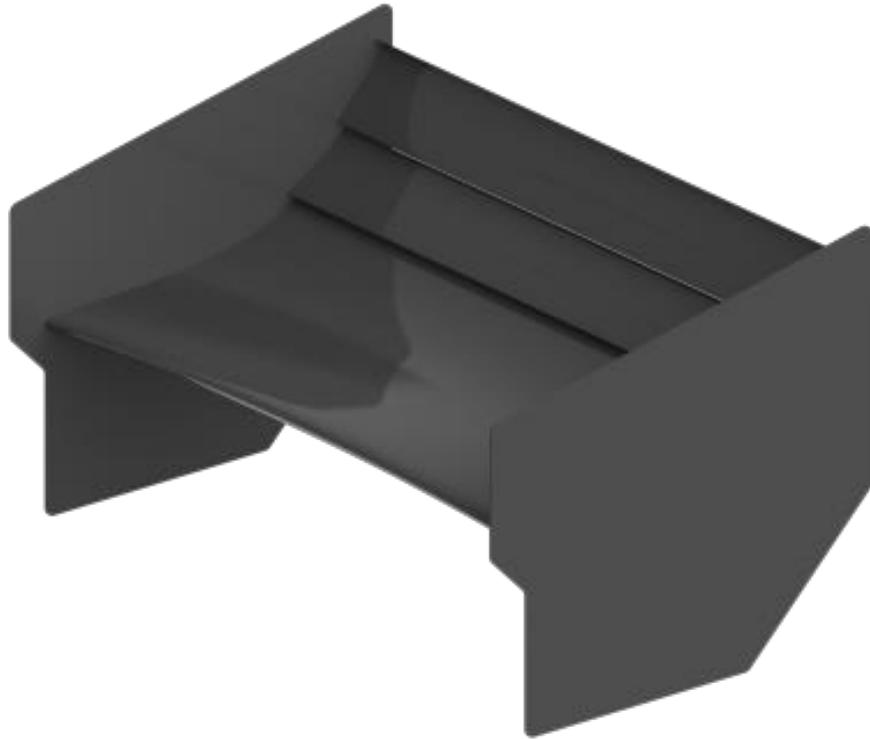


Aero: Rear Wing



Goals and Targets

Primary Functions:

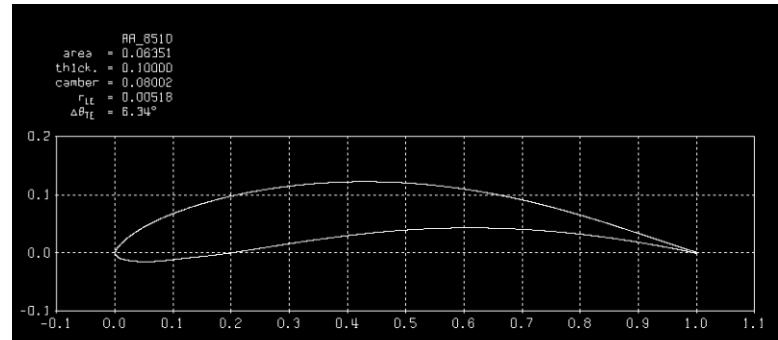
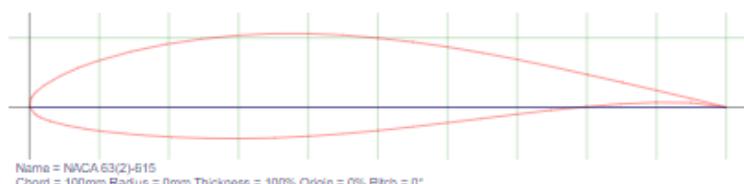
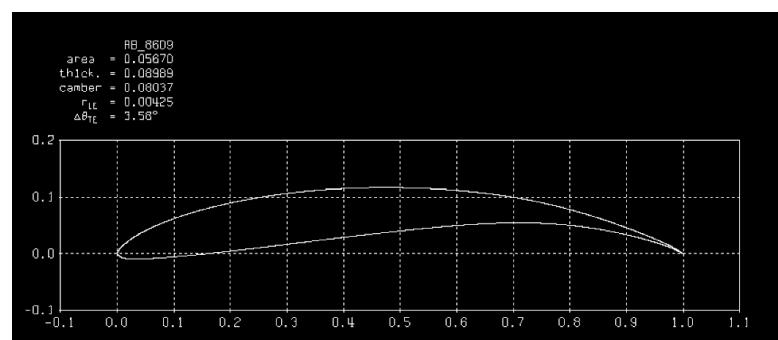
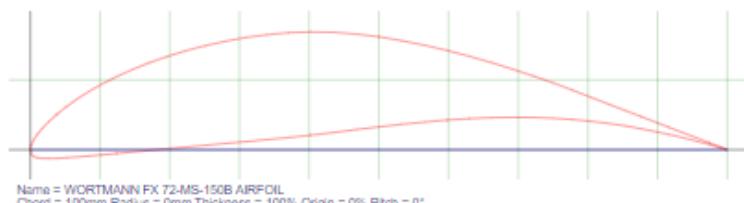
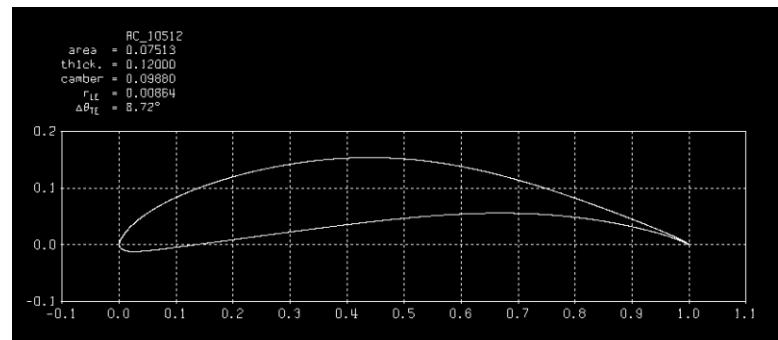
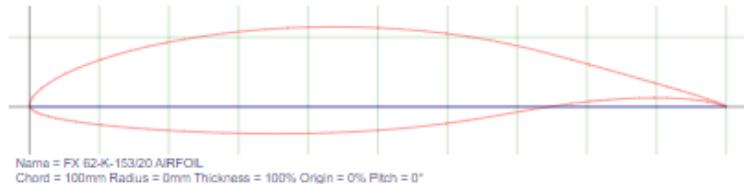
- Generate high down force from freestream air
- Balance vehicle center of pressure (CP) position
- Minimize number of wing sections
 - Weight and manufacturing

Total	
Efficiency	2.5
Drag (lbs)	41
Down Force (lbs)	102.5
CP (% wheelbase)	42%
Front	
Efficiency	8
Drag (lbs)	3
Down Force (lbs)	24
Side	
Efficiency	5
Drag (lbs)	8
Down Force (lbs)	40
Rear	
Efficiency	2.75
Drag (lbs)	16
Down Force (lbs)	44

Target performance for 35 mph straight line

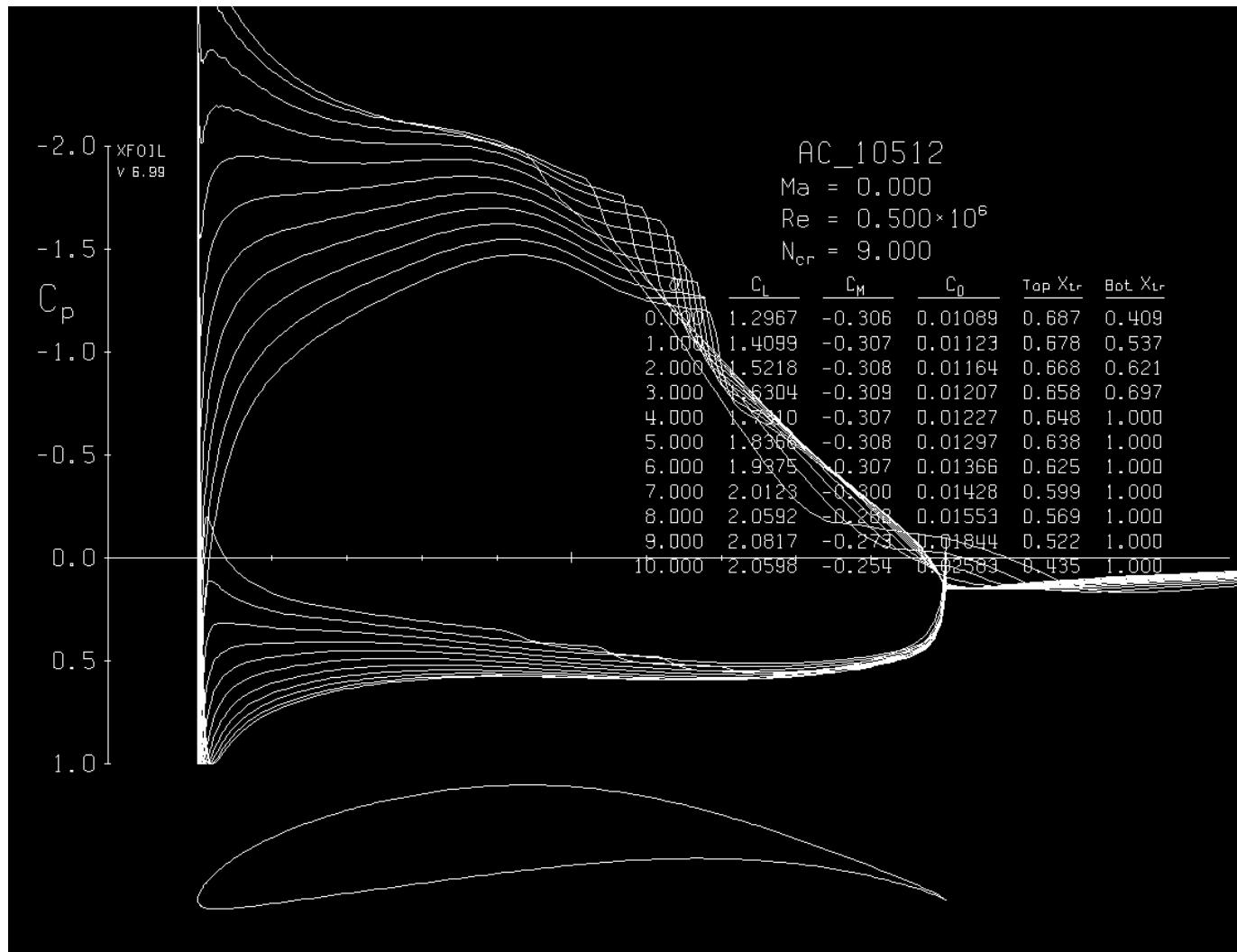
Main Foil Selection

- **Max camber and position,**
- **Max thickness and position**
- **Leading edge radius**
- **Database airfoils vs. XFOIL designs**



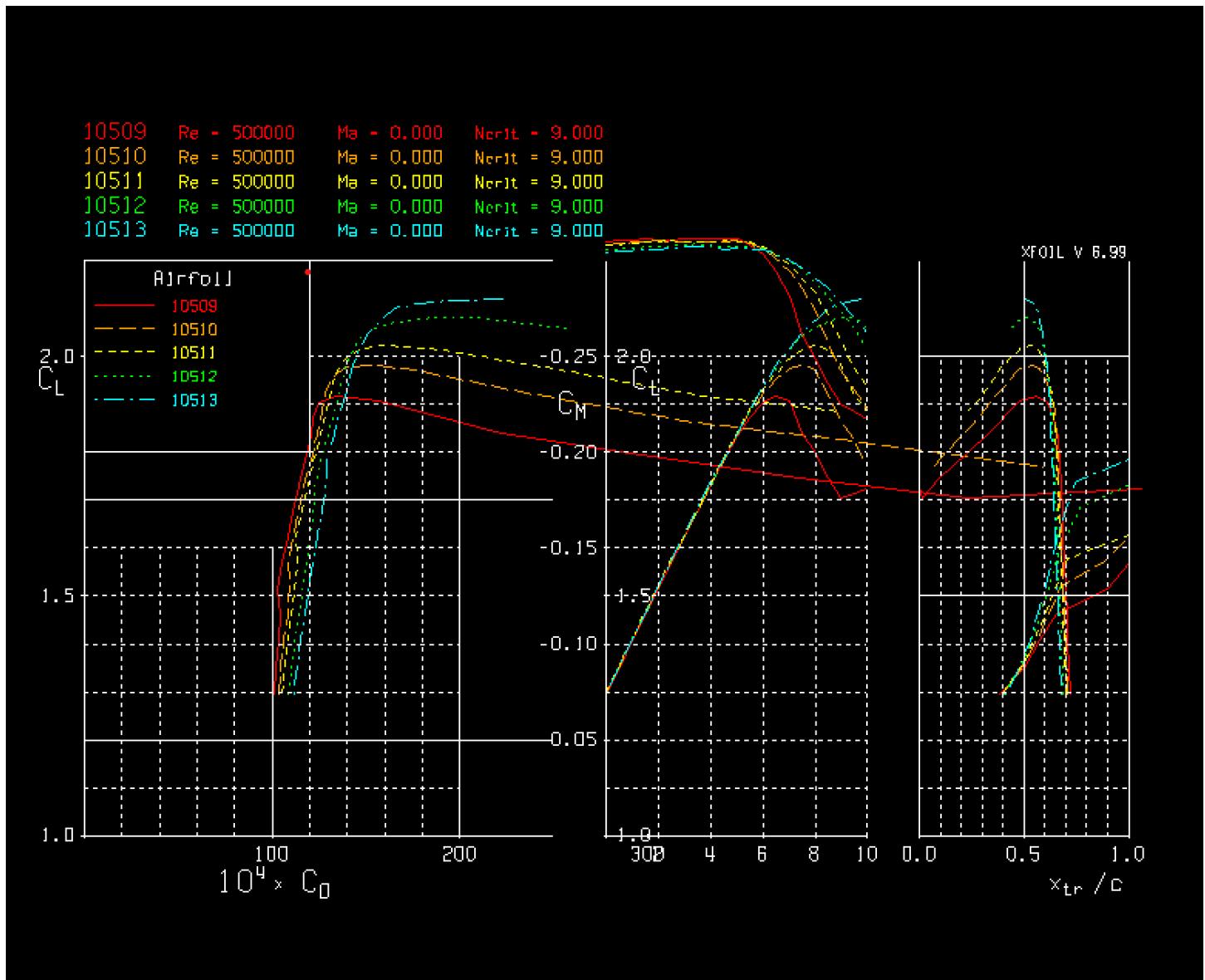
Main Foil Design

- **XFOIL 2D Geometry Design**
 - Camber, max thickness, and respective positions
 - Direct geometry splines
 - Velocity distribution modification
 - 2D AoA sweeps (Reynolds #: 500000)



Main Foil Design

- **2D AoA sweep polar comparisons**
- **Reynolds Number 500000**



Max Camber: 10% at 50% chord length, range of max thickness values

Main Foil Selection: AoA & Geometry

Rear Main Foil	Sim Type	Chord Length (in)	AOA (deg)	RWG Downforce (lbs)	RWG Drag (lbs)	Efficiency
AA_8510	SL 35 mph	14	0	5.74	0.82	7.00
AA_8510	SL 35 mph	14	2	7.36	0.93	7.93
AA_8510	SL 35 mph	14	4	8.76	1.11	7.88
AA_8510	SL 35 mph	14	5	9.96	1.19	8.38
AA_8510	SL 35 mph	14	6	10.39	1.30	8.02
AA_8510	SL 35 mph	14	8	11.73	1.57	7.47
Rear Main Foil	Sim Type	Chord Length (in)	AOA (deg)	RWG Downforce (lbs)	RWG Drag (lbs)	Efficiency
AA_8609	SL 35 mph	14	0	7.57	0.98	7.73
AA_8609	SL 35 mph	14	2	8.89	1.10	8.11
AA_8609	SL 35 mph	14	3	9.33	1.21	7.68
AA_8609	SL 35 mph	14	4	10.21	1.29	7.89
AA_8609	SL 35 mph	14	6	11.95	1.50	7.98
AA_8609	SL 35 mph	14	8	12.90	1.87	6.90
AA_8609	SL 35 mph	14	10	13.72	2.04	6.74
Rear Main Foil	Sim Type	Chord Length (in)	AOA (deg)	RWG Downforce (lbs)	RWG Drag (lbs)	Efficiency
AB_9509	SL 35 mph	14	0	7.80	0.98	7.95
AB_9509	SL 35 mph	14	2	8.61	1.12	7.66
AB_9509	SL 35 mph	14	3	9.96	1.20	8.33
AB_9509	SL 35 mph	14	4	10.48	1.31	8.02
AB_9509	SL 35 mph	14	6	12.01	1.53	7.87
AB_9509	SL 35 mph	14	8	13.27	1.88	7.07
AB_9509	SL 35 mph	14	10	14.18	2.06	6.87
AB_9510	SL 35 mph	14	4	10.32	1.32	7.80
AB_9510	SL 35 mph	14	6	12.03	1.55	7.75
AB_9510	SL 35 mph	14	8	13.01	1.82	7.14
AB_9510	SL 35 mph	14	10	14.21	2.04	6.95
AB_9511	SL 35 mph	14	4	10.13	1.34	7.59
AB_9511	SL 35 mph	14	6	11.68	1.54	7.59
AB_9511	SL 35 mph	14	8	13.34	1.84	7.23
AB_9511	SL 35 mph	14	10	14.57	2.11	6.91
AB_9512	SL 35 mph	14	4	10.58	1.33	7.98
AB_9512	SL 35 mph	14	6	11.44	1.54	7.42
AB_9512	SL 35 mph	14	8	13.41	1.83	7.34
AB_9512	SL 35 mph	14	10	14.40	2.03	7.09

Angle of attack trends were studied for airfoils of interest

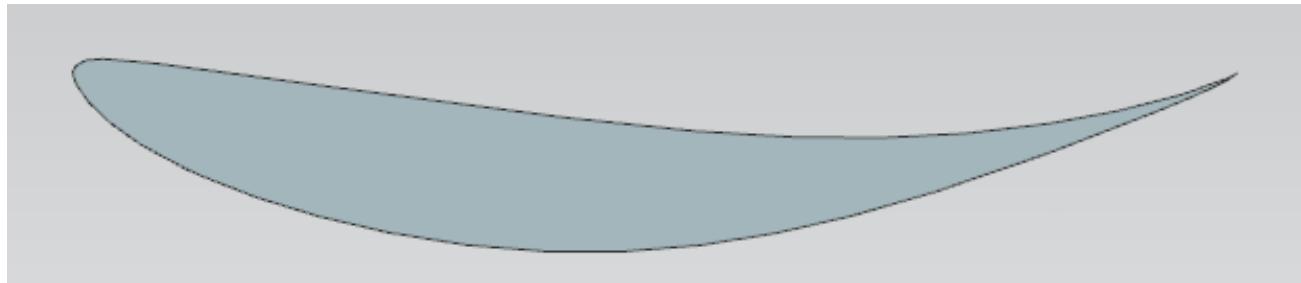
Main Foil Selection: AoA & Geometry

Rear Main Foil	Sim Type	Chord Length (in)	AOA (deg)	RWG Downforce (lbs)	RWG Drag (lbs)	Efficiency
AC_10510	SL 35 mph	14	6	12.08	1.62	7.44
AC_10510	SL 35 mph	14	8	13.94	1.92	7.27
AC_10510	SL 35 mph	14	10	14.93	2.14	6.96
AC_10510	SL 35 mph	14	12	15.74	2.47	6.38
AC_10510	SL 35 mph	14	14	16.01	2.74	5.84
AC_10512	SL 35 mph	14	6	12.52	1.65	7.59
AC_10512	SL 35 mph	14	8	14.08	1.95	7.23
AC_10512	SL 35 mph	14	10	14.31	2.17	6.60
AC_10512	SL 35 mph	14	12	15.92	2.46	6.46
AC_10512	SL 35 mph	14	14	16.70	2.80	5.96
AC_10514	SL 35 mph	14	6	12.11	1.67	7.23
AC_10514	SL 35 mph	14	8	13.72	1.97	6.96
AC_10514	SL 35 mph	14	10	14.97	2.16	6.92
AC_10514	SL 35 mph	14	12	15.29	2.40	6.38
AC_10514	SL 35 mph	14	14	16.00	2.72	5.89
Rear Main Foil	Sim Type	Chord Length (in)	AOA (deg)	RWG Downforce (lbs)	RWG Drag (lbs)	Efficiency
fx72150b_12in	SL 35 mph	12	6	10.04	1.35	7.44
fx72150b_12in	SL 35 mph	12	8	11.26	1.52	7.41
fx72150b_12in	SL 35 mph	12	10	11.83	1.70	6.95
fx72150b_12in	SL 35 mph	12	12	13.02	2.01	6.47
fx72150b_12in	SL 35 mph	12	14	13.30	2.21	6.01
fx72150b_13in	SL 35 mph	13	6	10.75	1.42	7.60
fx72150b_13in	SL 35 mph	13	8	11.84	1.60	7.39
fx72150b_13in	SL 35 mph	13	10	12.72	1.83	6.94
fx72150b_13in	SL 35 mph	13	12	13.89	2.11	6.58
fx72150b_13in	SL 35 mph	13	14	14.84	2.39	6.20
fx72150b_14in	SL 35 mph	14	0	7.16	1.00	7.15
fx72150b_14in	SL 35 mph	14	2	8.50	1.15	7.39
fx72150b_14in	SL 35 mph	14	4	10.12	1.32	7.69
fx72150b_14in	SL 35 mph	14	6	11.15	1.53	7.28
fx72150b_14in	SL 35 mph	14	8	13.31	1.88	7.08
fx72150b_14in	SL 35 mph	14	10	13.65	2.05	6.66
fx72150b_14in	SL 35 mph	14	12	14.82	2.31	6.43
fx72150b_15in	SL 35 mph	15	6	11.59	1.56	7.43
fx72150b_15in	SL 35 mph	15	8	13.44	1.84	7.32
fx72150b_15in	SL 35 mph	15	10	14.27	2.10	6.80
fx72150b_15in	SL 35 mph	15	12	15.08	2.37	6.35
fx72150b_15in	SL 35 mph	15	14	16.69	2.75	6.07
fx72150b_16in	SL 35 mph	16	6	12.45	1.69	7.37
fx72150b_16in	SL 35 mph	16	8	13.39	1.93	6.95
fx72150b_16in	SL 35 mph	16	10	15.34	2.26	6.78
fx72150b_16in	SL 35 mph	16	12	15.83	2.52	6.27
fx72150b_16in	SL 35 mph	16	14	17.03	2.93	5.82

Preliminarily sized the chord length while studying fx72150b

Main Foil Selection: AoA & Geometry

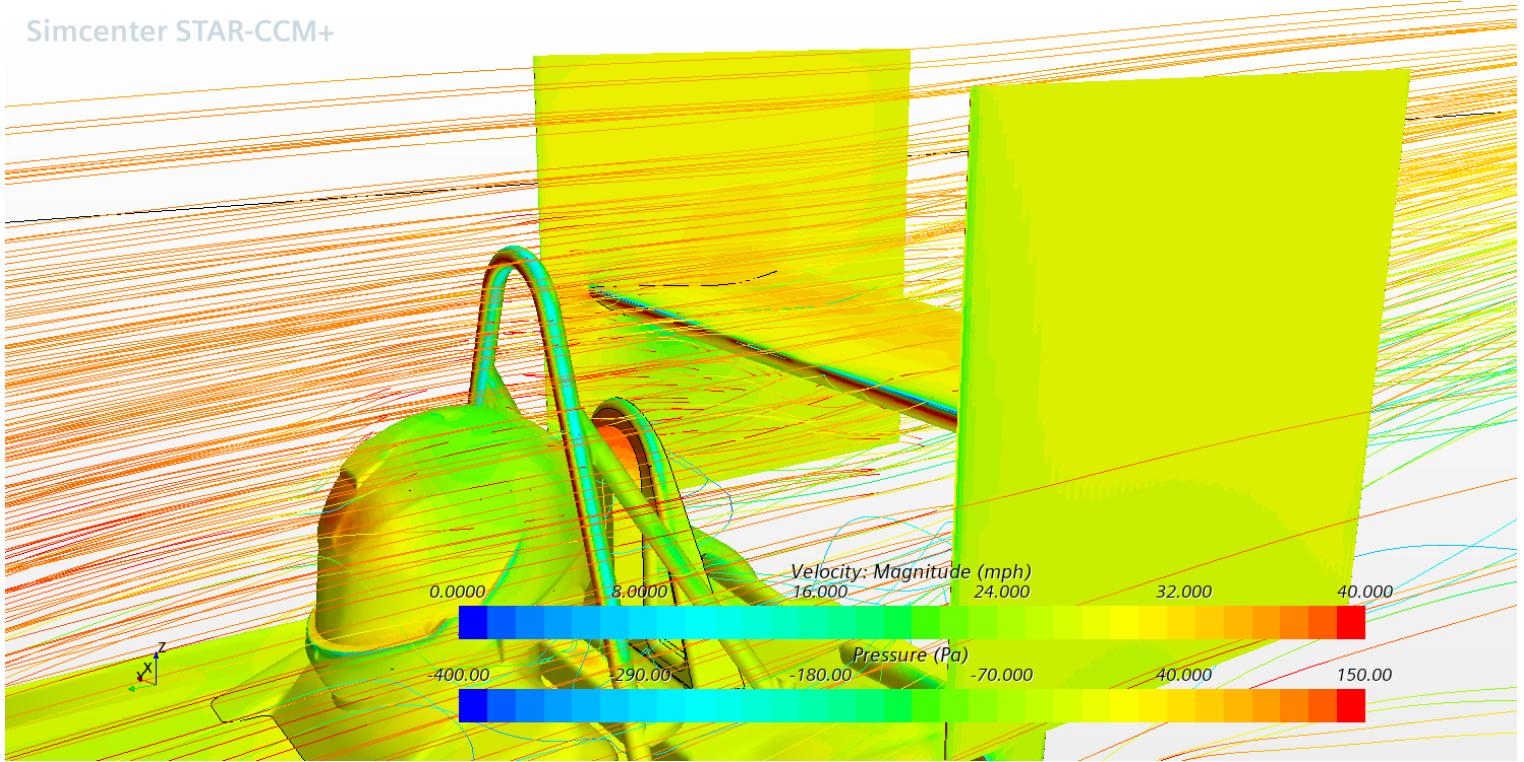
Rear Main Foil	Sim Type	Chord Length (in)	AOA (deg)	RWG Downforce (lbs)	RWG Drag (lbs)	Efficiency
fx62k153	SL 35 mph	14	0	4.43	0.71	6.23
fx62k153	SL 35 mph	14	2	5.99	0.81	7.43
fx62k153	SL 35 mph	14	4	6.88	0.94	7.31
fx62k153	SL 35 mph	14	6	8.68	1.11	7.83
fx62k153	SL 35 mph	14	8	10.21	1.35	7.56
fx62k153	SL 35 mph	14	10	11.35	1.55	7.33
fx62k153	SL 35 mph	14	12	12.45	1.83	6.81
Rear Main Foil	Sim Type	Chord Length (in)	AOA (deg)	RWG Downforce (lbs)	RWG Drag (lbs)	Efficiency
NACA 632615	SL 35 mph	14	0	3.23	0.66	4.91
NACA 632615	SL 35 mph	14	2	4.41	0.74	5.93
NACA 632615	SL 35 mph	14	4	6.17	0.86	7.22
NACA 632615	SL 35 mph	14	6	7.56	1.01	7.46
NACA 632615	SL 35 mph	14	8	9.10	1.21	7.49
NACA 632615	SL 35 mph	14	10	9.99	1.37	7.28
NACA 632615	SL 35 mph	14	12	11.45	1.66	6.88



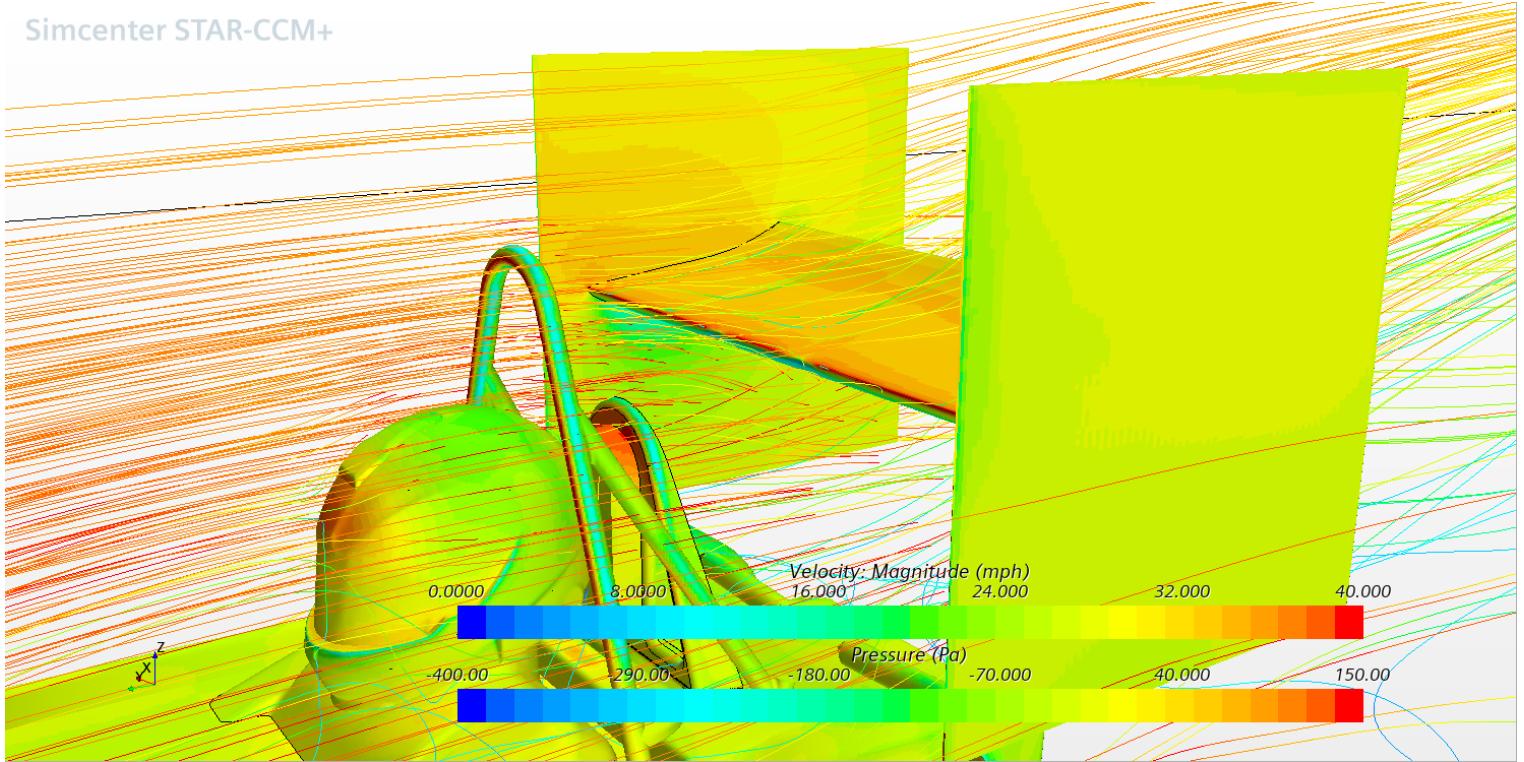
XFOIL design AC_10512: 14" chord length

Main Foil Selection: AoA & Geometry

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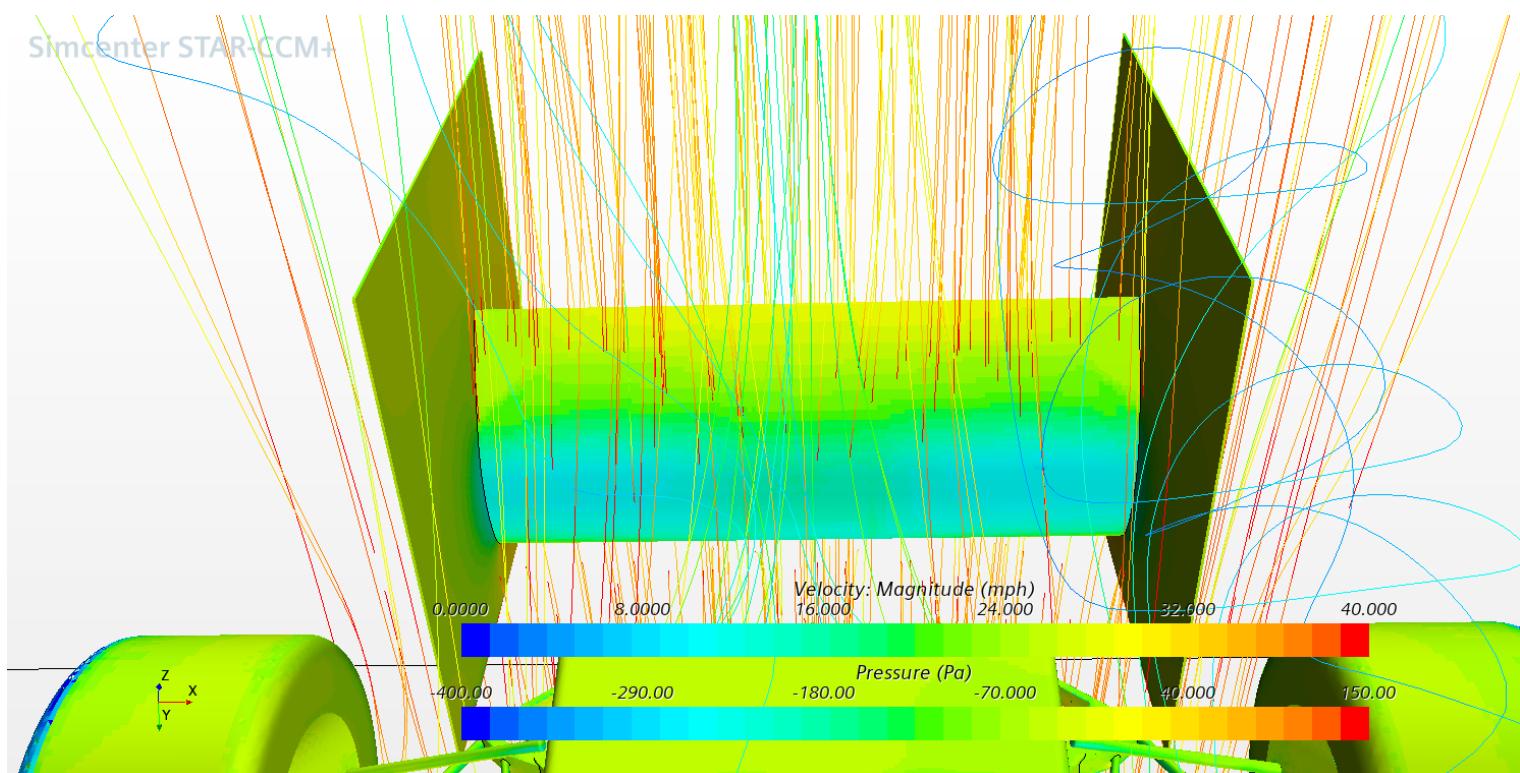
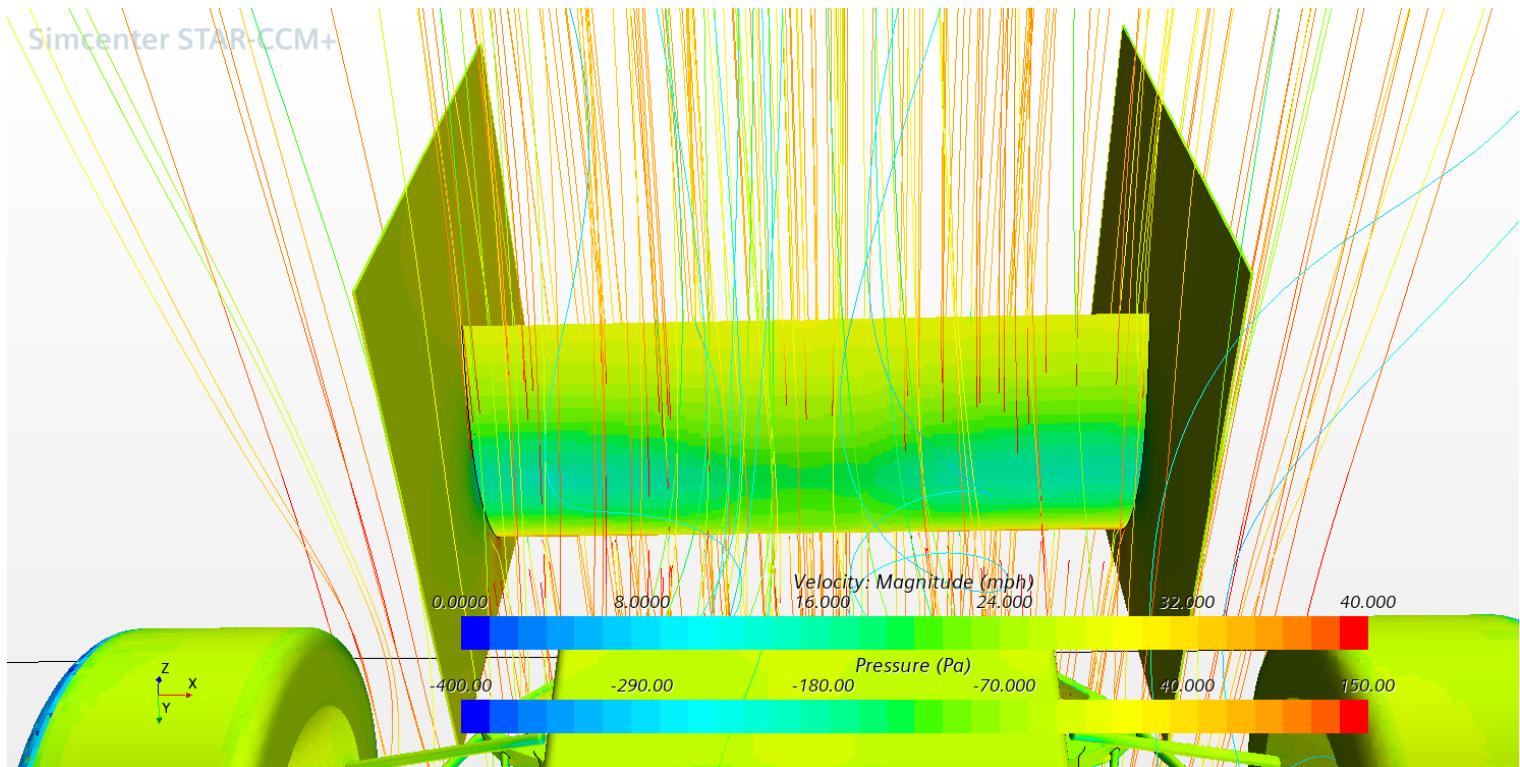
Simcenter STAR-CCM+



Investigating driver head impact: fx62150b SL 35.0 mph

AoA sweep: 0 deg – 12 deg

Main Foil Selection: AoA & Geometry



fx62150b SL 35.0 mph

AoA: 0 deg – 12 deg

Rear Wing Main: Position

SL 35 mph	AC_10512 DF (lbs) 12deg					
z (in)	2			15.43		
	1			15.12		
	0	15.33		14.85	14.76	14.27
	-1			14.59		
	-2			14.20		
		-2	-1	0	1	2
		y (in)				

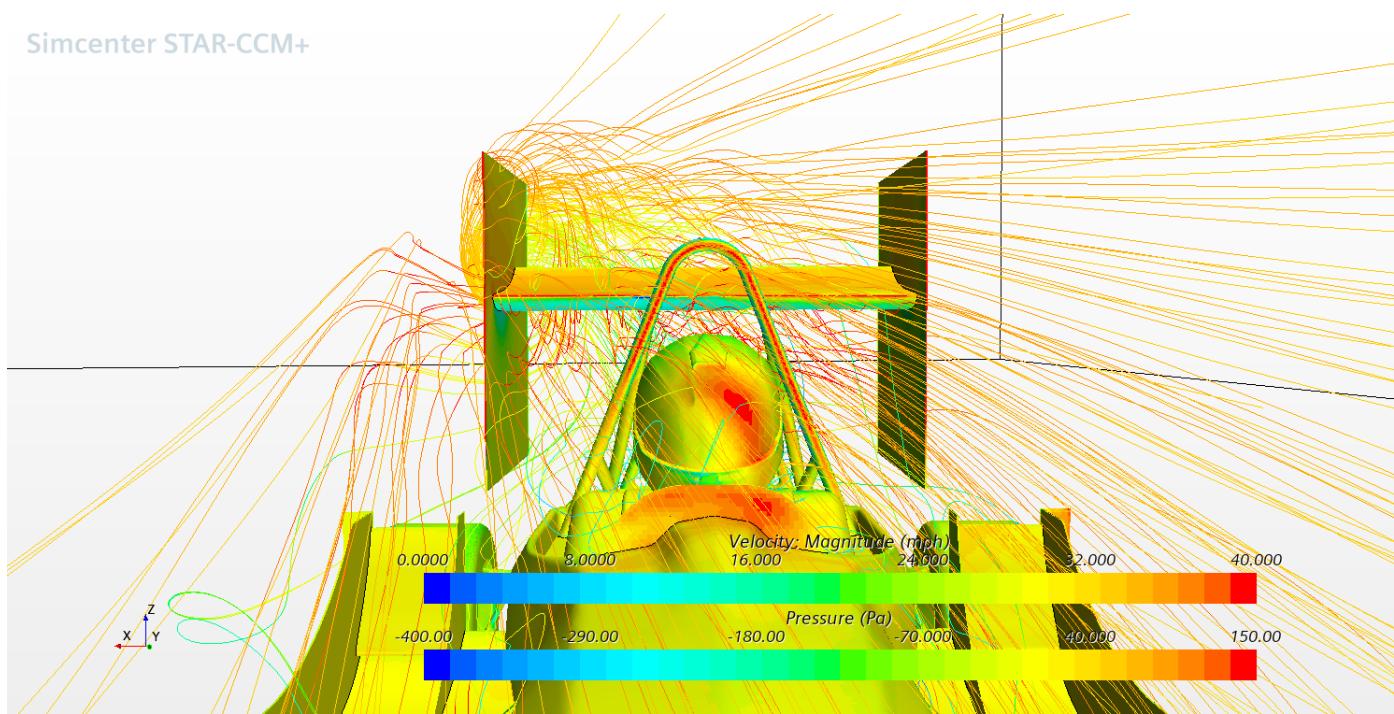
SL 35 mph	AC_10512 Drag (lbs) 12deg					
z (in)	2			2.88		
	1			2.83		
	0	2.78		2.79	2.84	2.80
	-1			2.77		
	-2			2.73		
		-2	-1	0	1	2
		y (in)				

YAW 35 mph	AC_10512 DF (lbs) 12deg					
z (in)	2	14.26	14.54	14.38		13.77
	1		14.12			
	0	13.68		13.82		13.30
	-1					
	-2					
		-2	-1	0	1	2
		y (in)				

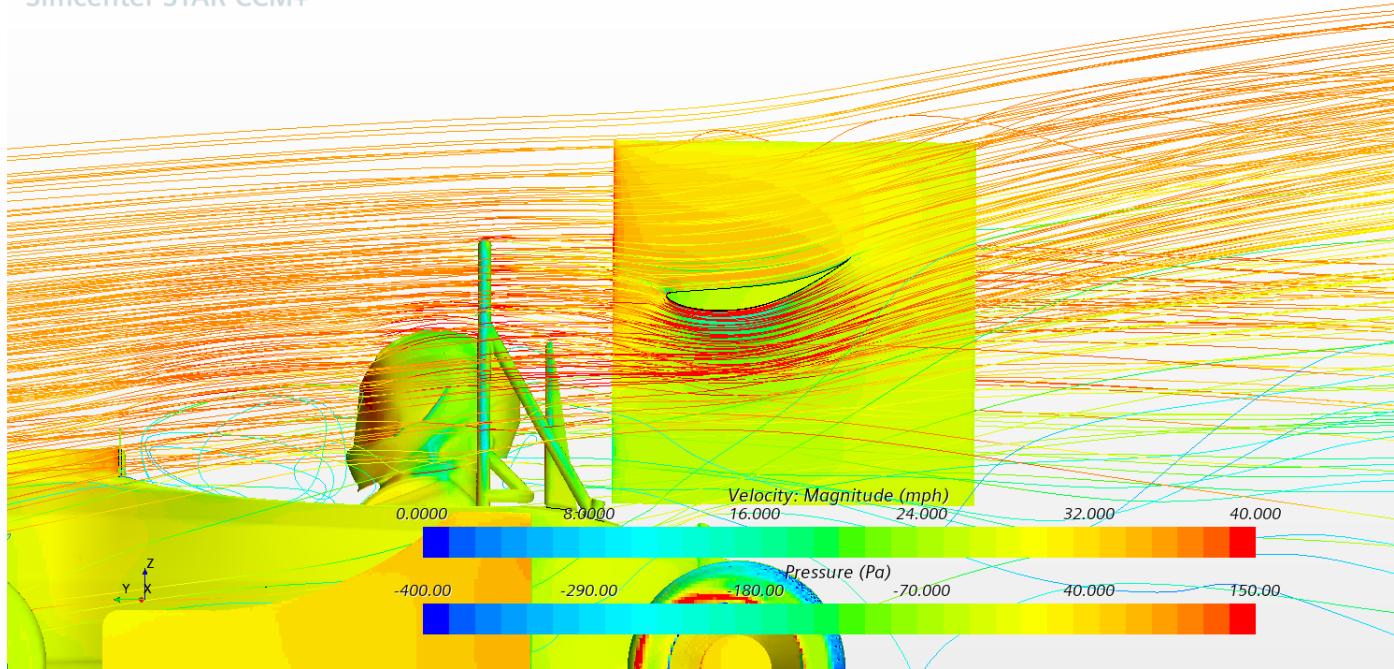
YAW 35 mph	AC_10512 Drag (lbs) 12deg					
z (in)	2	3.52	3.52	3.51		3.65
	1		3.46			
	0	3.40		3.36		3.40
	-1					
	-2					
		-2	-1	0	1	2
		y (in)				

Main Foil Selection: AoA & Geometry

Simcenter STAR-CCM+



Simcenter STAR-CCM+

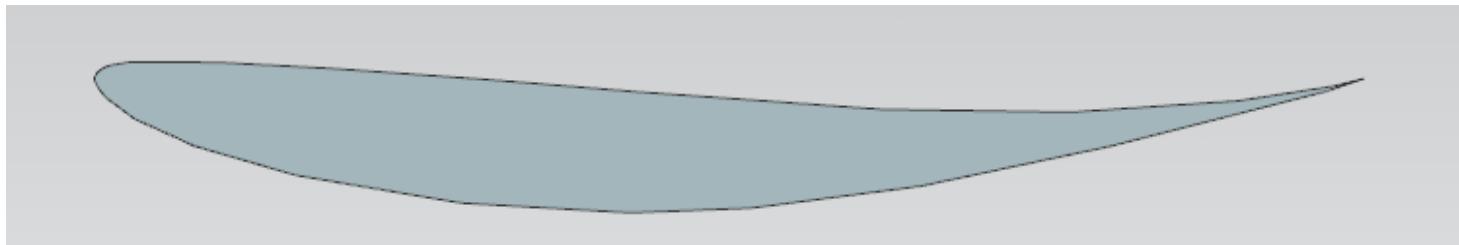


AC_10512 10° YAW 35.0 mph

4" from endplate front edge, 2" above endplate center

Secondary/Tertiary Foil Selection

- **Main: 2D AC_10512 14" chord length**
- **XFOIL 2D performance very similar to 3D CFD results**
- **1 initial AoA sweep -> geometry study -> chord length study**
- **Initial Gap: 2% main chord length.**
- **Initial Overlap: 3% main chord length**

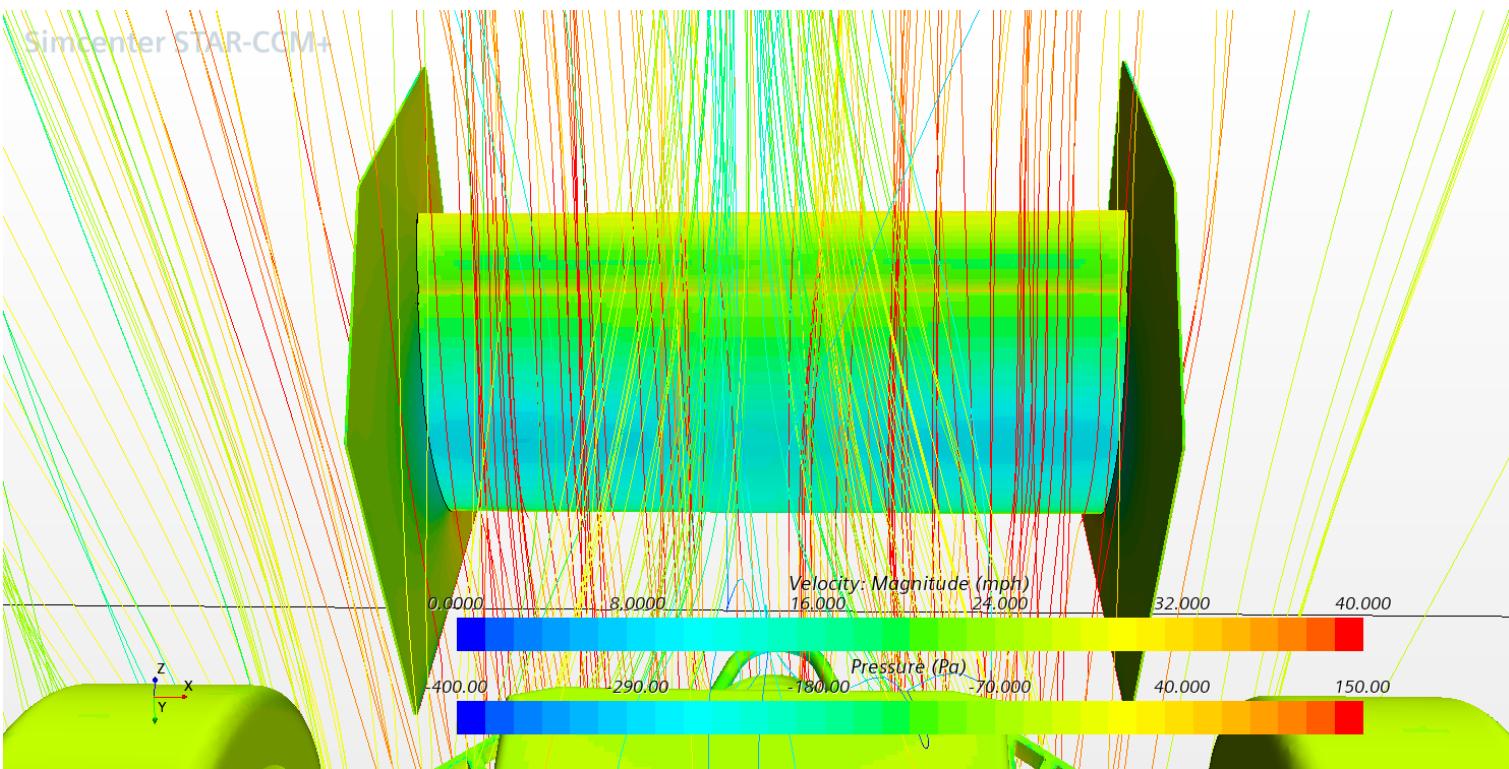
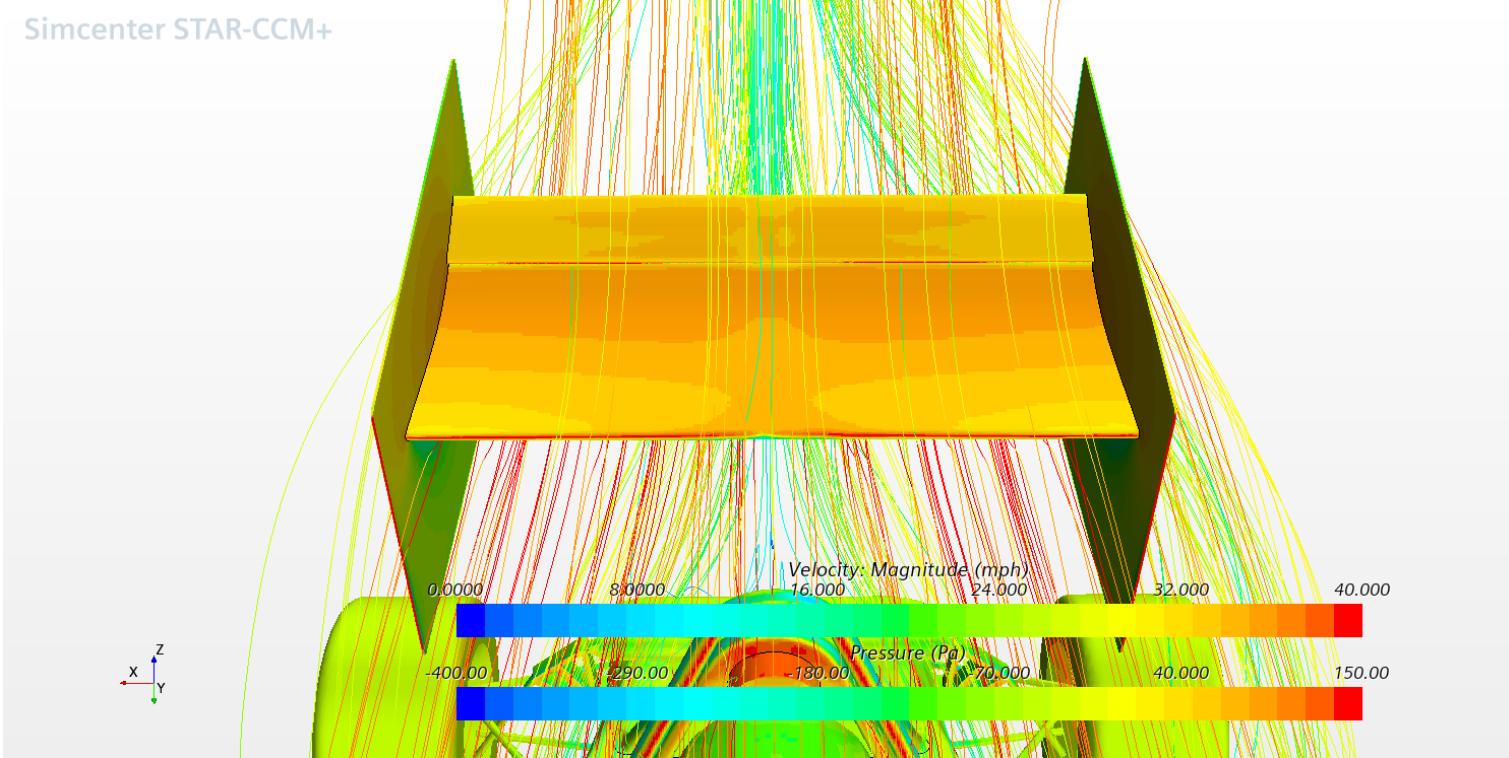


Secondary	Chord (%main)	Sec AoA	RWG DF (lbs)	RWG Drag (lbs)	Efficiency	Moment (lbf-in)	Frontal Area (in²)
AB_8609	28	31	27.37	6.97	3.92	3392.72	94.06
AB_8609	28	33	28.02	7.29	3.84	3378.29	97.44
AB_8609	28	34	27.72	7.15	3.88	3391.94	99.09
AB_8609	28	35	28.01	7.31	3.83	3387.54	100.71
AB_8609	36	33	30.01	8.04	3.73	3350.45	265.04
AB_9509	28	33	29.95	8.05	3.72	3349.36	265.03
AC_10512	28	33	27.51	7.01	3.92	3394.34	237.92
AC_5510	32	23	22.88	4.31	5.31	3058.25	194.24
AC_5510	32	27	24.53	4.86	5.05	3051.63	203.66

Secondary	Total DF (lbs)	Total Drag (lbs)	Efficiency	Main DF (lbs)	Main Drag (lbs)	Efficiency	Sec DF (lbs)	Sec Drag (lb)	Efficiency
AB_8609	92.58	33.11	2.80	2.81	2.66	1.06	24.67	3.85	6.41
AB_8609	92.96	33.47	2.78	2.93	2.90	1.01	25.21	3.92	6.43
AB_8609	92.95	33.33	2.79	2.79	2.79	1.00	25.04	3.90	6.43
AB_8609	93.44	33.39	2.80	2.86	2.91	0.98	25.27	3.94	6.41
AB_8609	94.62	34.77	2.72	3.92	3.72	1.05	26.41	3.92	6.73
AB_9509	94.63	34.58	2.74	3.72	3.65	1.02	26.35	3.93	6.70
AC_10512	92.63	33.17	2.79	2.59	2.68	0.97	25.03	3.88	6.46
AC_5510	84.69	25.95	3.26	2.69	1.68	1.60	20.22	2.27	8.90
AC_5510	86.81	26.72	3.25	3.17	2.13	1.49	21.39	2.37	9.04

Note: Last two sims were run later in design after revising secondary/tertiary geometry

Secondary/Tertiary Foil Selection



AC_5512 SL 35.0 mph

32% main chord length, 23 deg AoA, Gap 0.25", 0.48" Overlap

Justifying Configurations

- Single cascade vs. cascade & upper primary
 - Single cascade: viable, but only after overall package AoA adjustments
 - Upper primary: about same DF as secondary selection sims

NOTES	Package AoA	RWG DF (lbf)	RWG Drag (lbf)	Efficiency	Total DF (lbf)	Total Drag (lbf)	Efficiency
RWG Only	6	40.87	10.55	3.87	34.86	35.99	0.97
RWG Only	9	42.30	11.96	3.54	36.29	38.56	0.94

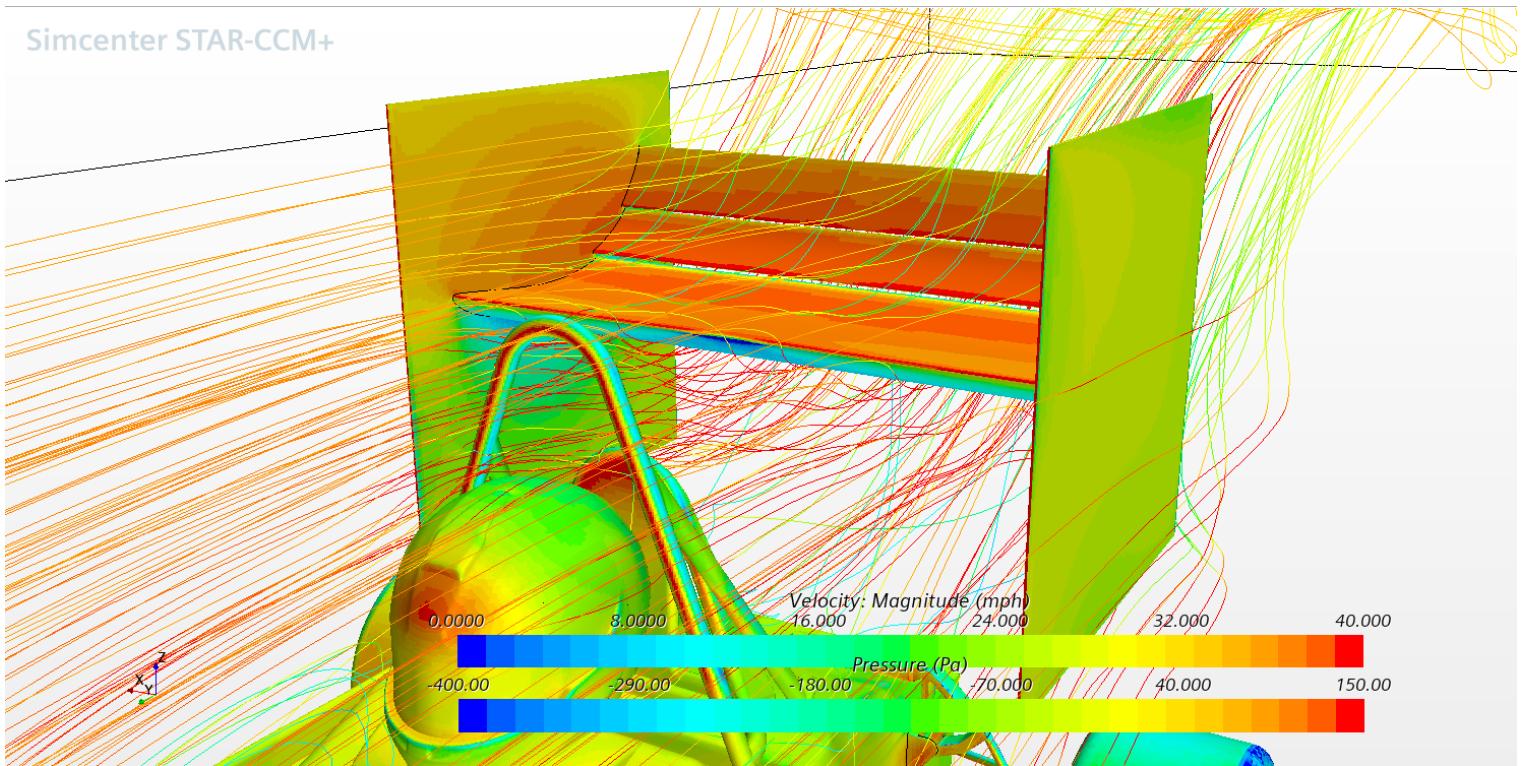
NOTES	Package AoA	Main DF (lbf)	Main Drag (lbf)	Efficiency	Sec DF (lbf)	Sec Drag (lbf)	Efficiency	Tert DF (lbf)	Tert Drag (lbf)	Efficiency
RWG Only	6	30.22	0.29	103.18	7.88	5.31	1.48	2.83	4.39	0.64
RWG Only	9	32.16	1.12	28.63	7.70	5.79	1.33	2.52	4.50	0.56

UpPrim	Main Cascade			RWG DF (lbs)	RWG Drag (lbs)	Efficiency	Total DF (lbs)	Total Drag (lbs)	Efficiency
y (in)	z (in)	y (in)	z (in)	RWG DF (lbs)	RWG Drag (lbs)	Efficiency	Total DF (lbs)	Total Drag (lbs)	Efficiency
3	8	5	-3	30.90	8.21	3.76	96.09	34.86	2.76
3	8	9	-3	28.93	7.76	3.73	93.78	34.30	2.73
3	8	9	-1	29.81	7.95	3.75	94.48	34.36	2.75

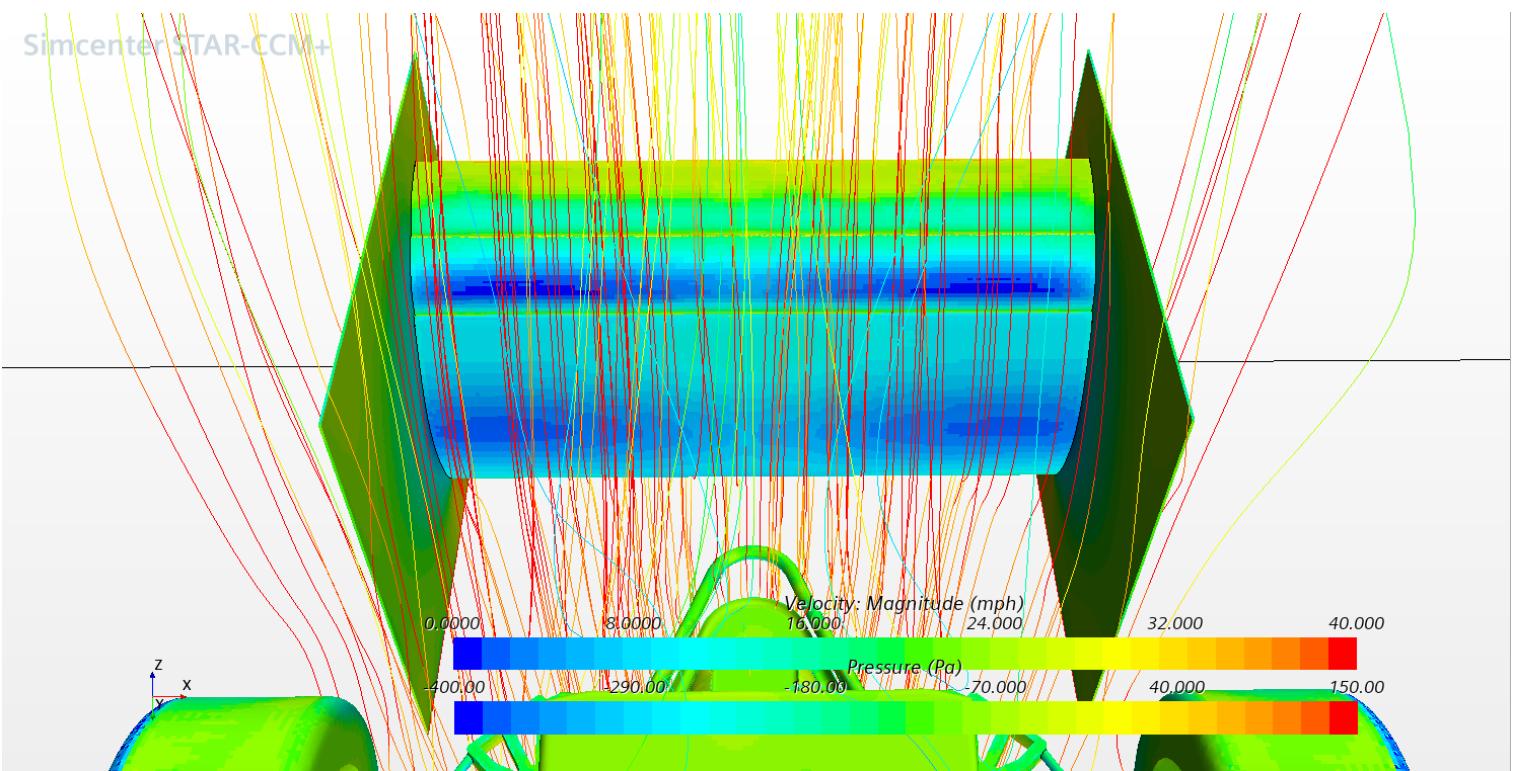
Main DF (lbs)	Main Drag (lbs)	Efficiency	Sec DF (lbs)	Sec Drag (lbs)	Efficiency	UpPrim DF (lbs)	UpPrim Drag (lbs)	Efficiency
19.73	3.75	5.26	2.99	2.99	1.00	8.26	0.99	8.32
20.68	3.54	5.84	2.83	2.77	1.02	5.52	0.99	5.60
21.46	3.82	5.61	2.83	2.78	1.02	5.62	0.88	6.38

Justifying Configurations

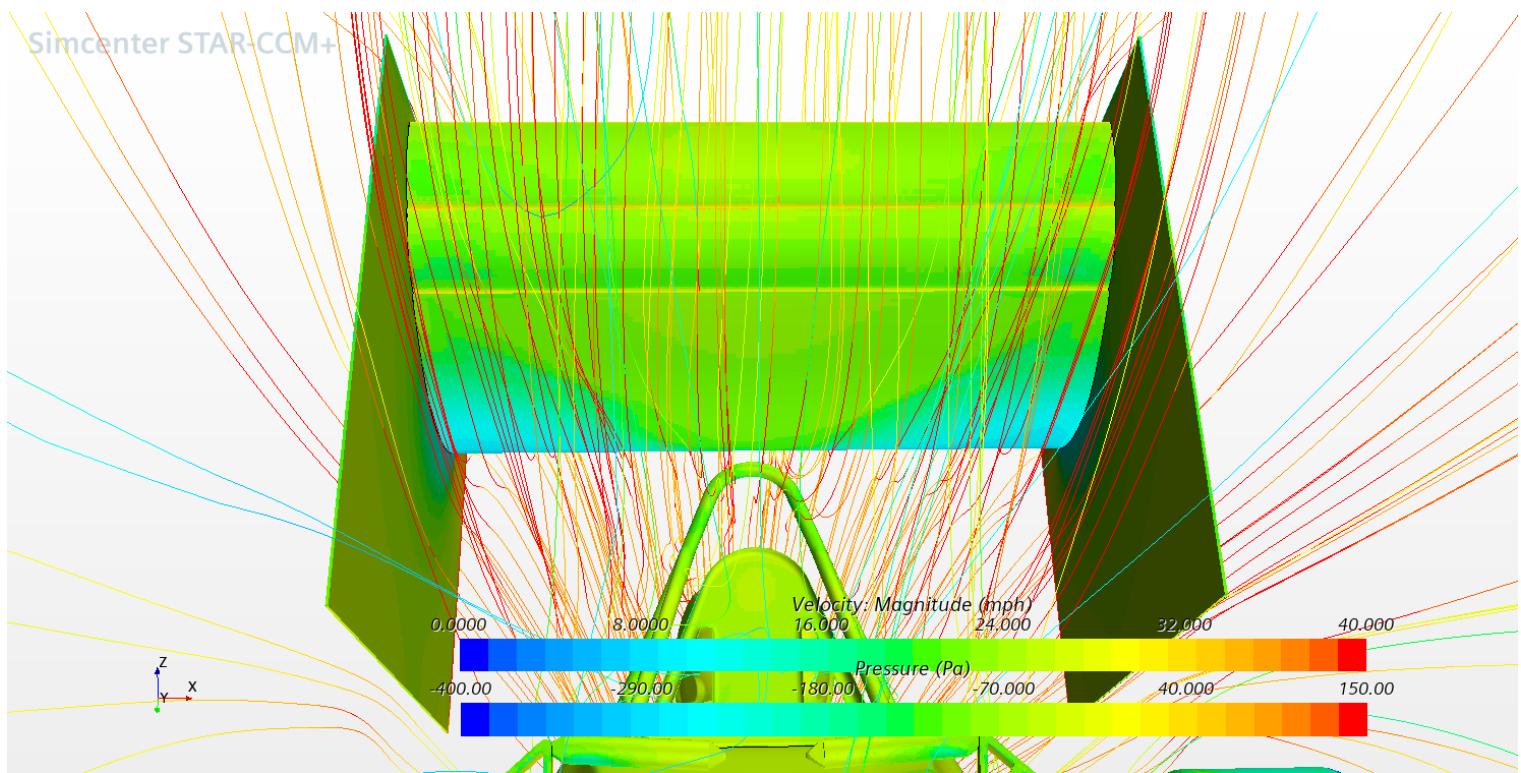
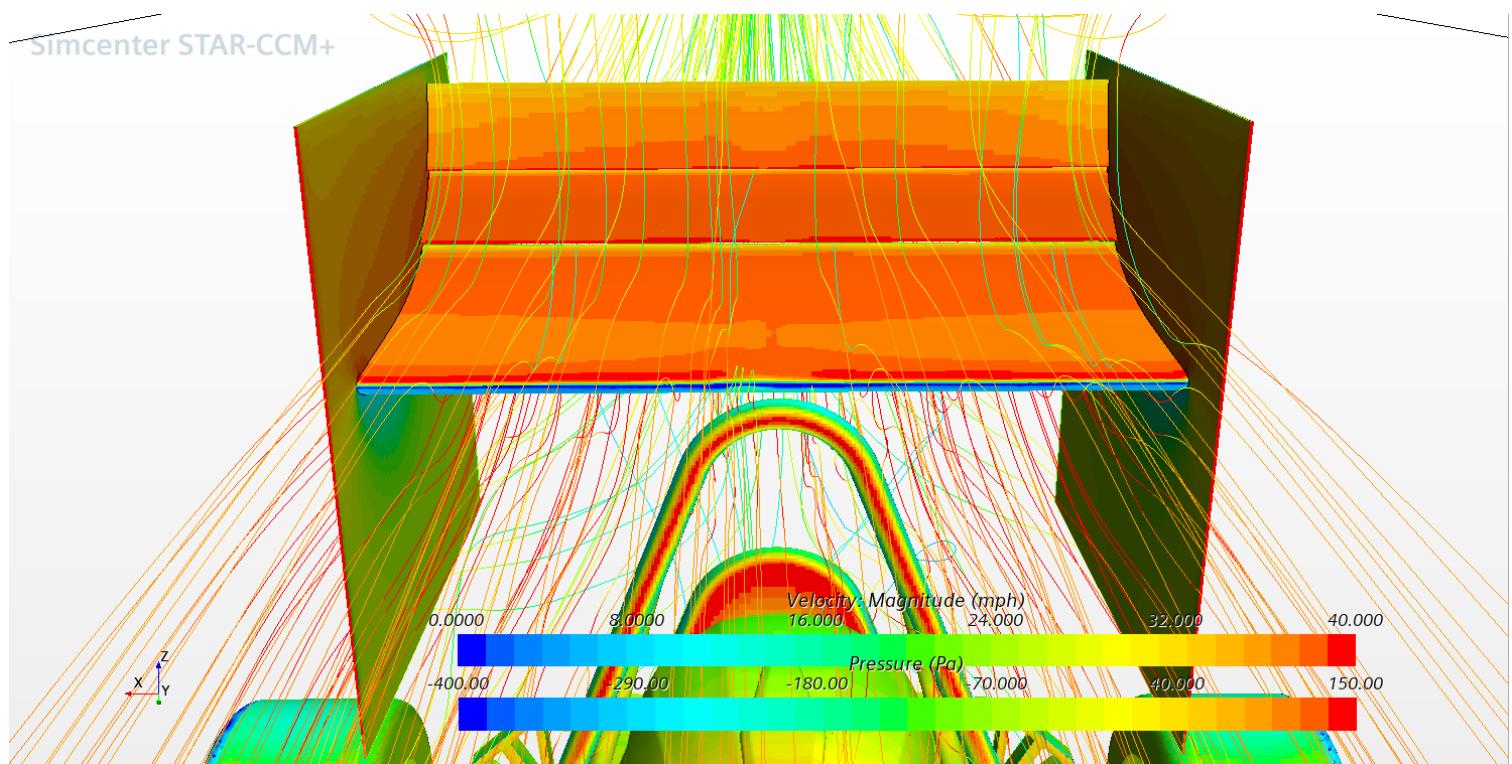
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*Single Cascade**6 deg Package AoA*

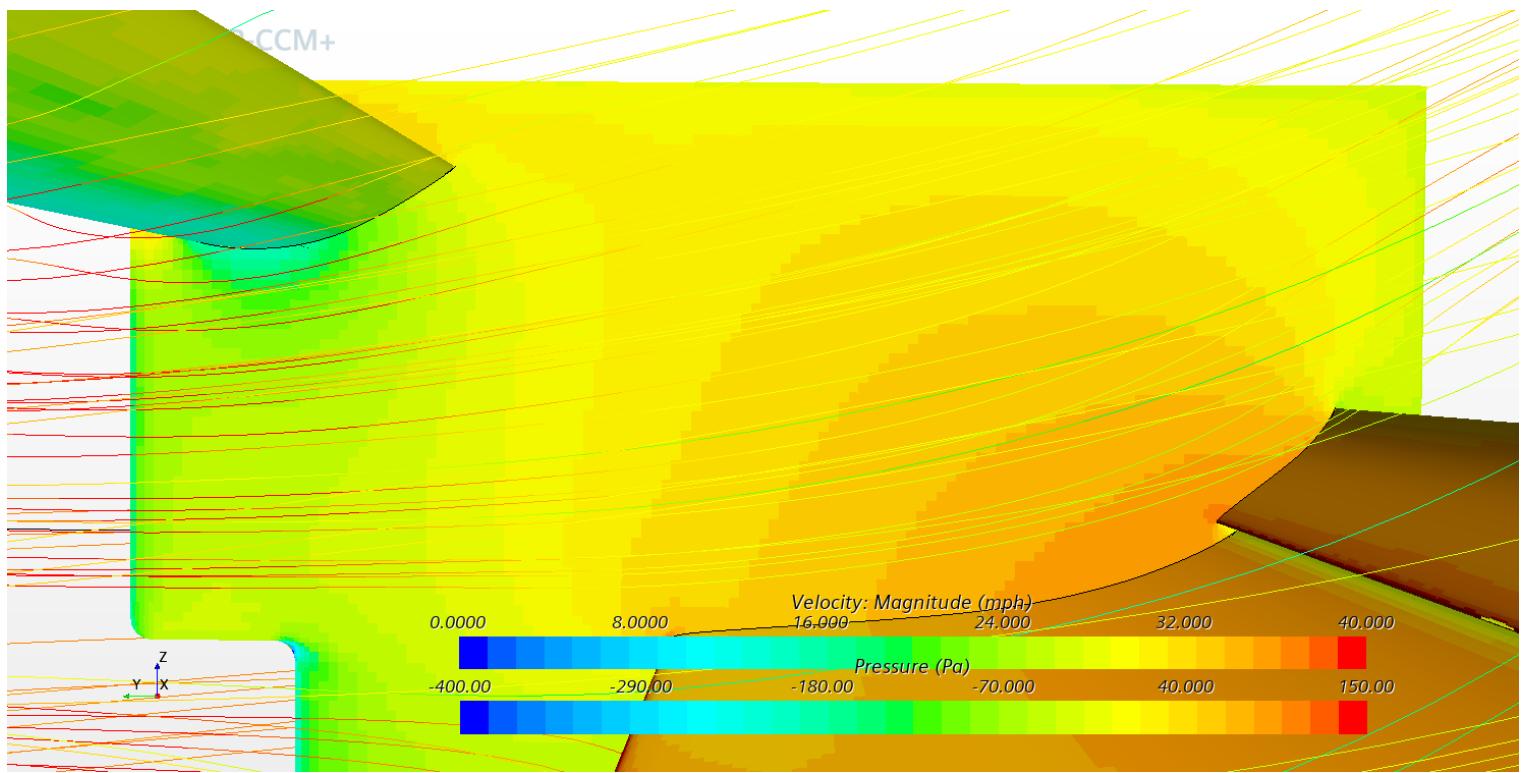
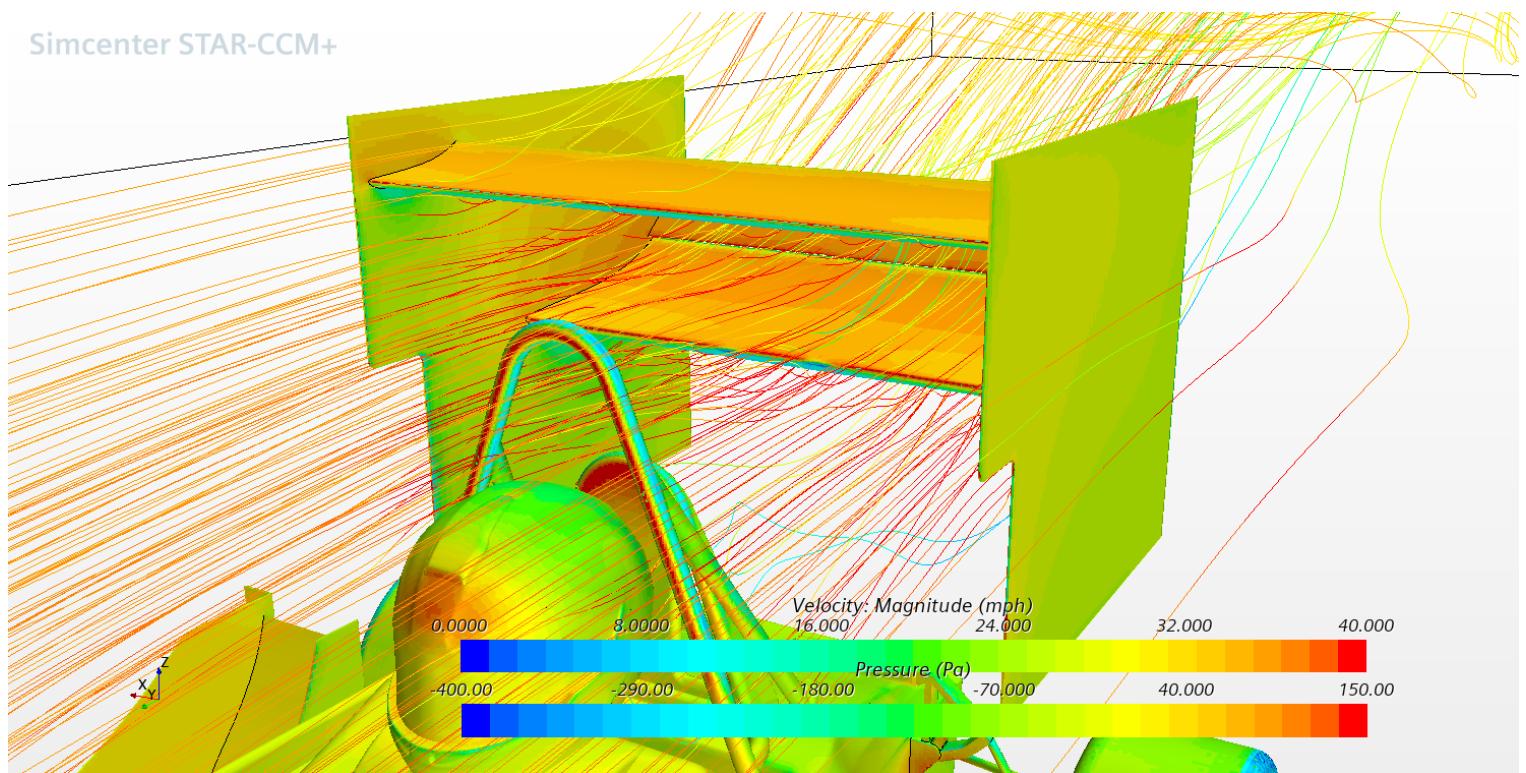
Justifying Configurations



Single Cascade
12 deg Package AoA

Justifying Configurations

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Upper Primary Package

32% main chord length, 17 deg AoA, Gap 0.4", 0.48" Overlap

Secondary/Tertiary Foil Selection

- **Main: 2D AC_10512 14" chord length**
- **Tertiary geometry same as secondary**
- **Gap optimization -> AoA adjustments**
- **32% main chord length**
- **Overlap set at 4% secondary chord length**

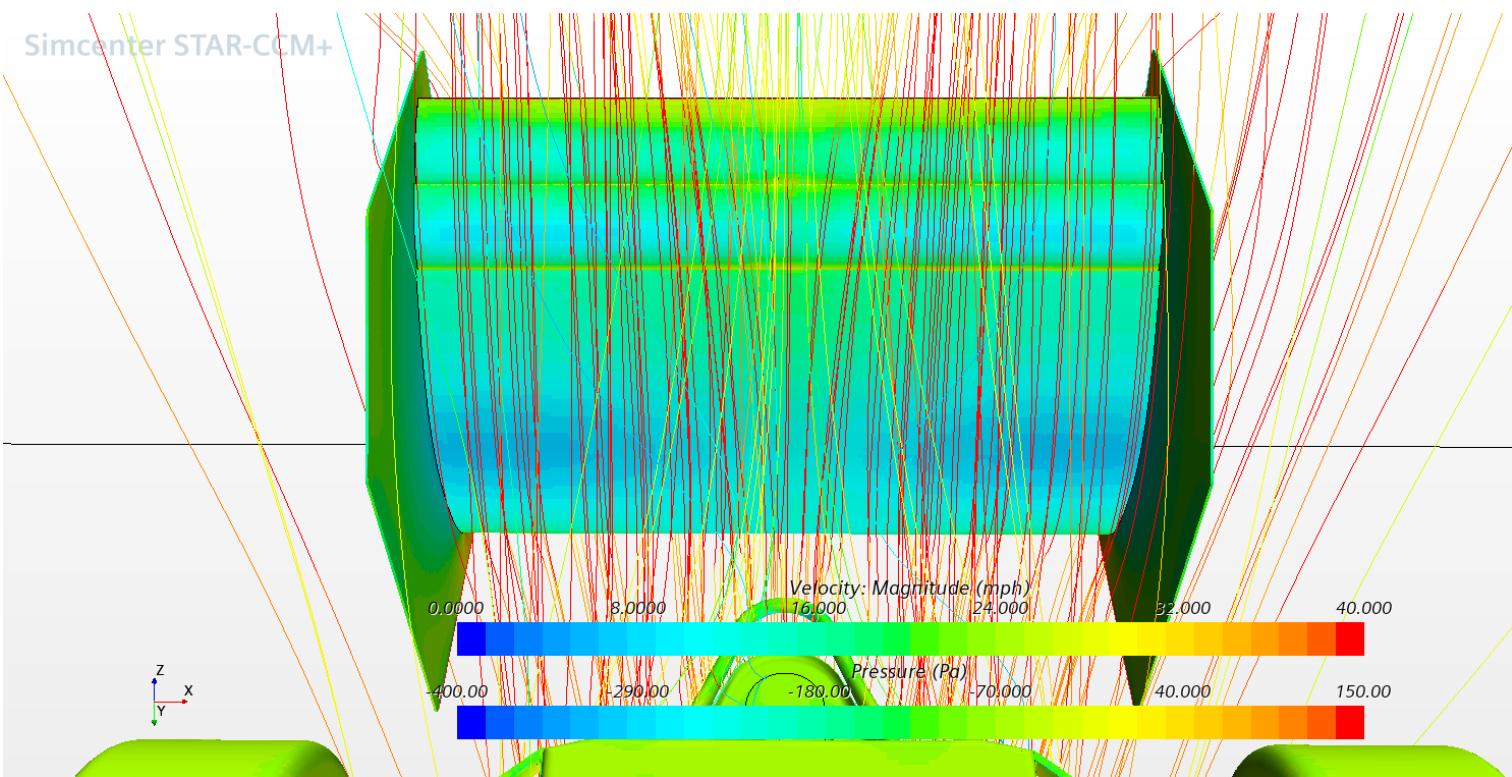
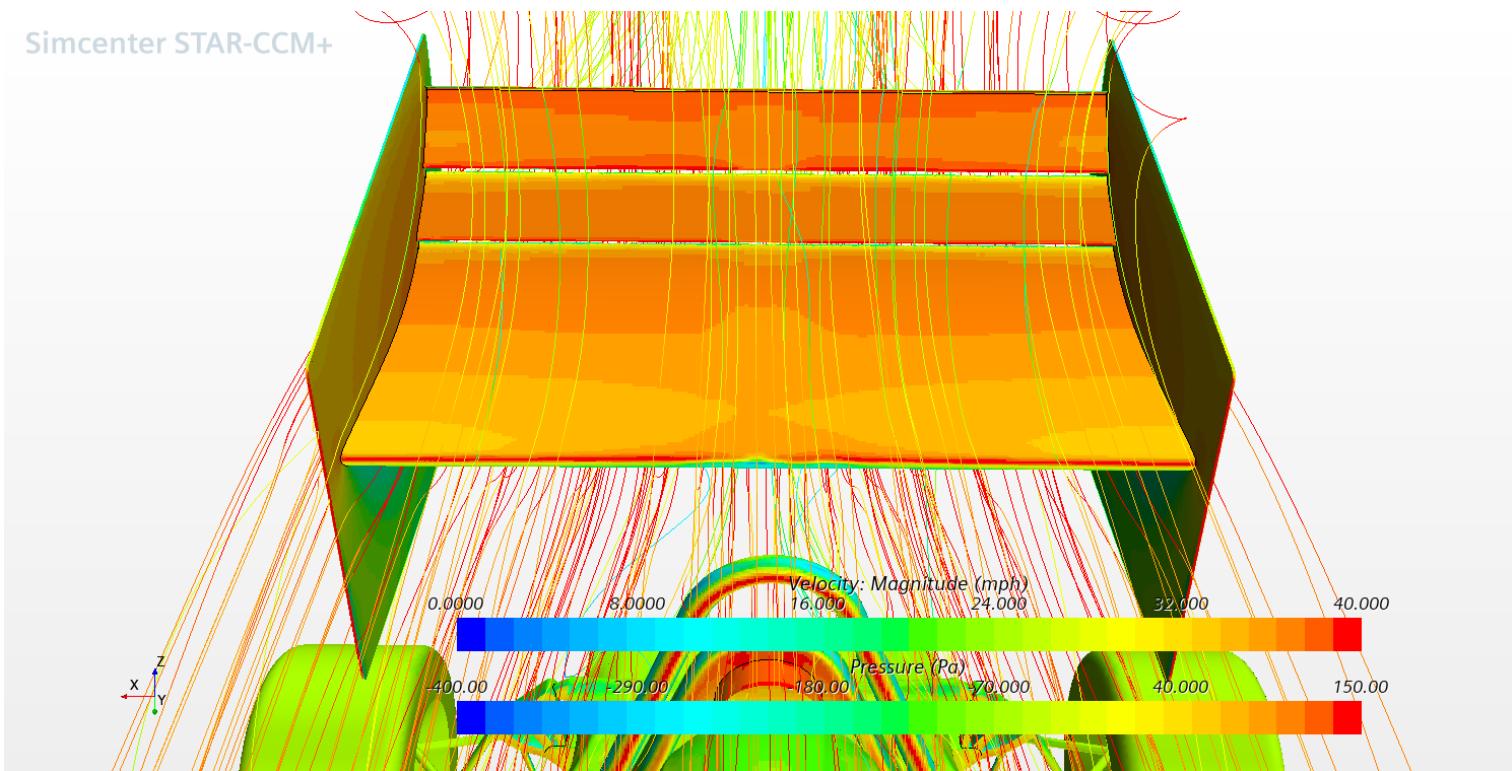
Sim REV	Tertiary	AoA (deg)	Gap (in)	RWG DF (lbs)	RWG Drag (lbs)	Efficiency	Moment (lbf-in)	Frontal Area (in ²)
AB_9509	AB_9509	27	0.25	42.22	14.43	2.93	3109.64	368.72
	AB_9509	27	0.35	42.28	14.46	2.92	3095.62	368.67
	AB_9509	27	0.45	41.46	14.07	2.95	3121.15	368.68
	AB_9509	30	0.30	42.07	14.55	2.89	3100.63	371.95
	AB_9509	25	0.4	41.83	14.23	2.94	3102.26	366.16
	AC_5510	17	0.4	40.13	12.14	3.31	2801.91	335.28
AC_5510	AC_5510	15	0.4	39.83	11.83	3.37	2910.96	330.50
	AC_5510	19	0.4	40.30	12.28	3.28	2876.67	337.04
	16" Main	AC_5510	17	0.4	41.36	12.71	3.25	2728.20
SL: 18" Main	AC_5510	17	0.4	40.09	12.83	3.12	2782.413939	367.28
Yaw: 18" Main	AC_5510	17	0.4	38.18	13.34	2.86	2730.88	367.68

Sim REV	Tertiary	AoA (deg)	Gap (in)	Total DF (lbs)	Total Drag (lbs)	Efficiency	Main DF (lbs)	Main Drag (lbs)	Efficiency
AB_9509	AB_9509	27	0.25	109.78	42.10	2.61	32.58	3.06	10.63
	AB_9509	27	0.35	109.40	42.21	2.59	32.57	3.05	10.66
	AB_9509	27	0.45	108.88	41.57	2.62	31.96	2.99	10.68
	AB_9509	30	0.30	109.31	42.24	2.59	32.61	3.06	10.65
	AB_9509	25	0.4	109.11	41.59	2.62	32.17	3.07	10.47
	AC_5510	17	0.4	105.13	36.16	2.91	29.96	2.71	11.07
AC_5510	AC_5510	15	0.4	106.26	35.86	2.96	29.83	2.72	10.98
	AC_5510	19	0.4	106.24	36.41	2.92	30.24	2.73	11.08
	16" Main	AC_5510	17	0.4	106.49	36.74	2.90	31.47	3.33
SL: 18" Main	AC_5510	17	0.4	106.43	37.40	2.85	30.62	3.74	8.18
Yaw: 18" Main	AC_5510	17	0.4	104.94	38.81	2.70	28.81	3.66	7.87

Sim REV	Tertiary	AoA (deg)	Gap (in)	Sec DF (lbs)	Sec Drag (lb)	Efficiency	Tert DF (lbs)	Tert Drag (lbs)	Efficiency
AB_9509	AB_9509	27	0.25	7.55	6.31	1.20	2.31	4.59	0.50
	AB_9509	27	0.35	7.45	6.20	1.20	2.48	4.74	0.52
	AB_9509	27	0.45	7.29	6.03	1.21	2.43	4.58	0.53
	AB_9509	30	0.30	7.55	6.33	1.19	2.14	4.70	0.45
	AB_9509	25	0.4	7.26	6.05	1.20	2.61	4.64	0.56
	AC_5510	17	0.4	6.32	4.11	1.54	3.94	4.91	0.80
AC_5510	AC_5510	15	0.4	6.16	4.02	1.53	3.92	4.69	0.84
	AC_5510	19	0.4	6.36	4.17	1.52	3.78	4.97	0.76
	16" Main	AC_5510	17	0.4	6.07	4.01	1.51	3.91	4.95
SL: 18" Main	AC_5510	17	0.4	5.72	3.76	1.52	3.85	4.92	0.78
Yaw: 18" Main	AC_5510	17	0.4	5.63	3.69	1.53	3.82	4.78	0.80

Note: Last six sims done later in design after revising secondary/tertiary geometry

Secondary/Tertiary Foil Selection

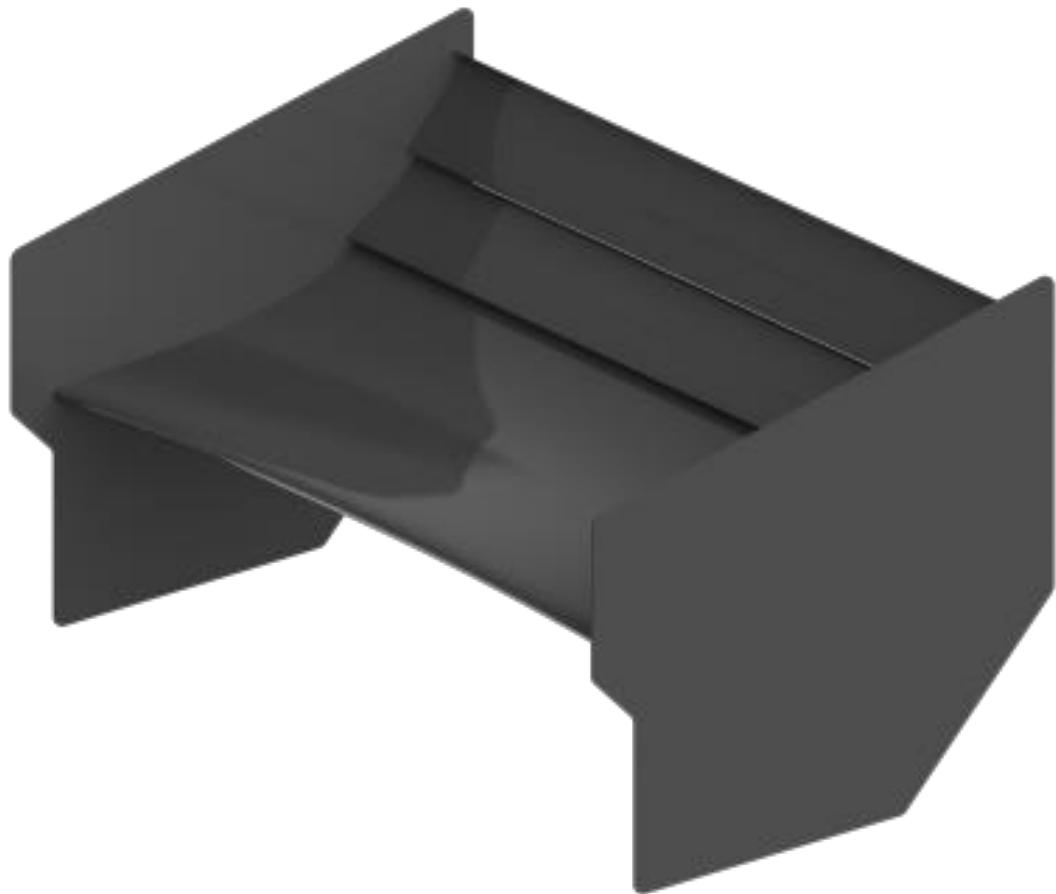


AC_5512 SL 35.0 mph

32% main chord length, 17 deg AoA, Gap 0.4", 0.48" Overlap

Endplate Cutouts

- **Top edge cutouts:**
 - TSAL rules compliance
- **Bottom edge trim:**
 - Reduce frontal area
 - Reduce performance changes between SL and yaw
- **Front corner cuts:**
 - Reduce performance changes between SL and yaw



Endplate Cutouts

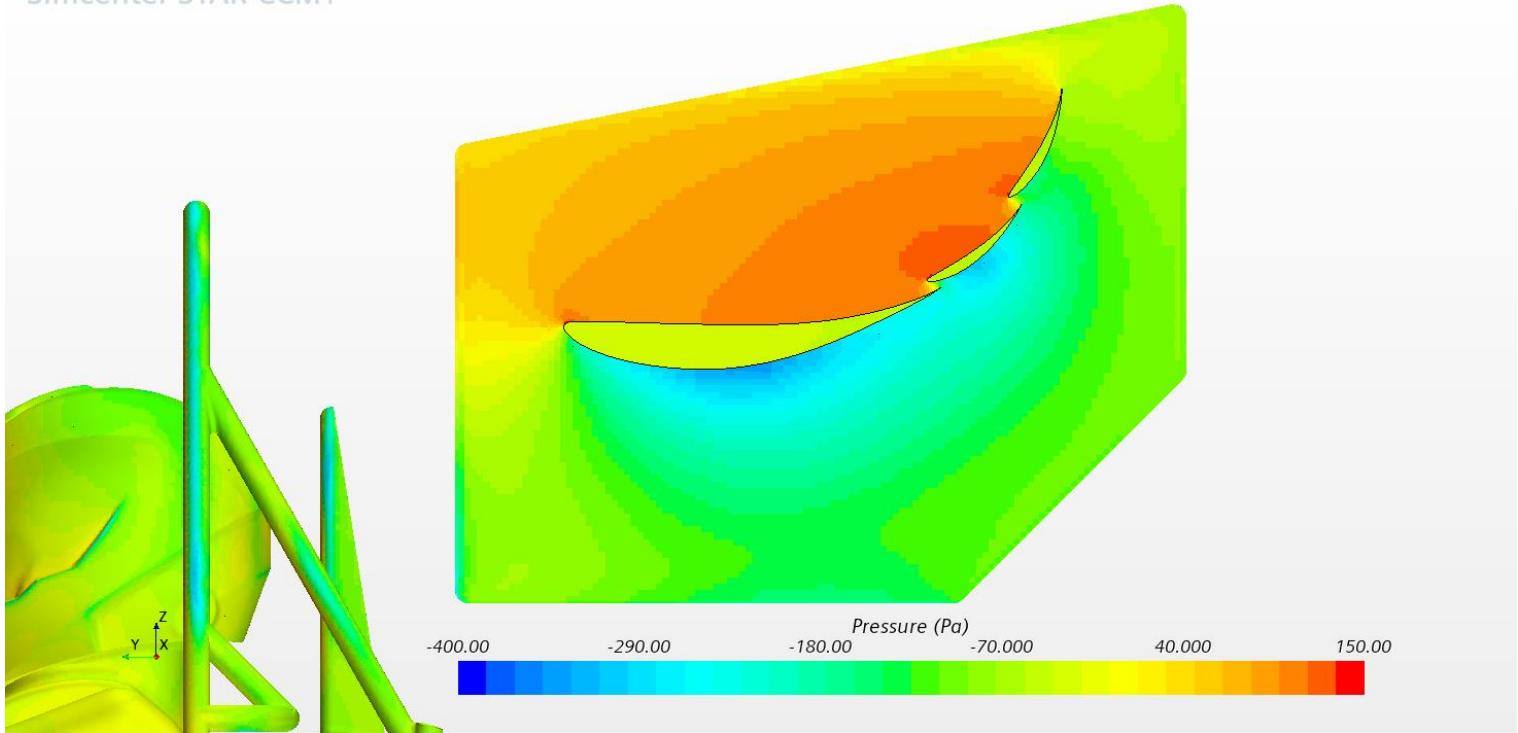
NOTES	RWG DF (lbs)	RWG Drag (lbs)	Efficiency	Moment (lbf-in)	Frontal Area (in^2)
SL: Large curve cut	42.20	14.86	2.84	3071.13	368.63
YAW: Large curve cut	41.66	15.21	2.74	2801.13	367.46
SL: Small curve cut	42.23	14.51	2.91	3101.25	368.63
YAW: Small curve cut	41.65	14.99	2.78	2821.04	367.46
SL: Straight angled cut	42.54	14.93	2.85	3072.67	368.63
YAW: Straight angled cut	41.88	15.47	2.71	2788.50	367.45
SL: Bottom rear corner	39.97	13.88	2.88	2539.41	366.18
YAW: Bottom rear corner	40.02	14.38	2.78	2418.25	365.01
SL: Bottom rear corner	40.10	14.01	2.86	2562.01	366.18
YAW: Bottom rear corner	39.78	14.44	2.75	2439.61	365.01
SL: Bottom rear corner	40.02	13.93	2.87	2569.67	366.18
YAW: Bottom rear corner	39.78	14.35	2.77	2454.95	364.98
SL: Bottom rear corner	39.37	13.66	2.88	2600.04	366.20
YAW: Bottom rear corner	38.86	13.92	2.79	2450.50	364.96

NOTES	Total DF (lbs)	Total Drag (lbs)	Efficiency	Main DF (lbs)	Main Drag (lbs)	Efficiency
SL: Large curve cut	109.07	42.12	2.59	32.20	3.22	10.00
YAW: Large curve cut	100.75	44.02	2.29	31.91	2.99	10.69
SL: Small curve cut	109.66	42.00	2.61	32.48	3.08	10.54
YAW: Small curve cut	100.81	44.14	2.28	32.07	2.85	11.25
SL: Straight angled cut	109.60	42.00	2.61	32.44	3.26	9.95
YAW: Straight angled cut	100.82	43.96	2.29	31.97	3.09	10.35
SL: Bottom rear corner	94.44	41.70	2.26	30.35	3.00	10.12
YAW: Bottom rear corner	94.40	43.25	2.18	30.50	2.80	10.91
SL: Bottom rear corner	94.68	41.73	2.27	30.53	3.10	9.85
YAW: Bottom rear corner	94.43	43.15	2.19	30.25	2.86	10.58
SL: Bottom rear corner	94.88	41.71	2.27	30.53	3.07	9.94
YAW: Bottom rear corner	94.72	43.17	2.19	30.29	2.80	10.80
SL: Bottom rear corner	94.39	41.44	2.28	29.96	2.90	10.33
YAW: Bottom rear corner	93.02	42.67	2.18	29.59	2.66	11.12

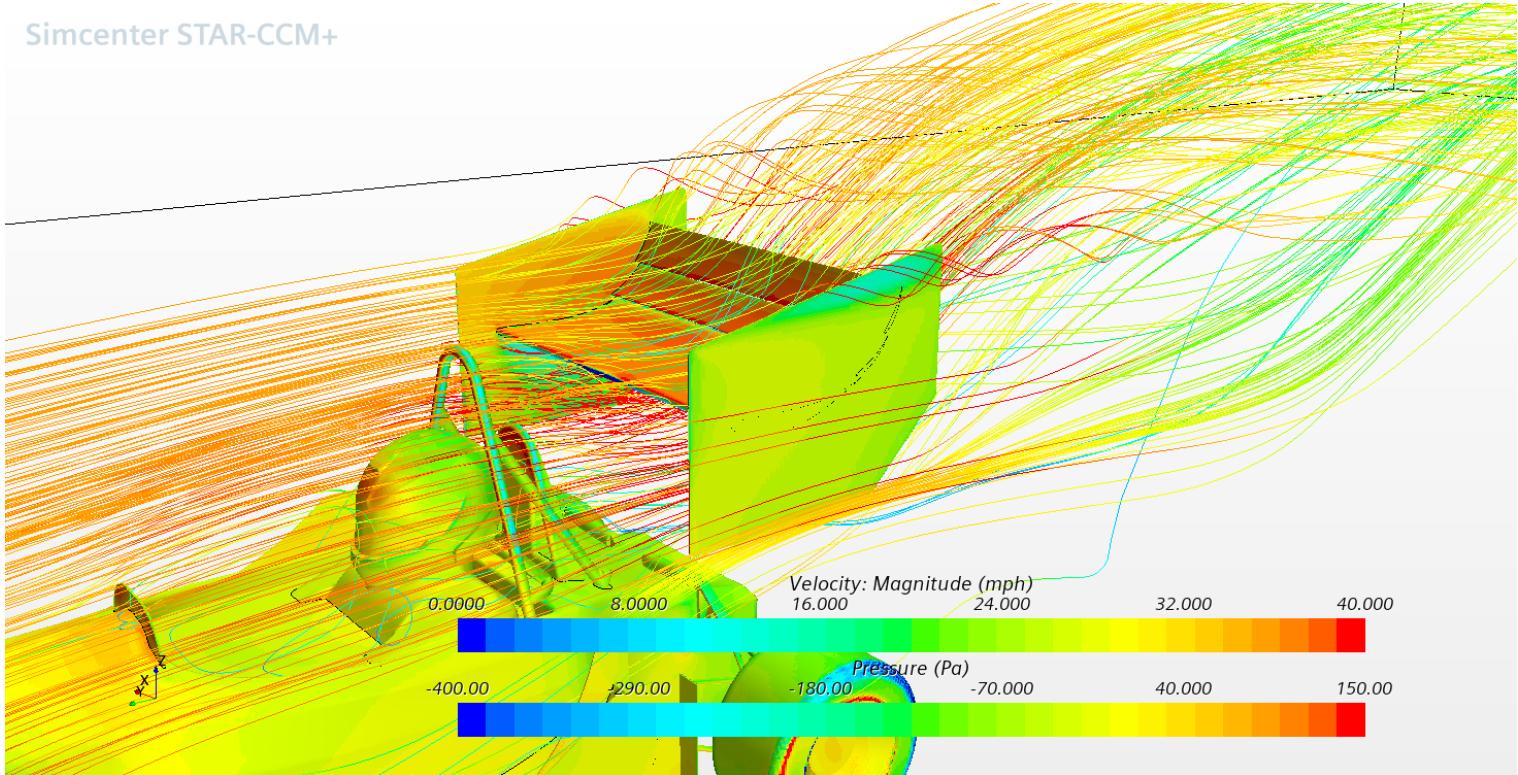
NOTES	Sec DF (lbs)	Sec Drag (lb)	Efficiency	Tert DF (lbs)	Tert Drag (lbs)	Efficiency
SL: Large curve cut	7.71	6.43	1.20	2.42	6.43	0.38
YAW: Large curve cut	7.48	6.20	1.21	2.37	6.20	0.38
SL: Small curve cut	7.57	6.30	1.20	2.36	4.67	0.51
YAW: Small curve cut	7.37	6.10	1.21	2.34	4.57	0.51
SL: Straight angled cut	7.78	6.48	1.20	2.41	4.75	0.51
YAW: Straight angled cut	7.59	6.29	1.21	2.40	4.68	0.51
SL: Bottom rear corner	7.21	5.97	1.21	2.56	4.52	0.57
YAW: Bottom rear corner	7.06	5.82	1.21	2.53	4.47	0.57
SL: Bottom rear corner	7.11	5.98	1.19	2.57	4.54	0.57
YAW: Bottom rear corner	7.06	5.82	1.21	2.54	4.50	0.56
SL: Bottom rear corner	7.06	5.93	1.19	2.56	4.52	0.57
YAW: Bottom rear corner	7.03	5.79	1.22	2.54	4.47	0.57
SL: Bottom rear corner	7.01	5.85	1.20	2.54	4.52	0.56
YAW: Bottom rear corner	6.88	5.64	1.22	2.47	4.34	0.57

Endplate Cutouts

Simcenter STAR-CCM+



Simcenter STAR-CCM+



Horizontal Bottom Edge Trim SL 35.0 mph

45 deg Rear Corner Cut

Endplate Cutouts

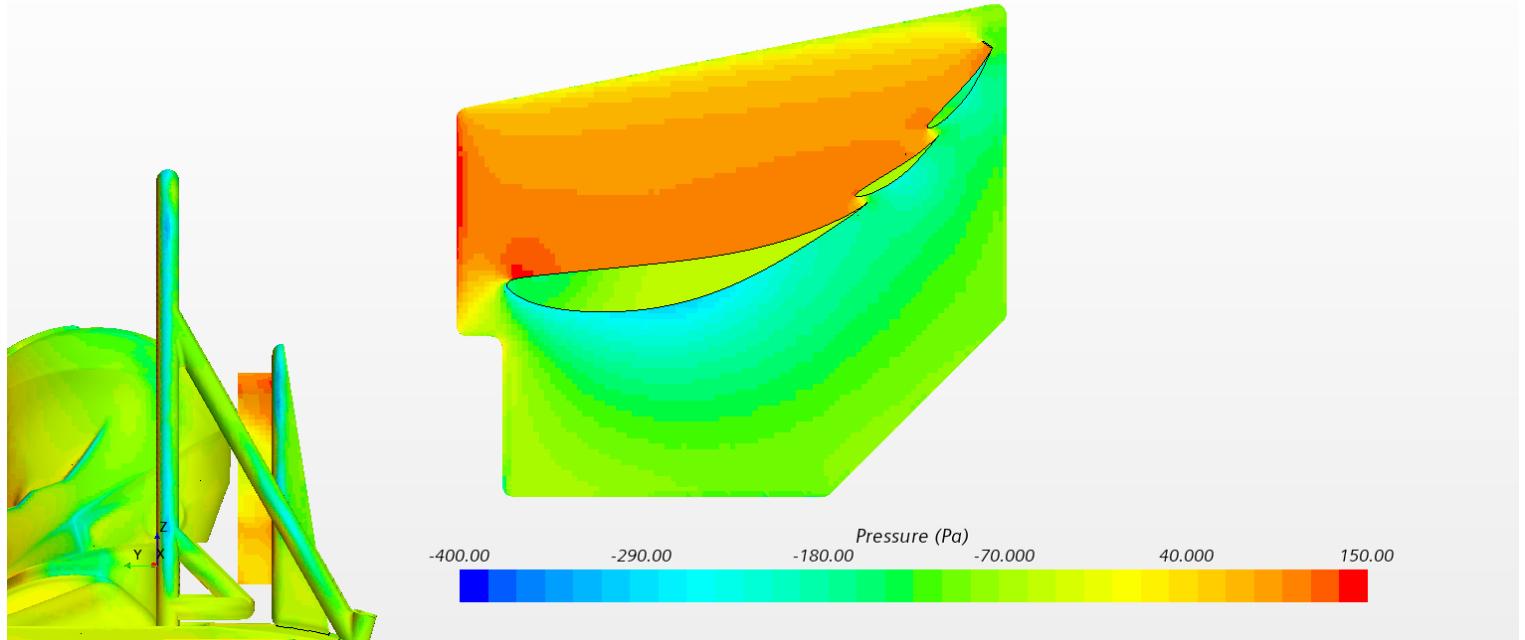
NOTES	RWG DF (lbs)	RWG Drag (lbs)	Efficiency	Moment (lbf-in)	Frontal Area (in ²)
SL: 2" front trim	42.55	14.34	2.97	2689.22	383.20
YAW: 2" front trim	40.46	14.78	2.74	2657.51	382.62
SL: 3" front trim	42.21	14.33	2.94	2691.63	383.25
YAW: 3" front trim	40.23	14.77	2.72	2626.47	382.58
SL: Front bottom corner	43.17	14.55	2.97	2647.81	383.33
YAW: Front bottom corner	40.61	14.88	2.73	2591.19	382.62
YAW: front top corner	40.52	14.88	2.72	2601.39	382.61
SL: Double Cut	43.12	14.52	2.97	2759.93	383.26
YAW: Double Cut	40.56	14.88	2.73	2603.09	382.62
YAW: Front bottom corner	40.54	14.83	2.73	2595.66	382.61
YAW: Front bottom corner	40.23	14.79	2.72	2589.18	382.61
YAW: front top corner	40.58	14.95	2.71	2589.57	382.68
YAW: front top corner	40.42	14.94	2.70	2593.03	382.68

NOTES	Total DF (lbs)	Total Drag (lbs)	Efficiency	Main DF (lbs)	Main Drag (lbs)	Efficiency
SL: 2" front trim	109.23	39.27	2.78	32.93	4.20	7.84
YAW: 2" front trim	107.59	40.30	2.67	30.95	4.08	7.59
SL: 3" front trim	108.97	39.24	2.78	32.63	4.23	7.71
YAW: 3" front trim	106.36	40.10	2.65	30.74	4.09	7.51
SL: Front bottom corner	109.50	39.14	2.80	33.45	4.28	7.82
YAW: Front bottom corner	106.85	40.16	2.66	31.08	4.13	7.53
YAW: front top corner	106.89	40.08	2.67	31.03	4.14	7.49
SL: Double Cut	111.40	39.23	2.84	33.43	4.30	7.77
YAW: Double Cut	107.07	40.17	2.67	31.02	4.16	7.45
YAW: Front bottom corner	106.82	40.11	2.66	31.03	4.14	7.49
YAW: Front bottom corner	106.27	39.89	2.66	30.76	4.15	7.42
YAW: front top corner	106.87	40.30	2.65	31.04	4.20	7.40
YAW: front top corner	106.72	40.23	2.65	30.89	4.21	7.34

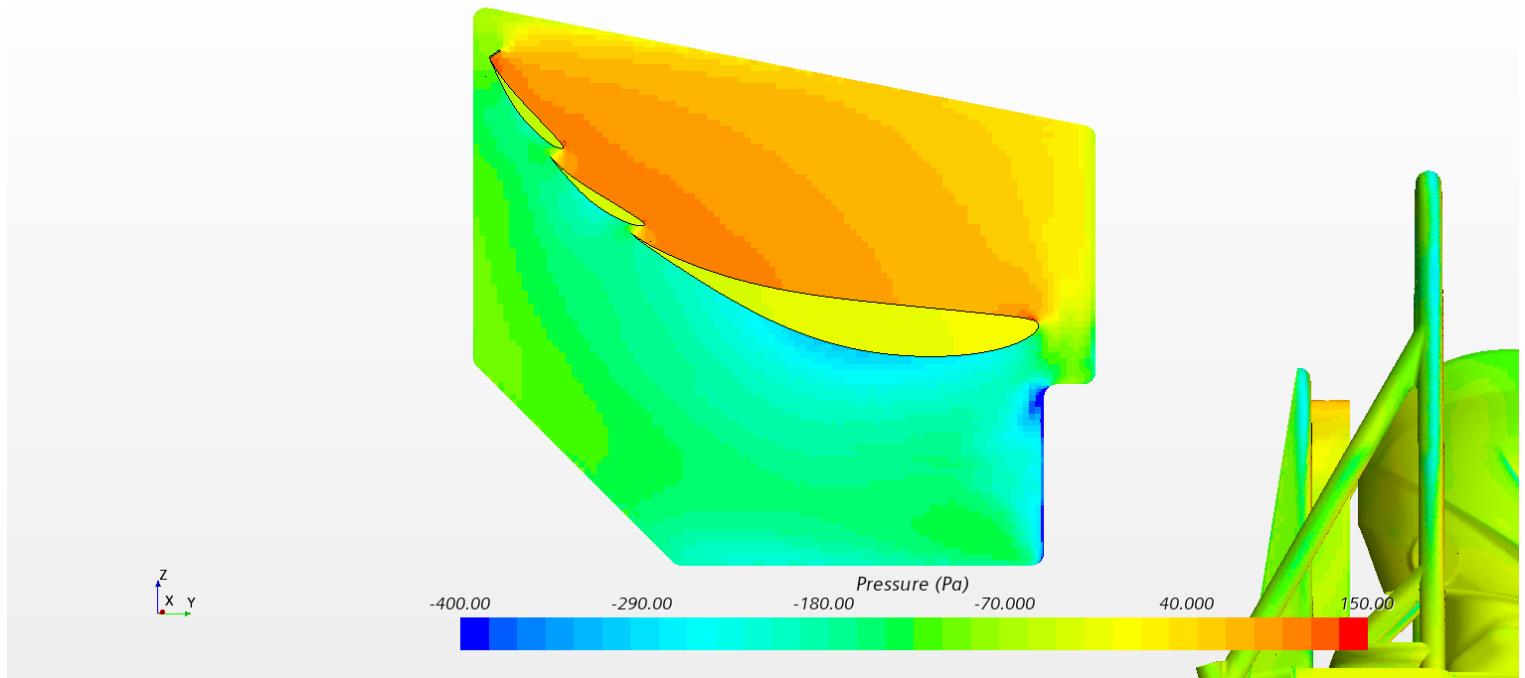
NOTES	Sec DF (lbs)	Sec Drag (lb)	Efficiency	Tert DF (lbs)	Tert Drag (lbs)	Efficiency
SL: 2" front trim	6.21	4.71	1.32	3.52	5.04	0.70
YAW: 2" front trim	6.03	4.52	1.33	3.56	4.99	0.71
SL: 3" front trim	6.19	4.69	1.32	3.50	5.02	0.70
YAW: 3" front trim	6.01	4.51	1.33	3.56	4.99	0.71
SL: Front bottom corner	6.19	4.71	1.31	3.63	5.19	0.70
YAW: Front bottom corner	6.04	4.55	1.33	3.57	5.06	0.71
YAW: front top corner	6.02	4.54	1.33	3.56	5.05	0.71
SL: Double Cut	6.18	4.70	1.31	3.59	5.16	0.70
YAW: Double Cut	6.04	4.55	1.33	3.56	5.05	0.71
YAW: Front bottom corner	6.02	4.53	1.33	3.55	5.04	0.71
YAW: Front bottom corner	6.00	4.51	1.33	3.55	5.03	0.71
YAW: front top corner	6.05	4.55	1.33	3.58	5.07	0.71
YAW: front top corner	6.04	4.55	1.33	3.58	5.07	0.71

Endplate Cutouts

Simcenter STAR-CCM+



Simcenter STAR-CCM+



Front Edge Trim Yaw 35.0 mph

Low Pressure Cut

Endplate Cutouts

Weights		
DF	Drag	Eff
2	3	1

NOTES	Score SL	Score YAW
YAW: Straight angled cut		40.05
SL: Bottom rear corner	41.17	
YAW: Bottom rear corner		39.68
SL: Bottom rear corner	41.04	
YAW: Bottom rear corner		38.98
SL: Bottom rear corner	41.12	
YAW: Bottom rear corner		39.30
SL: Bottom rear corner	40.65	
YAW: Bottom rear corner		38.76
SL: 2" front trim	45.07	
YAW: 2" front trim		39.31
SL: 3" front trim	44.37	
YAW: 3" front trim		38.87
SL: Front bottom corner	45.64	
YAW: Front bottom corner		39.31
YAW: front top corner		39.13
SL: Double Cut	45.66	
YAW: Double Cut		39.21
YAW: Front bottom corner		39.31
YAW: Front bottom corner		38.82
YAW: front top corner		39.02
YAW: front top corner		38.71

3D Main Element

- Take advantage of freestream air flowing around the driver head
- Optimize peak width to meet freestream air in a range of yaw angles
- Lower AoA on edge foils to utilize excess drag pounds



3D Main Element

- **Simulations run in SL and yaw.**
- **Varying amounts of edge foil AoA and 3D peak width.**

NOTES	Edge Depth (in)	Edge Width (in)	RWG DF (lbs)	RWG Drag (lbs)	Efficiency	Moment (lbf-in)	Frontal Area (in ²)
SL	1	6	42.13	14.82	2.84	3134.58	377.51
SL	2	6	42.07	14.73	2.86	3130.43	377.84
SL	3	6	42.15	14.73	2.86	3144.34	378.18
SL	1	6	42.81	14.95	2.86	3108.59	384.93
SL	2	6	43.23	15.49	2.79	3107.69	402.64
SL	2	6	45.25	15.83	2.86	2754.43	414.12
YAW	2	6	41.79	16.04	2.60	2568.40	413.24
SL	2	6	44.32	14.87	2.98	2734.25	401.31
YAW	2	6	40.91	15.12	2.70	2712.11	400.50
SL	2	4	44.20	14.83	2.98	2794.30	398.46
YAW	2	4	40.73	15.04	2.71	2699.94	397.68
SL	2	8	44.09	14.97	2.94	2704.37	404.17
YAW	2	8	40.85	15.21	2.69	2727.12	403.35

NOTES	Edge Depth (in)	Edge Width (in)	Total DF (lbs)	Total Drag (lbs)	Efficiency	Main DF (lbs)	Main Drag (lbs)	Efficiency
SL	1	6	111.15	43.04	2.58	32.73	3.50	9.36
SL	2	6	110.86	43.13	2.57	32.72	3.49	9.36
SL	3	6	111.14	43.17	2.57	32.83	3.50	9.38
SL	1	6	110.50	42.79	2.58	33.67	3.81	8.84
SL	2	6	111.19	43.43	2.56	34.52	4.58	7.54
SL	2	6	112.54	40.85	2.75	36.10	5.02	7.20
YAW	2	6	106.91	42.04	2.54	32.94	4.75	6.94
SL	2	6	110.94	39.70	2.79	35.04	4.88	7.18
YAW	2	6	109.14	41.09	2.66	31.92	4.67	6.84
SL	2	4	111.26	39.53	2.81	34.84	4.79	7.28
YAW	2	4	108.65	40.90	2.66	31.70	4.56	6.95
SL	2	8	109.85	39.69	2.77	34.89	5.01	6.96
YAW	2	8	109.38	41.20	2.65	31.93	4.78	6.68

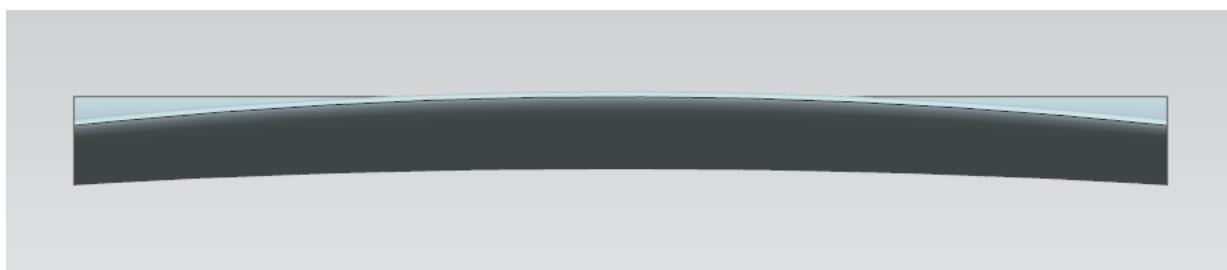
NOTES	Edge Depth (in)	Edge Width (in)	Sec DF (lbs)	Sec Drag (lb)	Efficiency	Tert DF (lbs)	Tert Drag (lbs)	Efficiency
SL	1	6	7.28	6.15	1.18	2.37	4.73	0.50
SL	2	6	7.25	6.11	1.19	2.35	4.67	0.50
SL	3	6	7.22	6.10	1.18	2.35	4.67	0.50
SL	1	6	7.03	6.00	1.17	2.35	4.68	0.50
SL	2	6	6.61	5.75	1.15	2.34	4.70	0.50
SL	2	6	6.09	5.02	1.21	3.17	5.38	0.59
YAW	2	6	5.82	4.77	1.22	3.11	5.22	0.60
SL	2	6	5.88	4.54	1.30	3.50	5.04	0.69
YAW	2	6	5.59	4.28	1.31	3.48	4.93	0.71
SL	2	4	5.95	4.58	1.30	3.52	5.05	0.70
YAW	2	4	5.63	4.30	1.31	3.48	4.92	0.71
SL	2	8	5.81	4.50	1.29	3.49	5.05	0.69
YAW	2	8	5.53	4.25	1.30	3.48	4.93	0.71

3D Main Element

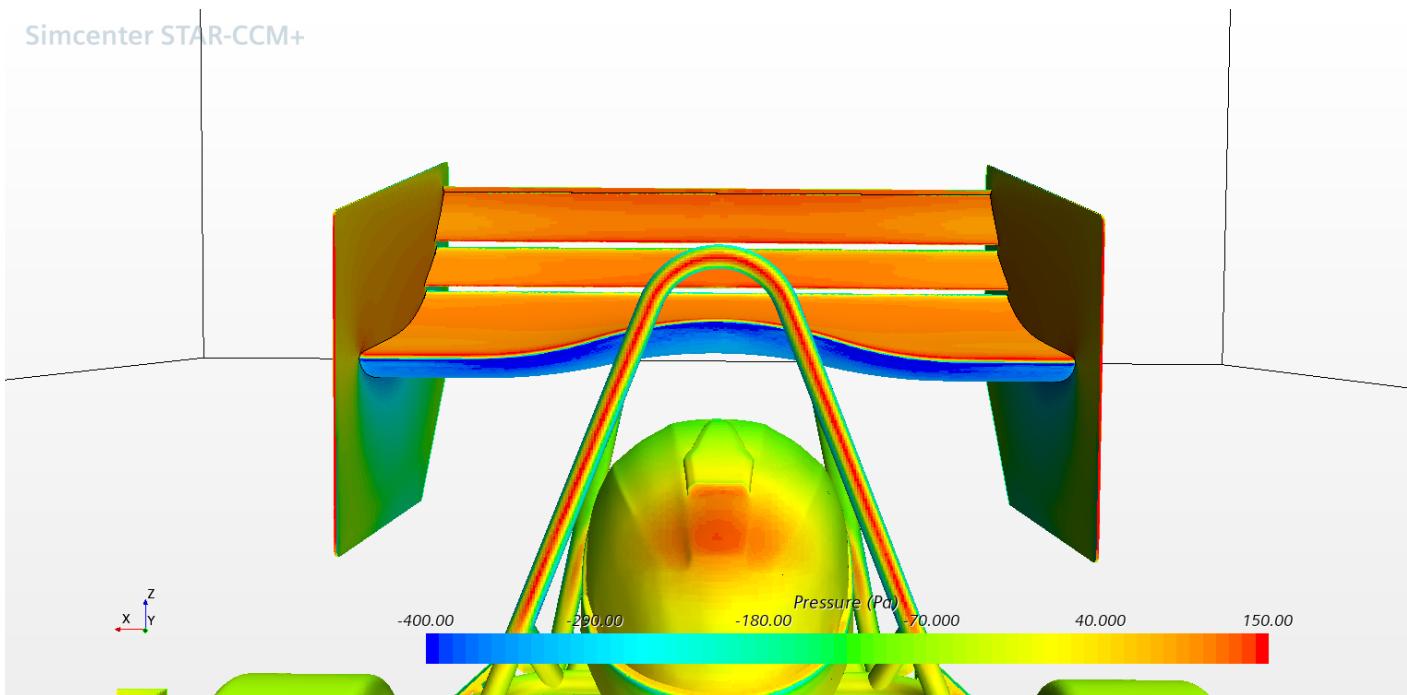
NOTES	Edge Depth (in)	Edge Width (in)	RWG DF (lbs)	RWG Drag (lbs)	Efficiency	Moment (lbf-in)	Frontal Area (in^2)
SL	2	2D	43.43	15.11	2.87	2743.59	416.12
Yaw	2	2D	40.81	15.44	2.64	2687.32	415.08
SL	2	Full3D	42.85	14.32	2.99	2757.10	383.21
Yaw	2	Full3D	40.52	14.73	2.75	2667.61	382.58
SL	2	Full3D	42.74	14.43	2.96	2706.93	388.43
Yaw	2	Full3D	40.61	14.89	2.73	2650.91	387.85
SL	1	Full3D	42.48	14.11	3.01	2706.85	376.44
Yaw	1	Full3D	40.11	14.54	2.76	2626.97	375.77

NOTES	Edge Depth (in)	Edge Width (in)	Total DF (lbs)	Total Drag (lbs)	Efficiency	Main DF (lbs)	Main Drag (lbs)	Efficiency
SL	2	2D	111.23	40.24	2.76	34.67	5.46	6.35
Yaw	2	2D	108.41	41.29	2.63	32.22	5.23	6.16
SL	2	Full3D	110.45	39.24	2.82	33.22	4.16	7.98
Yaw	2	Full3D	107.57	40.33	2.67	31.05	4.03	7.71
SL	2	Full3D	109.92	39.49	2.78	33.28	4.37	7.61
Yaw	2	Full3D	107.54	40.50	2.66	31.28	4.24	7.39
SL	1	Full3D	109.50	38.99	2.81	32.73	3.89	8.42
Yaw	1	Full3D	106.21	39.95	2.66	30.50	3.77	8.10

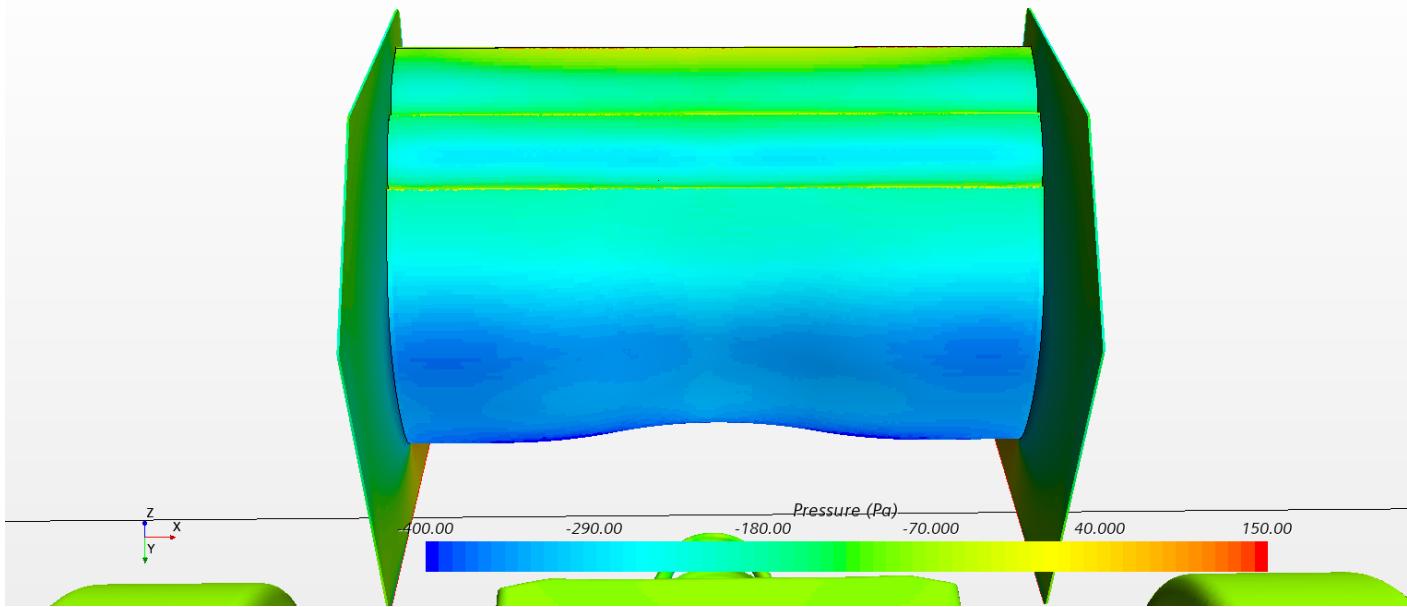
NOTES	Edge Depth (in)	Edge Width (in)	Sec DF (lbs)	Sec Drag (lb)	Efficiency	Tert DF (lbs)	Tert Drag (lbs)	Efficiency
SL	2	2D	5.45	4.28	1.27	3.42	4.96	0.69
Yaw	2	2D	5.24	4.09	1.28	3.43	4.89	0.70
SL	2	Full3D	6.23	4.72	1.32	3.51	5.03	0.70
Yaw	2	Full3D	6.01	4.51	1.33	3.54	4.97	0.71
SL	2	Full3D	6.07	4.63	1.31	3.50	5.03	0.70
Yaw	2	Full3D	5.89	4.45	1.32	3.53	4.96	0.71
SL	1	Full3D	6.35	4.78	1.33	3.50	5.03	0.70
Yaw	1	Full3D	6.13	4.57	1.34	3.55	4.96	0.72



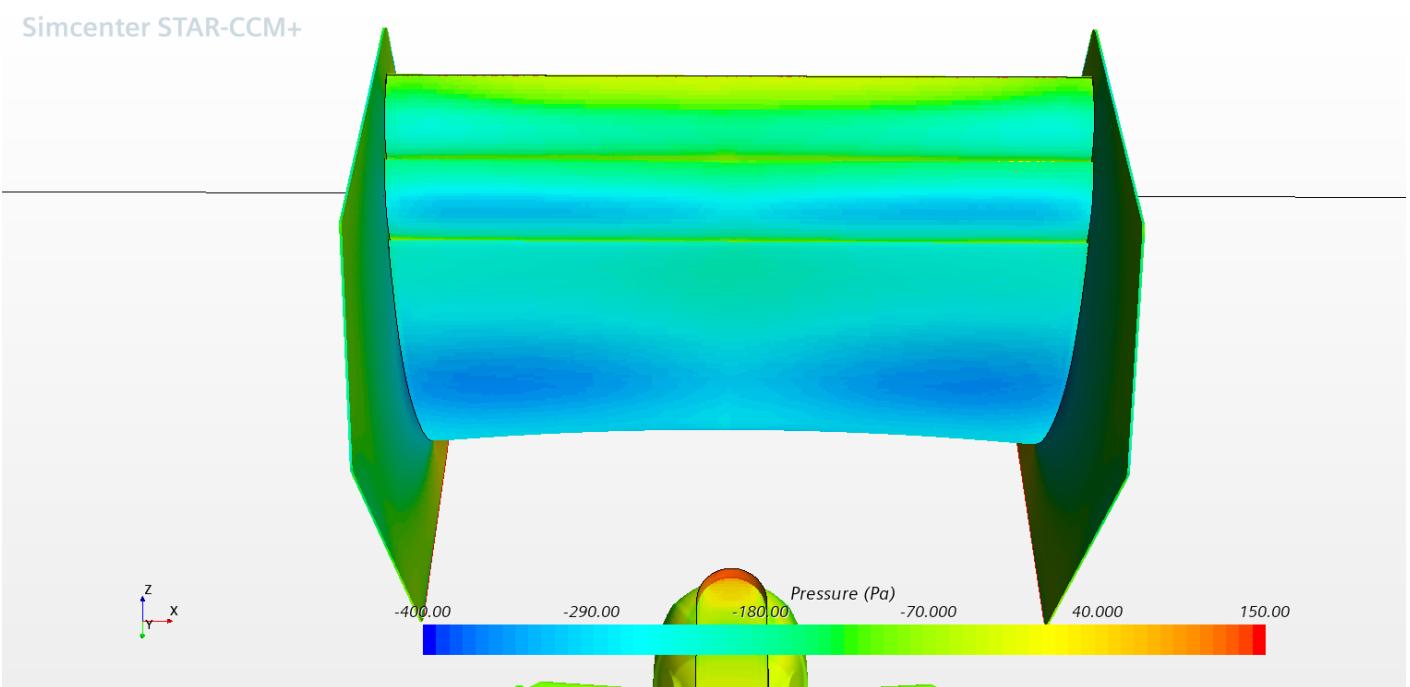
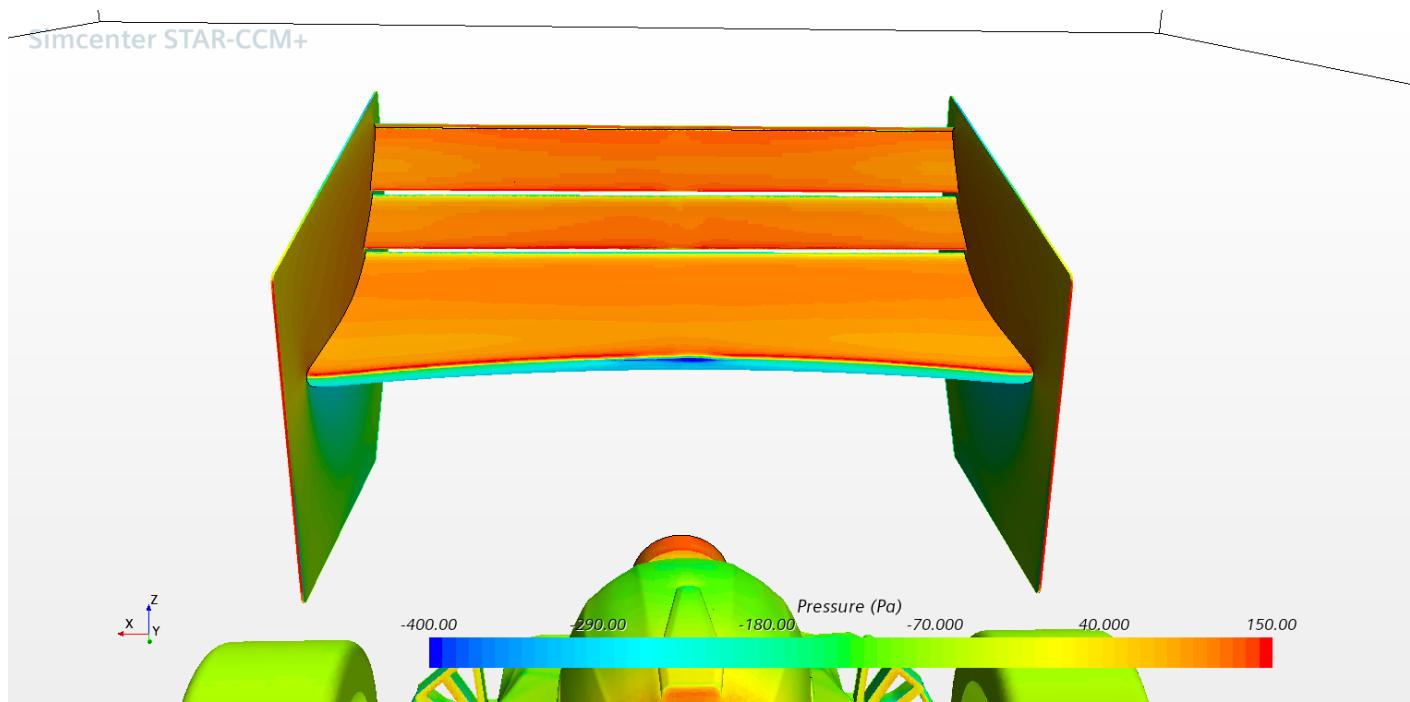
3D Main Element



Simcenter STAR-CCM+

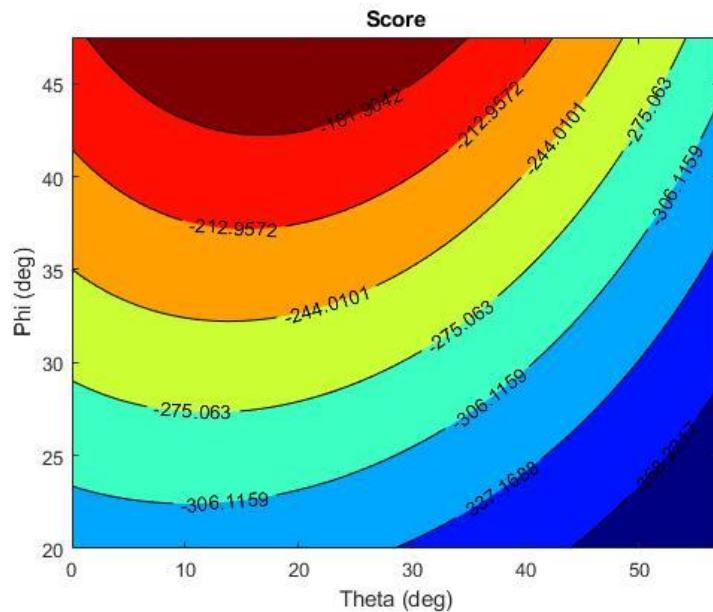
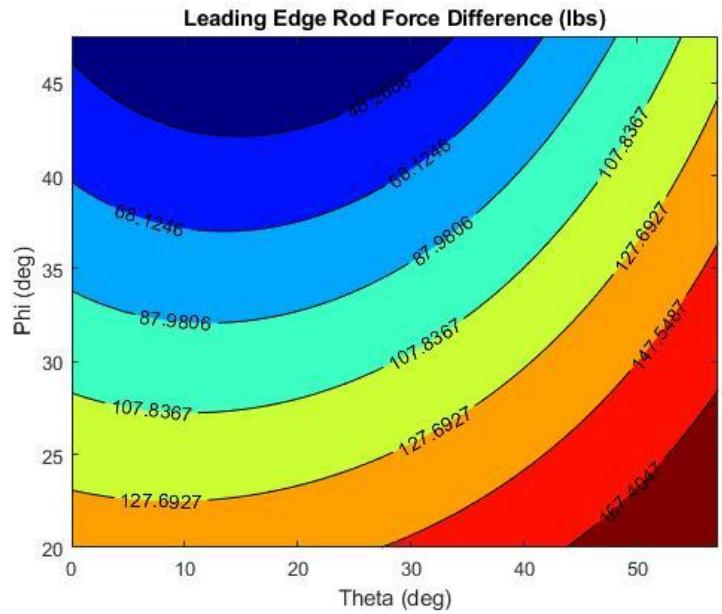
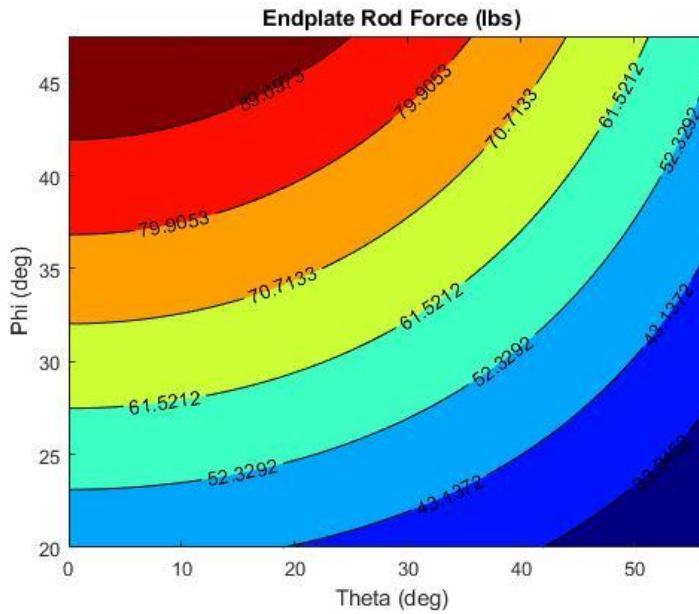


3D Main Element



Mounting Placement

- **Load case: 70 mph straight line aerodynamic loads**
- **Optimize placement of endplate carbon tube mount**
- **Minimize force in endplate support tube**
- **Minimize force difference in roll hoop tubes**

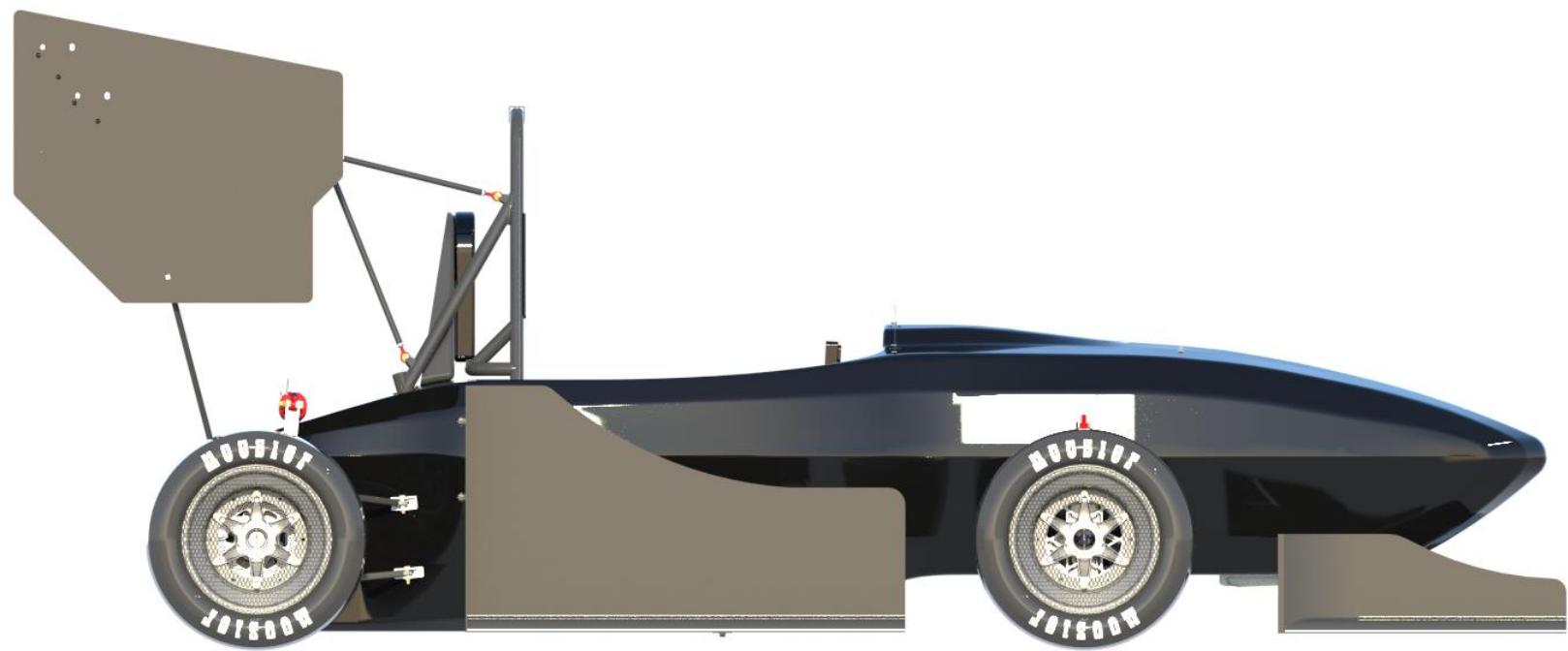


Rear Wing



SL 35.0 mph	
Efficiency	2.75
Drag (lbs)	14.65
Down Force (lbs)	40.27
YAW 35.0 mph	
Efficiency	2.64
Drag (lbs)	14.03
Down Force (lbs)	37.02

Full Package



SL 35.0 mph	
Efficiency	2.66
Drag (lbs)	41.95
Down Force (lbs)	111.62
Down Force to Weight	4.71
Cp (%Front)	42.06
YAW 35.0 mph	
Efficiency	2.57
Drag (lbs)	108.07
Down Force (lbs)	41.97
Down Force to Weight	4.56
Cp (%Front)	42.71