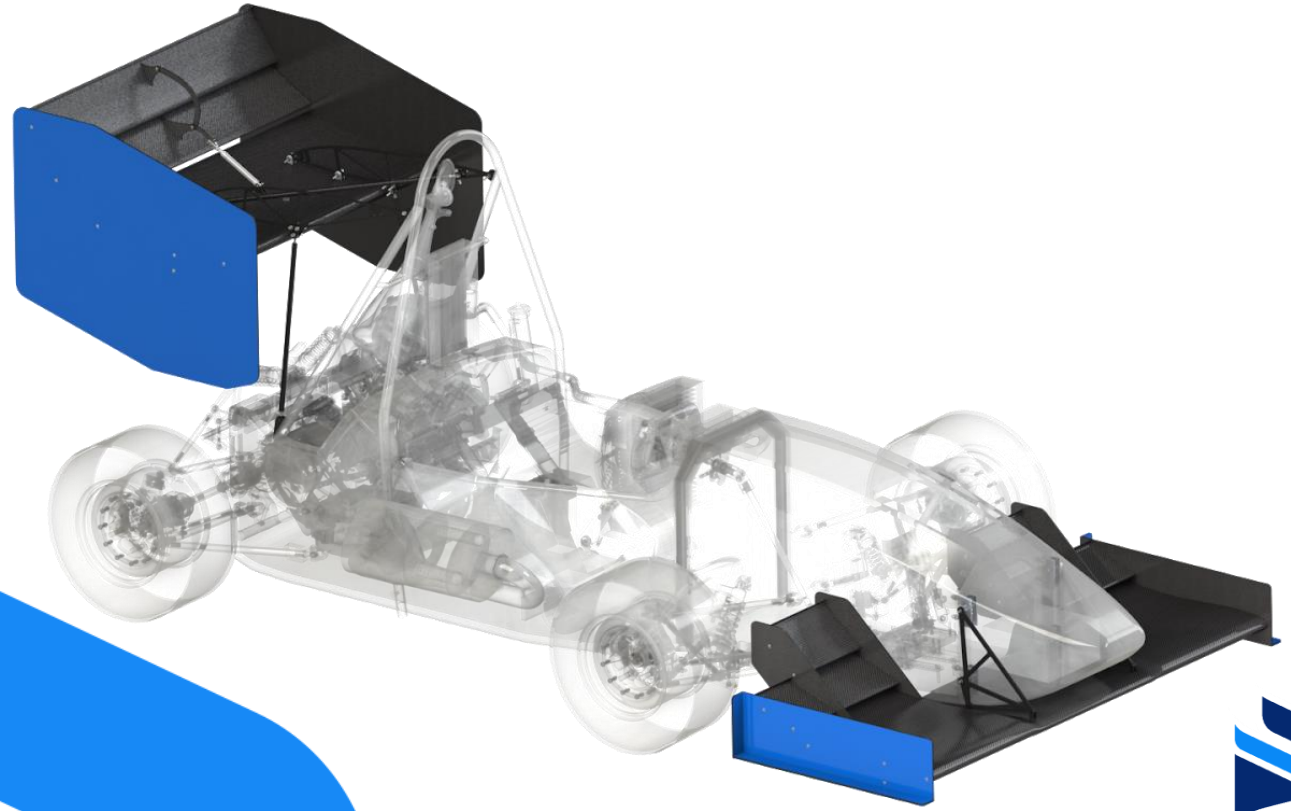
PBR20

Aerodynamics Design Presentation



UMSAE
Polar Bear Racing

University of Manitoba

Section at a Glance

- **Cl*A = -2.25**
  Front Wing -> -1.21
  Rear Wing -> -1.10
  (DRS Open -> -0.44)
- **Cd*A = 1.23**
  Front Wing -> 0.24
  Rear Wing -> 0.41
  (DRS Open -> 0.08)
- **L/D = -1.82**
  Front Wing -> -5.00
  Rear Wing -> -2.65
  (DRS Open -> -5.38)

- **Mass = 10.2 [*kg*]**
  Front Wing -> 4.5 [*kg*]
  Rear Wing -> 5.7 [*kg*]
- **Frontal Area = 1.05 [m^2]**
  Front Wing -> +0.05 [m^2] (mostly from muffler side)
  Rear Wing -> +0.24 [m^2]
- **Aerobalance = 50.0%**
  Adjustable from 41.5% to 57.0%

Section Goals

- **The goal: Increase points at competition**

Event	Points Delta
Endurance	+40.4
Fuel	-11.1
Autocross	+25.3
Skidpad	+9.9
Acceleration	+4.6
Cost	-2.2
Total	**+66.9**

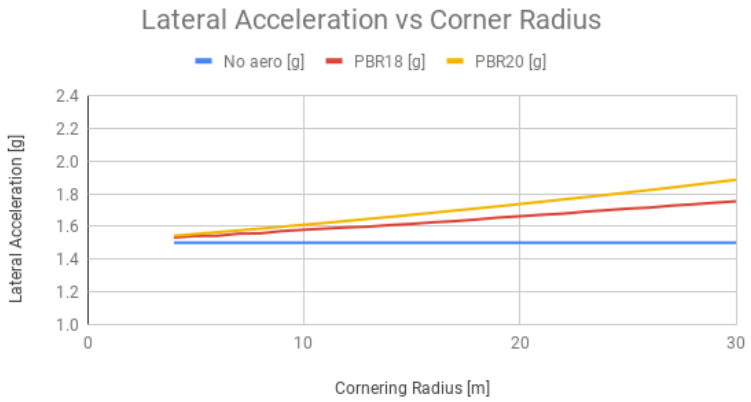
Parameter	Points Delta
Cl*A	+98.2
Cd*A	-18.1
Mass	-4.8

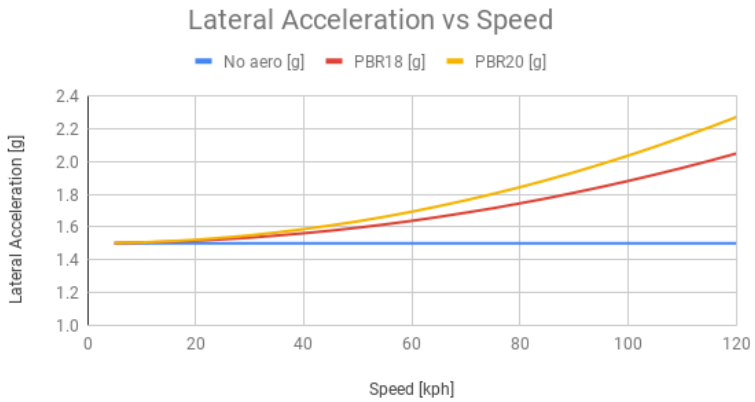
Sensitivities

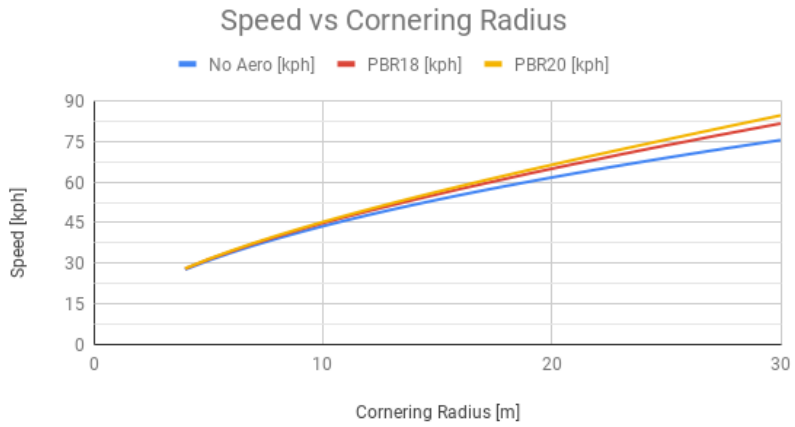
+0.1 Cl*A gives:	3.58 points	+0.028 Cl*A gives:	1 point
-0.1 Cd*A gives:	2.90 points	-0.034 Cd*A gives:	1 point
-0.1 [*kg*] gives:	0.04 points	-2.50 [*kg*] gives:	1 point

Critical L/D 0.81

Aerodynamic Performance Gains



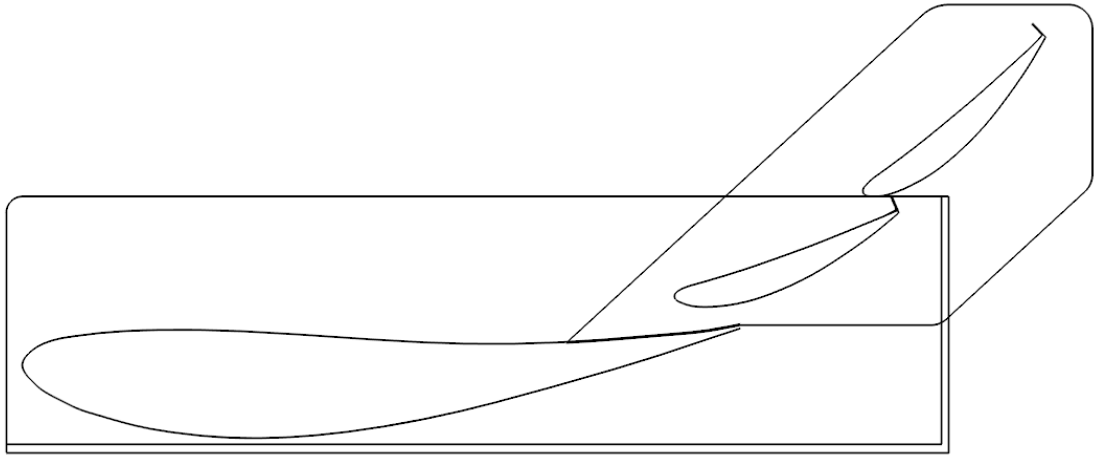




UMSAE Polar Bear Racing

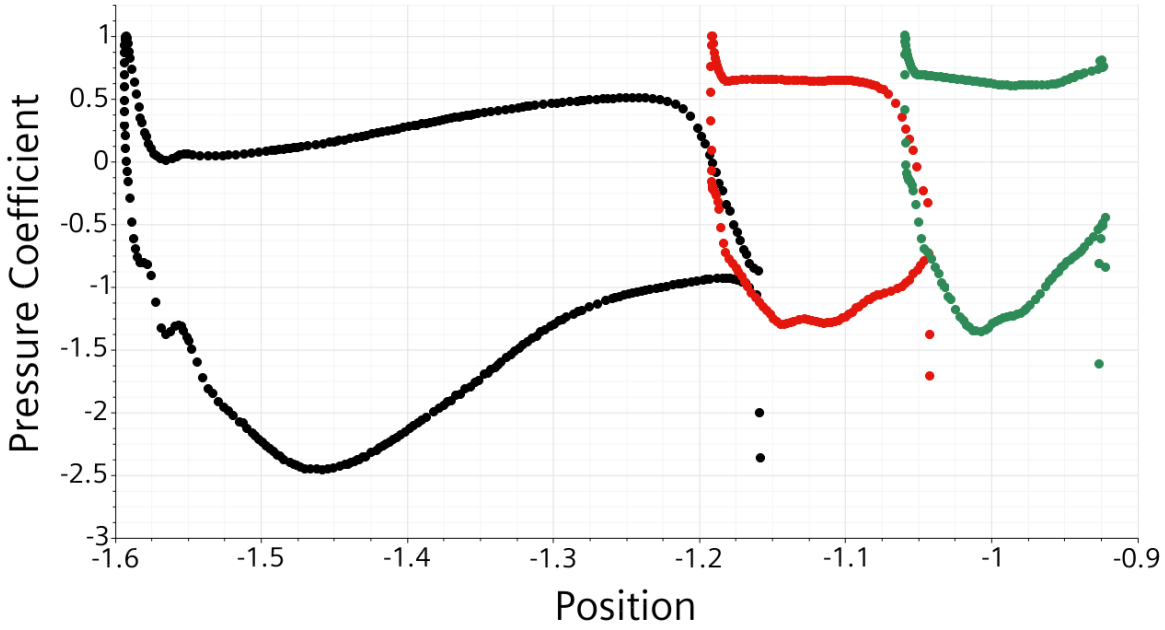
University of Manitoba

Front Wing

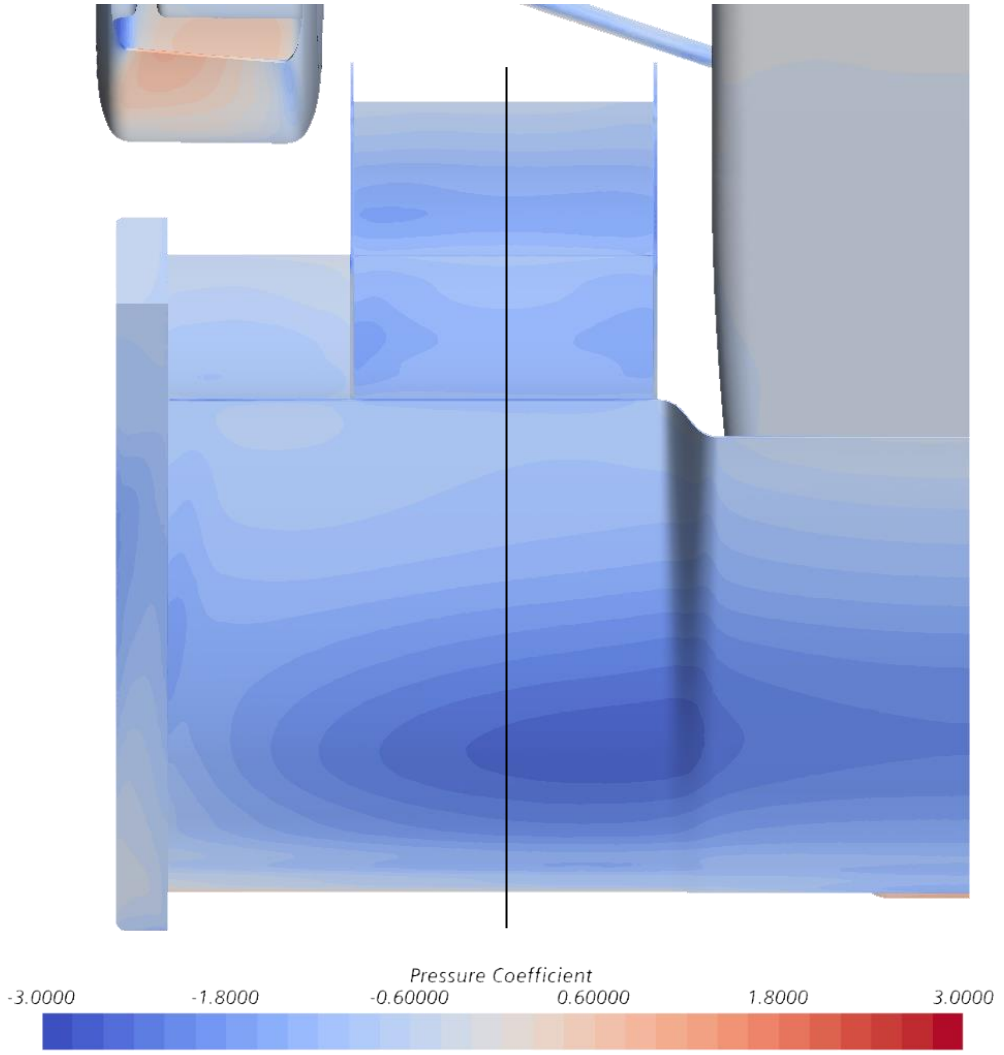


	Cord [*mm*]	Angle of Attack (relative) [*deg*]	Slot Gap (ground clearance) [*mm*]	Slot Overlap [*mm*]
Center Mainfoil	450	-5	70	n/a
Side Mainfoil	450	3	80	n/a
Flap 1	150	21 (18)	10	15
Flap 2	150	41 (20)	9	15

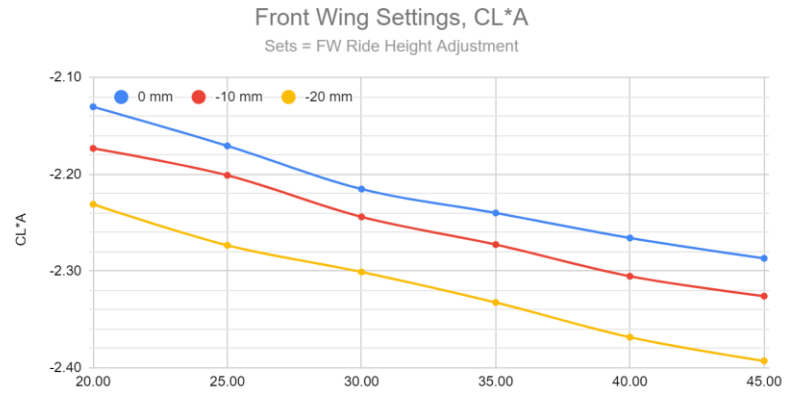
Front Wing

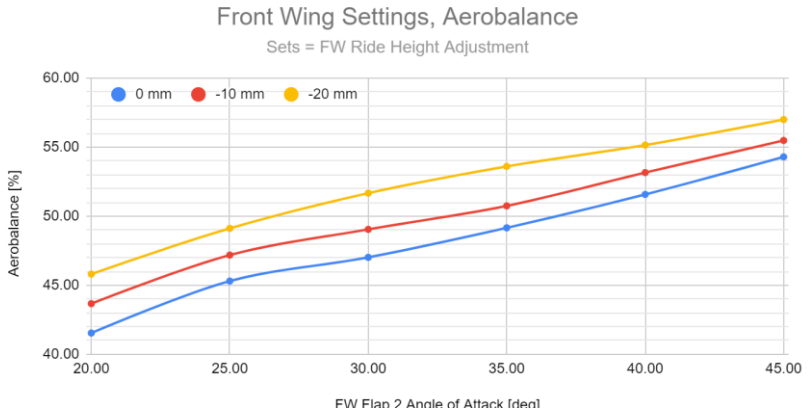


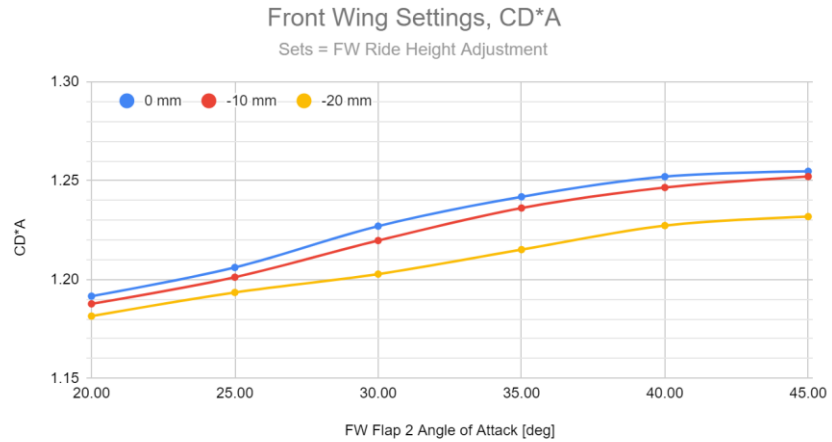
Font Wing Pressure Coefficient Profile, Y380

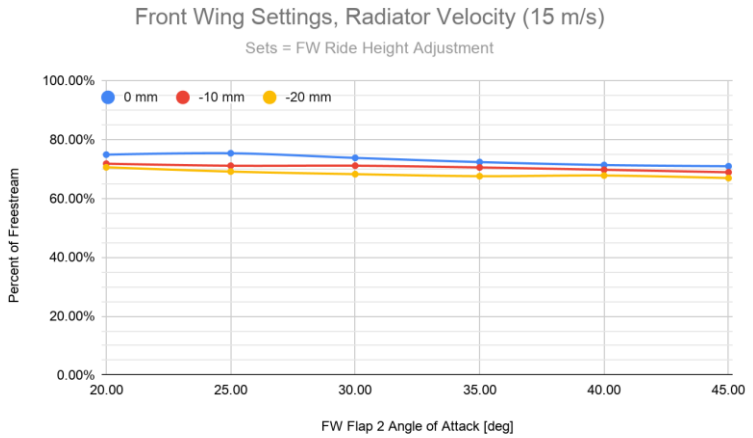


Front Wing – It moves!

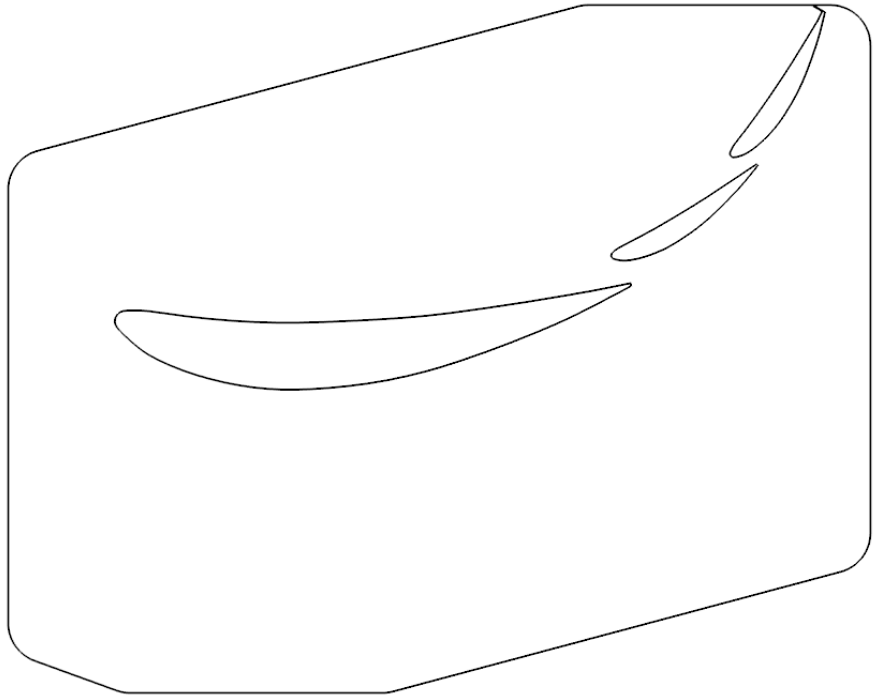






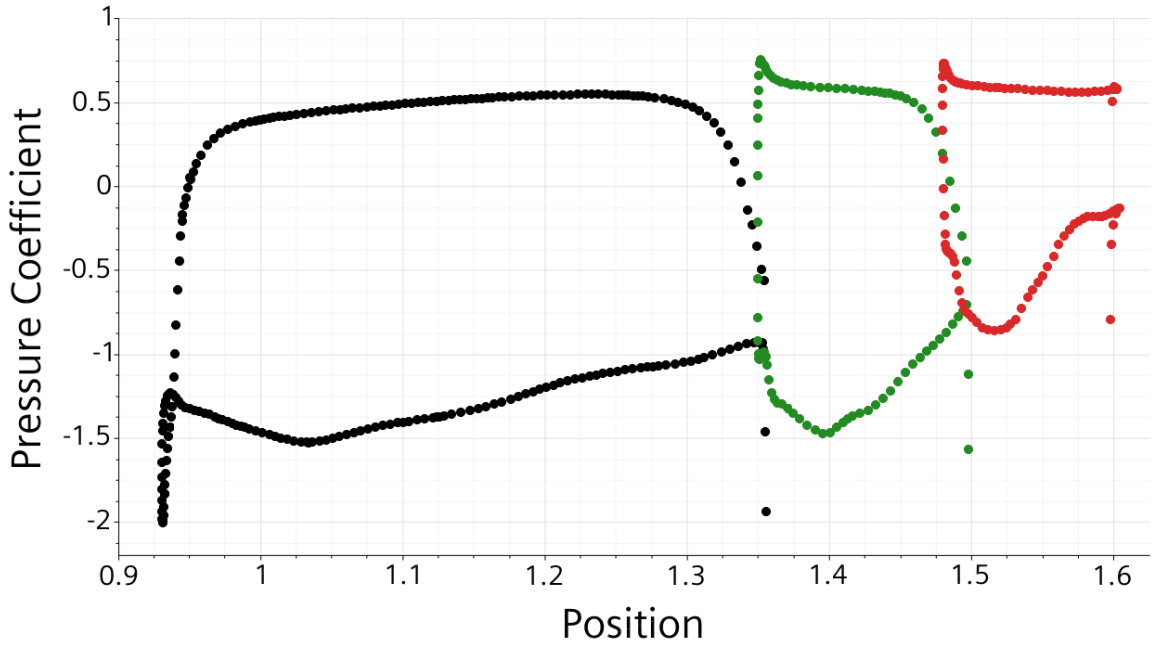


Rear Wing

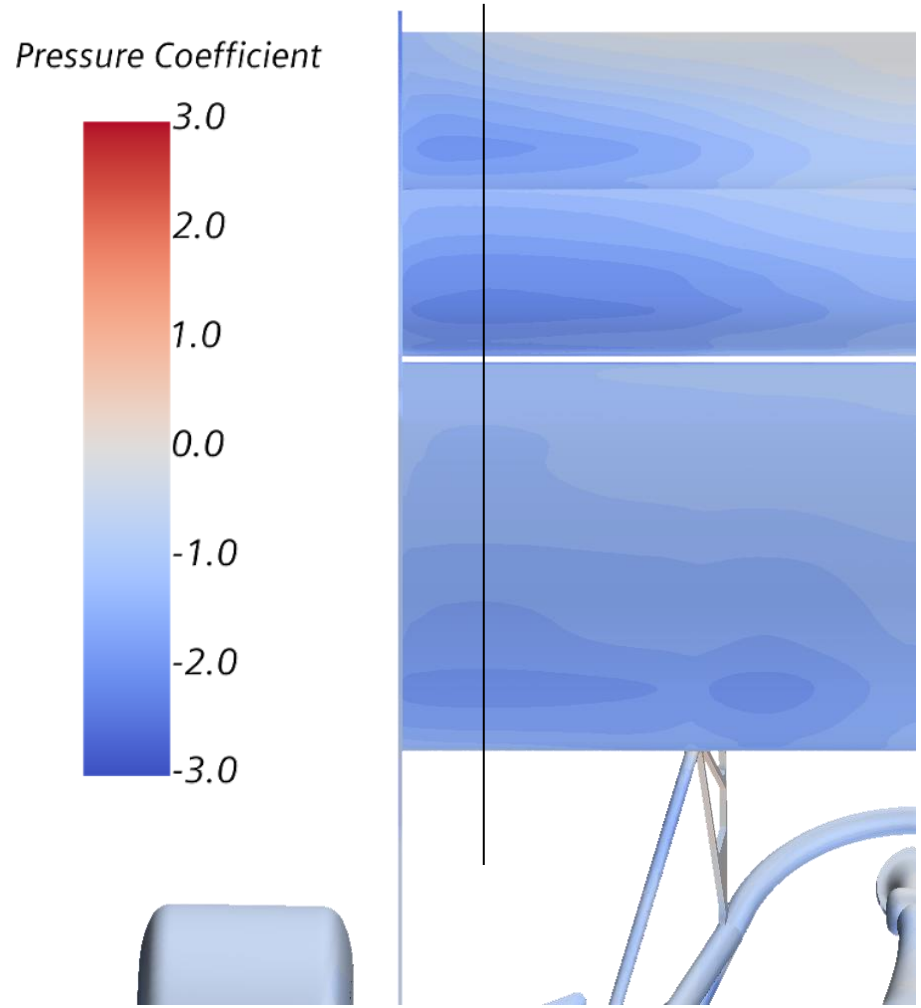


	Cord [*mm*]	Angle of Attack (relative) [*deg*]	Slot Gap (ground clearance) [*mm*]	Slot Overlap [*mm*]
Mainfoil	450	4	n/a	n/a
Flap 1	150	32.5 (28.5)	18.5	15
Flap 2	150	57.5 (25)	12.5	15

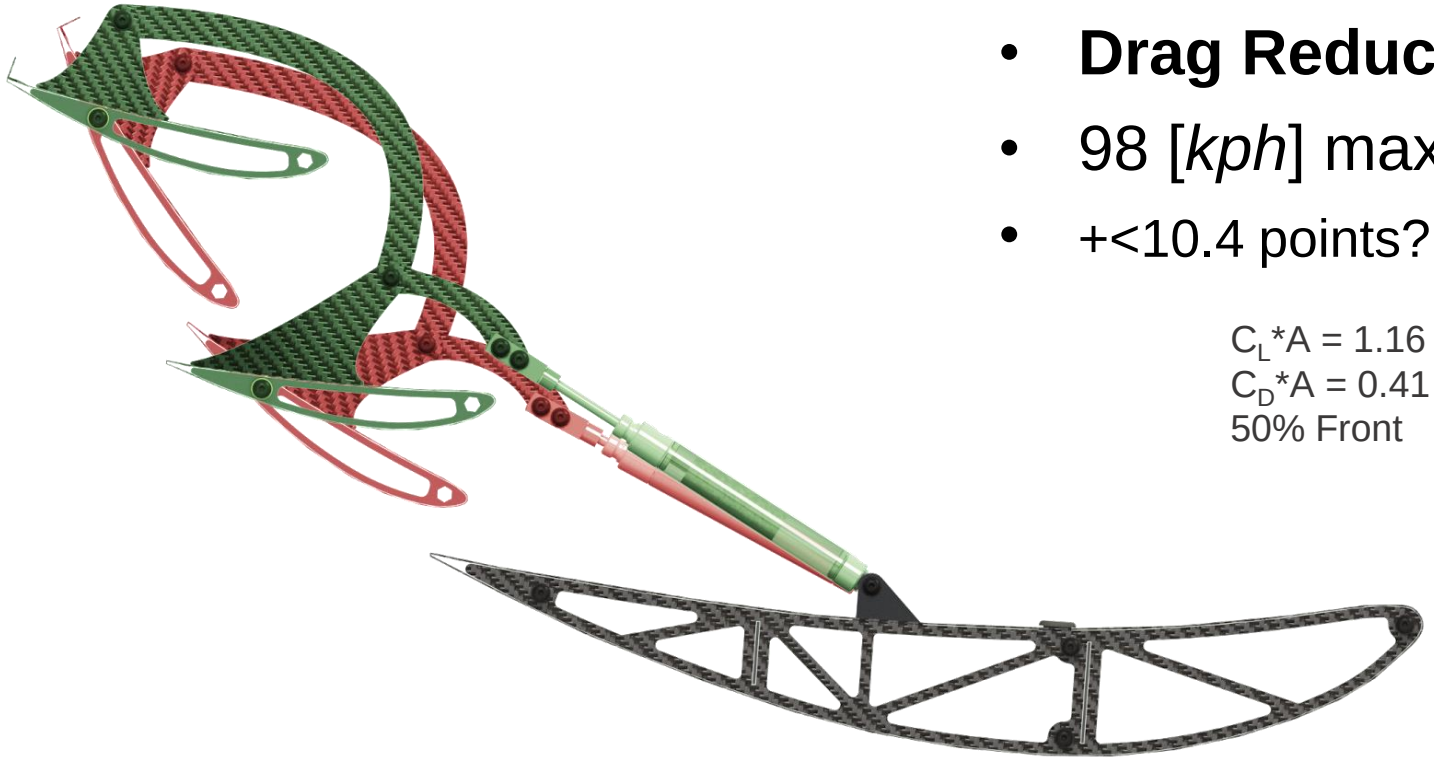
Rear Wing



Rear Wing Pressure Coefficient Profile, Y380



Rear Wing – It also moves!



- **Drag Reduction System**
- 98 [*kph*] maximum opening speed
- +<10.4 points?

C_L*A = 1.16
C_D*A = 0.41
50% Front

→

C_L*A = 0.46 (-0.7, -60%)
C_D*A = 0.058 (-0.352, -80%)
87% Front (+37% balance)

DRS Optimization - % changes in

Flap 2 Opening [deg] \ Flap 1 Opening [deg]	0	-5	-10	-15	-20	-25	-30	-35	-40
0	100	104	108	110	112	111	111	107	101
-5	104	108	114	115	116	115	113	110	104
-10	108	113	121	121	121	121	118	114	105
-15	113	119	124	128	126	127	123	117	110
-20	118	123	132	136	136	132	127	122	113
-25	125	130	136	142	148	143	136	125	115
-30	131	137	143	150	157	158	151	132	119
-35	139	146	151	159	166	169	166	147	125
-40	147	153	161	167	175	179	175	158	135
-45	154	161	169	176	183	192	191	172	147
-50	152	160	171	182	191	203	198	180	160
-55	144	155	166	178	184	196	196	183	160
-60	138	146	155	163	175	178	169	154	137
-65	131	137	145	153	156	163	158	138	123

L/D

Flap 2 Opening [deg] \ Flap 1 Opening [deg]	0	-5	-10	-15	-20	-25	-30	-35	-40
0	41	45	49	52	56	59	62	65	67
-5	42	45	50	53	57	59	63	66	68
-10	44	47	51	54	58	61	64	67	69
-15	45	48	51	56	59	63	65	68	71
-20	48	49	51	56	61	64	67	70	72
-25	50	51	53	57	61	65	69	71	75
-30	53	54	56	58	61	66	70	74	77
-35	56	57	58	60	63	67	72	76	80
-40	60	61	62	64	66	68	72	76	79
-45	67	68	67	68	69	73	75	77	79
-50	70	73	75	75	75	77	79	80	81
-55	70	73	76	81	83	85	86	86	85
-60	70	73	77	79	84	88	92	95	95
-65	71	73	76	80	83	88	93	96	97

Aerobalance

Flap 2 Opening [deg] \ Flap 1 Opening [deg]	0	-5	-10	-15	-20	-25	-30	-35	-40
0	100	88	76	68	61	56	52	49	48
-5	93	82	70	63	57	53	49	47	46
-10	87	77	66	58	53	49	46	44	43
-15	80	72	63	54	50	45	43	41	40
-20	73	67	59	51	45	42	40	38	37
-25	66	61	55	48	42	37	36	35	34
-30	59	54	50	45	39	34	31	31	31
-35	52	48	44	40	35	31	28	27	28
-40	44	42	38	35	31	28	26	25	26
-45	36	33	32	29	27	24	22	22	24
-50	33	28	26	23	22	20	19	19	22
-55	35	30	25	21	18	16	15	16	18
-60	36	31	27	23	19	16	14	14	15
-65	37	33	29	24	21	17	15	14	16

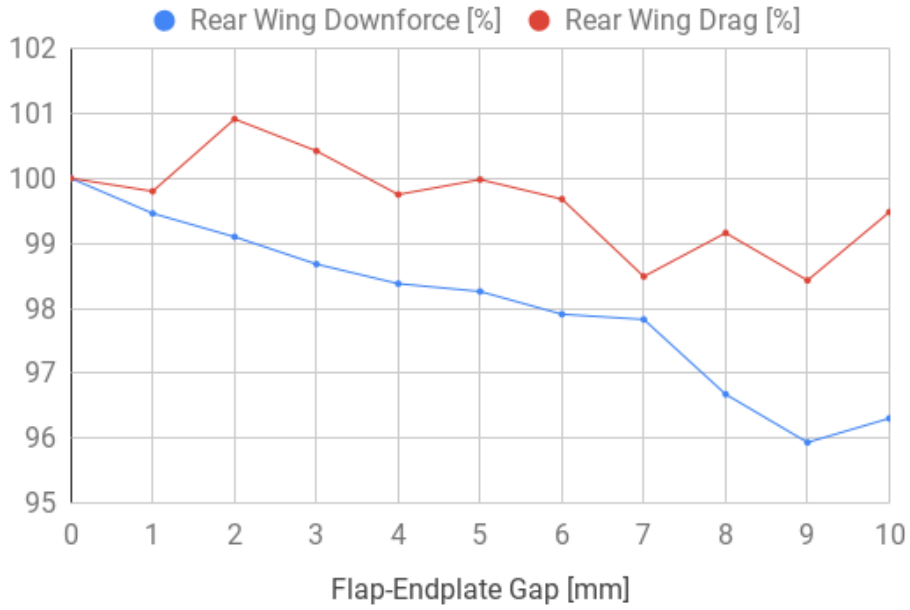
Drag

Flap 2 Opening [deg] \ Flap 1 Opening [deg]	0	-5	-10	-15	-20	-25	-30	-35	-40
0	100	91	82	75	68	62	57	53	48
-5	96	89	80	72	66	61	56	51	47
-10	94	87	80	71	65	60	54	50	45
-15	90	85	79	69	63	58	53	48	44
-20	87	83	78	70	61	55	50	46	42
-25	83	80	75	69	62	53	48	43	39
-30	77	75	71	67	61	54	47	41	37
-35	72	70	67	63	59	53	46	40	35
-40	65	64	61	58	54	50	45	39	36
-45	55	53	54	52	49	46	42	38	36
-50	50	45	44	42	42	40	37	35	35
-55	50	46	42	37	33	31	30	29	29
-60	49	45	41	37	33	28	23	21	21
-65	49	45	41	37	33	29	24	20	19

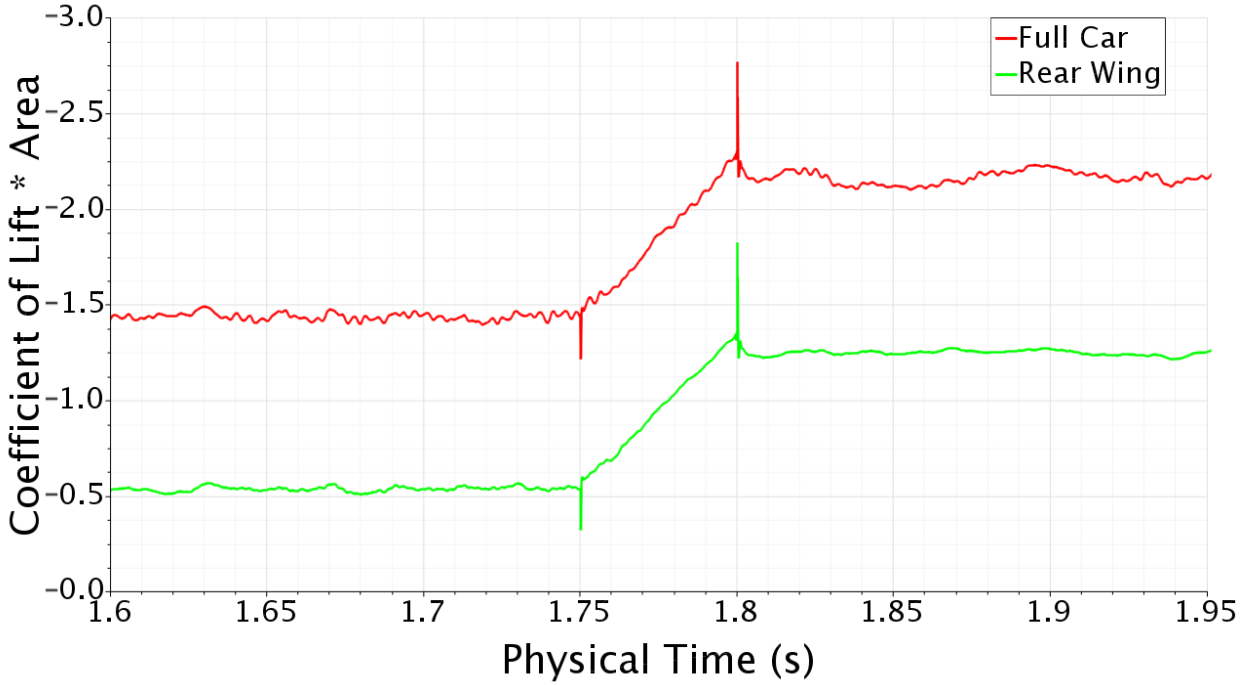
Downforce

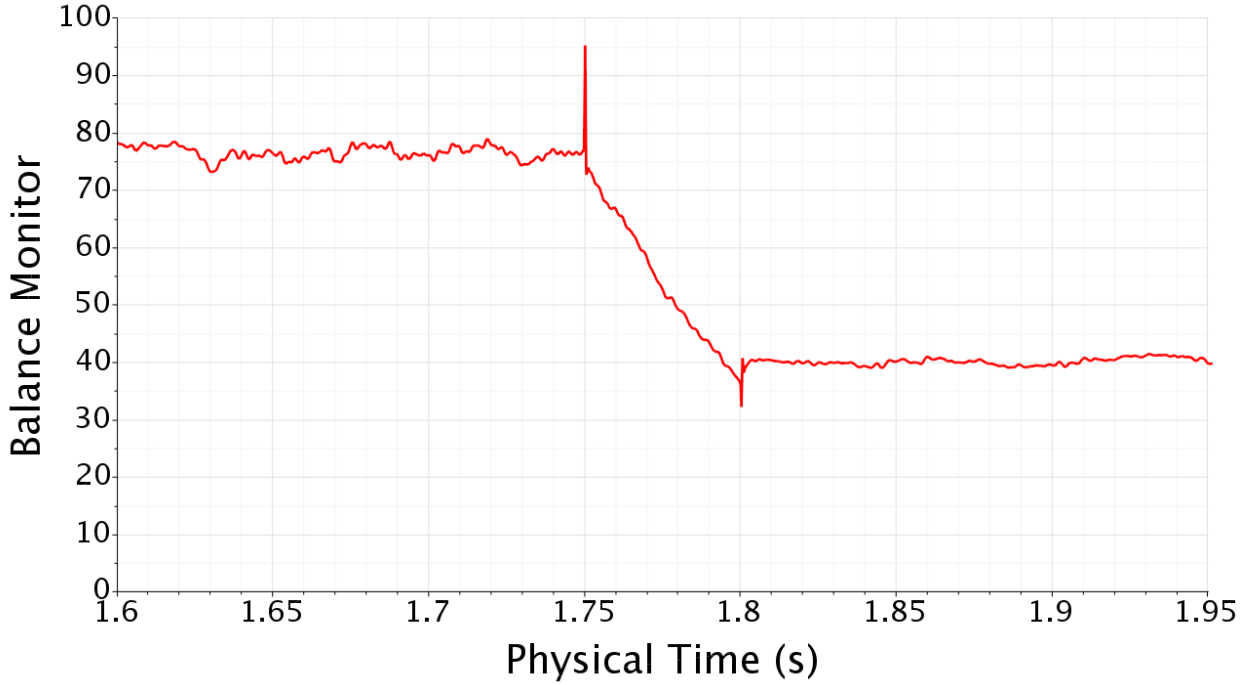
DRS Losses

	C_L*A		C_D*A	
	No Linkage	Linkage	No Linkage	Linkage
Mainfoil	0.7687	0.7644 **(-0.56%)**	0.0699	0.0695 **(-0.57%)**
Flap 1	0.2739	0.2715 **(-0.88%)**	0.1604	0.1591 **(-0.81%)**
Flap 2	0.115	0.1134 **(-1.39%)**	0.1782	0.1755 **(-1.52%)**
DRS Linkage	n/a	0.0001	n/a	0.0006
Overall	1.1575	1.1495 **(-0.69%)**	0.4084	0.4046 **(-0.93%)**



DRS - Closing


Full Car
Rear Wing
Coefficient of Lift * Area
-3.0
-2.5
-2.0
-1.5
-1.0
-0.5
-0.0
1.6
1.65
1.7
1.75
1.8
1.85
1.9
1.95
Physical Time (s)


Balance Monitor
100
90
80
70
60
50
40
30
20
10
0
1.6
1.65
1.7
1.75
1.8
1.85
1.9
1.95
Physical Time (s)

Aerostructures

FEA Inputs

- **35 [*m/s*] top speed (126 [*kph*]) + 15 [*m/s*] wind+gust (54 [*kph*]) = 50 [*m/s*] (180 [*kph*])**
- **1.5 Factor of Safety**
- **Full xyz aero load vector**
- **Acceleration loading from mass**
- **Buckling**

FEA Load Cases

- Cornering (max front wing)
- Braking (max front wing)
- 90 deg spin -> rear wing sideforce of 1000 [*N*] !
- 180 deg spin -> inconsequential
- Front wing jacking / big road bump
- Foot on front wing “Claude Case”
- Future -> Cone strike

Aerodynamic Mapping – Ride Height

CL*A		Height Front [mm]				
		10	20	30	40	50
Height Rear [mm]	10	-2.37	-2.25	-2.14	-2.04	-1.93
	20	-2.44	-2.31	-2.21	-2.10	-2.00
	30	-2.51	-2.38	-2.26	-2.16	-2.07
	40	-2.61	-2.45	-2.34	-2.22	-2.12
	50	-2.65	-2.51	-2.39	-2.28	-2.17

CD*A		Height Front [mm]				
		10	20	30	40	50
Height Rear [mm]	10	1.21	1.22	1.22	1.21	1.20
	20	1.21	1.23	1.23	1.22	1.21
	30	1.21	1.23	1.24	1.23	1.22
	40	1.25	1.22	1.25	1.24	1.23
	50	1.24	1.24	1.25	1.25	1.24

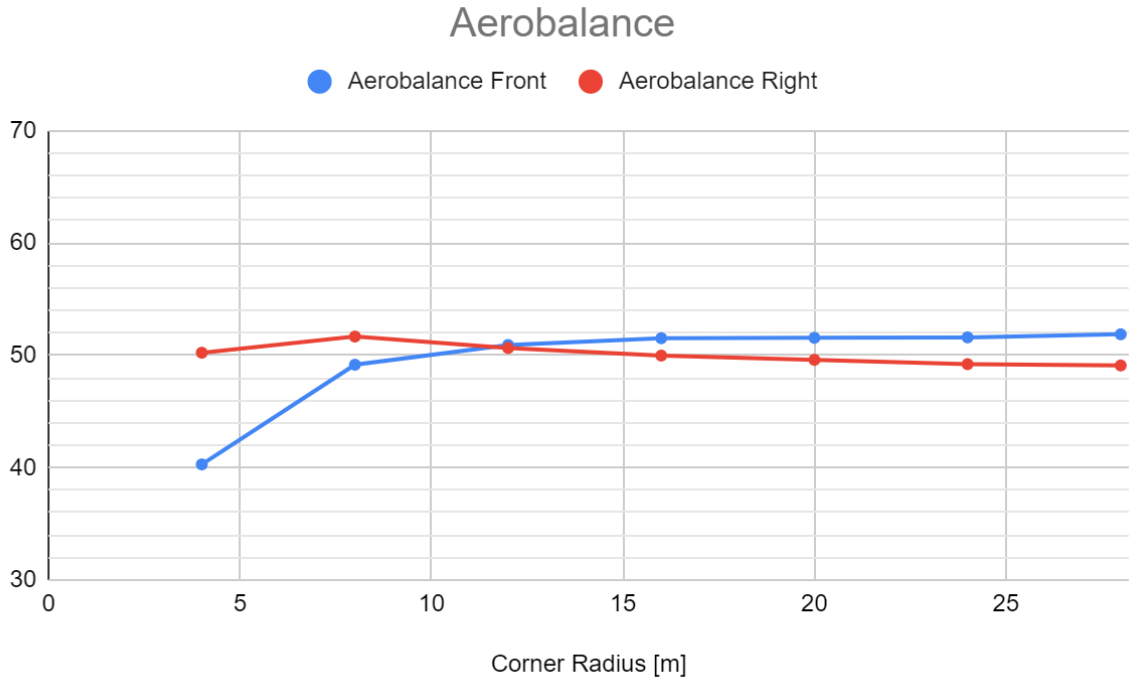
Aerobalance Front		Height Front [mm]				
		10	20	30	40	50
Height Rear [mm]	10	56.35	52.15	49.02	45.36	41.47
	20	58.31	54.38	50.74	47.20	43.73
	30	59.67	56.42	52.25	49.03	45.77
	40	59.21	58.24	53.63	50.63	47.39
	50	60.92	59.25	55.45	52.30	49.04

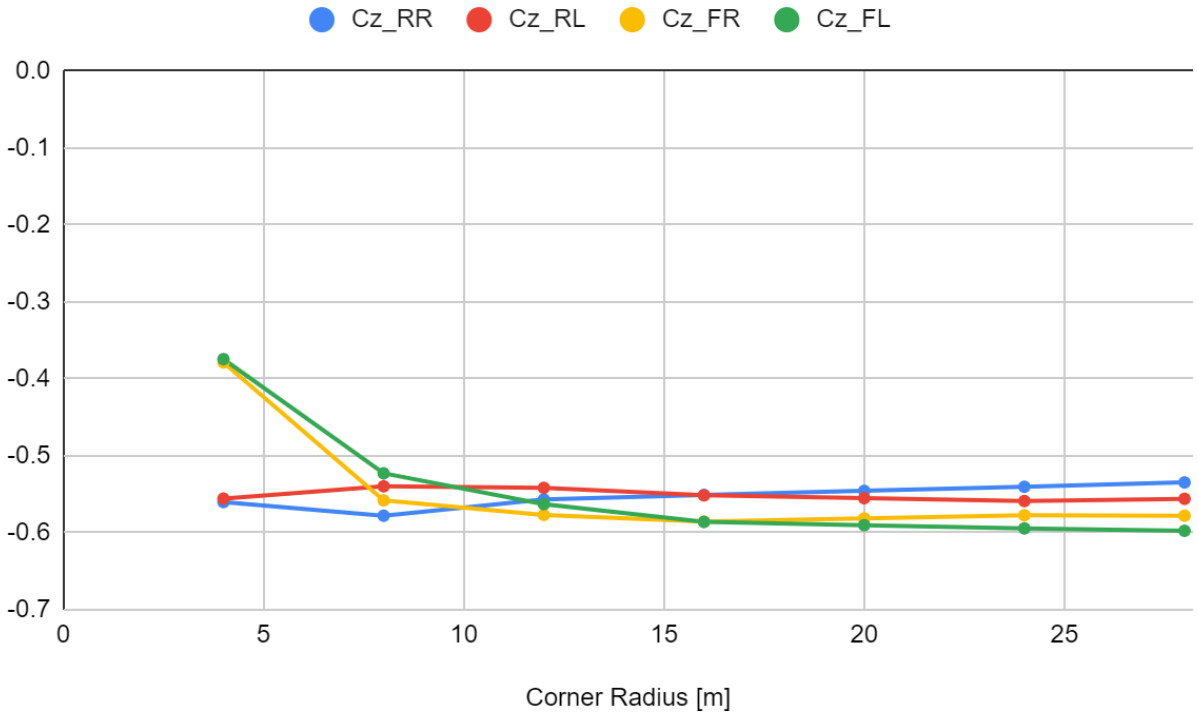
L/D		Height Front [mm]				
		10	20	30	40	50
Height Rear [mm]	10	-1.97	-1.84	-1.76	-1.69	-1.61
	20	-2.02	-1.88	-1.80	-1.73	-1.65
	30	-2.07	-1.93	-1.83	-1.76	-1.69
	40	-2.10	-2.00	-1.88	-1.79	-1.72
	50	-2.14	-2.03	-1.90	-1.82	-1.75

CzF		Height Front [mm]				
		10	20	30	40	50
Height Rear [mm]	10	-1.34	-1.17	-1.05	-0.92	-0.80
	20	-1.42	-1.26	-1.12	-0.99	-0.87
	30	-1.50	-1.34	-1.18	-1.06	-0.95
	40	-1.55	-1.42	-1.26	-1.12	-1.01
	50	-1.61	-1.49	-1.32	-1.19	-1.07

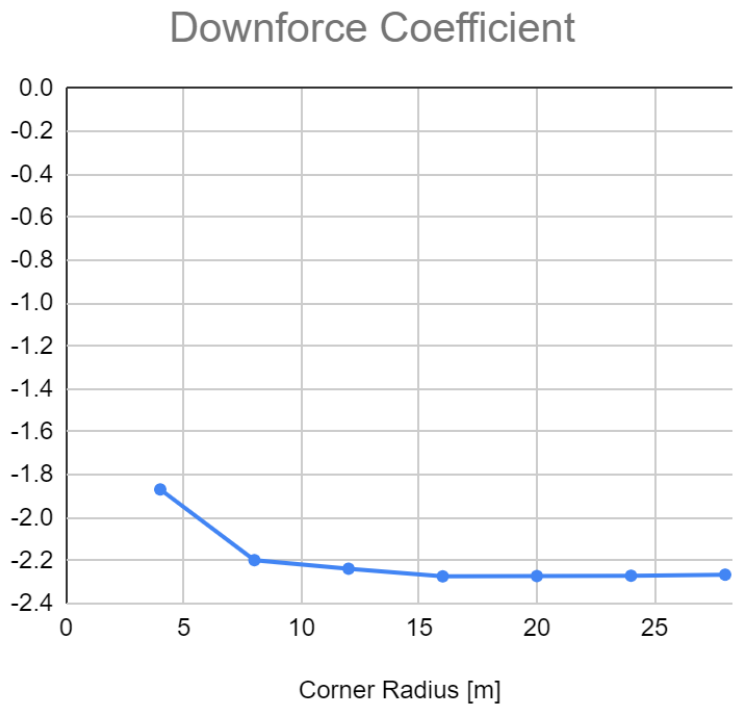
CzR		Height Front [mm]				
		10	20	30	40	50
Height Rear [mm]	10	-1.04	-1.08	-1.09	-1.11	-1.13
	20	-1.02	-1.05	-1.09	-1.11	-1.13
	30	-1.01	-1.04	-1.08	-1.10	-1.12
	40	-1.07	-1.02	-1.09	-1.10	-1.12
	50	-1.04	-1.02	-1.06	-1.09	-1.11

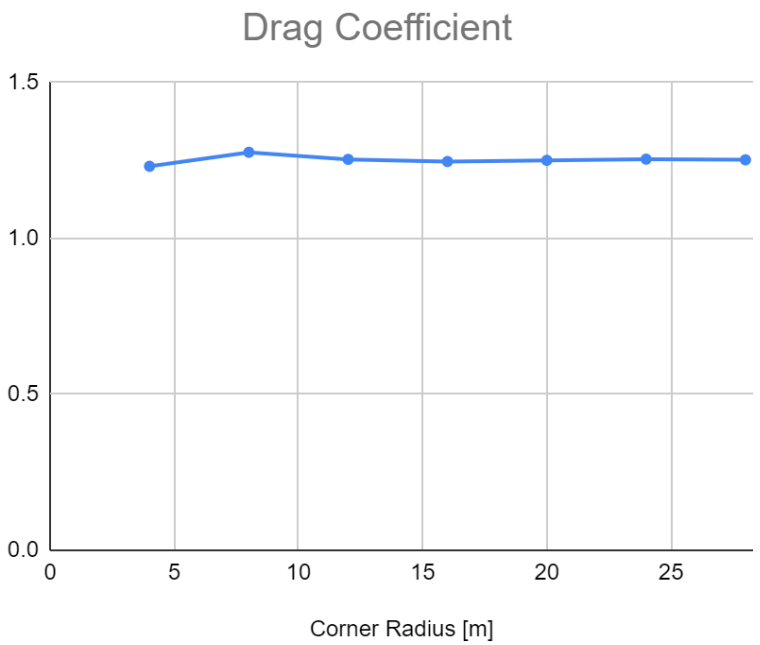
Aerodynamic Mapping - Cornering

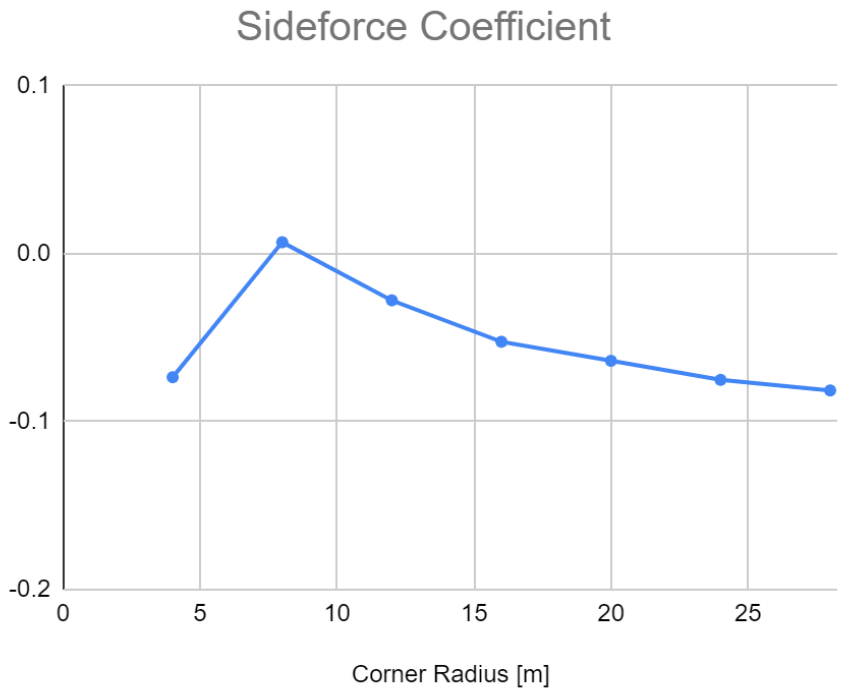




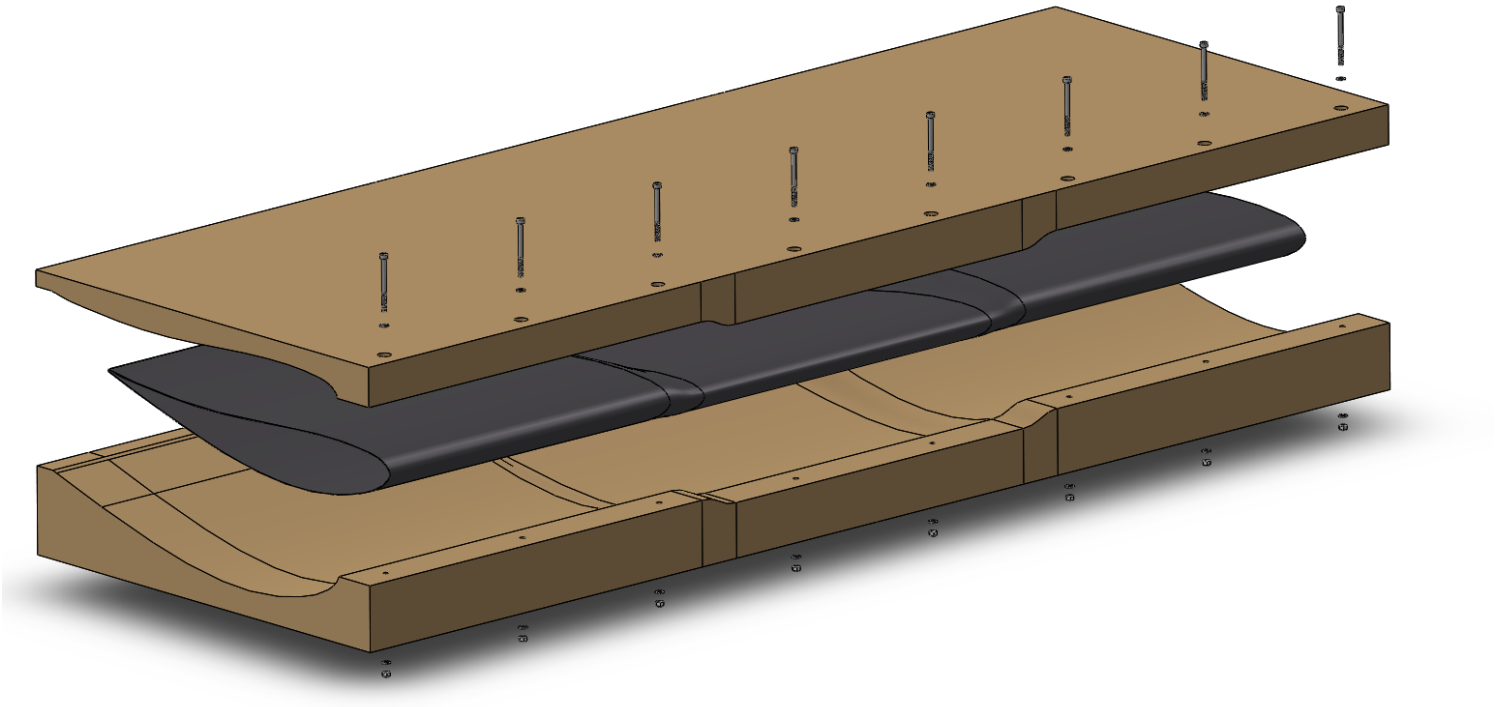
Aerodynamic Mapping - Cornering







Manufacturing



Validation - delayed due to pandemic

- Yarn tests
- Coast-downs
- Suspension potentiometers
- Flow visualization paint