Aerodynamics Preliminary Design Review

10/04/2025


122
AYRO
FLUKE
SAE
INTERNATIONAL
LOCKHEED MARTIN
HEXCEL
Duratech Coating
Chevron
Power
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122

Overview

Agenda

- High Level Goals
- Timeline
- Design
  - Front Wing
  - Rear Wing
  - Nosecone and Bodywork
  - Undertray
  - Sidepod
  - Inverted Wing
  - Firewall/Engine Cover
- Validation
  - Fan Curve
  - On-Car Pressure Tapping
  - Radiator MFR Study
  - Wind Tunnel Testing

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High Level Goals

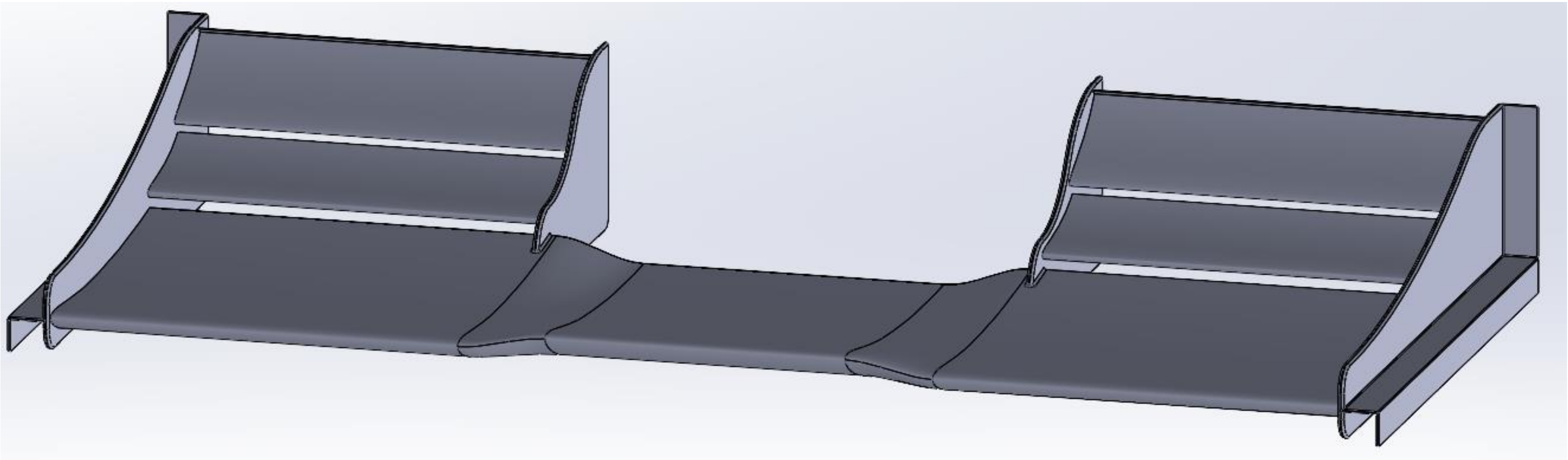
- Teamwide Goal Overview
  - **Finishing** Aero Package end of year (2025) to give composites enough time for manufacturing
  - Implement Aeromap for Lapsim
- System Level Goal Overview
  - Perform **testing and validation** activities to earn remaining design points
  - Find Front Wing performance
  - Prioritizing undertray development
  - Reach **3.0 CLA with 1.2 CDA**
  - Adding more blockages in simulations
  - Maintain **COP 0.05 rearward of CG** like previous years.
  - Reduce **weight** wherever we can

Front Wing Package

Front Wing Aero Design

- Front wing airfoil profile chosen
  - NACA 6408 with 15" chord length
  - Maximized longitudinal bounding box space
  - Increased ground effect
  - (Ideally) allows for ~same downforce without a 4th element on the inner cascade
    - 2025 CLA = -0.67 ,   Present CLA = -0.61

- Current Iteration
  - Negative AOA center section, twist AOA to positive along span
  - Deciding against main element tunnels (last year) because undertray performance is comparable to last year without it



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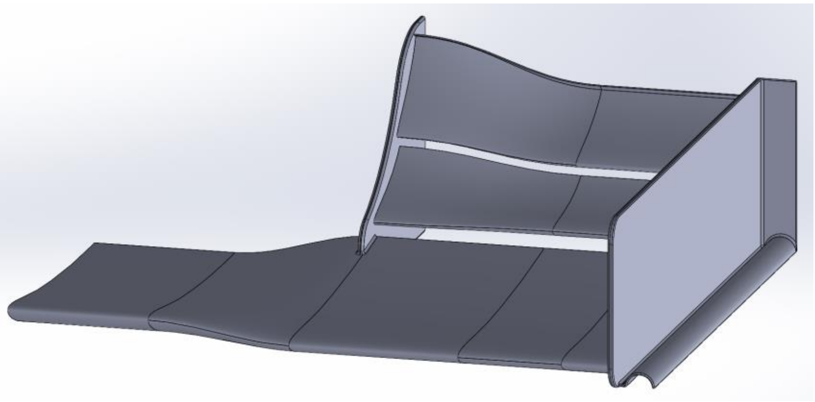
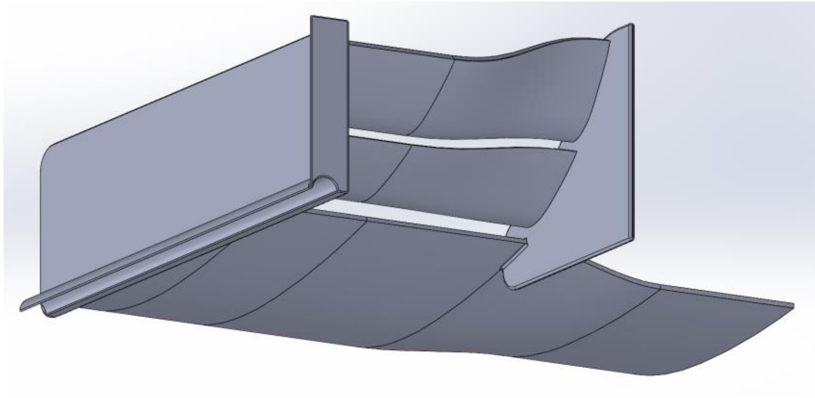
Front Wing Aero Design

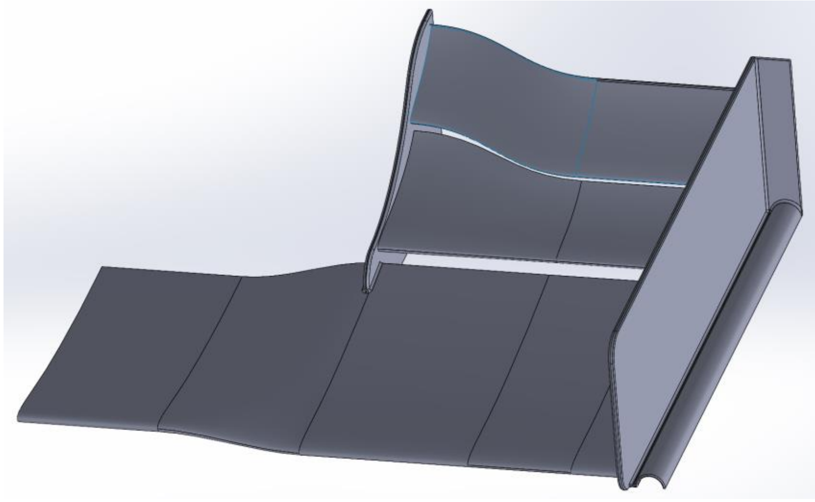
Next steps

- Secondary Geometry Experimentation
  - Twist AOA along span
  - Varying chord length along span
- Endplates
  - Outboard endplate geometries
    - Canards (airfoils / contoured geometries)
    - Inboard / Outwashing Airfoils
    - Curving Endplate outward rather than L-shape
- Footplate
  - Running sims on footplate width (moving the outer endplate
- Dependencies
  - Dynamic shock stiffness for pitch and roll ground clearances
  - Composite manufacturability always kept in mind, constant communication



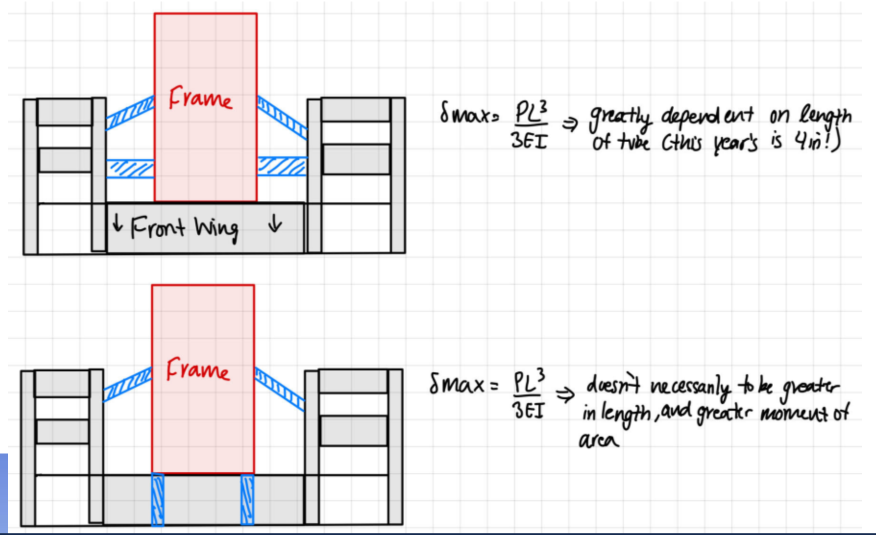


(Same CAD)

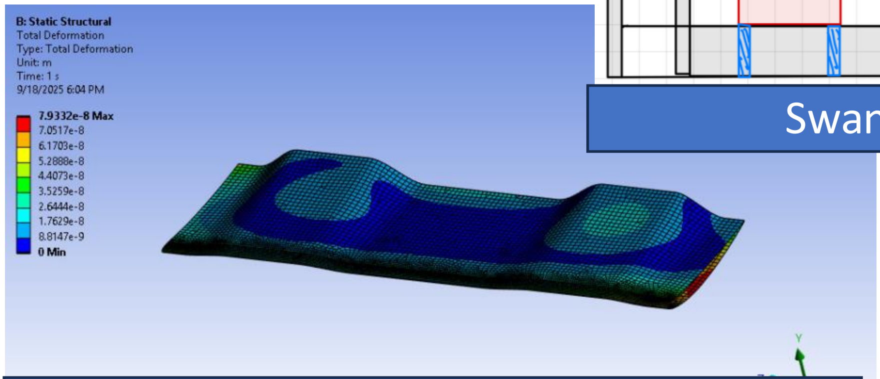


Front Wing Aerostructure

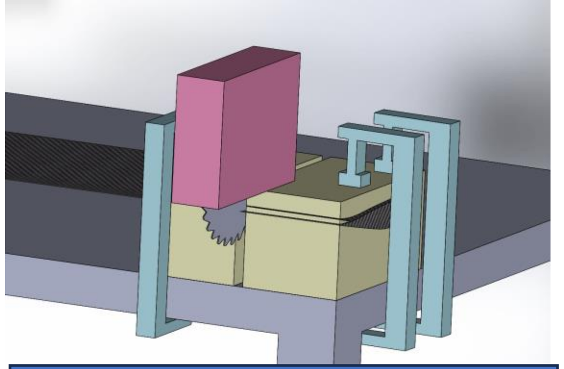
- **Previously**
  - Poor manufacturing: airfoils were not cut to their accurate sizes
  - Incorrect mold sizing, front wing was too heavy without any internal support, under-developed mounting
- **This year**
  - Utilizing aerodynamics loads for wing FEA and Validation (Heavy Focus on Analysis and)
    - Preliminary FEA workflow is still being established
      - Refining CFD -> FEA data processing
      - Multi-stage simulation timeline ((1) Reactionary Forces (2) Mounting Component Optimization (3) Full Scale Assembly)
      - Understanding hand calculations and simplifications for carbon fiber assemblies



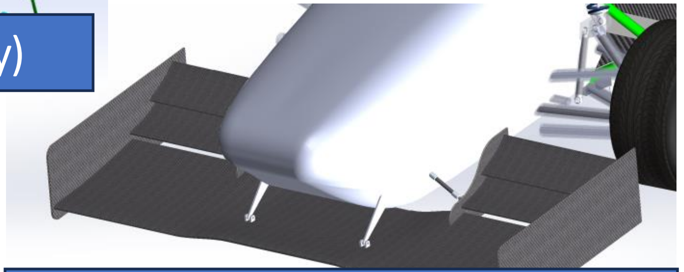
Swan Neck vs. Cantilever



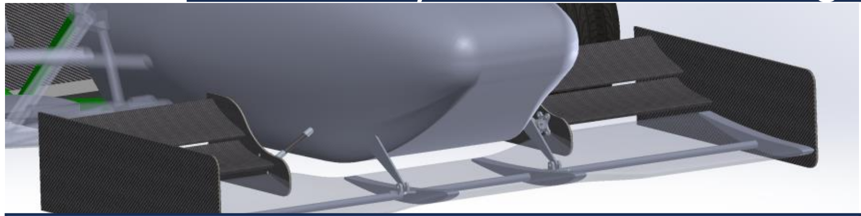
Pressure Distribution from CFD (6ply)



Airfoil Jig



Preliminary Direction- Mounting



Preliminary Direction- Internal

Front Wing Analysis

Aerostructure Analysis Flow Chart (Thank you Leo!)

Front Wing (ALL CFD-BASED) Yes, we are behind, but we have a plan…	End Date
Stage 0: **Integrating CFD data:** with correct car origin, proper pressure values, consistent load cases, and decreasing CFD -> FEA process time	
Stage 1: **Carbon only analysis**: only holes for main mounting points – meant for reactionary force (taken from CFD data) + implementing additional carloads (braking, acceleration, turning, side gusts)	Wed, Oct. 15
Stage 2: **Internal structure analysis**: optimizing rib material, spar (carbon tube vs. Sandwich panel layup) Stage 2: **Frame x aero integration:** focusing on tab positioning, tie rods vs. Swan neck for greater support in the front wing main, tie rod deformation, rod selection	CDR
Stage 4: **Full assembly analysis:** understanding how internal structure and mounting help distribute loads across front wing, Optimize individual features for worst case scenarios	Winter Break

Front Wing Manufacturing

Best Case Scenario	End Date
1) **Non-changing airfoil layups**: front wing secondaries (partial pieces), endplate flat panel layups 2) **Mold Development:** front wing main, preliminary undertray mold designed, curved secondary manufacturing strategies + 3D printed molds 3) **Finalize manufacturing for curved secondaries**: 3D printed vs. Carbon layup 4) **Mounting Component Selection:** finalize all tubes, all internal hardware, insert design, and endcap development	Mid October- Winter Break (depending on aero timeline and composite work capabilities)

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Nosecone and Bodywork

Nosecone and Bodywork Aero Design

- Work has been done to replicate last year's CAD methodology

Current Iteration

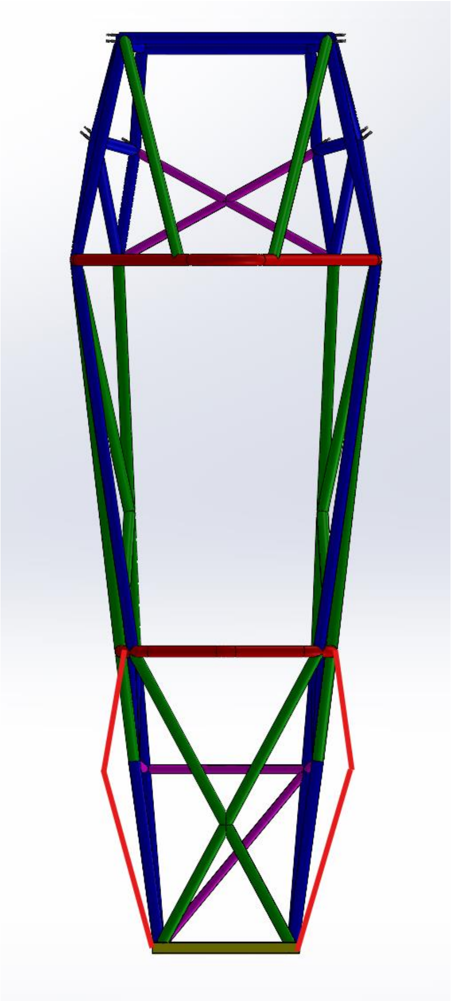
- Nosecone geometry shaped to smoothly go around the original protruding frame node (outlined in the red lines)
  - Recently updated frame node, prompting a new design direction

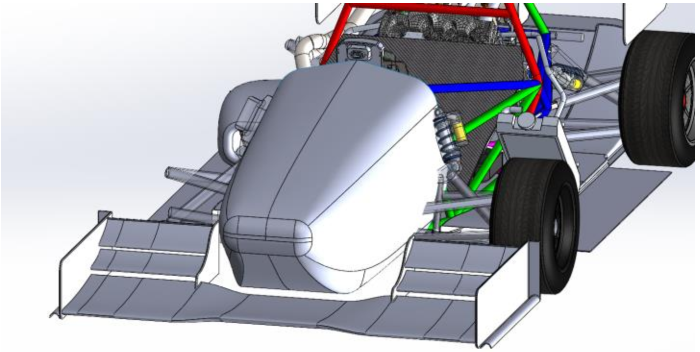
Next Steps (Blue lines)

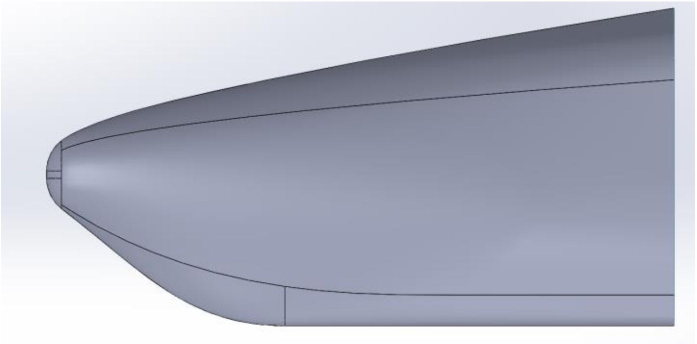
- Test flatter front face nosecone
  - Requires a new CAD methodology given that the nosecone tip geometry is changing
    - Ideally will be as simple as surface extrusions, trims, and fillets
- Test upwashing contour on the upper middle near roll hoop

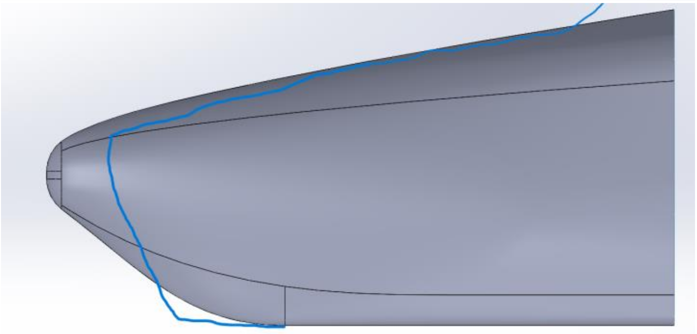
Dependencies

- Frame changes & IA









Bodywork Mounting

Previously

- Use zip ties for now because they are lightweight and easy to mount (but have to cut to unmount)
- Dzus tabs worked well because they allowed for easy removal and mounting of the carbon

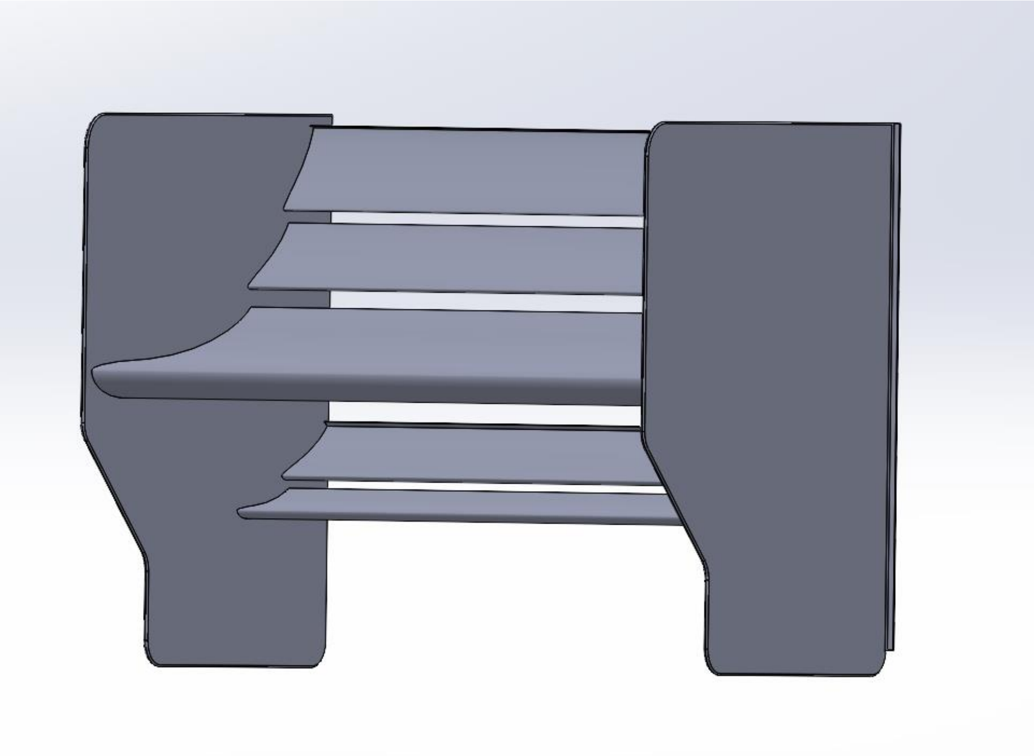
This year

- Zip ties are still an option, Lego hands printed from a more flexible-but equally as strong material maybe looked into - might get weaker if mounted and de mounted continuously
- Slap bracelet designs
- Dzus tabs for nose code

Rear Wing Package

Rear Wing Aero Design

- **Changes:**
  - Added a third element to main cascade
  - Tested curving rear wing main, saw negligible gains/not justifiable for manufacturing effort
- **Results:**
  - Curved main gave us 0.58 CL while 3 element maincascade gave us 0.76 CL (w/o firewall)
  - Baseline is 0.59 CL
  - With firewall, we see a bunch of separation at the 3rdelement, so we will try to mitigate this issue by testingengine cover iterations and reducing AOA



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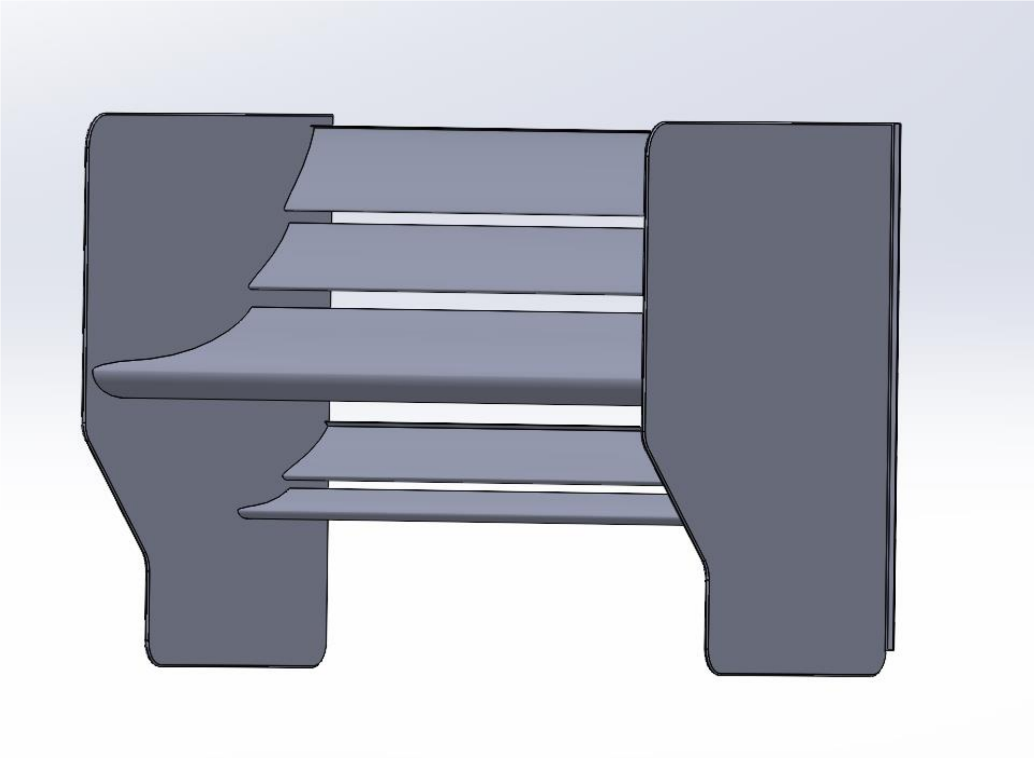
Rear Wing Aero Design

- **Next Steps:**
    - Without firewall, rear wing performs to about 0.76 CL, but with firewall, rear wing performance drops down to 0.57 CL
    - Configure a firewall that works with rear wing
    - Reduce AOA of the main cascade to see reattachment of airflow
    - Implement top intake design and headrest in sims for more accurate results
- **Dependencies:**
    - Powertrain



Rear Wing Mounting

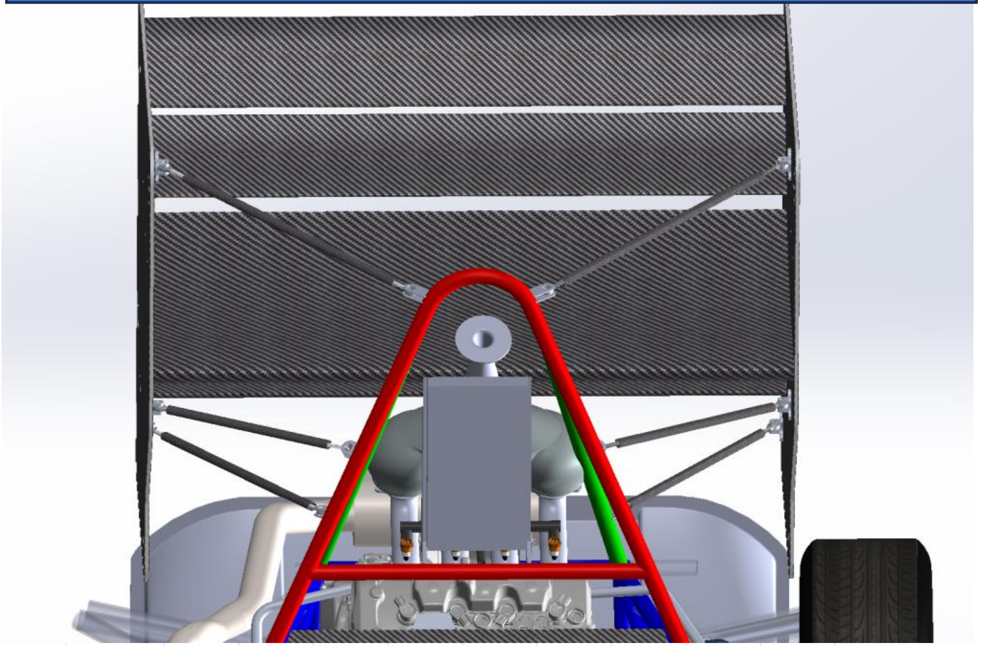
Previously

- Unstable mounting: susceptible to shaking, heavy side gusts
- Lack of internal support: the rear wing main lacked internal structure

This year

- Utilizing truss solver (Thank you Edward!) for balancing forces at various nodes of the rear wing
  - Preliminary positions for nodes calculated and CADED based on aero loads (drag and lift)
    - Refining mounting points, based on restriction in rear frame
    - Multi-stage simulation timeline ((1) Reactionary Forces (2) Mounting Component Optimization (3) Full Scale Assembly)
    - Understanding hand calculations and simplifications for carbon fiber assemblies

Truss solver x aero x frame



INPUTS

Frame Link Mount Positions

Link	x	y	z	
1	-250	120	940	mm
2	-250	-120	940	mm
3	-250	120	940	mm
4	-250	-120	940	mm
5	-750	230	380	mm
6	-750	-230	380	mm

Wing Mount Positions

Link	x	y	z	
1	-940	490	1080	mm
2	-940	-490	1080	mm
3	-700	490	660	mm
4	-700	-490	660	mm
5	-1080	490	500	mm
6	-1080	-490	500	mm

Load Positions

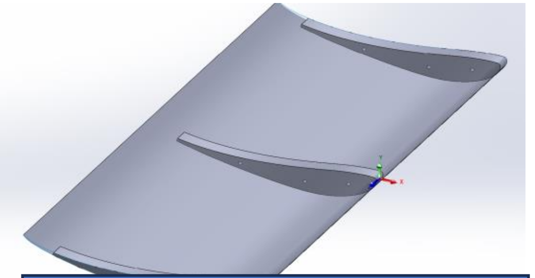
	x	y	z	
CG	-840	0	840	mm
Aero COP	-800	0	700	mm
Drag COP	-500	500	840	mm

	Load Inputs	Unit
Fx	-100.0	N
Fy	0.0	N
Fz	-950.0	N
Mx	0.0	Nm
My	0.0	Nm
Mz	0.0	Nm

	Load Outputs	Unit
Link 1	-215.5	N
Link 2	-215.5	N
Link 3	762.4	N
Link 4	762.4	N
Link 5	-388.9	N
Link 6	-388.9	N

-1625

26 to 25 750



RWING internal

Rear Wing Analysis

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Stage 2: **Internal structure analysis**: optimizing rib material, spar (carbon tube vs. Sandwich panel layup), rib cutouts for RWING main Stage 2: **Frame x aero integration:** focusing on tab positioning, tie rods vs. Swan neck for greater support in the front wing main, tie rod deformation, rod selection	CDR
Stage 4: **Full assembly analysis:** understanding how internal structure and mounting help distribute loads across front wing, Optimize individual features for worst case scenarios	Winter Break

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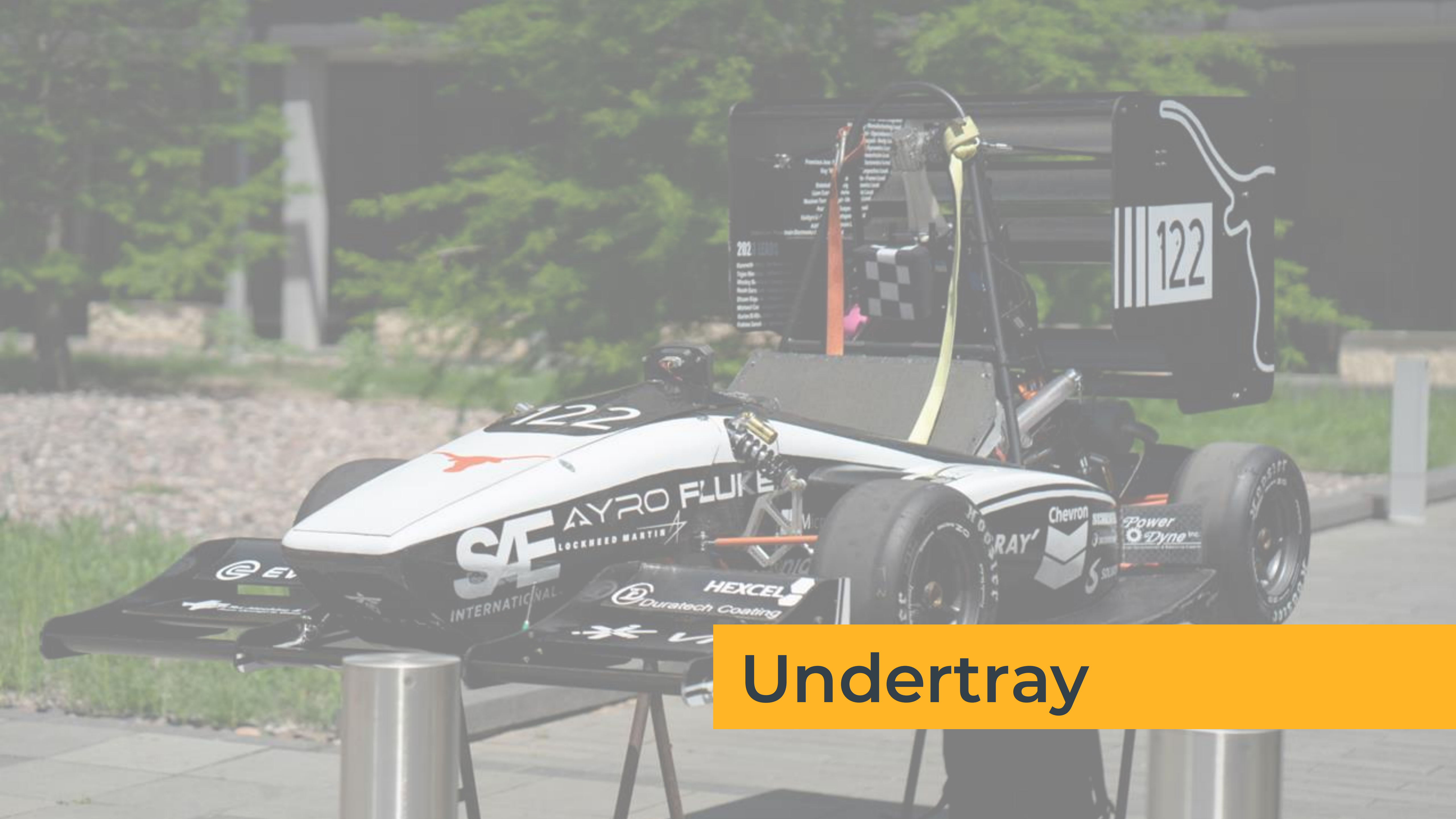
Rear Wing Analysis

Best Case Scenario	End Date
1) **Non-changing airfoil layups**: Rear wing main, rear wing secondaries, endplates 2) **Mold Development:** front wing main, preliminary undertray mold designed, curved secondary manufacturing strategies + 3D printed molds 3) **Finalize manufacturing for curved secondaries**: 3D printed vs. Carbon layup 4) **Mounting Component Selection:** finalize all tubes, all internal hardware, insert design, and endcap development	Mid October- Winter Break (depending on aero timeline and composite work capabilities)

LHR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Duratech Coating
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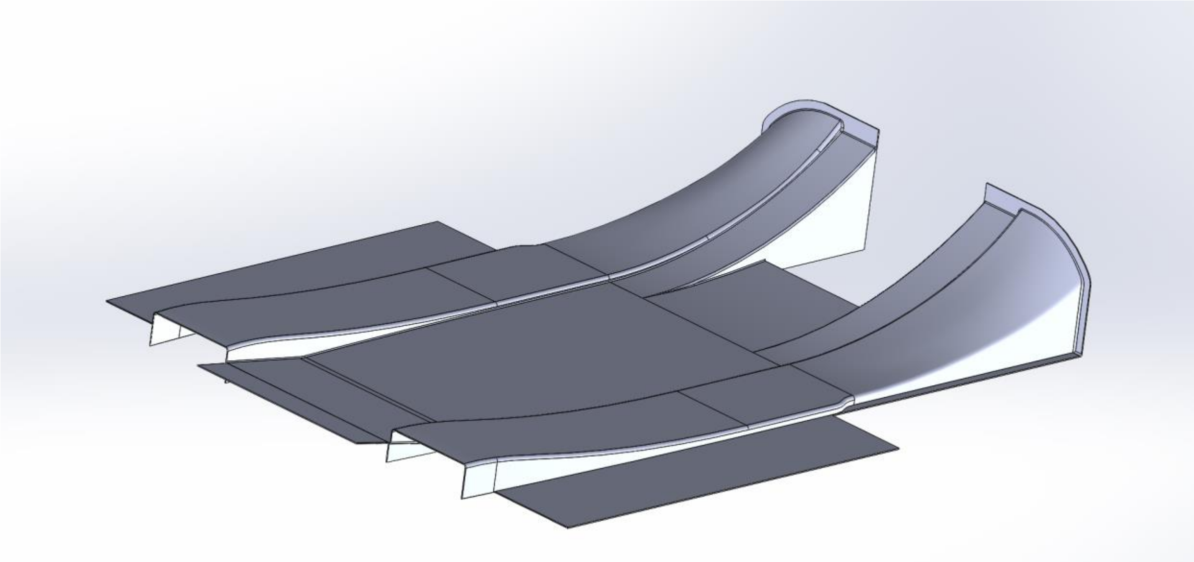
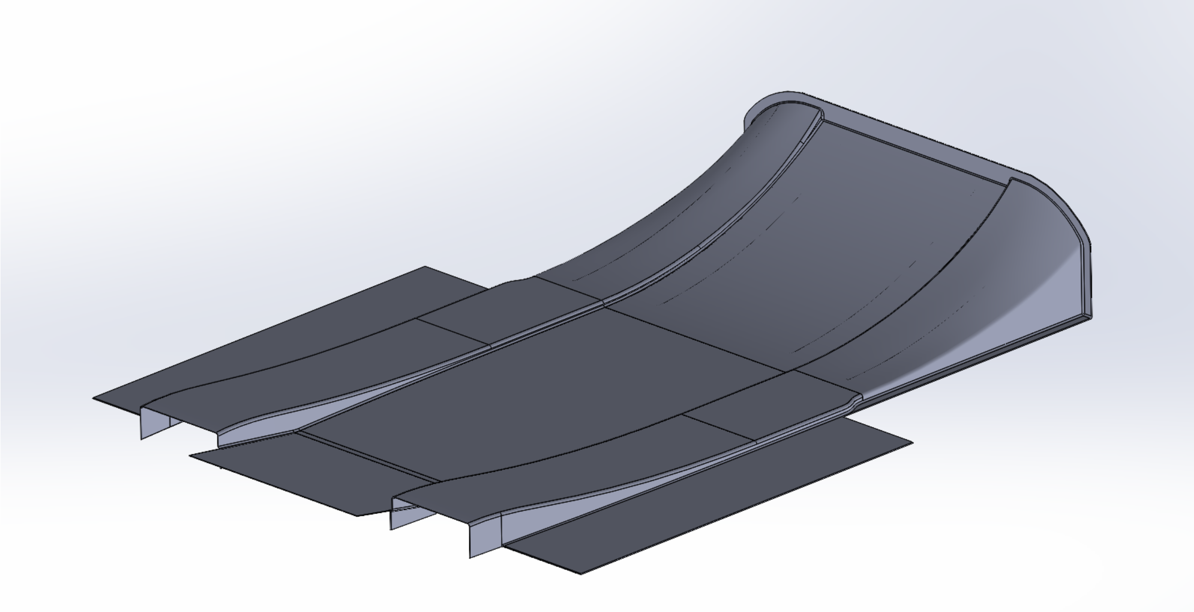
Power Dyne

Undertray

Undertray Aero Design

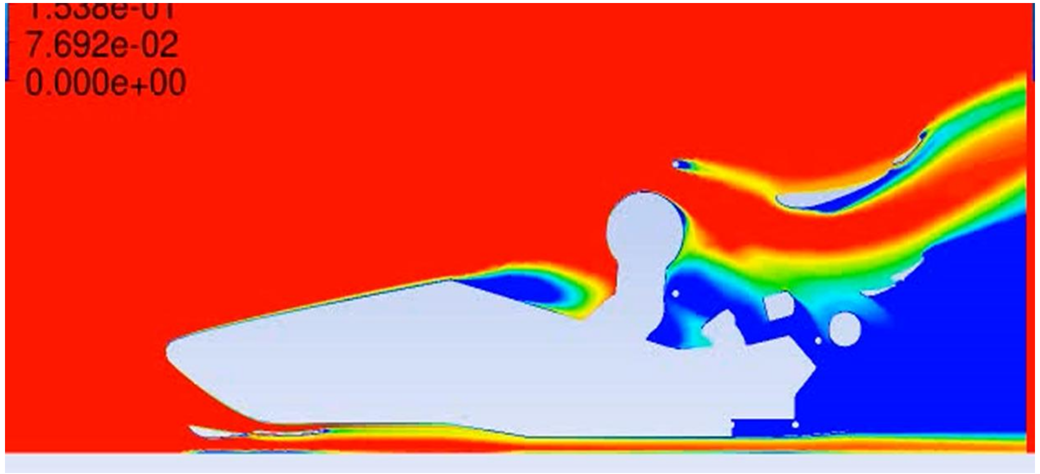
- **Changes**:
  - Sticking to Raccoon's undertray
  - Trying to cut central diffuser to diffuse before jacking point
  - Oil pan should not be going under the undertray so no more oil pan cutout
- **Next steps:**
  - Experiment with lower undertray ride height
  - Testing to reduce height of the flat plate since that is mainly affected by roll
  - Footplate on flat plate of undertray
  - Pressurize region between rear wheel and rear diffuser hopefully to avoid tire wake entering diffuser
- **Dependencies:**
  - Frame
  - Dynamics
  - Powertrain

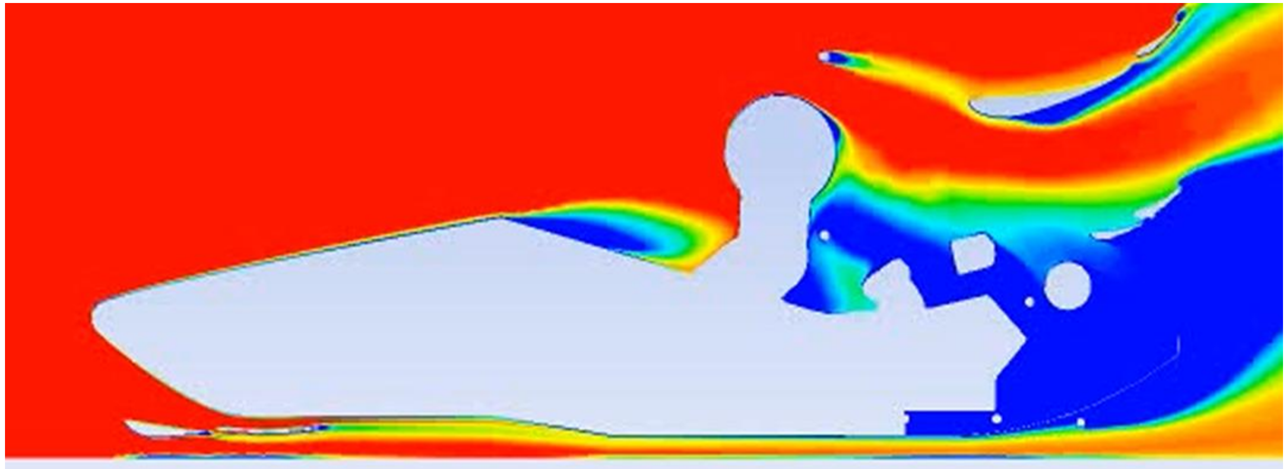


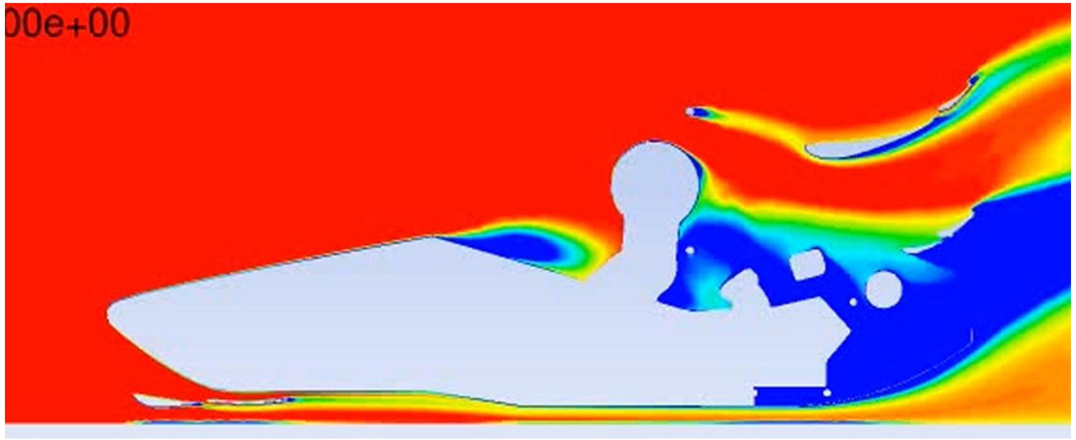


Undertray Aero Design

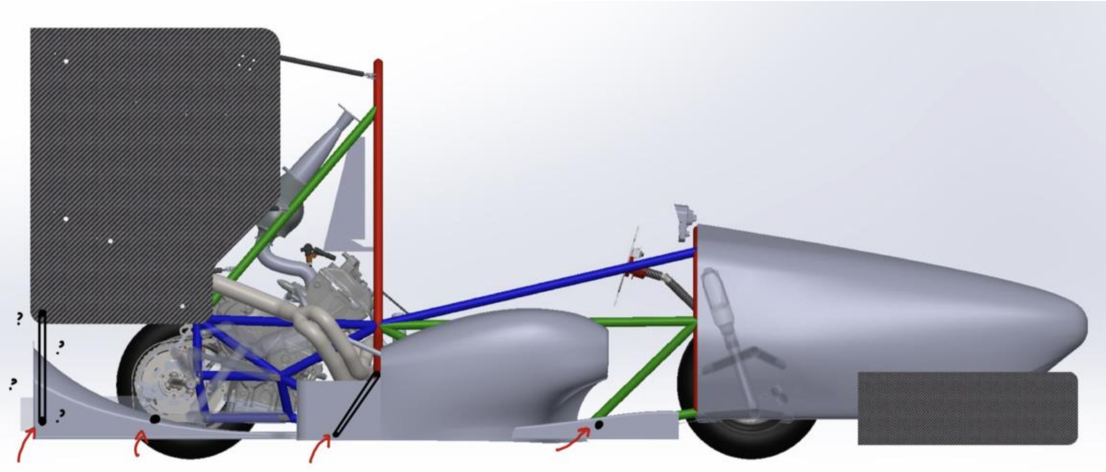
- **Results:**
  - Last year's undertray with jacking point is 0.41 CL
  - While the current undertray with a chopped central diffuser is 0.31 CL







Undertray Mounting



- **Previously**
  - Floppy diffuser: steel cables react horribly in compression
  - Lack of internal support: reduced ply counts and lack of foam core
  - Tie rods at the side pod inlet
- **This year**
  - Meeting stiffness targets by abstracting ply count correlation from wind tunnel testing
  - Utilizing tie rods for behind-side pod mounting, POSSIBLY diffuser-to-rear wing mounting, and then direct frame mounting via DZUS tabs for easier demounting
  - 3D prints for creating smooth transition between foam core and carbon fiber for side panels and tunnel region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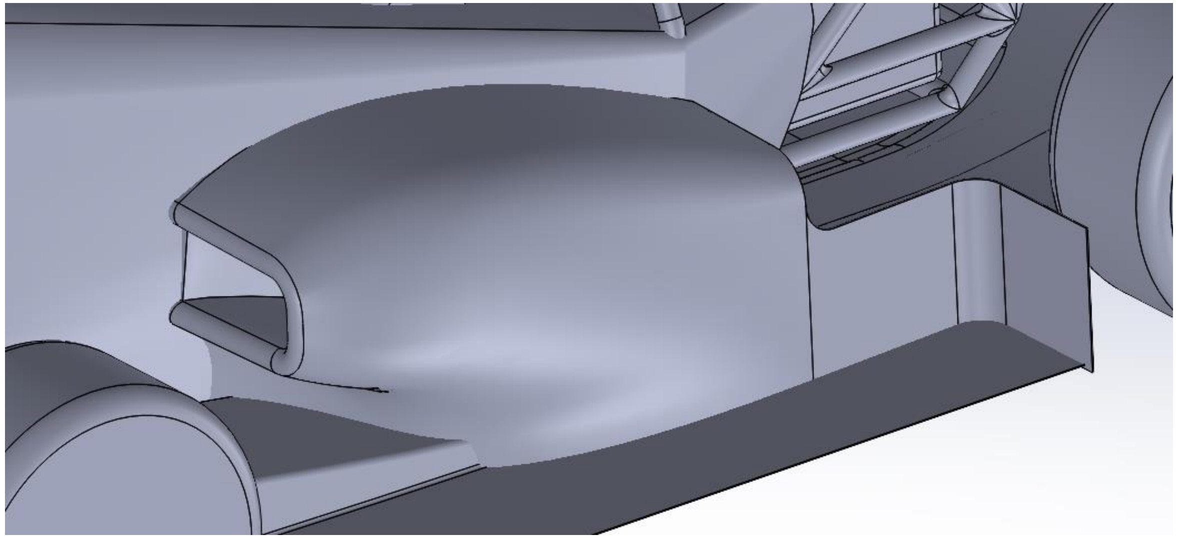
Sidepod

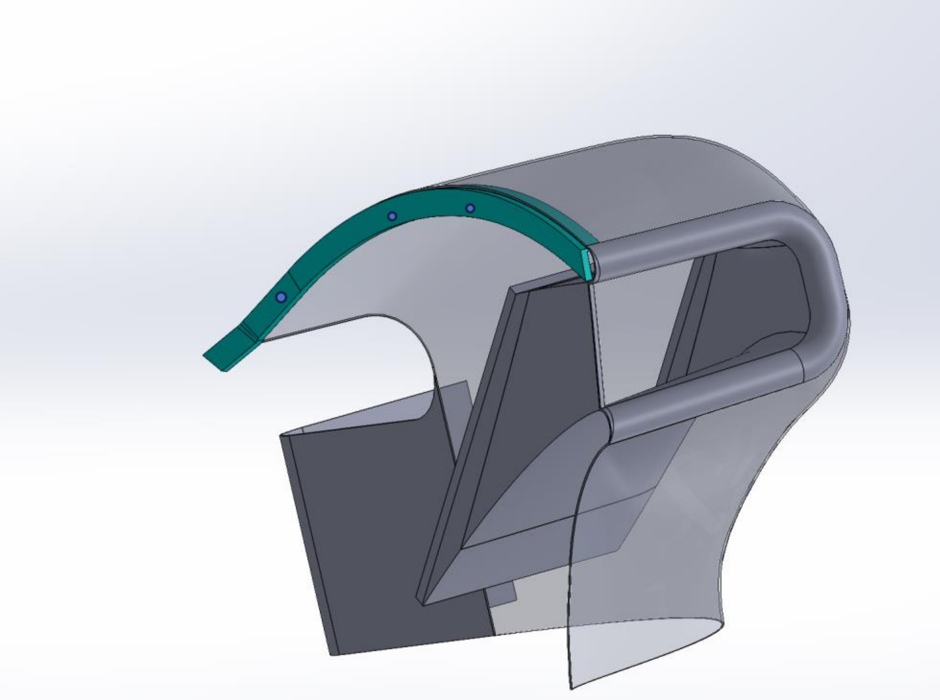
Sidepod Aero Design

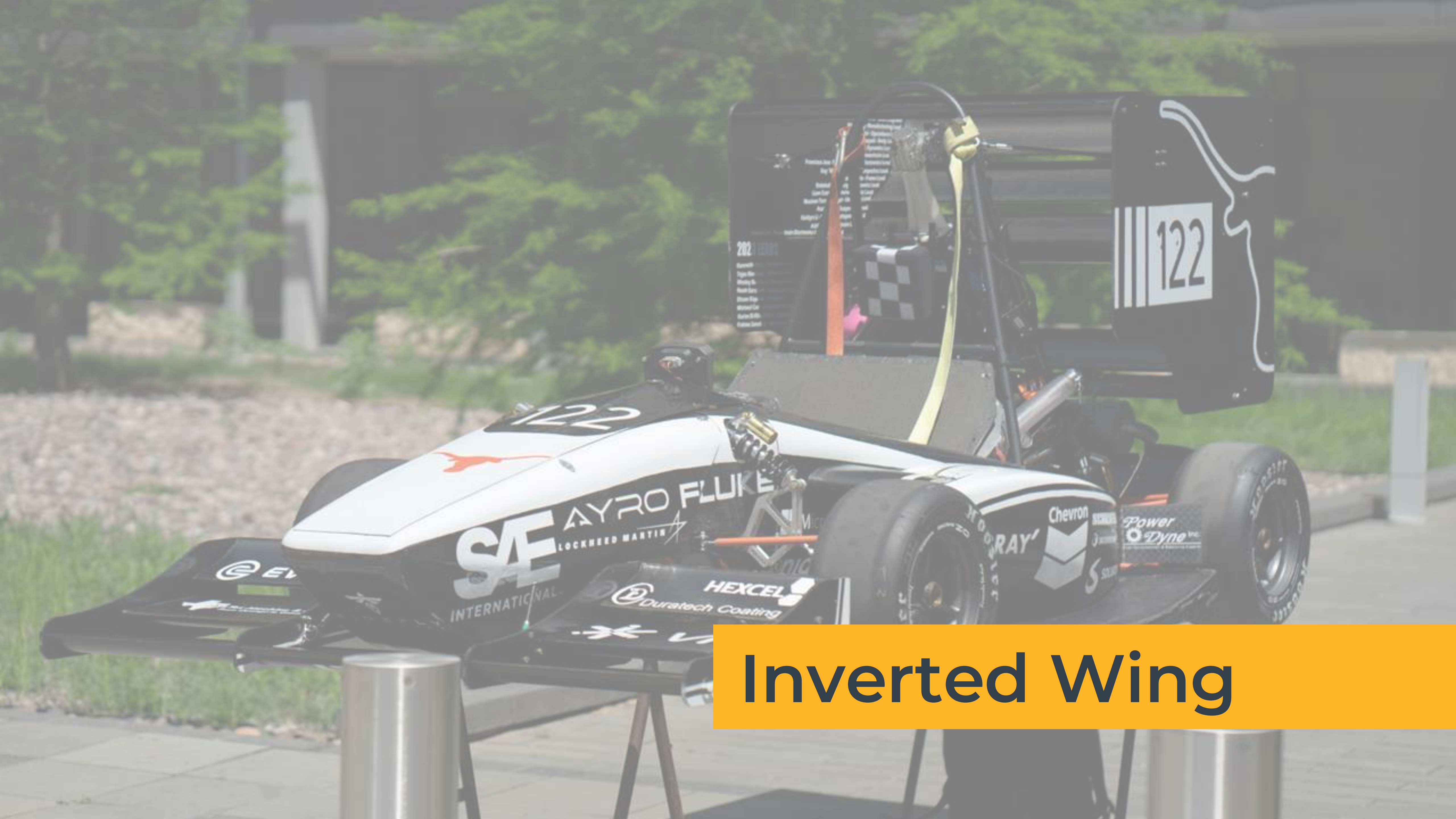
- **Changes:**
  - Nothing has been changed yet, we are sticking with last year's design
- **Next steps:**
  - Experiment with internal ducting
- **Dependencies:**
  - Side panel
  - Frame
  - Undertray



Sidepod Mounting Design

- **Previously**
  - Good, smooth integration of airducts to shroud and side pods
  - Could be cleaner in terms of alignment with body work
- **This year**
  - 3D printed L-bracket that attaches flush with the bodywork and travels across the surface of the side pod – it will be cut into pieces (not the full length like shown in the picture)
  - Smoother transition from under tray to sidepod and bodywork to sidepod

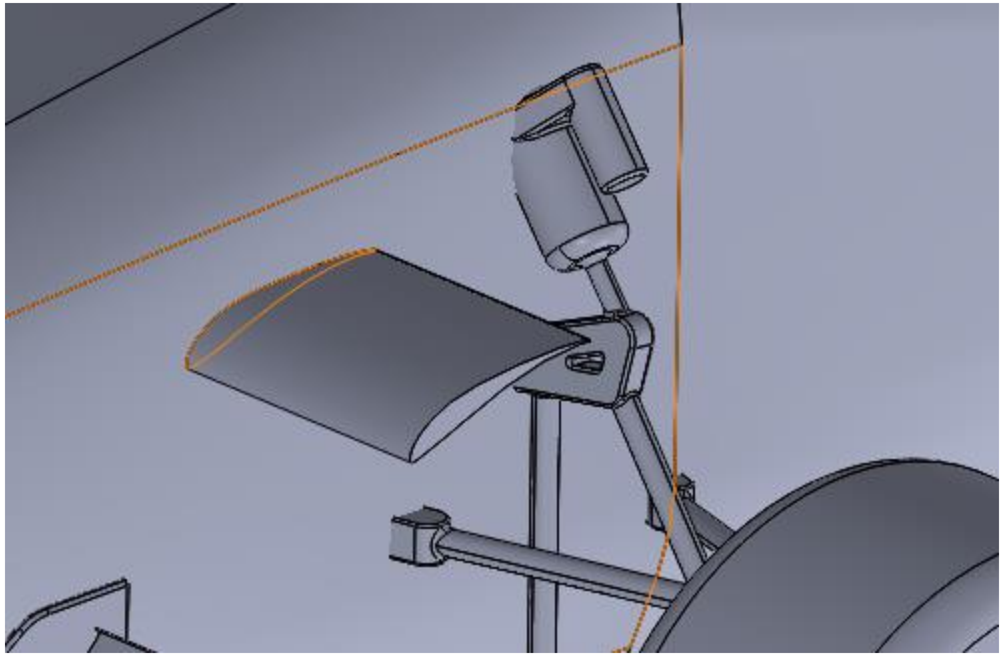


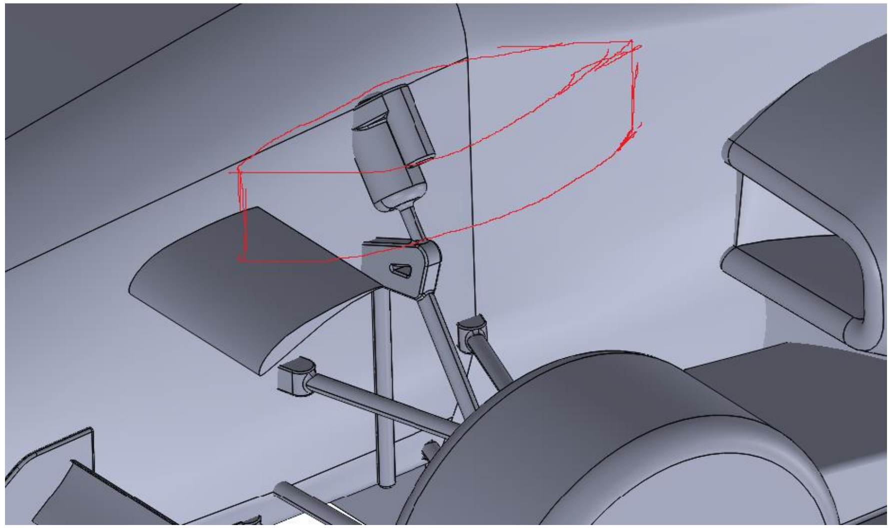


Inverted Wing

Inverted Wing Aero Design

- **Changes:**
  - Nothing has been changed at the moment
- **Next Steps:**
  - Will be implemented in the latter half of the season for balance shifting
  - Testing to see if control arm airfoil covers could be a good addition
  - Testing with shock covers for inverted wing positioning
    - Try to gain some mass flow through sidepod
- **Dependencies:**
  - Dynamics

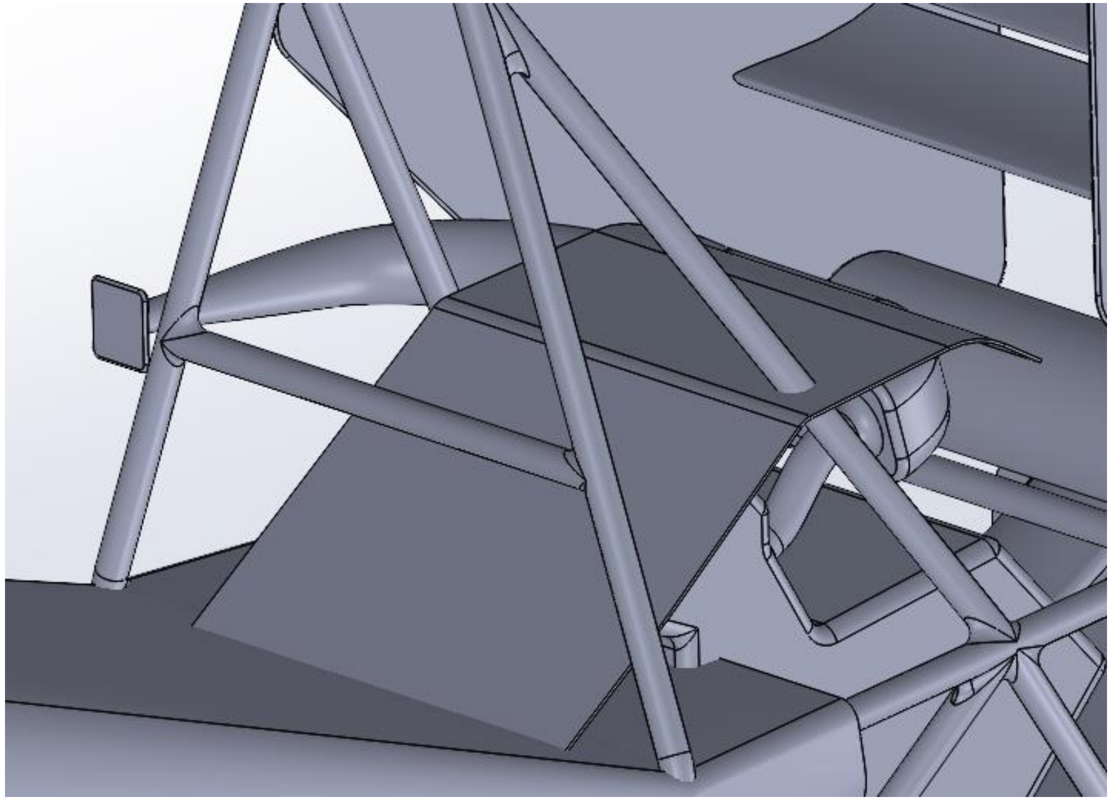




Firewall/Engine Cover

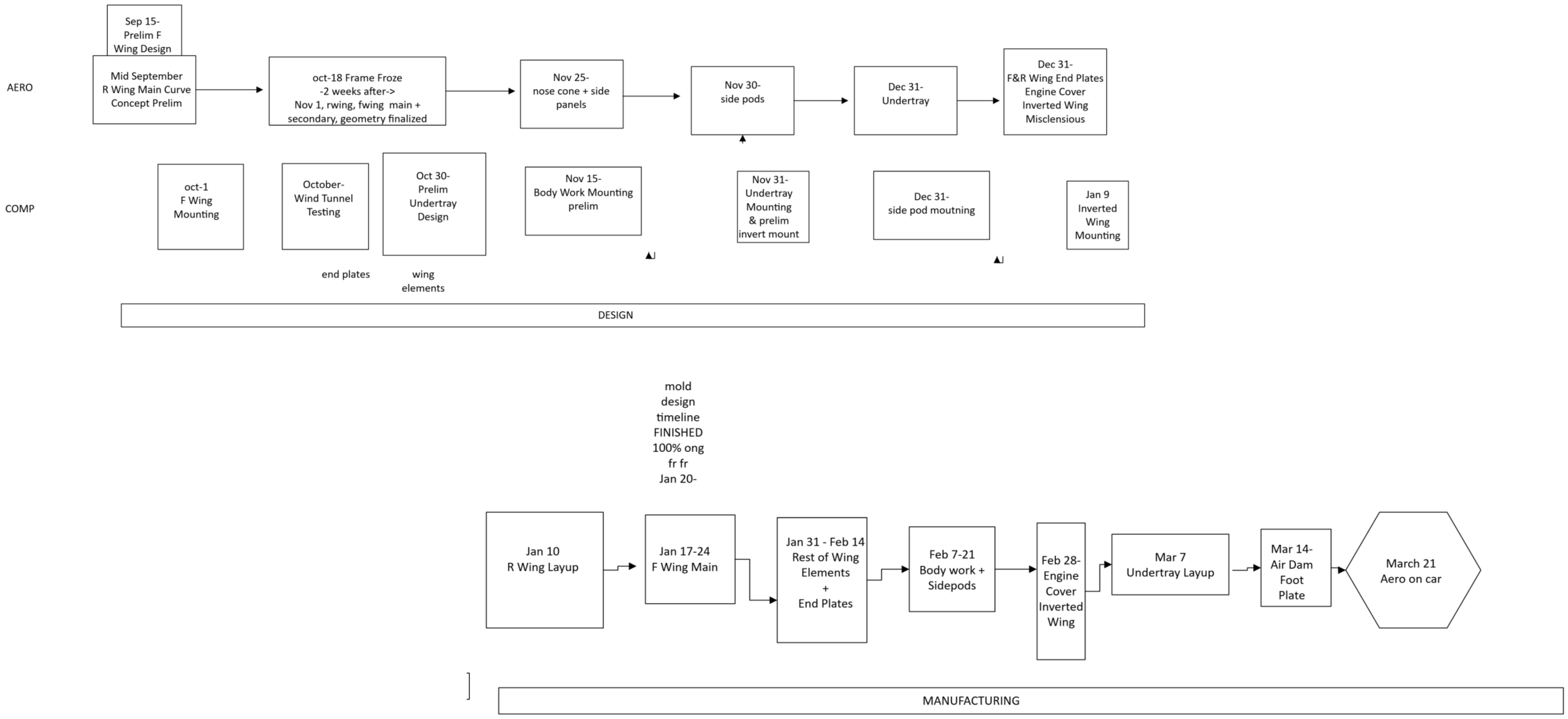
Firewall/Engine Cover Aero Design

- **Changes**:
  - Nothing has been changed at the moment
- **Next Steps:**
  - Cover all of engine bay
  - Test with different slope angles on the engine cover
  - Test flat wall vs angled wall
- **Dependencies:**
  - Powertrain
  - Dynamics
  - Rear wing



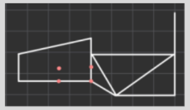
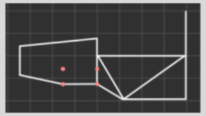
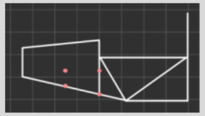
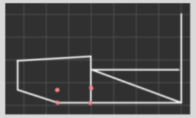
Timeline (link)

- **Note**: Facilities issues have pushed back COM R&D Timeline to mid November, the timelines below is a living document to be finalized when all Composites Facilities are back to normal.



Stepped Frame

- Preliminary CLA decrease of 0.1 (-0.64 to –0.74)
- Estimated ~1lb frame weight increase
- LapSim sweeps show decrease of ~3 seconds per 10 laps
  - CLA decrease outweighs weight increase

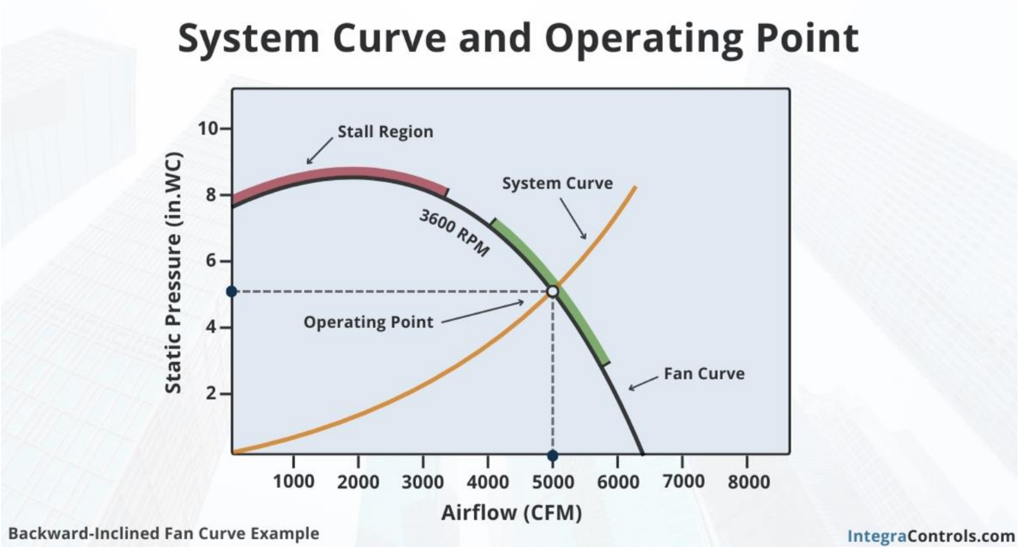
Category	Weight %	Configuration							
									
		Score	Reasoning	Score	Reasoning	Score	Reasoning	Score	Reasoning
Downforce Effect	30%	4		5		3		0	
Frame Manufacturability	20%	4		2		3		5	
Driver Anthropometrics	20%	4		3		4		4	
Dynamics Hardpoints	30%	3		3		0		5	
Total Score			3.7		3.4		2.3		3.3

Param Changed	Weight	CLa	Laptime (10 laps)	Average Velocity	Difference in Laptime
Last year	595	2.6	1639.148028	15.79988434	
Weight + 1	596	2.6	1639.283896	15.52704369	0.135868165
CLa + 0.1	595	2.7	1636.061131	15.56163372	-3.086897202
CLa + 0.2	595	2.8	1630.726449	15.61725392	-8.421579438
Weight + 1 + CLa + 0.2	596	2.8	1631.035396	15.61411081	-8.112632005

Testing & Validation

Fan Curve

- **Goal:** Plot fan pressure jump across different speeds and at different voltages to find the intersection with the radiator pressure drop function. These results can be input into CFD simulations for more accurate results.



__Test Plans:__

https://docs.google.com/document/d/1A2-rMCWE5qLJkZeuCOoU-zSUrAK7kW5N/edit?usp=sharing&ouid=109021406217322604834&rtpof=true&sd=true

On-Car Pressure Tapping

Goal: The main objective is to create a pressure map of the car to ensure they produce expected results at various points on each part.

This test includes total, static, and dynamic pressure, from which velocity can also be collected, and ride height measurements.

Test Plans:

https://docs.google.com/document/d/1GJ5_2uk6wbEsqQ45TdryyAFupXVu1gpS/edit?usp=sharing&ouid=109021406217322604834&rtpof=true&sd=true

Radiator MFR Study

<u>Goal:</u> The objective of this study is to find the mass flow rate of air that goes through the radiator. This theoretical MFR will be the standard for CFD simulations.

- c_p: specific heat of the coolant (water) = 4184 J / ℃
- Q: heat transfer rate for radiator, in watts (derived from the heat rejection based on the engine)
- $\Delta T = (T_{in} - T_{out})$: change in temperature of coolant
- T_{in} : Temperature of coolant through the inlet of the radiator
- T_{out} : Temperature of coolant at the outlet of the radiator
- $\dot{m}$ = Mass flow rate of the coolant

<u>Powertrain Equations:</u>

$Q = \dot{m}c_p(T_{in} - T_{out})$

$\dot{m}_{air} = Q\ (c_{p_{air}}(T_{in} - T_{out}))$

We want the mass flow rate of air, not coolant.

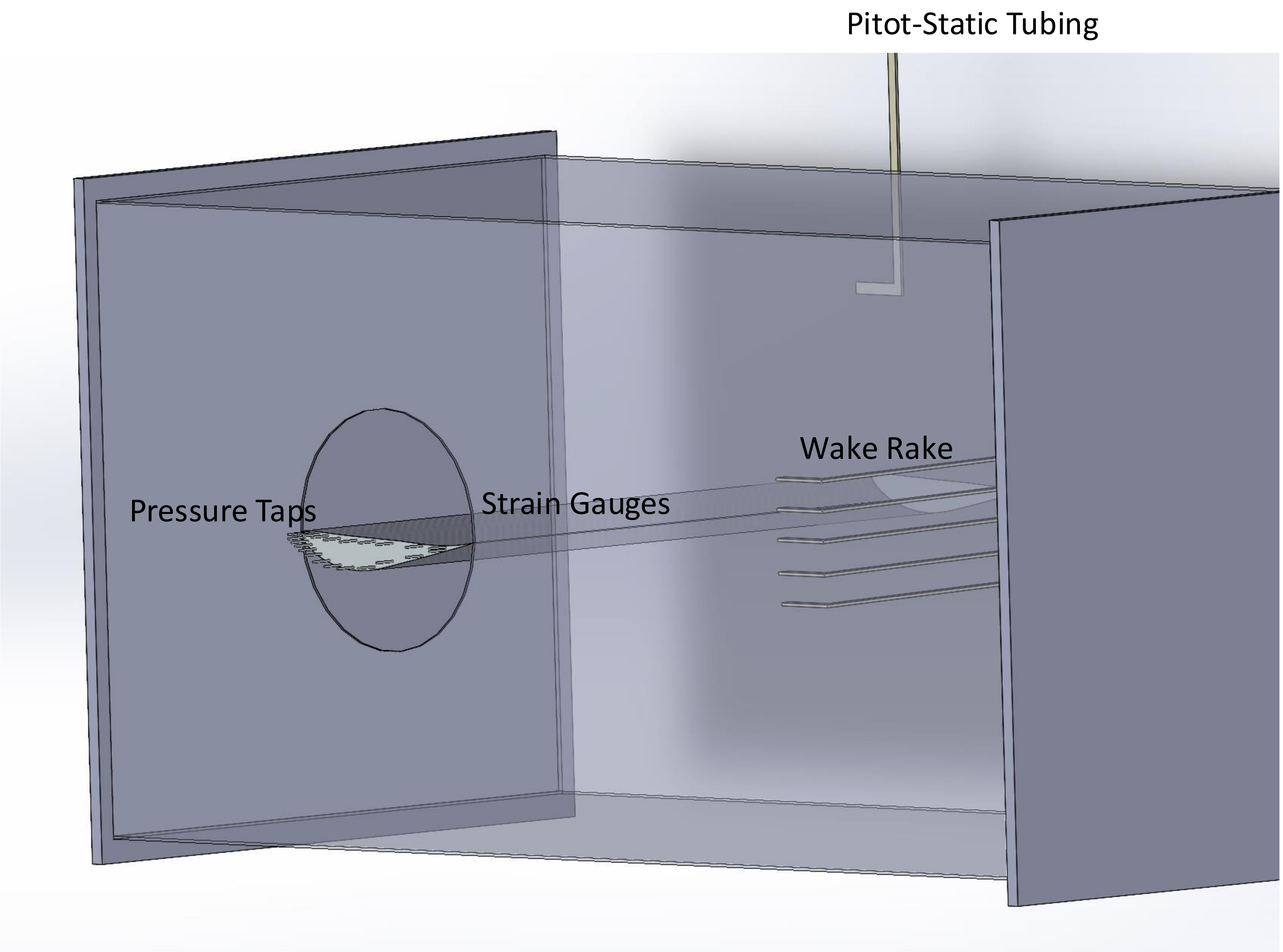
<u>Question: Is there a way to find temperature change of **air** going in and out of radiator faces?</u>

Aerostructures Wind Tunnel Test

- Goal: The wind tunnel testing aims to validate CFD predictions by measuring real pressure distributions and structural deflections on carbon fiber airfoils. These results will justify ply count selection, confirm stiffness requirements, and guide future layup refinements.
- Quantifiable data from testing - Dynamic Pressure, Freestream Velocity, and Static pressure at each tap, Strain

Test Plans:

https://utexas.sharepoint.com/:w:/r/sites/ENGR-LonghornRacing/_layouts/15/Doc.aspx?sourcedoc=%7BD88D8C1D-DFEE-4F21-B615-D1B0C61B98D4%7D&file=Wind%20Tunnel%20Testing%20Stage%201%20-%20Aero%20Validation.docx&action=default&mobileredirect=true


Pitot-Static Tubing
Wake Rake
Pressure Taps
Strain Gauges