LEEDS FORMULA RACE TEAM

Chassis Design for Class 2

MECH3890 Individual Engineering Project
"Chassis Design for Class 2"
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UNIVERSITY OF LEEDS

SCHOOL OF MECHANICAL ENGINEERING

MECH3890 Individual Engineering Project

TITLE OF PROJECT

Chassis Design for Class 2

PRESENTED BY	Paolo Binetti de Gennaro

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This project report presents my own work and does not contain any unacknowledged work from any other sources.

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Acknowledgments

I would like to thank Professor David Barton for his guidance and supervision throughout the year. I am very grateful for the time he has spent with me and for the chance of working on such an ambitious project.

I would also like to thank my parents for their moral support and the opportunity to study this year abroad.

Abstract

In 2017, the University of Leeds developed a plan to include, for the first time, those students with less experience in the design of a Class 2 entry vehicle [1]. This hope to be the first of many.

This report discusses the possibilities of improving the chassis which will compete this year. It shows what was done to increase the torsional stiffness and what method was used to design and analyse the spaceframe. This Class 2 entry will serve as a reference to next year's team.

Based on the literature review, the 2017-2018 SAE rules and few enhancements, it was possible to redesign the current structure. After an iterative process, the aim was accomplished, and it was possible to increase 12% the specific torsional stiffness and decrease 19% the weight of the chassis.

Table of Contents

List of Figures

List of Tables

Nomenclature

Parameter	Definition	Unit
F	Load	N
T	Torque	Nm
L	Wheelbase	m
w	Track	m
m	Mass	Kg
δ	Displacement	m
θ	Angular deflection	deg
K_T	Torsional Stiffness	Nm/deg

Abbreviations

SAE – Society of Automotive Engineers

FS – Formula Student

FEA – Finite Element Analysis

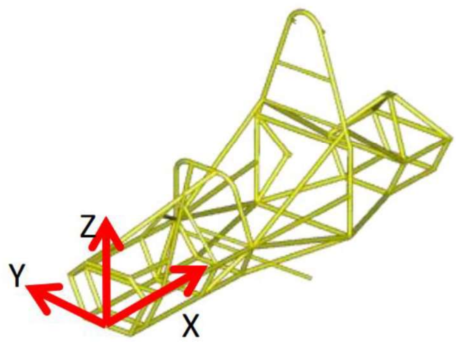
TS – Torsional Stiffness

SW – SolidWorks

Definition

The following coordinate system and labelling convention is used within these rules

- Longitudinal (X)
- Transverse (Y)
- Vertical (Z)



Chapter 1 – Introduction

1.0 Introduction

Formula student is a motorsport competition in which students from universities all across Europe, design, test and build a single-seat race car. The teams compete in a range of static and dynamic events to get the maximum number of points to win the competition [2].

Leeds Formula Race Team was one of the first British universities to compete in the event [3]. Although Leeds has never won the competition, it has scored the top of the UK Team’s several times. The team is divided into three smaller groups: Engine, Driveline & Brakes and Chassis & Suspension. It is crucial to work in a mutual feedback environment with other members to avoid mistakes and misunderstandings.

In 2017, the University of Leeds developed a plan to include, for the first time, those students with less experience in the design of a Class 2 entry vehicle. This vehicle will be the start point for the Class 1 Team for the upcoming year [1].

Analysing the current chassis (F18) and other designs from previous years through a finite element analysis led to the conclusion that some enhancements were required:

- Simplify the structure
- Minimise the weight
- Heighten the torsional stiffness
- Increase the overall strength
- Wider cockpit area
- Ease and cheapen the manufacture

Several spaceframes were modelled in SolidWorks until it was possible to reach out an optimised final iteration. Nevertheless, it is necessary to remember that there were other constraints besides these improvements, such as 2017-2018 Class 2 FS rules, suspension and engine mounting points.

1.1 Aim(s)

The aim of the project is to design and implement an optimised version of the F18 chassis for the 2016 Leeds Formula Student Class 2 Race Car. The frame must fit perfectly with the other components that were designed by the other members of the team. Lightness, strength and high stiffness will be the most important attributes to be designed.

1.2 Objectives

- Perform a literature review.
- Use the information learned to analyse and improve F18 Race Car critically.
- To design an enhanced spaceframe considering 2017-2018 Class 2 FS Rules.
- To model the design using SolidWorks.
- Carry out a finite element analysis (FEA) in ANSYS Workbench.
- To validate the design and look for new improvements.
- Finalise the chassis design of the Class 2 Race Car.
- Suggest future work to improve the car.
- Ensure the project report is complete to be delivered on 27 April 2017.

1.3 Deliverables

- Improvement of the F18 space frame chassis.
- SolidWork's model design.
- Improve ANSYS Workbench's knowledge.
- ANSYS Workbench's FEA.
- Final Report.

Chapter 2 - Literature Review

2.0 Introduction

A literature review was conducted in order to understand more about the main subject of the project. The objective in a race is to complete the event in the shortest amount of time. To achieve this, the driver must [4]:

- Maximise the acceleration
- Maintain the velocity during corners
- Delay the braking event as much as possible

The chassis is the single most important part of a vehicle because it holds all the other major systems and components [5]. All of them must fit perfectly to shape the vehicle and be able to give the best performance, which is related to the torsional stiffness and the weight of the car [6].

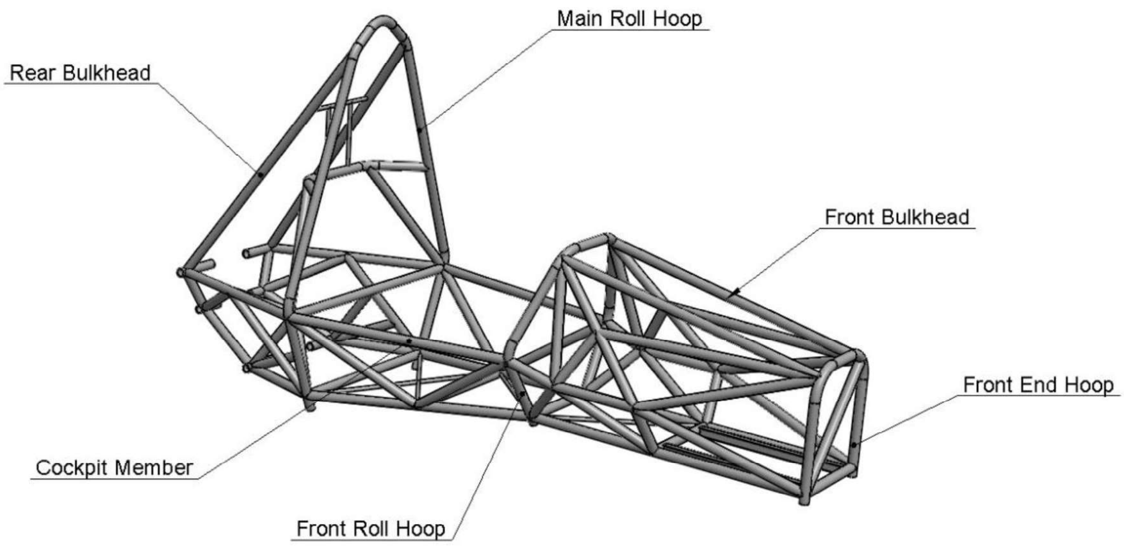


Figure 1 *Relevant parts of a Spaceframe.*

The aim of the project is to design and implement an optimised version of the F18 chassis for the 2016 Leeds Formula Student Class 2 Race Car. In order to accomplish this, a higher torsional stiffness is needed [7]. If a chassis is not rigid enough, it will no transfer the same amount of weight to each wheel causing a poor performance while driving [8].

2.1 Types of Chassis

According to Julian Happian-Smith [9], chassis are classified by:

- **Ladder frames:** The first and simplest structure. Consist in two large rails joined by several cross members (Figure 2).

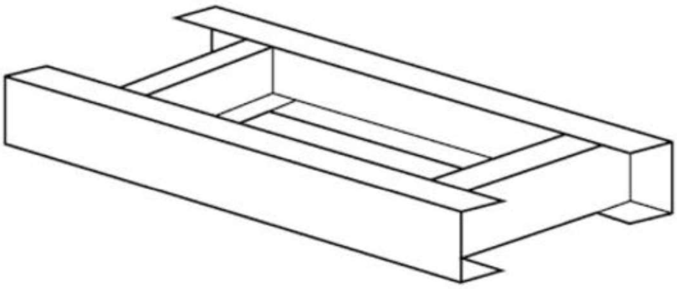


Figure 2 *Ladder frame [9].*

- **Cruciform frames:** Two cross straight beams joined at the centre that will only suffer bending moments (Figure 3).

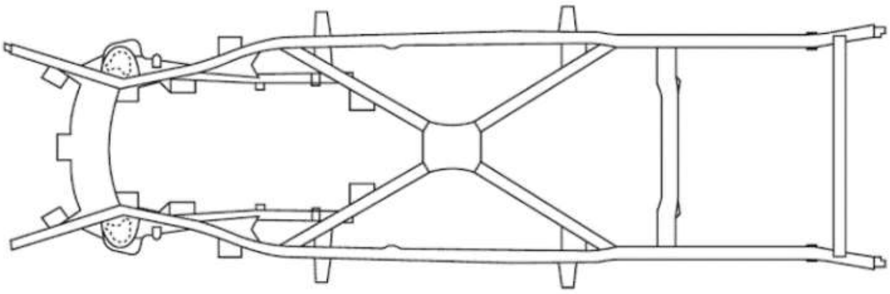


Figure 3 *Cruciform frame [9].*

- **Torque tube backbone frames:** One strong tubular member that connects the front and rear suspension mounting point's beams. In this structure, the backbone endure the bending and torsional loads (Figure 4).

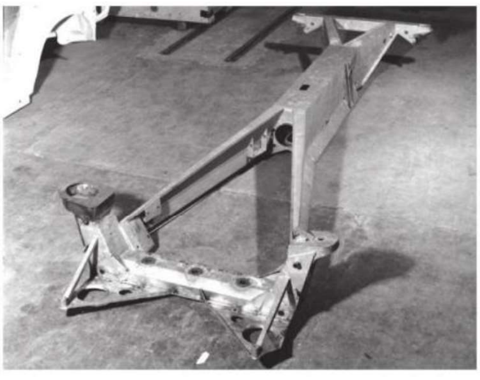


Figure 4 *Backbone frame [9].*

- **Space frames:** a three-dimensional open structure made of steel or aluminium tubes that are joined trying to form triangles. This structure is well known for be used in race cars for its low volume (Figure 5).

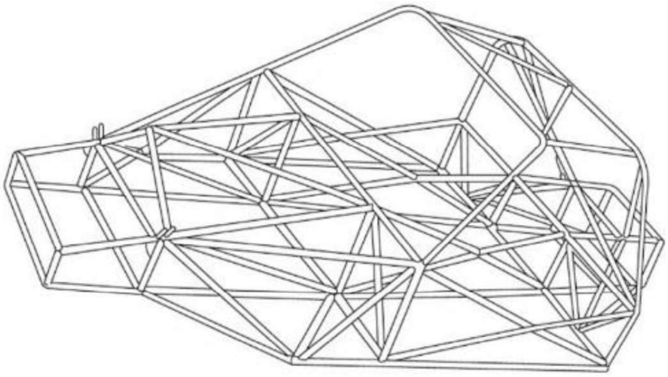


Figure 5 *Spaceframe [9].*

- **Integral structures or monocoque:** Three-dimensional frame made by steel or aluminium sheets. This structure is employed nowadays by all the current manufacturers because of its reliable performance (Figure 6).

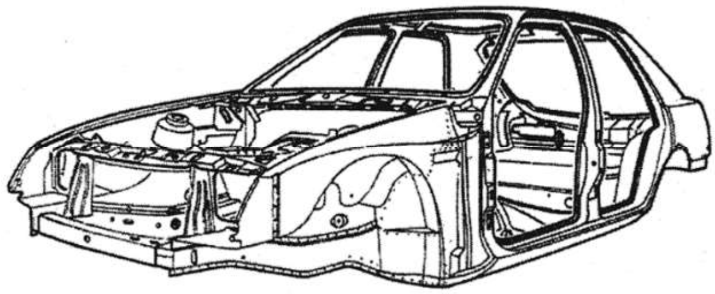


Figure 6 *Monocoque [9].*

2.2 Space Frames

After reading the SAE rules for the Formula Student Competition, it can be inferred that there are only two frames allowed: Space Frames and Monocoque. Thanks to all the information collected from early years, it was decided to opt for the first choice.

Spaceframes are three-dimensional structures made from tubes [10]. Although these frames are considered an evolution of ladder frames, there is a clear relationship with aircraft. Engineers used their knowledge in this particular field to build a chassis-less design that could be able to bear with all the external loads better. Austin A30, as seen in Figure 7, is claimed by Garrett to be the first example emerged in 1940's of a spaceframe [11].

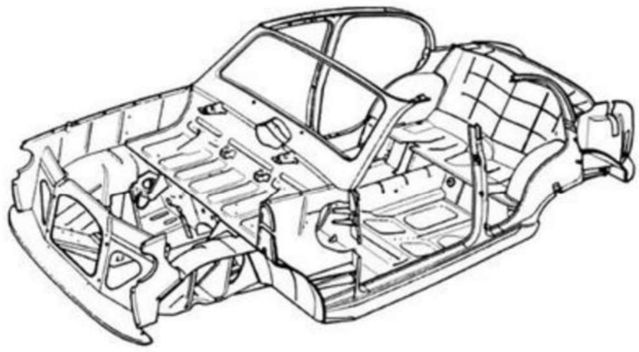


Figure 7 *Base Structure of the Austin A30 [11].*

It is a fact that this kind of frames has been used in sport racing cars because of its stiffness, lightness and strength. Fundamentals of designing a rigid chassis are the employment of triangles [12]. Notwithstanding, it has to fulfil some basic rules. Figure 8 shows a correct arrangement of a node-to-node triangulation. To achieve this, tubular members were welded forming nodes in order to resist all the tensions and loads.

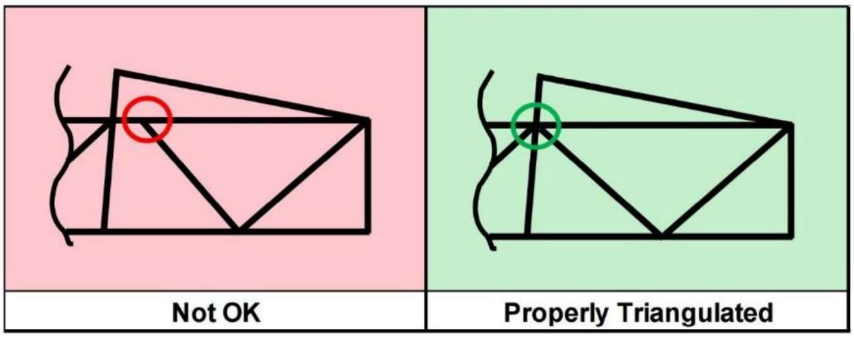


Figure 8 *Properly triangulated frame members [13].*

2.3 Loads applied to the chassis

During driving, some situations make the owner respond in a precise way to avoid an accident. Regarding these situations, there are some cases to consider [5, 9]:

- **Bending case:** y-axis is the one to suffer e. g. when the wheels of an axle hit a bump.
- **Torsion case:** twisting the x-axis.
- **Combined bending and torsion**.
- **Lateral loading:** y-axis suffers a displacement during a corner.
- **Fore and aft loading:** x-axis suffers a moment during acceleration and braking.

It is extremely necessary to take into account these cases in order to prevent structure breaks during competitions and be able to calculate its optimal shape. However, this project would only focus on the Torsional case as seen in Figure 9.

Figure 9 *Torsional Case [14].*

The torsional stiffness is the way to relate the deflection to the torque created when the chassis is moving [11]. It is of high relevance to highlight the importance of this parameter, as well as the weight because they play a crucial role when talking about the stability of the car. It is the job of the chassis designer to find the balance between them [4]. In Table 1, there could be seen some typical values to take into account when vehicles are designed.

Table 1 *Typical Torsional Stiffness values [15].*

Vehicle	Roll Stiffness [Nm/deg]
Formula SAE [16]	500 - 1500
Saloon [16]	300 - 800
Passenger [17]	500 - 2500
Sport [6]	500 - 5000
Formula One [6]	1500 - 7500

Due to the fact that is almost impossible to reproduce this situation, a simplify version was made [18]. Assuming that a frontal view of the chassis is seen in Figure 10, a torque was applied using two forces of 1000N each in the opposite direction in order to make the structure twist on the x-axis and be able to measure the amount of displacement (δ) and the angular deflection (θ). Further on, this method will be implemented in the FEA model in order to make a quicker simulation and shorten the iteration process. However, the load will be distributed on all the front suspension points instead of only two nodes.

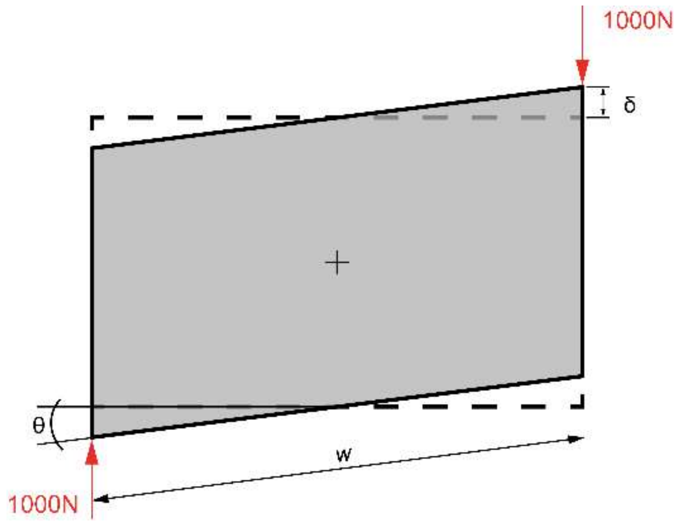


Figure 10 *Simple Torsion case.*

The torsional stiffness is determined [5] by

$$K_t = \frac{T}{\tan^{-1}\theta} = \frac{F \times w^2}{2\delta} \quad (1)$$

where:

K_t	is the torsional stiffness
T	is the torque applied
θ	is the angular deflection
F	is the load
w	is the track of the vehicle
δ	Is the displacement

2.4 General requirements

Every year the SAE establish a comprehensive set of rules that have to be followed to participate in the events [13]. As this project is focused on the chassis design, it was only analysed Part T from Articles 1-6.

Figure 11 shows a representation of a 95th percentile male. This requirement is essential because if the car does not meet this rule, it will not be able to pass the Technical Inspection, which means will not compete in the race.

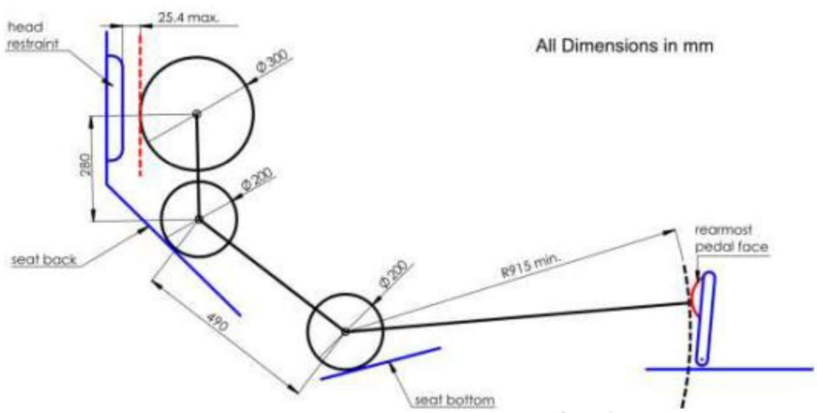


Figure 11 *95th percentile male [13].*

Moreover, in Figure 12 and 13 could be seen all the constraints to consider when constructing the Main Hoop and cockpit area.

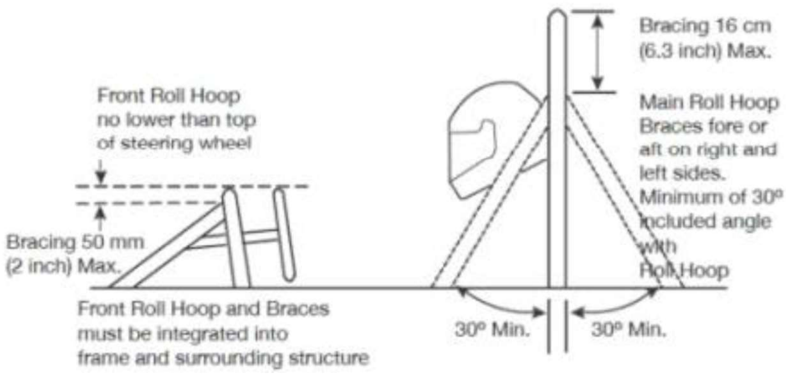


Figure 12 *Main Hoop Bracing [13].*

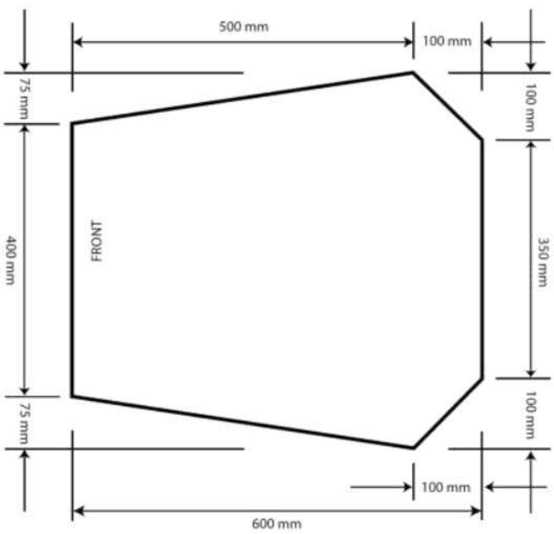


Figure 13 *Cockpit Opening [13].*

Safety is a key design feature to contemplate in the competition. That is the reason why SAE takes care in such a great way, as seen in Figure 14.

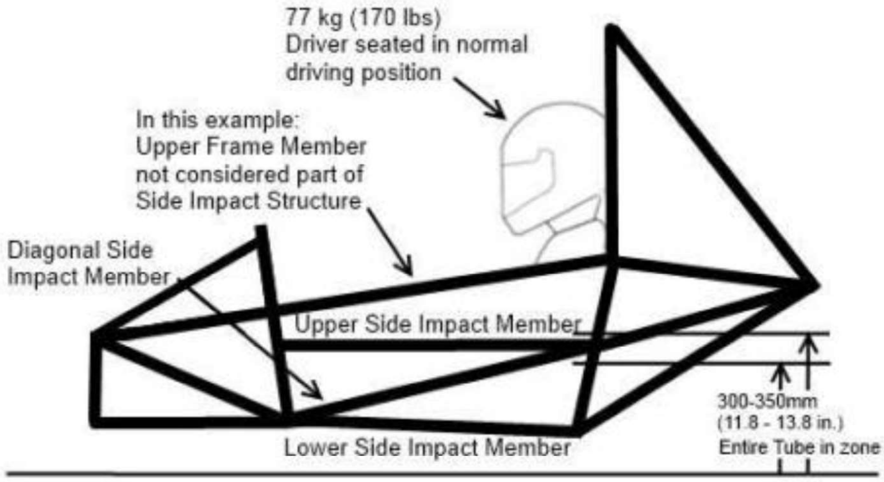


Figure 14 *Side Impact Structure [13].*

2.5 Materials

As stipulated in the Formula SAE rules [13], the primary structure of the chassis must be constructed of a baseline steel material and must have specified properties (as seen in Table 2 and 3). After considering a hybrid structure for the front, it was decided to implement a more realistic low carbon (mild) circular steel tube spaceframe due to the fact the main aim was to optimise the current chassis.

Table 2 *Non-Welded properties [13].*

Non-Welded strength for continuous material	
Young's Modulus (E)	200 GPa (29,000 ksi)
Yield Strength (Sy)	305 MPa (44.2 ksi)
Ultimate Strength (Su)	365 MPa (52.9 ksi)

Table 3 *Welded properties [13].*

Welded strength for discontinuous material	
Yield Strength (Sy)	180 MPa (26 ksi)
Ultimate Strength (Su)	300 MPa (43.5 ksi)

Figure 15 shows the Stress-Strain curve for this particular material. This curve plots the amount of strain at distinct intervals of stress in tension or compression and will be used to know if the structure is within the yield strength limit and what is the safety factor that could be utilized while designing.

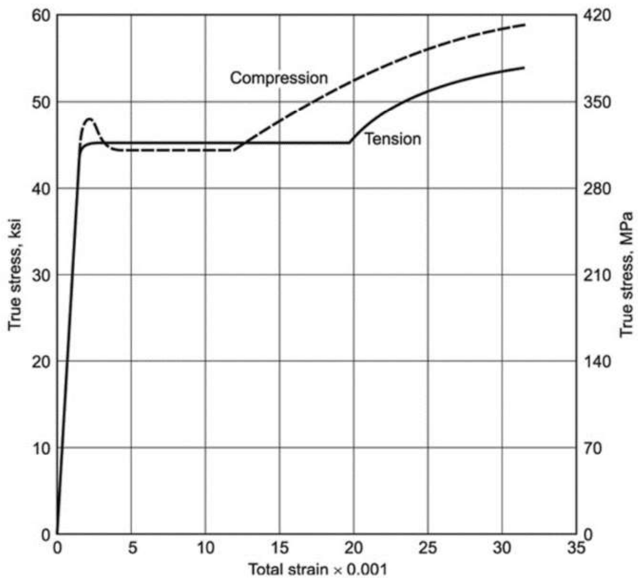


Figure 15 *Mild Steel Stress-Strain Curve [19]*

To satisfy the need for a lightweight structure, there were used the minimum dimensions of the tubing cross-section (Figure 16). Furthermore, it is important to know how to join these items. According to G. Davies [20], there are three fundamental techniques for doing this: welding, adhesive bonding and mechanical fastening. Nonetheless, the best and most economical option was welding.

ITEM or APPLICATION	OUTSIDE DIMENSION X WALL THICKNESS
Main & Front Hoops, Shoulder Harness Mounting Bar	Round 1.0 inch (25.4 mm) x 0.095 inch (2.4 mm) or Round 25.0 mm x 2.50 mm metric
Side Impact Structure, Front Bulkhead, Roll Hoop Bracing, Driver's Restraint Harness Attachment (except as noted above) EV: Accumulator Protection Structure	Round 1.0 inch (25.4 mm) x 0.065 inch (1.65 mm) or Round 25.0 mm x 1.75 mm metric or Round 25.4 mm x 1.60 mm metric or Square 1.00 inch x 1.00 inch x 0.047 inch or Square 25.0 mm x 25.0 mm x 1.20 mm metric
Front Bulkhead Support, Main Hoop Bracing Supports, Shoulder Harness Mounting Bar Bracing EV: Tractive System Components Protection	Round 1.0 inch (25.4 mm) x 0.047 inch (1.20 mm) or Round 25.0 mm x 1.5 mm metric or Round 26.0 mm x 1.2 mm metric
Bent Upper Side-Impact Member (T3.24.3a)	Round 1.375 inch (35.0mm) x 0.047 inch (1.20mm)

Figure 16 *Minimum Material Requirements [13].*

2.6 Finite Element Analysis

In the interest of accomplishing this project, a numerical approach was used to solve engineering problems that could not be solved by classical analytical methods. Finite element method solves partial differential equations that are determined by dividing the model into finite elements creating a *'mesh'* [21]. The overall solution gives the mechanical behaviour by means of displacement of each of these smaller pieces [22].

To reach and ease our objective a computer software (ANSYS Workbench) was learned and employed. Thanks to this program it was possible to perform a static structural analysis [23] which results were used to enhance the space frame.

The process that was used to analyse the design of the chassis has three phases:

- **Solid Modelling:** build a digital layout.
- **Simulation:** apply the actions, the materials and restraints.
- **Optimisation:** determine all the changes that can be done and repeat the process as many times as desired.

Chapter 3 – Design Process

3.0 Introduction

The first step in any design process is to analyse all the work done in previous years. Table 4, shows all the possible enhancements that could be applied to the frame after critical thinking and have done a finite element analysis.

Table 4 *Enhancements.*

Enhancements Vehicle	
Structure	Simpler, stronger and lighter
Manufacture	Easier and cheaper
Cockpit Area	Wider
Engine	Cradle system

In order to overcome all these problems, an iterative process was carried out. Nevertheless, there are other constraints to be considered. Formula Student Class 2 Team met at the beginning of the first semester with the objective of choosing the overall parameters (Table 5) and essential components of the car.

Table 5 *Vehicle Parameters.*

Class 2 FS Vehicle Parameters	
Wheelbase	1550mm
Distance from front axle to cg	945mm
Tyres	Hoosier 6x10
Engine	KTM 500 EXC 2014

3.1 Solid Modelling

The new chassis was modelled in a CAD software named SolidWorks. It was produced by an iterative process where optimisation was the goal, and all the previous boundary conditions were considered.

As said before, it is very important to communicate continuously during this procedure because it is the best system to avoid mistakes and save time. FS aims to let students feel as their team is a real company and experience day-to-day engineering problems.

In order to make the explanation of the design easier to understand, it was shaped in few simple steps.

1. Were created all the constraint planes, as seen in Figure 17, which define the boundaries of the chassis.

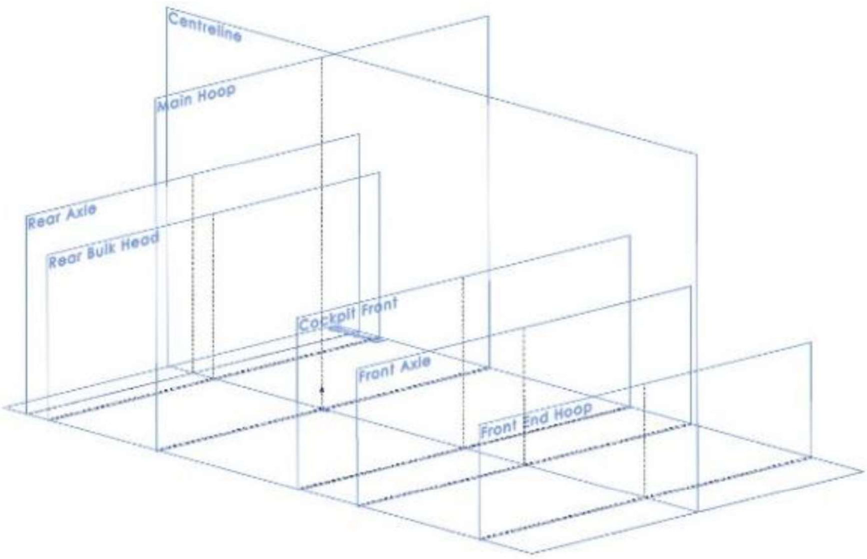


Figure 17 *Constraint Planes.*

2. After having spoken with the Suspension team, it was possible to know the exact coordinates of the front and rear mounting points. Accordingly, the suspension boxes, shown in Figure 18, were built using a 3D sketch.

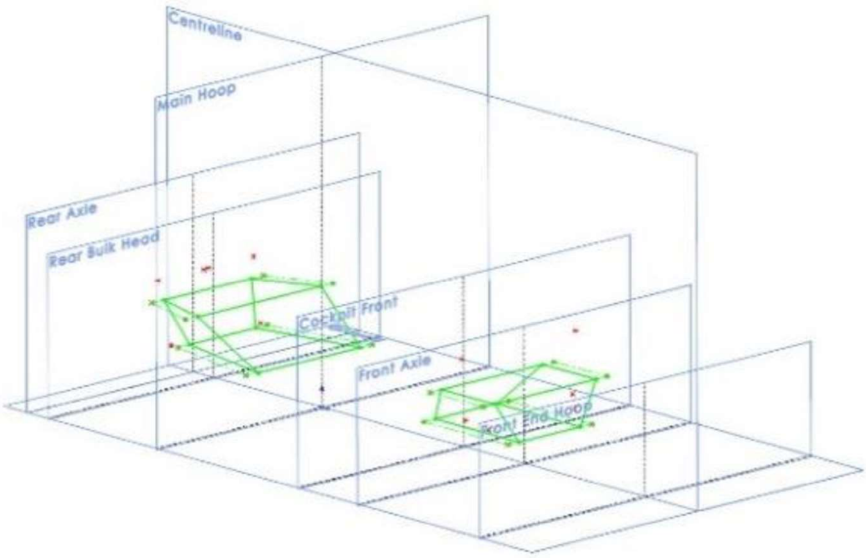


Figure 18 *Suspension Boxes.*

3. Using the previous technique, it was possible to determine the wireframe (Figure 19) of the structure. In addition, was also necessary to include the engine mounting points that were given by the Engine team.

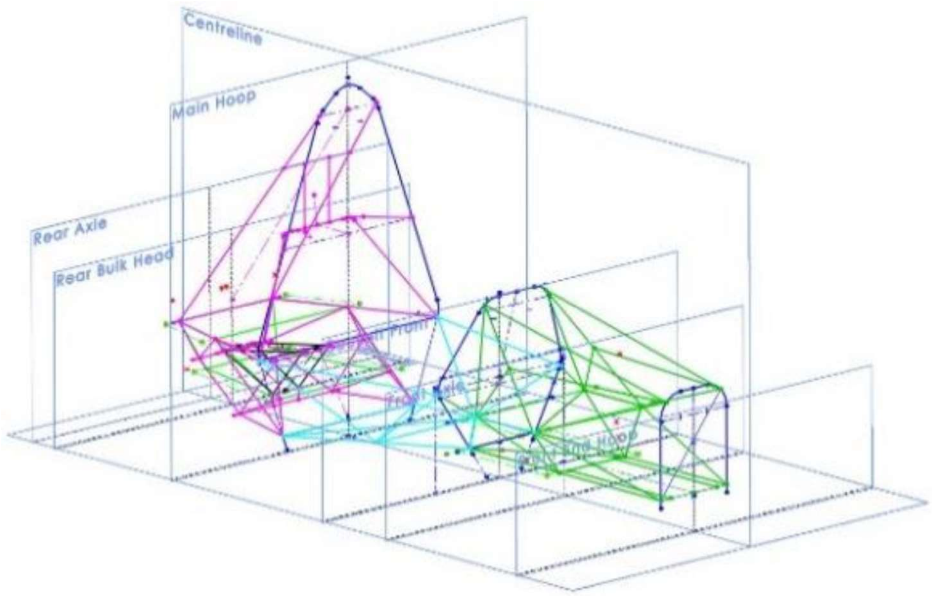


Figure 19 *Sketch of the structure.*

4. A SolidWorks feature was used to make all the structural members from the previous sketch, and it was set the position of the cradle. Moreover, all the excess material was removed by another feature named Trim/Extend. As a result, the spaceframe is defined in Figure 20.

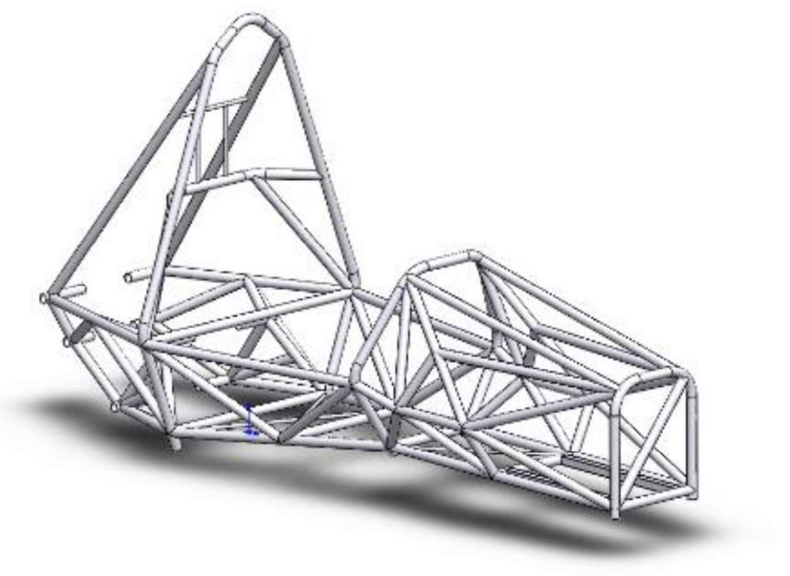


Figure 20 *SW final model.*

3.2 Software validation

A simplify structure was created in ANSYS Workbench's and SolidWorks to know if similar results could be determined. Figure 21 and 22 show the displacement calculated by each software.

Thanks to the previous experiment, it is possible to affirm that there is only a 5.93% difference in the solution. However, as ANSYS is well known to be very accurate and SW is new in solving this kind of analysis, during this project the first software is going to be used.

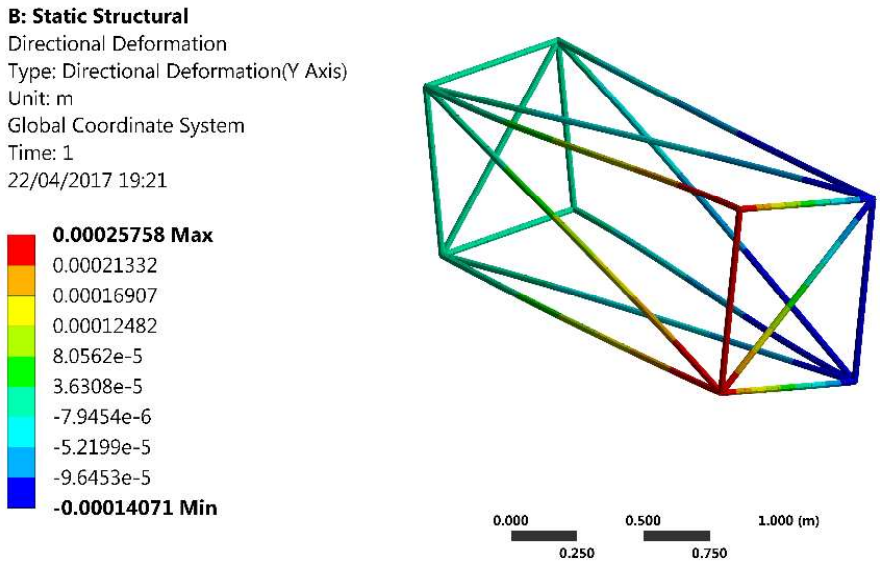


Figure 21 *Ansys Workbench's FEA*

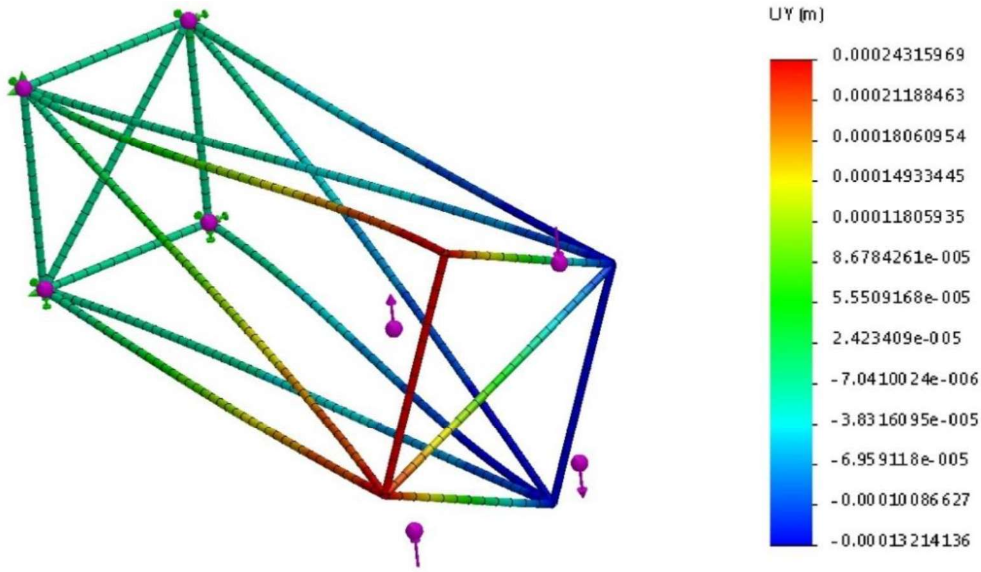


Figure 22 *SolidWork's FEA.*

3.3 Finite Element Analysis

ANSYS Workbench was used to analyse the model made in the previous part of the project. As done before, few steps help to understand how the analysis was done.

1. Once a Static Structural analysis was chosen, it was defined the material of the spaceframe (Figure 15).
2. SolidWork's geometry (Figure 23) was imported to the current interface using a STP file. The software uses beam elements that afterwards have to be assigned to the relevant cross section of the chosen tubes.

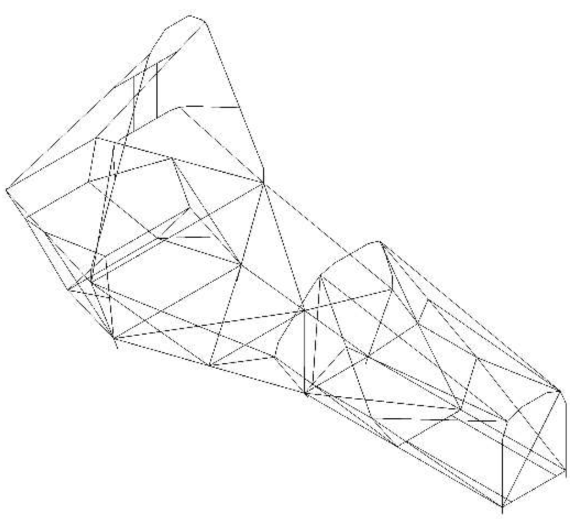


Figure 23 *Geometry imported.*

3. A mesh of each element of the model (Figure 24) was created using an automatic method and a body sizing of 0.01m in order to obtain the most accurate solution possible.

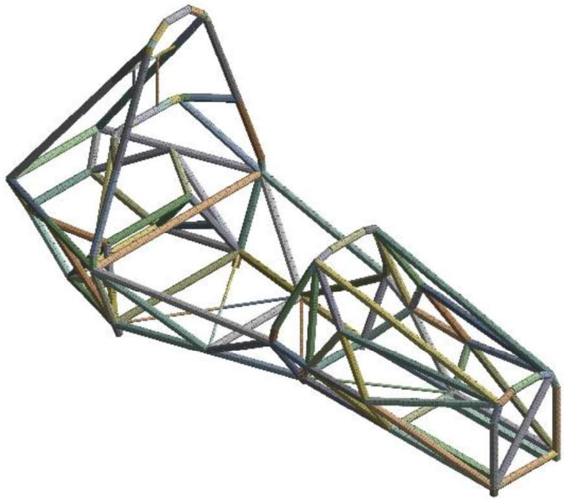


Figure 24 *Mesh creation.*

4. As said in section 2.3 of the Literature Review, a simplify version was used to calculate the Torsional Stiffness of the design. In Figure 25, there could be seen the loads and fixtures that were used in the finite element analysis. The rear of the chassis was constrained in all directions, and an input of 1000N on each side was distributed into its corresponding nodes.

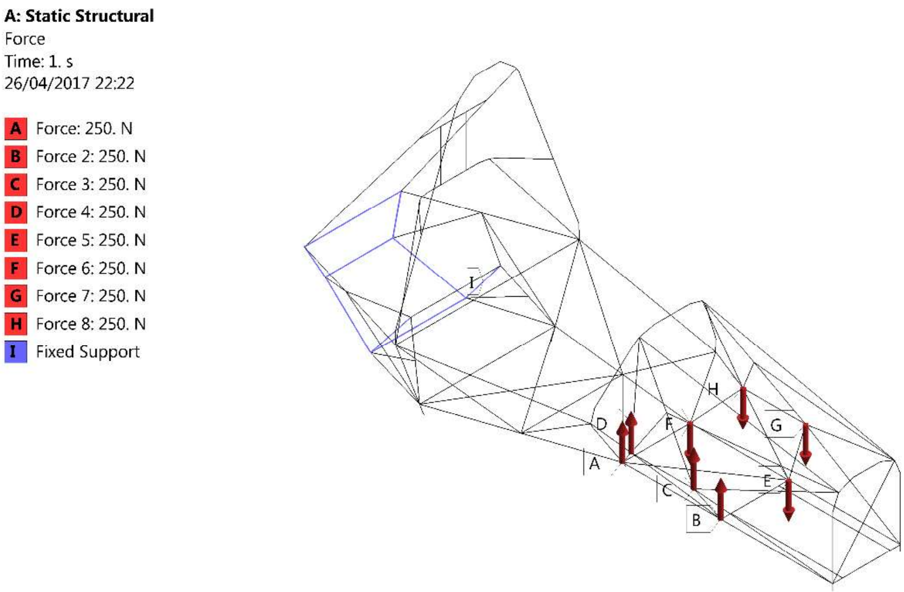


Figure 25 *Analysis Settings.*

5. Finally, the Equivalent (von-Mises) Stress and Deformation were calculated and are shown in Figure 26 and 27.

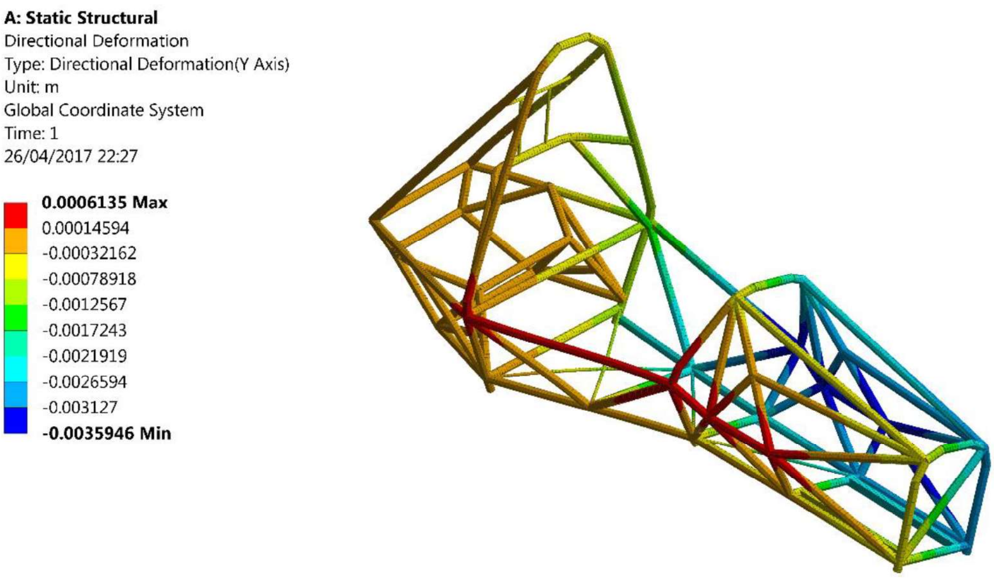


Figure 26 *Directional Deformation (Y Axis).*

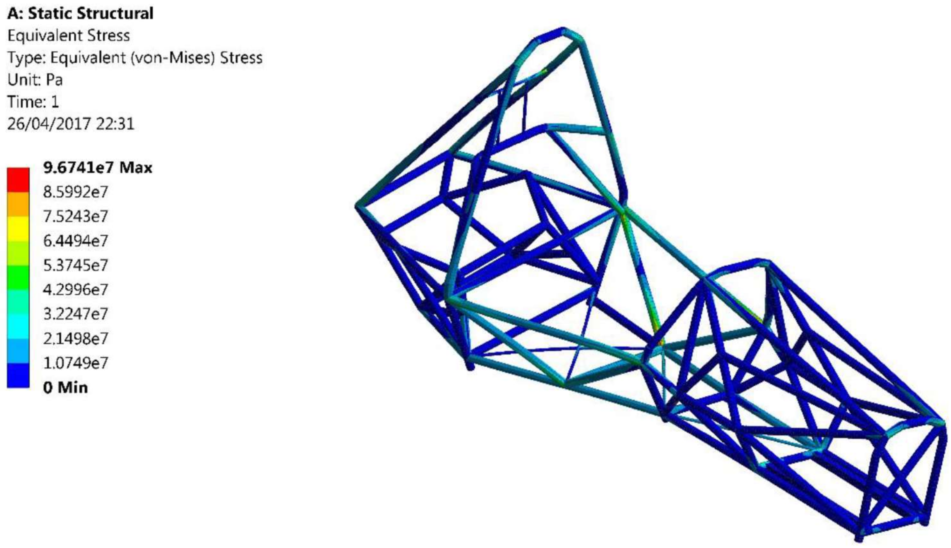


Figure 27 *Equivalent Stress.*

Moreover, in Table 6 the displacements that were calculated with a different number of elements, are shown. The aim of this is to know when exactly the graph remains constant in order to make the simulation efficient and not waste time.

Table 6 *Mesh convergence.*

Body Sizing	Number of elements	Max. Displacement (m)
1	148	0.00046271
0.75	150	0.00046271
0.5	161	0.00046271
0.25	225	0.00052893
0.1	441	0.00054147
0.05	796	0.00054911
0.01	3735	0.00054904

Figure 28 shows that after 796 body elements, there is no diminishing of the accuracy when calculating the displacement because it stabilises and gives a constant result.

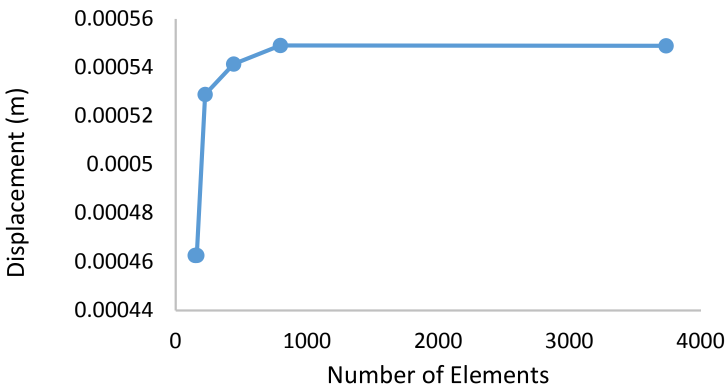


Figure 28 *Displacement (Y axis) for each number of elements.*

3.4 Final Design

After all the previous work, it was possible to reach the ultimate solution. Figure 29, 30 and 31 show different views in order to perceive the minimum details of the design.

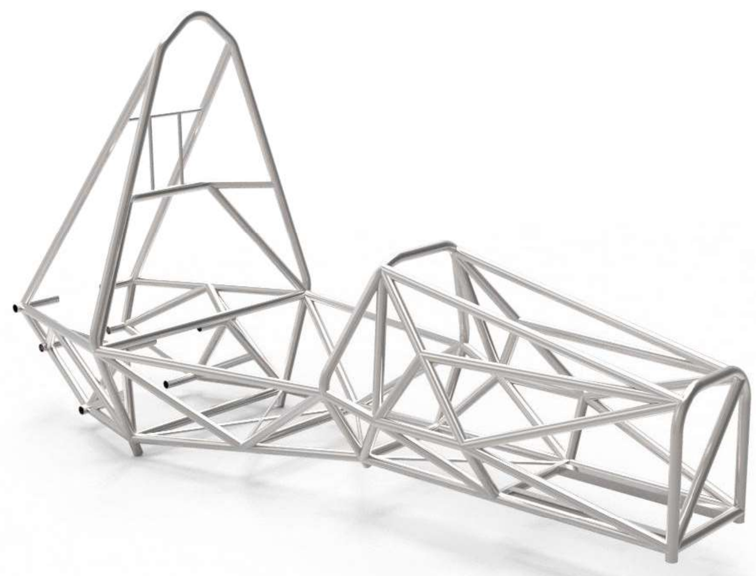


Figure 29 *Isometric view of the chassis.*

Figure 30 *Frontal View of the chassis.*

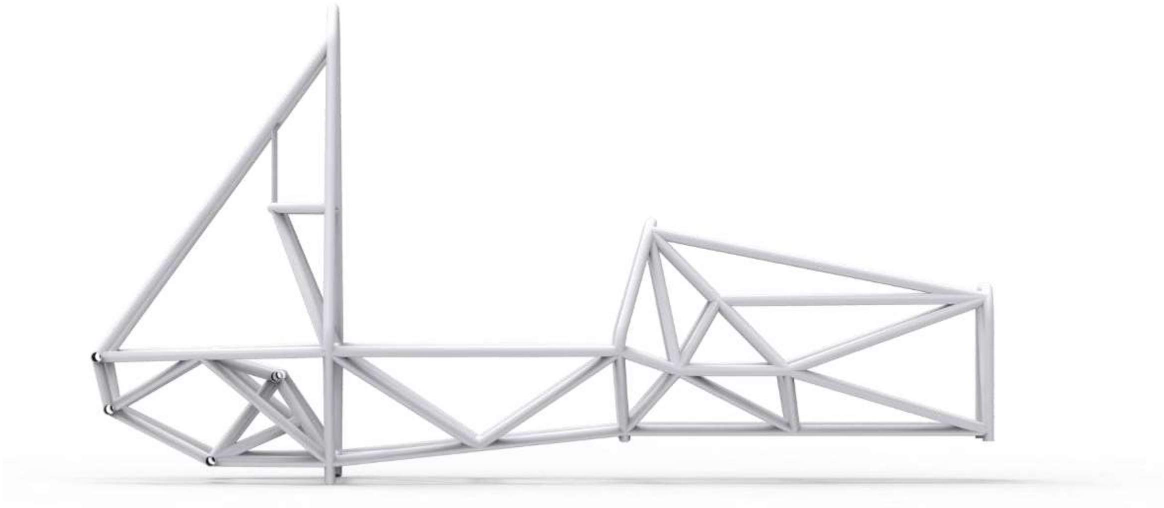


Figure 31 *Lateral view of the chassis.*

Chapter 4 – Discussion

4.0 Iterative Process

The chassis design was made through an iterative process. This means that after each analysis, some improvements were implemented in the design until the desired solution was reached.

There were done several iterations, but only four of them showed significant changes to be explained before arriving at the final frame. Figure 32 shows how the front bulkhead was modified to fit better with the suspensions mounting points.

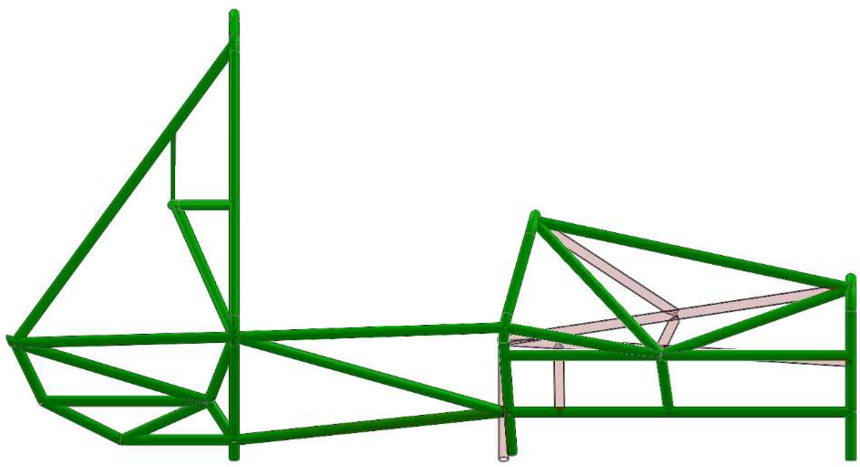


Figure 32 *Differences between 1st (red) and 2nd iteration (green).*

In Figure 33 it is possible to see a weight reduction and a better triangulation to avoid any structural problem.

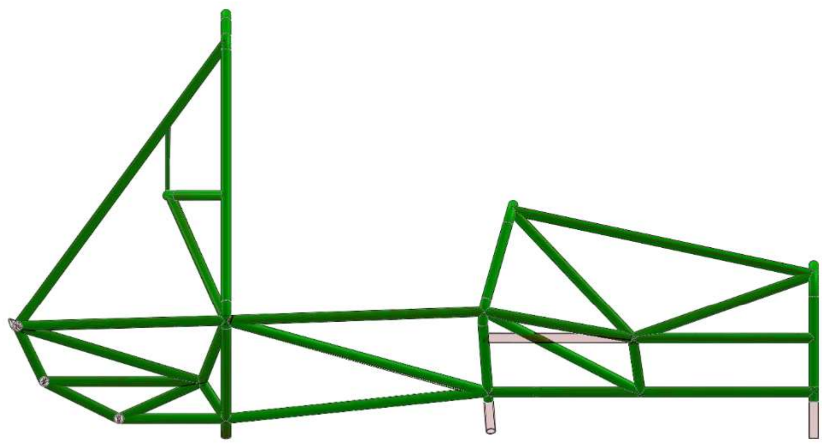


Figure 33 *Differences between 2nd (red) and 3rd iteration (green).*

After dealing with some problems with the suspension, it was necessary to change all the rear and front bulkhead. Moreover, it was used a ‘v’ instead of a diagonal bar in the cockpit member, as seen in Figure 34.

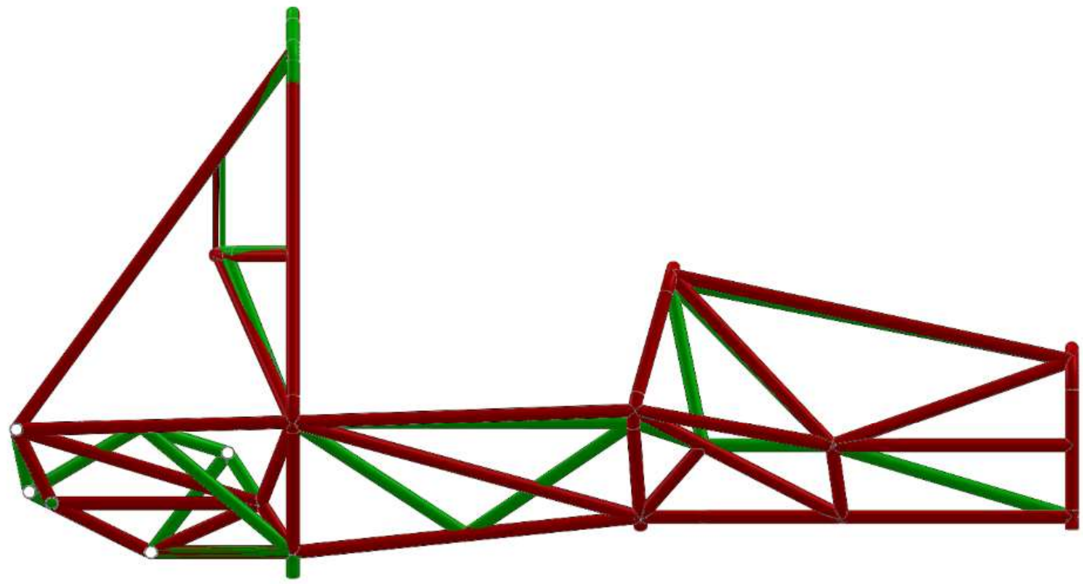


Figure 34 *Differences between 3rd (red) and 4th iteration (green).*

To end the iteration process, there were incorporated more triangulations to the design to give more stiffness to the overall structure.

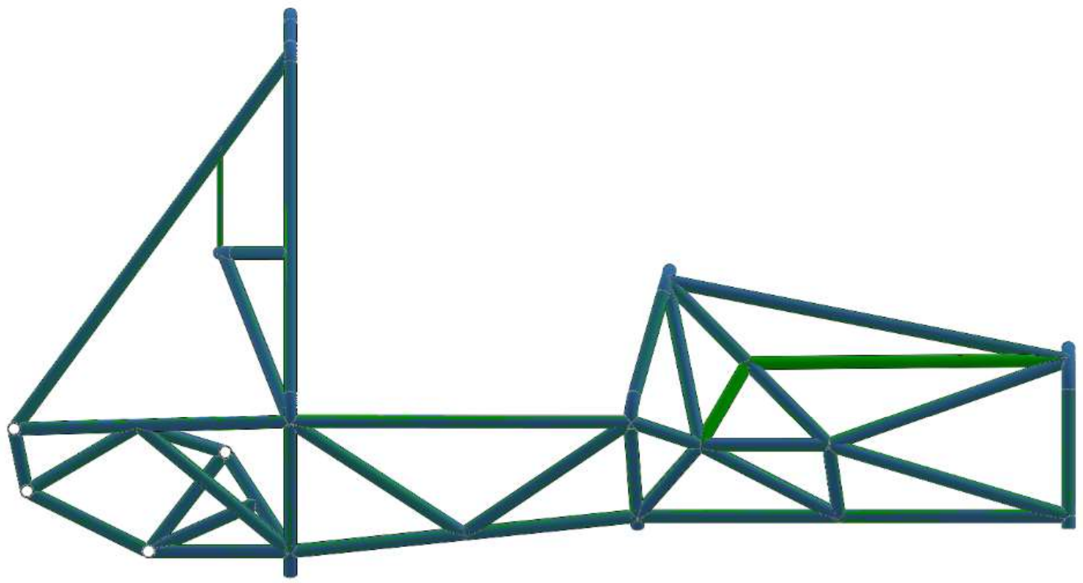


Figure 35 *Differences between 4th (blue) and final iteration (green).*

4.1 Design analysis

The results obtained from the FEA analysis are shown below in Table 7. As could be seen, the last iteration is the one that gives the less displacement. However, Iteration 4 (IT4) has shown to have the higher value for Specific Torsional Stiffness, which indicates that is the best version.

Table 7 *Comparison between iterations.*

Chassis	m [kg]	F [N]	*w* [m]	δ [m]	K_T [Nm/deg]	Specific K_T [Nm/deg/kg]
IT1	34.43	1000	0.47	0.00076097	5066.48	147.17
IT2	33.99	1000	0.50	0.00072868	5987.98	176.16
IT3	34.84	1000	0.50	0.00069681	6261.85	179.74
IT4	32.91	1000	0.46	0.0006208	5974.86	181.55
IT5	33.53	1000	0.46	0.0006135	6045.95	180.31

In Figure 36, 37 and 38 the torsional stiffness and the specific torsional stiffness were plotted in order to compare these iterations easily. During the design process, these values were incremented 19%, 22% and 3% respectively.

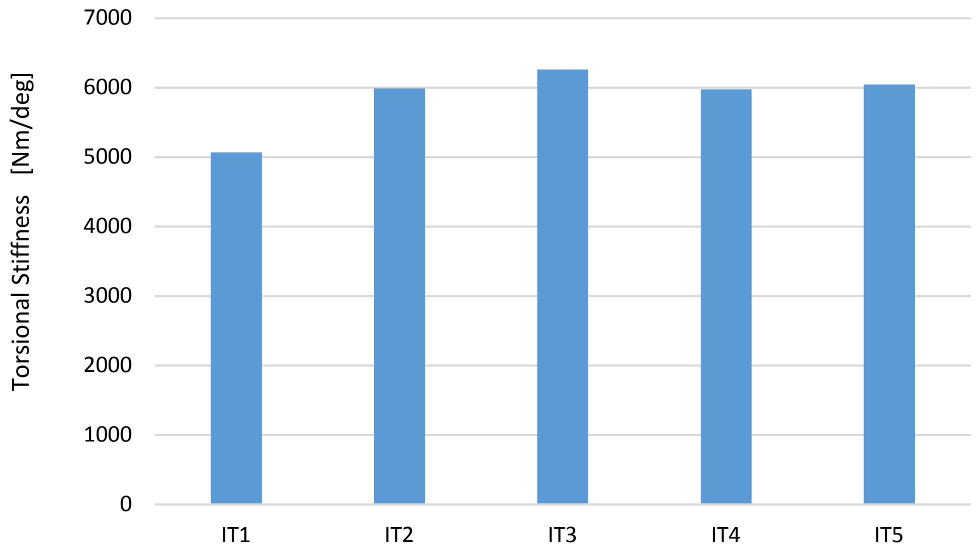


Figure 36 *Comparison of Torsional Stiffness between iterations.*

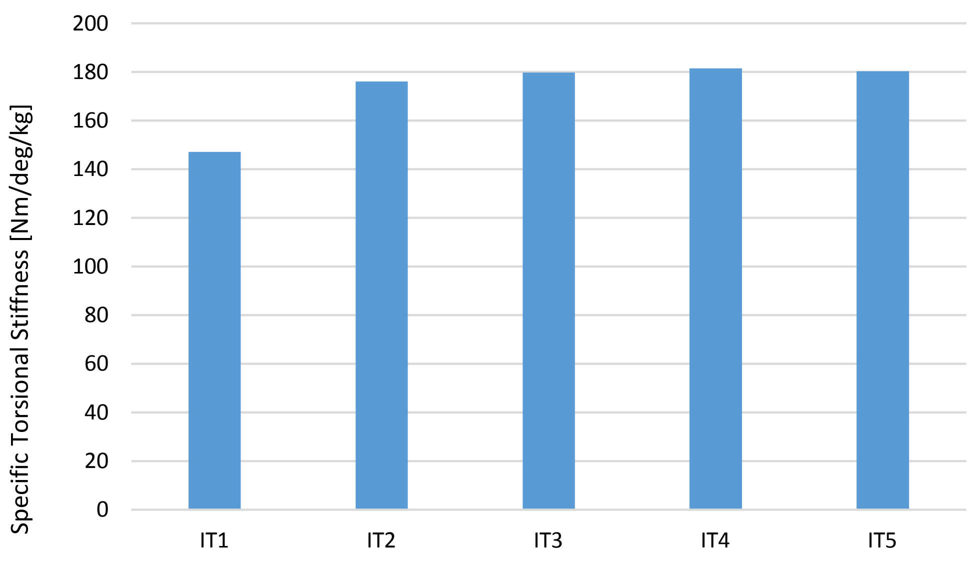


Figure 37 *Comparison of Specific Torsional Stiffness between iterations.*

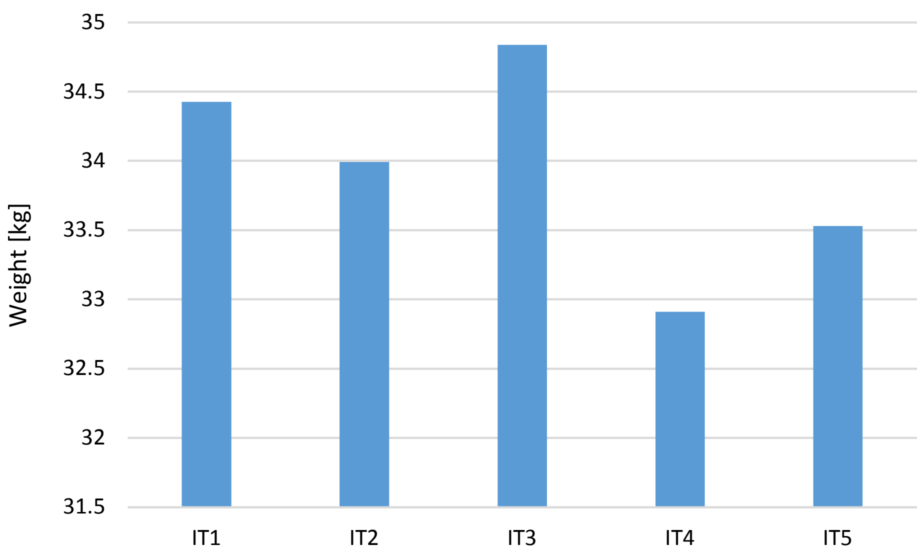


Figure 38 *Comparison of the overall weight between iterations.*

On the other hand, it has to be verified that every iteration meets with the properties of the material. As seen in Figure 39, the factor of safety, which is represented as a blue shade, is very high that means this chassis is within the Yield Strength Limit and could be further improved.

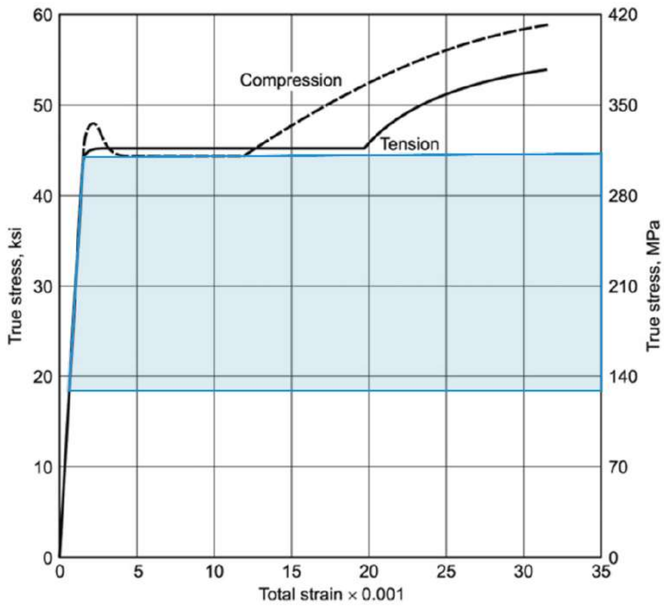


Figure 39 *Safety factor.*

In Table 8 a comparison was made with the current chassis and the one designed. As could be seen, the new spaceframe is 12% stiffer and 19% lighter than the previous. Nevertheless, the track of the car was increased by a 4%. All these improvements give the structure a high performance, excellent stability and the possibility to accelerate more at the corners.

Table 8 *Comparison between current and the designed chassis.*

Chassis	m [kg]	F [N]	*w* [m]	δ [m]	K_T [Nm/deg]	Specific K_T [Nm/deg/kg]
IT4	32.91	1000	0.46	0.0006208	5974.86	181.55
F18	39.3	1500	0.48	0.00093044	6375.54	162.31

Chapter 5 – Conclusions

5.0 Conclusions

During the project, several spaceframes were designed and analysed using two different softwares. There were encountered some problems with the importation of the SolidWorks model to ANSYS Workbench. In addition, the model had to be made another time because of incompatibilities. Nevertheless, the results proved that the main aim of the project was achieved. It was able to make a comparison between them in order to contrast these results. The new spaceframe is 12% stiffer and 19% lighter than the previous. Nonetheless, the track of the car was increased by a 4%. All these improvements give the structure a high performance, great stability and the possibility to accelerate more at the corners.

The suspension, engine and all the other components perfectly fit which met with the principal goal of the team. Furthermore, as this is the Class 2 entry, all the information allows next year team to have a point of reference. The new optimised chassis is ready for the Formula Student competition. Therefore, all the 2017-2018 rules and regulations were considered.

5.1 Future work

Regarding future work, the next step is to study a hybrid chassis made of composite panels. Other teams had successfully implemented this kind of vehicle. If the team would like to design and manufacture one, they should work very hard to find several sponsors.

There are additional improvements that could be done to the design:

- Investigate different materials.
- Ease the manufacture.

As this was a Class 2 entry, it was tried to optimise the current chassis taking into account the same initial parameters that Class 1 has. However, the first team had less time to develop the chassis because of the manufacturing process.

Everything that had been done will be available for next year's teams in order to compare and create a database with the results this project had achieved.

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Appendices

A. Formula SAE Rules

In this section, there were attached all the rules used during the project. These rules are continuously changing in order to deliver a greater level of safety for the teams.

2017-18 FORMULA SAE RULES

PART T - GENERAL TECHNICAL REQUIREMENTS

ARTICLE 1: VEHICLE REQUIREMENTS & RESTRICTIONS

T1.1 Technical Inspection

The following requirements and restrictions will be enforced through technical inspection. Noncompliance must be corrected and the car re-inspected before the car is allowed to operate under power.

T1.2 Modifications and Repairs

T1.2.1 Once the vehicle has been presented for judging in the Cost or Design Events, or submitted for Technical Inspection, and until the vehicle is approved to compete in the dynamic events, i.e. all the inspection stickers are awarded, the only modifications permitted to the vehicle are those directed by the Inspector(s) and noted on the Inspection Form.

T1.2.2 Once the vehicle is approved to compete in the dynamic events, the ONLY modifications permitted to the vehicle are those listed below. They are also referred to in PART S - Static Event Regulations.

a. Adjustment of belts, chains and clutches
b. Adjustment of brake bias
c. Adjustment of the driver restraint system, head restraint, seat and pedal assembly
d. Substitution of the head restraint or seat insert for different drivers
e. Adjustment to engine operating parameters, e.g. fuel mixture and ignition timing, and any software calibration changes
f. Adjustment of mirrors
g. Adjustment of the suspension where no part substitution is required, (except that springs, sway bars and shims may be changed)
h. Adjustment of tire pressure
i. Adjustment of wing angle, but not the location
j. Replenishment of fluids
k. Replacement of worn tires or brake pads. Replacement tires and brake pads must be identical in material/composition/size to those presented and approved at Technical Inspection.
l. The changing of wheels and tires for “wet” or “damp” conditions as allowed in PART D - Dynamic Event Regulations.
m. Recharging low voltage batteries
n. Recharging high voltage accumulators

T1.2.3 The vehicle must maintain all required specifications, e.g. ride height, suspension travel, braking capacity (pad material/composition), sound level and wing location throughout the competition.

T1.2.4 Once the vehicle is approved for competition, any damage to the vehicle that requires repair, e.g. crash damage, electrical or mechanical damage will void the Inspection Approval. Upon the completion of the repair and before re-entering into any dynamic competition, the vehicle MUST be re-submitted to Technical Inspection for re-approval.

ARTICLE 2: GENERAL DESIGN REQUIREMENTS

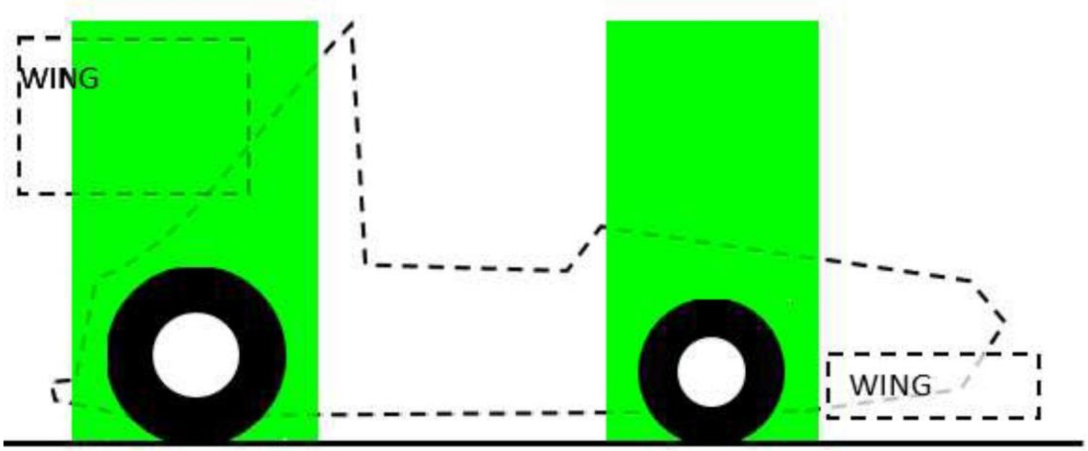
T2.1 Vehicle Configuration

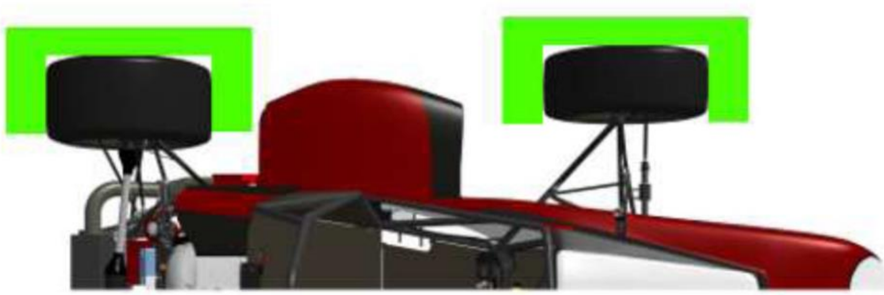
The vehicle must be open-wheeled and open-cockpit (a formula style body) with four (4) wheels that are not in a straight line.

Definition of "Open Wheel" - Open Wheel vehicles must satisfy all of the following criteria:

a. The top 180 degrees of the wheels/tires must be unobstructed when viewed from vertically above the wheel.
b. The wheels/tires must be unobstructed when viewed from the side.
c. No part of the vehicle may enter a keep-out-zone defined by two lines extending vertically from positions 75mm in front of and 75mm behind, the outer diameter of the front and rear tires in the side view elevation of the vehicle, with tires steered straight ahead. This keep- out zone will extend laterally from the outside plane of the wheel/tire to the inboard plane of the wheel/tire. See the figure "Keep Out Zones" below.
d. Must also comply with the dimensions/requirements of ARTICLE 9: Aerodynamic Devices.

NOTE: The dry tires will be used for all inspections.





T2.2 Bodywork

There must be no openings through the bodywork into the driver compartment from the front of the vehicle back to the roll bar main hoop or firewall other than that required for the cockpit opening. Minimal openings around the front suspension components are allowed.

T2.3 Wheelbase

The car must have a wheelbase of at least 1525 mm (60 inches). The wheelbase is measured from the center of ground contact of the front and rear tires with the wheels pointed straight ahead.

T2.4 Vehicle Track

The smaller track of the vehicle (front or rear) must be no less than 75% of the larger track.

T2.5 Visible Access

All items on the Inspection Form must be clearly visible to the technical inspectors without using instruments such as endoscopes or mirrors. Visible access may be provided by removing body panels | or by providing removable access panels.

ARTICLE 3: DRIVER'S CELL T3.1

Vehicle Structure - 2 Options

Teams may, at their option, design their vehicle to comply with either of two (2) separate, but related, sets of requirements and restrictions. Specifically, teams may elect to comply with **either**:

a. Part T Article 3 "Drivers Cell" as defined below **or**
b. Part AF "Alternate Frame Rules" as found in Appendix AF and the FSAE website.

T3.1.1 Notice Requirement - Teams planning to use the Part AF "Alternate Frame Rules" must notify the Rules Committee of their intent by the date posted on the SAE Website. The instructions for notification appear in Part AF. The Rules Committee will review the submission and notify the team if the request is granted. Part AF has significant analytical requirements and as it is still in development this application process will insure that the Committee can handle the workload and give teams the support they may require to show certification as well as insure the teams have the technical capability to analyse their design and prove compliance with the AF Rules.

T3.1.2 Alternate Frame Rules use requires the submission of the "Structural Requirements Certification Form (SRCF)" which **supersedes** the "Structural Equivalency Spreadsheet".

Teams submitting a Structural Requirements Certification Form (SRCF) **do not** have to submit a Structural Equivalency Spreadsheet (SES).

T3.2 General Requirements

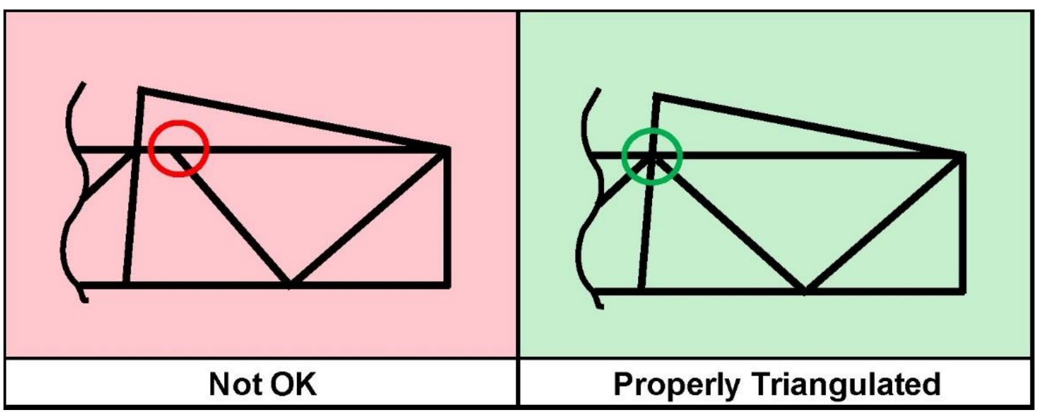
Among other requirements, the vehicle's structure must include two roll hoops that are braced, a front bulkhead with support system and Impact Attenuator, and side impact structures.

T3.3 Definitions

The following definitions apply throughout the Rules document:

a. Main Hoop - A roll bar located alongside or just behind the driver's torso.
b. Front Hoop - A roll bar located above the driver's legs, in proximity to the steering wheel.
c. Roll Hoops - Both the Front Hoop and the Main Hoop are classified as "Roll Hoops"
d. Roll Hoop Bracing Supports - The structure from the lower end of the Roll Hoop Bracing back to the Roll Hoop(s).
e. Frame Member - A minimum representative single piece of uncut, continuous tubing.

f. Frame - The “Frame” is the fabricated structural assembly that supports all functional vehicle systems. This assembly may be a single welded structure, multiple welded structures or a combination of composite and welded structures.
g. Primary Structure - The Primary Structure is comprised of the following Frame components:
    i. Main Hoop,
    ii. Front Hoop,
    iii. Roll Hoop Braces and Supports,
    iv. Side Impact Structure,
    v. Front Bulkhead,
    vi. Front Bulkhead Support System and
    vii. All Frame Members, guides and supports that transfer load from the Driver’s Restraint System into items 1 through 6.
h. Major Structure of the Frame - The portion of the Frame that lies within the envelope defined by the Primary Structure. The portion of the Main Hoop above a horizontal plane located at the top of the upper side impact bar and the Main Hoop Bracing are not included in defining this envelope.
i. Front Bulkhead - A planar structure that defines the forward plane of the Major Structure of the Frame and functions to provide protection for the driver’s feet.
j. Impact Attenuator - A deformable, energy absorbing device located forward of the Front Bulkhead.
k. Side Impact Zone - The area of the side of the car extending from the top of the floor to 350 mm (13.8 inches) above the ground and from the Front Hoop back to the Main Hoop.
l. Node-to-node triangulation - An arrangement of frame members projected onto a plane, where a co-planar load applied in any direction, at any node, results in only tensile or compressive forces in the frame members. This is also what is meant by “properly triangulated”.



T3.4 Minimum Material Requirements

T3.4.1 Baseline Steel Material

The Primary Structure of the car must be constructed of:

Either: Round, mild or alloy, steel tubing (minimum 0.1% carbon) of the minimum dimensions specified in the following table,

Or: Approved alternatives per Rules T3.5, T3.6 and T3.7.

ITEM or APPLICATION	OUTSIDE DIMENSION X WALL THICKNESS
Main & Front Hoops, Shoulder Harness Mounting Bar	Round 1.0 inch (25.4 mm) x 0.095 inch (2.4 mm) or Round 25.0 mm x 2.50 mm metric
Side Impact Structure, Front Bulkhead, Roll Hoop Bracing, Driver's Restraint Harness Attachment (except as noted above) EV: Accumulator Protection Structure	Round 1.0 inch (25.4 mm) x 0.065 inch (1.65 mm) or Round 25.0 mm x 1.75 mm metric or Round 25.4 mm x 1.60 mm metric or Square 1.00 inch x 1.00 inch x 0.047 inch or Square 25.0 mm x 25.0 mm x 1.20 mm metric
Front Bulkhead Support, Main Hoop Bracing Supports EV: Tractive System Components Protection	Round 1.0 inch (25.4 mm) x 0.047 inch (1.20 mm) or Round 25.0 mm x 1.5 mm metric or Round 26.0 mm x 1.2 mm metric
Bent Upper Side-Impact Member (T3.24.3a)	Round 1.375 inch (35.0mm) x 0.047 inch (1.20mm)

T3.4.2 The use of alloy steel does not allow the wall thickness to be thinner than that used for mild steel.

T3.4.3 The following items in a specific application are NOT rules deviations and do not require approval:

- Using tubing of the specified outside diameter but with greater wall thickness
- Using tubing of the specified wall thickness and a greater outside diameter
- Replacing round tubing with square tubing of the same or larger size to those listed above

T3.4.4 Except for inspection holes, any holes drilled in any regulated tubing require the submission of an SES.

T3.4.5 Steel properties used for calculations to be submitted in an SES or SRCF must be the following:

Non-Welded strength for continuous material calculations:

Young's Modulus (E) = 200 GPa (29,000 ksi)
Yield Strength (Sy) = 305 MPa (44.2 ksj)
Ultimate Strength (Su) = 365 MPa (52.9 ksi)

Welded strength for discontinuous material such as joint calculations:

Yield Strength (Sy) = 180 MPa (26ksi)
Ultimate Strength (Su) = 300 MPa (43.5 ksi)

Where welded tubing reinforcements are required (e.g. inserts for bolt holes or material to support suspension cutouts) the tubing must retain the baseline cold rolled strength while using the welded strength for the additional reinforcement material.

T3.4.6 Any tubing smaller than 1"x0.047" (or an approved alternative as per Rules T3.5, T3.6 or T3.7) is not considered structural and will be ignored when assessing compliance to any rule listed within Part T.

T3.4.7 Any tubing thickness less than 0.047" (or an approved alternative as per Rules T3.5, T3.6 or T3.7) is not considered structural and will be ignored when assessing compliance to any rule.

T3.5 Alternative Tubing, Tubing Geometry and Materials - General Notes for all Applications

T3.5.1 Alternative tubing geometry and/or materials may be used except that the Main Roll Hoop and Main Roll Hoop Bracing must be made from steel, i.e. the use of aluminium or titanium tubing or composites for these components is prohibited.

T3.5.2 Titanium or magnesium on which welding has been utilized may not be used for any part of the Primary Structure. This includes the attachment of brackets to the tubing or the attachment of the tubing to other components.

T3.5.3 If a team chooses to use alternative tubing and/or materials, they must submit a "Structural Equivalency Spreadsheet" per Rule T3.9. The teams must submit calculations for the material they have chosen, demonstrating equivalence to the minimum requirements found in Section T3.4.1 for yield and ultimate strengths in bending, buckling and tension, for buckling modulus and for energy dissipation. (The Buckling Modulus is defined as EI, where, E = modulus of Elasticity, and I = area moment of inertia about the weakest axis.)

T3.5.4 Tubing cannot be of thinner wall thickness than listed in T3.6 or T3.7.

T3.5.5 If a bent tube (or member consisting of multiple tubes that are not in a line) is used anywhere in the primary structure, other than the front and main roll hoops, an additional tube must be attached to support it. The attachment point must be the position along the tube where it deviates farthest from a straight line connecting both ends. The support tube must have the same diameter and thickness as the bent tube, terminate at a node of the chassis, and be angled no more than 30 degrees from the plane of the bent tube. **Braces attached to the upper side impact member are not required to meet the 30 degrees from the plane of the bent tube requirement.**

T3.5.6 Any chassis design that is a hybrid of the baseline and monocoque rules, must meet all relevant rules requirements, e.g. a sandwich panel side impact structure in a tube frame chassis must meet the requirements of rules T3.27, T3.28, T3.29, T3.30 and T3.33.

NOTE: It is allowable for the properties of tubes and laminates to be combined to prove equivalence. For example, in a side-impact structure consisting of one tube as per T3.4 and a laminate panel, the panel only needs to be equivalent to two side-impact tubes.

T3.6 Alternative Steel Tubing

Minimum Wall Thickness Allowed

MATERIAL & APPLICATION	MINIMUM WALL. THICKNESS
Steel Tubing for Front and Main Roll Hoops, and Shoulder Harness Mounting Bar	2.0 mm (0.079 inch)
Steel Tubing for Roll Hoop Bracing, Roll Hoop Bracing Supports, Side Impact Structure, Front Bulkhead, Front Bulkhead Support, Driver’s Harness Attachment (except as noted above), Protection of HV accumulators, and protection of HV tractive systems	1.2 mm (0.047 inch)

Minimum Wall Thickness Allowed for teams satisfying physical testing requirements:

MATERIAL & APPLICATION	MINIMUM WAIT. THICKNESS
Steel Tubing for Front and Main Roll Hoops, and Shoulder Harness Mounting Bar	1.6 mm (0.065 inch)
Steel Tubing for Roll Hoop Bracing, Roll Hoop Bracing Supports, Side Impact Structure, Front Bulkhead, Front Bulkhead Support, Driver’s Harness Attachment (except as noted above), Protection of HV accumulators, and protection of HV tractive systems	0.9 mm (0.035 inch)

a. All steel is treated equally - there is no allowance for alloy steel tubing, e.g. SAE 4130, to have a thinner wall thickness than that used with mild steel.

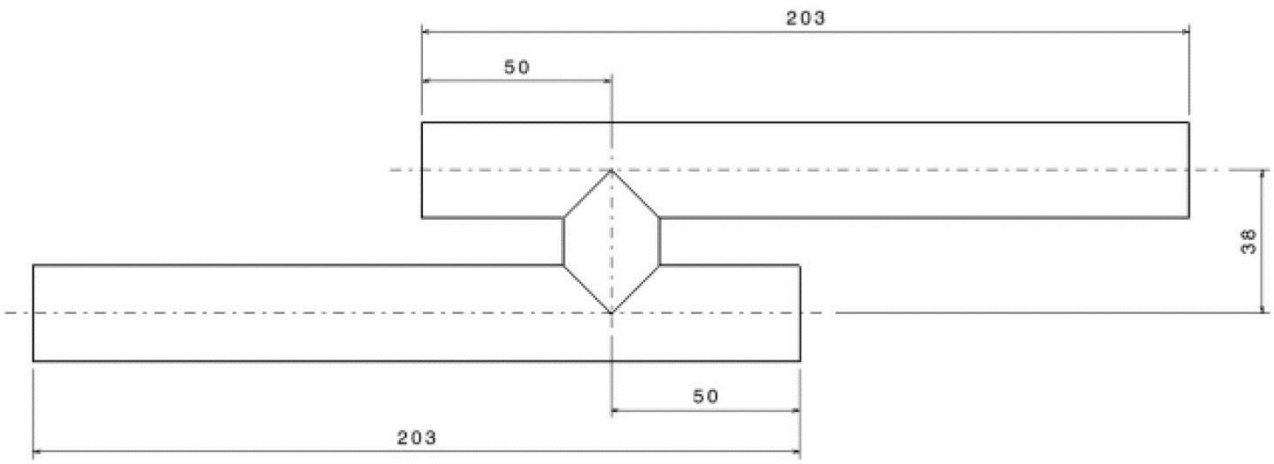
b. To maintain EI with a thinner wall thickness than specified in T3.4.1, the outside diameter MUST be increased.

c. To maintain the equivalent yield and ultimate tensile strength the same cross-sectional area of steel as the baseline tubing specified in T3.4.1 MUST be maintained.

d. Teams using the Alternative Frame Rules must comply with rule T3.6.

T3.6.1 Test samples representing the joining method to be used on the Primary Structure must be constructed by team members and pull tested to determine joint strength and quality.

T3.6.2 Test samples must be constructed in an “H” pattern with two parallel 203mm (8 inches) long tubes separated by 38mm (1.5 inches) measured from the tube centerline. The connecting tube must be perpendicular to the parallel tubes and be 50mm (2 inches) from the top end of one tube and 50mm (2 inches) from the bottom end of the other tube.



T3.6.3 Construction of the test samples must meet the following requirements:

a. The test samples must use the same mild/alloy steel as is used in the construction of the chassis.
b. For each alternative configuration that is used in the vehicle design both the alternative and baseline must be tested and compared.
c. Two samples of each joint must be manufactured and tested, two each of the baseline and two each of the alternative joint. NOTE: this means the minimum number of tests is four.

Baseline joint			Alternate tube thickness joint	
inches	metric		inches	metric
1"x0.095" to 1"x0.047"	25.4mm x 2.4 mm to 25.4mm x 1.2 mm	-->	1"x0.095" to 1.375"x0.035"	25.4mm x 2.4 mm to 34.9mm x 0.9 mm
1"x0.063" to 1"x0.047"	25.4mm x 1.6 mm to 25.4mm x 1.2 mm	-->	1"x0.063" to 1.375"x0.035"	25.4mm x 1.6 mm to 34.9mm x 0.9 mm
1"x0.047" to 1"x0.047"	25.4mm x 1.2 mm to 25.4mm x 1.2 mm	-->	1"x0.047" to 1.375"x0.035"	25.4mm x 1.2 mm to 34.9mm x 0.9 mm
1"x0.047" to 1"x0.047"	25.4mm x 1.2 mm to 25.4mm x 1.2 mm	-->	1.375"x0.035" to 1.375x0.035"	34.9mm x 0.9 mm to 34.9mm x 0.9 mm

d. The thinnest wall thickness tube must be the short perpendicular tube between the parallel tubes.
e. Teams may modify or add material at the ends of the test samples for mounting into a pull test machine. Mounting end modifications must be consistent across all test samples.
f. Any post welding heat treatment such as annealing must be consistent across all test samples and with the actual vehicle frame. Altering the shape of the weld is not allowed (no grinding or sanding).

T3.6.4 Test samples must be pull tested to failure. Force vs. Deflection curves for all samples must be submitted for review in the SES. The “physical test requirement” is satisfied if the minimum failure load for both "Alternate tube thickness" test samples is within 95 percent of the minimum failure load of either corresponding "Baseline joint" test sample. Test results must be documented in the SES or SRCF and test samples must be available to technical inspectors at competition

T3.7 Aluminium Tubing Requirements

T3.7.1 Minimum Wall Thickness: Aluminium Tubing 3.0 mm (0.118 inch)

T3.7.2 The equivalent yield strength must be considered in the "as-welded" condition, (Reference: WELDING ALUMINUM (latest Edition) by the Aluminium Association, or THE WELDING HANDBOOK, Volume 4, 7th Ed., by The American Welding Society), unless the team demonstrates and shows proof that the frame has been properly solution heat treated and artificially aged.

T3.7.3 Should aluminium tubing be solution heat-treated and age hardened to increase its strength after welding; the team must supply sufficient documentation as to how the process was performed. This includes, but is not limited to, the heat-treating facility used, the process applied, and the fixturing used.

T3.8 Composite Materials

T3.8.1 If any composite or other material is used, the team must:

- Present documentation of material type, e.g. purchase receipt, shipping document or letter of donation, and of the material properties.

- Submit details of the composite lay-up technique as well as the structural material used (cloth type, weight, and resin type, number of layers, core material, and skin material if metal) .

- Submit calculations demonstrating equivalence of their composite structure to one of similar geometry made to the minimum requirements found in Section T3.4.1. Equivalency calculations must be submitted for energy dissipation, yield and ultimate strengths in bending, buckling, and tension. Submit the completed "Structural Equivalency Spreadsheet" per Section T3.9.

T3.8.2 Composite materials are not allowed for the Main Hoop or the Front Hoop.

T3.9 Structural Documentation - SES or SRCF Submission

All equivalency calculations must prove equivalency relative to steel grade SAE/AISI 1010**.**

T3.9.1 All teams MUST submit either a STRUCTURAL EQUIVALENCY SPREADSHEET (SES) or a STRUCTURAL REQUIREMENTS CERTIFICATION FORM (SCRF).

Teams complying with the Part T Article 3 "Drivers Cell" rules MUST submit a Structural Equivalence Spreadsheet (SES), even if they are NOT planning to use alternative materials or tubing sizes to those specified in T3.4.1 Baseline Steel Materials.

Teams following the Part AF "Alternate Frame Rules" MUST submit a Structural Requirements Certification Form (SRCF). See Rule Part AF - AF2.1.

T3.9.2 The use of alternative materials or tubing sizes to those specified in T3.4.1 "Baseline Steel Material," is allowed, provided they have been judged by a technical review to have equal or superior properties to those specified in T3.4.1.

T3.9.3 Approval of alternative material or tubing sizes will be based upon the engineering judgment and experience of the chief technical inspector or his appointee.

T3.9.4 The technical review is initiated by completing the "Structural Equivalency Spreadsheet" (SES) using the format given in Appendix T-1.

T3.9.5 Structural Equivalency Spreadsheet - Submission

a. Address - SESs must be submitted to the officials at the competition you are entering at the address shown in the Appendix or indicated on the competition website.
b. Due Date - SESs must be submitted no later than the date indicated on the competition website. Penalties for Late Submission will be imposed per A8.4.1. SES/SRCF forms are evaluated in the order in which they are received with late submissions reviewed last. Please submit SES/SRCF as early as possible to reduce the chance of late SES/SRCF approval which could delay the completion of your vehicle.
c. Acknowledgement - North America competitions - SESs submitted for vehicles entered into competitions held in North America will be acknowledged automatically by the fsaeonline website.

Do Not Resubmit SES's unless instructed to do so.

T3.9.6 Vehicles completed under an approved SES must be fabricated in accordance with the materials and processes described in the SES.

T3.9.7 Teams must bring a copy of the approved SES with them to Technical Inspection.

Comment - The resubmission of an SES that was written and submitted for a competition in a previous year is strongly discouraged. Each team is expected to perform their own tests and to submit SESs based on their original work. Understanding the engineering that justifies the equivalency is essential to discussing your work with the officials.

T3.10 Main and Front Roll Hoops - General Requirements

T3.10.1 The driver's head and hands must not contact the ground in any rollover attitude.

T3.10.2 The Frame must include both a Main Hoop and a Front Hoop as shown in Figure 1.

T3.10.3 When seated normally and restrained by the Driver's Restraint System, the helmet of a 95th percentile male (anthropometrical data) and all of the team's drivers must:

a. Be a minimum of 50.8 mm (2 inches) from the straight line drawn from the top of the main hoop to the top of the front hoop. (Figure 1a)
b. Be a minimum of 50.8 mm (2 inches) from the straight line drawn from the top of the main hoop to the lower end of the main hoop bracing if the bracing extends rearwards. (Figure 1b)
c. Be no further rearwards than the rear surface of the main hoop if the main hoop bracing extends forwards. (Figure 1c)

95th Percentile Male Template Dimensions

A two dimensional template used to represent the 95th percentile male is made to the following dimensions:

- A circle of diameter 200 mm (7.87 inch) will represent the hips and buttocks.
- A circle of diameter 200 mm (7.87 inch) will represent the shoulder/cervical region.
- A circle of diameter 300 mm (11.81 inch) will represent the head (with helmet).
- A straight line measuring 490 mm (19.29 inch) will connect the centers of the two 200 mm circles.
- A straight line measuring 280 mm (11.02 inch) will connect the centers of the upper 200 mm circle and the 300 mm head circle.

HELMET CLEARANCE

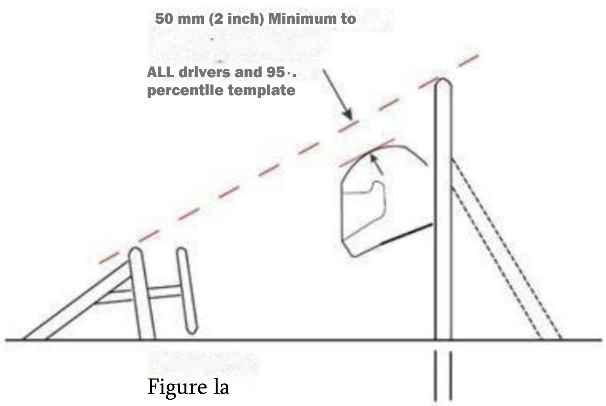
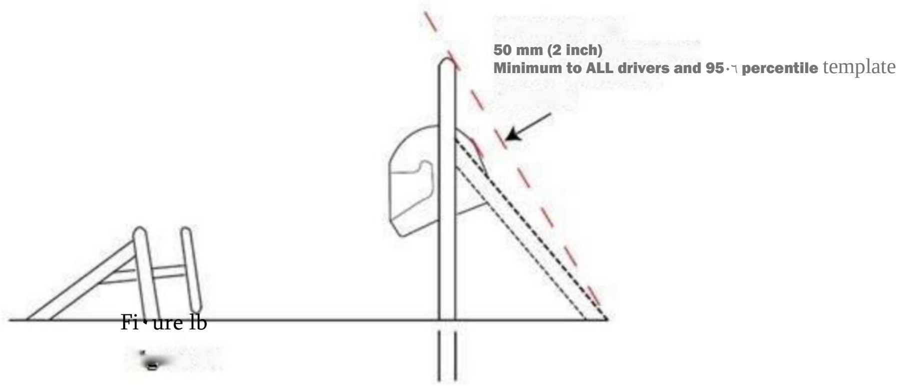


Figure la



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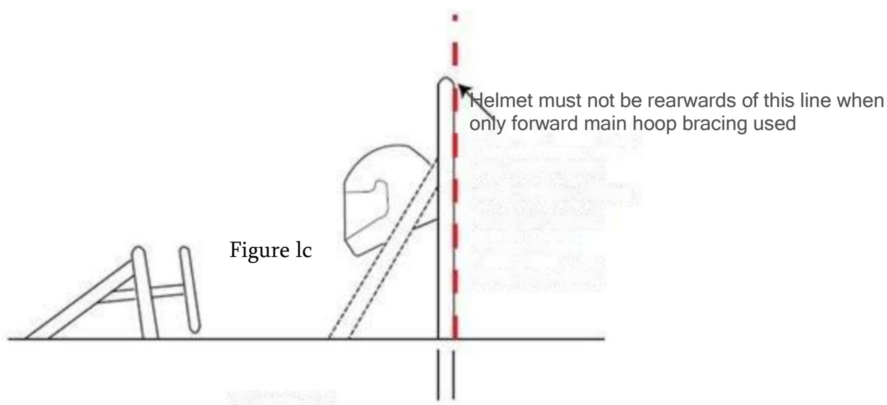

Figure lc

T3.10.4 The 95th percentile male template will be positioned as follows: (See Figure 2.)

a. The seat will be adjusted to the rearmost position,
b. The pedals will be placed in the most forward position.
c. The bottom 200 mm circle will be placed on the seat bottom such that the distance between the center of this circle and the rearmost face of the pedals is no less than 915 mm (36 inches).
d. The middle 200 mm circle, representing the shoulders, will be positioned on the seat back.
e. The upper 300 mm circle will be positioned no more than 25.4 mm (1 inch) away from the head restraint (i.e. where the driver's helmet would normally be located while driving).

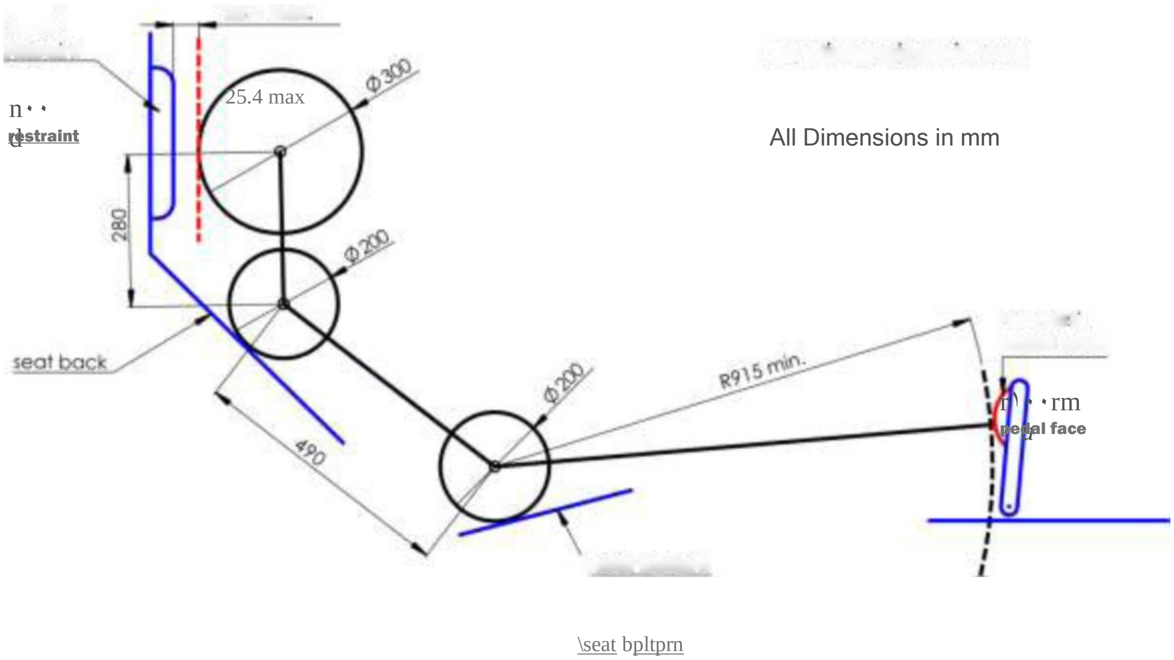

Figure 2

T3.10.5 If the requirements of T3.10.4 are not met with the 95th percentile male template, the car will NOT receive a Technical Inspection Sticker and will not be allowed to compete in the dynamic events.

T3.10.6 Drivers who do not meet the helmet clearance requirements of T3.10.3 will not be allowed to drive in the competition.

T3.10.7 The minimum radius of any bend, measured at the tube centerline, must be at least three times the tube outside diameter. Bends must be smooth and continuous with no evidence of crimping or wall failure.

T3.10.8 The Main Hoop and Front Hoop must be securely integrated into the Primary Structure using proper triangulation.

T3.11 Main Hoop

T3.11.1 The Main Hoop must be constructed of a single piece of uncut, continuous, closed section steel tubing per Rule T3.4.1.

T3.11.2 The use of aluminium alloys, titanium alloys or composite materials for the Main Hoop is prohibited.

T3.11.3 The Main Hoop must extend from the lowest Frame Member on one side of the Frame, up, over and down the lowest Frame Member on the other side of the Frame.

T3.11.4 In the side view of the vehicle, the portion of the Main Roll Hoop that lies above its attachment point to the upper Side Impact Tube, must be within ten degrees (10°) of the vertical.

T3.11.5 In the side view of the vehicle, any bends in the Main Roll Hoop above its attachment point to the Major Structure of the Frame must be braced to a node of the Main Hoop Bracing Support structure with tubing meeting the requirements of Roll Hoop Bracing as per Rule T3.4.1.

T3.11.6 In the side view of the vehicle, the portion of the Main Roll Hoop that lies below the upper side impact member attachment point may be inclined at any angle to the vertical in the forward direction but, it can only be inclined rearward within ten degrees (10°) of the vertical.

T3.11.7 In the front view of the vehicle, the vertical members of the Main Hoop must be at least 380 mm (15 inch) apart (inside dimension) at the location where the Main Hoop is attached to the bottom tubes of the Major Structure of the Frame.

T3.12 Front Hoop

T3.12.1 The Front Hoop must be constructed of closed section metal tubing per Rule T3.4.1.

T3.12.2 The Front Hoop must extend from the lowest Frame Member on one side of the Frame, up, over and down to the lowest Frame Member on the other side of the Frame.

T3.12.3 With proper triangulation, it is permissible to fabricate the Front Hoop from more than one piece of tubing.

T3.12.4 The top-most surface of the Front Hoop must be no lower than the top of the steering wheel in any angular position.

T3.12.5 The Front Hoop must be no more than 250 mms (9.8 inches) forward of the steering wheel. This distance must be measured horizontally, on the vehicle centerline, from the rear surface of the Front Hoop to the forward most surface of the steering wheel rim with the steering in the straight-ahead position.

T3.12.6 In side view, no part of the Front Hoop can be inclined at more than twenty degrees (20°) from the vertical.

T3.13 Main Hoop Bracing

T3.13.1 Main Hoop braces must be constructed of closed section steel tubing per Rule T3.4.1.

T3.13.2 The Main Hoop must be supported by two braces extending in the forward or rearward direction on both the left and right sides of the Main Hoop.

T3.13.3 In the side view of the Frame, the Main Hoop and the Main Hoop braces must not lie on the same side of the vertical line through the top of the Main Hoop, i.e. if the Main Hoop leans forward, the braces must be forward of the Main Hoop, and if the Main Hoop leans rearward, the braces must be rearward of the Main Hoop.

T3.13.4 The Main Hoop braces must be attached as near as possible to the top of the Main Hoop but not more than 160 mm (6.3 in) below the top-most surface of the Main Hoop. The included angle formed by the Main Hoop and the Main Hoop braces must be at least thirty degrees (30°). See Figure 3.

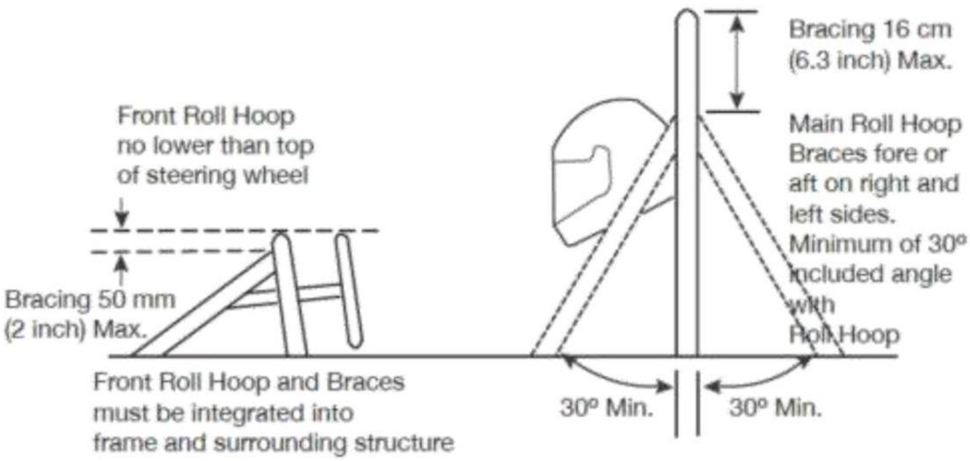

FIGURE 3

T3.13.5 The Main Hoop braces must be straight, i.e. without any bends.

T3.13.6 The Main Hoop Braces must be securely integrated into the Frame and be capable of transmitting all loads from the Main Hoop into the Major Structure of the Frame without failing.

T3.13.7 The lower end of the Main Hoop Braces must be supported back to the Main Hoop by a minimum of two Frame Members on each side of the vehicle; an upper member and a lower member in a properly triangulated configuration.

a. The upper support member must attach to the node where the upper Side Impact Member attaches to the Main Hoop.
b. The lower support member must attach to the node where the lower Side Impact Member attaches to the Main Hoop.

NOTE: Each of the above members can be multiple or bent tubes provided the requirements of T3.5.5 are met.

Note: Examples of acceptable configurations of members can be found in Appendix T-4.

T3.13.8 All the Frame Members of the Main Hoop Bracing Support system listed above must be constructed of closed section tubing per Section T3.4.1.

T3.13.9 If any item which is outside the envelope of the Primary Structure is attached to the Main Hoop braces, then additional bracing must be added to prevent bending loads in the braces in any rollover attitude

T3.14 Front Hoop Bracing

T3.14.1 Front Hoop braces must be constructed of material per Rule T3.4.1.

T3.14.2 The Front Hoop must be supported by two braces extending in the forward direction on both the left and right sides of the Front Hoop.

T3.14.3 The Front Hoop braces must be constructed such that they protect the driver's legs and should extend to the structure in front of the driver's feet.

T3.14.4 The Front Hoop braces must be attached as near as possible to the top of the Front Hoop but not more than 50.8 mm (2 in) below the top-most surface of the Front Hoop. See Figure 3.

T3.14.5 If the Front Hoop leans rearwards by more than ten degrees (10°) from the vertical, it must be supported by additional bracing to the rear. This bracing must be constructed of material per Rule T3.4.1.

T3.14.6 The driver's feet and legs must be completely contained within the Major Structure of the Frame. While the driver's feet are touching the pedals, in side and front views, no part of the driver's feet or legs can extend above or outside of the Major Structure of the Frame.

T3.14.7 The Front Hoop braces must be straight, i.e. without any bends

T3.15 Other Bracing Requirements

Where the braces are not welded to steel Frame Members, the braces must be securely attached to the Frame using 8 mm Metric Grade 8.8 (5/16 in SAE Grade 5), or stronger, bolts. Mounting plates welded to the Roll Hoop braces must be at least 2.0 mm (0.080 in) thick steel.

T3.16 Other Side Tube Requirements

If there is a Roll Hoop brace or other frame tube alongside the driver, at the height of the neck of any of the team's drivers, a metal tube or piece of sheet metal must be firmly attached to the Frame to prevent the drivers' shoulders from passing under the roll hoop brace or frame tube, and his/her neck contacting this brace or tube.

T3.17 Mechanically Attached Roll Hoop Bracing T3.17.1 Roll Hoop bracing may be mechanically attached.

T3.17.2 Any non-permanent joint at either end must be either a double-lug joint as shown in Figures 4 and 5, or a sleeved butt joint as shown in Figure 6.

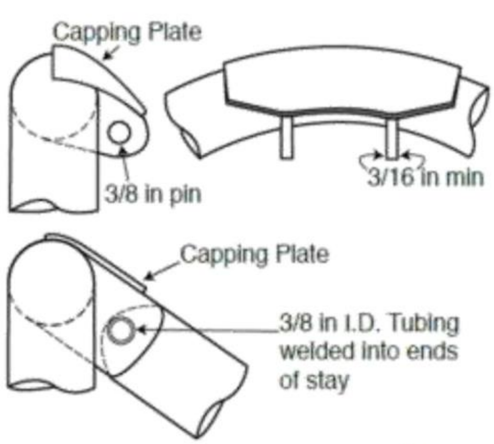

FIGURE 4

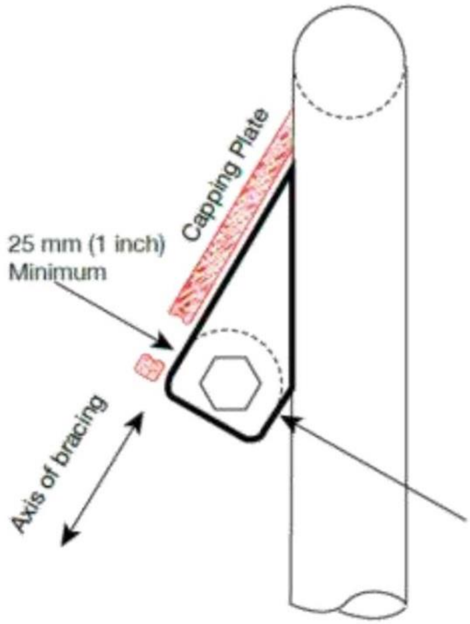

FIGURE 5

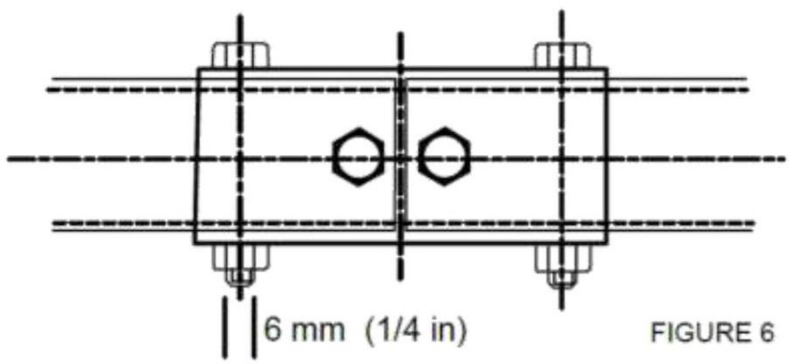

FIGURE 6

T3.17.3 The threaded fasteners used to secure non-permanent joints are considered critical fasteners and must comply with ARTICLE 11:

T3.17.4 No spherical rod ends are allowed.

T3.17.5 For double-lug joints, each lug must be at least 4.5 mm (0.177 in) thick steel, measure 25 mm (1.0 in) minimum perpendicular to the axis of the bracing and be as short as practical along the axis of the bracing.

T3.17.6 All double-lug joints, whether fitted at the top or bottom of the tube, must include a capping arrangement (Figures 4 & 5).

T3.17.7 In a double-lug joint the pin or bolt must be 10 mm Metric Grade 9.8 (3/8 in. SAE Grade 8) minimum. The attachment holes in the lugs and in the attached bracing must be a close fit with the pin or bolt.

T3.17.8 For sleeved butt joints (Figure 6), the sleeve must have a minimum length of 76 mm (3 inch); 38 mm (1.5 inch) either side of the joint, and be a close-fit around the base tubes. The wall thickness of the sleeve must be at least that of the base tubes. The bolts must be 6 mm Metric Grade 9.8 (1/4 inch SAE Grade 8) minimum. The holes in the sleeves and tubes must be a close-fit with the bolts.

T3.18 Bulkhead

T3.18.1 The Front Bulkhead must be constructed of closed section tubing per Rule T3.4.1.

T3.18.2 Except as allowed by T3.18.3, The Front Bulkhead must be located forward of all non-crushable objects, e.g. batteries, master cylinders, hydraulic reservoirs.

T3.18.3 The Front Bulkhead must be located such that the soles of the driver's feet, when touching but not applying the pedals, are rearward of the bulkhead plane. (This plane is defined by the forward-most surface of the tubing.) Adjustable pedals must be in the forward most position.

T3.19 Front Bulkhead Support

T3.19.1 The Front Bulkhead must be securely integrated into the Frame.

T3.19.2 The Front Bulkhead must be supported back to the Front Roll Hoop by a minimum of three Frame Members on each side of the vehicle; an upper member; lower member and diagonal brace to provide triangulation.

a. The upper support member must be attached within 50mm (2") of the top surface of the Front Bulkhead, and attach to the Front Roll Hoop within a zone extending 100mm (4") above and 50mm (2") below the Upper Side Impact member. **If the upper support member is further than 100mm (4") above the Upper Side Impact member, then properly triangulated bracing is required to transfer load to the Main Hoop, either via the Upper Side Impact member, or an additional member that meets the size requirements of T3.4, transmitting load from the junction of the Upper Support Member with the Front Hoop.**
b. The lower support member must be attached to the base of the Front Bulkhead and the base of the Front Roll Hoop.
c. The diagonal brace must properly triangulate the upper and lower support members **NOTE**: Each of

the above members can be multiple or bent tubes provided the requirements of T3.5.5 are met.

Note: Examples of acceptable configurations of members can be found in Appendix T-4.

T3.19.3 All the Frame Members of the Front Bulkhead Support system listed above must be constructed of closed section tubing per Section T3.4.1.

T3.20 Impact Attenuator (IA)

T3.20.1 Forward of the Front Bulkhead there must be an Impact Attenuator Assembly, consisting of an Impact Attenuator and an Anti-Intrusion Plate.

T3.20.2 The Impact Attenuator must be:

a. At least 200 mm (7.8 in) long, with its length oriented along the fore/aft axis of the Frame.
b. At least 100 mm (3.9 in) high and 200 mm (7.8 in) wide for a minimum distance of 200 mm (7.8 in) forward of the Front Bulkhead.
c. Attached securely to the Anti-Intrusion Plate or directly to the Front Bulkhead.

NOTE: An officially approved "standard" Impact Attenuator can be found in Appendix T-3. T3.20.3 The

Anti-Intrusion Plate must:

a. Be a 1.5 mm (0.060 in) solid steel or 4.0 mm (0.157 in) solid aluminum plate, or an approved alternative as per T3.38.
b. Attach securely and directly to the Front Bulkhead.
c. Have an outer profile that meets the requirements of T3.20.5.

T3.20.4 The accepted methods of attaching the Impact Attenuator Assembly, Impact Attenuator and AntiIntrusion Plate are:

a. Welding, where the welds are either continuous or interrupted. If interrupted, the weld/space ratio must be at least 1:1. All weld lengths must be greater than 25 mm (1").
b. Bolted joints, using a minimum of eight (8) 8 mm Metric Grade 8.8 (5/16" SAE Grade 5) bolts with positive locking. The distance between any two bolt centers must be at least 50 mm (2").

The Impact Attenuator may also be attached to the Anti-Intrusion Plate using a structural adhesive. The adhesive must be appropriate for use with both substrate types. Equivalency of this bonded joint to a welded or bolted joint must be documented in the team's SES submission.

All attachment types must provide adequate load paths for transverse and vertical loads in the event of off-axis impacts. Segmented foam attenuators must have all segments bonded together to prevent sliding or parallelogramming.

The attachment of the Impact Attenuator Assembly to a monocoque structure must be documented in the team's SES submission. This must prove the attachment method is equivalent to the bolted joints described above and that these bolted joints will fail before any other part of the monocoque.

T3.20.5 The requirements for the outside profile of the Impact Attenuator Assembly are dependent on the method of attachment to the Front Bulkhead:

For welded joints the profile must extend at least to the centerline of the Front Bulkhead tubes on all sides.

For bolted joints the profile must match the outside dimensions of the Front Bulkhead around the entire periphery.

T3.20.6 If a team uses the "standard" FSAE Impact Attenuator, and the outside profile of the Anti-Intrusion Plate extends beyond the "standard" Impact Attenuator by more than 25 mm (1") on any side, a diagonal or X-brace made from 1.00" x 0.049" steel tube, or an approved equivalent per T3.5, must be included in the Front Bulkhead.

Teams may choose to not brace the bulkhead, but physical testing must then be carried out to prove that the Anti-Intrusion Plate does not permanently deflect more than 25 mm (1").

T3.21 Impact Attenuator Data Requirement

T3.21.1 All teams must submit an Impact Attenuator Data Report using the Impact Attenuator Data (IAD) Template found in Appendix T-2.

The report must be submitted electronically in Adobe Acrobat ® format (*.pdf file) to the address and by the date indicated in the Action Deadlines provided on the relevant competition website.

The report must be a single file named as follows: carnumber_schoolname_competition code_IAD.pdf using your assigned car number, the complete school name and competition code (see A2.6)

e.g. 087_University of SAE_FSAEM_IAD.pdf Penalties

for Late Submission will be imposed per A8.4.1.

Impact Attenuator Reports will be evaluated by the organizers and passed to the Design Event Captain for consideration in that event.

T3.21.2 The report must include:

a. Test data that proves that the Impact Attenuator Assembly, when mounted on the front of a vehicle with a total mass of 300 kg (661 lbs.) and impacting a solid, non-yielding impact barrier with a velocity of impact of 7.0 meters/second (23.0 ft/sec), decelerates the vehicle at a rate not exceeding 20 g's average and 40 g's peak. The energy absorbed in this event must meet or exceed 7350 Joules.

   NOTE: These are the attenuator functional requirements not test requirements. Quasi-static testing is allowed.
b. Calculations showing how the reported absorbed energy and decelerations have been derived.
c. A schematic of the test method.
d. Photos of the attenuator, annotated with the height of the attenuator before and after testing. Teams

using the standard Impact Attenuator are not required to submit test data with their IAD Report, but all other requirements must be included. In addition, photos of the actual attenuator and evidence that it meets the design criteria in Appendix T-3 must be appended to the report.

This can be a receipt or packing slip from the supplier.

T3.21.3 During any test, the Impact Attenuator must be attached to the Anti-Intrusion plate using the intended vehicle attachment method.

The Impact Attenuator Assembly must be attached to a structurally representative section of the intended chassis. There must be at least 50 mm clearance rearwards of the Anti-Intrusion Plate to the test fixture.

No part of the Anti-Intrusion Plate may permanently deflect more than 25mm (1") beyond the position of the Anti-Intrusion Plate before the test.

Teams using Impact Attenuators (typically structural noses) directly attached to the Front Bulkhead, which shortcut the load path through the bulk of the Anti-Intrusion Plate, must conduct an additional test. This test must prove that the Anti-hrtrusion Plate can withstand a load of 120kN (300kg multiplied by 40g), where the load applicator matches the minimum Impact Attenuator dimensions. NOTE 1: The 25 mm (1") spacing represents the front bulkhead support and insures that the plate does not intrude excessively into the cockpit.

NOTE 2: A solid block of material in the shape of the front bulkhead is not "structurally representative". The test fixture must have equivalent strength and stiffiress to a baseline front bulkhead.

T3.21.4 Dynamic testing (sled, pendulum, drop tower, etc) of the Impact Attenuator may only be conducted at a dedicated test facility. Thjs facility may be part of die University, but must be supervised by professional staff or the University faculty. Teams are not allowed to construct their own dynamic test apparatus.

When using acceleration data from the dynamic test, the average deceleration must be calculated based on the raw unfiltered data.

If peaks above the 40g limit are present in the data, a Channel Filter Class (CFC) 60 (100Hz) filter per SAE Recommended Practice J211 "Instrumental for Impact Test", or a 100 Hz, 3rd order, low pass Butterworth (-3dB at 100 Hz) filter may be applied.

T3.21.5 Quasi-static testing may be performed by teams using their University's facilities/equipment, but teams are advised to exercise due care when performing all tests.

T3.21.6 Teams with any non-crushable object(s) that do not meet the requirements of T3.22.2 c) must prove the combination of their Impact Attenuator Assembly and non-crushable object(s) do not exceed the peak deceleration of rule T3.21.2. Any of the following methods may be used to prove the design does not exceed 120kN:

a. Physical testing of the Impact Attenuator Assembly including any required non-crushable object(s). See fsaeonline.com FAQs for an example of the structure to be included in the test for wings and wing mounts.
b. Combining the peak force from physical testing of the Impact Attenuator Assembly with the failure load for the mounting of the non-crushable object(s), calculated from fastener shear and/or link buckling.
c. Combining the "standard" Impact Attenuator peak load of 95kN with the failure load for the mounting of the non-crushable object(s), calculated from fastener shear and/or link buckling.

T3.22 Non-Crushable Objects

T3.22.1 All non-crushable objects (e.g. batteries, master cylinders, hydraulic reservoirs) inside the primary structure must have 25 mm (1") clearance to the rear face of the Impact Attenuator Anti-Intrusion Plate.

T3.22.2 All non-crushable objects outside the primary structure must be either:

a. Included in the Impact Attenuator physical test
b. Subject to an analysis approach as per T3.21.6 b) or T3.21.6 c)
c. Mounted rearwards of an imaginary transverse vertical plane, offset forwards from the Impact Attenuator Anti-Intrusion Plate by a distance equal to the height of the crushed impact attenuator.

T3.23 Front Bodywork

T3.23.1 Sharp edges on the forward facing bodywork or other protruding components are prohibited.

T3.23.2 All forward facing edges on the bodywork that could impact people, e.g. the nose, must have forward facing radii of at least 38 mm (1.5 inches). This minimum radius must extend to at least forty-five degrees (45°) relative to the forward direction, along the top, sides and bottom of all affected edges. **T3.24 Side Impact Structure for Tube Frame Cars**
The Side Impact Structure must meet the requirements listed below.

T3.24.1 The Side Impact Structure for tube frame cars must be comprised of at least three (3) tubular members located on each side of the driver while seated in the normal driving position, as shown in Figure 7.

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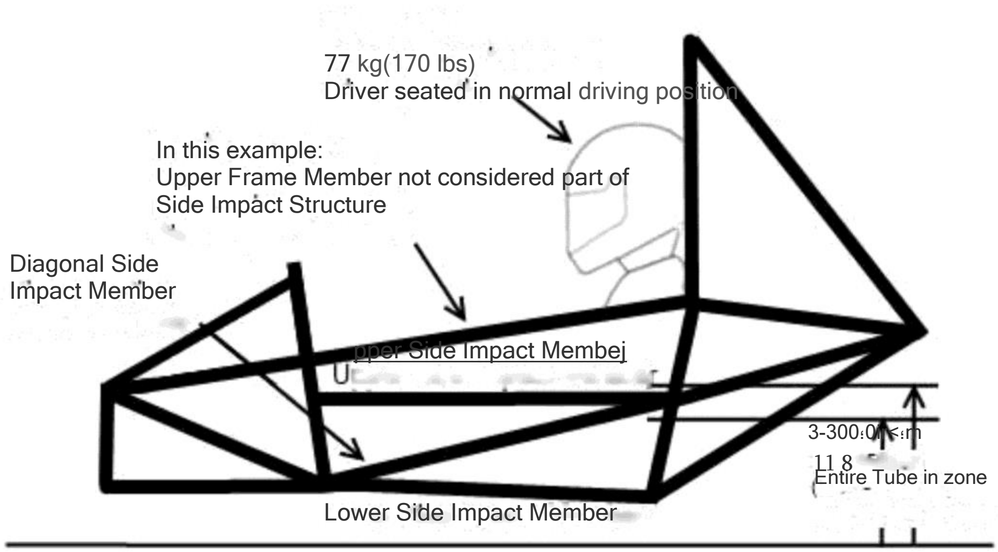


FIGURE 7

T3.24.2 The three (3) required tubular members must be constructed of material per Section T3.4.

T3.24.3 The locations for the three (3) required tubular members are as follows:

a. The upper Side Impact Structural member must connect the Main Hoop and the Front Hoop. With a 77kg (170 pound) driver seated in the normal driving position all of the member must be at a height between 300 mm (11.8 inches) and 350 mm (13.8 inches) above the ground. The upper frame rail may be used as this member if it meets the height, diameter and thickness requirements.
If the member is bent or non-continuous, the minimum tube size must be 1 3/8” x 0.047” (35mm x 1.2 mm) or equivalent.
b. The lower Side Impact Structural member must connect the bottom of the Main Hoop and the bottom of the Front Hoop. The lower frame rail/frame member may be this member if it meets the diameter and wall thickness requirements.
c. The diagonal Side Impact Structural member must connect the upper and lower Side Impact Structural members forward of the Main Hoop and rearward of the Front Hoop.

T3.24.4 With proper triangulation, it is permissible to fabricate the Side Impact Structural members from more than one piece of tubing.

T3.25 Inspection Holes

T3.25.1 The Technical Inspectors may check the compliance of all tubes. This may be done by the use of ultra-sonic testing or by the drilling of inspection holes at the inspector's request.

T3.26 Composite Space Frames

Composite space frames are not prohibited by the rules, but any team wishing to build a composite space frame must seek approval from their organizing body. The team, at a minimum, must provide test data on the actual joints used in the frame. These tests must include static strength testing on representative configurations from all locations in the frame. An assessment of the ability of the joints to handle cyclic loading must also be assessed. This information must be included in the structural equivalency submission or the structural requirements certification submission, whichever approach the team is using.

NOTE: Given the extra complexity of a composite space frame and the detailed review process that will be required, teams are encouraged to submit their documents well in advance early of the deadline and to attain approval before starting their vehicle build.

T3.27 Monocoque General Requirements

All equivalency calculations must prove equivalency relative to steel grade SAE/AISI 1010**.**

T3.27.1 All sections of the rules apply to monocoque structures except for the following sections which supplement or supersede other rule sections.

T3.27.2 Monocoque construction requires an approved Structural Equivalency Spreadsheet, per Section T3.9.
The form must demonstrate that the design is equivalent to a welded frame in terms of energy dissipation, yield and ultimate strengths in bending, buckling and tension. Information must include: material type(s), cloth weights, resin type, fiber orientation, number of layers, core material, and layup technique. The 3-point bend test and shear test data and pictures must also be included as per T3.30 | Monocoque Laminate Testing. The Structural Equivalency must address each of the items below.
Data from the laminate testing results must be used as the basis for any strength or stiffness calculations.

T3.27.3 Composite and metallic monocoques have the same requirements.

T3.27.4 Composite monocoques must meet the materials requirements in Rule T3.8 Composite Materials.

T3.28 Monocoque Inspections

Due to the monocoque rules and methods of manufacture it is not always possible to inspect all aspect of a monocoque during technical inspection. For items which cannot be verified by an inspector it is the responsibility of the team to provide documentation, both visual and/or written, that the requirements have been met. Generally, the following items should be possible to be confirmed by | the technical inspector:

a. Verification of the main hoop outer diameter and thickness where it protrudes above the monocoque
b. Visual verification that the main hoop goes to the lowest part of the tub, locally. This may be difficult as the tube is allowed to be integrated into the laminate but there is often a contour that comes from the tube that is visible.
c. Verify mechanical attachment of main hoop to tub exists and matches the SES, at all points shown on the SES.
d. Verify visually or by feel that the front roll hoop is installed. Verify mechanical attachment (if included) against the SES.

Items such as the size and composition of the front roll hoop, when integrally bonded to the monocoque, must be proven with documentation that shows dimensions on the tubes and pictures of the dimensioned tube being included in the layup. A team found to be improperly presenting any evidence of the manufacturing process will be barred from competing with a monocoque through at least the following year.

T3.29 Monocoque Buckling Modulus - Equivalent Flat Panel Calculation

When specified in the rules, the EI of the monocoque must be calculated as the EI of a flat panel with the same composition as the monocoque about the neutral axis of the laminate. The curvature of the panel and geometric cross section of the monocoque must be ignored for these calculations.

NOTE: Calculations of EI that do not reference T3.29 may take into account the actual geometry of the monocoque.

T3.30 Monocoque Laminate Testing

T3.30.1 **Side Impact Laminate** - Teams must build a representative test panel with the same design, laminate, and fabrication method as used in the monocoque side impact zone (defined in T3.33) as a flat panel and perform a 3-point bending test on this panel. They must prove by physical testing that a panel I measuring 275mm (10.8”) x 500 mm (19.7”) has at least the same properties as two baseline steel side impact tubes (See T3.4.1 “Baseline Steel Materials”) for buckling modulus, yield strength, ultimate strength and absorbed energy. The data from these tests and pictures of the test samples must be included in the SES, the test results will be used to derive strength, stiffness, and absorbed energy properties used in the SES formulae for side impact laminate panels. The test specimen must be presented at technical inspection. If the test specimen does not meet these requirements, then the monocoque side impact zone must be strengthened appropriately.

T3.30.2 Teams are required to make an equivalent test with two side impact baseline steel tubes (SAE/AISI 1010) such that any compliance in the test rig can be accounted for and to establish an absorbed energy value of the baseline tubes. Baseline tubes must be tested to a minimum displacement of 12.7mm (0.5 inch). The calculation of absorbed energy will use the integral of force times displacement from the initiation of load to 12.7mm (0.5 inch).

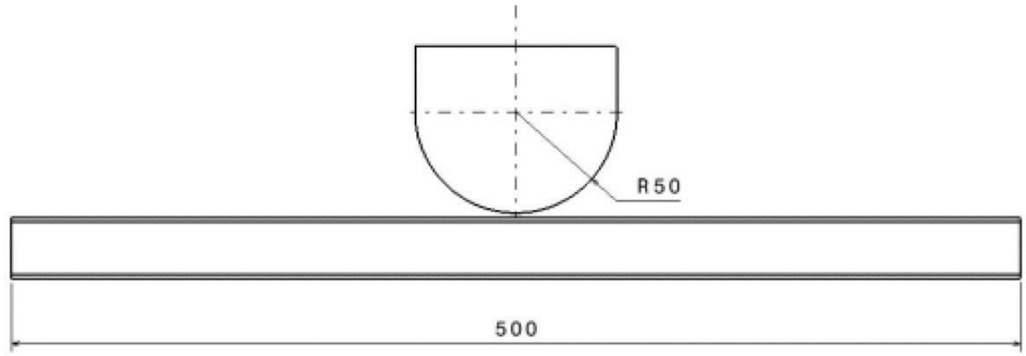
T3.30.3 Primary structure laminate other than side impact – Teams must build representative test panels for each ply schedule used in the regulated regions of the monocoque as a flat panel and perform a 3- point bending test on these panels. The test panels must measure 275mm (10.8”) x 500 mm (19.7”).

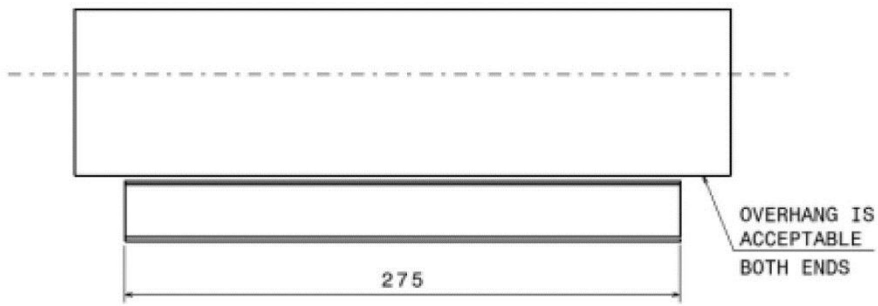
The data from these tests and pictures of the test samples must be included in the SES, the test results will be used to derive strength and stiffiress properties used in the SES formula for all laminate panels. The test specimen must be presented at technical inspection.

T3.30.4 The load applicator used to test any panel/tubes as required by T3.30.1, T3.30.2, or T3.30.3 must be metallic and have a radius of 50mm (2 inch).

The load applicator must overhang the test piece to prevent edge loading.

It is not acceptable to place any other material between the load applicator and the items on test.





T3.30.5 Perimeter shear tests must be completed by measuring the force required to push or pull a 25mm (1") diameter flat punch through a flat laminate sample.

The sample, measuring at least 100mm x 100mm (3.9" x 3.9"), must have core and skin thicknesses identical to those used in the actual monocoque and be manufactured using the same materials and processes.

The fixture must support the entire sample, except for a 32mm (1.25") hole aligned co-axially with the punch. The sample must not be clamped to the fixture.

The force-displacement data and photos of the test setup must be included in the SES.

The first peak in the load-deflection curve must be used to determine the skin shear strength; this may be less than the minimum force required by T3.33.3/T3.34.4.

The maximum force recorded must meet the requirements of T3.33.3/T3.34.4.
N: The edge of the punch and hole in the fixture may include an optional fillet up-to a maximum radius of 1mm (0.040").

T3.31 Monocoque Front Bulkhead

See Rule T3.27 for general requirements that apply to all aspects of the monocoque. In addition, when modeled as an "L" shaped section the EI of the front bulkhead about both vertical and lateral axis must be equivalent to that of the tubes specified for the front bulkhead under T3.18. The length of the section perpendicular to the bulkhead may be a maximum of 25.4mm (1") measured from the rearmost face of the bulkhead.

Furthermore, any front bulkhead which supports the IA plate must have a perimeter shear strength equivalent to a 1.5 mm thick steel plate.

T3.32 Monocoque Front Bulkhead Support

T3.32.1 In addition to proving that the strength of the monocoque is adequate, the monocoque must have equivalent EI to the sum of the EI of the six (6) baseline steel tubes that it replaces.

T3.32.2 The EI of the vertical side of the front bulkhead support structure must be equivalent to at least the EI of one baseline steel tube that it replaces when calculated as per rule T3.29 Monocoque Buckling Modulus.

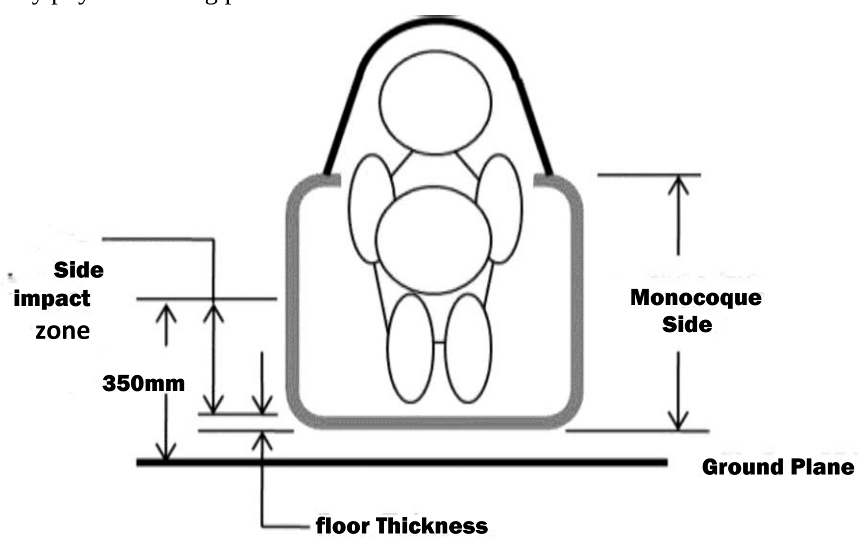
T3.32.3 The perimeter shear strength of the monocoque laminate in the front bulkhead support structure should be at least 4kN (880 pounds) for a section with a diameter of 25 mm (1 inch). This must be proven by a physical test completed as per T3.30.2 and the results include in the SES

T3.33 Monocoque Side Impact

T3.33.1 In the region longitudinally forward of the Main Roll Hoop and aft of the Front Roll Hoop and vertically from 350 mm (13.8 inches) above the ground to the bottom surface of the floor of the monocoque must have a Buckling Modulus (E*I) equal to three (3) baseline steel tubes that it replaces.

T3.33.2 The vertical side impact zone between the upper surface of the floor and 350 mm (13.8 inches) above the ground must have a Buckling Modulus (E*I) equivalent to two baseline steel tubes and half the horizontal floor must have a Buckling Modulus (E*I) equivalent to one baseline steel tube per Rule T3.29 Monocoque Buckling Modulus.

T3.33.3 The vertical side impact zone between the upper surface of the floor and 350 mm (13.8 inches) above the ground must have an absorbed energy equivalent to two baseline steel tubes. Proof of equivalent absorbed energy is determined by physical testing per rule T3.30.2 and T3.30.3.



T3.33.4 The perimeter shear strength of the monocoque laminate should be at least 7.5 kN (1700 pounds) for a section with a diameter of 25mm (1 inch). This must be proven by physical test completed as per T3.30.2 and the results included in the SES.

T3.34 Monocoque Main Hoop

T3.34.1 The Main Hoop must be constructed of a single piece of uncut, continuous, closed section steel tubing per T3.4.1 and extend down to the bottom of the monocoque.

T3.34.2 The Main Hoop must be mechanically attached at the top and bottom of the monocoque and at intermediate locations as needed to show equivalency.

T3.34.3 Mounting plates welded to the Roll Hoop must be at least 2.0 mm (0.080 inch) thick steel.

T3.34.4 Attachment of the Main Hoop to the monocoque must comply with T3.39.

T3.35 Monocoque Front Hoop

T3.35.1 Composite materials are not allowed for the front hoop. See Rule T3.27 for general requirements that apply to all aspects of the monocoque.

T3.35.2 Attachment of the Front Hoop to the monocoque must comply with Rule T3.39.

T3.35.3 Fully laminating the front hoop into the monocoque is acceptable. Equivalence to at least four mounts compliant with Rule T3.40 must be shown in the SES.

Evidence as per T3.28 must be shown to pass technical inspection.

NOTE: The use of adhesive as the sole method of attaching the front hoop to the monocoque is not acceptable. Fully laminating means encapsulating the hoop with an appropriate number and arrangement of plies.

T3.36 Monocoque Front and Main Hoop Bracing

T3.36.1 See Rule T3.27 for general requirements that apply to all aspects of the monocoque.

T3.36.2 Attachment of tubular Front or Main Hoop Bracing to the monocoque must comply with Rule T3.39.

T3.37 Monocoque Impact Attenuator Attachment

The attachment of the Impact Attenuator to a monocoque structure requires an approved "Structural Equivalency Spreadsheet" per Rule T3.9 that shows the equivalency to a minimum of four (4) 8 mm Metric Grade 8.8 (5/16 inch SAE Grade 5) bolts.

T3.38 Monocoque Impact Attenuator Anti-Intrusion Plate

T3.38.1 Composite AI plates must not fail in a frontal impact. Strength of the AI plate must be verified by physical testing or a combination of physical testing and analysis. All physical test results and any analysis completed must be included in the SES.

T3.38.2 Strength of composite AI plates may be verified by physical testing under rules T3.21.2 and T3.21.3.

T3.38.3 Strength of composite AI plates may be verified by laminate material testing and calculations of 3- point bending and perimeter shear analysis. Composite laminate materials must be tested under T3.30.3 and T3.30.5. Analysis of the AI plate under 3-point bending must show the AI plate does not fail under a static load of 120 kN distributed over 150mm of length, and perimeter shear analysis must show each attachment can hold 20 kN in any direction.

T3.39 Monocoque Attachments T3.39 still under review

T3.39.1 In any direction, each attachment point between the monocoque and the other primary structure must be able to carry a load of 30kN.

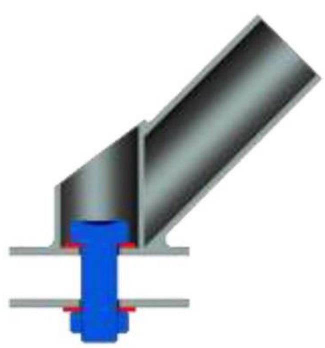
T3.39.2 The laminate, brackets, backing plates and inserts must have sufficient stiffness, shear area, bearing area, weld area and strength to carry the specified 30kN load in any direction. Data obtained from the laminate perimeter shear strength test (T3.30.5) should be used to prove adequate shear area is provided.

Proof that the brackets are adequately stiff must be documented in the SES. Hand calculations, or FEA with supporting hand calculations are both acceptable. The use of FEA alone is not acceptable.

T3.39.3 Each attachment point requires a minimum of two (2) 8 mm Metric Grade 8.8 (5/16 inch SAE Grade 5) bolts

T3.39.4 Each attachment point requires steel backing plates with a minimum thickness of 2 mm. Alternate materials may be used for backing plates if equivalency is approved.

T3.39.5 The Front Hoop Bracing, Main Hoop Bracing and Main Hoop Bracing Supports only may use one (1) 10 mm Metric Grade 8.8 (3/8 inch SAE Grade 5) bolt as an alternative to T3.39.3 if the bolt is on the centerline of tube similar to the figure below.



T3.39.6 No crushing of the core is permitted

T3.39.7 Main Hoop bracing attached to a monocoque (i.e. not welded to a rear space frame) is always considered "mechanically attached" and must comply with Rule T3.17.

T3.40 Monocoque Driver's Harness Attachment Points

T3.40.1 The monocoque attachment points for the shoulder and lap belts must support a load of 13 kN (~3000 pounds) before failure.

T3.40.2 The monocoque attachment points for the ant-submarine belts must support a load of 6.5 kN (~1500 pounds) before failure.

T3.40.3 If the lap belts and anti-submarine belts are attached to the same attachment point, then this point must support a load of 19.5 kN (~4500 pounds) before failure.

T3.40.4 The strength of lap belt attachment and shoulder belt attachment must be proven by physical test where the required load is applied to a representative attachment point where the proposed layup and attachment bracket is used.

a. Edges of the test fixture supporting the sample must be a minimum of 125mm (5 inches) from the load application point (load vector intersecting a plane).
b. The width of the shoulder harness test sample must not be any wider than the shoulder harness "panel height" (see Structural Equivalency Spreadsheet) used to show equivalency for the shoulder harness mounting bar.
c. Designs with attachments near a free edge may not support the free edge during the test. Harness loads must be tested with the worst case for the range of angles specified in T5.3.5 and T5.4.4.

NOTE: the rule is intended that the test specimen, to the best extent possible, represent the car as driven at competition. Teams are expected to test a panel in as close a configuration to what is built in the car as possible

ARTICLE 4: COCKPIT T4.1 Cockpit Opening

T4.1.1 In order to ensure that the opening giving access to the cockpit is of adequate size, a template shown in Figure 8 will be inserted into the cockpit opening. It will be held horizontally and inserted vertically until it has passed below the top bar of the Side Impact Structure (or until it is 350 mm (13.8 inches) above the ground for monocoque cars). Fore and aft translation of the template will be permitted during insertion.

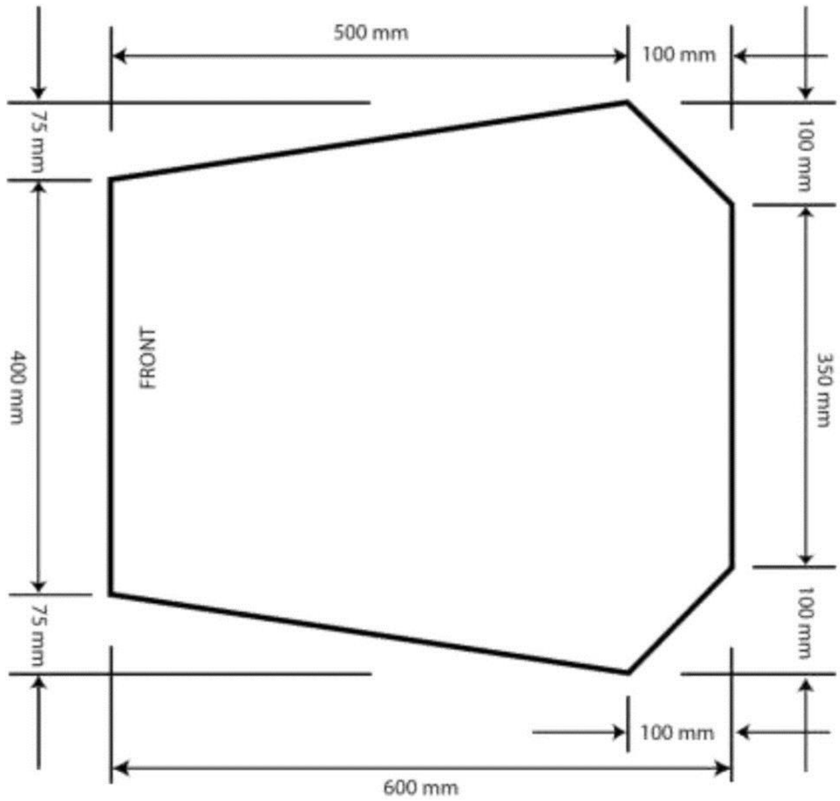


FIGURE 8

T4.1.2 During this test, the steering wheel, steering column, seat and all padding may be removed. The shifter or shift mechanism may not be removed unless it is integral with the steering wheel and is removed with the steering wheel. The firewall may not be moved or removed.

NOTE: As a practical matter, for the checks, the steering column will not be removed. The technical inspectors will maneuver the template around the steering column shaft, but not the steering column supports.

T4.2 Cockpit Internal Cross Section:

T4.2.1 A free vertical cross section, which allows the template shown in Figure 9 to be passed horizontally through the cockpit to a point 100 mm (4 inches) rearwards of the face of the rearmost pedal when in the inoperative position, must be maintained over its entire length. If the pedals are adjustable, they will be put in their most forward position.

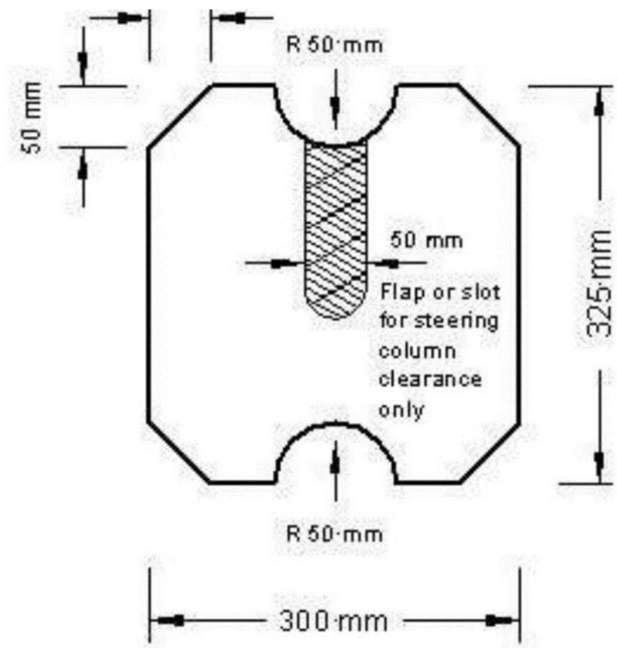


FIGURE 9

T4.2.2 The template, with maximum thickness of 7mm (0.275 inch), will be held vertically and inserted into the cockpit opening rearward of the Front Roll Hoop, as close to the Front Roll Hoop as the car's design will allow.

T4.2.3 The only items that may be removed for this test are the steering wheel, and any padding required by Rule T5.8 "Driver's Leg Protection" that can be easily removed without the use of tools with the driver in the seat. The seat may NOT be removed.

T4.2.4 Teams whose cars do not comply with T4.1.1 or T4.2.1 will not be given a Technical Inspection Sticker and will NOT be allowed to compete in the dynamic events.

NOTE: Cables, wires, hoses, tubes, etc. must not impede the passage of the templates required by T4.1.1 and T4.2.

T4.3 Driver's Seat

T4.3.1 The lowest point of the driver's seat must be no lower than the bottom surface of the lower frame rails or by having a longitudinal tube (or tubes) that meets the requirements for Side Impact tubing, passing underneath the lowest point of the seat.

T4.3.2 When seated in the normal driving position, adequate heat insulation must be provided to ensure that the driver will not contact any metal or other materials which may become heated to a surface temperature above sixty degrees C (60°C). The insulation may be external to the cockpit or incorporated with the driver's seat or firewall. The design must show evidence of addressing all three (3) types of heat transfer, namely conduction, convection and radiation, with the following between the heat source, e.g. an exhaust pipe or coolant hose/tube and the panel that the driver could contact, e.g. the seat or floor:

a. Conduction Isolation by:
   i. No direct contact between the heat source and the panel, or
   ii. A heat resistant, conduction isolation material with a minimum thickness of 8 mm (0.3 in) between the heat source and the panel.
b. Convection Isolation by a minimum air gap of 25 mm (1 inch) between the heat source and the panel
c. Radiation Isolation by:
   i. A solid metal heat shield with a minimum thickness of 0.4 mm (0.015 in) or
   ii. Reflective foil or tape when combined with T4.3.2.a.ii above.

T4.4 Floor Close-out

All vehicles must have a floor closeout made of one or more panels, which separate the driver from the pavement. If multiple panels are used, gaps between panels are not to exceed 3 mm (1/8 inch). The closeout must extend from the foot area to the firewall and prevent track debris from entering the car. The panels must be made of a solid, non-brittle material.

T4.5 Firewall

T4.5.1 A firewall must separate the driver compartment from all components of the fuel supply, the engine oil, the liquid cooling systems and any high voltage system (PART EV - EV 1.1). It must protect the neck of the tallest driver. It must extend sufficiently far upwards and/or rearwards such that any point less than 100 mm (4 ins.) above the bottom of the helmet of the tallest driver shall not be in direct line of sight with any part of the fuel system, the cooling system or the engine oil system.

T4.5.2 The firewall must be a non-permeable surface made from a rigid, fire resistant material.

T4.5.3 Any firewall must seal completely against the passage of fluids, especially at the sides and the floor of the cockpit, i.e. there can be no holes in a firewall through which seat belts pass.

T4.5.4 Pass-through for wiring, cables, etc. are allowable if grommets are used to seal the pass-through. Also, multiple panels may be used to form the firewall but must be sealed at the joints.

<u>**EV CARS ONLY**</u>

In addition a firewall must separate the driver compartment from all tractive system components. **NOTE**: this includes any HV wiring.

The tractive system firewall must be composed of two layers:

a. One layer, facing the tractive system side, must be made of aluminum with a thickness between 0.5 and 0.7 mm. This part of the tractive system firewall must be grounded according to FSAE Rule PART EV - EV4.3.
b. The second layer, facing the driver, must be made of an electrically insulating material. The material used for the second layer must meet UL94-V0, FAR25 or equivalent. The second layer must not be made of CFRP.
c. The thickness of second layer must be sufficient to prevent penetrating this layer with a 4 mm wide screwdriver and 250N of force. The firewall must be rigidly mounted.

For tractive system firewalls, a sample of the firewall must be presented at technical inspection.

Conductive parts (except for the chassis) may not protrude through the firewall or must be properly insulated, see requirements above, on the driver side.

T4.6 Accessibility of Controls

All vehicle controls, including the shifter, must be operated from inside the cockpit without any part of the driver, e.g. hands, arms or elbows, being outside the planes of the Side Impact Structure defined in Rule T3.24 and T3.33.

T4.7 Driver Visibility

T4.7.1 General Requirement

The driver must have adequate visibility to the front and sides of the car. With the driver seated in a normal driving position he/she must have a minimum field of vision of two hundred degrees (200°) (a minimum one hundred degrees (100°) to either side of the driver). The required visibility may be obtained by the driver turning his/her head and/or the use of mirrors.

T4.7.2 Mirrors

If mirrors are required to meet Rule T4.7.1, they must remain in place and adjusted to enable the required visibility throughout all dynamic events.

T4.8 Driver Egress

All drivers must be able to exit to the side of the vehicle in no more than 5 seconds. Egress time begins with the driver in the fully seated position, hands in driving position on the connected steering wheel and wearing the required driver equipment. Egress time will stop when the driver has both feet on the pavement.

ARTICLE 5: DRIVERS EQUIPMENT (BELTS AND COCKPIT PADDING)

T5.1 Belts - General

T5.1.1 Definitions

a. A 5-point system - consists of a 76 mm (3 inch) wide lap belt, approximately 76 mm (3 inch) wide shoulder straps and a single approximately 51 mm (2 inch) wide anti-submarine strap. The single anti-submarine strap must have a metal-to-metal connection with the single release common to the lap belt and shoulder harness.

b. A 6-point system - consists of a 76 mm (3 inch) wide lap belt, approximately 76 mm (3 inch) wide shoulder straps and two (2) approximately 51 mm (2 inch) wide leg or anti-submarine straps.

c. A 7-point system - system is the same as the 6-point except it has three (3) anti-submarine straps, two (2) from the 6-point system and one (1) from the 5-point system.

   NOTE: 6 and 7-point harnesses to FIA specification 8853/98 and/or SFI Specification 16.5 with approximately 51 mm (2 inch) lap belts are acceptable.

d. An "upright driving position" is defined as one with a seat back angled at thirty degrees (30°) or less from the vertical as measured along the line joining the two 200 mm circles of the template of the 95^{th} percentile male as defined in Rule T3.10.3 and positioned per T3.10.4.

e. A "reclined driving position" is defined as one with a seat back angled at more than thirty degrees (30°) from the vertical as measured along the line joining the two 200 mm circles of the template of the 95^{th} percentile male as defined in Rule T3.10.3 and positioned per T3.10.4.

f. The "chest-groin line" is the straight line that in side view follows the line of the shoulder belts from the chest to the release buckle.

T5.1.2 Harness Requirements

All drivers must use a 5, 6 or 7-point restraint harness meeting the following specifications:

a. All driver restraint systems must meet SFI Specification 16.1, SFI Specification 16.5, or FIA specification 8853/98.
b. The belts must bear the appropriate dated labels.
c. The material of all straps must be in perfect condition.
d. There must be a single release common to the lap belt and shoulder harness using a metal-to- metal quick release type latch.
e. To accommodate drivers of differing builds, all lap belts must incorporate a tilt lock adjuster ("quick adjuster"). A tilt lock adjuster in each portion of the lap belt is highly recommended.
   Lap belts with "pull-up" adjusters are recommended over "pull-down" adjusters.
f. Cars with a "reclined driving position" (see 5.1.1.e above) must have either a 6 point or 7 -point harness, AND have either anti-submarine belts with tilt lock adjusters ("quick adjusters") or have two (2) sets of anti-submarine belts installed.
g. The shoulder harness must be the over-the-shoulder type. Only separate shoulder straps are permitted (i.e. "y"-type shoulder straps are not allowed). The "H"-type configuration is allowed.
h. It is mandatory that the shoulder harness, where it passes over the shoulders, be 76 mm (3 inch) wide, except as noted below. The shoulder harness straps must be threaded through the three bar adjusters in accordance with manufacturer's instructions.
i. When the HANS device is used by the driver, FIA certified 51 mm (2 inch) wide shoulder harnesses are allowed. Should a driver, at any time not utilize the HANS device, then 76 mm (3 inch) wide shoulder harnesses are required.

T5.1.3 Harness Replacement

SFI spec harnesses must be replaced following December 31st of the 2nd year after the date of manufacture as indicated by the label. FIA spec harnesses must be replaced following December 31st of the year marked on the label.

NOTE: FIA belts are normally certified for five (5) years from the date of manufacture.

T5.1.4 The restraint system must be worn tightly at all times.

T5.2 Belt, Strap and Harness Installation - General

T5.2.1 The lap belt, shoulder harness and anti-submarine strap(s) must be securely mounted to the Primary Structure. Such structure and any guide or support for the belts must meet the minimum requirements of T3.4.1.

NOTE: Rule T3.5.5 applies to these tubes as well so a non-straight shoulder harness bar would require support per T3.5.5

T5.2.2 The tab or bracket to which any harness is attached must have:

a. A minimum cross sectional area of 60 sq. mm (0.093 sq. in) of steel to be sheared or failed in tension at any point of the tab, and
b. A minimum thickness of 1.6 mm (0.063 inch).
c. Where lap belts and anti-submarine belts use the same attachment point, a minimum cross sectional area of 90 sq. mm (0.140 sq. in) of steel to be sheared if failed in tension at any point of the tab.
d. Where brackets are fastened to the chassis, two fasteners of 6mm Metric Grade 8.8 (1/4 inch SAE Grade 5) fasteners or stronger must be used.

e. Where a single shear tab is welded to the chassis, the tab to tube welding must be on both sides of the base of the tab.

NOTE: Double shear attachments are preferred. Where possible, the tabs and brackets for double shear mounts should also be welded on both sides.

T5.2.3 Harnesses, belts and straps must not pass through a firewall, i.e. all harness attachment points must be on the driver's side of any firewall.

T5.2.4 The attachment of the Driver's Restraint System to a monocoque structure requires an approved Structural Equivalency Spreadsheet per Rule T3.9.

T5.2.5 The restraint system installation is subject to approval of the Chief Technical Inspector.

T5.3 Lap Belt Mounting

T5.3.1 The lap belts must pass around the pelvic area below the Anterior Superior Iliac Spines (the hip I bones).

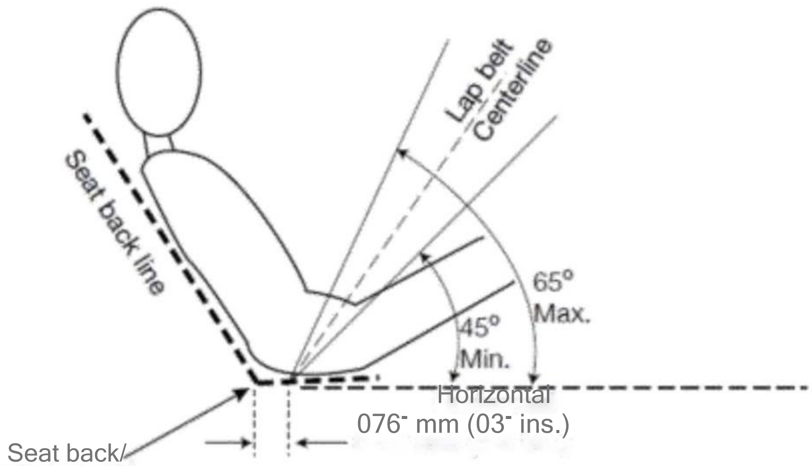
T5.3.2 The lap belts must not be routed over the sides of the seat. The belts must come through the seat at the I bottom of the sides of the seat to maximize the wrap of the pelvic surface and continue in a straight line to the anchorage point.

T5.3.3 Where the belts or harness pass through a hole in the seat, the seat must be rolled or grommeted to prevent chafing of the belts.

T5.3.4 To fit drivers of differing statures correctly, in side view, the lap belt must be capable of pivoting freely by using either a shouldered bolt or an eye bolt attachment. Mounting lap belts by wrapping them around frame tubes is not acceptable.

T5.3.5 With an "upright driving position", in side view the lap belt must be at an angle of between forty-five degrees (45°) and sixty-five degrees (65°) to the horizontal. This means that the centerline of the lap belt at the seat bottom should be between 0 - 76 mm (0 - 3 inches) forward of the seat back to seat bottom junction. (See Figure 10)

FIGURE 10
Lap Belt Angle



T5.3.6 With a "reclined driving position", in side view the lap belt must be between an angle of sixty degrees (60°) and eighty degrees (80°) to the horizontal.

T5.3.7 Any bolt used to attach a lap belt, either directly to the chassis or to an intermediate bracket, must be a minimum of 10mm Metric Grade 8.8 (3/8 inch SAE Grade 5)

T5.4 Shoulder Harness

T5.4.1 The shoulder harness must be mounted behind the driver to structure that meets the requirements of T3.4.1. However, it cannot be mounted to the Main Roll Hoop Bracing or attendant structure without additional bracing to prevent loads being transferred into the Main Hoop Bracing.

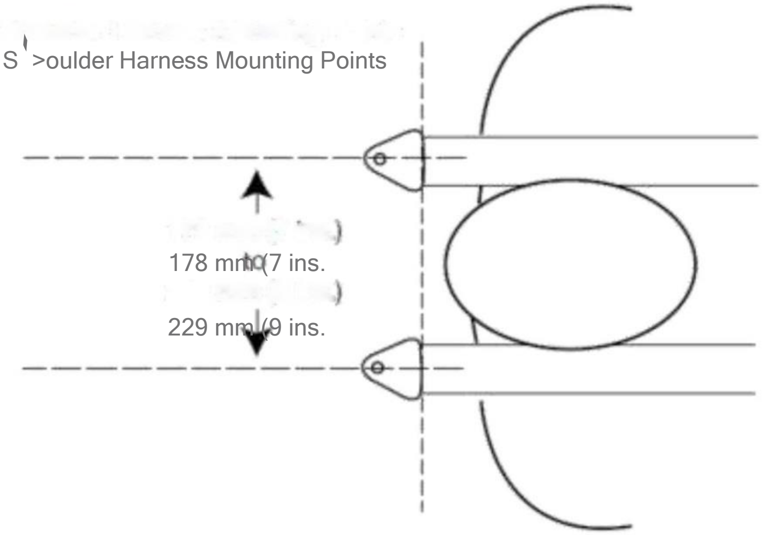
T5.4.2 If the harness is mounted to a tube that is not straight, the joints between this tube and the structure to which it is mounted must be reinforced in side view by triangulation tubes to prevent torsional rotation of the harness mounting tube. Supporting calculations are required. Analysis Method: Use 7kN load per attachment and the range of angles in T5.4.5 calculate that the bent Shoulder Harness Bar triangulation stresses are less than As Welded Yield Strength (T3.4.1 note 4) for combined bending and shear and does not fail in column buckling. If the team chooses not to perform the strength analysis rule T3.5.5 will apply.

T5.4.3 The strength of any shoulder harness bar bracing tubes must be proved in the relevant tab of the team's SES submission.

T5.4.4 The shoulder harness mounting points must be between 178 mm (7 inches) and 229 mm (9 inches) apart. (See Figure 11)

FIGURE 11

S >oulder Harness Mounting Points

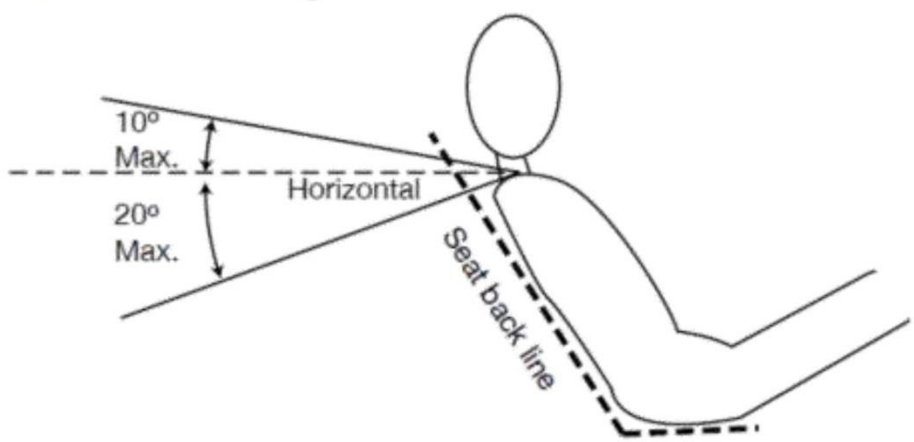


T5.4.5 From the driver’s shoulders rearwards to the mounting point or structural guide, the shoulder harness must be between ten degrees (10°) above the horizontal and twenty degrees (20°) below the horizontal. (See Figure 12).

T5.4.6 Any bolt used to attach a shoulder harness belt, either directly to the chassis or to an intermediate bracket, must be a minimum of 10mm Metric Grade 8.8 (3/8 inch SAE Grade 5)

FIGURE 12

Shoulder Harness Angle



T5.5 Anti-Submarine Belt Mounting

T5.5.1 The anti-submarine belt of a 5-point harness must be mounted in line with, or angled slightly forward | (up to twenty degrees (20°)) of, the driver’s chest-groin line.

T5.5.2 The anti-submarine belts of a 6-point harness must be mounted either:

a. With the belts going vertically down from the groin, or angled up to twenty degrees (20°) rearwards. The anchorage points should be approximately 100 mm (4 inches) apart. Or
b. With the anchorage points on the Primary Structure at or near the lap belt anchorages, the driver sitting on the anti-submarine belts, and the belts coming up around the groin to the release buckle.

T5.5.3 Any bolt used to attach an anti-submarine belt, either directly to the chassis or to an intermediate bracket, must be a minimum of 8mm Metric Grade 8.8 (5/16 inch SAE Grade 5)

T5.6 Head Restraint

T5.6.1 A head restraint must be provided on the car to limit the rearward motion of the driver's head.

T5.6.2 The restraint must:

a. Be vertical or near vertical in side view.
b. Be padded with an energy absorbing material such as Ethafoam® or Ensolite® with a minimum thickness of 38 mm (1.5 inches).
c. Have a minimum width of 15 cms (6 inches).
d. Have a minimum area of 235 sq. cms (36 sq. inches) AND have a minimum height adjustment of 17.5 cms (7 inches), OR have a minimum height of 28 cms (11 inches).
e. Be located so that for each driver:
    i. The restraint is no more than 25 mm (1 inch) away from the back of the driver's helmet, with the driver in their normal driving position.
    ii. The contact point of the back of the driver's helmet on the head restraint is no less than 50 mm (2 inch) from any edge of the head restraint.

NOTE 1: Head restraints may be changed to accommodate different drivers (See T1.2.2).
NOTE 2: The above requirements must be met for all drivers.
NOTE 3: Approximately 100mm (4") longitudinal adjustment is required to accommodate 5th to 95th Percentile drivers. This is not a specific rules requirement, but teams must have sufficient longitudinal adjustment and/or alternative thickness head restraints available, such that the above requirements are met by all their drivers.

T5.6.3 The restraint, its attachment and mounting must be strong enough to withstand a force of 890 Newtons (200 lbs. force) applied in a rearward direction.

T5.7 Roll Bar Padding

Any portion of the roll bar, roll bar bracing or frame which might be contacted by the driver's helmet must be covered with a minimum thickness of 12 mm (0.5 inch) of padding which meets SFI spec 45.1 or FIA 8857-2001.

T5.8 Driver's Leg Protection

T5.8.1 To keep the driver's legs away from moving or sharp components, all moving suspension and steering components, and other sharp edges inside the cockpit between the front roll hoop and a vertical plane 100 mm (4 inches) rearward of the pedals, must be shielded with a shield made of a solid material. Moving components include, but are not limited to springs, shock absorbers, rocker arms, antiroll/sway bars, steering racks and steering column CV joints.

T5.8.2 Covers over suspension and steering components must be removable to allow inspection of the mounting points.

ARTICLE 6: GENERAL CHASSIS RULES

T6.1 Suspension

T6.1.1 The car must be equipped with a fully operational suspension system with shock absorbers, front and rear, with usable wheel travel of at least 50.8 mm (2 inches), 25.4 mm (1 inch) jounce and 25.4 mm (1 inch) rebound, with driver seated. The judges reserve the right to disqualify cars which do not represent a serious attempt at an operational suspension system or which demonstrate handling inappropriate for an autocross circuit.

T6.1.2 All suspension mounting points must be visible at Technical Inspection, either by direct view or by removing any covers.

T6.2 Ground Clearance

Ground clearance must be sufficient to prevent any portion of the car, other than the tires, from touching the ground during track events. Intentional or excessive ground contact of any portion of the car other than the tires will forfeit a run or an entire dynamic event.

Comment: The intention of this rule is that sliding skirts or other devices that by design, fabrication or as a consequence of moving, contact the track surface are prohibited and any unintended contact with the ground which either causes damage, or in the opinion of the ‘dynamic event organizers’ could result in damage to the track, will result in forfeit of a run or an entire dynamic event

T6.3 Wheels

T6.3.1 The wheels of the car must be 203.2 mm (8.0 inches) or more in diameter.

T6.3.2 Any wheel mounting system that uses a single retaining nut must incorporate a device to retain the nut and the wheel in the event that the nut loosens. A second nut (“jam nut”) does not meet these requirements.

T6.3.3 Standard wheel lug bolts are considered engineering fasteners and any modification will be subject to extra scrutiny during technical inspection. Teams using modified lug bolts or custom designs will be required to provide proof that good engineering practices have been followed in their design.

T6.3.4 Aluminum wheel nuts may be used, but they must be hard anodized and in pristine condition.

T6.4 Tires

T6.4.1 Vehicles may have two types of tires as follows:

a. Dry Tires - The tires on the vehicle when it is presented for technical inspection are defined as its “Dry Tires”. The dry tires may be any size or type. They may be slicks or treaded.
b. Rain Tires - Rain tires may be any size or type of treaded or grooved tire provided:
    i. The tread pattern or grooves were molded in by the tire manufacturer, or were cut by the tire manufacturer or his appointed agent. Any grooves that have been cut must have documentary proof that it was done in accordance with these rules.
    ii. There is a minimum tread depth of 2.4 mms (3/32 inch).

NOTE: Hand cutting, grooving or modification of the tires by the teams is specifically prohibited.

T6.4.2 Within each tire set, the tire compound or size, or wheel type or size may not be changed after static judging has begun. Tire warmers are not allowed. No traction enhancers may be applied to the tires after the static judging has begun, or at any time on-site at the competition.

NOTE: Due to the hazardous nature (significant health effects) of some traction modifier ingredients, teams are advised to closely follow manufacturers recommended procedures for safely handling and use of traction modifiers, if used before competition.

T6.5 Steering

T6.5.1 The steering wheel must be mechanically connected to the front wheels, i.e. “steer-by-wire” or electrically actuated steering of the front wheels, is prohibited.

T6.5.2 The steering system must have positive steering stops that prevent the steering linkages from locking up (the inversion of a four-bar linkage at one of the pivots). The stops may be placed on the uprights or on the rack and must prevent the tires from contacting suspension, body, or frame members during the track events.

T6.5.3 Allowable steering system free play is limited to seven degrees (7°) total measured at the steering wheel.

T6.5.4 The steering wheel must be attached to the column with a quick disconnect. The driver must be able to operate the quick disconnect while in the normal driving position with gloves on.

T6.5.5 Rear wheel steering, which can be electrically actuated, is permitted but only if mechanical stops limit the range of angular movement of the rear wheels to a maximum of six degrees (6°). This must be demonstrated with a driver in the car and the team must provide the facility for the steering angle range to be verified at Technical Inspection.

T6.5.6 The steering wheel must have a continuous perimeter that is near circular or near oval, i.e. the outer perimeter profile can have some straight sections, but no concave sections. “H”, “Figure 8”, or cutout wheels are not allowed.

T6.5.7 In any angular position, the top of the steering wheel must be no higher than the top-most surface of the Front Hoop. See Figure 3.

T6.5.8 Steering systems using cables for actuation are not prohibited by T6.5.1 but additional documentation must be submitted. The team must submit a failure modes and effects analysis report with design details of the proposed system as part of the structural equivalency spreadsheet (SES) or structural requirements certification form (SRCF). The report must outline the analysis that was done to show the steering system will function properly, potential failure modes and the effects of each failure mode and finally failure mitigation strategies used by the team. The organizing committee will review the submission and advise the team if the design is approved. If not approved, a non-cable based steering system must be used instead.

T6.5.9 The steering rack must be mechanically attached to the frame; if fasteners are used they must be compliant with Rule T11.2.

T6.5.10 Joints between all components attaching the steering wheel to the steering rack must be mechanical and be visible at Tech Inspection. Bonded joints without a mechanical backup are not permitted.

T6.6 Jacking Point

T6.6.1 A jacking point, which is capable of supporting the car's weight and of engaging the organizers' "quick jacks", must be provided at the rear of the car.

T6.6.2 The jacking point is required to be:

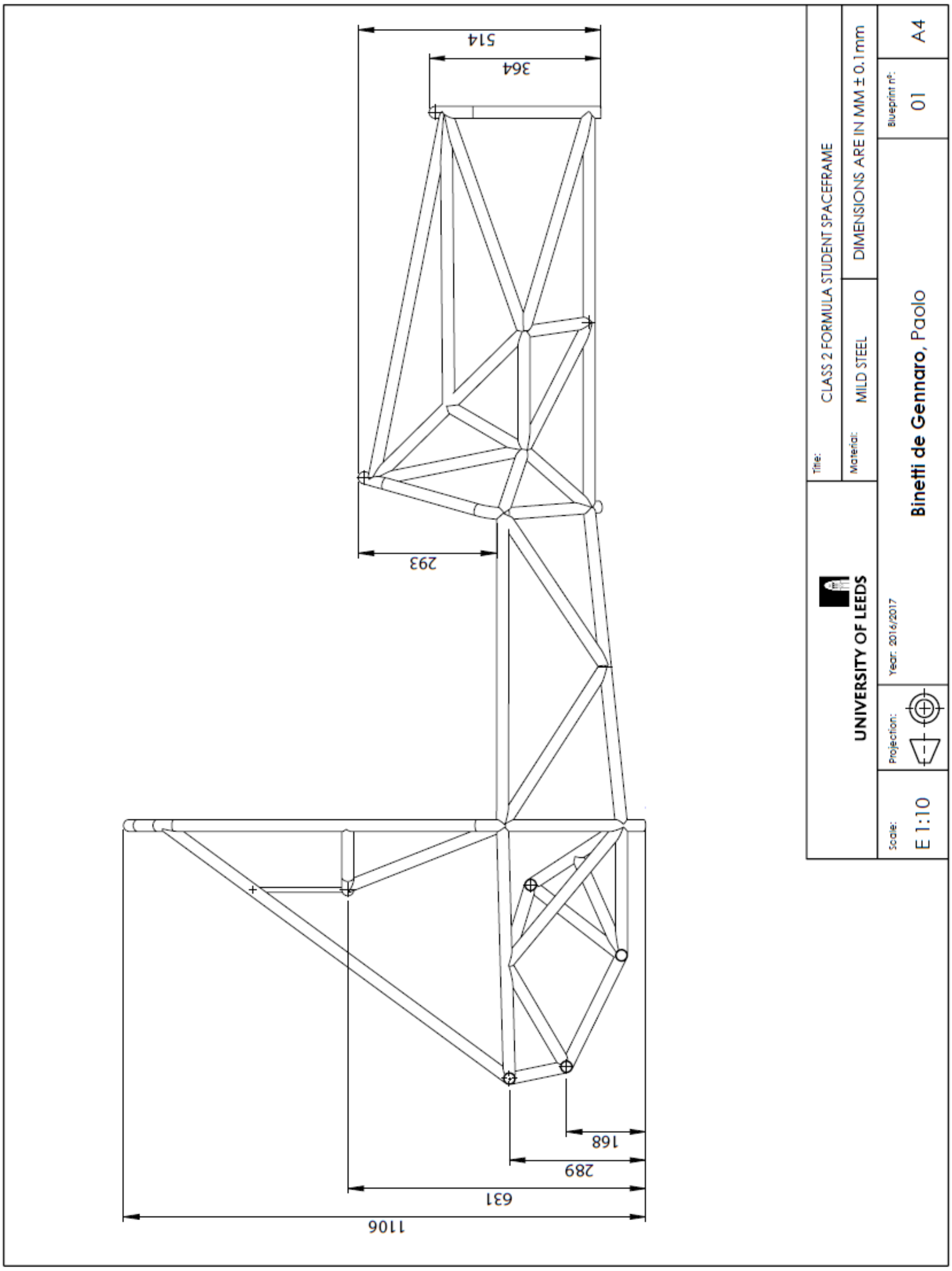
a. Visible to a person standing 1 meter (3 feet) behind the car.
b. Painted orange.
c. Oriented horizontally and perpendicular to the centerline of the car
d. Made from round, 25 - 29 mm (1 - 1 1/8 inch) O.D. aluminum or steel tube
e. A minimum of 300 mm (12 inches) long
f. Exposed around the lower 180 degrees (180°) of its circumference over a minimum length of 280 mm (11 in)
g. The height of the tube is required to be such that:
    i. There is a minimum of 75 mm (3 in) clearance from the bottom of the tube to the ground measured at tech inspection.
    ii. With the bottom of the tube 200 mm (7.9 in) above ground, the wheels do not touch the ground when they are in full rebound.
h. Access from the rear of the tube must be unobstructed for at least 300mm of its length **Comment on Disabled Cars** - The organizers and the Rules Committee remind teams that cars disabled on course must be removed as quickly as possible. A variety of tools may be used to move disabled cars including quick jacks, dollies of different types, tow ropes and occasionally even boards. We expect cars to be strong enough to be easily moved without damage. Speed is important in clearing the course and although the course crew exercises due care, parts of a vehicle can be damaged during removal. The organizers are not responsible for damage that occurs when moving disabled vehicles. Removal/recovery workers will jack, lift, carry or tow the car at whatever points they find easiest to access. Accordingly, we advise teams to consider the strength and location of all obvious jacking, lifting and towing points during the design process.

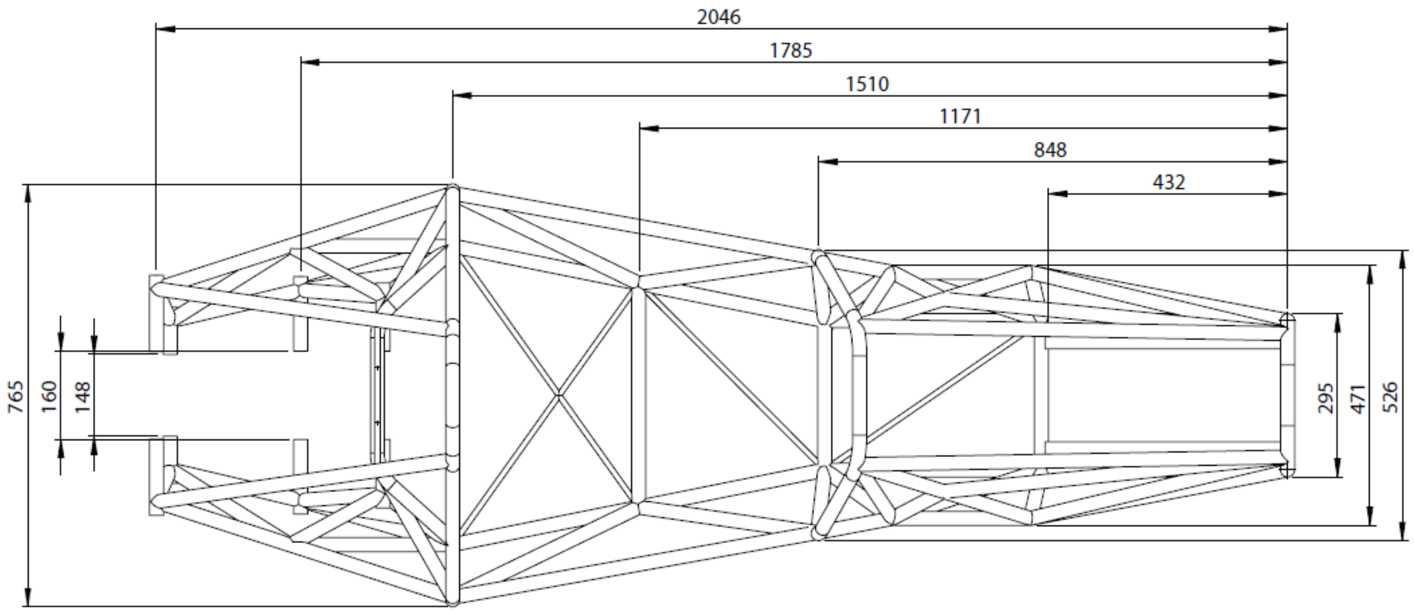
T6.7 Rollover Stability

T6.7.1 The track and center of gravity of the car must combine to provide adequate rollover stability.

T6.7.2 Rollover stability will be evaluated on a tilt table using a pass/fail test. The vehicle must not roll when tilted at an angle of sixty degrees (60°) to the horizontal in either direction, corresponding to 1.7 G's. The tilt test will be conducted with the tallest driver in the normal driving position.

B. Engineering Drawings





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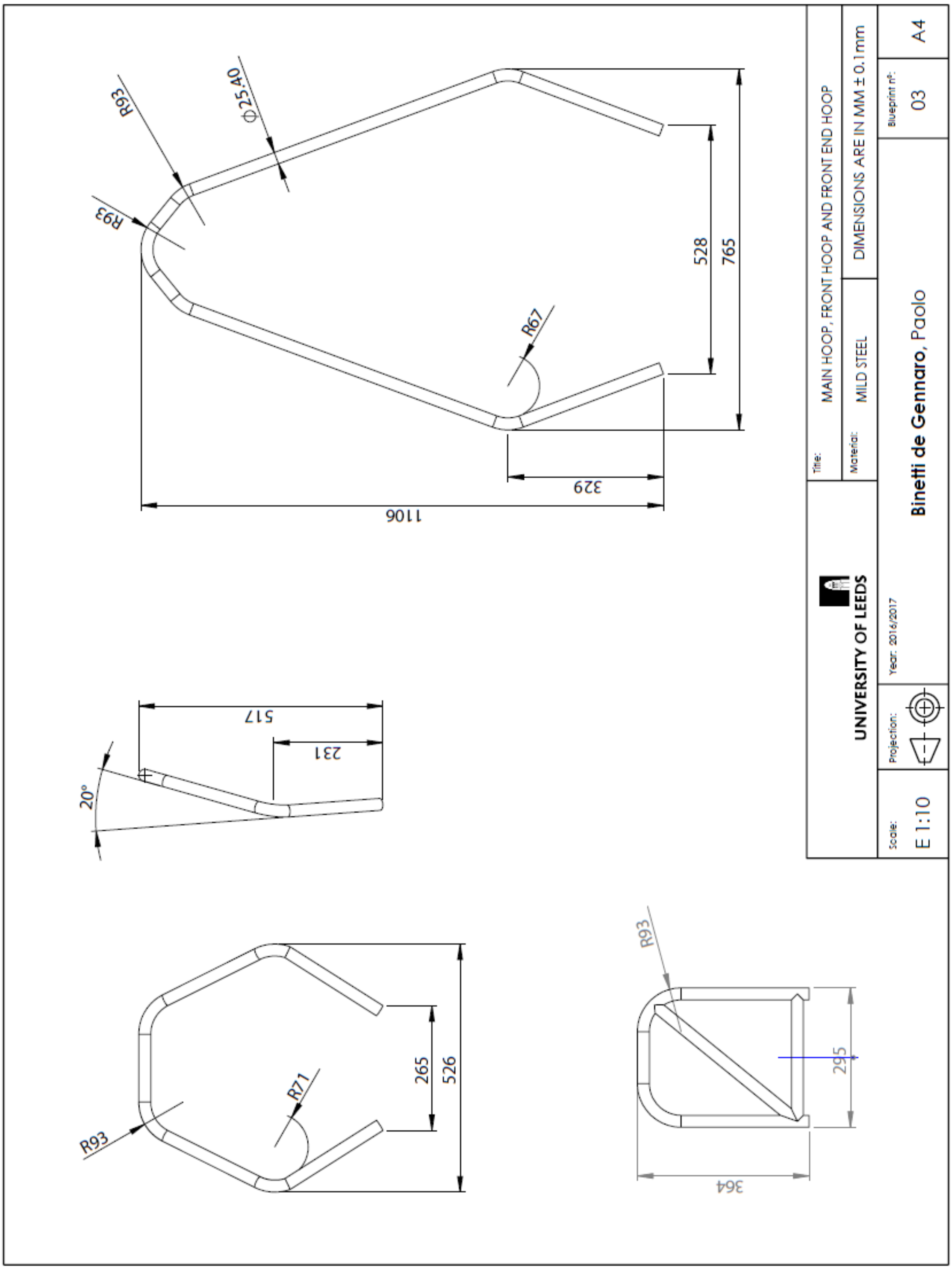
			Material: MILD STEEL	DIMENSIONS ARE IN MM ± 0.1mm
Scale: E 1:10	Projection:	Year: 2016/2017 **Binetti de Gennaro**, Paolo	Blueprint nº: 02	A4


MAIN HOOP, FRONT HOOP AND FRONT END HOOP
DIMENSIONS ARE IN MM ± 0.1mm
Title:
Material:
MILD STEEL
Blueprint nº:
03
A4
Binetti de Gennaro, Paolo
UNIVERSITY OF LEEDS
Year: 2016/2017
Projection:
Scale:
E 1:10
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R93
528
765
R67
329
1106
517
231
20°
265
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364

C. Gantt chart

In this section, a Gantt chart (Figure 40) was attached. This timetable was followed for the correct accomplishment of the project.

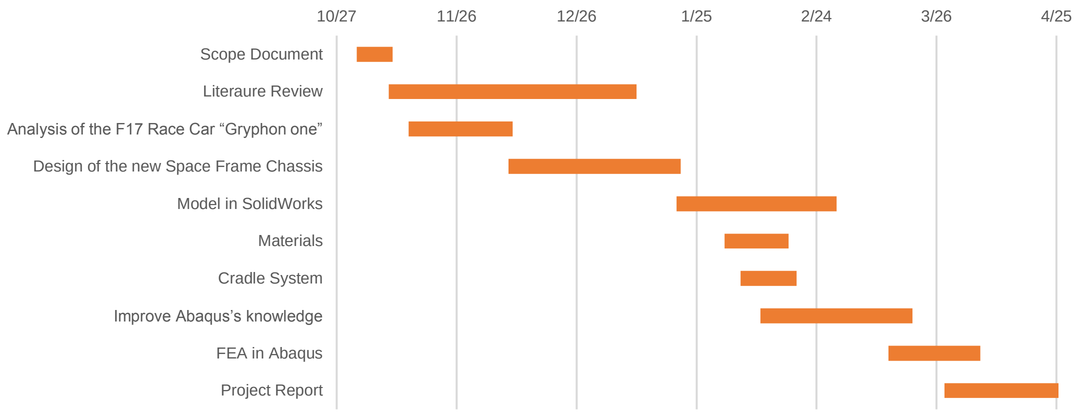

Figure 40 *Gantt Chart.*

D. Risk Assessment

In this section, there was attached a risk assessment, which helps to identify all the possible risks during the fulfilment of the project. Moreover, an evaluation was done and possible mitigation strategies to reduce them were given.

Table 9 *Risk Assesment.*

Risk Description	Likelihood	Impact	Exposure	Mitigation
Overall Literature Review.	1	3	3	Reduce the **likelihood** and **impact** of this occurring by: • Learn new techniques of research. • Assisting to all the Information Searching Sessions. • Not only rely on books.
Analysis of the "F18".	1	2	2	Reduce the **likelihood** and **impact** of this occurring by: • Talk with Formula Student's members. • Ask professor's help.
Consideration of all the 2016 Class 2 FS Rules.	1	3	3	Reduce the **likelihood** and **impact** of this occurring by: • Contrast with other members.
Design.	1	2	2	Reduce the **likelihood** and **impact** of this occurring by: • Talk with other members. • Know the characteristics of other components. • Ergonomics.
FEA.	3	3	9	Reduce the **likelihood** and **impact** of this occurring by: • Learn more about FEA. • Talk with MECH3900 professor.
Materials.	2	3	6	Reduce the **likelihood** and **impact** of this occurring by: • Research. • Talk with other FS Teams.
Cradle system.	2	2	4	Reduce the **likelihood** and **impact** of this occurring by: • Ask professor's help.
Knowledge of triangulation.	2	2	4	Reduce the **likelihood** and **impact** of this occurring by: • Ask professor's help.
Availability of the software's license.	1	3	3	Reduce the **likelihood** and **impact** of this occurring by: • Talk with Peter Hayward.
Knowledge specific features of the software.	2	2	4	Reduce the **likelihood** and **impact** of this occurring by: • Research. • Talk with Peter Hayward.
Fatal Error using software.	2	3	6	Reduce the **likelihood** and **impact** of this occurring by: • Use one software at a time. • Save every 10 minutes.
Loss Backup.	3	3	9	Reduce the **likelihood** and **impact** of this occurring by: • Save every 10 minutes. • Save on different devices.
Deliverability the report on the deadline.	1	3	3	Reduce the **likelihood** and **impact** of this occurring by: • Follow the Gantt chart.

E. Supervisor Meeting Log

Date of Meeting	Summary of discussion	Objectives of next meeting	Supervisors initials
13/10/16	Discussion about how is going to be the project. Model in SolidWorks. FEA Abaqus? ANSYS? Hybrid?	Start researching. Talk with Alisson Jones about Abaqus.	
20/10/16	Introduction of the Scoping Document. To take into account when designing the chassis.	Read and learn more about chassis and how to design regarding SAE rules.	
26/10/16	Ethical assignment doubts and how to improve it. How to focus the topic on my project. Write the aim of the project.	Research about other teams. Gantt Chart. Talk with Peter Hayward.	
04/11/16	Introduction of the report. Project Risk Assessment.	Literature review.	
17/11/16	How the project was going.	Talk with Class 1 in order to know who designs the current chassis.	
24/11/16	Analyse the case study of last year.	Review and look more books.	
01/12/16	Understand how to make a better design. How to do weldments in SolidWorks.	Read different books and investigate about FEA softwares.	
26/01/17	Literature review doubts. Scoping document feedback. Talked with Sameer.	First chassis design considering the rules.	
09/02/17	First chassis design. Make a FEA of a simple model to understand better. Engine cradle.	First design iteration with improves.	
09/03/17	How to get the best triangulation.	Torsional stiffness calculations	
15/03/17	How to know the load applied in every suspension point. Torsional stiffness explanation and FEA.	Better FEA.	
23/03/17	First calculations. Write a FS intro.	Finish the design and report.	