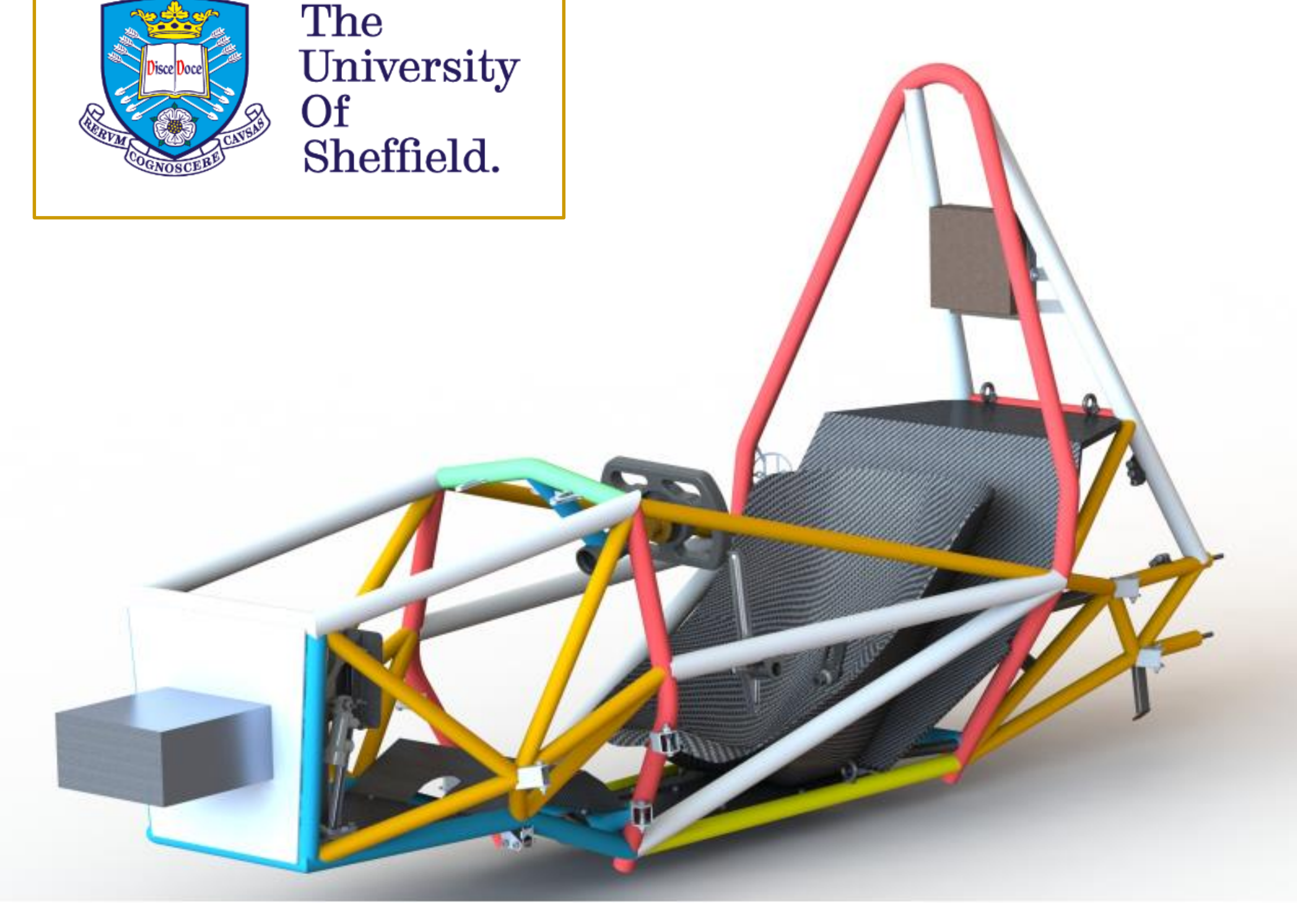
GENESIS

SHEFFIELD FORMULA RACING

White Paper

The University Of Sheffield.



WHO ARE WE?

Sheffield Formula Racing (SFR) is the University of Sheffield's Formula Student team. Run by the IMECHE, Formula student is a competition in which teams from universities across the world design build and race a single seat race car. SFR are a close-knit group of 50 dedicated undergraduate engineers who design and build a formula racing car outside of regular studies. The team was founded in 2009, and completed its 11th year of competition this July. Each year SFR's innovative engineers seek to constantly develop engineering design skills and improve the quality of the car to better the results each year.

The entire process, from design through to racing, is completed and managed by members of the team. Below you can see our project management hierarchy to ensure our aims and objectives can be achieved.

Tel +44(0)1926 889300
Email: info@grm-consulting.co.uk
WWW.GRM-CONSULTING.CO.UK WWW.TRUFORM-OPT.COM WWW.ROBOTBIKE.CO

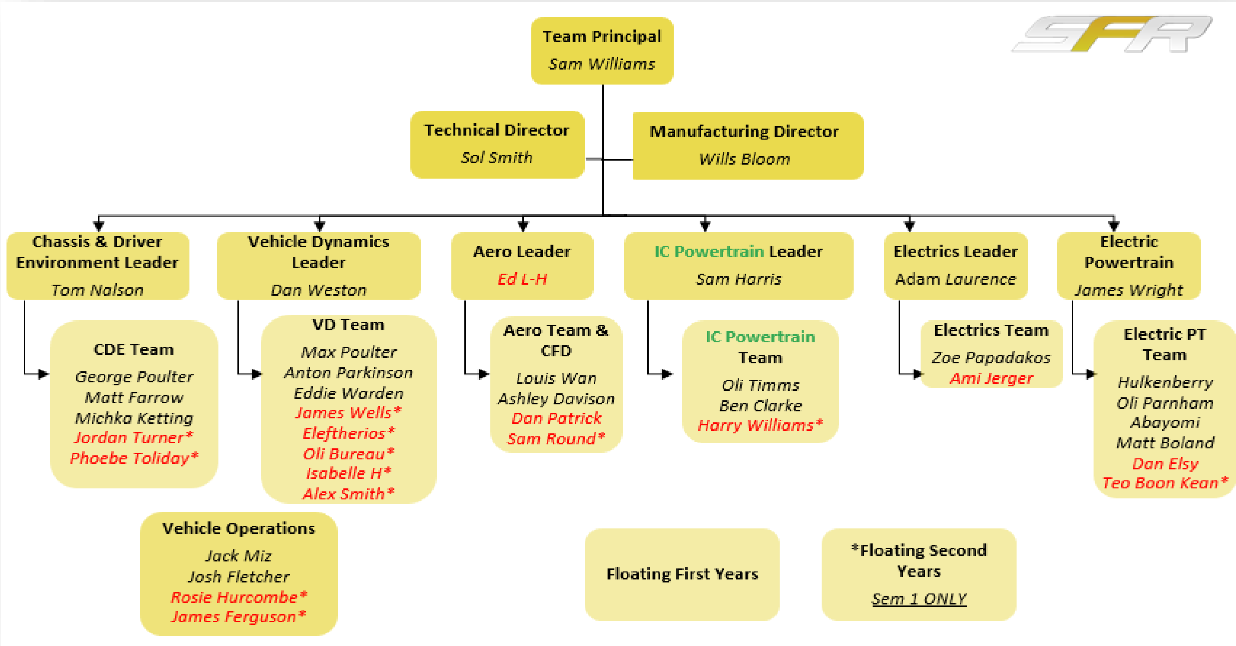


Figure 1: Primary Roles

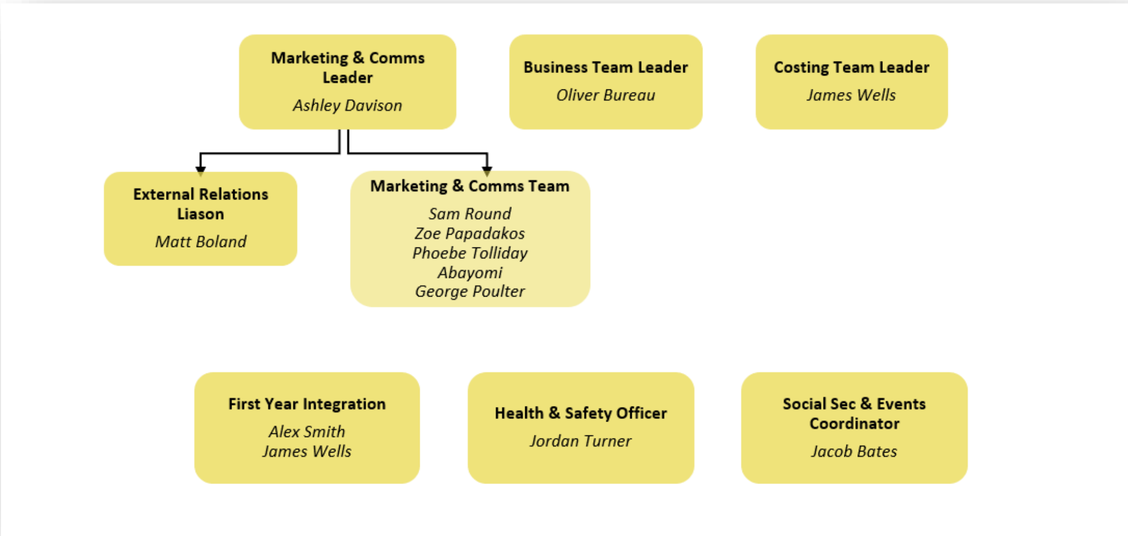


Figure 2: Secondary Roles

2020 – 2021 Aims & Objectives

Shortly after the UK went into lockdown, Formula Student (FS) unfortunately cancelled all competitions, worldwide. As such, we were unfortunately unable to attend both the British and Dutch events, the latter of which was intended to be our international debut. Just prior to lockdown, we had a complete design, a full chassis and countless parts manufactured. The team was extremely disappointed not to be able to build the car – SFR11.

Our Aim: Regain top 5 FSUK team status

Objectives:

- Produce a reliable, well tested SFR11B for competition next year
- Collect as much data as possible on characteristics and specification of the car, allowing us to validate current simulation methods such as FEA, CFD and Lapsim
- Make use of the data to gain an advantage in design of a future, fully electric car that will replace the ICE and compete in a class 2 entry next year
- Work on future development projects such as a carbon fibre monocoque and carbon fibre wheel rims

GENESIS

I was first introduced to GENESIS whilst completing a year in industry at **Williams Formula One Team** within their structure department. My typical day consisted mostly of finite element analysis and hand calculations to validate and suggest improvements to a variety of designs including the chassis, suspension components and aerodynamic devices.

As I could directly see potential for the software to aid the design and development of our Formula Student vehicle, I contacted Martin Gambling in hope of securing sponsorship to use the software.

CDE Aims and Objectives

Aim: Create a system that is suitable for all drivers.

Objectives:

- Improve driver ergonomics by designing for the tallest driver
- Deliver a chassis earlier than before
- Increase engineering design and optimisation
- Better the quality of CAD and drawings produces
- Better the quality of manufactured parts
- Increase communication with other sub teams and aim to meet their requirements

Chassis

I was the 2019-2020 Chassis and Driver Environment (CDE) Leader and consequently was responsible for the design and manufacture of chassis.

For all 11 iterations of SFR we have used a steel space frame chassis design. This is mainly due to it been relatively cheap to manufacture with materials widely available and the design and analysis process been simple, compared to a composite fibre monocoque.

Arguably, the most important performance measure of a race car chassis is the hub to hub torsional stiffness. A compliant chassis effects the roll stiffness distribution between the front and rear axles and must be considered in the suspension dynamics and tuning. It also causes a time delay to the load transfer between the front and rear axles. As such, a general target stiffness between 2-10 times the roll stiffness is typically aimed for. However, with increased stiffness usually comes with increased mass at a diminishing returns rate; consequently, there is a compromise between the two.

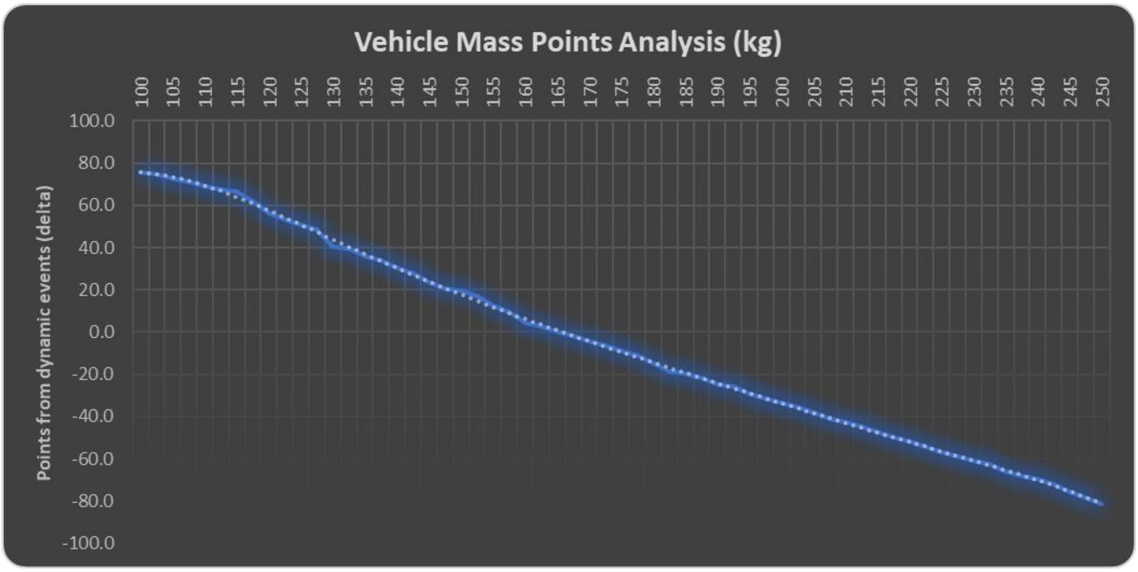


Figure 3: Lap time simulation sweep for vehicle mass effect on competition points

Lap time simulation (LTS) is a tool the heavily used to direct the design philosophy of our vehicle. Figure 3 shows how important minimising the mass of the vehicle is on scoring points in the dynamic events at competition including: Sprint, endurance, skid pad and acceleration.

Analysis

Traditionally, SFR have developed a finite element model (FEM) of the chassis using one-dimensional beam elements in ANSYS. Using a simplified torsional load case, whereby the rear bulkhead is assumed to be fixed and an arbitrary couple is applied at the front wishbones, the chassis is developed across numerous iterations via a trial and error process and engineering judgment. Figure 4 shows this load case. This process typically takes 6-10 weeks with most of time spent tuning the steel tube specifications. The design is heavily constrained by competition rules and vehicle dynamics architecture and so tube outer diameter (OD) and wall thickness are 2 parameters that can heavily influence the torsional stiffness of the chassis.

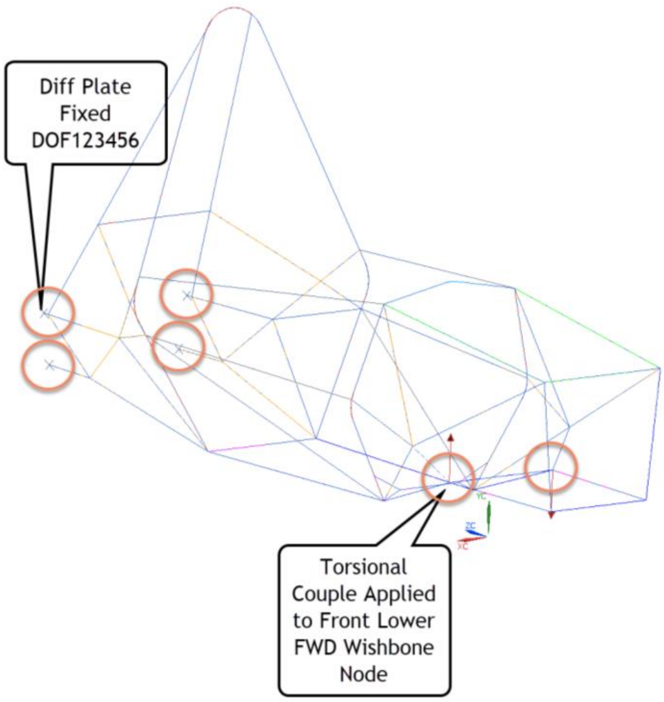


Figure 4: Torsion load case

For SFR11 we aimed to create a system that was suitable for all drivers. Consequently, this meant some chassis geometry was compromised to ensure our tallest driver could sit in a comfortable position. Along with other vehicle dynamic architecture changes, the first iteration of the SFR11 chassis was lacking in torsional stiffness relative to SFR10.

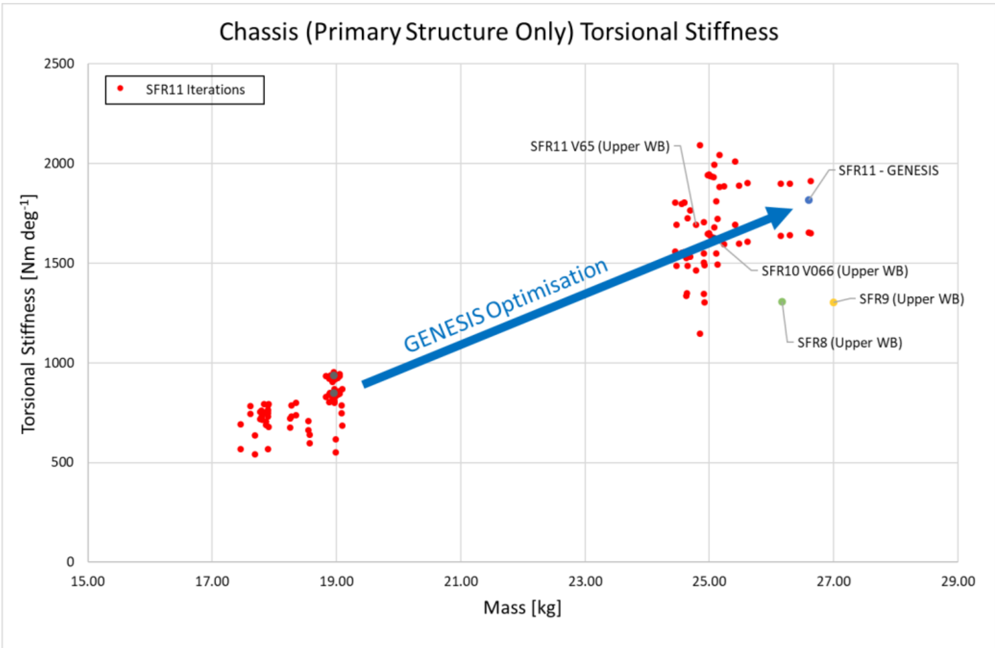


Figure 5: Chassis torsional stiffness vs mass tracker

Tel +44(0)1926 889300
Email: info@grm-consulting.co.uk
WWW.GRM-CONSULTING.CO.UK WWW.TRUFORM-OPT.COM WWW.ROBOTBIKE.CO

Figure 5 shows a plot tracking the SFR11 chassis development. Our traditional method of manually iterating geometry was first completed using a baseline tube measuring 25.4mm x 1.22mm. This is represented by the bubble of points in the lower left corner, highlighting that it has marginal impact on stiffness or mass of the chassis. Next, GENESIS was utilised to help optimise tube specifications. A sizing optimisation was performed. GENSIS was useful as it has the ability to specify groups of beam elements to specific optimisation constraints. For example, the main and front roll hoops are required by rules to have a minimum thickness of 2mm, whereas the rest of the structure can be just 1.2mm. By allowing certain groups of elements to reduce to 1.2mm, whilst others can only reduce to 2mm, are more refined design can be achieved. By setting an optimisation goal of a specified torsional stiffness, GENESIS' optimisation algorithms were successful in refining our chassis and suggesting suitable tube dimensions to achieve our design goal.

Figure 6 and Figure 7 show the results that were generated by GENESIS.

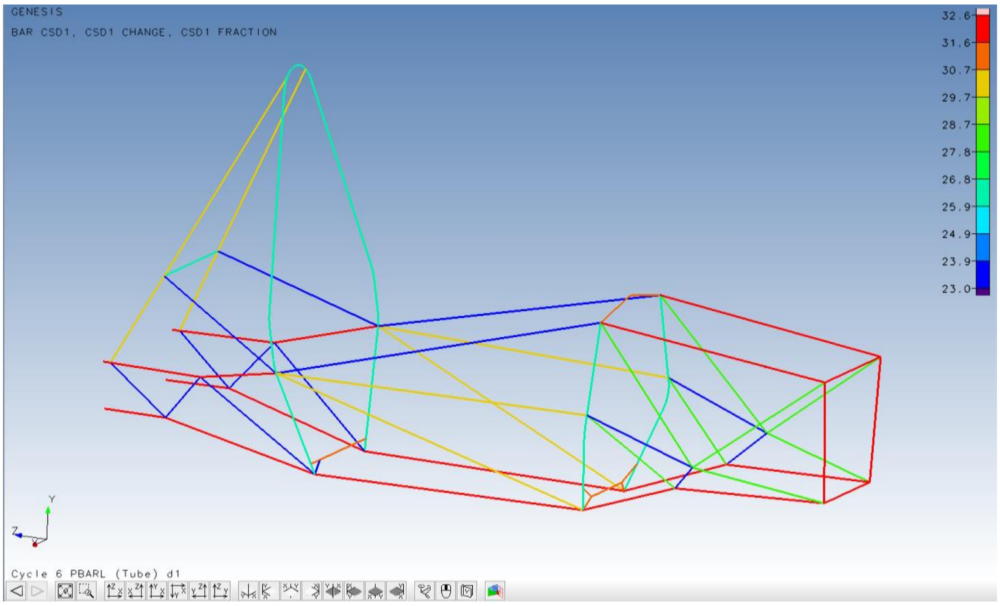


Figure 6: GENESIS results, tube OD

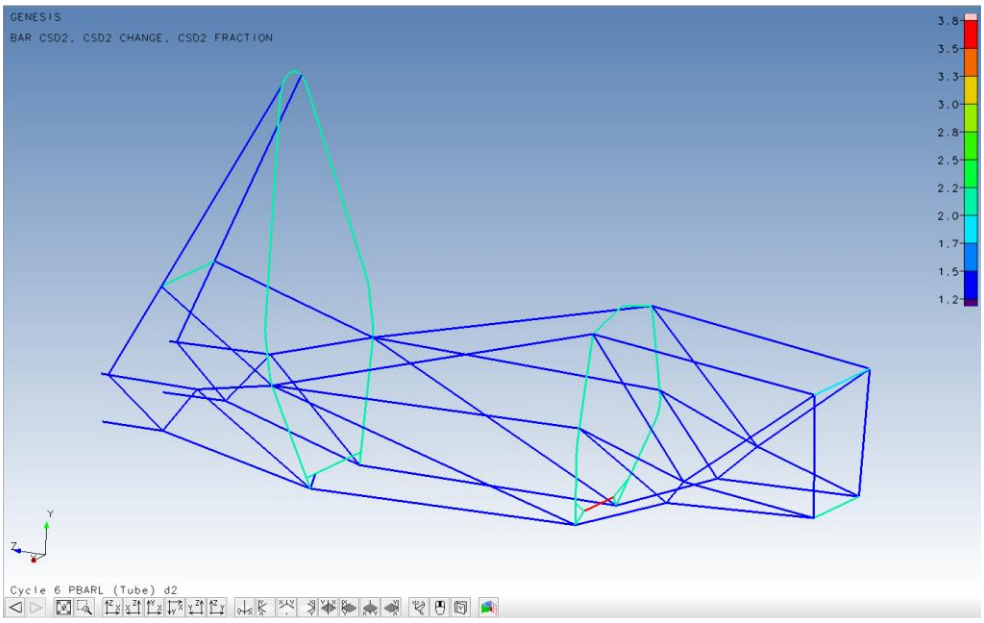


Figure 7: GENESIS results, tube wall thickness

Tel +44(0)1926 889300
Email: info@grm-consulting.co.uk
WWW.GRM-CONSULTING.CO.UK WWW.TRUFORM-OPT.COM WWW.ROBOTBIKE.CO

As highlighted by the blue arrow in Figure 5, a huge amount of iterations were removed from our traditional design process. After this, a tube supplier was consulted to find out available tube specifications. A handful more iterations were required to convert the GENESIS output into a manufacturable design within the suppliers' catalogue of tubes.

We predict that from using GENESIS, we approximately halved our iteration period from 10 weeks to just 5 weeks. We were also able to achieve our lightest, yet stiffest chassis to date, despite the significant improvement on SFR10's design. We believe that the next step for SFR is to progress to a composite monocoque for any other substantial gains to be achieved.

Final Design

Figure 8 shows a CAD render of our final space frame chassis for SFR11. Similarly, Figure 9 shows a full render of the chassis and driver environment design. Figure 10 shows the SFR11 chassis drawing and final tube specifications.

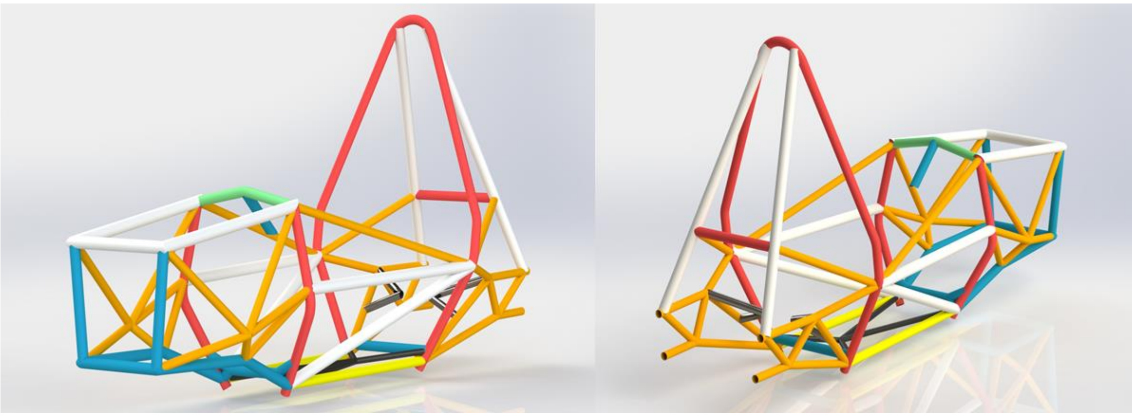


Figure 8: SFR11 chassis render

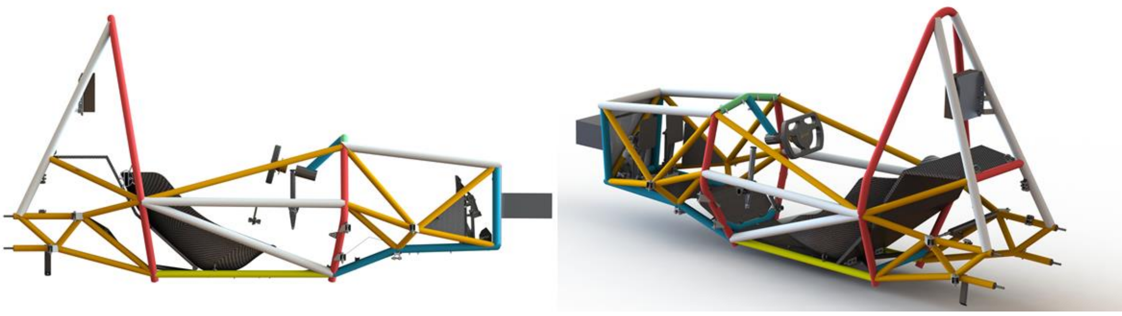


Figure 9: SFR CDE render

Tel +44(0)1926 889300
Email: info@grm-consulting.co.uk
WWW.GRM-CONSULTING.CO.UK WWW.TRUFORM-OPT.COM WWW.ROBOTBIKE.CO

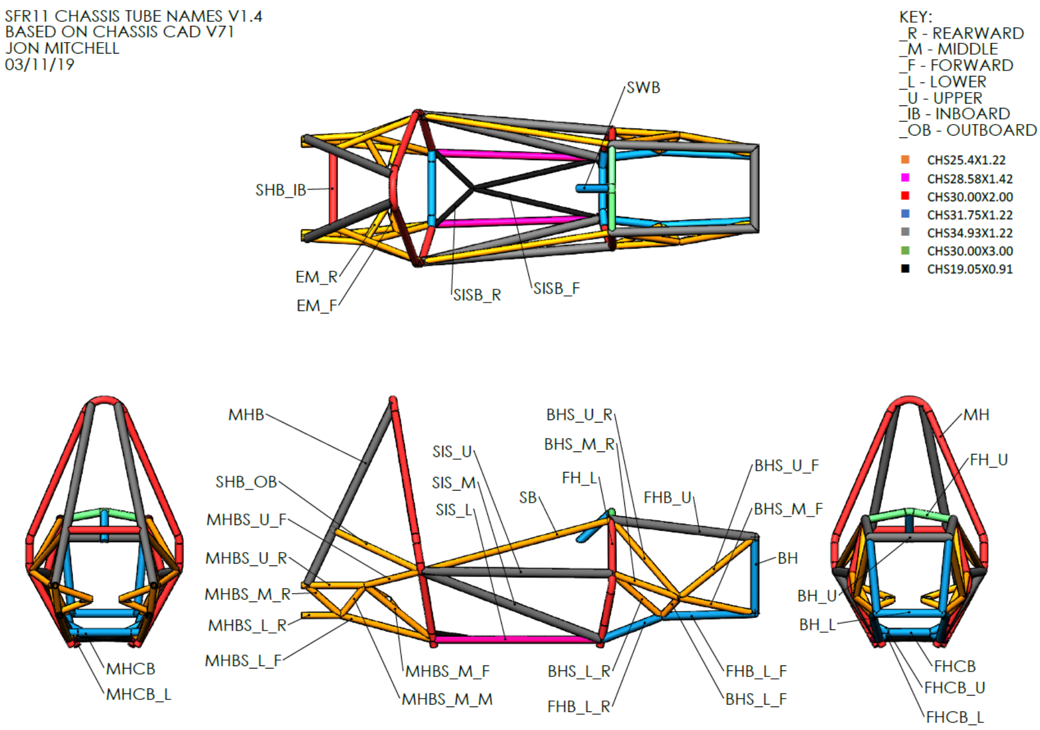


Figure 10: SFR11 chassis drawing

BENEFITS OF USING GENESIS

- Guides new designs:
  - By applying the technology at the concept design phase, engineers will be led towards the most structurally efficient use of material and therefore the lightest design
- Identifies and resolves design issues
  - Using the Finite Element (FE) method, GENESIS can quickly identify areas where designs need to improve and then use any number of structural optimisation techniques (topology, sizing, shape, topometry, topography) to improve the design in the most efficient way possible
- Reduce mass and material cost of existing designs
  - Based on the applied loads and the required performance criteria, GENESIS can quickly identify which part of an existing design is surplus to requirements and remove it, leaving only the key structural load paths necessary for your part
- Reduces development time
  - By guiding engineers towards the most structurally efficient use of material, GENESIS can help reduce the time spent designing and therefore minimise the time to market

VR&D GENESIS FEATURES

- Complete Finite Element Analysis Solver
- Comprehensive Optimisation Toolset including:
  - Topology, Gauge & Sizing, Topometry, Shape and Free-Shape,Topography / Bead Pattern
  - Composites
- Complete Composite Analysis & Optimisation Environment
- Powerful Design Understanding and Improvement Tools