

OXFORD BROOKES RACING



Developing a Composite EV Formula Student Race Car



Coltrane Kamikura – Structures Lead

- Degree(s)
 - BSc Mechanical Engineering from Rutgers (2024)
 - MSc Motorsports Engineering from Oxford Brookes (2025)
- Experience(s)
 - Jobs
 - 2023 SpaceX Starship Intern
 - 2024 ASG Programming Engineering Intern
 - FS/FSAE
 - 2020 Rutgers Powertrain Member
 - 2021-2024 Rutgers Chassis Lead
 - 2024 Rutgers Design Lead
 - 2025 Oxford Brookes Racing Structures Lead



SpaceX Starship and OBR25 Chassis, 25% lighter than OBR24.





Sean Mitchell – 1st Year Structures Member

- Degree:
 - MEng Motorsport Engineering (2029)
- Experiences:
 - 2023-2024 Promess Incorporated: Final Assembly Intern
 - 2024-Present OBR: Structures Member



Laminating the 2025 chassis.

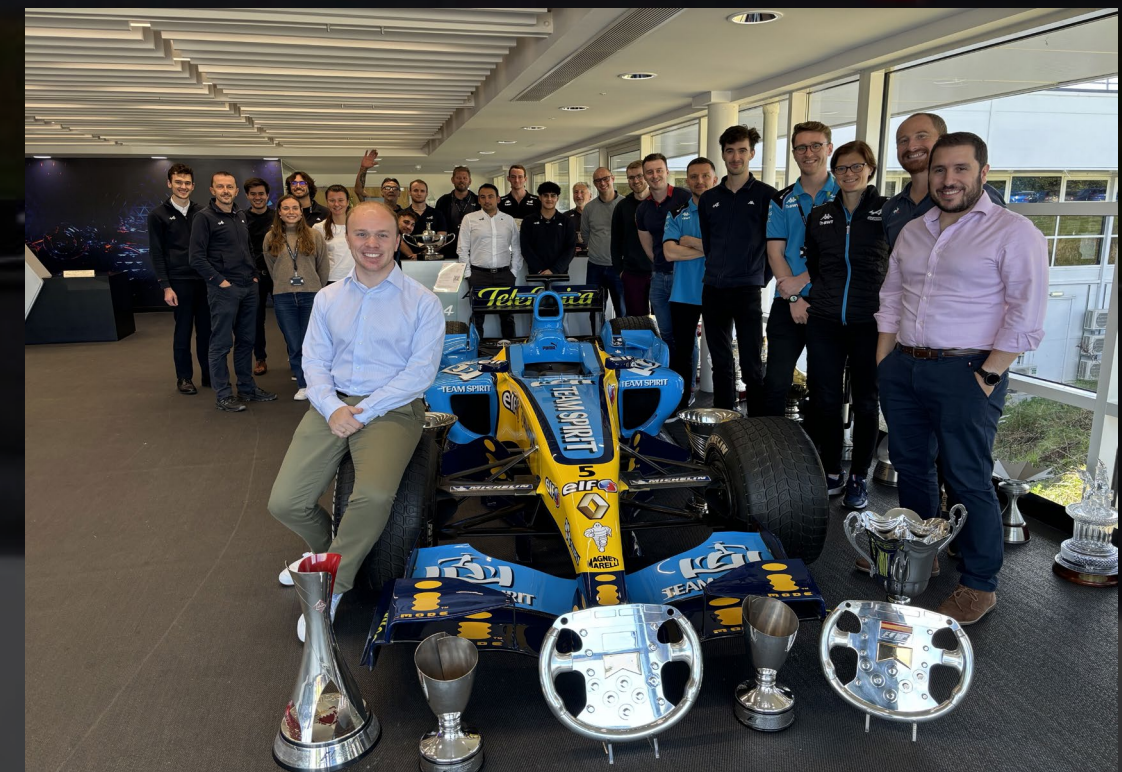


Samuel Mussett – 3rd Year Structures Member

- Degree(s)
 - Beng Mechanical Engineering (Graduating Sep 25')
- Experience(s)
 - Jobs
 - Alpine F1 Structures Intern
 - FS/FSAE
 - OBR22 Manufacturing Lead
 - OBR23 Suspension Lead
 - Technical Scrutineer at FSUK & FSCZ 24' while on placement
 - OBR25 S1 Chief Mechanical Engineer



Team success at FS Czech 23, reaching design finals!



Placement leaving photo with department!



What is Formula Student?

- Formula Student is an international engineering competition where students from over 800 universities **design, build, and compete** in formula style vehicles.
- Electric, Internal Combustion, Driverless, and Hybrid classes!



Formula Student Germany

Who is Oxford Brookes Racing?



Oxford Brookes Racing (OBR) is Oxford Brookes' Formula Student team. The team is highly international and consists of 500+ students (both PG and UG) from over 25 different countries. We are located in the heart of motorsport valley and have the highest number of graduates employed in F1 teams out of any university in the UK.



Formula Student Austria 2019



2025 Team Structure

Who is Oxford Brookes Racing?



Starting in 2019 entering concept, we began the transition from ICE to EV, due to the increased points scored at competition per GBP spent. Backing by the universities interest in EV powertrains and battery cell research aided in the switch.

Our 2025 competitor is a 4WD 80 kW electric vehicle with a full carbon tub, in-hub epicyclic gearboxes, torque vectoring, a 546V battery pack, and much more.



2024 FSUK Competition Team

MISSION STATEMENT



To develop **versatile graduates** able to excel in a **high-performance team.**

To build a **multi-year legacy** as a competitive, high-quality team.



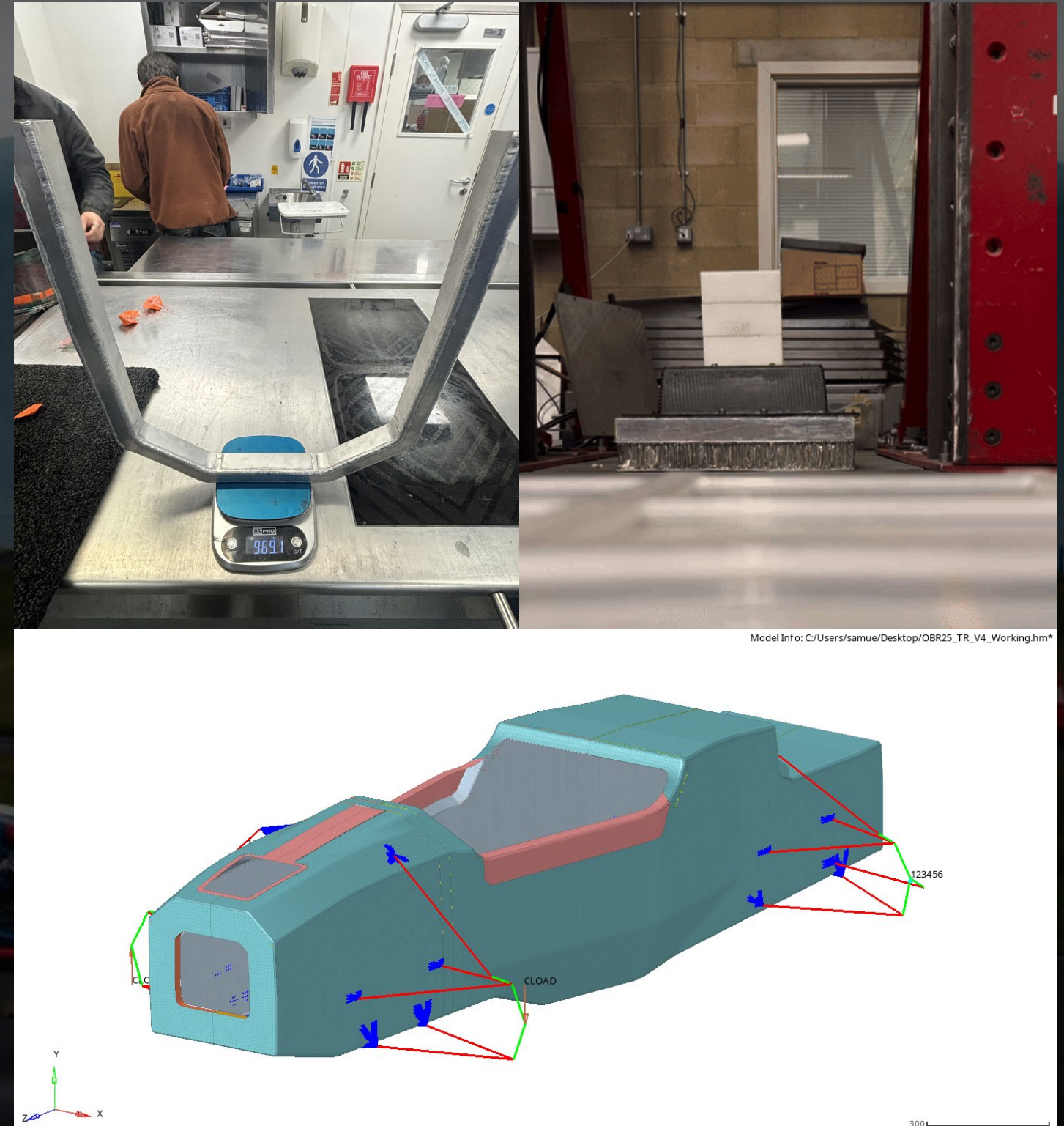
Team Goals

1. To win FSUK
2. Top 10 Finish at FSCz
3. Resolve all previous season faults
4. 4x Simulated: Scrutineering Sessions
Dynamic Event Days
Static Event Days



1. Structures Section

- Brainchild of @Samuel Mussett
- Developed in the summer of 2024 to bring the team closer to industry, generating versatile graduates.
- Recognised students were graduating without an appreciation for applied structural theory in the motorsport discipline.
- Structures would analyse and report on all the CAT-A mechanical parts on the car, composite or metallic.
- Goals:
 - Standardised in-depth hand analysis
 - Standardised Factor of Safety targets
 - Remove mass
 - Bring FEA methods to students
- Overall team goal to lose 10% of mass (24.8 kg) for 2025



2025 rectangular front hoop, Cranfield impact testing, and torsional simulation.



2. Read the Regulations

- Three of our biggest rules:
 - If an asymmetrical lay-up is used in the primary structure, the thinner skin must have a thickness of at least 40 % of the thicker skin or 1 mm whichever is lower. [T3.4.4]
 - For any laminate in the primary structure and/or the TSAC, the maximum weight content of parallel fibres, relative to the weight of all fibres in the laminate, is 50 %. All fibres laid within any orientation +/-10° count as parallel in this case. [T3.4.3]
 - (During shear test) [...] If an asymmetrical lay-up is used, the thinner skin must face the punch. [T3.5.10]

Fibre Direction	Fibre Weight (gsm)				Total Fibre Weight (gsm)	Weight % of Parallel Fibres
	0	90	+45	-45		
FBH	735	735	600	600	2670	27.53
FBHS	280	0	172.5	172.5	625	44.80
FHB	280	0	172.5	172.5	625	44.80
SIS V	420	0	312.5	312.5	1045	40.19
SIS H	420	0	312.5	312.5	1045	40.19
SHB	280	0	172.5	172.5	625	44.80
MHBS	280	0	172.5	172.5	625	44.80
ACPS V	620	200	312.5	312.5	1445	42.91
TSPS REAR	620	200	312.5	312.5	1445	42.91
ACCUM. FLOOR	620	200	312.5	312.5	1445	42.91
REAR ROCKER SUPPORT	280	0	172.5	172.5	625	44.80

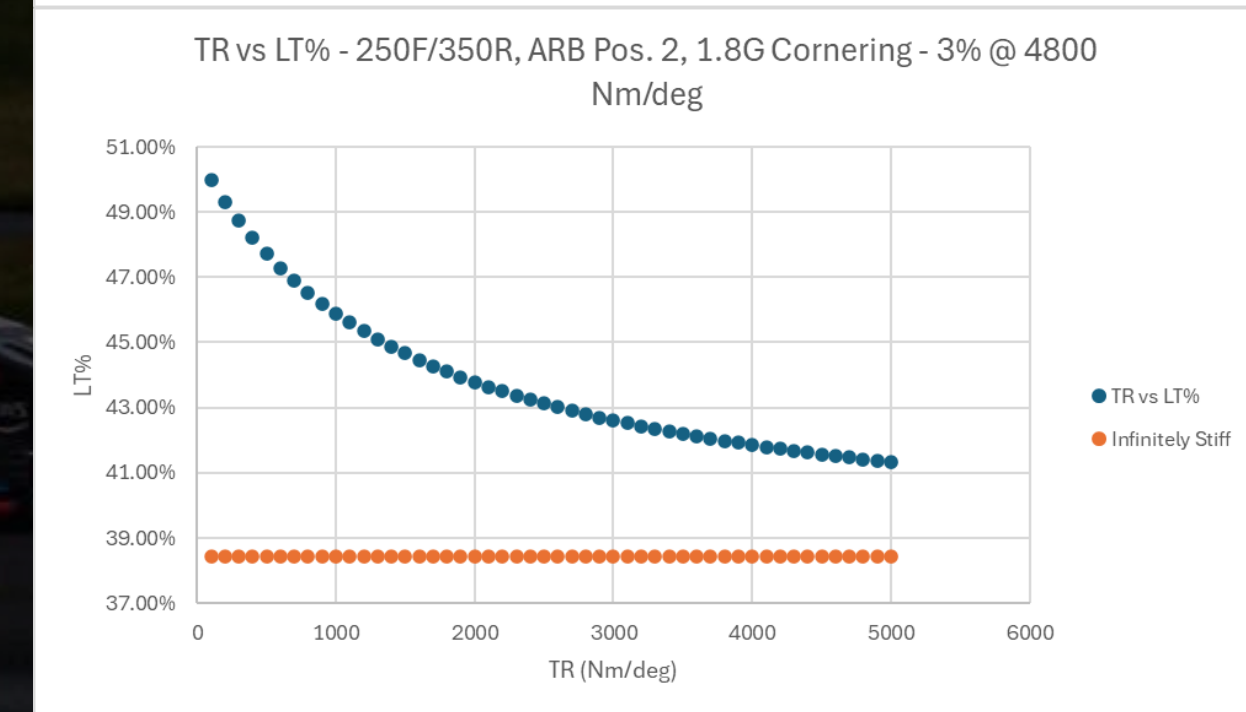
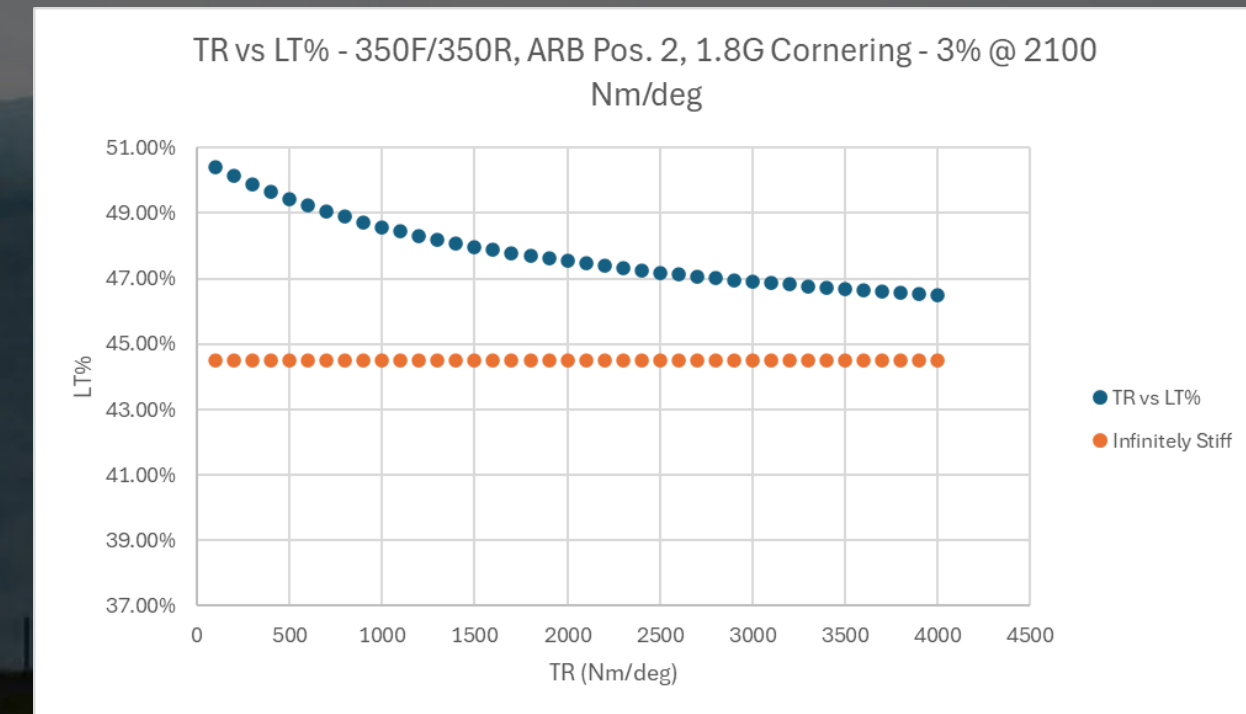


Proof of fibre directions <50% and the differences in skin thickness of the front bulkhead.



3. Plan

- Design your laminate to meet regulations and structural requirements
 - Longitudinal, Horizontal Bending
 - Horizontal Lozenging
 - Torsion
 - Multiple spring rates
- Longitudinal fibres and fibres that cross between opposite corners (e.g. FR → RL) are your best bet to maximise performance for mass.
 - 45s chosen as torsional direction for manufacturing and material usage efficiency
- Torsional rigidity goal <3% difference in lateral load transfer % when compared to a fully rigid structure



Torsional rigidity vs. lateral load transfer % for multiple spring rates.

4. Test and Retest

- 2 tests are required for all composite parts:
 - 3 Point Bend
 - 25 mm Shear
- Driver harness tests are completed to 15 kN+ based on regulations
- Shear is the hardest to pass, as certain areas need a strong and thick laminate
 - Side impact areas – 7.5kN
 - Front impact area – 4kN
- Struggles with shear test led to 6082-T6 Al front bulkhead area for minimal mass



Shear testing (top left), tear out testing (top right), skin buckling (bottom left), and 3PB testing (bottom right)



5. Prove Equivalency

- FSUK and FSCz allow for use of geometry in stiffness calculations, with testing results from flat panels – allows for lighter parts
 - Maximising usage of this allows for significant mass reduction
- All laminate areas must be equivalent to a certain # of steel tubes
- Flat panel skin calculations:
 - Ultimate Tensile Strength
 - Youngs' Modulus
 - Moment of Inertia
- Inserts
 - Perimeter shear based on previous testing data
- With aggressive mass reduction plans, retesting will likely be required!

T3.2.1 Table 4 shows the minimum requirements for the members of the primary structure if made from steel tubing.

Item or application	Minimum wall thickness	Minimum cross sectional area	Minimum area moment of inertia
Main and front hoops, shoulder harness mounting bar	2.0 mm	173 mm ²	11 320 mm ⁴
Impact structures, front bulkhead, roll hoop bracing, driver's restraint harness attachment (except as noted above)	1.2 mm	119 mm ²	8509 mm ⁴
Front bulkhead support, main hoop bracing supports	1.2 mm	91 mm ²	6695 mm ⁴

Table 4: Minimum Material Requirements

Rule T3.2.1: The steel tube equivalency that is required to meet for each structure of the chassis

Front Bulkhead		Enter construction type		Composite only	
Material Property	Baseline	Your Tube	Your Composite	Your Total	
Material type	Steel	Steel	Other 2		
Tubing Type	Round	Round	NA		
Material name /grade	Steel	Steel	FBH		
Youngs Modulus, E	2.00E+11	2.00E+11	3.31E+10		
Yield strength, Pa	3.05E+08	3.05E+08	1.38E+08		
UTS, Pa	3.65E+08	3.65E+08	1.38E+08		
Yield strength, welded, Pa	1.80E+08	1.80E+08	N/A		
UTS welded, Pa	3.00E+08	3.00E+08	N/A		
UTS shear, Pa	2.19E+08		1.22E+08		
Bulkhead Width (tubes only)		400			
Bulkhead Height (tubes only)		350			
Number of tubes	2	2			
Tube OD, mm	25.4	25.4			
Wall, mm	1.6	1.6			
Thickness of panel, mm			24.63		
Thickness of core, mm			20		
Thickness of inner skin, mm			1.5		
Thickness of outer skin, mm			3.13		
Panel height, mm			160		
OD, m	0.0254	No tubes			
Wall, m	0.0016				
I, m ⁴	8.51E-09		1.54E-07	1.54E-07	
EI	3.40E+03		5.94E+03	5.94E+03	174.6
Area, mm ²	239.3		740.8	740.8	NA
Yield tensile strength, N	7.30E+04		1.02E+05	1.02E+05	140.4
UTS, N	8.73E+04		1.02E+05	1.02E+05	117.3
Yield tensile strength, N as welded	4.31E+04		1.02E+05	1.02E+05	238.0
UTS, N as welded	7.18E+04		1.02E+05	1.02E+05	142.8
Max load at mid span to give UTS for 1m long tube, N	1.96E+03		6.91E+03	6.91E+03	353.3
Max deflection at baseline load for 1m long tube, m	1.20E-02		6.86E-03	6.86E-03	57.3
Energy absorbed up to UTS, J	1.17E+01		8.38E+01	8.38E+01	715.1
Perimeter shear, N (monocoques only)	4.93E+05		N/A	5.75E+05	116.5

Calculations conducted to prove equivalency (front bulkhead)

6. Build

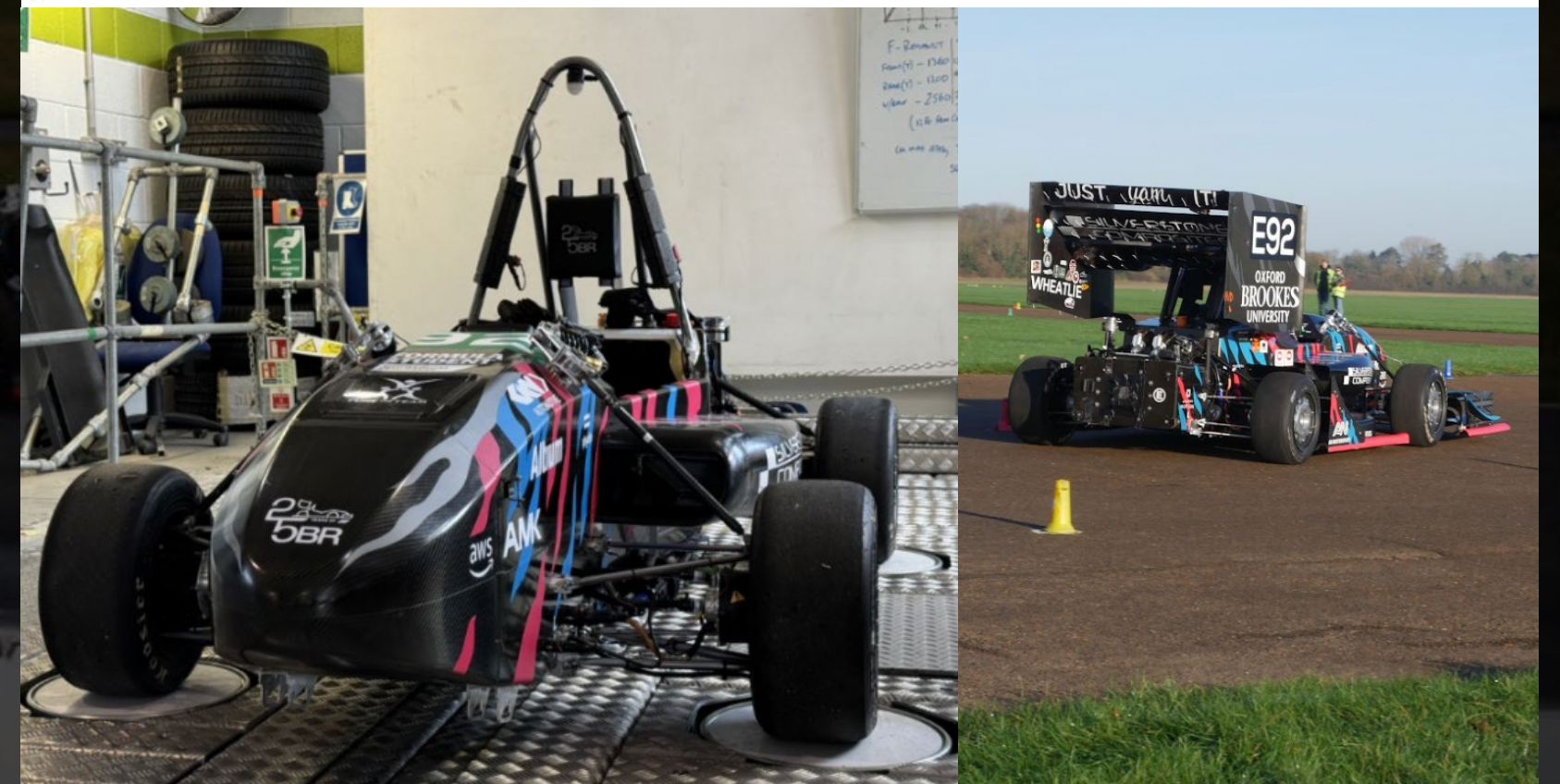
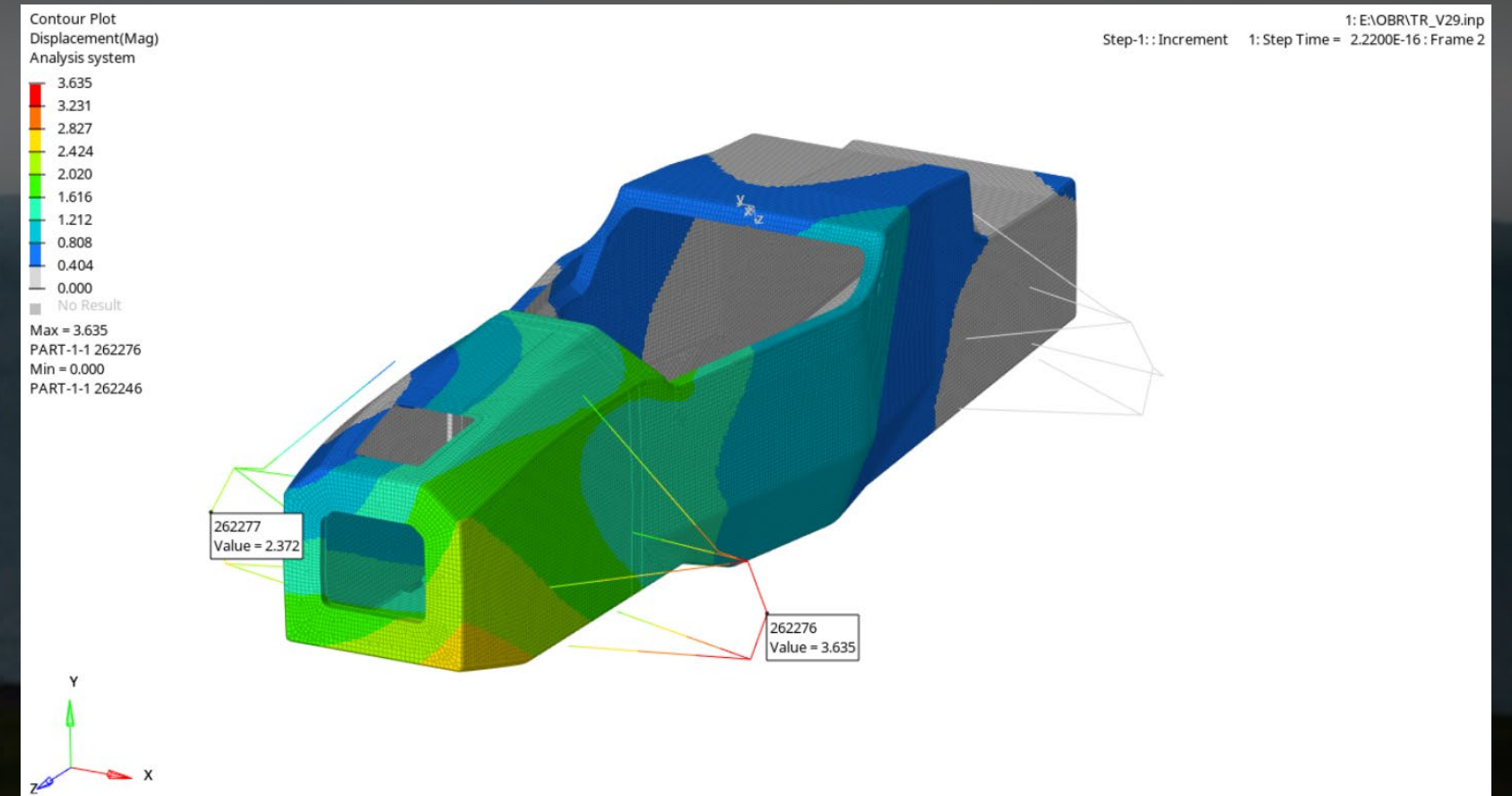
- 3 stage cure:
 - Outer skin
 - Core
 - Inner skin + joining
- Fibres used include T800, C245T and M55J donated by Silverstone Composites.
- Female mould is made of high temp tooling carbon to try to match the CTE between materials.
- Lack of experience laminating the unidirectional fibres led to a 25% longer manufacturing time.



Lamination and bagging of chassis, complete and trimmed chassis w/ those who built it.

7. Validation

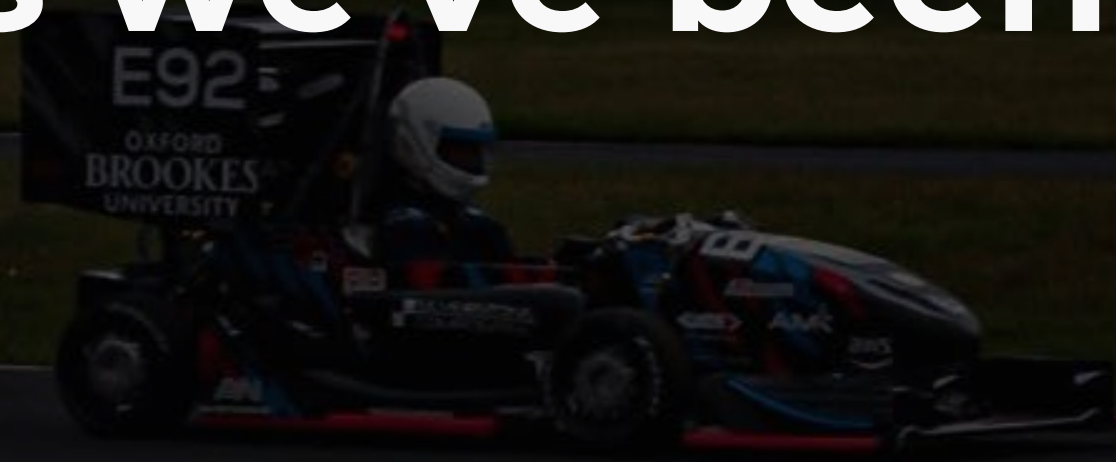
- 22.5 kg final mass exceeding our 24 kg target!
- Simulation of torsional rigidity based on industry standards and knowledge gained from Trimech.
 - 4438 Nm/deg
- Half twist method mimicked on Brookes' 4 post rig in first week of June 25'
- Testing, testing, testing – 200 km testing target allows for lots of validation on all components.



Torsional simulation, 4 post rig half twist testing, and testing on track.

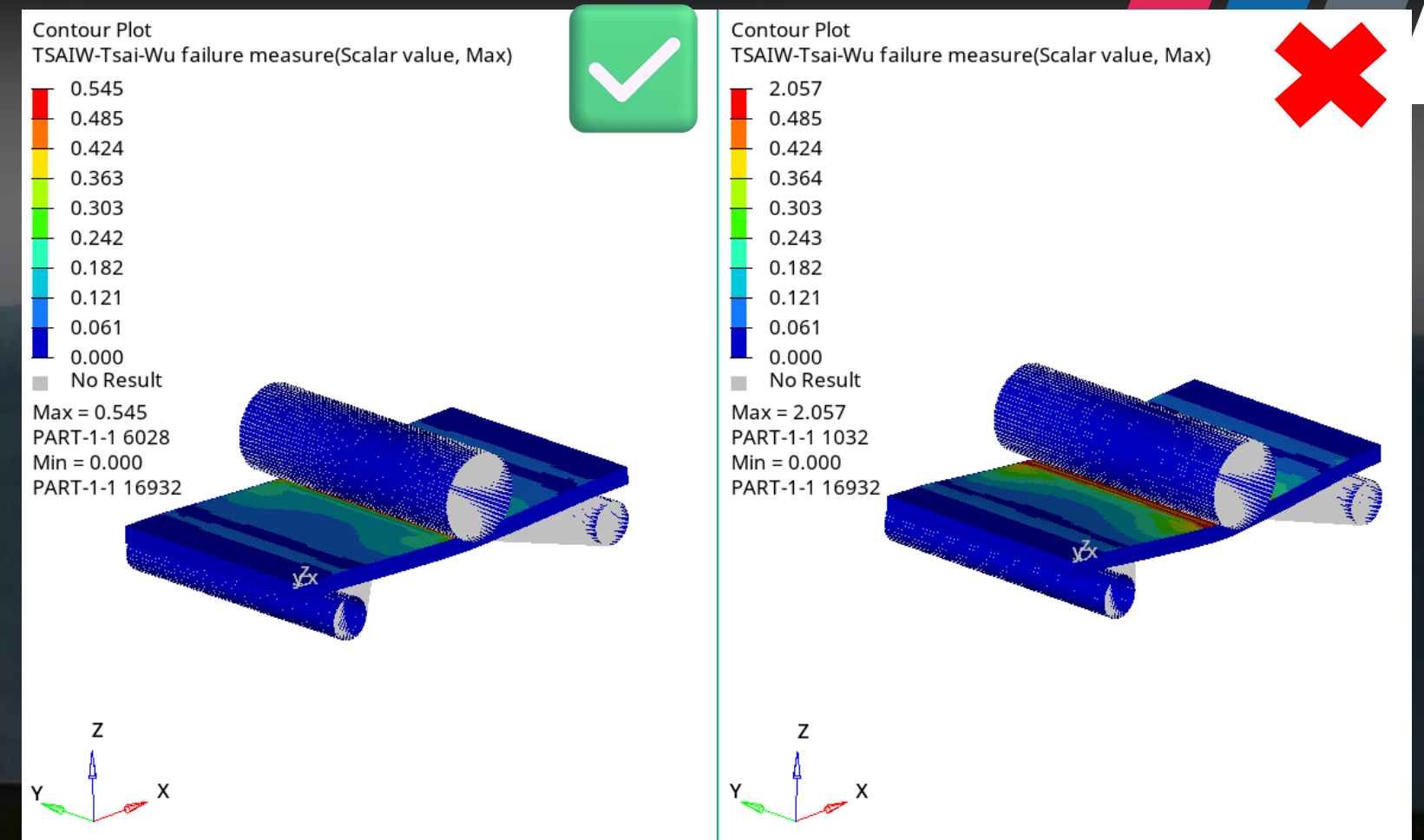


Other models we've been working on...



3 Point Bend Model

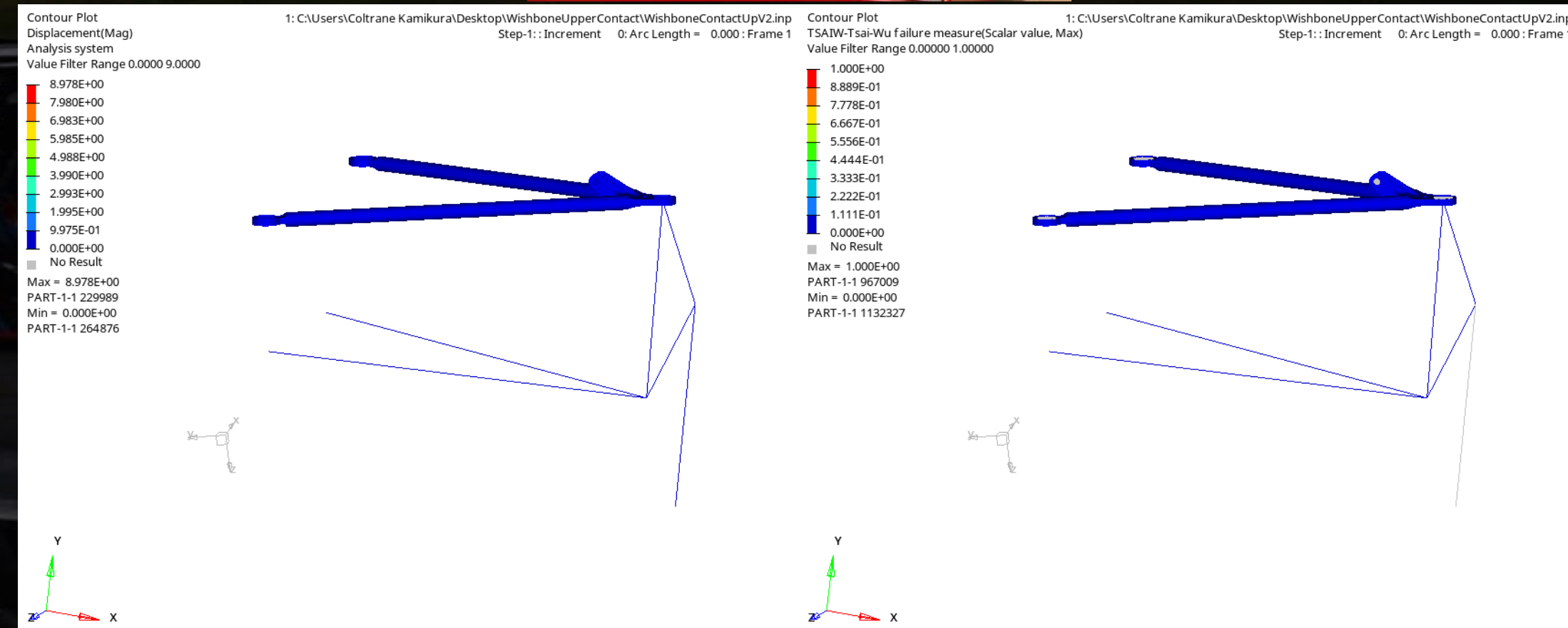
- Purpose:
 - Mass saving
 - 50% (12 hr) reduction in turnaround time for laminate design/redesign
- Loads/Constraints:
 - Loaded by load applicator and supported by support tubes as in real world testing.
 - Non-linear geometry is used to better understand buckling, stiffness, and displacement before failure
- Mass Saved (Chassis):
 - Old Mass: 29.4 kg
 - Measured New Mass: 22.5 kg (-7.1 kg)



3PB model and real-world test.

Wishbones

- Purpose:
 - Reduce unsprung mass
 - Understand fatigued bond capability
- Loads/Constraints:
 - Vehicle dynamic loads are estimated by hand based on grip limits and applied into the wishbones from the contact patch
 - Wishbones are rotationally free at clevis points on chassis
- Predicted Mass Saved:
 - Old Mass: 2.3 kg
 - New Mass: 1.2 kg (-1.1 kg)



Displacement (left), Tsai Wu index (right), and testing of bond method for upper wishbones.

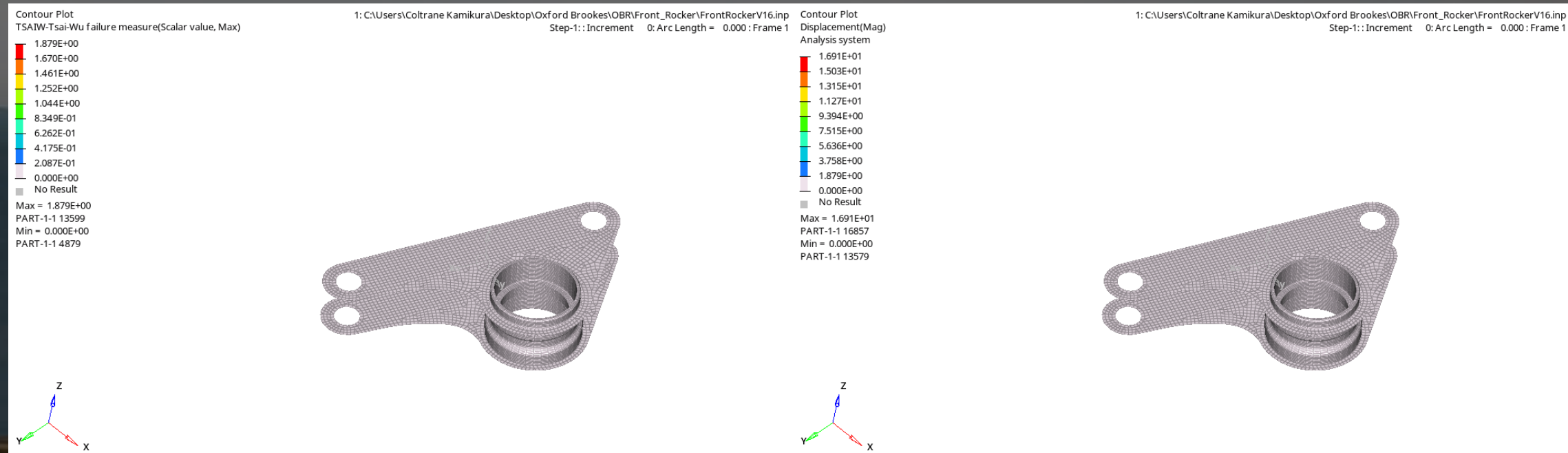
Rockers



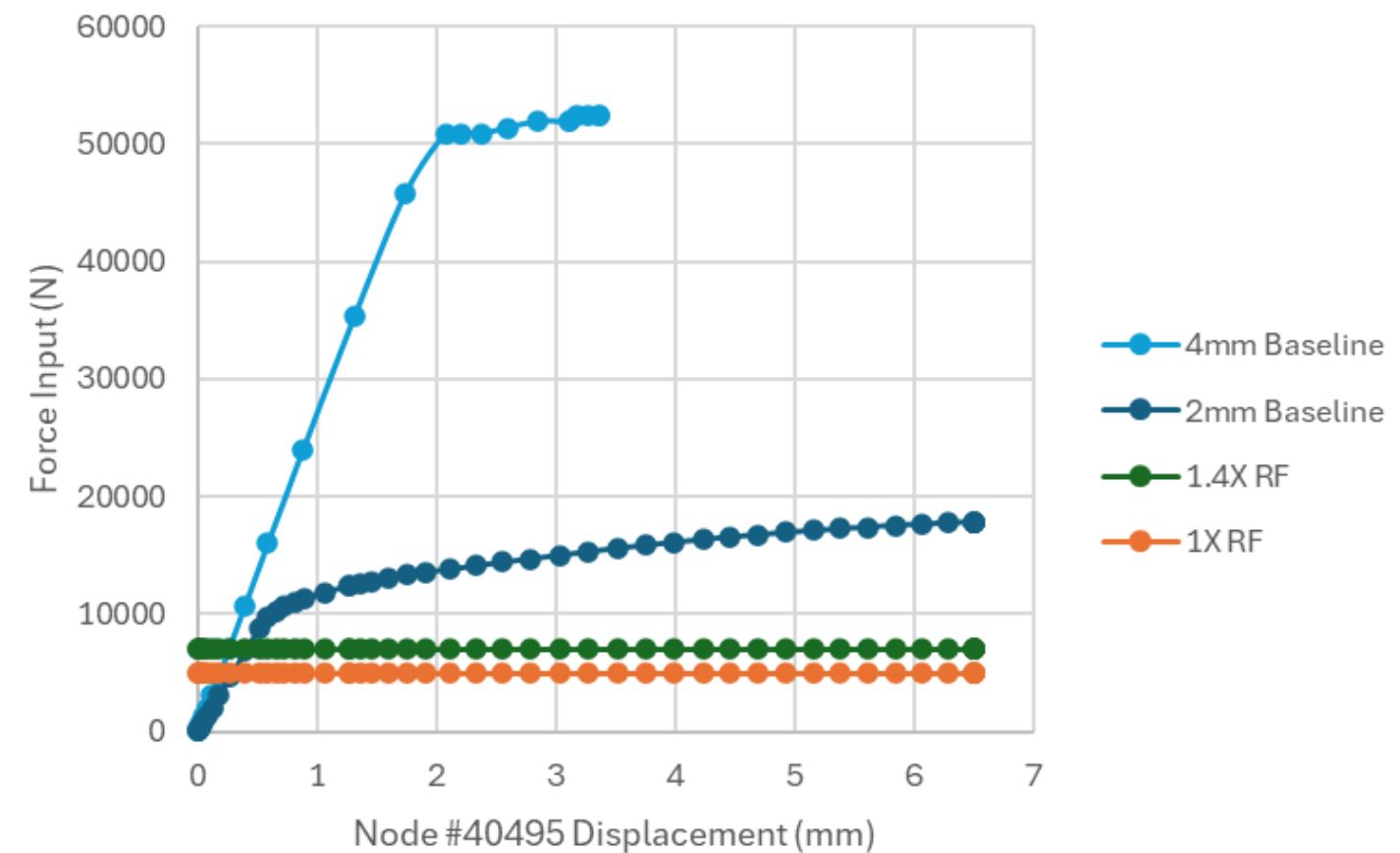
- Purpose:
 - Mass saving
 - Investigate composite fatigue with student-built composites

- Loads/Constraints:
 - 3G bump load is simulated
 - Constrained by a fully compressed damper (rigid)
 - Non-linear geometry is used to better understand buckling modes

- Predicted Mass Saved:
 - Old Mass: 510g total
 - New Mass: 257g total (-253 g)



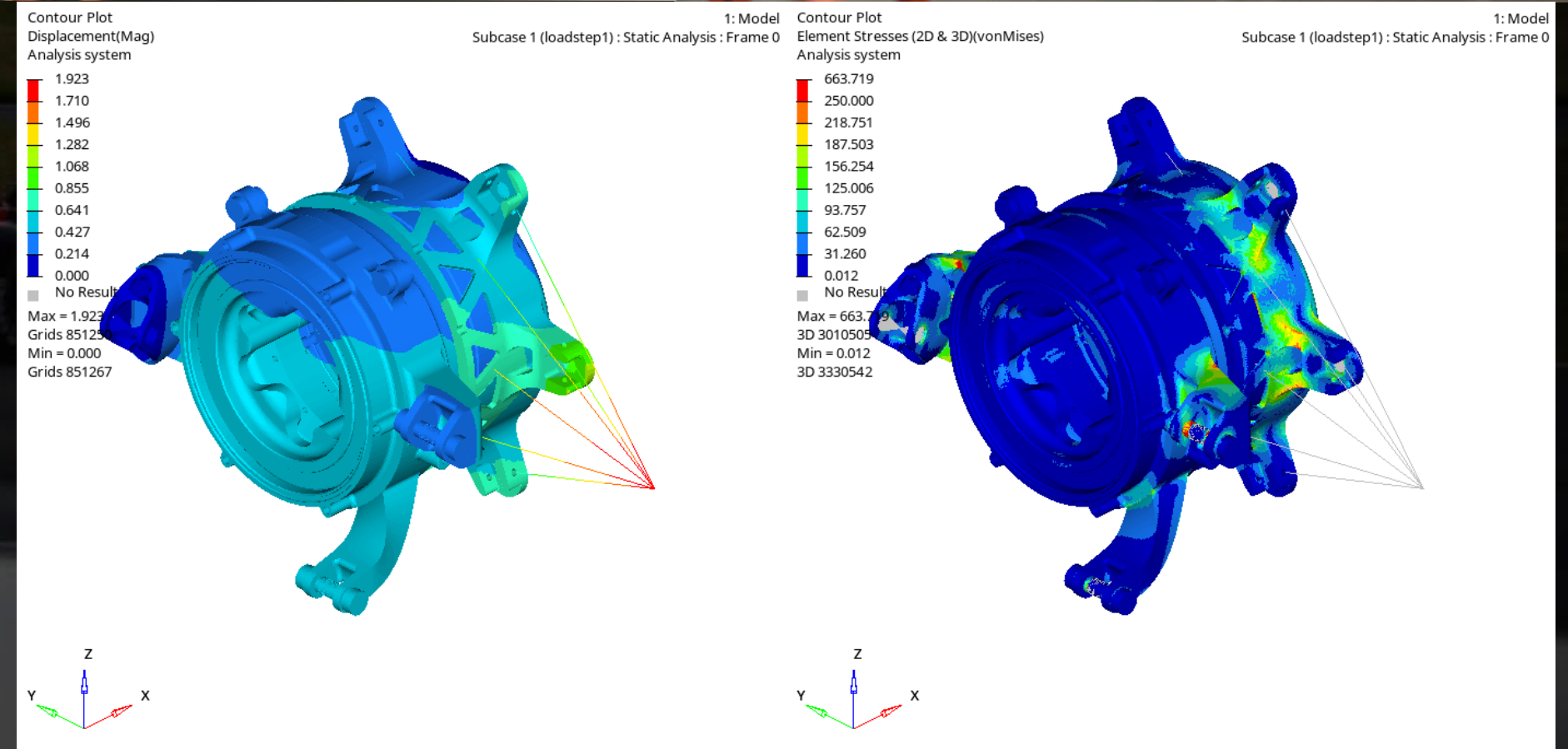
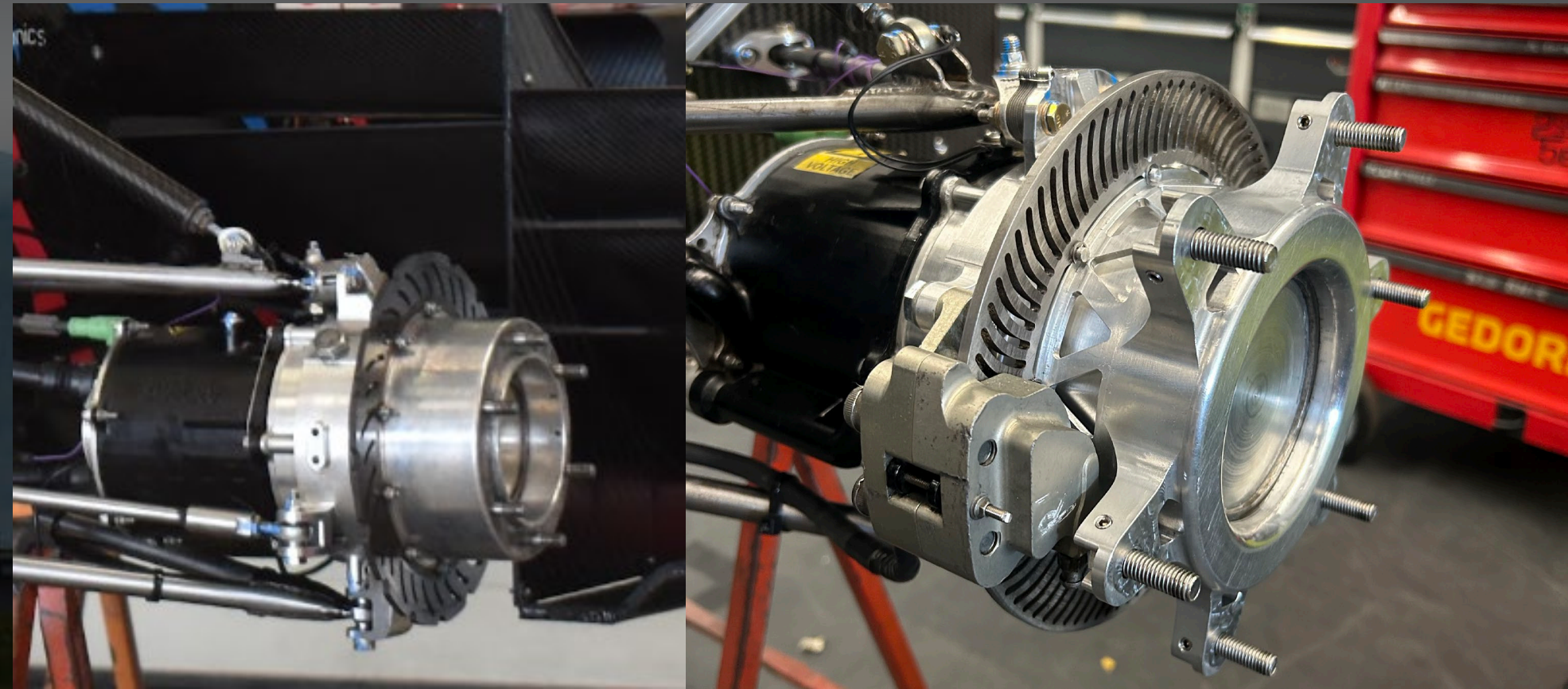
Riks Method Stiffness Study, Front Rocker, 3G Bump



Tsai Wu (left), displacement (right), and stiffness of front rockers.

Uprights and Hubs

- Purpose:
 - Remove mass
 - Alter wheel mounting mechanism by reducing parts
- Loads/Constraints:
 - Forces applied at contact patch
 - Constraints applied at the chassis side of wishbone geometry (rigids)
 - Simulation of load into the upright mounts including fidelity of fastener behaviour
- Mass Saved:
 - Old Mass: 864g each (upright)
 - Measured New Mass: 707g each (-157 g)



Upright and hub assembly on the car and an FE model.

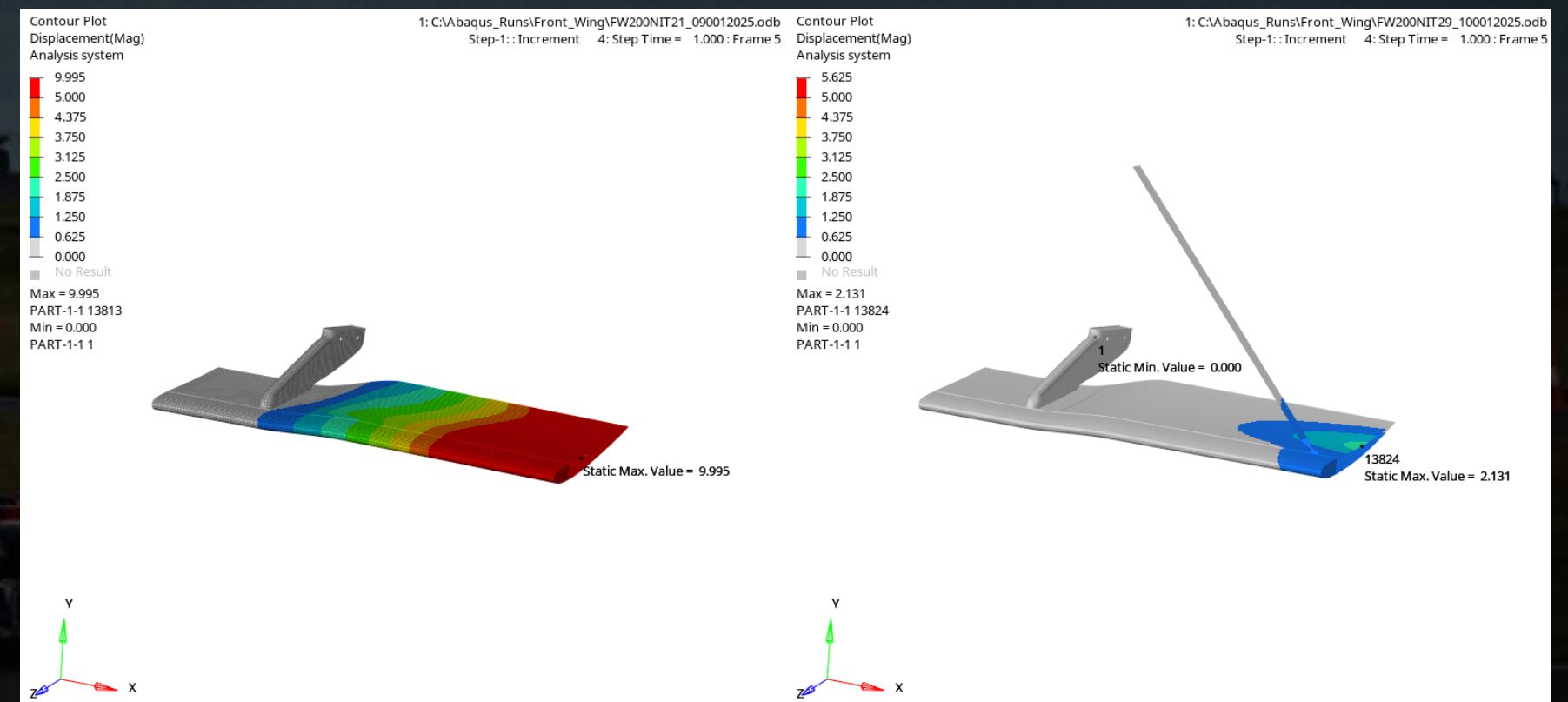


Front Wing

- Purpose:
 - New Front Wing for this season
 - Previous Wing on car since 2019'
 - Mass Saving
 - Full car downforce increase
 - New VD requirement for Aero Balance Adjustment
- Loads/Constraints:
 - Half Wing with asymmetric BC's
 - Pushdown compliance & strength scrutineering test
- Predicted Mass Saved:
 - Old Mass: 6kg
 - New Mass: 3.8kg (-2.2kg)

T8.3 Aerodynamic Devices Stability and Strength

- T8.3.1 Any aerodynamic device must be able to withstand a force of 200N distributed over a minimum surface of 225 cm² and not deflect more than 10 mm in the load carrying direction.
- T8.3.2 Any aerodynamic device must be able to withstand a force of 50 N applied in any direction at any point and not deflect more than 25 mm.

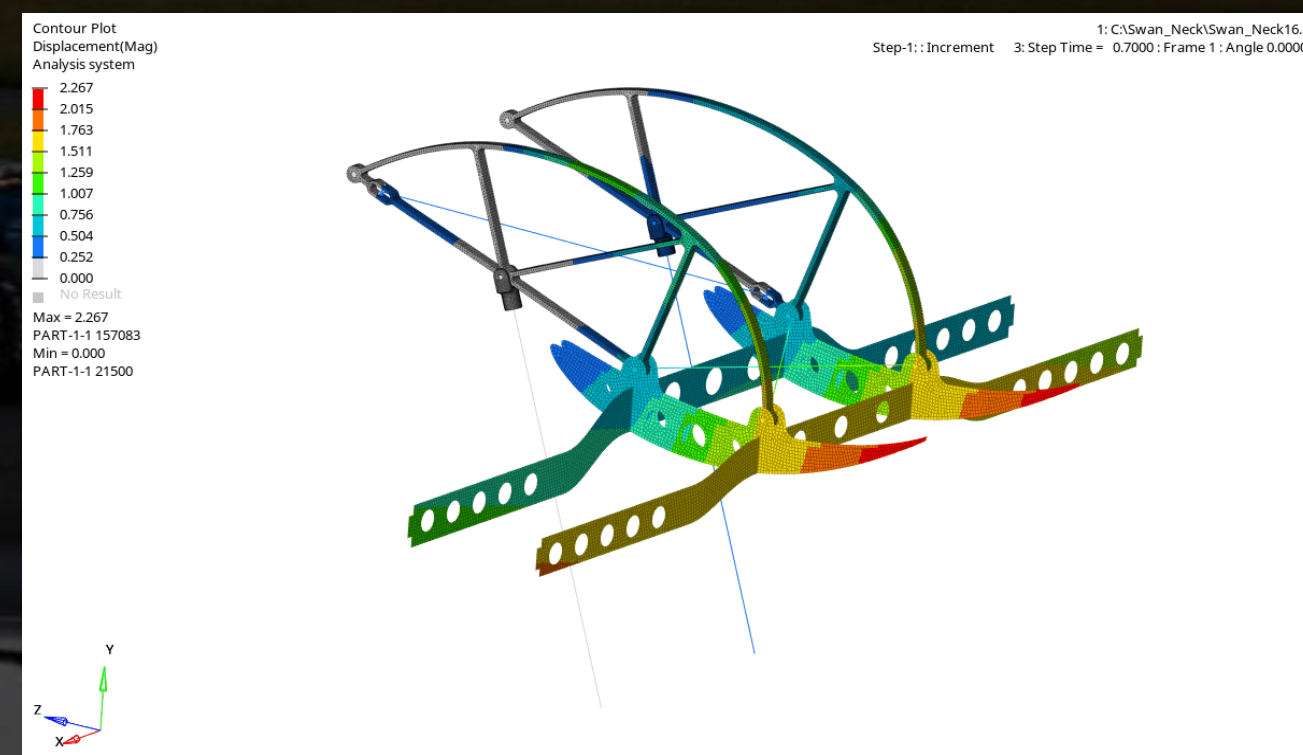
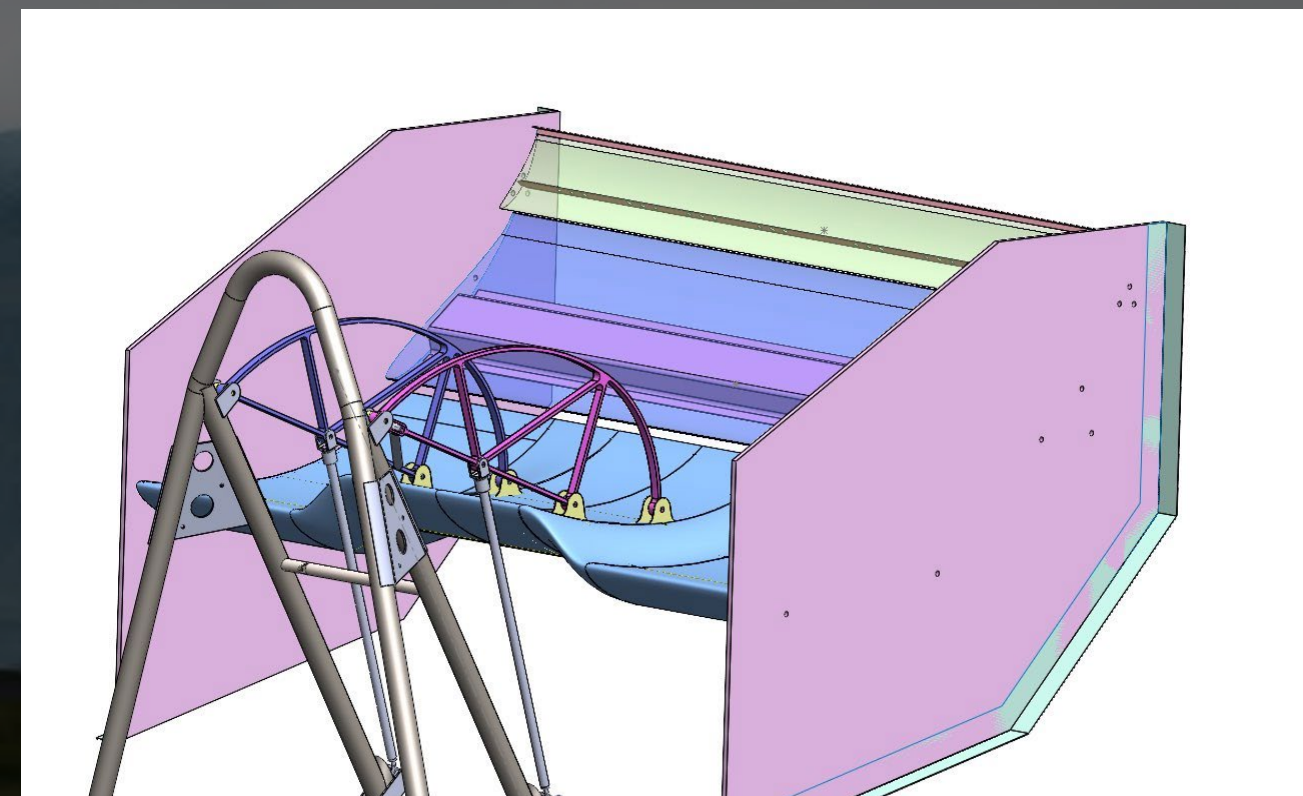


FW Deflection without tensioner (left), with tensioner (right)



Rear Wing

- Purpose:
 - Mass Saving
 - Full car downforce increase
 - Z-Cross Bar Integrated
 - Rotation Control
- Loads/Constraints:
 - Pushdown compliance & strength scrutineering test
 - Lateral G Loading
- Predicted Mass Saved:
 - Old Mass: 7.3kg
 - New Mass: 4.7kg (-2.6kg)



RW Full CAD (Top), FEA Stiffness Plot (Bottom)



Thank you to TriMech for their support!

