

## FORMULA STUDENT 2024 RULES

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## INTRODUCTION

Formula Student UK (FS) is an educational challenge organised by the Institution of Mechanical Engineers (IMechE) for the purpose of educating and preparing students of engineering and other disciplines for their future careers.

The competition is governed and executed in line with four key values:

1. Safety – to maintain the highest standards of safety throughout the event.
2. Education – to focus on providing the best educational experience for all those involved, including competitors, volunteers and visitors.
3. Openness – to be open to collaboration with other competitions and parties, to embrace new ideas and to allow different vehicle concepts to compete together within a common rule set.
4. Inclusive – to deliver an event that allows all teams to be at their best: new or established, elite or amateur, domestic or international.

The IMechE is supported by volunteers from Industry and Academia that together form the Formula Student Organising Committee (the Committee). The Committee includes the IMechE Formula Student Project Manager and Project Executive and volunteers: Chairmen, Chief Judge, Clerk of the Course, Head Judges, Chief Scrutineers, Dynamic Events Captains and other volunteers representing key functional areas. The Committee is supported by sub-committees for Scrutineering, Dynamic Events, Electric Vehicles and FS-AI. The rule set for the competition is continuously reviewed by the Committee and updated at least once a year with the aim of providing the best educational experience for students and volunteers whilst maintaining the highest standards for safety.

FS operates under a permit from the national motorsport governing body, Motorsport UK. The dynamic events are overseen by a licensed Clerk of the Course, supported by nationally registered marshals and officials as well as volunteers with industrial and/or Formula Student experience.

The static events are judged by a mix of experienced engineering industry professionals (from backgrounds including motorsport, automotive, aerospace and supply chain partners) as well as recent graduates and learned academic authorities.

The Competition is composed of three classes:

- Formula Student (FS Class),
- FS-AI (Formula Student Artificial Intelligence),
- Concept Class.

The Formula Student Rules consist of two documents:

- Formula Student 2024 Rules (this document),
- Formula Student AI 2024 Rules (driverless vehicle regulations).

The scope of Formula Student 2024 Rules covers FS Class, Concept Class and any FS-AI Class regulations that are common and integrated with FS Class (i.e., a single rule within a rules section, denoted by [DV Only]). All FS-AI specific rules sections are defined in the Formula Student AI 2024 Rules. Therefore, when understanding the regulations for FS-AI class, both rule sets must be considered.

These Formula Student 2024 Rules are written to be as closely aligned as is practicable with the '2024 Formula Student Rules/FSG Rules', with specific targeted changes for the following reasons:

- Mitigation of safety risks based on experience from the UK events, partner events and Motorsport UK regulator,
- Relaxation of rules, in some but not all cases, which create a barrier to entry for FSAE based vehicles,
- UK specific administrative items required to meet the educational goals of the competition as defined by the IMechE and the Committee.

FS Class permits vehicles designed to Formula Student 2024 Rules/FSG Rules. Vehicles built to the Formula SAE Rules (FSAE) are also eligible but must conform to all relevant Formula Student Rules as defined above.

FS-AI rules (Driverless Vehicles) define the regulations for the two driverless classes, where teams use their own vehicle (Autonomous Driving System Class - ADS) or the IMechE ADS-DV (Autonomous Driving System – Dedicated Vehicle) is used (Dynamic Driving Task Class - DDT).

- ADS Class follows the administrative and technical regulation as defined in "Formula Student 2024 Rules" and the "Formula Student AI 2024 Rules" document, where the "Formula Student AI 2024 Rules" take precedent,
- For DDT class all technical, inspection, static and dynamic regulations are covered by the document "Formula Student AI 2024 Rules" in addition to some changes to the administrative regulations where the FS-AI rules take precedent.

The Formula Student AI 2024 Rules can be found on the Formula Student website.

## CONCEPT CLASS INTRODUCTION

Teams may enter Concept Class, competing in static events only (Business Plan Presentation, Cost & Manufacturing, Engineering Design and Lap Time Simulation). Concept Class entries are assumed to be focused on ultimately providing an FS Class entry in a future competition year.

Formula Student allows combustion engine vehicles, electric vehicles and alternative fuelled vehicles; it is assumed that Concept Class entries pay full attention to this important FS specific design brief.

A key design choice for entrants is that of powertrain type. Teams must provide detailed understanding of this choice in their conceptual design decisions.

There are several documents required to be submitted prior the event: the documents are those required for FS Class with some exceptions related to the running vehicle. Key Dates for Concept Class submissions can be found on the Formula Student website.

The submissions required prior to the event are:

- Design Concept Specification,
- Engineering Design Report,
- Engineering Design Spec Sheet,
- LTS Input Deck,
- LTS Model Validation Test Plan,
- Business Plan Presentation slide deck,
- Cost Report comprising,
- BOM for Frame and Body only,
- Cost Explanation File,
- Supporting documents for Frame and Body only.

NOTE: The requirement for pre-judging submissions of individual Engineering Design Score Sheet Category presentations may be added. If required, teams will be informed via email and the Key Dates spreadsheet will be updated. We aim to inform teams of this requirement no later than April for a June submission deadline.

Penalties for lateness, non-submission, and poor-quality submission are as per FS Class.

## CHANGELOG

Document	Version	Change
Formula Student 2024 Rules	V1.0	N/A – New Baseline Rules
	V1.1	First formal release for 2024 competition

Rule	Version	Change
A2.2.1	1.0	Clarified to make it clear that the rule only applies to reuse of a chassis in the Formula Student class of an event.
A2.2.4	1.0	Revised rule to only allow reuse of the chassis if changing powertrain type.
A4.5.3	1.0	Added requirement if the Faculty Advisor is not on-site at the event
A5.5	1.0	Vehicle Status Report requirement removed.
A6.3.1	1.0	Added requirement for team leaders to attend daily team briefing
T2.2.3	1.0	Minimum radius increased from 1mm to 3mm.
T3.9.5	1.0	Updated as per Future Changes section from 2023 rules.
T3.17.2	1.0	Updated as per Future Changes section from 2023 rules.
T3.17.8	1.0	Revised bracing requirements to align with other rulesets.
T3.17.9	1.0	Added specific requirements for honeycomb standard IAs.
T4.3.4	1.0	Clarified that the positioning of the upper 300mm circle of the 95 <sup>th</sup> percentile template.
T4.6.2	1.0	Removed conduction isolation requirement as this is made redundant by the requirement for a 25mm air gap.
T4.6.2	1.1	Reinstated conduction isolation for option ii) of radiation isolation only
T7.2.6	1.0	Clarified minimum catch-can volume requirements for CV water coolant circuits
T10.1.2/3	1.0	Revised wording to make it clearer that equivalent imperial fasteners are permitted.
T11.1.5	1.0	Added max voltage for LV hybrid motor controllers & inverters
T11.4.7	1.0	Added requirement for the colour of shutdown buttons
T11.7.8	1.0	Added restriction for LV hybrid batteries
T13.4.5	1.0	Added requirement to demonstrate fire extinguisher purchase or servicing in the last 2 calendar years.
CV1.1	1.0	Added LV hybrids. Clarified that HV Hybrids are an AFV.
CV2.1	1.0	Added sustainable fuel types.
CV2.4	1.0	Various changes to align with other rulesets.

CV3.1.3	1.0	Quantitative temperature added to rule, as per Future Changes section from 2023 rules.
CV4.1.1	1.0	Updated figure for LV hybrids.
CV5	1.0	Added Low Voltage Hybrids section.
EV1.2.1	1.0	Clarified test voltage, added working voltage requirement
EV1.2.1	1.1	Only require working voltage if specified on the datasheet
EV2.2.1	1.1	Removed 60kW power limit for 4wd vehicles
EV4.10	1.0	Aligned with FSG, but retained requirement for independent power supply.
EV6.3.2	1.1	Added Bender ISOMETER® iso165C-1, A-ISOMETER® iso-F1 IR155-4203 and -4204
S3.9.6, S5.4.6	1.0	Added rule that cars cannot be fuelled during static event if the car has not passed the Tilt Test.
S3.4-3.6	1.0	Updated to reduce the number of sections requiring a DBOM.
S3.4.4	1.0	Removed the requirement to include fasteners in the DBOM.
S3.4.5	1.0	Clarified requirements for bespoke manufactured fasteners
S3.6.3/S4.4.2	1.0	Clarified requirements for R&D costs and some other capital overheads
S7.1	1.0	Clarified available forms of support from the software provider
S7.2.2	1.0	Clarified that LTS is a stand-alone event and submissions are not expected to match the team's FS Class or Concept Class vehicle.
S7.3.9	1.0	Revised damper curves to be a predefined set of force vs velocity curves.
D7.9.2	1.0	Added note that the efficiency factors are under review and will be updated in a later release of the rules
D9.1.5	1.0	Revised wording to be non CV specific
EV4.6.2	1.0	Specified which module of the Energy meter is referenced by this rule



## ABBREVIATIONS

<b>ADR</b>	Autonomous Design Report	<b>ESF</b>	Electrical System Form
<b>AFV</b>	Alternative Fuel Vehicle	<b>ESO</b>	Electrical System Officer
<b>AIP</b>	Anti-Intrusion Plate	<b>ESOQ</b>	Electrical System Officer Qualification
<b>AIR</b>	Accumulator Isolation Relay	<b>ETC</b>	Electronic Throttle Control
<b>AMI</b>	Autonomous Mission Indicator	<b>EV</b>	Electric Vehicle
<b>AMS</b>	Accumulator Management System	<b>FTO</b>	Fuel Type Order
<b>APPS</b>	Accelerator Pedal Position Sensor	<b>HPI</b>	High Pressure Injection
<b>AS</b>	Autonomous System	<b>HSC</b>	Hybrid System Container
<b>ASB</b>	Autonomous System Brake	<b>HSF</b>	Hybrid System Form
<b>ASF</b>	Autonomous System Form	<b>HV</b>	High Voltage
<b>ASMS</b>	Autonomous System Master Switch	<b>HVD</b>	High Voltage Disconnect
<b>ASR</b>	Autonomous System Responsible	<b>IA</b>	Impact Attenuator
<b>ASRQ</b>	ASR Qualification	<b>IAD</b>	Impact Attenuator Data
<b>ASSI</b>	Autonomous System Status Indicator	<b>IMD</b>	Insulation Monitoring Device
<b>BOM</b>	Bill of Material	<b>LPI</b>	Low Pressure Injection
<b>BOTS</b>	Brake Over-Travel Switch	<b>LV</b>	Low Voltage
<b>BPP</b>	Business Plan Presentation Event	<b>LVMS</b>	Low Voltage Master Switch
<b>BPPV</b>	Business Plan Pitch Video	<b>LVS</b>	Low Voltage System
<b>BSPD</b>	Brake System Plausibility Device	<b>MU</b>	Magazine Uploads
<b>CBOM</b>	Costed Bill of Material	<b>OC</b>	Off-course
<b>CRD</b>	Cost Report Documents	<b>OEM</b>	Original Equipment Manufacturer
<b>CV</b>	Internal Combustion Engine Vehicle	<b>PCB</b>	Printed Circuit Board
<b>DBOM</b>	Detailed Bill of Material	<b>R2D</b>	Ready-to-drive
<b>DC</b>	Driverless Cup	<b>RES</b>	Remote Emergency System
<b>DI</b>	Direct Injection	<b>RMS</b>	Root Mean Square
<b>DNA</b>	Did Not Attempt	<b>SCS</b>	System Critical Signal
<b>DNF</b>	Did Not Finish	<b>SDC</b>	Shutdown Circuit
<b>DOO</b>	Down or Out	<b>SES</b>	Structural Equivalency Spreadsheet
<b>DQ</b>	Disqualified	<b>TMD</b>	Team Member Designation
<b>DSS</b>	Design Spec Sheet	<b>TPS</b>	Throttle Position Sensor
<b>DV</b>	Driverless	<b>TS</b>	Tractive System
<b>EAIR</b>	ESF Add Item Request	<b>TSAC</b>	Tractive System Accumulator Container
<b>EBS</b>	Emergency Brake System	<b>TSAL</b>	Tractive System Active Light
<b>ECU</b>	Electronic Control Unit	<b>TSMP</b>	Tractive System Measuring Point
<b>EDR</b>	Engineering Design Report	<b>TSMS</b>	Tractive System Master Switch
<b>EI</b>	Flexural Rigidity	<b>USS</b>	Unsafe Stop

## SECTION A – ADMINISTRATIVE REGULATIONS

### **A1 COMPETITION OVERVIEW**

#### **A1.1 Competition Objective**

A1.1.1 The competition challenges teams of university students to conceive, design, fabricate, develop and compete with small, formula style, race cars. The envisaged “target customer” for these vehicles is an amateur (non-professional) driver.

A1.1.2 There are three entry classes: FS Class, FS-AI Class and Concept Class

A1.1.3 Entrants to Concept Class are to be designed based on being able to be manufactured and to then compete in FS Class in the immediate subsequent competition year.

#### **A1.2 Competition Procedure**

A1.2.1 The competition accepts entries for the following vehicle types:

- Internal Combustion Engine Vehicle (CV),
- Electric Vehicles (EV),
- Alternative Fuel Vehicles (AFV),
  - High Voltage Hybrid powertrains are permitted in this vehicle type.
- Driverless Vehicles (DV).

A1.2.2 All vehicles must meet the requirements defined in Section T and Section CV, EV or AFV, depending on their powertrain type.

A1.2.3 The competition starts with a series of technical inspections described in Section IN to check the vehicle for safety and compliance with the rules.

A1.2.4 The competition is divided into a series of static and dynamic events described in Sections S and D.

A1.2.5 The maximum achievable points for FS Class are listed in Table 1.

A1.2.6 The maximum achievable points for Concept Class are listed in Table 2.

A1.2.7 In either FS Class or FS-AI Class, if there are no finishers in any dynamic events, then no Overall Winner award will be given for that class.

A1.2.8 The CV, EV or AFV team with the most overall points will win the competition.

A1.2.9 The official language of the competition is English.

FS Class	Points
Static Events:	
Lap Time Simulation	20
Business Plan Presentation	115
Cost and Manufacturing	115
Engineering Design	150
Dynamic Events:	
Skid Pad	75
Acceleration	75
Autocross / Sprint	100
Efficiency	100
Endurance	250
Total Points	1000

Table 1: Maximum points awarded – FS Class

Concept Class	Points
Static Events:	
Lap Time Simulation	40
Business Plan Presentation	120
Cost and Manufacturing	150
Engineering Design	150
Total Points	460

Table 2: Maximum points awarded – Concept Class

## **A2 VEHICLE ELIGIBILITY**

### **A2.1 Student Competition**

- A2.1.1 Vehicles entering the competition must be conceived, designed and maintained by the student team members without direct involvement from professional engineers, racers, machinists or related professionals.
- A2.1.2 The student team may use any information from professionals or from academics, provided this information is given as a discussion of alternatives with their pros and cons.
- A2.1.3 Professionals may not make design decisions or drawings.
- A2.1.4 Students should manufacture and assemble as much of the vehicle as possible.

### **A2.2 First Year Vehicles**

- A2.2.1 A vehicle must only compete for one competition year, it's "first year", counting from the first day onsite at its first competition. Such a vehicle is defined as "new". A vehicle may not compete in Formula Student class of the same event (e.g. Formula Student UK FS Class) in the following season, even if two events occur within a one-year period.
- A2.2.2 A team may attend a competition with their vehicle as a "non-competitor" if the team were registered for the Competition but have officially withdrawn prior to the event and have written permission from the Competition officials.  
  
A "non-competitor" cannot take part in any official or practice static or dynamic events. Practice scrutineering and technical rule clarifications are allowed, where time permits, priority will be given to registered entrants.
- A2.2.3 To be classified as new, a vehicle must have a newly manufactured chassis, with significant changes in the primary structure to its predecessor.  
  
[DV Only] Driverless Vehicles (DVs) may reuse a previous chassis from any year, but must be fully compliant with the current version of the rules. The Automated Driving System shall be developed for each new competition year.
- A2.2.4 Teams may apply to reuse a previous year's chassis only if they are changing powertrain type, from CV to EV, or CV to AFV .
  - Requests must be submitted via the Formula Student Question Database (FSQD) before the Structural Equivalency Spreadsheet (SES) deadline,
  - Requests will be reviewed by the Chief Judge or Chief Technical Scrutineer, their decision will be final.

## **A3 RULES OF CONDUCT**

### **A3.1 General Officials Authority**

- A3.1.1 The officials reserve the right to revise the schedule, date and location of the competition and/or interpret or modify the competition rules at any time and in any manner that is, in their sole judgment, required for safe and efficient operation.
- A3.1.2 All team members are required to cooperate with and follow all instructions from the officials.
- A3.1.3 Official announcements shall be considered part of the rules.
- A3.1.4 All guidelines and clarifications posted in the “Rules and Important Documents” sections on the competition website for the current season including the competition handbook are considered part of the rules. The “Key Dates” document is considered part of the Rules.

### **A3.2 Official Instructions**

- A3.2.1 Failure of a team member to follow an instruction or command directed specifically to that team or team member will result in 25 penalty points being deducted from the team’s overall score.

### **A3.3 Arguments with Officials**

- A3.3.1 Argument with, or disobedience to, any official will result in the team being disqualified from the competition.

### **A3.4 Unsportsmanlike Conduct**

- A3.4.1 In the event of unsportsmanlike conduct, 25 penalty points will be deducted from the team’s overall score. A second violation will result in the team being disqualified from the competition.

### **A3.5 Violations of Intent**

- A3.5.1 Violation of the intent of a rule will be considered a violation of the rule itself.
- A3.5.2 Any parts, devices or software fragments designed with the intent to violate a rule, will be considered as a violation.

### **A3.6 Questions about the Rules**

- A3.6.1 Questions about the rules may be asked to the officials.
- A3.6.2 The frequently asked questions (FAQ) section on the competition website must be checked before submitting a question.
- A3.6.3 The officials will only answer questions that are not already answered in the rules or FAQs or that require a new or novel interpretation.
- A3.6.4 Questions must be submitted to the Formula Student Questions Database (FSQD) which can be accessed here: <https://teams.formulastudent.com/FAQ/AskAQuestion>
- A3.6.5 Clarifications issued in response to questions about the rules may only be valid for one competition year. If you are submitting a question to reconfirm a previous clarification, the ID number of the original question should be referenced in the new question.

A3.6.6 Clarifications issued by other events may not be valid at Formula Student, if you are entering multiple events ensure you check the legality of your design with all event organisers.

### **A3.7 Protests**

A3.7.1 If a team has a question about scoring, judging, policies or any official action it must be brought to the officials' attention within the announced protest period for an informal preliminary review before a protest can be filed.

A3.7.2 A team may protest any rule interpretation, score or official action which they feel has caused some actual, non-trivial, harm to their team, or has had a substantive effect on their score.

A3.7.3 All protests must be filed in writing and presented to the officials by the team captain. In order to have a protest considered, a team must post a 25-point protest bond which will be forfeited if their protest is rejected.

A3.7.4 Protests concerning any aspect of the competition must be filed within the protest period announced by the competition organisers in the Team Handbook, or within 30 minutes of the scores of the event to which the protest relates being posted.

A3.7.5 The decision of the officials regarding any protest will be in written form and is final.

### **A3.8 Advertising Regulations**

A3.8.1 To ensure full compliance with UK and European legislation, teams are not permitted to display any form of tobacco or cigarette advertising on their vehicles or display areas. The organisers also reserve the right to instruct teams to remove or cover any other vehicle or display area markings that may be illegal or likely to cause offence.

### **A3.9 Car Covering**

A3.9.1 Covering or obscuring any competing car or any part of a competing car is considered unsportsmanlike conduct. Teams could receive a penalty of up to 50 points for car covering, at the discretion of the Chief Judge.

A3.9.2 During the entire Competition, except as permitted below, no screen, cover or other obstruction which in any way obscures any part of a car will be allowed at any time in the paddock, garages, pit lane or grid. The following are permitted:

- A cover over the car in the garage or paddock overnight,
- A cover over the car in the pit lane or on the grid if it is raining,
- Covers on the tyres to prevent debris pick-up,
- Covers over severely damaged cars or components.

A3.9.3 Any car part stored in front of the car will be considered as an obstruction unless it is stored flat on the ground and does not totally or partially hide the car. Anybody standing in front of the car is considered as an obstruction to the visibility unless they must work on the car. A line of people in front of the car is strictly prohibited.

## **A4 GENERAL REQUIREMENTS FOR TEAMS & PARTICIPANTS**

### **A4.1 Teams per University**

A4.1.1 For FS Class and Concept Class a university may register two (2) teams for each class, if they are different power-train types (CV, EV or AFV).

For FS-AI Class a university may enter one (1) ADS and one (1) DDT entry.

A4.1.2 Notwithstanding A4.1.1, registration for Formula Student in the UK may be restricted to one (1) vehicle per class, per university, regardless of powertrain or vehicle type, depending on available space.

A4.1.3 Teams which are formed with members from two or more universities are treated as a single team.

### **A4.2 Team Members and Participants**

A4.2.1 Faculty Advisors are required to confirm that adequate insurance cover is in place, including but not limited to personal accident insurance for all drivers and public liability insurance (minimum £15m) for the team.

Declaration that cover is in place must be provided when a place in the competition is offered, accepted and payment is due. Teams will not be permitted to participate without this confirmation.

All participants who are not UK residents must provide proof of valid individual health insurance for the competition. This must be provided prior to attendance at any live event in accordance with the Key Dates document. Participants will not be accredited for any live events without evidence of cover.

A4.2.2 All participants must sign the Motorsport UK liability waiver. This must be completed by each participant via their team member account prior to attendance at any live event in accordance with the Key Dates document.

A4.2.3 A team member may only be part of one team, work on one vehicle and take part in static and dynamic events for only one team. Any teams found to be in contravention of this rule may receive a 25 point penalty.

A4.2.4 Each team must have one team member identified as the Team Captain. The Team Captain is the main contact person for the officials during the registration process and the competition.

A4.2.5 Persons who have previously attended any official event as a judge are not allowed to participate as team members.

A4.2.6 Team members must be enrolled as degree seeking undergraduate or graduate students in any university. Team members who have graduated within the seven-month period prior to the competition remain eligible to participate.

A4.2.7 Students seeking a post graduate degree or equivalent are eligible to compete.

A4.2.8 Team members must be at least 18 years of age.

A4.2.9 Team members who will drive a competition vehicle at any time during the competition

must hold a valid, government issued, photographic driver's licence for passenger cars, or a recognised National Sporting Authority (ASN) approved karting or car motorsport licence.

A4.2.10 Drivers who have driven for a professional racing team in a national or international series at any time may not drive in any competition event.

- A "professional racing team" is defined as a team that provides racing cars and enables drivers to compete in national or international racing series and employs staff in order to achieve this.

A4.2.11 Students studying at a UK university must be a member of the Institution of Mechanical Engineers to compete at Formula Student.

- International students with a 'home FS competition' may be a member of the engineering organisation that organises their home event (e.g. we will accept German students who are VDI members). If you do not have one of these home events in your country: SAE International, SAE Australasia, SAE Brazil, VDI, VDE, or ATA, your team must become IMechE members.
- Student Affiliate membership is FREE to all Formula Student team members, regardless of discipline. To apply for Student Affiliate Membership:
  - Create or login to your Formula Student team account,
  - Select 'Student Affiliate Form' on the navigation bar,
  - Complete the application form and submit your application.
- Team Leaders must ensure that all team members become IMechE members as defined in the Key Dates Document which can be found at:
 

<https://www.imeche.org/events/formula-student/team-information/key-dates>
- Membership numbers must be quoted in the Team Member Details section of your account prior to the event.
- Faculty Advisor membership of an engineering institution is optional.

A4.2.12 Students who became an IMechE affiliate member in a previous competition year do not need to apply again. They must inform [membership@imeche.org](mailto:membership@imeche.org) that they are continuing to compete in Formula Student in this competition year and supply their name and membership number.

### **A4.3 [EV ONLY] Electrical System Officer**

A4.3.1 Every participating team must appoint at least one Electrical System Officer (ESO) for the event. The ESO(s) is responsible for all electrical operations during the event.

A4.3.2 Where multiple ESOs are appointed, the team must clearly identify which ESO is responsible for which activities. Where responsibility is re-allocated, this must be done with the prior agreement of all ESOs involved.

A4.3.3 The ESO(s) is the only person in the team who may declare the vehicle electrically safe, in order for work to be performed on any system of the vehicle by the team.

A4.3.4 The ESO(s) must be valid team members, which means that they must have student status, see A4.2.6, A4.2.7 and A4.2.8.



- A4.3.5 The ESO(s) must be contactable by phone at any time during the competition.
- A4.3.6 An ESO must accompany the vehicle whenever it is operated or moved around the competition site.
- A4.3.7 The ESO is not allowed to be a driver, unless a second ESO is named by the team who is not a driver. If the second ESO is also a driver then they cannot compete in the same dynamic event as the first driver, or a third ESO is required.
- A4.3.8 The ESO must be certified or must have received appropriate practical training, whether formal or informal, for working with high voltage systems in automotive vehicles. Details of the training must be provided to the organizers on the ESO/ESA form for approval.

#### **A4.4 [DV Only] Autonomous System Responsible**

- A4.4.1 To operate the AS every participating team must appoint at least one ASR for the competition. This person is responsible for all autonomous operations of the vehicle during the competition, which includes any work on the autonomous system as well as racing and testing.
- A4.4.2 For vehicles with an electric drivetrain the ASR(s) must fulfil A4.3 and therefore replace the ESO. The team may not register additional ESOs.
- A4.4.3 The ASR(s) are the only persons in the team allowed to declare the autonomous system safe, so that work on any system of the vehicle may be performed by the team, or the vehicle may be operated in manual or autonomous mode.
- A4.4.4 The ASR(s) must be a valid team member, which means that they must have student status, see A4.2.6, A4.2.7 and A4.2.8.
- A4.4.5 The ASR(s) must accompany the vehicle whenever it is operated or moved around at the competition site.
- A4.4.6 If only one ASR is named by the team, the ASR may not be a driver.
- A4.4.7 The ASR(s) must be properly qualified to handle the autonomous system and to understand and deal with problems and failures. A bachelor's degree in computer science, electrical engineering, mechatronics, automation engineering, robotics or similar is a sufficient qualification.
- A4.4.8 All ASRs are required to attend the team briefing as per the official Event Schedule for the live event.

#### **A4.5 Faculty Advisor**

- A4.5.1 Each team must have a Faculty Advisor appointed by the university.
- A4.5.2 The Faculty Advisor is expected to accompany the team to the competition's live event and will be considered by competition officials to be the official representative of the university, with responsibility for the behaviour and conduct of all team members during the event.

The Faculty Advisor is expected to ensure that wherever possible the regulations and their university's Health and Safety protocols are followed at all times.

- A4.5.3 If the Faculty Advisor is unable to accompany the team at any time during the event they

must send a signed letter to the event officials, nominating who is responsible for the behaviour and conduct of all team members in their absence.

A4.5.4 Faculty Advisors may advise their teams on general engineering and engineering project management theory.

A4.5.5 Faculty Advisors may not design, build or repair any part of the competition vehicle or directly participate in the development of any documentation or presentation.

#### **A4.6 [EV ONLY] Electrical System Advisor (ESA)**

A4.6.1 The ESA must be a professionally competent person(s), nominated by the team, who can advise on the electrical and control systems that will be integrated into the vehicle. It is acceptable for the Faculty Advisor to be the ESA if all the requirements below are met.

A4.6.2 The ESA must supply details of their experience of electrical and/or control systems engineering as employed in the car on the ESO/ESA form for approval by the organisers. It is likely that the ESA will be a Chartered Engineer or someone of equivalent status.

A4.6.3 The ESA must have significant practical experience of the technology that is being developed and its implementation into vehicles or other safety critical systems such that they are adequately qualified to advise the team on their proposed electrical and control system designs.

NOTE: It may be necessary to have more than one ESA to achieve this requirement.

A4.6.4 The ESA must advise the team such that the merits of any relevant engineering solutions can be discussed, questioned and approved before being implemented into the final vehicle design.

A4.6.5 The ESA should advise the students on the required training so that they are competent to work with the systems on the vehicle.

A4.6.6 The ESA must review and sign the Electrical System Form to confirm that in principle the vehicle has been designed using good engineering practices.

A4.6.7 The ESA must ensure that the team discusses any unusual aspects of the design with the rules committee to reduce the risk of exclusion or significant changes being required to pass technical inspection.

A4.6.8 All EV team members are required to have basic electrical safety training to ensure they are aware of the risks and know how to respond in the event of an incident. Details of this training should be documented in the ESO/ESA form.

#### **A4.7 Registration**

A4.7.1 Registration for Formula Student must be completed online. Online registration must be performed by the Team Leader and official Faculty Advisor connected with the registering university.

A4.7.2 Registration for Formula Student UK is limited to a fixed number of competing cars. There is no limit to how many teams may be on the reserve list. A reserve team will be notified when a registration slot becomes available.

A4.7.3 Registration for Formula Student is via submission of a Design Concept Specification document by the date specified in the Key Dates document. There are no exceptions to

this registration policy.

- A4.7.4 Registration fees must be paid to the Institution of Mechanical Engineers by the deadline specified in the Key Dates document.
- A4.7.5 In the event of a team withdrawing from the competition, registration fees are not refundable. In the event that the competition is cancelled entirely by the organisers, the option to defer entry fees to a future competition will be offered. Depending on the circumstances around the cancellation, a full or partial refund may be offered. Changes to the event schedule, dates or venue are pursuant to Rule A3.1.1.
- A4.7.6 FS Class teams may request to change their entry to Concept Class prior to the deadline published in the Key Dates document. This will be subject to capacity in Concept Class.
- A4.7.7 FS-AI ADS teams may request to change their entry to DDT prior to the deadline published in the Key Dates document. This will be subject to capacity in DDT class.

#### **A4.8 Team Member Registration Requirements**

- A4.8.1 Team Leaders must ensure that every participant's name, including the Faculty Advisors, is listed in the Manage Members section of their Team Account. It is the Team Leader's responsibility to ensure that all team members have their own individual accounts. The following is also required:
- Driver's licence numbers must be listed for participants who intend to drive a competition vehicle.
  - IMechE Membership Number (where required by A4.2.11)
  - Emergency Contact Details for each team member and the Faculty Advisor must be submitted online by the deadline specified in the Key Dates document.
- A4.8.2 Details of on-site registration requirements for the live event will be communicated via the Team Handbook, release date as per Key Dates document.

#### **A4.9 Newcomer Registration**

- A4.9.1 Teams who will be competing in their first season of the FSAE/FS calendar with a running vehicle and have not won a major award at a previous competition, and teams that have been absent from FSAE/FS for at least 5 years will be eligible for the Newcomer Award.

Eligible teams should email [fs@imeche.org](mailto:fs@imeche.org) to advise organisers of their Newcomer status.

#### **A4.10 Vehicle Shipping**

- A4.10.1 Vehicle shipments by commercial carrier must comply with the laws and regulations of nations from which, and to which, the car is being sent. Teams are advised to consult with their shipping company or freight forwarder to be sure their shipment fully complies with all relevant, customs, import/export and aviation shipping requirements.
- A4.10.2 Shipments must be sent with the sending team or university listed as the receiving party. Neither the competition organisers nor the competition sites can be listed as the receiving party. The Institution of Mechanical Engineers will not take responsibility for any shipments or any associated charges. Further details on vehicle shipping can be found on the Formula Student website.

## **A5 DOCUMENTATION & DEADLINES**

### **A5.1 Required Documents and Forms**

A5.1.1 Several competition critical documents must be submitted prior to the competition live event. Full details of the document names, format, method of submission and deadlines can be found in the Key Dates document published on the Formula Student website.

NOTE: The Key Dates document is updated frequently so please check that you are working from the most up to date version as published on the website.

A5.1.2 Where applicable, templates for the required submissions can be found here:

<https://www.imeche.org/events/formula-student/team-information/forms-and-documents>

A5.1.3 Documents submitted in contradiction to the requirements set out in the Key Dates document, including blank document submissions, will be considered as “Not Submitted”.

### **A5.2 Submission**

A5.2.1 Uploaded documents can only be viewed by:

- Registered members on the team list of the university’s Formula Student team account, including Team Leaders, Team Members and Faculty Advisors,
- Authorised Judges, Officials and Scrutineers,
- IMechE Staff.

A5.2.2 By submitting documents via the competition website, the team agrees that they may be reproduced and distributed by the officials, in both complete and edited versions, for educational purposes.

A5.2.3 Documents or videos that are largely incomplete or not readable/viewable will be considered as “Not Submitted”.

A5.2.4 Team Leaders are responsible for ensuring that all of their team’s submissions are uploaded or sent no later than the published deadline. Account creation for online document submission is explained on the FS website.

A5.2.5 The format, method of submission, initial deadline and final deadline are all defined in the Key Dates document published here:

<https://www.imeche.org/events/formula-student/team-information/key-dates>

A5.2.6 SES and IAD submissions are reviewed in the order that they are received. Teams are strongly encouraged to submit these well before the submission deadline.

A5.2.7 All documents submitted online through your Team Account will generate a confirmation email stating the date and time of your upload. This will be sent to your primary team contact, as defined in your registration form.

- You are strongly advised to print and retain this confirmation email for the final version of each submission,
- If the primary contact email changes you must inform [formulastudent@imeche.org](mailto:formulastudent@imeche.org).

### **A5.3 Late Submission or Non-Submission**

- A5.3.1 The penalties for submitting documents later than the initial and final deadlines are defined in the Key Dates document on the Formula Student website.
- A5.3.2 Volunteer judges evaluate all the required submissions, it is essential that they have enough time to complete their work. There are no exceptions to the document submission deadlines and late submissions will incur penalties.
- A5.3.3 Any penalty for late submission or non-submission of documents required for the Static Events will be deducted from the related event score, not the overall competition score.

### **A5.4 Correction Requests**

- A5.4.1 Judge / Official requested resubmissions to documents must be submitted no more than 14 days after the request is sent, as per the Key Dates document.
- A5.4.2 Separate requests for different parts within one document or form will be treated independently.
- A5.4.3 The document types that may be subject to resubmission requests by Judges / Officials are listed in the Key Dates document. Teams have the option to replace any uploaded documents with a new file at any time before the “Submission Deadline” or, where applicable the “Final Date for Late Submission” in the Key Dates document.
- A5.4.4 Where applicable, between the “Submission Deadline” (document deadline before lateness applies) and the “Final Date for Late Submission” replacement documents are classified as late submissions and the appropriate lateness penalties will be applied, unless you were asked to resubmit by the Judge / Official reviewing your submission.

### **A5.5 SES Approval**

- A5.5.1 SES for all vehicles (except DDT) must be submitted in line with the competition Key Dates document. All SES will be reviewed by Scrutineering and awarded a ‘Approved or ‘Failed’ as part of pre-event checks. Teams who have received a ‘Failed’ result will be able to correct the SES and resubmit as many times as is needed prior to the resubmission deadline specified in the competition Key Dates document. Teams will not be able to pass scrutineering and dynamically compete without an approved SES.

### **A5.6 Design Concept Specification**

- A5.6.1 All teams must submit a Design Concept Specification (DCS) by way of application to compete in the 2024 competition. Submission of the DCS is via your Team Account as per the Key Dates document.

## **A6 GENERAL RULES**

### **A6.1 Removing the Vehicle from the Site**

A6.1.1 Teams who remove their vehicle ([EV ONLY] or tractive system accumulator) from the competition site after the competition has begun will be disqualified from the competition.

### **A6.2 Forfeit for Non-Appearance**

A6.2.1 It is the responsibility of each team to be in the right place at the right time.

A6.2.2 If a team is not present and ready to compete at the scheduled time, they forfeit their attempt at that event.

### **A6.3 Team Briefing**

A6.3.1 The team leader and all drivers for a particular day must attend the team briefing for that day as per the official Event Schedule for the live event.

### **A6.4 Testing and Work Safety**

A6.4.1 Teams are reminded that cars built according to the Formula Student and Formula SAE rules are not designed or intended for racing or use at high speed, or in confined areas where they might impact with solid objects, including safety barriers.

Teams are advised to develop and run their vehicles on large, substantially open areas, and to do so only under similar speed and cornering conditions as they would face at official FSAE or FS events.

- It is further advised that all cars are checked by a Motorsport UK safety scrutineer. Please email [fs@imeche.org](mailto:fs@imeche.org) to arrange this.

The competition officials disassociate themselves from all activities of the teams besides their own competition live event and associated events.

A6.4.2 All teams are advised to follow best engineering, manufacturing, machining and health and safety practices and common sense when working on the vehicle and when operating the vehicle, before, during and after a competition.

A6.4.3 The vehicles must not participate in events not suitable for this type of vehicle like hill climbs, drag races or similar.

A6.4.4 Teams must never use their vehicles for wheel-to-wheel races.

A6.4.5 The following listed requirements are considered the minimum for a testing/operating environment to qualify as safe. Following these guidelines does not guarantee safety under all circumstances:

- Driver wearing full protection gear according to T13.3,
- Working TSAL, IMD, AMS, ASSI, RES, EBS, APPS/brake pedal plausibility check, APPS, and ETC plausibility check if applicable,
- Rules compliant chassis and mounted impact attenuator,
- No other passenger cars, trucks etc. being parked or driven on the same premise at the same time, unless the areas are clearly separated,

- No running under low visibility conditions,
- No running at speeds above typical event speeds,
- No running in areas where crashing into obstacles at the height of the driver's head is possible, such that parts of the vehicle may pass below an obstacle, but the driver's head can be trapped between the obstacle and the main hoop for example.

A6.4.6 The organisers hereby reserve the right to deduct points, or exclude individuals or teams from future competitions, if they act in such a way, at any time, as to actually or potentially bring the Formula Student name into disrepute.

Teams or individuals associated with them, displaying and/or running their vehicles at any events organised by themselves or others, who use the Formula Student name while doing so, and act irresponsibly or recklessly, may at the organiser's sole discretion be deemed to have acted in breach of this rule.

#### **A6.5 Onsite Working Safety**

A6.5.1 Everyone in the dynamic area and everybody working on the vehicle must wear appropriate, closed-toed shoes.

A6.5.2 Appropriate personal protective equipment must be used.

A6.5.3 Any operation producing litter or debris, e.g. cutting of carbon fibre, must not be performed in the pits.

A6.5.4 When jacking up the vehicle, a safe and stable support device rated for the load must be used.

#### **A6.6 Alcohol and Illegal Material**

A6.6.1 Drivers should not consume alcohol at least 24 hours before any event they are competing in and may be subject to random breathalyser checks.

A6.6.2 If any team member is tested with an alcohol level higher than 0.0 %, they will be immediately disqualified for the rest of the competition. A second team member being found to have an alcohol level higher than 0.0% will result in the entire team being disqualified immediately.

#### **A6.7 Vehicle Movement**

A6.7.1 Vehicles must not move under their own power anywhere other than on the practice or competition tracks.

A6.7.2 [EV ONLY] The detachable handle or key of the Tractive System Master Switch (TSMS) must be completely removed and kept by an ESO. The lockout/tagout function of the TSMS, see EV6.2.2, must be used.

A6.7.3 [EV ONLY] The High Voltage Disconnect (HVD), see EV4.8, must be disconnected at all times (including taking part in static events) if the vehicle has not passed electrical inspection.

A6.7.4 [DV ONLY] DV vehicles must also have their autonomous system deactivated when being moved around the paddock (see T14.7). The detachable handle or key of the Autonomous System Master Switch (ASMS) must be completely removed and kept by an ASR. The lockout/tagout function of the ASMS, see T14.7.8, must be used.

- A6.7.5 Vehicles must be pushed at a normal walking pace by means of a “push bar”, see T13.1, and with a team member in the cockpit wearing the required driver equipment as defined in T13.3 except for helmet, arm restraints and balaclava.
- A6.7.6 The team member in the cockpit must have full control of steering and braking.
- A6.7.7 When the push bar is attached to the vehicle, the engine/tractive system must remain switched off.
- A6.7.8 Vehicles with wings are required to have two team members walking on either side of the vehicle whenever the vehicle is being pushed.
- A6.7.9 Any team found ‘running with the car’ may have their tech sticker removed and will have their car confiscated and quarantined by the Chief Technical Scrutineer for a minimum of one hour. The one hour will start and end at the discretion of the Chief Technical Scrutineer.

#### **A6.8 [CV ONLY] Engine Running**

- A6.8.1 Running engines are not allowed in the pits.
- A6.8.2 Engine running is allowed in the engine test area and in the dynamic area, when the following conditions are met:
- The vehicle must have passed mechanical inspection,
  - The vehicle must be jacked up using a quick jack, see T13.2,
  - A driver, wearing required driver equipment, see T13.3, must be seated in the cockpit,
  - A fire extinguisher must be immediately available,
  - Driven wheels can only remain fitted to the vehicle if they will not rotate,
  - No one is allowed under the vehicle while the engine is running.
- A6.8.3 Cranking engines in the pits is allowed, when the following conditions are met:
- The vehicle has passed mechanical inspection,
  - The driven axles are securely jacked up,
  - Gearbox is in neutral,
  - All driven wheels are removed,
  - Connectors to all injectors and ignition coils are detached,
  - A fire extinguisher must be placed next to the engine.

#### **A6.9 Fuelling and Oil**

- A6.9.1 Fuelling may only take place at the fuel station and must be conducted by officials only.
- A6.9.2 Open fuel containers are not permitted at the competition.
- A6.9.3 Waste fuel and oil should be disposed of at the location specified in the Event Handbook.



**A6.10 [EV ONLY] Working on the Tractive System**

- A6.10.1 Activities on the Tractive System (TS), except for the accumulator (see A6.11) must take place in the pit.
- A6.10.2 All activities require the attendance of the ESO.
- A6.10.3 For activities on the inactive TS, the following procedure must be carried out:
- The vehicle must be barred from anyone not involved in the work, by using barrier tape,
  - The Tractive System Master Switch (TSMS) must be switched off,
  - It must be assured that the TS cannot be restarted by, at a minimum, using the lockout/tag out of the TSMS,
  - A check for zero-potential must be carried out,
  - A sign that declares the vehicle is electrically safe must be installed. The name of the ESO who is supervising the activities must be noted on the sign. This ESO is the only person who may remove the sign and the barrier.
- A6.10.4 In case of measurements on the active TS or activation of the TS for testing purposes, the following steps must be followed:
- The vehicle must be located in either the EV scrutineering area or one of the permitted “TS Active” zones (see Team Handbook for details),
  - The vehicle must be barred from anyone not involved in the work, by using barrier tape,
  - The vehicle must be jacked up and the driven wheels removed,
  - One team member must be prepared to push a shutdown button at any time,
  - The TS must only be activated for as long as necessary,
  - Appropriate insulated tools and equipment must be used,
  - Safety glasses with side shields and compliant safety gloves must be worn by all participating team members when parts of the TS are exposed,
  - No other work on the vehicle is permitted when the TS is active.
- A6.10.5 If the TSAL is flashing red or malfunctioning, the TS is considered as active.
- A6.10.6 There must be at least one team member present, who is not directly involved in the work, but who could assist in case of an incident.

**A6.11 [EV ONLY] Working on Tractive System Accumulators**

- A6.11.1 Opening or working on Tractive System Accumulator Containers (TSACs) is only allowed in the provided workplaces in the charging area, see A6.12.
- A6.11.2 All activities require the attendance of an ESO.
- A6.11.3 Whenever the TSACs are opened, the cell segments must be separated with the maintenance plugs, see EV5.4.3.
- A6.11.4 Appropriate insulated tools and equipment must be used.

- A6.11.5 Safety glasses with side shields and compliant safety gloves must be worn by all participating team members.
- A6.11.6 There must be at least one team member present, who is not directly involved in the work conducted on the accumulator, but who could assist in case of an incident.
- A6.11.7 Moving accumulator cells and/or accumulator segment(s) around at the competition site is only permitted if they are inside a completely closed TSAC.
- A6.11.8 Additional safety measures may be included in the respective competition handbook.

**A6.12 [EV ONLY] Charging**

- A6.12.1 There will be a separated charging area on the competition site. Charging TS accumulators is only allowed inside this area.
- A6.12.2 Accumulators must be removed from the vehicle and placed on the TSAC hand cart, see EV8.1, for charging.
- A6.12.3 The labels required in EV5.3.8 and EV5.3.9 must be visible during charging.
- A6.12.4 No grinding, drilling, etc. is allowed in the charging area.
- A6.12.5 At least one ESO who has knowledge of the charging process must stay with the accumulator(s) during charging.

**A6.13 Team Radios**

- A6.13.1 Any team radios must comply with PMR446:  
[https://www.ofcom.org.uk/data/assets/pdf\\_file/0025/85156/ir\\_2009\\_analogue\\_and\\_digital.pdf](https://www.ofcom.org.uk/data/assets/pdf_file/0025/85156/ir_2009_analogue_and_digital.pdf)
- A6.13.2 Operating on any other frequencies, or with transmission powers greater than 0.5W requires a licence from OFCOM.
- A6.13.3 All team telemetry must be transmitted on a 2.4Ghz frequency. Teams must not transmit on a 5Ghz or any other frequency.

**A6.14 Official Event Schedule**

- A6.14.1 The master version of the Event Schedule will be posted on the competition website. In the event of any differences between the master version and any version published elsewhere, then the timings published in the master version prevail.

**A6.15 Static Event Judging Schedule**

- A6.15.1 In respect for the volunteer judges, teams must notify officials of any inability to attend a scheduled judging session by the date and time specified in the Team Handbook. Please refer to Rule S1 for applicable penalties if this is not adhered to.
- A6.15.2 In exceptional circumstances teams may be offered an alternative scheduled time, but this cannot be guaranteed, and teams must make their best efforts to attend at their original allocated judging time and location.

**A6.16      Mandatory Safety Briefings**

- A6.16.1    The Event Schedule details the time and location of all mandatory safety briefings. Failure to attend these briefings and receive the allocated wristband will result in that team member being unable to complete their intended role(s).

## SECTION T – GENERAL TECHNICAL REQUIREMENTS

### T1 DEFINITIONS

#### T1.1 Chassis Definitions

- T1.1.1 Chassis – 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.
- T1.1.2 Chassis member – A minimum representative single piece of uncut, continuous tubing or equivalent structure.
- T1.1.3 Front bulkhead – A planar structure that defines the forward plane of the chassis and provides protection for the driver's feet.
- T1.1.4 Front bulkhead support – A structure that defines the side of the chassis from the front bulkhead back to the top of the upper side impact structure and the bottom of the front hoop.
- T1.1.5 Front hoop – A roll bar located above the driver's legs, in proximity to the steering wheel.
- T1.1.6 Impact Attenuator (IA) – A deformable, energy absorbing device located forward of the front bulkhead.
- T1.1.7 Main hoop – A roll bar located alongside or just behind the driver's torso.
- T1.1.8 Monocoque – A chassis made of composite material.
- T1.1.9 Node-to-node triangulation – An arrangement of chassis 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 chassis members as shown in Figure 1.

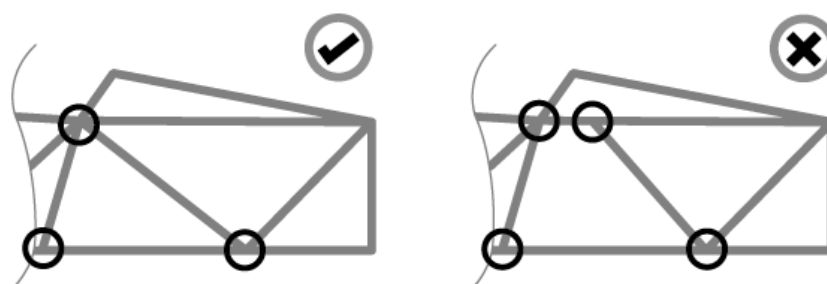


Figure 1: Node-to-node triangulation of chassis members (left correct and right incorrect)

- T1.1.10 Primary structure – The primary structure is comprised of the following components:

- Main hoop,
- Front hoop,
- Roll hoop braces and supports,
- Side impact structure,
- Front bulkhead,
- Front bulkhead support system,

- All chassis members, guides and supports that transfer load from the driver's restraint system into the above-mentioned components of the primary structure,
- [EV ONLY] structures mentioned under EV4.4.2 and EV5.5.2,
- [CV ONLY] structures mentioned under CV1.3.2.

- T1.1.11 Roll hoops – Both the front hoop and the main hoop are classified as “roll hoops”.
- T1.1.12 Roll hoop bracing – The structure from a roll hoop to the roll hoop bracing support.
- T1.1.13 Roll hoop bracing supports – The structure from the lower end of the roll hoop bracing back to the roll hoop(s).
- T1.1.14 Rollover protection envelope – The volume enclosed by a series of intersecting planes, where each plane is tangent to the outermost extremities of the elements described in T1.1.10, as shown in Figure 2.

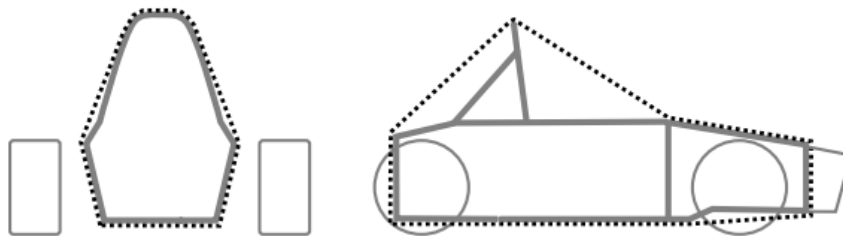


Figure 2: Rollover Protection Envelope.

- T1.1.15 Side impact structure – The area of the side of the chassis between the front hoop and the main hoop and from the chassis floor to the height as required in T3.15 above the lowest inside chassis point between front hoop and main hoop.
- T1.1.16 Surface envelope – The volume enclosed by multiple planes, each of which are tangent to the outermost surface of the primary structure and the outside edges of the four tyres, see Figure 3.

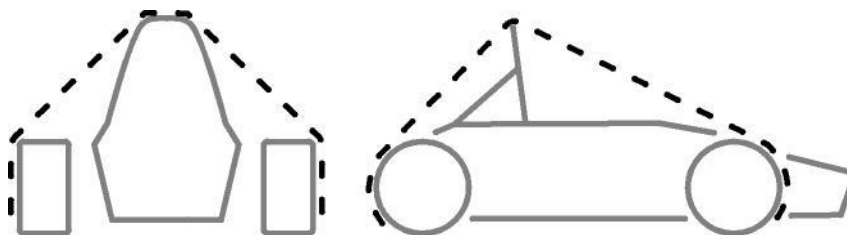


Figure 3: Surface Envelope without the rollover protection envelope, see T1.1.14.

## T1.2 Material Definitions

- T1.2.1 Fire Retardant – A material meeting one of the following standards:
- UL94 V-0 for the minimum used material thickness
  - FAR 25.853(a)(1)(i)

Equivalent standards are only accepted, if the team shows equivalence and this is approved by the officials prior to the event.

### **T1.3 Electrical Definitions**

- T1.3.1 Direct Connection – Two devices or circuits are directly connected if the connection is not routed through any common PCB and does not include any devices or functionality other than overcurrent protection.

### **T1.4 Driving Mode Definitions**

- T1.4.1 Manual Mode – A vehicle is considered in manual mode when driven by a human driver. The AS must be deactivated in this case, the ASMS is in “Off” position.
- T1.4.2 Autonomous Mode – A vehicle is considered in autonomous mode when the AS is activated, the ASMS is in “On” position. This is required to participate in the DV dynamic events.

## T2 GENERAL DESIGN REQUIREMENTS

### T2.1 Vehicle Configuration

- T2.1.1 The vehicle must be designed and fabricated in accordance with good engineering practices.
- T2.1.2 The vehicle must be open-wheeled, single seat and open cockpit (a formula style body) with four wheels that are not in a straight line.
- T2.1.3 Open wheel vehicles must satisfy the following (see also Figure 4):
- The wheel/tyre assembly must be unobstructed when viewed from the side.
  - No part of the vehicle may enter a keep-out-zone defined by two lines extending vertically from positions 75 mm in front of and 75 mm behind the outer diameter of the front and rear tyres in the side view of the vehicle, with steering straight ahead. This keep-out zone extends laterally from the outside plane of the wheel/tyre to the inboard plane of the wheel/tyre assembly.

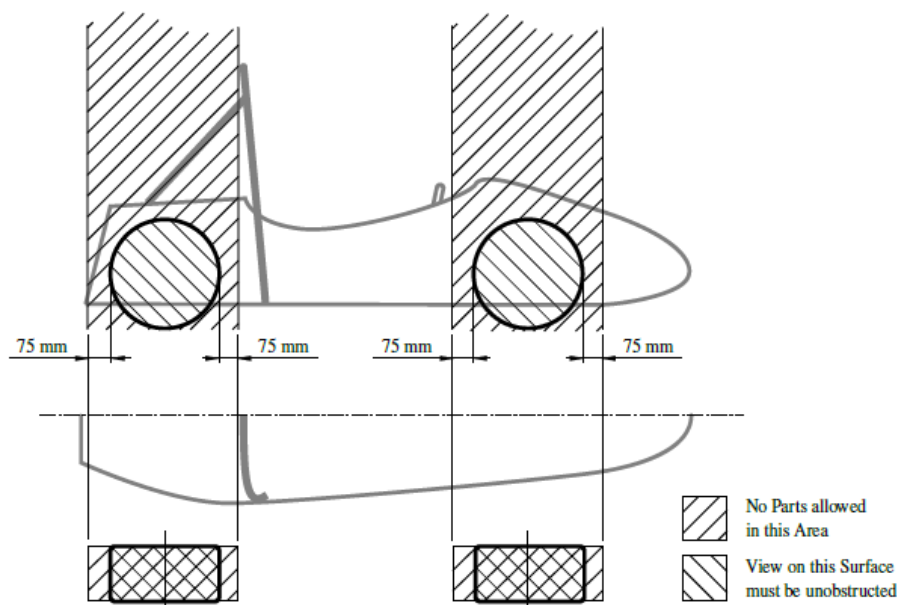


Figure 4: Keep-out-zones for the definition of an open-wheeled vehicle

### T2.2 Bodywork

- T2.2.1 There must be no openings through the bodywork into the driver compartment other than that required for the cockpit opening. Minimal openings around the front suspension and steering system components are allowed.
- T2.2.2 Enclosed chassis structures and structures between the chassis and the ground must have two venting holes of at least 25 mm diameter in the lowest part of the structure to prevent accumulation of liquids. Additional holes are required when multiple local lowest parts exist in the structure.
- T2.2.3 All edges of the bodywork that could come into contact with a pedestrian must have a minimum radius of 3 mm.
- T2.2.4 The bodywork in front of the front wheels must have a radius of at least 38mm extending at

least 45° relative to the forward direction, along the top, sides and bottom of all affected edges.

### **T2.3 Suspension**

- T2.3.1 The vehicle must be equipped with fully operational front and rear suspension systems including shock absorbers and a usable wheel travel of at least 50mm and a minimum jounce of 25 mm with driver seated.
- T2.3.2 The minimum static ground clearance of any portion of the vehicle, other than the tyres, including a driver, must be 30mm.
- T2.3.3 All suspension mounting points must be visible at technical inspection, either by direct view or by removing any covers.

### **T2.4 Wheels**

- T2.4.1 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.
- T2.4.2 Standard wheel lug bolts and studs must be made of steel and are considered engineering fasteners. Teams using modified lug bolts, studs or custom designs will be required to provide proof that good engineering practices have been followed in their design. Wheel lug bolts and studs must not be hollow.
- T2.4.3 Aluminium wheel nuts may be used, but they must be hard anodized and in pristine condition.
- T2.4.4 Extended or composite wheel studs are prohibited.
- T2.4.5 Wheel spacers are permitted. Laminated or multiple spacers per wheel are not permitted.

### **T2.5 Tyres**

- T2.5.1 Vehicles must have two types of tyres as follows:
- Dry tyres - The tyres on the vehicle when it is presented for technical inspection are defined as its “dry tyres”.
  - Wet tyres - Wet tyres may be any size or type of treaded or grooved tyre provided:
    - i. The tread pattern or grooves were moulded in by the tyre manufacturer or were cut by the tyre manufacturer or their 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 mm.
- T2.5.2 Tyres on the same axle must have the same manufacturer, size and compound.
- T2.5.3 Tyre warmers are not allowed.
- T2.5.4 Special agents that increase traction may not be added to the tyres or track surface.

### **T2.6 Steering**

- T2.6.1 Steering systems using cables or belts for actuation are prohibited. [DV ONLY] This does not apply for autonomous steering actuators.



- T2.6.2 The steering wheel must directly mechanically actuate the front wheels.
- T2.6.3 The steering system must have positive steering stops that prevent the steering linkages from locking up. The stops must be placed on the rack and must prevent the tyres and rims from contacting any other parts. Steering actuation must be possible during standstill.
- T2.6.4 Allowable steering system free play is limited to a total of 7° measured at the steering wheel.
- T2.6.5 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.
- T2.6.6 The steering wheel must be no more than 250mm rearward of the front hoop. This distance is measured horizontally, on the vehicle centreline, from the rear surface of the front hoop to the forward most surface of the steering wheel with the steering in any position.
- T2.6.7 The steering wheel must have a continuous perimeter that is near circular or near oval. The outer perimeter profile may have some straight sections, but no concave sections.
- T2.6.8 In any angular position, the top of the steering wheel must be no higher than the top-most surface of the front hoop.
- T2.6.9 The steering rack must be mechanically attached to the chassis.
- T2.6.10 Joints between all components attaching the steering wheel to the steering rack must be mechanical and visible at technical inspection. Bonded joints without a mechanical backup are not permitted. The mechanical backup must be designed to solely uphold the functionality of the steering system.
- T2.6.11 Rear wheel steering, which can be electrically actuated, is permitted if mechanical stops limit the range of angular movement of the rear wheels to a maximum of 6°. This must be demonstrated with a driver in the vehicle and the team must provide the equipment for the steering angle range to be verified at technical inspection.

## **T2.7 Wheelbase**

- T2.7.1 The vehicle must have a wheelbase of at least 1525 mm.

## **T2.8 Track and Rollover Stability**

- T2.8.1 The smaller track of the vehicle (front or rear) must be no less than 75 % of the larger track.
- T2.8.2 The track and centre of gravity of the vehicle must combine to provide adequate rollover stability.

### T3 GENERAL CHASSIS DESIGN

#### T3.1 General Requirements

T3.1.1 Among other requirements, the vehicle's structure must include:

- Two roll hoops that are braced
- A front bulkhead with support system and Impact Attenuator (IA)
- Side impact structures

#### T3.2 Minimum Material Requirements

T3.2.1 Table 3 shows the minimum requirements for the members of the primary structure if made from steel tubing.

Item or application	Minimum wall thickness	Minimum cross-sectional area	Minimum area moment of inertia
Main and front hoops, shoulder harness mounting bar	2.0mm	175mm <sup>2</sup>	11320mm <sup>4</sup>
Side impact structure, front bulkhead, roll hoop bracing, driver's restraint harness attachment (except as noted above)	1.2mm	119 mm <sup>2</sup>	8509 mm <sup>4</sup>
Front bulkhead support, main hoop bracing supports	1.2mm	91 mm <sup>2</sup>	6695 mm <sup>4</sup>

Table 3: Minimum Material Requirements

T3.2.2 The Primary Structure of the car must be constructed of:

- Round, mild or alloy steel (minimum 0.1% carbon) of the minimum dimensions specified in T3.2.1
- Approved 'Alternative Materials' as per T3.3.
- Approved 'Composite Structure' as per T3.4.

T3.2.3 Except for inspection holes, any holes drilled in any part which is a member of the primary structure must be documented in the SES.

T3.2.4 The steel properties used for the calculations in the SES must be:

##### Non-welded strength for continuous material calculations:

- Young's Modulus (E) = 200 GPa
- Yield Strength (Sy) = 305 MPa
- Ultimate Strength (Su) = 365 MPa

##### Welded strength for discontinuous material such as joint calculations:

- Yield Strength (Sy) = 180 MPa
- Ultimate Strength (Su) = 300 MPa

T3.2.5 Any tubing with a wall thickness less than 1.2mm or a minimum area moment of inertia less than  $6695 \text{ mm}^4$  is considered non-structural and will be ignored when assessing compliance to any rule regarding the vehicle structure.

**T3.2.6** If a member of the primary structure (except for the roll hoops) is a bent tube or made from multiple tubes an additional tube must support it. This support tube must:

- Have its attachment point at the position along the bend tube where it deviates farthest from a straight line connecting both ends.
- Be of the same dimension as the supported tube(s).
- Terminate at a node of the chassis.
- Be angled no more than  $30^\circ$  from the plane of the supported tube(s).

T3.2.7 Any welded seams shape must not be mechanically altered in any way.

T3.2.8 Where bonded joints are applicable and governed by the rules, a 50% reduction shall be applied to all datasheet adhesive values. Properties from adhesive tests must be derived from a statistically significant number of samples. Bonded joints in the primary structure must be documented in the SES.

### **T3.3 Alternative Materials**

T3.3.1 Alternative materials may be used for all parts of the Primary Structure and the TSAC with the following exceptions:

- The main hoop and the main hoop bracing must be steel
- The front hoop must be metal
- Any welded structures of the primary structure must be steel
- However, the front hoop may be an aluminium welded structure

T3.3.2 If any materials other than steel tubing are used in the primary structure or the TSAC, physical testing is required to show equivalency to the minimum material properties for steel in T3.2.

### **T3.4 Composite Structures**

T3.4.1 If composite structures are used in the primary structure or the TSAC, the Flexural Rigidity (EI) of that structure must be calculated with the tools and formulas in the SES. The actual geometry and curvature of the panel may be taken into account for the main hoop bracing support, the front hoop bracing, the front bulkhead support structure and the shoulder harness bar. For all other areas the EI must be calculated as the EI of a flat panel about its neutral axis. This panel must have the same composition as the structure used in the chassis.

T3.4.2 If composite materials are used in the primary structure or the TSAC the SES must include:

- Material type(s)
- Cloth weights
- Resin type
- Fibre orientation

- Number of layers
- Core material
- Lay-up technique
- 3-point-bend test and shear test data

T3.4.3 For any laminate in the primary structure or the TSAC, the maximum weight content of parallel fibres, relative to the weight of all fibres in the laminate, is 50 %. All fibres laid within any orientation  $\pm 10^\circ$  count as parallel in this case.

T3.4.4 Wherever backing plates are required, they must be fully supported by the structure they are attached to.

### **T3.5 Laminate Testing**

T3.5.1 If composite materials are used for any part of the primary structure or the TSAC the team must:

- Build a representative test panel which must measure exactly 275 mm  $\times$  500mm that has the same design, laminate and fabrication method as used for the respective part of the primary structure represented as a flat panel. The sides of the test panel must not be laminated (core material must be visible).
- Perform a 3-point bending test on this panel
- The data from these tests and pictures of the test samples and test setup must be included in the SES. In the pictures, the following must be identifiable: distance between the two supports, dimensions of the load applicator and test sample marking as per T3.5.4. The test results must be used to derive strength and stiffness properties used in the SES formula for all laminate panels.

T3.5.2 If a panel represents side impact structure it must be proven that it has at least the same properties as two steel tubes meeting the requirements for side impact structure tubes for buckling modulus, yield strength and absorbed energy.

T3.5.3 Composite structures with different core thicknesses but otherwise identical construction may use material properties derived from a single test panel. The panel with the thicker core must be tested and the structure using derived material properties may not use a core thickness of less than 67 % of the tested panel.

T3.5.4 The test samples must be presented at technical inspection. All samples must be marked with the following non-removable information: laminated structure acronym and date of testing.

T3.5.5 The distance between the two test panel supports must be at least 400 mm.

T3.5.6 The load applicator used to test any panel or tube must be metallic and have a radius of 50mm.

T3.5.7 The load applicator must overhang the test piece to prevent edge loading.

T3.5.8 There must be no material between the load applicator and the test piece.

T3.5.9 Perimeter shear tests must be completed which measure the force required to push or pull a 25 mm diameter flat punch through a flat laminate sample. The sample must be at least

100mm × 100mm. Core and skin thicknesses must be identical to those used in the actual chassis structure and be manufactured using the same materials and processes.

- T3.5.10 The test fixture must support the entire sample, except for a 32mm hole aligned co-axially with the punch. The sample must not be clamped to the fixture.

### **T3.6 Structural Documentation**

- T3.6.1 All teams must submit a Structural Equivalency Spreadsheet (SES).
- T3.6.2 The SES spreadsheet form can be downloaded from the competition website.
- T3.6.3 SE3D submission is not required for Formula Student UK.
- T3.6.4 Vehicles must be fabricated in accordance with the materials and processes described in the SES.
- T3.6.5 Teams must bring a copy of the approved SES to technical inspection.
- T3.6.6 As part of the SES submission, teams will be required to provide evidence of a new chassis via a written comparison describing the physical differences between the submitted Primary Structure design with that of the most recent previous.

SES demonstrating minimal change in design between their old and new chassis will be passed to the Design Judges for consideration of penalty points under Rule S5.7.2.

Photographic evidence demonstrating a 'new chassis' will be required for Chassis Scrutineering as per Rule IN5.1.1.

Teams who fail to satisfy Rule A2.2 will be disqualified from the competition.

- T3.6.7 Reports submitted on time, but which do not contain the required information (e.g. a "placeholder report" submitted to avoid penalties but without the required data) will be treated as a non-submission.
- T3.6.8 SES submission will be graded based on the completeness and quality of information provided in SES. It will not be an appraisal of the quality of design. Grades will range from A to F based on the following definitions:
- A. Completed to a high standard with clear graphics, notes and engineering justification.
  - B. Completed to a good standard with clear graphics and notes.
  - C. Completed to a minimum acceptable standard.
  - D. Notes and graphics difficult to read and/or poorly presented.
  - E. Repeat of the same errors for the same or similar design as in a previous year's original submission.
  - F. Late submission, incorrect SES template or major sections missing such that SES is deemed a 'non-submission'.

Grades will be published online and shared with Design Judges. No points will be awarded for grades A-E. An F grade will carry 10 to 50 penalty points.

### **T3.7 Roll Hoops**

- T3.7.1** Both roll hoops must be securely integrated to the primary structure using node-to-node triangulation or equivalent joining methods.

**T3.7.2** The minimum radius of any bend, measured at the tube centreline, must be at least three times the tube outside diameter. Bends must be smooth and continuous with no evidence of crimping or wall failure.

**T3.7.3** In a plane perpendicular to the longitudinal axis of the vehicle and through the lower endpoints of the roll hoop, no part of the primary structure may lie below 30mm of the endpoints of the roll hoop.

**T3.7.4** Roll hoops attached to a composite primary structure must be mechanically attached at the top and bottom of both sides of that structure and at intermediate locations if needed to show equivalency. The front hoop requires a minimum of six attachment points. The lower roll hoop tubing attachment points must be within 50mm of the endpoints of the roll hoop.

**T3.7.5** Mounting plates welded to the roll hoops must be at least 2mm thick steel or 3 mm thick aluminium, dependent of the roll hoop material.

**T3.7.6** Both roll hoops must have one 4.5 mm inspection hole in a non-critical straight location and its surface at this point must be unobstructed for at least 180°.

### **T3.8 Main Hoop**

**T3.8.1** The main hoop must be constructed of a single piece of uncut, continuous, closed section steel tubing.

**T3.8.2** In side view the portion of the main hoop which is above its upper attachment point to the side impact structure must be inclined less than 10° from vertical.

**T3.8.3** In side view any bends in the main hoop above its upper attachment point to the primary structure must be braced to a node of the main hoop bracing support structure with tubing meeting the requirements of main hoop bracing.

**T3.8.4** In side view any portion lower than the upper attachment point to the side impact structure must be inclined either forward or less than 10° rearward.

### **T3.9 Front Hoop**

**T3.9.1** The front hoop must be constructed of a continuous and closed section.

**T3.9.2** If the front hoop is made from more than one piece, it must be supported by node-to-node triangulation or an equivalent construction.

**T3.9.3** In side view, no part of the front hoop can be inclined more than 20° from vertical.

**T3.9.4** If the front hoop is a welded construction made from multiple aluminium profiles, the equivalent yield strength must be considered in the as-welded condition unless the team demonstrates and shows proof that it has been properly solution heat treated and artificially aged. The team must supply sufficient documentation proving the appropriate heat treatment process was performed.

**T3.9.5** Fully laminating the front hoop to the monocoque is acceptable. Fully laminating means that the hoop must be encapsulated with laminate around its whole circumference, see Figure 5. Equivalence to T3.7.4 must be shown in the SES. The laminate encapsulating the front hoop must overlap by at least 25mm on each side. It must have the same lay-up as the laminate that it is connecting to.

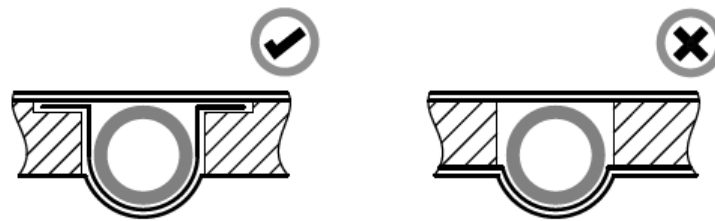


Figure 5: Front hoop laminating requirements

### T3.10 Main Hoop Bracing

- T3.10.1 The main hoop must be supported to the front or the rear by bracing tubes on each side of the main hoop.
- T3.10.2 In side view the main hoop and the main hoop braces must not lie on the same side of a vertical line coincident with the top of the main hoop.
- T3.10.3 The main hoop braces must be attached to the main hoop **no lower than 160mm** 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 30°**.
- T3.10.4 The main hoop braces must be straight.
- T3.10.5 The lower ends of the main hoop braces must be supported back to the upper attachment point of the main hoop to the side impact structure and to the lower attachment point of the main hoop to the side impact structure by a node-to-node triangulated structure or equivalent composite structure.
- T3.10.6 If any item which extends outside of the primary structure is attached to the main hoop braces, additional bracing is required to prevent bending loads in a rollover situation.

### T3.11 Front Hoop Bracing

- T3.11.1 The front hoop bracing **attaches on each side of the front hoop** as well as the structure forward of the driver's feet. A minimum of **two tubes without any bends** must be **straight on a line in side view of the frame** and must have **a minimum distance of 100 mm between each other** at the front hoop.
- T3.11.2 The front hoop bracing structure must be attached **no lower than 50mm** below the top-most surface of the front hoop, see Figure 6.

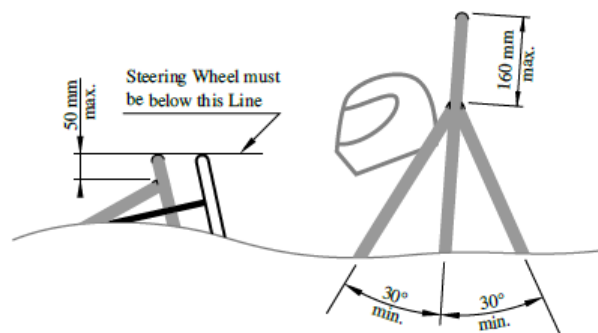


Figure 6: Front hoop bracing, main hoop bracing and steering wheel requirements

- T3.11.3 If the front hoop is inclined more than 10° to the rear, additional braces extending rearwards

are required.

**T3.11.4** Composite front hoop bracing structures and their attachments cannot be counted towards the front bulkhead support structures and vice-versa for the structural equivalency documentation.

**T3.12 Mechanically Attached Roll Hoop Bracing**

**T3.12.1** Any non-welded joint at either end of a bracing must be either a double-lug joint, see Figure 7, or a sleeved joint, see Figure 8. Spherical rod ends are prohibited.

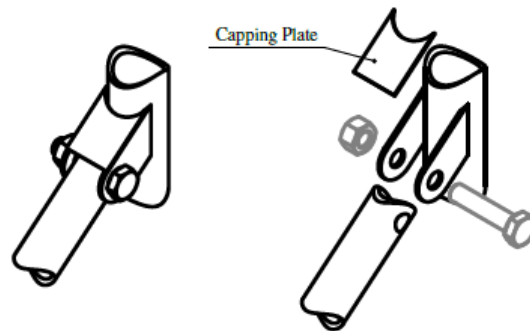


Figure 7: Double lug joint

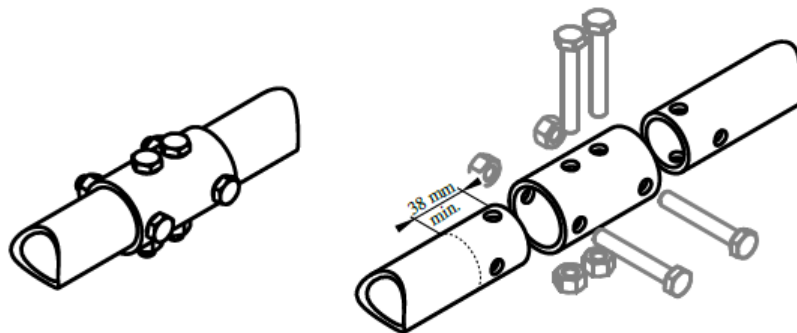


Figure 8: Sleeved joint

**T3.12.2** If threaded fasteners are used, they are considered critical fasteners and must comply with T10.1.

**T3.12.3** Double lug-joints must include a capping arrangement, see Figure 7.

**T3.12.4** In a double lug joint each lug must be at least 4.5mm thick and the pin or bolt must be 10mm metric grade 8.8 minimum. The attachment holes in the lugs and in the attached bracing must be a close fit with the pin or bolt.

**T3.12.5** For sleeved joints the sleeve must have a minimum length of 38mm 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 bracing tubes. The bolts must be 6mm metric grade 8.8 minimum. The holes in the sleeves and tubes must be a close-fit with the bolts.

**T3.13 Front Bulkhead**

**T3.13.1** Any alternative material used for the front bulkhead must have a perimeter shear strength



equivalent to a 1.5mm thick steel plate.

**T3.13.2** If the front bulkhead is part of a composite structure and is modelled as an “L” shape, the EI of the front bulkhead about the vertical and lateral axes must be equivalent to a steel tube meeting the requirements for the front bulkhead. The length of the section perpendicular to the bulkhead may be a maximum of 25mm measured from the rearmost face of the bulkhead.

**T3.13.3** In front view the driver’s feet must be within the outside perimeter of the Front Bulkhead.

### **T3.14 Front Bulkhead Support**

**T3.14.1** The front bulkhead must be supported back to the front hoop by a minimum of three tubes on each side; an **upper member**, a **lower member** and **diagonal bracing** to provide triangulation.

- The upper support member must be attached a **maximum of 50mm** below the top-most surface of the front bulkhead and a maximum of 50mm below to 100mm above the intersection of the front hoop and upper side impact member.

If the attachment point of the upper support member is greater than 100mm above the upper side impact member, **node-to-node triangulated bracing** is required to transfer load to the main hoop.

- **The lower support member must be attached to the base of the front bulkhead and the base of the front hoop.**
- **The diagonal bracing must triangulate the upper and lower support members node-to-node.**

**T3.14.2** If the front bulkhead support is part of a composite structure, it must have equivalent EI to the sum of the EI of the six baseline steel tubes that it replaces.

**T3.14.3** 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.

**T3.14.4** The perimeter shear strength of the monocoque laminate in the front bulkhead support structure must be at least 4kN.

### **T3.15 Side Impact Structure**

**T3.15.1** The side impact structure must consist of at least three steel tubes, see T3.2, on each side of the cockpit, see Figure 9.

- The upper member must connect the main hoop and the front hoop. It must be at a height **between 240mm and 320mm** above the lowest inside chassis point between the front and main hoop.
- The lower member must connect the **bottom of the main hoop** and the **bottom of the front hoop**.
- The diagonal member must **triangulate the upper and lower member** between the roll hoops node-to-node.

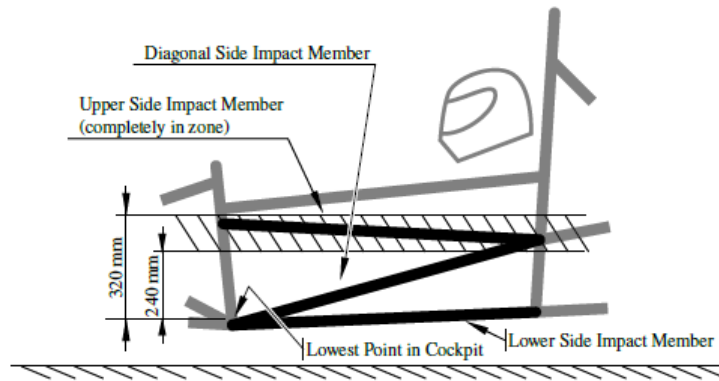


Figure 9: Side impact structure

**T3.15.2** If the side impact structure is part of a composite structure, the following is required:

- The region that is longitudinally forward of the main hoop and aft of the front hoop and vertical from the bottom surface of the chassis to 320mm above the lowest inside chassis point between the front and main hoop must have an EI equal to the three baseline steel tubes that it replaces, see Figure 10.
- The vertical side impact structure must have an EI equivalent to two baseline steel tubes and half the horizontal floor must have an EI equivalent to one baseline steel tube.
- The vertical side impact structure must have an absorbed energy equivalent to two baseline steel tubes.
- The perimeter shear strength must be at least 7.5kN.

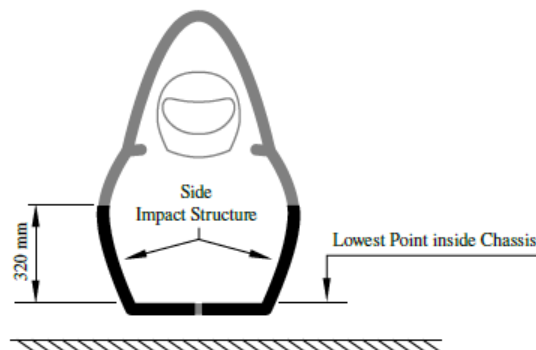


Figure 10: Side impact structure monocoque

### **T3.16 Bolted Primary Structure Attachments**

- T3.16.1** If two parts of the primary structure are bolted together, each attachment point between the two parts must be able to carry a load of 30kN in any direction.
- T3.16.2** Data obtained from the laminate perimeter shear strength test must be used to prove that adequate shear area is provided.
- T3.16.3** Each attachment point requires a minimum of two 8mm metric grade 8.8 bolts and steel backing plates with a minimum thickness of 2mm.

T3.16.4 For the attachment of front hoop bracing, main hoop bracing, and main hoop bracing support to the primary structure, the use of one 10mm metric grade 8.8 bolt is sufficient, if the bolt is on the centreline of the tube, see Figure 11.

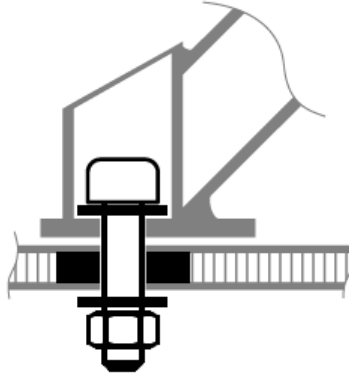


Figure 11: Bolted roll hoop bracing support

T3.16.5 When using bolted joints within the primary structure, no crushing of the laminate core material is permitted.

T3.16.6 For bolted AIP to Front Bulkhead attachments, and if two or more composite panels in the Primary Structure are bolted together, for each 200 mm of reference perimeter a minimum of one 8 mm metric grade 8.8 bolt must be used. Smaller bolts may be used if equivalency is proven. The bolts must be evenly distributed around the circumference. The reference perimeter is the outside perimeter of the attached part at the connection. The bolts are considered critical fasteners and must comply with T10.

### T3.17 Impact Attenuator

T3.17.1 Each vehicle must be equipped with an Impact Attenuator (IA) and Anti-Intrusion Plate (AIP).

T3.17.2 The IA must be:

- Installed forward of the front bulkhead,
- At least 100mm high and 200mm wide for a minimum distance of 200mm forward of the front bulkhead,
- No portion of the front face of the IA can be positioned more than 350 mm above the ground,
- Not able to penetrate the front bulkhead in the event of an impact,
- Attached securely and directly to the AIP, by welding or a minimum of four (4) 8mm metric grade 8.8 bolts. The bolts are considered critical fasteners and must comply with T10.1,
- Not part of the non-structural bodywork,
- Designed with a closed front section,
- No wider or higher than the AIP.

T3.17.3 The AIP must be 1.5mm solid steel, 4.0mm solid aluminium or permitted alternative

(T3.17.5).

- If the AIP is bolted to the front bulkhead, it must be the same size as the outside dimensions of the front bulkhead and comply with T3.16.6,
- If it is welded to the front bulkhead, it must extend at least to the centreline of the front bulkhead tubing in all directions,
- The AIP must not extend past the outside edges of the front bulkhead.

**T3.17.4** Alternative methods of attaching the IA to the AIP are permissible if equivalency to four (4) 8mm metric grade 8.8 bolts is proven.

**T3.17.5** Alternative AIP designs are permissible if equivalency to T3.17.3 is proven by physical testing as per T3.19.

**T3.17.6** The attachment of the IA and AIP must be designed to provide an adequate load path for transverse and vertical loads in the event of off-centre and off-axis impacts. Segmented foam attenuators must have the segments bonded together to prevent sliding or parallelogramming.

**T3.17.7** The attachment of the IA and/or AIP to a monocoque structure must comply with T3.16.6 and requires an approved SES, as per T3.6.

**T3.17.8** If a team uses a standard FSAE IA and the front bulkhead width is greater than 400mm and/or its height is greater than 350mm, a diagonal or X-bracing made from 25mm × 1.5mm steel tubing, or an approved equivalent per T3.2, must be included in the front bulkhead.

**T3.17.9** If the standard IA is the honeycomb type:

- The IA material must be pre-crushed type
- Adhesive used to mount the IA to the AIP must have a shear strength of at least 24 MPa

**T3.17.10** If a standard IA is used but does not comply with the requirements of, physical testing must be carried out to prove that the AIP does not permanently deflect more than 25 mm.

### **T3.18 Impact Attenuator Data Requirement**

**T3.18.1** All teams must submit an IA Data report using the Impact Attenuator Data (IAD) template provided on the Formula Student website.

- If a report does not use this template, it will automatically incur a 10-point design penalty,
- **Templates from other Formula Student/FSAE competitions are not acceptable. The report will still be assessed to ensure that the IA meets the rules requirements and to allow the team to compete,**
- Minor violations in report layout will be dealt with via the downgrading process outlined in Rule T3.18.5.

**T3.18.2** Reports submitted late will incur lateness penalties as described in the Key Dates document published on the Formula Student website. However, these reports will still be assessed to ensure that the IA meets the rules requirements and to allow the team to compete.

- T3.18.3 Reports submitted on time, but which do not contain the required information (e.g. a “placeholder report” submitted to avoid penalties but without the required test data) will be treated as a non-submission and dealt with according to Rule T3.18.2.
- T3.18.4 Reports will be assessed by a team of judges using a common approach. A selection of reports will be moderated by the Lead IAD Judge to ensure consistency.
- T3.18.5 Reports will be assessed according to the following process, in order to grade them from A to F:
- Reports are initially assigned a grade according to the type of testing carried out. Dynamic tests are initially assigned a ‘B’ grade; Quasi-static (crush) tests a ‘C’ grade; and teams using a Standard IA an ‘E’ grade.
  - The report is then assessed to ensure that the IA meets the rules requirements for energy absorption, deceleration levels, dimensions, mounting arrangements etc. Impact Attenuators which do not meet these requirements will automatically incur a 10-point penalty, and the team will be contacted by the Judges to determine appropriate modifications or re-design to allow them to compete.
  - If the IA design meets the rules, the report will then be assessed for quality. Minor items of missing information or poor explanation or presentation may lead to the report being downgraded by up to two grades. Teams will be contacted and asked to supply missing information, but the downgrade will remain. A high-quality report may be upgraded by up to two grades.
  - IA reports for a standard FSAE IA may be upgraded by up to two grades if they include additional analysis or testing – for example finite element simulation or testing of material samples.
- T3.18.6 Once the report has been graded, the grade will be converted into design penalty points as follows:
- A = 0 points; B = 0 points; C = 1 point; D = 4 points; E = 8 points; F = 10 points.
  - These penalties will be forwarded to the Head Design Judge for inclusion in the overall design score.

### **T3.19 Impact Attenuator Test Requirements**

- T3.19.1 The IA assembly, when mounted on the front of a vehicle with a total mass of 300 kg and impacting a solid, non-yielding impact barrier with a velocity of impact of 7 m/s, must meet the following requirements:
- Decelerate the vehicle at a rate not exceeding 20g average and 40g peak,
  - The energy absorbed in this event must meet or exceed 7350 J,
  - Teams using the standard IA are not required to submit test data with their IAD report, but all other requirements must be included.
- T3.19.2 During the IA test:
- The IA must be attached to the AIP using the intended vehicle attachment method,
  - The IA assembly must be attached to a test fixture that has geometry, stiffness and

strength representative of the intended chassis. When alternative materials are used for the AIP, the test fixture must be a copy of the intended chassis (i.e. materials, lay-up, joining methods),

- There must be at least 50mm clearance rearwards of the AIP to the test fixture,
- No part of the AIP may permanently deflect more than 25mm beyond the position of the AIP before the test.

**T3.19.3** Teams using IAs (typically structural noses) directly attached to the front bulkhead, which shortcut the load path through the bulk of the AIP, must conduct an additional test. This test must prove that the AIP can withstand a load of 120kN (300kg multiplied by 40g), where the load applicator matches the minimum IA dimensions.

**T3.19.4** Vehicles with aerodynamic devices and/or sensors in front of the AIP must not exceed the peak deceleration of T3.19.1 for the combination of their IA assembly and the non-crushable object(s). Any of the following three methods may be used to prove the design does not exceed 120kN:

- Physical testing of the IA assembly including any attached non-crushable object(s), or structurally representative dummies, in front of the AIP,
- Combining the peak force from physical testing of the IA assembly with the failure load for the mounting of the non-crushable object(s), calculated from fastener shear and/or link buckling,
- Combining the “standard” IA 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.

**T3.19.5** Dynamic testing (sled, pendulum, drop tower, etc) of the IA may only be conducted at a dedicated test facility. This facility may be part of the university but must be supervised by professional staff. Teams are not allowed to design their own dynamic test apparatus.

**T3.19.6** 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 100 Hz, 3<sup>rd</sup> order, low pass Butterworth (–3 dB at 100Hz) filter may be applied.

## **T3.20 Non-Crushable Objects**

**T3.20.1** All non-crushable objects (e.g. pedals, master cylinders, hydraulic reservoirs) must be rearward of the rear most plane of the front bulkhead and at least 25mm behind the AIP at any time, except for sensors, aerodynamic devices and their mountings.

## T4 COCKPIT

### T4.1 Cockpit Opening

**T4.1.1** The size of the cockpit opening needs to be sufficient for the template shown on the left of Figure 12 to pass vertically from the cockpit opening to below the upper side impact member when held horizontally. The template may be moved fore and aft.

**T4.1.2** If the side impact structure is not made of tubes, the template must pass until it is 320mm above the lowest inside chassis point between the front and main hoop.

**T4.1.3** The steering wheel, seat and all padding may be removed for the template to fit. Any other parts may only be removed if they are integrated with the steering wheel.

### T4.2 Cockpit Internal Cross Section

**T4.2.1** The cockpit must provide a free internal cross section sufficient for the template shown on the right in Figure 12 to pass from the cockpit opening to a point 100mm rearwards of the face of the rearmost pedal in an inoperative position. The template may be moved up and down. Adjustable pedals must be in their most forward position.

**T4.2.2** The steering wheel and any padding that can be removed without the use of tools while the driver is seated may be removed for the template to fit.

**T4.2.3** The driver's feet and legs must be completely contained within the primary structure when the driver is seated normally, and the driver's feet are touching the pedals. In side and front views, any part of the driver's feet or legs must not extend above or outside of this structure.

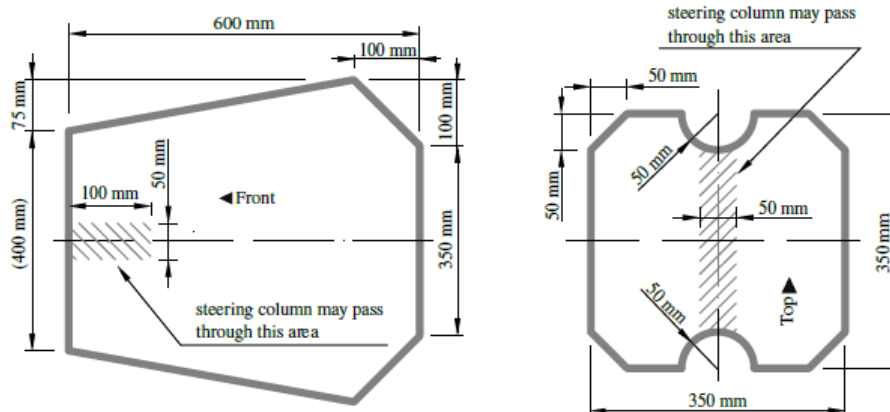


Figure 12: Cockpit opening template (left) and cockpit internal cross section template (right)

### T4.3 Percy (95<sup>th</sup> percentile male)

**T4.3.1** When seated normally and restrained by the driver's restraint system, the helmet of a 95<sup>th</sup> percentile male and all the team's drivers must, see Figure 13:

- Be a minimum of 50mm away from the straight line drawn from the top of the main hoop to the top of the front hoop,
- Be a minimum of 50mm away 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,
- Be no further rearwards than the rear surface of the main hoop if the main hoop bracing

extends forwards.

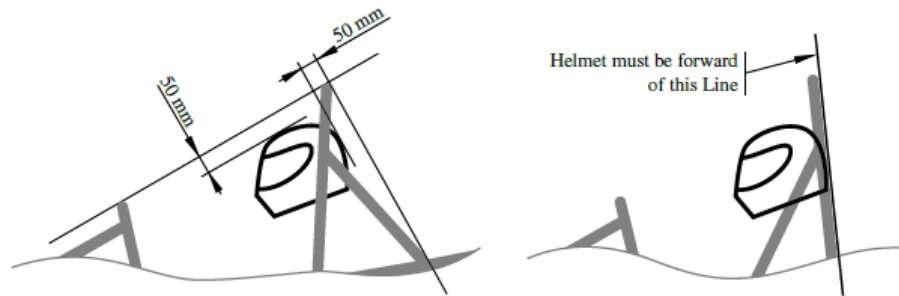


Figure 13: Minimum helmet clearance

- T4.3.2 The 95<sup>th</sup> percentile male is represented by a two-dimensional figure consisting of two circles of 200mm diameter (one representing the hips and buttocks and one representing the shoulder region) and one circle of 300mm (representing the head with helmet).
- T4.3.3 The two 200mm circles are connected by a straight line measuring 490 mm. The 300mm circle is connected by a straight-line measuring 280mm with the upper 200mm circle.
- T4.3.4 The figure has to be positioned in the vehicle as follows, see Figure 14:
- The seat adjusted to the rearmost position,
  - The pedals adjusted to the front-most position,
  - The bottom 200mm circle placed on the seat bottom. The distance between the centre of the circle and the rearmost actuation face of the pedals must be minimum 915mm,
  - The middle circle positioned on the seat back,
  - The upper 300mm circle positioned no more than 25 mm away from the head restraint.

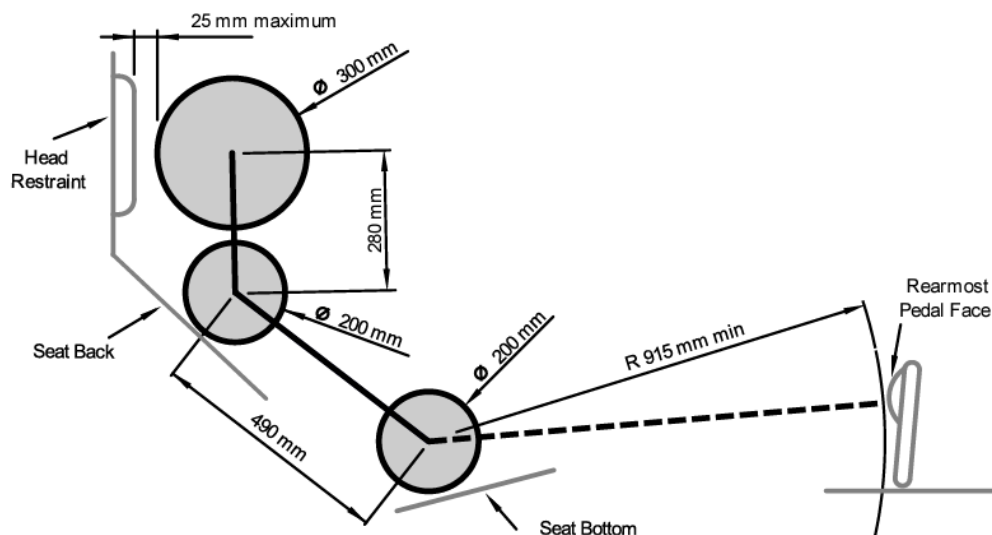


Figure 14: Percy placement

#### T4.4 Side Tubes

- T4.4.1 If there is any chassis member alongside the driver at the height of the neck of any of the



drivers in the team, a metal tube or piece of sheet metal must be attached to the chassis to prevent the driver's shoulders from passing under that chassis member.

#### **T4.5 Non-Welded Driver's Harness Attachment**

- T4.5.1 Any harness attachment to a monocoque must be using one 10mm metric grade 8.8 bolt or two 8 mm metric grade 8.8 bolts (or bolts of an equivalent standard) and steel backing plates with a minimum thickness of 2 mm.
- T4.5.2 Any harness that is fastened to the primary structure using brackets must use two 8 mm metric grade 8.8 or stronger fasteners.
- T4.5.3 It must be proven that the attachments for shoulder and lap belts can support a load of 13kN and the attachment points of the anti-submarine belts can support a load of 6.5kN.
- T4.5.4 If the lap belts and anti-submarine belts are attached less than 100mm apart, these must support a total load of 19.5kN.
- T4.5.5 The strength of lap belt and shoulder belt attachments must be proven by physical testing where the required load is applied to a representative attachment point with the lay-up and attachment brackets as used in the actual chassis. The following requirements must be met:
- Edges of the test fixture supporting the sample must be a minimum of 125mm from the load application point,
  - The width of the shoulder harness test sample must not be any wider than the shoulder harness panel height used to show equivalency for the shoulder harness mounting bar,
  - 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 the angles specified for the driver's harness.

#### **T4.6 Driver's Seat**

- T4.6.1 The lowest point of the driver's seat must, in side view, not extend below the upper face of the lowest side impact structure member or have a longitudinal tube (or tubes) that meets the material requirements for the side impact structure (T3.2), passing underneath the lowest point of the seat.
- T4.6.2 Adequate heat insulation must be provided to ensure that the driver is not able to contact any parts of the vehicle with a surface temperature above 60°C. The insulation may be external to the cockpit or incorporated with the driver's seat or firewall. The design must meet the following minimum requirements between the heat source and the part that the driver could contact:
- Convection insulation by a minimum air gap of 25mm
  - Radiation insulation by:
    - i. A solid metal heat shield with a minimum thickness of 0.4mm, or,
    - ii. Reflective foil or tape, combined with conduction isolation material with a minimum thickness of 8 mm between the heat source and the panel the driver could contact.

#### **T4.7 Floor Closeout**

- T4.7.1 All vehicles must have a floor closeout made of one or more panels, which separate the driver from the ground.
- T4.7.2 The closeout must extend from the front bulkhead to the firewall.
- T4.7.3 The panels must be made of a solid, non-brittle material.
- T4.7.4 If multiple panels are used, gaps between panels may not exceed 3mm.

#### **T4.8 Firewall**

- T4.8.1 A firewall must separate the driver compartment from all components of:
  - The fuel supply system,
  - The engine oil,
  - The liquid cooling systems,
  - The low voltage battery,
  - Any part of the air intake system forward of a vertical plane through the front face of the driver head restraint support, excluding any padding, set to its most rearward position,
  - Any TS component, see EV1.1.1.
- T4.8.2 The firewall must cover any line projected from any point on the parts mentioned in T4.8.1 to any part of the tallest driver below a plane 100mm above the bottom of the helmet.
- T4.8.3 The firewall must be a non-permeable surface made from a rigid, fire-retardant material, see T1.2.1, which must be rigidly mounted to the vehicle's structure.
- T4.8.4 The firewall must seal completely against the passage of fluids, especially at the sides and the floor of the cockpit.
- T4.8.5 Pass-throughs for wiring, cables, etc. are permitted if grommets are used to seal the pass-through.
- T4.8.6 Multiple panels may be used to form a firewall but must overlap at least 5mm and be sealed at the joints. Any sealing material must not be vital to the structural integrity of the firewall.
- T4.8.7 [EV ONLY] The tractive system firewall between driver and tractive system components must be composed of two layers:
  - One layer, facing the tractive system side, must be made of aluminium with a thickness of at least 0.5mm. This part of the tractive system firewall must be grounded according to EV3.1,
  - The second layer, facing the driver, must be made of an electrically insulating and fire-retardant material, see T1.2.1. The second layer must not be made of CFRP,
  - The thickness of the second layer must be sufficient to prevent penetrating this layer with a 4mm wide screwdriver and 250N of force,
  - A sample of the tractive system firewall must be presented at technical inspection.

T4.8.8 [EV ONLY] Conductive parts, except for the chassis and firewall mounting points, may not protrude through the TS firewall or must be properly insulated on the driver's side. The driver must not be able to touch uninsulated firewall mounting points while operating the vehicle.

T4.8.9 [EV ONLY] TS parts outside of the Rollover Protection Envelope that meet the requirements of EV4.4.3 do not need a firewall.

#### **T4.9 Accessibility of Controls**

T4.9.1 All vehicle controls must be operated from inside the cockpit without any part of the driver, e.g. hands, arms or elbows, being outside the vertical planes tangent to the outermost surface of the side impact structure.

#### **T4.10 Driver Visibility**

T4.10.1 The driver must have adequate visibility to the front and sides of the vehicle. Seated in a normal driving position, the driver must have a minimum field of vision of 100° to either side. The required visibility may be obtained by the driver turning their head and/or the use of mirrors.

T4.10.2 If mirrors are required to meet T4.10.1, they must remain in place and be adjusted to enable the required visibility throughout all dynamic events.

#### **T4.11 Driver Egress**

T4.11.1 All drivers must be able to exit to the side of the vehicle in less than 5 s with the driver in the fully seated position, hands in the driving position on the connected steering wheel (in all possible steering positions), wearing the required driver equipment as in T13.3 and properly secured by the Driver Restrain System as in T5. The egress time will stop when the driver has both feet on the ground.

## **T5 DRIVER RESTRAINT SYSTEM**

### **T5.1 Definitions**

- T5.1.1 6-point system – Consists of a two-piece lap belt , two shoulder straps and two leg or anti-submarine straps.
- T5.1.2 7-point system – Consists of two lap belts, two shoulder belts, two leg or anti-submarine Belts and a negative g or Z belt.
- T5.1.3 Upright driving position – Position with a seat back angled at 30° or less from the vertical as measured along the line joining the two 200mm circles of the 95<sup>th</sup> percentile male template as defined in T4.3 and positioned per T4.3.4.
- T5.1.4 Reclined driving position – Position with a seat back angled at more than 30° from the vertical as measured along the line joining the two 200mm circles of the 95<sup>th</sup> percentile male template as defined in T4.3 and positioned per T4.3.4.

### **T5.2 Belts - General**

- T5.2.1 All drivers must use a 6-point or 7-point restraint harness meeting the following specifications:
  - All driver restraint systems must meet SFI Specification 16.1, SFI Specification 16.5, SFI Specification 16.6, FIA specification 8853/98 or FIA specification 8853/2016,
  - The belts must bear the appropriate dated labels,
  - The material of all straps must be in perfect condition,
  - There must be a single metal-to-metal latch type quick release for all straps,
  - 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,
  - Vehicles with a “reclined driving position” must have either anti-submarine belts with tilt lock adjusters (“quick adjusters”) or have two sets of anti-submarine belts installed,
  - 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,
  - The shoulder harness straps must be threaded through the three bar adjusters in accordance with the manufacturer’s instructions,
  - When a Frontal Head Restraint (FHR) is used by the driver, FIA certified 50mm wide shoulder harnesses are allowed.
- T5.2.2 SFI spec harnesses must be replaced following December 31<sup>st</sup> of the 2<sup>nd</sup> year after the date of manufacture as indicated by the label. FIA spec harnesses must be replaced following December 31<sup>st</sup> of the year marked on the label.
- T5.2.3 The restraint system must be worn tightly at all times.

### **T5.3 Belt, Strap and Harness Installation - General**

- T5.3.1 The lap belt, shoulder harness and anti-submarine strap(s) must be securely mounted to the

primary structure. This structure and any guide or support for the belts must meet the minimum requirements of T3.2.

T5.3.2 The tab or bracket to which any harness is attached must have:

- A minimum cross-sectional area of  $60\text{mm}^2$  of steel, or equivalent alternative, to be sheared or failed in tension at any point of the tab, and,
- A minimum thickness of 1.6mm (steel) or 4mm (aluminium).

Where lap belts and anti-submarine belts use the same attachment point, a minimum cross-sectional area of  $90\text{mm}^2$  of steel, or equivalent alternative, to be sheared, if failed in tension, at any point of the tab.

T5.3.3 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.

T5.3.4 The attachment of the driver's restraint system to a monocoque structure requires an approved SES per T3.6. The lap belts and anti-submarine belts must not be routed over the sides of the seat. Where the belts or harness pass through a hole in the seat, the seat must be rolled or grommited to prevent chafing of the belts.

#### **T5.4 Lap Belt Mounting**

T5.4.1 The lap belt must pass around the pelvic area below the anterior superior iliac spines (the hip bones).

T5.4.2 The lap belts should come through the seat at the 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.

T5.4.3 In side view, the lap belt must be capable of pivoting freely by using either a shouldered bolt or an eye bolt attachment.

T5.4.4 With an "upright driving position", in side view the lap belt must be at an angle of between  $45^\circ$  and  $65^\circ$  to the horizontal.

T5.4.5 With a "reclined driving position", in side view the lap belt must be between an angle of  $60^\circ$  and  $80^\circ$  to the horizontal.

T5.4.6 The centreline of the lap belt at the seat bottom should be between 0mm to 76mm forward of the seat back to seat bottom junction as in Figure 15.

#### **T5.5 Shoulder Harness**

T5.5.1 The shoulder harness must be mounted behind the driver to a structure that meets the requirements of the primary structure. However, it cannot be mounted to the main hoop bracing or attendant structure without additional bracing to prevent loads being transferred into the main hoop bracing.

T5.5.2 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 T5.5.5, calculate that the bent shoulder harness bar triangulation stresses are less than as welded yield

strength T3.2.4 for combined bending and shear and does not fail in column buckling. If the team chooses not to perform the strength analysis T3.2.6 will apply.

- T5.5.3 The strength of any shoulder harness bar and bracing tubes must be proved in the relevant tab of the team's SES submission.
- T5.5.4 The shoulder harness mounting points must be between 180mm and 230mm apart, measured centre to centre.
- T5.5.5 From the driver's shoulders rearwards to the mounting point or structural guide, the shoulder harness must be between 10° above the horizontal and 20° below the horizontal as in Figure 15.

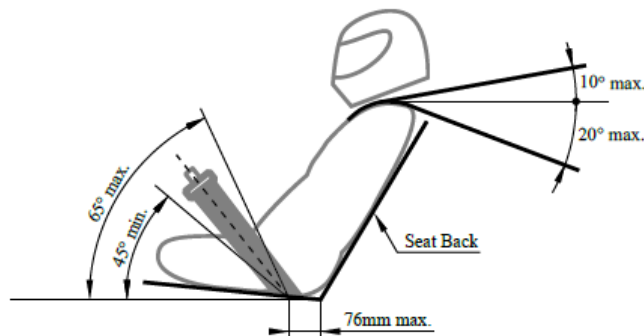


Figure 15: Lap belt and shoulder harness mounting

- T5.5.6 Any bracket used to mount the shoulder harness must not be able to contact the driver in the event of an impact.
- T5.5.7 If a Forward Head Restraint (FHR) is to be used by any driver, the team must demonstrate compliance to the FHR manufacturer's instructions, relevant FIA guidance pertaining to shoulder harness installation when using a FHR, and all other relevant FS rules.
- T5.5.8 Where T5.5.7 applies, the shoulder harness installation must be rules legal for all drivers.

## **T5.6 Anti-Submarine Belt Mounting**

- T5.6.1 The anti-submarine belts of a 6-point or 7-point harness must be mounted either:
- With the belts going vertically down from the groin or angled up to twenty degrees (20°) rearwards, the anchorage points should be approximately 100mm (4 inches) apart, see Figure 16.

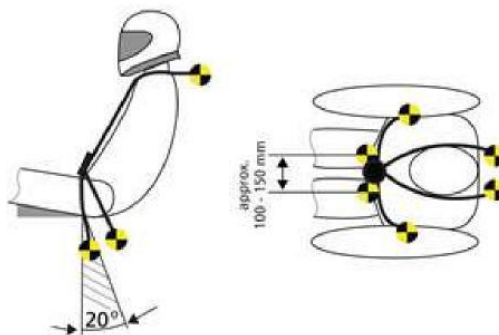


Figure 16: Anti-submarine belt angled mounting arrangement

- 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, see Figure 17.

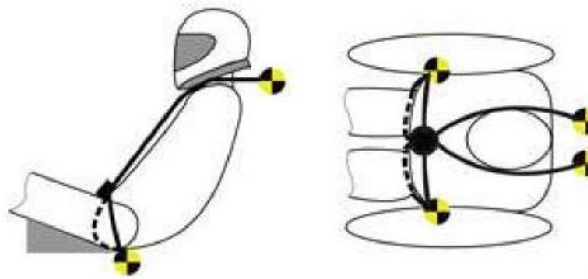


Figure 17: Anti-submarine belt mounting arrangement - Primary Structure

- T5.6.2 All anti-submarine belts must be installed so that they go in a straight line from the anchorage point(s) the first point where the belts touch the driver's body for the 6-point or 7-point mounting, without touching any hole in the seat or any other intermediate structure.

#### **T5.7 Head Restraint**

- T5.7.1 A head restraint must be provided on the vehicle to limit the rearward motion of the driver's head.

- T5.7.2 The Head Restraint padding must:

- Be vertical or near vertical in side view,
- Be an energy absorbing material that meets SFI Spec 45.2, or is listed in the FIA Technical List No. 17 as a "Type B Material for single seater cars": CONFOR M foam CF-42 (pink) or CF-42M (pink). CF-42AC (pink) is acceptable,
- Have a minimum thickness of 38mm,
- Have a minimum width of 15cm and minimum height of 15cm,
- Be covered with a thin, flexible material that contains a ~20mm diameter inspection hole in a surface other than the front surface.

For all drivers, the Head Restraint must be located and adjusted so that:

- The Head Restraint is no more than 25mm away from the back of the driver's helmet, with the driver in their normal driving position,
- The contact point of the back of the driver's helmet on the Head Restraint is no less than 50mm from any edge of the Head Restraint,
- All material and structure of the Head Restraint is within the Rollover Protection Envelope (see T1.1.14).

- T5.7.3 The head restraint and its mounting must withstand a force of 890N applied in the rearward direction at any point on its surface.

#### **T5.8 Roll Bar Padding**

- T5.8.1 Any portion of the roll bar, roll bar bracing or chassis which might be contacted by the driver's

helmet must be covered with a minimum thickness of 12mm of padding which meets SFI spec 45.1 or FIA 8857-2001.

#### **T5.9 Driver Leg Protection**

- T5.9.1 All moving suspension and steering components and other sharp edges inside the cockpit between the front hoop and a vertical plane 100mm rearward of the pedals, must be shielded with solid material.
- T5.9.2 Covers over suspension and steering components must be removable to allow inspection of the mounting points.

#### **T5.10 Driver Arm Protection**

- T5.10.1 The combination of the Primary Structure, driver position and harness installation must be such that while the driver is in the fully seated position, hands in the driving position on the connected steering wheel (in all possible steering positions) and wearing the required driver equipment:
- Can turn the steering wheel lock to lock.
  - Cannot move their arms (while still holding onto the connected steering wheel) such that any part of the driver falls outside of the Rollover Protection Envelope. (e.g. the arm restraints or the chassis should prevent arms/elbows from falling outside of the Rollover Protection Envelope).

Note: this will be checked for each driver prior to the Egress Test.



## **T6 BRAKE SYSTEM**

### **T6.1 Brake System - General**

- T6.1.1 The vehicle must be equipped with a hydraulic brake system that acts on all four wheels and is operated by a single control.
- T6.1.2 The brake system must have two independent hydraulic circuits such that in the case of a leak or failure at any point in the system, effective braking power is maintained on at least two wheels. Each hydraulic circuit must have its own fluid reserve, either by the use of separate reservoirs or by the use of a dammed reservoir.
- T6.1.3 A single brake acting on a limited-slip differential is acceptable.
- T6.1.4 “Brake-by-wire” systems are prohibited.  
  
[DV ONLY] In autonomous mode, it is allowed to use “brake-by-wire”. In manual mode, T6.1.1 applies.
- T6.1.5 Unarmoured plastic brake lines are prohibited.
- T6.1.6 The brake system must be protected from failure of the drivetrain, see T7.3.2, from touching any movable part and from minor collisions.
- T6.1.7 In side view any portion of the brake system that is mounted on the sprung part of the vehicle must not be below the lower surface of the chassis.
- T6.1.8 The brake pedal and its mounting must be designed to withstand a force of 2kN without any failure of the brake system or pedal box. This may be tested by pressing the pedal with the maximum force that can be exerted by any official when seated normally.
- T6.1.9 The brake pedal must be fabricated from steel or aluminium or machined from steel, aluminium or titanium.
- T6.1.10 [EV ONLY] The first 90 % of the brake pedal travel may be used to regenerate brake energy without actuating the hydraulic brake system. The remaining brake pedal travel must directly actuate the hydraulic brake system, but brake energy regeneration may remain active.
- T6.1.11 All brake fluid reservoirs must be shielded from the driver with an impermeable barrier which has a thickness of at least 0.5mm.

### **T6.2 Brake Over-Travel Switch**

- T6.2.1 A brake pedal over-travel switch must be installed on the vehicle as part of the shutdown circuit, as in EV6 or CV4.1. This switch must be installed so that in the event of a failure in at least one of the brake circuits the brake pedal over-travel will result in the shutdown circuit being opened. This must function for all possible brake pedal and brake balance settings without damaging any part of the vehicle.
- T6.2.2 Repeated actuation of the switch must not close the shutdown circuit, and it must be designed so that the driver cannot reset it.
- T6.2.3 The brake over travel-switch must be a mechanical single pole, single throw switch, commonly known as a two-position switch, push-pull or flip type, it may consist of a series connection of switches.

**T6.3 Brake Light**

T6.3.1 The vehicle must be equipped with one brake light that is illuminated if and only if one of the following criteria are met:

- The hydraulic brake system is actuated,
- [EV ONLY] The regenerative braking system is actuated in accordance with T6.1.10,
- [EV ONLY] The regenerative braking system is actuated upon release of the accelerator pedal and the deceleration exceeds  $1\text{m/s}^2 \pm 0.3\text{m/s}^2$ . The team must prove the function of the brake light during technical inspection by elevating the nose of the car to an angle of 6 degrees to simulate a deceleration of  $1\text{m/s}^2$  with the regenerative braking system active or by another method agreed in advance with the scrutineers.

T6.3.2 The brake light must meet the following requirements:

- A red light with a black background.
- Rectangular, triangular or near round shape.
- Minimum illuminated surface of  $15\text{cm}^2$  with even luminous intensity.
- Clearly visible from the rear in very bright sunlight.
- When LED lights are used without a diffuser, they may not be more than 20mm apart.
- If a single line of LEDs is used, the minimum length is 150 mm.

T6.3.3 In side view the brake light must be orientated vertical or near vertical and mounted between the wheel centreline and driver's shoulder level. Viewed from the back it should be positioned approximately at the vehicle's centreline.

## **T7 POWERTRAIN**

### **T7.1 Transmission and Drive**

- T7.1.1 Any transmission and drivetrain may be used.
- T7.1.2 Movement of the vehicle without a person in the vehicle and with the master switch(es) in the off position must be possible.

### **T7.2 Coolant Fluid and System Sealing**

- T7.2.1 [CV ONLY] Water-cooled engines must only use plain water.
- T7.2.2 [EV ONLY] TS components may only use plain water, air or oil as the coolant.
- T7.2.3 Cooling systems using plain water (except outboard wheel motors and their cooling hoses) must have a heat resistant (permanently rated for at least 100 °C), rigid and rigidly mounted cover which meets the requirements of T4.8.
- T7.2.4 Any cooling or lubrication system must be sealed to prevent leakage.
- T7.2.5 Separate catch cans must be employed to retain oil from any vents of a cooling system or engine lubrication system. Each catch-can must have a minimum volume of 10% of the fluid being contained or 900ml whichever is greater.
- T7.2.6 Any vent for systems containing plain water, other than cooling of an IC engine which must comply with the volume requirements of T7.2.5, must have a catch-can with a minimum volume of 10% of the fluid being contained or 100ml, whichever is greater.
- T7.2.7 All parts of the engine cooling or lubrication systems, including their mountings, must be made of material that is permanently rated for temperatures of at least 120°C or the temperature the respective fluids may reach whichever is higher. The use of unmodified Original Equipment Manufacturer (OEM) components in their design context is allowable.
- T7.2.8 Catch cans must be rigidly mounted to the chassis and located rearwards of the firewall below the driver's shoulder level.
- T7.2.9 Any catch can must vent through a hose with a minimum internal diameter of 3mm down to the bottom level of the chassis and must exit outside the bodywork.

### **T7.3 Drive Train Shields and Guards**

- T7.3.1 The lowest point of any lubrication system can only be lower than the line between the lowest point of the main hoop and the lowest chassis member behind the lubrication system if it is protected from hitting the ground by a structure mounted directly to the chassis.
- T7.3.2 Exposed rotating final drivetrain parts, chains, belts and brake discs not mounted within a wheel, must be fitted with scatter shields. Scatter shields and their mountings must:
- Cover chains and belts from the drive sprocket to the driven sprocket/chain wheel/belt or pulley.
  - Start and end parallel to the lowest point of the driven sprocket/chain wheel/belt or pulley.
  - Be constructed of non-perforated 2mm steel or 3mm aluminium alloy 6061-T6.

- Be centred on the centreline of the part(s) being protected and remain aligned with the part(s) under all conditions.
  - Be attached with 6mm metric grade 8.8 or stronger fasteners and must comply with T10.1.
- T7.3.3 Scatter shields for high-speed rotating final drivetrain parts (such as electric motors, clutches, sprockets, gears etc.) that have an OEM casing that do not comply with T7.3.2 may be used, if material is added to achieve the minimum required thickness.
- T7.3.4 [EV ONLY] When an electrical motor casing is rotating around the stator or is perforated, a scatter shield must be included around the motor. This scatter shield must be at least 1 mm thick and made from aluminium alloy 6061-T6 or steel.
- T7.3.5 Scatter shields for chains, belts and brake discs must have a minimum width of at least three times the width of the chain, belt or brake disc. The minimum material requirements are:
- For metallic chains, belts and brake discs: 2mm steel.
  - For non-metallic chains and belts: 3mm aluminium alloy 6061-T6.
- T7.3.6 Finger guards are required to cover any parts that spin while the vehicle is stationary. Finger guards may be made of lighter material, sufficient to resist finger forces. Mesh or perforated material may be used but must prevent the passage of a 12mm diameter object through the guard.

## **T8 AERODYNAMIC DEVICES**

### **T8.1 Definition Aerodynamic Device**

T8.1.1 A specifically designed structure mounted on the vehicle to guide the airflow around the vehicle, increasing the downforce acting on the vehicle and/or lowering its drag. The mounting of this structure is not regarded as an aerodynamic device, unless it is intentionally designed to be one.

T8.1.2 No power device (e.g. fan) may be used to move or remove air from under the vehicle.

### **T8.2 Restrictions for Aerodynamic Devices**

T8.2.1 Height restrictions:

- All aerodynamic devices forward of a vertical plane through the rearmost portion of the front face of the driver head restraint support, excluding any padding, set to its most rearward position, must be lower than 500mm from the ground.
- All aerodynamic devices in front of the front axle and extending further outboard than the most inboard point of the front tyre/wheel must be lower than 250mm from the ground.
- All aerodynamic devices rearward of a vertical plane through the rearmost portion of the front face of the driver head restraint support, excluding any padding, set to its most rearward position must be lower than 1.2m from the ground.

T8.2.2 Width restrictions:

- All aerodynamic devices lower than 500mm from the ground and further rearward than the front axle, must not be wider than a vertical plane touching the most outboard point of the front and rear wheel/tyre.
- All aerodynamic devices higher than 500mm from the ground, must not extend outboard of the most inboard point of the rear wheel/tyre.

T8.2.3 Length restrictions:

- All aerodynamic devices must not extend further rearward than 250mm from the rearmost part of the rear tyres.
- All aerodynamic devices must not extend further forward than 700mm from the fronts of the front tyres.

T8.2.4 All restrictions must be fulfilled with the wheels pointing straight and with any suspension setup with or without a driver seated in the vehicle.

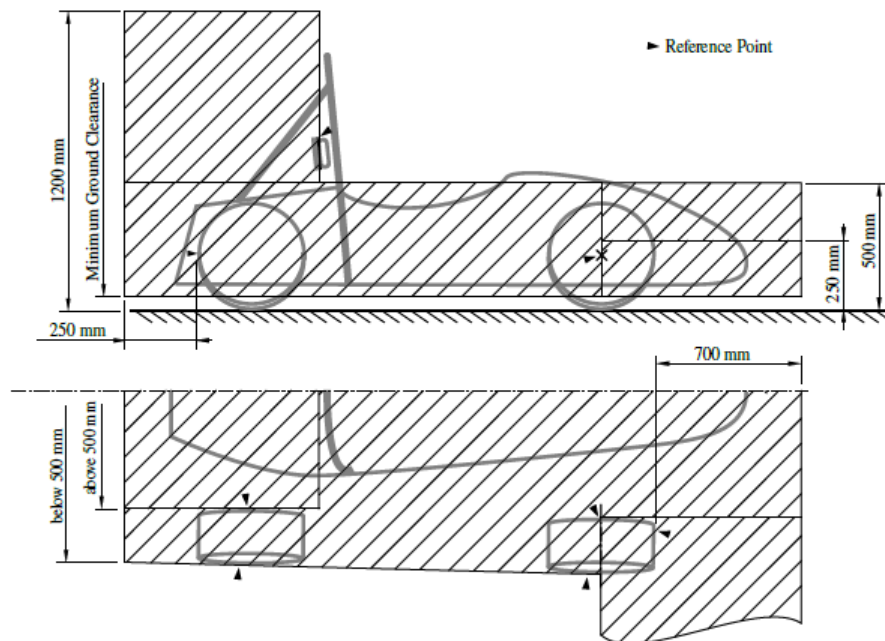


Figure 18: Maximum dimensions and positioning of aerodynamic devices.  
The positioning space is further restricted, see T2.1

### T8.3 Minimum Edge Radii of Aerodynamic Devices

T8.3.1 All forward facing edges of aerodynamic devices that could contact a pedestrian must have a minimum radius of 5mm for all horizontal edges and 3mm for vertical edges.

### T8.4 Aerodynamic Devices Stability and Strength

T8.4.1 Any aerodynamic device must be able to withstand a force of 200N distributed over a minimum surface of 225cm<sup>2</sup> and not deflect more than 10mm in the load carrying direction.

T8.4.2 Any aerodynamic device must be able to withstand a force of 50N applied in any direction at any point and not deflect more than 25mm.

T8.4.3 A lower force may be applied, e.g. 100N instead of 200N. The allowable deflections will be scaled by the ratio of the applied load/200N for T8.4.1 or applied load/50N for T8.4.2.

T8.4.4 If any vehicle on track is observed to have large, uncontrolled movements of aerodynamic devices, then officials may Black with Orange Circle Flag the car for inspection and the car may be excluded from that run and prevented from further running until any issue identified is rectified.

## **T9 COMPRESSED GAS SYSTEMS AND HIGH PRESSURE HYDRAULICS**

### **T9.1 Compressed Gas Systems**

**T9.1.1** Any system on the vehicle that uses a compressed gas as an actuating medium must comply with the following requirements:

- The working gas must be non-flammable.
- The pressure inside compressed gas systems must not exceed 10bar.
- Compressed gas cylinders/tanks may exceed the 10bar limit, if a pressure regulator, which limits the output pressure to a maximum of 10bar, is mounted directly onto them.
- Gas cylinders/tanks and any pressure regulators must be of proprietary manufacture, designed and built for the pressure being used, certified and labelled or stamped appropriately.
- Gas cylinders/tanks and lines must be protected from rollover, collision from any direction, or damage resulting from the failure of rotating equipment.
- Gas cylinders/tanks and their pressure regulators must be located within the rollover protection envelope T1.1.14 but must not be located in the cockpit.
- Gas cylinders/tanks must be securely mounted to the chassis, engine or transmission.
- The axis of gas cylinders/tanks must not point at the driver.
- Gas cylinders/tanks must be insulated from any heat sources.
- All used parts must be appropriate for the maximum possible operating pressure.

### **T9.2 High Pressure Hydraulic Pumps and Lines**

**T9.2.1** The driver and anyone standing outside the vehicle must be shielded from any hydraulic pumps and lines with line pressures of 2100kPa or higher. The shields must be steel or aluminium with a minimum thickness of 1mm. Brake lines are not considered as high-pressure hydraulic lines.

### **T9.3 Gaseous Fuel Systems**

**T9.3.1** Any gas system on the vehicle that is used as a means of propulsion or energy source (e.g. to charge a battery through a fuel cell) must comply with the following requirements:

- **Working Gas** - The working gas may be flammable, but only if it is to be burned or used for the sole means of propulsion of the vehicle.
- **Cylinder Certification** - The gas cylinder/tank must be of proprietary manufacture, designed and built for the pressure being used, certified by an accredited testing laboratory in the country of its origin, and labelled or stamped appropriately. The following standard for composite cylinders applies: ISO11439 for hydrogen containers or NGV1 or ECE-R110 for natural gas, methane or similar gases. In accordance with cylinder standards, cylinders found to have external defects such as abrasions or chemical corrosion must not be used.
- **Pressure Regulation** - Where cylinders are interchangeable the pressure regulator must be mounted directly onto the gas cylinder/tank. If the vehicle is to be refuelled with the

cylinder on-board the vehicle, the cylinder must be fitted with an internal solenoid, supplied by Dynetek or Teleflex GFI, this must be followed by an excess flow valve prior to fitting of a regulator. The inlet to the solenoid must be directly coupled to a check valve, with a cracking pressure no greater than 1psi to ensure gas flow may only flow out of the cylinder via the regulator.

- Protection - The gas cylinder/tank and lines must be protected from rollover, collision from any direction, or from damage resulting from the failure of rotating equipment. It is advised ECE-R110 documents are consulted for recommendations regarding the safe installation of gas systems.
- Cylinder Location- The gas cylinder/tank and the pressure regulator must be located either rearward of the Main Roll Hoop and within the Primary Structure envelope, or in a structural side-pod that meets the requirements of T3.2. It must not be located in the cockpit.
- Cylinder Mounting - The gas cylinder/tank must be securely mounted to the Frame, engine or transmission.
- Cylinder Axis - The axis of the gas cylinder/tank must not point at the driver.
- Insulation - The gas cylinder/tank must be insulated from any heat sources, e.g. the exhaust system.
- Lines and Fittings - The gas lines and fittings must be appropriate for the maximum possible operating pressure of the system and must be assembled according to manufacturer's recommendations. As part of the safety form, for gas systems teams must:
  - i. Provide gas system diagrams,
  - ii. Provide details of all components used in the system so that they can be approved by the rules committee. (These can be approved prior to submission of the safety documents if required),
  - iii. Provide details of proof testing for pressurization of the whole system to working pressure in addition to a leak test on all fittings. (If the testing is not conducted before the safety documentation is submitted then this information must be available at scrutineering),
  - iv. Demonstrate single failure tolerant design; other than the tank and gas lines, the system must be capable of containing the gas in the event that any failure occurs in any one component. Where reasonably possible a component failure should cause the fuel solenoid to close. Teams must be able to demonstrate how to identify whether a component functions correctly or not.
- The maximum allowable storage pressure is 350bar.
- All gas cylinders, regulators, solenoid valves and other equipment exposed to pressurized gas must be appropriately certified for use with the gas being used and the pressure that they are being used at.
- Where vehicle refuelling is to be carried out onsite the following cylinder connections are to be used:



- i. 350bar hydrogen: SAE J2600-H35 and ISO 17268,
- ii. 200 bar CNG: ISO 14469.
- Ventilation - any leaked gas should be able to freely dissipate without pockets of gas accumulating. Gas detection systems must be placed in the most likely escape paths for gas but should not create an obstacle to the escaping gas.

**T10 FASTENERS****T10.1 Critical Fasteners**

- T10.1.1 Critical fasteners are defined as bolts, nuts, and other fasteners utilized in the primary structure, the steering, braking, driver's harness, suspension systems and those specifically designated as critical fasteners in the respective rule.
- T10.1.2 All threaded critical fasteners must be at least 4mm metric grade 8.8 (OEM parts 3 mm metric grade 8.8), SAE Grade 5 or equivalent, or as specified in the referencing rule, whichever is larger diameter.
- T10.1.3 All threaded critical fasteners must be of the type hexagon bolts (e.g. ISO 4017, ISO 4014) or socket head cap screws (e.g. ISO 4762, DIN 7984, ISO 7379) including their fine-pitch thread versions. Alternative fasteners (including but not limited to AS, AN and NAS) are permitted if the team can show equivalence.
- T10.1.4 Any bolted joint in the primary structure using either tabs or brackets, must have an edge distance ratio " $e/D$ " of 1.5 or greater. " $D$ " equals the hole diameter and " $e$ " equals the distance from the hole centreline to the nearest free edge of the tab or bracket. Any tabs attaching suspension members to the primary structure are not required to meet this rule.

**T10.2 Securing Fasteners**

- T10.2.1 All critical fasteners must be secured from unintentional loosening by the use of positive locking mechanisms.
- T10.2.2 The following methods are accepted as positive locking mechanisms:
- Correctly installed safety wiring,
  - Cotter pins,
  - Nylon lock nuts (ISO 7040, ISO 10512, EN 1663 or equivalent) for low temperature locations (80 °C or less),
  - Prevailing torque lock nuts (DIN 980, ISO 7042 or equivalent, and jet nuts or K-nuts),
  - Locking plates,
  - Tab washers,
  - Any locking mechanism based on pre-tensioning or an adhesive is not considered a positive locking mechanism.
- T10.2.3 Snap or retaining rings according to DIN 471, DIN 472, or equivalent standard, are permitted in OEM applications and for securing bearings and springs.
- T10.2.4 A minimum of two full threads must project from any lock nut.
- T10.2.5 All spherical rod ends and spherical bearings on the steering or suspension must be in double shear or captured by having a screw/bolt head or washer with an outer diameter that is larger than the spherical bearing housing inner diameter.
- T10.2.6 Adjustable tie-rod ends must be constrained with a jam nut to prevent loosening.

## **T11 ELECTRICAL COMPONENTS**

### **T11.1 Low Voltage System**

T11.1.1 The Low Voltage System (LVS) is defined as

- [CV ONLY] all electrical circuits of the vehicle,
- [EV ONLY] every electrical part that is not part of the TS, see EV1.1.1.

T11.1.2 The maximum permitted voltage that may occur between any two electrical connections in the LVS is 60 V DC or 25 V AC RMS.

T11.1.3 All LVS parts must be adequately insulated.

T11.1.4 [CV ONLY] The following systems are excluded from the LVS voltage limit, see T11.1.2:

- High voltage systems for ignition,
- High voltage systems for injectors,
- Voltages internal to OEM charging systems designed for <60 VDC output.

T11.1.5 [CV ONLY] The maximum permitted voltage for motor controller/inverter low power control signals is 75 V DC

T11.1.6 [EV ONLY] The LVS must not use orange wiring or conduit.

T11.1.7 [EV ONLY] The LVS must be grounded to the chassis.

### **T11.2 Master Switches**

T11.2.1 Master switches, see T11.3, EV6.2 and T14.7, must be a mechanical switch of the rotary type, with a red, removable handle. The handle must have a width of at least 50mm and must only be removable in electrically open position. They must be direct acting, i.e. they must not act through a relay or logic.

T11.2.2 Master switches must be located on the right side of the vehicle, in proximity to the main hoop, at the 95<sup>th</sup> percentile male driver's shoulder height, as defined in T4.3, and be easily actuated from outside the vehicle. The centre of any master switch must not be mounted lower than the vertical distance of the template's (see T4.3) middle circle centre to the ground surface multiplied by 0.8.

T11.2.3 The "ON" position of the switch must be in the horizontal position and must be marked accordingly. The "OFF" position of the master switch must also be clearly marked.

T11.2.4 Master switches must be rigidly mounted to the vehicle and must not be removed during maintenance.

T11.2.5 Master switches must be mounted next to each other.

### **T11.3 Low Voltage Master Switch**

T11.3.1 An LVMS according to T11.2 must completely disable

- [EV ONLY] power to the LVS,
- [CV ONLY] power from the Low Voltage (LV) battery and the alternator to the LVS.

T11.3.2 The LVMS must be mounted in the middle of a completely red circular area of  $\geq 50$  mm diameter placed on a high contrast background.

T11.3.3 The LVMS must be marked with “LV” and a symbol showing a red spark in a white edged blue triangle.

#### **T11.4 Shutdown Buttons**

T11.4.1 A system of three shutdown buttons must be installed on the vehicle.

T11.4.2 Each shutdown button must be a push-pull or push-rotate mechanical emergency switch where pushing the button opens the shutdown circuit, see EV6.1 and CV4.1.

T11.4.3 One button must be located on each side of the vehicle behind the driver’s compartment at approximately the level of the driver’s head. The minimum allowed diameter of the shutdown buttons on both sides of the vehicle is 40mm. The buttons must be easy reachable from outside the vehicle.

T11.4.4 One shutdown button serves as a cockpit-mounted shutdown button and must

- Have a minimum diameter of 24mm,
- Be located in easy reach of a belted-in driver,
- Be alongside of the steering wheel and unobstructed by the steering wheel or any other part of the vehicle.

T11.4.5 The international electrical symbol consisting of a red spark on a white-edged blue triangle must be affixed in close proximity to each shutdown button.

T11.4.6 Shutdown buttons must be rigidly mounted to the vehicle and must not be removed during maintenance.

T11.4.7 Shutdown buttons must be coloured red.

#### **T11.5 Inertia Switch**

T11.5.1 An inertia switch must be part of the shutdown circuit, see EV6.1 and CV4.1, such that an impact will result in the shutdown circuit being opened. The inertia switch must latch until manually reset.

T11.5.2 The device must trigger due to an omnidirectional peak acceleration of  $\leq 8$  g for a half sine test pulse of  $\geq 50$ ms length and  $\leq 13$ g for a half sine test pulse of  $\geq 20$ ms length. The “Sensata Resettable Crash Sensor” should meet those requirements.

T11.5.3 The device must not include any semiconductor components.

T11.5.4 The device must be rigidly attached to the vehicle. It must be possible to demount the device so that its functionality may be tested by shaking it.

#### **T11.6 Brake System Plausibility Device**

T11.6.1 A standalone non-programmable circuit, the BSPD, must open the shutdown circuit, see EV6.1 and CV4.1, when hard braking occurs, whilst

- [EV ONLY]  $\geq 5$  kW power is delivered to the motors,
- [CV ONLY] The throttle position is more than 25% over idle position.

The shutdown circuit must remain open until power cycling the LVMS or the BSPD may reset itself if the opening condition is no longer present for more than 10s.

- T11.6.2 The action of opening the shutdown circuit must occur if the implausibility is persistent for more than 500ms.
- T11.6.3 The BSPD must be directly supplied, see T1.3.1, from the LVMS, see T11.3.
- T11.6.4 Standalone is defined as there is no additional functionality implemented on all required Printed Circuit Boards (PCBs). The interfaces must be reduced to the minimum necessary signals, i.e. power supply, required sensors and the shutdown circuit. Supply and sensor-signals must not be routed through any other devices before entering the BSPD.
- T11.6.5 To detect hard braking, a brake system pressure sensor must be used. The threshold must be chosen such that there are no locked wheels, and the brake pressure is  $\leq 30\text{bar}$ .
- T11.6.6 [EV ONLY] To measure power delivery, a DC circuit current sensor only must be used. The threshold must be chosen to an equivalent of 5kW for maximum TS voltage.
- T11.6.7 It must be possible to separately disconnect each sensor signal wire for technical inspection.
- T11.6.8 All necessary signals are System Critical Signal (SCS), see T11.9.
- T11.6.9 [EV ONLY] The team must prove the function of the BSPD during technical inspection by sending an appropriate signal that represents the current, in order to achieve 5 kW whilst pressing the brake pedal. This test must prove the functionality of the complete BSPD except for any commercially available current sensors.
- T11.6.10 [EV ONLY] The BSPD including all required sensors must not be installed inside the TSAC.

## **T11.7 Low Voltage Batteries**

- T11.7.1 LV batteries are all batteries connected to the LVS.
- T11.7.2 LV batteries must be securely attached to the chassis and located within the rollover protection envelope, see T1.1.14.
- T11.7.3 Any wet-cell battery located in the driver compartment must be enclosed in a non-conductive, waterproof (according to IPX7 or higher, IEC 60529) and acid resistant container.
- T11.7.4 LV batteries must have a rigid and sturdy casing.
- T11.7.5 Ungrounded terminals must be insulated.
- T11.7.6 LV batteries must have overcurrent protection, not more than 100mm from ungrounded terminals, that trips at or below the maximum specified discharge current of the cells within the time periods specified on the datasheet for the battery.

For example, if the datasheet specifies a continuous discharge current of 70A, a 10 second discharge pulse current of 120A and a 1 second discharge pulse current of 150A, the overcurrent protection must not allow any of these requirements to be exceeded.

- T11.7.7 All LV batteries using chemistries other than lead acid must be:
  - Presented at technical inspection with markings identifying it for comparison to a datasheet and/or other documentation proving the pack and supporting electronics meet all rules requirements.

- Directly accessible with a fire extinguisher nozzle of 35mm diameter x 150mm long, without removing body panels and with the driver seated normally in the vehicle. Covers which can be easily "punched through" are acceptable.

Any such cover or access location must be identified using the appropriate symbol below and be clearly visible to marshals approaching the car.



Figure 19: Fire Port location markings

If the LV battery is positioned greater than 50mm inboard of the access location, then a tube of at least 35mm diameter must be present to direct the discharge from the extinguisher towards the LV battery. The tube must be no more than 750mm in length. Any access tube must be separated from the driver by a firewall as specified in T4.8.

NOTE: A tube routed from an engine bay opening to the battery packs could be acceptable if compliant with the rules.

- Identified with the symbol below (minimum height 75mm and showing the appropriate battery chemistry) on each side of the car AND adjacent to any labels required by T11.7.T145200.32896.1988739072.



Figure 20: Battery Chemistry marking

T11.7.8 Battery packs based on lithium chemistry other than lithium iron phosphate ( $\text{LiFePO}_4$ ) and all LV hybrid system energy stores, regardless of chemistry type:

- Must include overcurrent protection that trips at or below the maximum specified discharge current of the cells,
- Must have a fire-retardant casing, see T1.2.1.
- Must include overtemperature protection of at least 30 % of the cells, meeting EV5.8.4, that trips when any cell leaves the allowed temperature range according to the manufacturer's datasheet, but not more than 60°C, for more than 1s and disconnects the battery,
- Must include voltage protection of all cells that trips when any cell leaves the allowed voltage range according to the manufacturer's datasheet for more than 500ms and disconnects the battery,
- It must be possible to display all cell voltages and measured temperatures, e.g. by connecting a laptop,
- Signals needed to fulfil these requirements are SCS, see T11.9.

T11.7.9 All batteries must be separated from the driver and sources of heat by a firewall as specified in T4.8.

T11.7.10 All batteries that are less than 350mm above the ground must be shielded from front, side and rear impact collisions, by a fully triangulated structure meeting T3.2 or equivalent.

## **T11.8 Accelerator Pedal Position Sensor**

T11.8.1 T11.8 only applies for electric vehicles, see chapter EV, or internal combustion vehicles using Electronic Throttle Control (ETC), see CV1.6.

T11.8.2 The APPS must be actuated by a foot pedal.

T11.8.3 Pedal travel is defined as percentage of travel from fully released position to a fully applied position where 0% is fully released and 100% is fully applied.

T11.8.4 The foot pedal must return to the 0% position when not actuated. The foot pedal must have a positive stop preventing the mounted sensors from being damaged or overstressed. Two springs must be used to return the foot pedal to the 0% position and each spring must work when the other is disconnected. Springs in the APPS are not accepted as return springs.

T11.8.5 At least two separate sensors must be used as APPSs. Separate is defined as not sharing supply or signal lines.

T11.8.6 If analogue sensors are used, they must have different, non-intersecting transfer functions. A short circuit between the signal lines must always result in an implausibility according to T11.8.9.

T11.8.7 The APPS signals are SCSs, see T11.9.

T11.8.8 If an implausibility occurs between the values of the APPSs and persists for more than 100ms

- [EV ONLY] The power to the motor(s) must be immediately shut down completely. It is not necessary to completely deactivate the tractive system, the motor controller(s) shutting down the power to the motor(s) is sufficient,

- [CV ONLY] The power to the electronic throttle must be immediately shut down.
- T11.8.9 Implausibility is defined as a deviation of more than ten percentage points pedal travel between any of the used APPSs or any failure according to T11.9.
- T11.8.10 If three sensors are used, then in the case of an APPS implausibility, any two sensors that are plausible may be used to define the torque target and the 3rd APPS may be ignored.
- T11.8.11 It must be possible to separately disconnect each APPS signal and power wires to check all functionalities.
- T11.8.12 A fully released accelerator pedal in manual mode must result in:
- [EV ONLY] A wheel torque of  $\leq 0$  Nm,
  - [CV ONLY] An idle position or lower throttle set-point. This may only be exceeded during a gearshift for a maximum of 500ms.
- T11.8.13 When any kind of digital data transmission is used to transmit the APPS signal, the ESF must contain a detailed description of all the potential failure modes that can occur, the strategy that is used to detect these failures and the tests that have been conducted to prove that the detection strategy works. The failures to be considered must include but are not limited to the failure of the APPS, APPS signals being out of range, corruption of the message and loss of messages and the associated time outs.
- T11.8.14 Any algorithm or electronic control unit that can manipulate the APPS signal, for example for vehicle dynamic functions such as traction control, may only lower the total driver requested torque and must never increase torque unless it is exceeded during a gearshift. Thus the drive torque which is requested by the driver may never be exceeded.

## **T11.9 System Critical Signal**

- T11.9.1 SCS are defined as all electrical signals which
- Influence actions on the shutdown circuit, see EV6.1 and CV4.1,
  - Influence the wheel torque,
  - [EV ONLY] Influence indicators according to EV5.8.9, EV4.10 or EV6.3.7,
  - [DV ONLY] Influence indicator according to T15.3.3.
- T11.9.2 Any of the following SCS single failures must result in a safe or error state of all connected systems:
- Failures of signals transmitted by cable:
    - i. Open circuit,
    - ii. Short circuit to ground.
  - Failures of analogue sensor signals transmitted by cable:
    - i. Short circuit to supply voltage.
  - Failures of sensor signals used in programmable devices:
    - i. Implausibility due to out of range signals, e.g. mechanically impossible angle of an angle sensor.



- Failures of digitally transmitted signals by cable or wireless:
  - i. Data corruption (e.g. checked by a checksum),
  - ii. Loss and delay of messages (e.g. checked by transmission time outs).

Signals might be a member of multiple signal classes, e.g. analogue signals transmitted by cable might be a member of T11.9.2.a, T11.9.2.b and T11.9.2.c.

If a signal failure is correctable, e.g. due to redundancy or worst case values, the safe or error state must be entered as soon as an additional non correctable failure occurs.

**T11.9.3** The maximum allowed delay of messages according to T11.9.2.d must be chosen depending on the impact of delayed messages to the connected system but must not exceed 500ms.

**T11.9.4** Safe and error states are defined depending on the signals as follows:

- Error State
  - i. signals only influencing indicators – indicator(s) not illuminated which indicate a failure of its own function or of the connected system,

Note: In this case it is not possible to identify from the indicator(s) whether a safe state has been entered and further action by the team is required to confirm this or what additional action is required to enter a safe state.

- Safe State
- signals only influencing indicators – Indicating a failure of its own function or of the connected system,
- low voltage battery signals – At least one pole is electrically disconnected from the rest of the vehicle,
- [EV ONLY] For all others signals – opened shutdown circuit and opened AIRs,
- [CV ONLY] For all others signals – opened shutdown circuit and stopped engine.

**T11.9.5** Indicators according to T11.9.1 with safe state “illuminated” (e.g. absence of failures is not actively indicated) must be illuminated for 1s to 3s for visible check after power cycling the LVMS.

**T11.9.6** The ESF must contain a detailed description of all the potential failure modes that can occur for each SCS, the strategy that is used to detect these failures and the tests that have been conducted to prove that the detection strategy works. The failures to be considered must include but are not limited to the failure of sensors and actuators, signals being out of range, corruption of the message and loss of messages and the associated time outs.

## **T11.10 Sensors & Electrical Components Mounting**

**T11.10.1** All sensors and components must be securely mounted. For all mounts, T2.2.3 applies.

**T11.10.2** Sensors and components may not come into contact with the driver’s helmet under any circumstances.

**T11.10.3** All sensors and components must be positioned within the surface envelope, see T1.1.16. Actors for aerodynamic devices must be within the box defined in T8.2.

- T11.10.4 Passive antennas, but not their mounts, that are exclusively acting as such with the longest side  $< 100\text{mm}$  may protrude from the surface envelope.
- T11.10.5 Antennas may also be mounted on the aerodynamic devices, if they do not protrude from the bounding box of the device.
- T11.10.6 Additionally, sensors may be mounted with a maximum distance of  $500\text{mm}$  above the ground and less than  $700\text{mm}$  forward of the front of the front tyres (see Figure 21). They must not exceed the width of the front axle (measured at the height of the hubs).

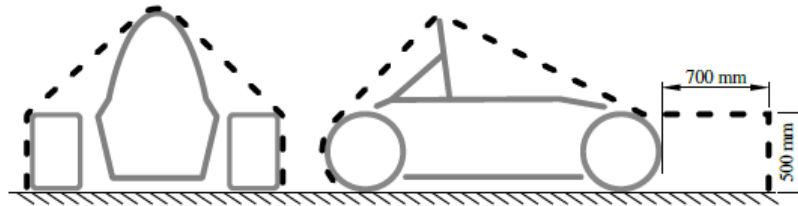


Figure 21: Envelope to mount sensor systems.

- T11.10.7 The body of any video/photographic camera which is not exclusively used as sensor for the AS unit must be secured at a minimum of two points on different sides of the camera body. If a tether is used to restrain the camera, the tether length must be limited so that the camera cannot contact the driver. Such camera installations must be approved at technical inspection.

## **T12 VEHICLE IDENTIFICATION**

### **T12.1 T12.1 Vehicle Number**

T12.1.1 Each team will select an available number at the time of its entry into Formula Student. Vehicle numbers 1-10 are reserved for the top 10 overall finishers at last year's Formula Student competition.

T12.1.2 Vehicle numbers must appear on the vehicle at the front and both sides as follows:

- Height: At least 150mm high.
- Font: Roman Sans-Serif characters. Italic, outline, serif, or shadow numbers are prohibited.
- Stroke width and spacing between numbers: At least 20mm.
- Colour: Either white numbers on a black background or black numbers on a white background.
- Background shape: The number background must be one of the following: round, oval, square or rectangular. There must be at least 25mm between the edge of the numbers and the edge of the background.
- Clear: The numbers must not be obscured by parts of the vehicle.

T12.1.3 Any car which uses electrical energy as a means of propulsion must use a light green background for the numbers. Note: it is not necessary, but is permissible, to have a letter E before the number.

T12.1.4 Any car which uses a gaseous fuel must use an orange background for the numbers.

### **T12.2 University Name**

T12.2.1 The university name must be written fully. Only the following abbreviations in the university name are accepted, if the city name is written fully:

- University - Uni
- Technical University - TU
- University of Applied Sciences - UAS
- Berufsakademie - BA
- If the university officially uses an abbreviation in their proper name, this abbreviation is accepted.

T12.2.2 The university name must be displayed and written in Roman Sans-Serif characters of at least 50mm high on both sides of the vehicle.

T12.2.3 The characters must be clearly visible at a distance and placed on a high contrast background.

### **T12.3 Timing Equipment**

T12.3.1 All vehicles will get timing equipment provided by the competition organizers.

T12.3.2 The transponder mounting requirements are:

- Orientation – The transponder must be mounted vertically and orientated so the number can be read “right-side up”.
- Location – The transponder must be mounted on the driver’s right side of the car forward of the front roll hoop. The transponder must be no more than 60cm (24 in) above the track.
- Obstructions – There must be an open, unobstructed line between the antenna on the bottom of the transponder and the ground. Metal and carbon fibre may interrupt the transponder signal. The signal will normally transmit through fibreglass and plastic. If the signal will be obstructed by metal or carbon fibre, a 10.2cm (4 in) diameter opening may be cut, the transponder mounted flush with the opening, and the opening covered with a material transparent to the signal.
- Protection – Mount the transponder where it will be protected from being hit by cones.

#### **T12.4 Formula Student Logo**

- T12.4.1 Each car will be required to append three (3) Formula Student logos, 20cm x 15cm. One (1) marking to the front end of the nose of the car and one (1) on each side panel, ideally above the race number plate or within the top third of the side panels, (these will be supplied by the organisers). No sponsor or other markings will be permitted to encroach on these areas. A document showing the requirements can be found here:

<https://www.imeche.org/events/formula-student/team-information/logo-usage>

Alternatively, teams may incorporate the Formula Student logo into their own colour/graphics schemes, in any of the permitted colour options, providing the logo meets the size and location requirements above and does not breach the Institution Brand Guidelines – see the Formula Student Website. The logo is available in various formats on the Use of Logos webpage.

**T13 VEHICLE AND DRIVER EQUIPMENT****T13.1 Push Bar**

- T13.1.1 Each team must have a removable device (called the push bar) that attaches to the rear of the vehicle and allows two people to push and pull the vehicle while standing erect behind the vehicle.
- T13.1.2 The push bar must have a red colour.
- T13.1.3 The push bar must be presented during technical inspection.
- T13.1.4 The push bar must be capable of slowing and stopping the forward motion of the vehicle and pulling it rearwards.
- T13.1.5 An approved fire extinguisher, see T13.4, must be mounted to the push bar such that it is quickly accessible.
- T13.1.6 [EV ONLY] Two pairs of high voltage insulating gloves and a multimeter with two 4mm banana plug test leads rated for 1000V CAT III or better must be attached to the push bar. The High Voltage (HV) gloves must be protected by a case or similar means from mechanical damage, humidity and sunlight. It must be possible to open the case without using tools.

**T13.2 Quick Jack**

- T13.2.1 Each team must have a removable device (called the quick jack) that lifts up the vehicle, so that all driven wheels are at least 100mm off the ground and the vehicle is adequately supported. All non-driven wheels must not touch anything else than the ground.
- T13.2.2 The lifting of the vehicle with the quick jack must be possible by one person and not require actions other than positioning and operating the quick jack itself.
- T13.2.3 In the lifted position the vehicle must stand securely and stable and the quick jack must be locked and secured. This must function without the support of a person or additional weights.
- T13.2.4 The quick jack must have a red colour.
- T13.2.5 In addition to a quick jack, each team must have a set of jack stands, trestles or similar, that will safely support the complete car for inspections during scrutineering while not presenting a tripping hazard to the scrutineers and team members.

The stands/trestles must:

- Support the car with all four wheels a minimum of 100mm off the ground,
- When in place, be completely within the plan profile of the car.

**T13.3 Driver Equipment**

- T13.3.1 The equipment specified below must be worn by the driver anytime while in the cockpit with the engine running or with the tractive system active for electric vehicles and anytime between starting a dynamic event and either finishing or abandoning a dynamic event. Removal of any driver equipment during the event will result in disqualification.
- T13.3.2 A well-fitting, closed face helmet that meets one of the following certifications and is labelled as such:

- Snell SA2010, SAH2010, SA2015, SA2020, EA2018,
- FIA 8859-2015, FIA 8860-2004, FIA 8860-2010, FIA 8860-2016, FIA 8860-2018,
- SFI Foundation SFI 31.1/2020.

Any kart standard helmets, including but not limited to Snell K, CMR or CMS standards are not permitted for use at Formula Student.

Non-UK teams may also use helmets that comply with their own sanctioning body, but these helmets must also be permitted by the FSAE Rules. Approval for use of alternative helmets to those listed above must be sought from [formulastudent@imeche.org](mailto:formulastudent@imeche.org). Note: the reference number in the helmet must be included.

Open faced helmets are prohibited.

All helmets to be used in the competition must be presented during Technical Inspection where approved helmets will be stickered. The organiser reserves the right to impound all non-approved helmets until the end of the competition.

The use of a Frontal Head Restraint (FHR) is not mandatory at Formula Student but is strongly recommended. If an FHR is used:

- The combination of helmet and FHR standards must comply with the table published on the Motorsport UK website here:  
<https://www.motorsportuk.org/wp-content/uploads/2022/04/2022-04-12-recognised-helmet-standards-fhr.pdf>
- The FHR and shoulder harnesses must be properly adjusted as per the manufacturer's recommendations. Guidance notes published by the FIA can be found here:  
[https://www.fia.com/sites/default/files/hans\\_guide\\_and\\_installation\\_spec\\_19.03.2022.pdf](https://www.fia.com/sites/default/files/hans_guide_and_installation_spec_19.03.2022.pdf)  
[https://www.fia.com/sites/default/files/hybrid\\_fhr\\_guide\\_and\\_installation\\_spec\\_19.03.2022.pdf](https://www.fia.com/sites/default/files/hybrid_fhr_guide_and_installation_spec_19.03.2022.pdf)
- Any driver using an FHR must wear the FHR during their driver egress test.

T13.3.3 A balaclava which covers the driver's head, hair and neck, made from acceptable fire-resistant material as defined in T13.3.11, or a full helmet skirt of acceptable fire-resistant material.

T13.3.4 The driver's suit must comply with FIA 8856-2000 or FIA 8856-2018. Non-UK teams may also use driver's suits that comply with their own sanctioning body, but these driver suits must also be permitted by the 2020 Formula Student Rules. Approval to use alternative driver's suits to those listed above must be sought from [formulastudent@imeche.org](mailto:formulastudent@imeche.org) Note: a scan of the suit label must be supplied with the submission.

T13.3.5 Fire resistant underwear (long pants and long sleeve t-shirt). This fire-resistant underwear must be made from acceptable fire-resistant material as listed in T13.3.11 and must cover the driver's body completely from neck down to ankles and wrists.

T13.3.6 Fire resistant socks made from acceptable fire-resistant material as defined in T13.3.11, that cover the bare skin between the driver's suit and the boots or shoes.

T13.3.7 Fire resistant shoes made from acceptable fire-resistant material as defined in T13.3.11. The

shoes must be certified to the standard and labelled as such:

- SFI Spec 3.3,
- FIA Standard 8856-2000,
- FIA Standard 8856-2018.

T13.3.8 Fire resistant gloves made from acceptable fire-resistant material as defined in T13.3.11. Gloves of all leather construction or fire-resistant gloves constructed using leather palms with no insulating fire resisting material underneath are not acceptable.

T13.3.9 Arm restraints are required and must be worn such that the driver can release them and exit the vehicle unassisted regardless of the vehicle's position. Arm restraints must be commercially manufactured according to SFI Standard 3.3 or equivalent.

T13.3.10 All driver equipment covered in T13.3: must be in good condition. Specifically, it must not have any tears, rips, open seams, areas of significant wear or abrasion or stains which might compromise fire resistant performance. The officials reserve the right to impound all non-approved driver equipment until the end of the competition.

T13.3.11 For the purpose of this section some, but not all, of the approved fire-resistant materials are: Carbon X, Indura, Nomex, Polybenzimidazole (commonly known as PBI) and Proban.

T13.3.12 T-shirts, socks or other undergarments made from nylon or any other synthetic material which will melt when exposed to high heat are prohibited.

T13.3.13 A second complete set of driver equipment (e.g. balaclava, suit, underwear, socks, shoes and gloves), except arm restraints and helmet, are required and must be presented at technical inspection. Exchange of driver equipment between drivers at driver change is prohibited, except for arm restraints and helmet. A second complete set of driver equipment is not required for FS-AI entries.

#### **T13.4 Fire Extinguishers**

T13.4.1 Each team must have at least two dry chemical/dry powder fire extinguishers with a minimum firefighting agent capacity of 0.9kg.

T13.4.2 The following are the minimum accepted ratings:

- USA, Canada and Brazil: 10BC or 1A 10BC,
- Europe: 34B or 5A 34B,
- Australia: 20BE or 1A 10BE.

Extinguishers of larger capacity (higher numerical ratings) are acceptable.

T13.4.3 Aqueous Film Forming Foam (AFFF) fire extinguishers are prohibited. Halon extinguishers and systems are prohibited.

T13.4.4 All extinguishers must be equipped with a manufacturer installed pressure/charge gauge.

T13.4.5 All fire extinguishers must have proof of purchase or service (e.g., a dated service tag) within the last two (2) calendar years, i.e., 2023 or 2024.

T13.4.6 Except for the initial inspection, one extinguisher must readily be available in the team's paddock area, and the second must accompany the vehicle wherever the vehicle is moved. Both extinguishers must be presented with the vehicle at technical inspection.

T13.4.7 Handheld fire extinguishers are not permitted to be mounted on or in the vehicle.

### **T13.5 Camera Mounts**

T13.5.1 The mounts for video/photographic cameras must be of a safe and secure design:

- All camera installations must be approved and sealed at technical inspection,
- Helmet mounted cameras are prohibited,
- The body of any camera or recording unit that weighs more than 0.25kg must be secured at a minimum of two points on different sides of the camera body. If a tether is used to restrain the camera, the tether length must be limited so that the camera cannot contact the driver.

[DV ONLY] Cameras used as input sensors for driverless vehicles are exempted and must follow T11.10 instead.



## **T14 [DV ONLY] AUTONOMOUS SYSTEM**

### **T14.1 Definitions**

T14.1.1 Each vehicle must implement a full AS according to T14, to run in autonomous mode.

T14.1.2 [CV ONLY] The following definitions apply to maintain the same wording as for Electric Vehicles:

- Ready-to-drive (R2D) – Engine is running, and a gear is engaged,
- TS active – Engine is running but gearbox is in neutral (also assumed for TS not active),
- TS activation button – The engine start button is the equivalent,
- Accumulator Isolation Relay (AIR) - The fuel pump relay (see Figure 21) is the equivalent.

### **T14.2 Teleoperated driving**

T14.2.1 Teleoperated driving is not allowed.

### **T14.3 Data logger**

T14.3.1 The officials may provide a standardised data logger that must be installed during the competition. Further specifications for the data logger and required hardware and software interfaces can be found on the Formula Student Website.

T14.3.2 The intent of the data logger is to understand and reproduce the system state in case of failure. This includes a basic set of signals defined on the Formula Student Website and the set of vehicle-individual signals that have to be monitored by the Autonomous System Brake (ASB) to ensure redundancy and fault detection.

### **T14.4 Remote Emergency System**

T14.4.1 Every vehicle must be equipped with a standard RES specified on the Formula Student Website. The system consists of two parts, the remote control and the vehicle module.

T14.4.2 The RES must be purchased by the team.

T14.4.3 The RES has two functions:

- When the remote emergency stop button is pressed, it must open the DV Shutdown Circuit (SDC) defined in T14.5,
- When the “Go” button is pressed, the preselected autonomous mission is started.

T14.4.4 The RES vehicle module must be directly integrated in the vehicle’s SDC with one of its relays hard-wired in series to the shutdown buttons.

T14.4.5 The RES relay, which is integrated into the SDC, may be bypassed by a normally closed relays, when driving manually. The relay must be directly supplied by the ASMS, see T14.7, and must have either a forcibly guided or a mirrored normally open contact which is directly connected in series to the ASMS.

T14.4.6 The antenna of the RES must be mounted unobstructed and without interfering parts in proximity (other antennas, etc.).

**T14.5 Shutdown Circuit**

T14.5.1 If the SDC is opened by the AS or the RES, it has to be latched open by a non-programmable logic that can only be reset manually (either via a button outside of the vehicle, in proximity to the ASMS, or via LVMS power cycle).

T14.5.2 The SDC may only be closed by the AS, if the following conditions are fulfilled:

- Manual Driving: Manual Mission is selected, the AS has checked that ASB is deactivated (No autonomous brake actuation possible),
- Autonomous Driving: Autonomous Mission is selected, ASMS is switched on and sufficient brake pressure is built up (brakes are closed).

**T14.6 Signals**

T14.6.1 Any signal of the AS is a SCS. If failures lead to loss of environment perception and/or localization, the system must react accordingly.

**T14.7 Autonomous System Master Switch**

T14.7.1 Each vehicle must be equipped with an ASMS, according to T11.2.

T14.7.2 The ASMS must be mounted in the middle of a completely blue circular area of  $\geq 50$  mm diameter placed on a high contrast background.

T14.7.3 The ASMS must be marked with "AS".

T14.7.4 The power supply of the steering and braking actuators must be switched by

- LVMS,
- ASMS.

Other than stated in T11.2.1, non-programmable logic may be used as part of the ASMS.

T14.7.5 When the ASMS is in "Off" position, the following must be fulfilled:

- No steering, braking and propulsion actuation can be performed by request of the autonomous system,
- The sensors and the processing units can stay operational,
- The vehicle must be able to be pushed as specified in A6.7,
- It must be possible to operate the vehicle manually as a normal CV or EV.

T14.7.6 It is strictly forbidden to switch the ASMS to the "On" position if a person is inside the vehicle.

T14.7.7 After switching the ASMS to the "On" position, the vehicle may not start moving, until the "AS driving" state is entered (Figure 17).

T14.7.8 The ASMS must be fitted with a "lockout/tagout" capability to prevent accidental activation of the AS. The ASR must ensure that the ASMS is locked in the off position whenever the vehicle is outside the dynamic area or driven in manual mode.

**T14.8 Steering Actuation**

T14.8.1 Steering system actuation (movement) must only happen if the vehicle is R2D.

T14.8.2 The steering system may remain active during an emergency brake manoeuvre while the vehicle is in movement.

T14.8.3 Manual steering must be possible without manual release steps (e.g. operating manual valves / (dis-) connecting mechanical elements) while the ASMS is switched “Off”.

#### T14.9 Actuator Decoupling

T14.9.1 It is not allowed to remove any parts of the autonomous system for dynamic events.

T14.9.2 The actuators may be disconnected for manual driving if:

- no parts are removed for disconnection.
- the disconnection mechanism cannot block manual operation in any position.
- the disconnection mechanism is securely locked in both positions.

#### T14.10 Autonomous System Status Definitions

T14.10.1 The Emergency Brake System (EBS) is considered to be “activated”, if its power supply is cut after passing the initial check-up sequence (T15.3.1). Brakes may only be released after performing manual steps.

T14.10.2 The status of the AS must be determined according to the flowchart in Figure 22.

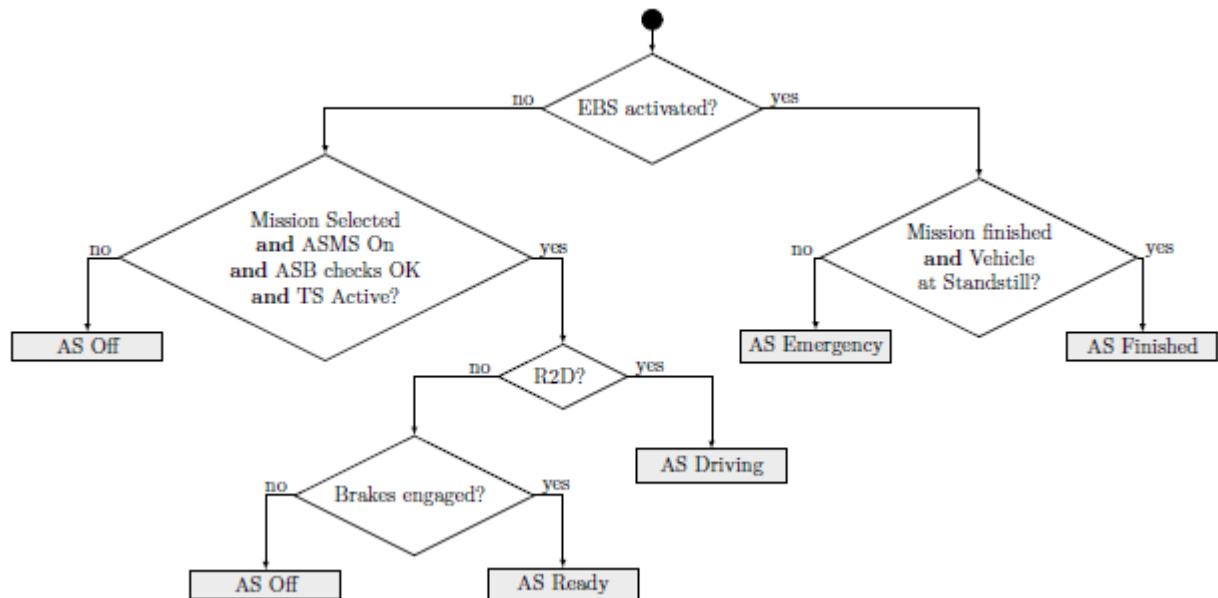


Figure 22: AS Status Flowchart

T14.10.3 R2D may only be activated by the “Go” signal from the RES, after the system has remained in “AS Ready” for at least 5s.

T14.10.4 Performing manual steps, other than activating the TS, at the car while the ASMS is switched “On” is prohibited.

#### T14.11 Autonomous System Status Indicators

T14.11.1 The vehicle must include three ASSIs that must indicate the status of the AS (as defined in T14.10) correlating to illumination as shown:

AS Off off	AS Ready yellow continuous	AS Driving yellow flashing	AS Emergency blue flashing	AS Finished blue continuous
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The ASSIs may not perform any other functions.

T14.11.2 One ASSI must be located on each side of the vehicle behind the driver's compartment, in a region 160mm below the top of the main hoop and 600mm above the ground. The third ASSI must be located at the rear of the vehicle, on the vehicle centreline, near vertical, 160mm below the top of the main hoop and more than 100mm above the brake light.

T14.11.3 Each ASSI must have a dark background and a rectangular, triangular or near round shape with a minimum illuminated surface of 15 cm<sup>2</sup>. The ASSIs must be clearly visible in very bright sunlight. When LED lights are used without a diffuser, they may not be more than 20 mm apart. If a single line of LEDs is used, the minimum length is 150 mm. At least one ASSI must be visible from any angle of the vehicle.

T14.11.4 The status "AS Emergency" has to be indicated by an intermittent sound with the following parameters:

- On-/off-frequency: 1Hz to 5Hz,
- Duty cycle 50%,
- Sound level greater than 90dBA, fast weighting in a radius of 2m around the vehicle,
- Duration between 8s and 10s after entering "AS Emergency".

## **T14.12 Autonomous Missions**

T14.12.1 The AS must at least implement the following missions:

- Acceleration,
- Skidpad,
- [DC ONLY] Autocross,
- [DC ONLY] Trackdrive,
- EBS test,
- Inspection,
- Manual driving.

T14.12.2 The inspection mission will be used during technical inspection while the vehicle is jacked up and all wheels are removed.

T14.12.3 The inspection mission is defined by slowly spinning the drivetrain and actuating the steering system with a sine wave. After 25s to 30s the mission is finished and the transition to "AS Finish" must be initialized.

T14.12.4 The selected mission must be indicated by the Autonomous Mission Indicator (AMI).

T14.12.5 The AMI must be easily readable and can either be part of the dashboard or located next to the ASMS. If an e-ink display is used, it must be visible that the shown mission is up to date.

The AMI is considered SCS.

#### **T14.13 Autonomous System Form**

T14.13.1 Prior to the competition, all teams must submit a clearly structured documentation of their entire AS (including ASB) called ASF.

**T15 [DV ONLY] AUTONOMOUS SYSTEM BRAKE****T15.1 Technical Requirements**

- T15.1.1 To run in autonomous mode, the vehicle must be equipped with an ASB that features an EBS as part of it (see T15.2).
- T15.1.2 All specifications of the brake system from T6 remain valid.
- T15.1.3 The tractive system is not considered to be a brake system.
- T15.1.4 Manual braking must always be possible.
- T15.1.5 Brake master cylinders must not be connected in series.
- T15.1.6 The ASB may be part of the hydraulic brake system. For all components of pneumatic and hydraulic brake actuation not covered by T6, T9 is applied.
- T15.1.7 The ASB must be designed so that it can be easily deactivated by a maximum of two deactivation points.
- T15.1.8 All deactivation points of the ASB must:
- Work without the aid of electrical power,
  - Be in proximity to each other,
  - Either be mounted in proximity to the ASMS or on the top side of the vehicle between front bulkhead and front hoop close to the vehicles centre line,
  - Be operable by maximum two simple push/pull and/or turning actions, the order and direction of these actions must be shown next to the deactivation points,
  - Be marked with “Brake release”,
  - Have a red handle.
- T15.1.9 The use of push-in fittings is prohibited in function critical pneumatic circuits of the ASB and any other system which uses the same energy storage without proper decoupling.

**T15.2 Emergency Brake System**

- T15.2.1 The EBS must only use passive systems with mechanical energy storage. Electrical power-loss at EBS must lead to a direct emergency brake manoeuvre with the performance specified in T15.4.
- T15.2.2 The EBS must be supplied by LVMS, ASMS, RES and a relay which is supplied by the SDC (parallel to the AIRs but must not be delayed).

**T15.3 Functional Safety**

- T15.3.1 An initial check has to be performed to ensure the ASB is able to build up brake pressure as expected, before AS transitions to “AS Ready”.
- T15.3.2 After the initial check the ASB and its SCS must be continuously monitored for failures.
- T15.3.3 A red indicator light in the cockpit that is easily visible from inside and outside the cockpit even in bright sunlight and clearly marked with the lettering “ASB” must light up if the SDC is opened due to an ASB failure.

T15.3.4 The vehicle must automatically transition to the safe state, if:

- The functionality according to T15.2.1 cannot be ensured,
- An (additional) single point of failure would lead to total loss of brake capability.

T15.3.5 The safe state is the vehicle at a standstill, brakes engaged to prevent the vehicle from rolling, and an open SDC.

T15.3.6 To get to the safe state, the vehicle must perform an autonomous brake manoeuvre described in section T15.4 and IN6.2.

#### **T15.4 Emergency Brake System Performance**

T15.4.1 The system reaction time (the time between opening of the SDC and the start of the deceleration) must not exceed 200ms.

T15.4.2 The average deceleration must be greater than  $8\text{m/s}^2$  under dry track conditions.

T15.4.3 In case of a single failure the ASB should be designed to achieve at least half of the performance specified in T15.4.2.

T15.4.4 Whilst decelerating, the vehicle must remain in a stable driving condition.

T15.4.5 The performance of the system will be tested at technical inspection, see IN6.2.

## SECTION CV – INTERNAL COMBUSTION ENGINE VEHICLES

### CV1 INTERNAL COMBUSTION ENGINE POWERTRAINS

#### CV1.1 Engine Limitation

CV1.1.1 The engine(s) used to power the vehicle must be piston engine(s) using a four-stroke primary heat cycle with a displacement not exceeding 710 cm<sup>3</sup> per cycle. LV hybrid powertrains must use electrical energy storage. HV hybrid powertrains are permitted as an AFV.

#### CV1.2 Starter

CV1.2.1 Each vehicle must be equipped with an on-board starter, which must be used to start the vehicle.

CV1.2.2 [DV ONLY] For autonomous operation the vehicle must be equipped with an additional engine start button next to the LVMS, see T11.3, which can be easily actuated from outside the vehicle. Using the external engine start button, the engine may only start if

- The ASMS (see T14.7) is switched on and,
- The gearbox is in neutral.

CV1.2.3 [DV ONLY] There must be a green light next to the engine start button, which indicates that the gearbox is in neutral. It must be marked with the letter “N”. This letter must have a minimum height of 25mm.

CV1.2.4 [DV ONLY] The AS must not be able to (re-)start the engine.

#### CV1.3 Air Intake System

CV1.3.1 All parts of the engine air and fuel control systems (including the throttle and the complete air intake system, including the air filter and any air boxes, must lie within the surface envelope, see T1.1.16).

CV1.3.2 Any portion of the air intake system that is less than 350mm above the ground must be shielded from front, side or rear impact collisions by structure equivalent to that defined in T3.15 for a side impact structure.

CV1.3.3 The intake manifold must be securely attached to the engine block or cylinder head with brackets and mechanical fasteners. The threaded fasteners used to secure the intake manifold are considered critical fasteners and must comply with T10. Rubber bushings or hoses are not considered as securely attached.

CV1.3.4 Intake systems with significant mass or cantilever from the cylinder head must be supported to prevent stress to the intake system. Supports to the engine must be rigid. Supports to the chassis must incorporate isolation to allow for engine movement and chassis torsion.

CV1.3.5 An air filter must be installed at the entry of the Intake System that will protect the powertrain from the ingress of dirt and debris.

#### CV1.4 Throttle

CV1.4.1 The vehicle must be equipped with a throttle body. The throttle body may be of any size or design.



CV1.4.2 The throttle must be actuated mechanically by a foot pedal, i.e. via a cable or a rod system, see CV1.5, or by an ETC system, see CV1.6.

CV1.4.3 Throttle position is defined as percentage of travel from fully closed to fully open where 0% is fully closed and 100% is fully open. The idle position is the average position of the throttle body while the engine is idling.

CV1.4.4 The throttle system mechanism must be protected from debris ingress to prevent jamming.

### **CV1.5 Mechanical Throttle Actuation**

CV1.5.1 CV1.5 can only be used if no ETC system is used.

CV1.5.2 The throttle actuation system must use at least two return springs located at the throttle body, so that the failure of any one of the two springs will not prevent the throttle returning to the idle position.

CV1.5.3 Each return spring must be capable of returning the throttle to the idle position with the other disconnected.

CV1.5.4 Springs in the Throttle Position Sensor (TPS) are not acceptable as return springs.

CV1.5.5 Throttle cables must be located at least 50mm from any exhaust system component and out of the exhaust stream.

CV1.5.6 Throttle cables or rods must have smooth operation and must not have the possibility of binding or sticking. They must be protected from being bent or kinked by the driver's foot during operation or when entering the vehicle.

CV1.5.7 A positive pedal stop must be incorporated on the accelerator pedal to prevent over-stressing the throttle cable or actuation system.

### **CV1.6 Electronic Throttle Control**

CV1.6.1 CV1.6 only applies if ETC is used.

CV1.6.2 The team must be able to demonstrate the functionality of all safety features and error detections of the ETC system at technical inspection.

CV1.6.3 The ETC system must be equipped with at least the following sensors:

- Accelerator Pedal Position Sensors (APPSs) as defined in T11.8.
- Two Throttle Position Sensors (TPSs) to measure the throttle position.
- One Brake System Encoder (BSE) to measure brake system pressure to check for plausibility.

CV1.6.4 All ETC signals are System Critical Signals (SCSs), see T11.9.

CV1.6.5 When power is removed, the electronic throttle must immediately close at least to idle position  $\pm 5\%$ . An interval of one second is allowed for the throttle to close to idle, failure to achieve this within the required interval must result in immediate disabling of power to ignition, fuel injectors and fuel pump. This action must remain active until the TPS signals indicate the throttle has returned to idle position  $\pm 5\%$  for at least one second.

CV1.6.6 If plausibility does not occur between the values of at least two TPSs and this persists for more than 100ms, the power to the electronic throttle must be immediately shut down. Plausibility is defined as a deviation of less than ten percentage points between the sensor values as defined in CV1.4.3 and no detected failures as defined in T11.9.

[DV Only] AS must check this signal consistency on a low level itself.

CV1.6.7 The electronic throttle must use at least two sources of energy capable of returning the throttle to the closed position. One of the sources may be the device that normally actuates the throttle, e.g. a DC motor, but the other device(s) must be a return spring that can return the throttle to the idle position in the event of a loss of actuator power.

CV1.6.8 Springs in the TPSs are not acceptable as return springs.

CV1.6.9 The power to the electronic throttle must be immediately shut down, as defined in CV1.6.5, if the throttle position differs by more than 10 % from the expected target TPS position for more than 500ms.

CV1.6.10 An ETC system that is commercially available, but does not comply with CV1.6, may be used, only if it does comply with the intent of the rules and is approved by the officials. To obtain approval, the team must:

- Submit a rules question to ask the event organizers if that ETC system may be used.
- Include the specific ETC rule(s) that the commercial system deviates from.
- Include sufficient technical details of these deviations to allow the acceptability of the commercial system to be determined.

## **CV1.7 Intake System Restrictor**

CV1.7.1 In order to limit the power capability from the engine(s), a single circular restrictor must be placed in the intake system and all engine(s) airflow must pass through this restrictor. The only allowed sequence of components are the following:

- For naturally aspirated engines, the sequence must be: throttle body, restrictor, and engine, see Figure 23,
- For turbocharged or supercharged engines, the sequence must be: restrictor, compressor, throttle body, engine, see Figure 24.

CV1.7.2 The maximum restrictor diameters which must be respected at all times during the competition are:

- Gasoline fuelled vehicles - 20mm,
- E 85 fuelled vehicles - 19mm.

CV1.7.3 The restrictor must be located to facilitate measurement during the inspection process.

CV1.7.4 The circular restricting cross section may not be movable or flexible in any way, e.g. the restrictor must not be part of the movable portion of a barrel throttle body.

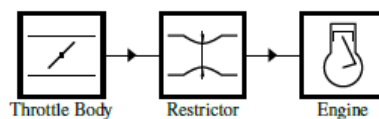


Figure 23: Intake configuration for naturally aspirated engines.

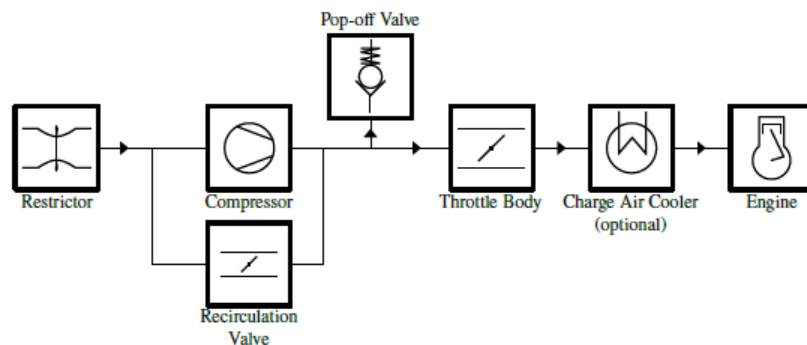


Figure 24: Intake configuration for turbocharged or supercharged engines.

### CV1.8 Turbochargers and Superchargers

- CV1.8.1 The intake air may be cooled with an intercooler. Only ambient air may be used to remove heat from the intercooler system. Air-to-air and water-to air intercoolers are permitted. The coolant of a water-to-air intercooler system must be plain water without any additives.
- CV1.8.2 If pop-off valves, recirculation valves, or heat exchangers (intercoolers) are used, they may only be positioned in the intake system as shown in Figure 19.
- CV1.8.3 Plenums anywhere upstream of the throttle body are prohibited. A “plenum” is any tank or volume that is a significant enlargement of the normal intake runner system.
- CV1.8.4 The maximum allowable internal diameter of the intake runner system between the restrictor and throttle body is 60mm diameter, or the equivalent area of 2827mm<sup>2</sup> if non-circular.

### CV1.9 Crankcase / Engine Lubrication Venting

- CV1.9.1 Any crankcase or engine lubrication vent lines routed to the intake system must be connected upstream of the intake system restrictor.
- CV1.9.2 Crankcase breathers that pass through the oil catch tank(s) to exhaust systems, or vacuum devices that connect directly to the exhaust system, are prohibited.

**CV2 FUEL AND FUEL SYSTEM****CV2.1 Fuel**

CV2.1.1 The basic fuels available at Formula Student are unleaded gasoline (Sustainable 95RON E10 and 99RON E5) and E85.

- Information on these fuels can be viewed at:  
<https://www.imeche.org/events/formula-student/team-information/general-information>
- The basic fuel types may be changed at the discretion of the event organisers. Other fuels may be available at the discretion of the organising body.

CV2.1.2 The vehicles must be operated with the fuel provided at the competition.

CV2.1.3 No agents other than fuel and air may be induced into the combustion chamber.

CV2.1.4 The temperature of fuel introduced into the fuel system may not be changed with the intent to improve calculated efficiency.

**CV2.2 Fuel System Location Requirements**

CV2.2.1 All parts of the fuel storage and supply system must lie within the surface envelope, see T1.1.16. In side view no portion of the fuel system can project below the lower surface of the chassis.

CV2.2.2 Any portion of the Fuel System, except for the fuel tank filler neck and sight tube (as defined in CV2.6), must be located within the Rollover Protection Envelope.

CV2.2.3 All parts of the fuel storage and supply system must be adequately protected against any heat sources and located at least 50mm from any exhaust system component.

CV2.2.4 All parts of the fuel system which can come in contact with the fuel must be rated for permanent contact with fuel.

CV2.2.5 Any portion of the Fuel System that is less than 350mm above the ground must be shielded from front, side and rear impact collisions, by a fully triangulated structure meeting T3.2 or equivalent.

**CV2.3 Fuel Tank**

CV2.3.1 The fuel tank is defined as the part of the fuel containment device that is in contact with the fuel. It may be made of a rigid material or a flexible material.

CV2.3.2 The fuel tank must be securely attached to the vehicle structure with mountings that allow some flexibility such that chassis flex cannot unintentionally load the fuel tank.

CV2.3.3 The fuel tank must not touch any part of the vehicle other than its mounting and parts of the fuel system at any time.

CV2.3.4 Any fuel tank that is made from a flexible material, for example a bladder fuel cell or a bag tank, must be enclosed within a rigid fuel tank container which is securely attached to the vehicle structure. Fuel tank containers (containing a bladder fuel cell or bag tank) may be load carrying.

CV2.3.5 The fuel system must have a provision for emptying the fuel tank if required.

CV2.3.6 The fuel tank, by design, must not have a variable capacity.

#### **CV2.4 Fuel Lines for Low Pressure Systems**

CV2.4.1 Fuel lines between fuel tank and fuel rail and return lines must:

- Have reinforced rubber fuel lines with an abrasion protection with a fuel hose clamp which has a full 360° wrap, a nut and bolt system for tightening and rolled edges to prevent the clamp cutting into the hose, or,
- Have metal braided hoses with crimped-on or reusable, threaded fittings,
- Have Barbed fittings if a hose and clamp connection is used.
- Be rated for temperatures of at least 120 deg.C.

CV2.4.2 The use of unmodified OEM fuel lines and connectors, including those manufactured from plastic, is permitted.

CV2.4.3 Fuel lines must be securely attached to the vehicle and/or engine.

CV2.4.4 All fuel lines must be shielded from possible rotating equipment failure or collision damage.

CV2.4.5 All fuel lines must be installed in such a way that any leaks can not result in the accumulation of fuel in the cockpit.

#### **CV2.5 Fuel Injection System Requirements**

CV2.5.1 Low Pressure Injection (LPI) fuel systems are those functioning at a pressure below 10bar and High-Pressure Injection (HPI) fuel systems are those functioning at 10bar pressure or above. Direct Injection (DI) fuel systems are those where the injection occurs directly into the combustion chamber.

CV2.5.2 The following requirements apply to LPI fuel systems:

- The fuel lines must comply with CV2.4,
- The fuel rail must be securely attached to the engine cylinder block, cylinder head, or intake manifold with mechanical fasteners. The threaded fasteners used to secure the fuel rail are considered critical fasteners and must comply with T10,
- The use of fuel rails made from plastic, carbon fibre or rapid prototyping flammable materials is prohibited. However, the use of unmodified OEM Fuel Rails manufactured from these materials is acceptable.

CV2.5.3 The following requirements apply to HPI and DI fuel systems:

- All high-pressure fuel lines must be stainless steel rigid line or Aeroquip FC807 smooth bore PTFE hose with stainless steel reinforcement and visible Nomex tracer yarn. Use of elastomeric seals is prohibited. Lines must be rigidly connected every 100mm by mechanical fasteners to structural engine components,
- The fuel rail must be securely attached to the engine cylinder head with mechanical fasteners. The fastening method must be sufficient to hold the fuel rail in place with the maximum regulated pressure acting on the injector internals and neglecting any assistance from in-cylinder pressure acting on the injector tip. The threaded fasteners used to secure the fuel rail are considered critical fasteners and must comply with T10,

- The fuel pump must be rigidly mounted to structural engine components,
- A fuel pressure regulator must be fitted between the high and low pressure sides of the fuel system in parallel with the DI boost pump. The external regulator must be used even if the DI boost pump comes equipped with an internal regulator,
- Prior to the tilt test specified in IN7, engines fitted with mechanically actuated fuel pumps must be run to fill and pressure the system downstream of the high-pressure pump.

## CV2.6 Fuel Tank Filler Neck and Sight Tube

CV2.6.1 The fuel tank must have a filler neck which:

- Has at least an inner diameter of 35mm at any point between the fuel tank and the top of the fuel filler cap.
- Is angled at no more than 30° from the vertical
- Is accompanied by a clear fuel resistant sight tube above the top of the fuel tank with a length of at least 125mm vertical height for reading the fuel level, see Figure 25.
- Is made of material that is permanently rated for temperatures of at least 120 °C.

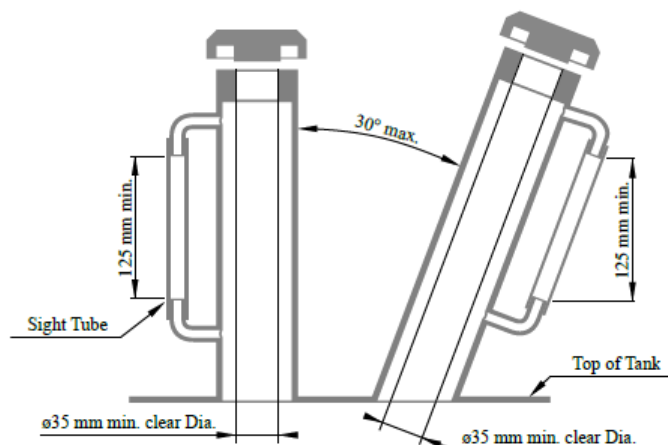


Figure 25: Minimum requirements fuel tank filler neck

CV2.6.2 A clear filler neck tube may be used as a sight tube.

CV2.6.3 A permanent, non-moveable, clear and easily visible fuel level line must be located between 12mm and 25mm below the top of the visible portion of the sight tube. This line will be used as the fill line for the tilt test (IN7.1), and before and after the endurance test to measure the amount of fuel used during the endurance event.

CV2.6.4 The filler neck opening must be directly accessible without removing any parts of the vehicle except for the fuel filler cap.

CV2.6.5 The filler neck must have a fuel filler cap that can withstand severe vibrations or high pressures such as could occur during a vehicle rollover event.

## CV2.7 Tank Filling Requirement

CV2.7.1 The fuel tank must be capable of being filled to capacity without manipulating the tank or the vehicle in any manner. The fuel system must be designed in a way that during refuelling

of the vehicle on a level surface, the formation of air cavities or other effects that cause the fuel level observed at the sight tube to drop after movement or operation of the vehicle (other than due to consumption) is prevented.

CV2.7.2 The fuel system must be designed such that the spillage during refuelling cannot contact the driver position, exhaust system, hot engine parts, or the ignition system.

#### **CV2.8 Venting Systems**

CV2.8.1 The fuel tank venting systems must be designed such that fuel cannot spill during hard cornering or acceleration.

CV2.8.2 All fuel vent lines must be equipped with a check valve to prevent fuel leakage when the tank is inverted. All fuel vent lines must exit outside the bodywork.

### **CV3 EXHAUST SYSTEM AND NOISE CONTROL**

#### **CV3.1 Exhaust System General**

- CV3.1.1 The exhaust outlet must be routed to the side or rear of the vehicle and so that the driver is not subjected to fumes at any speed considering the draft of the vehicle.
- CV3.1.2 The exhaust outlet(s) must not extend more than 450mm behind the centreline of the rear axle and shall be no more than 600mm above the ground.
- CV3.1.3 Any exhaust components (headers, mufflers, etc.) that protrude from the side of the body in front of the rear axle centreline must be shielded to prevent contact by persons approaching the vehicle or a driver exiting the vehicle. The temperature of the outer surface of any shield must not exceed 55°C at any time.
- CV3.1.4 The application of fibrous/absorbent material, e.g. “header wrap”, to the outside of an exhaust manifold or exhaust system is prohibited.
- CV3.1.5 The use of rubber mounts directly between the exhaust and exhaust clamp is prohibited for both the exhaust and silencer.

#### **CV3.2 Maximum Sound Level**

- CV3.2.1 The maximum sound level test speed for a given engine will be the engine speed that corresponds to an average piston speed of 15.25m/s. The calculated speed will be rounded to the nearest 500rpm. The maximum permitted sound level up to this calculated speed is 110dB(C), fast weighting.
- CV3.2.2 The idle test speed for a given engine will be up to the team and determined by their calibrated idle speed. If the idle speed varies then the vehicle will be tested across the range of idle speeds determined by the team. At idle the maximum permitted sound level is 103dB(C), fast weighting.

### **CV4 SHUTDOWN SYSTEM**

#### **CV4.1 Shutdown Circuit**

- CV4.1.1 The shutdown circuit directly controls all electrical power to the ignition, fuel injectors and all fuel pumps. It must act through a minimum of two mechanical relays (or equivalent solid-state switching devices). One relay for the fuel pump and at least one relay for injection and ignition.

An explanatory schematic of the required shutdown circuit is shown in **Error! Reference source not found..**

- CV4.1.2 The shutdown circuit is defined as a series connection of at least the LVMS, see T11.3, the BSPD, see T11.6, three shutdown buttons, see T11.4, the BOTS, see T6.2 and the inertia switch, see T11.5.
- CV4.1.3 All circuits that are part of the shutdown circuit must be designed in a way, that in the de-energized/disconnected state they open the shutdown circuit.



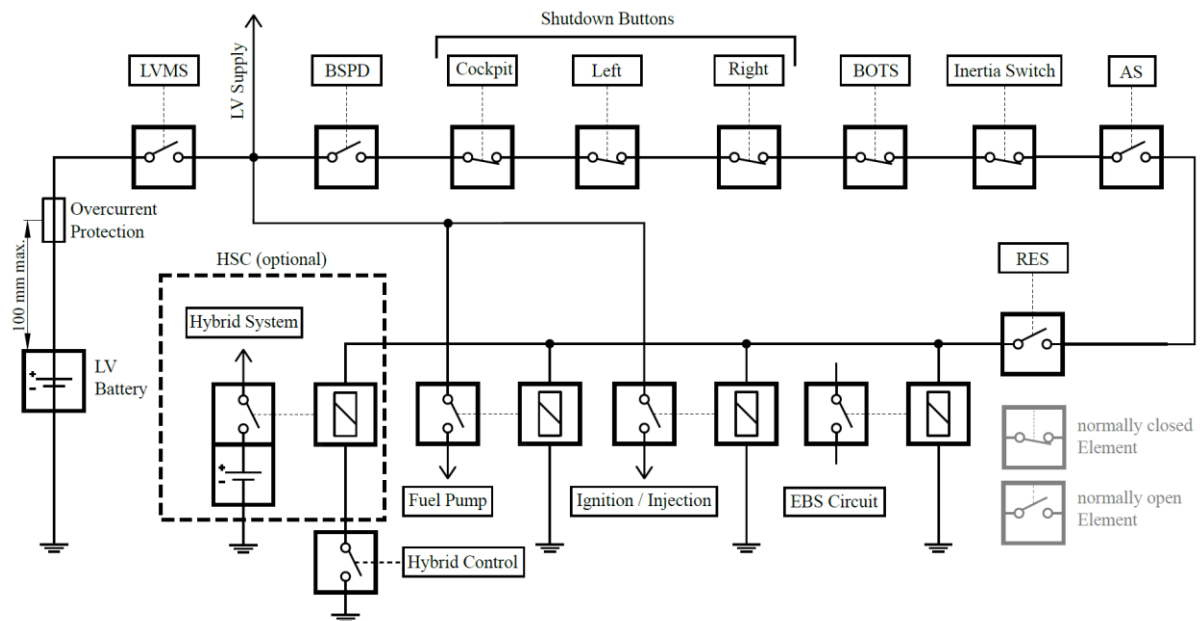


Figure 26: Explanatory example schematic of the required shutdown circuit

## CV5 LV HYBRID SYSTEM

### CV5.1 LV Hybrid System General

- CV5.1.1 The LV hybrid system must be a LVS, T11.1 and T11.7 are applicable for all LV hybrid system components.
- CV5.1.2 All electrical parts of the LV hybrid system, except for ground terminals, must be protected to a minimum of IPxxB when energised.
- CV5.1.3 The Hybrid Storage Container (HSC) is defined as the electrical energy storage system, including the AIR and overcurrent protection that is used in the hybrid powertrain.
- CV5.1.4 A firewall, see T4.8, must be positioned between the HSC and the fuel tank.
- CV5.1.5 The HSC must be positioned according to T11.7.2, all other LV hybrid system components must be positioned within the surface envelope, see T1.1.16.
- CV5.1.6 The high current path of the LV hybrid system must meet EV4.5.16.
- CV5.1.7 LV hybrid motors must meet EV2.1.
- CV5.1.8 The LV hybrid system may only be activated when the combustion engine is running or during engine start.
- CV5.1.9 The organisers may require the fitment of an Energy Meter, see EV4.6. The fuel efficiency of any LV hybrid systems will be calculated on a State of Charge (SOC) neutrality basis.

### CV5.2 Hybrid Storage Container

- CV5.2.1 The HSC must be attached to the primary structure, see T1.1.10, and meet EV5.5.9.
- CV5.2.2 A disconnection mechanism, designed as an AIR, must be integrated in to the HSC, disconnecting the positive pole of the HSC. The AIR must be compliant with EV5.6.3.

CV5.2.3 The maximum weight of all elements in the hybrid system that store electrical energy (e.g. battery cells or supercapacitors), including all casings and tabs integral to them, is 3 kg.

CV5.2.4 The HSC must be removable to be inspected at Technical Inspection and it must be possible to easily check the weight.

### **CV5.3 LV Hybrid System Form**

CV5.3.1 A LV Hybrid System Form (HSF) must be submitted by the date published in the Key Dates document using the HSF template.

CV5.3.2 If no HSF is submitted, or the HSF is not approved, the HSC must not be fitted to the vehicle at the competition.

## SECTION EV – ELECTRIC VEHICLES

### EV1 DEFINITIONS

#### EV1.1 Tractive System

EV1.1.1 Tractive System (TS) – every part that is electrically connected to the motor(s) and TS accumulators.

EV1.1.2 TS Enclosures – every housing or enclosure containing parts of the TS.

#### EV1.2 Electric

EV1.2.1 Galvanic Isolation – two electric circuits are defined as galvanically isolated, if all of the following conditions are true:

- The resistance between both circuits is  $\geq 500 \Omega/V$ , related to the maximum TS voltage of the vehicle, at a test voltage of maximum TS voltage or 250 V, whichever is higher.
- The isolation test voltage RMS, AC for 1 min, between both circuits is higher than three times the maximum TS voltage or 750 V, whichever is higher.
- The working voltage of the isolation barrier, if specified in the datasheet, is higher than the maximum TS voltage.

## **EV2      ELECTRIC POWERTRAIN**

### **EV2.1      Motors**

- EV2.1.1    Only electric motors are allowed.
- EV2.1.2    Motor attachments must follow T10.
- EV2.1.3    Motor casings must follow T7.3.
- EV2.1.4    The motor(s) must be connected to the accumulator through a motor controller.

### **EV2.2      Power Limitation**

- EV2.2.1    The TS power, measured by the Energy Meter, must not exceed +80kW.
- EV2.2.2    Negative TS power (regenerating energy), measured by the Energy Meter, is permissible and unrestricted.
- EV2.2.3    Supplying power to the motor(s) such that the car is driven in reverse is prohibited.

### **EV2.3      APPS / Brake Pedal Plausibility Check**

- EV2.3.1    The commanded motor torque must be 0 Nm, if the mechanical brakes are actuated and the APPS, see T11.8, signals pedal travel equivalent to >25% desired motor torque or >5kW, whichever is lower, at the same time, for longer than 500ms.
- EV2.3.2    The commanded motor torque must remain at 0Nm until the APPS signals less than 5% pedal travel and 0Nm desired motor torque, regardless of whether the brakes are still actuated or not.

**EV3 GENERAL REQUIREMENTS****EV3.1 Grounding**

EV3.1.1 TS Enclosures, see EV1.1.2, must consist of either:

- A grounded solid layer made of at least 0.5 mm thick electrically conductive material, aluminium or better, having a resistance below 300 mΩ, measured with a current of 1 A, to LVS ground and able to continuously carry at least 10 % of the TS accumulator main fuse current rating, or
- Be fully made from electrically insulating materials having an isolation resistance of at least 2 MΩ, measured with a voltage of 500 V. The enclosure must be rigid and must prevent possible mechanical penetrations. Protruding electrically conductive parts, such as fasteners or connectors, must follow EV3.1.2.

EV3.1.2 Electrically conductive seat, driver harness, and firewall mounting points as well as the aluminium layer of the TS firewall, see T4.8, and the LVS ground measuring point, see EV4.7.8, must have a resistance below 300 mΩ, measured with a current of 1 A, to LVS ground and be able to continuously carry at least 10 % of the TS accumulator main fuse current rating.

EV3.1.3 Parts of the vehicle which may become electrically conductive (e.g. completely coated metal parts, carbon fibre parts, etc.) within 100mm of any TS component must have a resistance below 100Ω to LVS ground.

EV3.1.4 The rotating part of the wheels does not need to be grounded.

**EV3.2 Overcurrent Protection**

EV3.2.1 All electrical systems must have appropriate overcurrent protection.

EV3.2.2 The continuous current rating of the overcurrent protection must not be greater than the continuous current rating of any electrical component, for example wire, busbar or other conductor that it protects. i.e. if multiple pins of a connector are used to carry currents in parallel, each pin must be appropriately protected.

EV3.2.3 All fuses must have an interrupt current rating which is higher than the theoretical short circuit current of the system that it protects.

EV3.2.4 All overcurrent protection devices must be rated for the highest voltage in the systems they protect. All devices used must be rated for DC.

EV3.2.5 All overcurrent protection devices that are part of the TS must not rely on programmable logic. The overcurrent protection function of unmodified commercially available motor controllers/inverters for the motor outputs may rely on programmable logic.

EV3.2.6 The overcurrent protection must be designed for the expected surrounding temperature range but at least for 0°C to 85 °C

EV3.2.7 The TS high current path through the accumulator(s) must be fused.

## **EV4 TRACTIVE SYSTEM**

### **EV4.1 General Requirements**

- EV4.1.1 The maximum permitted voltage that may occur between any two electrical connections is 600VDC and for motor controller/inverters internal low power control signals 630 VDC.
- EV4.1.2 All components in the TS must be rated for the maximum TS voltage. The TS area of a PCB, see EV4.3.6, is considered as one component. Every input connected to the TS must be rated to the maximum TS voltage.
- EV4.1.3 All components must be rated for the maximum possible temperature that may occur during use.
- EV4.1.4 Fans with >50W power must not be connected to the TS.

### **EV4.2 Tractive System Enclosures**

- EV4.2.1 Every housing or enclosure containing parts of the TS system, must be labelled with (a) reasonably sized sticker(s) according to "ISO 7010-W012" (triangle with black lightning bolt on yellow background). The sticker must also contain the text "High Voltage" if the voltage is more than 60VDC or 25VAC.

### **EV4.3 Separation of Traction System and Grounded Low Voltage System**

- EV4.3.1 The entire TS and LVS must be galvanically isolated, see EV1.2.1 and IN4.1.1.
- EV4.3.2 All connections from a TS component to external devices, such as laptops must include galvanic isolation, see EV1.2.1.
- EV4.3.3 TS and LVS circuits must be physically segregated such that they are not running through the same conduit or connector, except for interlock circuit connections.
- EV4.3.4 Where both TS and LVS are present within an enclosure, they must be separated by barriers made of moisture resistant insulating materials or maintain the following spacing through air, or over a surface:

	Voltage	Spacing
	$U < 100\text{VDC}$	10mm
	$100\text{VDC} < U < 200\text{VDC}$	20mm
	$U > 200\text{VDC}$	30mm

Table 4: TS and LVS separation requirements

- EV4.3.5 Components and cables capable of movement must be positively restrained to maintain spacing.

- EV4.3.6 If TS and LVS are on the same PCB, they must be on separate well defined areas of the board, meeting the spacing requirements in Table 5, each area clearly marked with “TS” or “LV”. The outline of the area required for spacing must be marked.

Voltage	Over Surface	Through (Cut in board)	Air Conformal Coating
0VDC to 50VDC	1.6mm	1.6mm	1.0mm
50VDC to 150 VDC	6.4mm	3.2mm	2.0mm
150 VDC to 300 VDC	9.5mm	6.4mm	3.0mm
300 VDC to 600 VDC	12.7mm	9.5mm	4.0mm

Table 5: Spacing required between TS and LV

“Conformal coating” is referring to a coating insulator, solder resist is not a coating.

- EV4.3.7 Teams must be prepared to demonstrate spacing on team-built equipment. For inaccessible circuitry, spare boards must be available. These do not have to be fully assembled.

#### EV4.4 Positioning of Tractive System Parts

- EV4.4.1 With the exception of what is permitted according to EV4.4.3, all parts belonging to the TS including cables and wiring must be located within the rollover protection envelope, see T1.1.14. “Part” is the whole device such as the complete HVD.

- EV4.4.2 Any part of the TS that is less than 350 mm above the ground must be shielded from side and rear impact collisions by structure according to T 3.15 (with exception of the first point under T 3.15.1) and must follow T 3.16 when having bolted attachments.

TS wiring in front of the front roll hoop may alternatively be shielded by the front bulkhead support structure according to T3.14.

- EV4.4.3 Outboard wheel motors are allowed only if:

- Interlocks are routed such that the shutdown circuit, see EV6.1, is opened before the TS wiring or its connection fails, or in the event of a suspension failure
- TS wiring is not able to reach the cockpit opening or the driver regardless of where it breaks
- wiring outside of the rollover protection envelope, see T 1.1.15 is minimum length
- wiring outside of an impact structure or front bulkhead support structure, see EV 4.4.2, is minimum length
- Minimum length is the shortest distance plus extra wiring caused by bending radius.
- An interlock is added such that the shutdown circuit, see EV6, is opened if the TS wiring is damaged,
- The opening of the shutdown circuit occurs before the failure of the TS wiring,
- TS wiring is not able to reach the cockpit opening or the driver regardless of where it breaks,

- Wiring outside of the rollover protection envelope, see T1.1.14, is minimum length, where minimum length is the shortest distance plus extra wiring required by bend radius,
  - Wiring outside of an impact structure or front bulkhead support structure, see EV4.4.2, is minimum length.
- EV4.4.4 In side or front view any part of the TS must not project below the lower surface of the chassis.
- EV4.4.5 Additional regulations apply for TS accumulators, see EV5.5.
- EV4.5 Tractive System Insulation, Wiring and Conduit**
- EV4.5.1 All live parts of the TS must be protected from being touched. This must include team members working on or inside the vehicle. This is tested with a 100mm long, 6mm diameter insulated test probe when the TS enclosures are in place.
- EV4.5.2 Insulation material that is rated for the maximum TS voltage must be used. Using only insulating tape or rubber-like paint for insulation is prohibited.
- EV4.5.3 The temperature rating for TS wiring, connections and insulation must be appropriate for the expected surrounding temperatures but at least 85 °C.
- EV4.5.4 TS components and containers must be protected from moisture in the form of rain or puddles to a minimum of IPX2, see IN9.
- EV4.5.5 It must be possible to clearly assign and prove wire gauge, temperature rating and insulation voltage to each used wire.
- EV4.5.6 All TS wiring must be completed to professional standards with appropriately sized conductors and terminals and with adequate strain relief and protection from loosening due to vibration etc.
- EV4.5.7 TS wiring must be located out of the way of possible snagging or damage.
- EV4.5.8 All TS wiring that runs outside of TS enclosures must
- Be enclosed in separate orange non-conductive conduit or use an orange shielded cable. The conduit must be securely anchored to the vehicle, but not to wire, at least at each end,
  - Be securely anchored at least at each end so that it can withstand a force of 200N without straining the cable end crimp.
- Body work is not sufficient to meet this enclosure requirement.
- EV4.5.9 Any shielded cable must have the shield grounded.
- EV4.5.10 Every TS connector outside of a housing must include a pilot contact/interlock line which is part of the shutdown circuit. Housings only used to avoid interlocks are prohibited.
- EV4.5.11 All TS connections must be designed so that they use intentional current paths through conductors such as copper or aluminium and should not rely on steel bolts to be the primary conductor.
- EV4.5.12 All TS connections must not include compressible material such as plastic in the stack-up or



as a fastener. FR-4 is allowed.

EV4.5.13 TS connectors outside of TS enclosures must be designed in a way, that the TS cannot be activated, see EV4.11, if connected in any way other than the design intent configuration.

EV4.5.14 All electrical connections, including bolts, nuts and other fasteners, in the high current path of the TS must be secured from unintentional loosening by the use of positive locking mechanisms that are suitable for high temperatures, see T10.2.

Components, e.g. inverters, certified for automotive use might be allowed without positive locking feature, if connections are completed as recommended by the manufacturers datasheet and no positive locking is possible.

The team must be able to demonstrate that they have assessed the risk of loosening of these connections and describe this and the control methods applied in their ESF.

EV4.5.15 Teams must be prepared to demonstrate positive locking. For inaccessible connections, appropriate photographs must be available.

EV4.5.16 Soldered connections in the high current path are only allowed if all of the following are true:

- Connections on PCBs,
- The connected devices are not cells or wires,
- The devices are additionally mechanically secured against loosening.

#### **EV4.6 Energy Meter**

EV4.6.1 A calibrated Energy Meter will be provided by the officials and must be inserted during competition. The Energy Meter measures TS voltage and TS current.

EV4.6.2 The Datalogger module of the Energy Meter must be in an easily accessible location so that it is possible for the officials to check its operation and insert/remove the memory stick at any time.

EV4.6.3 The Energy Meter must not be installed within the TSAC.

EV4.6.4 All current supplying the TS must run through the Energy Meter. The Energy Meter must be inserted in the negative TS supply between the most negative AIR(s) and the inverters.

EV4.6.5 The TS voltage sense connection of the Energy Meter must be directly connected, see T1.3.1, to the most positive AIR(s) on vehicle side.

EV4.6.6 The Energy Meter LV connection must be supplied from the LVMS. The Energy Meter requires a stable 12V supply, so regulators or voltage converters are permitted if necessary. There should be no switching or relays between the LV source and the Energy Meter.

EV4.6.7 The specification of the Energy Meter will be available on the Formula Student website.

#### **EV4.7 Tractive System Measuring point**

EV4.7.1 Two TSMPs must be installed directly next to the master switches, see EV6.2.

EV4.7.2 The TSMPs must be directly connected, see T1.3.1, to the intermediate circuit capacitors even if the HVD has been opened or the TS accumulator is disconnected.

- EV4.7.3 4mm shrouded banana jacks of rated for 1000 V CAT III or better must be used.
- EV4.7.4 The TSMPs must be marked “TS+” and “TS-” and exclusively mounted on orange back-ground.
- EV4.7.5 The TSMPs must be protected by a non-conductive housing that can be opened without tools. The cover must always be mechanically linked to the vehicle.
- EV4.7.6 Each TSMP must be secured with a current limiting resistor according to Table 6, below. Fusing of the TSMPs is prohibited. The resistors power rating must be chosen such that they are able to continuously carry the current if both TSMPs are short circuited.

Maximum TS Voltage	Resistor Value
$U_{max} < 200 \text{ VDC}$	5k $\Omega$
$200 \text{ VDC} < U_{max} \leq 400 \text{ VDC}$	10k $\Omega$
$400 \text{ VDC} < U_{max} \leq 600 \text{ VDC}$	15k $\Omega$

Table 6: TSMP Resistor requirements

- EV4.7.7 All electrical connections needed for TSMP, including bolts, nuts and other fasteners, must be secured from unintentional loosening by the use of positive locking mechanisms. Bolted connections must follow T10.2, soldered connections EV4.5.16
- EV4.7.8 Next to the TSMPs, a LVS ground measuring point must be installed. A 4mm black shrouded banana jack must be connected to LVS ground and must be marked “GND”.

#### **EV4.8 High Voltage Disconnect**

- EV4.8.1 It must be possible to disconnect at least one pole of the TS accumulator by quickly removing an unobstructed and directly accessible element, fuse or connector. It must be possible to disconnect the HVD without removing any bodywork. The HVD must be above 350mm from the ground and easily visible when standing behind the vehicle. Remote actuation of the HVD through a long handle, rope or wire is not permitted.
- EV4.8.2 An untrained person must be able to remove the HVD within 10s when the vehicle is in ready-to-race condition.
- EV4.8.3 A dummy connector or similar may be required to restore the system’s isolation, see EV4.5. The dummy connector must be green and clearly identifiable to an observer when in use. It must be attached to the push bar, see T1.3.1, if not in use.
- EV4.8.4 The HVD must be clearly marked with “HVD”.
- EV4.8.5 No tools must be necessary to open the HVD. An interlock is required, see EV4.5.10.

#### **EV4.9 Discharge Circuit**

- EV4.9.1 If a discharge circuit is required to meet EV6.1.5, it must be designed to handle the maximum TS voltage permanently.
- After three subsequent discharges within 15s in total, the discharge time specified in EV6.1.5 may be exceeded. Full discharging functionality must be given after a reasonable time with a deactivated discharge circuit.
- EV4.9.2 The discharge circuit must be wired in a way that it is always active whenever the shutdown circuit is open. Furthermore, the discharge circuit must be fail-safe such that it still

discharges the intermediate circuit capacitors if the HVD has been opened or the TS accumulator is disconnected.

EV4.9.3 Fusing of the main current discharge path is prohibited.

#### **EV4.10 Traction System Active Light**

EV4.10.1 The vehicle must include a single TSAL that must indicate the TS status. The TSAL must not perform any other functions. A TSAL with multiple LEDs in one housing is allowed.

EV4.10.2 The TSAL itself must have a red light, flashing continuously with a frequency between 2Hz and 5Hz and a duty cycle of 50%, active whenever the LVS is active and for at least 15 minutes after it is switched off (see EV4.10.16) and the voltage across any DC-link capacitor exceeds the lower of either:

- 60VDC or 50VACRMS,
- Half the nominal TS voltage.

EV4.10.3 The TSAL itself must have a green light, continuously on, active whenever the LVS is active and for at least 15 minutes after it is switched off (see EV4.10.16) and ALL of the following conditions are true:

- All AIRs are opened.
- The pre-charge relay, see EV5.7.2, is opened.
- The voltage at the vehicle side of the AIRs inside the TSAC does not exceed 60VDC or 50VACRMS.

EV4.10.4 The voltage detection for the TSAL must be performed inside the respective TS enclosure.

EV4.10.5 The described states of the relays (opened/closed) are the actual mechanical states. The mechanical state can differ from the intentional state, i.e. if a relay is stuck. Any circuitry detecting the mechanical state must meet EV5.6.2.

EV4.10.6 The voltage detection circuit of the red light and the relay state and voltage detection circuit of the green light must be independent. Any plausibility check between both lights is not allowed. A TSAL state with both lights simultaneously active might occur and must not be prevented.

EV4.10.7 The TSAL must:

- Be located lower than the highest point of the main hoop and including the mounting within the rollover protection envelope, see T1.1.16.
- Be no lower than 75mm from the highest point of the main hoop.
- Not be able to contact the driver's helmet in any circumstances.

EV4.10.8 The entire illuminated surface of the TSAL must be clearly visible:

- Except for angles less than 10° on each side which are blocked by the main hoop.
- From a point 1.60m vertically from ground level, within 3m horizontal radius from the TSAL.
- In direct sunlight.

EV4.10.9 The TSAL and all required circuitry must be hard-wired electronics. Software control is not permitted.

- EV4.10.10 A green indicator light in the cockpit must illuminate if the TSAL green light is on, see EV4.10.3. It must be clearly marked “TS off”, and the light must be easily visible even in bright sunlight.
- EV4.10.11 Signals influencing the TSAL and the indicator according to EV4.10.10 are SCS, see T11.9. The individual safe state of each of the TSAL lights is off. The TSAL has an active indication of the absence of failures (continuous green illumination) and thus the red light must not be illuminated for a visible check, see T11.9.6.
- EV4.10.12 The TSAL’s red light voltage detection circuit, see EV4.10.2, does not need to detect an open circuit, as required by T11.9. A plausibility check must not be implemented.
- EV4.10.13 The TSAL’s green light relay state detection circuit, see EV4.10.3, does not need to detect an open circuit, as required by T11.9, when the intentional state of the used (auxiliary) contact is opened. A plausibility check against the intentional relay state must be implemented in a way that the TSAL’s green light stays off after the open circuit is detectable.
- EV4.10.14 The TSAL’s green light voltage detection circuit, see EV4.10.3, does not need to detect an open circuit, as required by T11.9, when no voltage is present. A plausibility check against the intentional relay states must be implemented in a way that the TSAL’s green light stays off after the open circuit of the accumulator voltage detection circuit is detectable.
- EV4.10.15 The latching required by EV4.10.13 and EV4.10.14 must not be triggered during normal operation conditions and must only be reset by power cycling the LVS.
- EV4.10.16 The TSAL power supply must:
- Comply with T11.7 and be capable of powering the TSAL for at least 15 minutes after the LVS has been switched off. It is permissible for the TSAL to be powered by the LVS whenever this is switched on.
  - Not be used to power any other systems,
  - Comply with all requirements of T11.1 but must not be de-activated by opening the LVMS (see T11.3).
- EV4.10.17 It is permissible for the ESO to deactivate the TSAL when the LVS is switched off and if the TS is confirmed to be deactivated.
- It must not be possible to activate the TS if the TSAL is in a deactivated state,
  - The driver must not be able to deactivate the TSAL.
- EV4.11 Activating the Tractive System**
- EV4.11.1 The TS is active if any of the AIRs or the pre-charge relay are closed.
- EV4.11.2 The driver must be able to activate and deactivate the TS from within the cockpit without the assistance of any other person.
- EV4.11.3 [DV ONLY] The ASR must be able to activate the TS from outside the vehicle with an external TS activation button in proximity to the TSMS if and only if the ASMS is in “On” position.
- EV4.11.4 Closing the shutdown circuit by any part defined in EV6.1.2 must not (re-)activate the TS. Additional action must be required.

- EV4.11.5 [DV ONLY] The AS must not be able to (re-)activate the TS.
- EV4.11.6 The vehicle is ready-to-drive as soon as the motor(s) will respond to the input of the APPS.
- EV4.11.7 After the TS has been activated, additional actions must be required by the driver to set the vehicle to ready-to-drive mode (e.g. pressing a dedicated start button). The transition to ready-to-drive mode must only be possible during the actuation of the mechanical brakes and a simultaneous dedicated additional action.
- EV4.11.8 The ready-to-drive mode must be left immediately when the shutdown circuit is opened.

**EV4.12 Ready-To-Drive Sound**

- EV4.12.1 The vehicle must make a characteristic sound, continuously for at least one second and a maximum of three seconds while entering ready-to-drive mode.
- EV4.12.2 The sound level must be a minimum of 90dB(A), fast weighting. The sound level will be measured with a free-field microphone placed free from obstructions in a radius of 2m around the vehicle.
- EV4.12.3 The sound must be easily recognisable. No animal voices, parts of songs or sounds that could be interpreted as offensive are permissible.
- EV4.12.4 The vehicle must not make any other sounds similar to the ready-to-drive sound.

**EV5 TRACTIVE SYSTEM ENERGY STORAGE****EV5.1 Definitions**

- EV5.1.1 Cell – a battery cell or super-capacitor.
- EV5.1.2 Cell Energy – the maximum cell voltage times the nominal capacity of the used cell.
- EV5.1.3 TS Accumulator – all cells that store the electrical energy to be used by the TS as a whole.
- EV5.1.4 Tractive System Accumulator Container (TSAC) – the container itself, which contains the TS accumulator.
- EV5.1.5 TS Accumulator Segments – sub-divisions of the TS accumulator.

**EV5.2 Allowed Tractive System Cells**

- EV5.2.1 All types of cells except molten salt and thermal batteries are allowed.
- EV5.2.2 Fuel cells are prohibited.

**EV5.3 Tractive System Energy Storage – General Requirements**

- EV5.3.1 All cells that store the TS energy must be enclosed in a TSAC.
- EV5.3.2 Each TS accumulator segment must not exceed:
- a maximum voltage of 120 VDC,
  - a maximum energy of 6 MJ, see EV5.1.2,
  - a maximum mass of 12kg.
- EV5.3.3 If spare TS accumulators are used, they must be of the same size, weight and type as those that are replaced.
- EV5.3.4 Spare cells must be stored in an electrically insulated container made of fire-retardant material, see T1.2.1. The container must be labelled according to EV5.3.8.
- EV5.3.5 Spare accumulators and spare cells should be presented at technical inspection.
- EV5.3.6 It must be possible to open the TSAC for technical inspection.
- EV5.3.7 Each TSAC must be removable from the vehicle while still remaining rules compliant without the need to install extra components. A dummy connector or similar may be used to restore the system's isolation, see EV4.5.
- EV5.3.8 The vehicle number, the university name and the ESO phone number(s) must be displayed and written in Roman Sans-Serif characters of at least 20mm high on the lid of each TSAC. The characters must be clearly visible and placed on a high contrast background.
- EV5.3.9 All TS Accumulators using chemistries other than lead acid must be:
- (a) Directly accessible with a fire extinguisher nozzle of 35mm diameter x 150mm long, without removing body panels and with the driver seated normally in the vehicle. Covers which can be easily "punched through" are acceptable.
- Any such cover or access location must be identified using the appropriate symbol below and be clearly visible to marshals approaching the car.



Figure 27: Fire Port marking

If the TS Accumulator(s) is positioned greater than 50mm inboard of the access location, then a tube of at least 35mm diameter must be present to direct the discharge from the extinguisher towards the TS Accumulator(s). The tube must be no more than 750mm in length. Any access tube must be separated from the driver by a firewall as specified in T4.8.

- (b) Identified with the symbol below (minimum height 75mm and showing the appropriate battery chemistry) on each side of the car AND adjacent to any labels required by EV5.3.9(a).



Figure 28: Battery Chemistry marking

#### **EV5.4 Tractive System Energy Storage – Electrical Configuration**

- EV5.4.1 Every TSAC must contain at least one fuse and at least two AIRs, see EV5.6 and EV3.2.7.
- EV5.4.2 LVS must not be included in the TSAC except where inherently required. Exceptions include the AIRs, TS DC/DC converters, the Accumulator Management System (AMS), the Insulation Monitoring Device (IMD), parts of the TSAL and cooling fans.

- EV5.4.3 Maintenance plugs must allow electrical separation of all TS accumulator segments, see EV5.3.2. The separation must affect both poles of all segments including first and last segment.
- EV5.4.4 Maintenance plugs must:
- Not require tools to separate the TS accumulator segments,
  - Be non-conductive on surfaces that do not provide any electrical connection,
  - Be designed in a way, that it is physically impossible to electrically connect them in any way other than the design intent configuration,
  - Be designed such that it is clearly visible whether the connection is open or closed. Electrically controlled switches must not be used.
- EV5.4.5 Each TS accumulator segment must be electrically insulated by the use of suitable rigid and fire retardant, see T1.2.1, material between the segments and on top of the segment to prevent arc flashes caused by inter-segment contact or by parts/tools accidentally falling into the TSAC during maintenance.
- EV5.4.6 Every wire used in an TSAC, regardless of whether it is part of the LVS or TS, must be rated to the maximum TS voltage.
- EV5.4.7 Each TSAC must have a prominent indicator, a voltmeter or a red LED visible even in bright sunlight that will illuminate whenever a voltage greater than 60 VDC or half the maximum TS voltage, whichever is lower, is present at the vehicle side of the AIRs.
- EV5.4.8 The indicator must be clearly visible while disconnecting the TSAC from the vehicles. The indicator must be clearly marked with “Voltage Indicator”
- EV5.4.9 The indicator must be hard wired electronics without software control, directly supplied by the TS and always working, even if the accumulator is disconnected from the LVS or removed from the vehicle.
- EV5.5 Tractive System Energy Storage – Mechanical Configuration**
- EV5.5.1 All TSACs must be attached to the primary structure, or any structure fixed to the primary structure, which meet the minimum specification for side impact structures. All TSACs must lie completely within the Rollover Protection Envelope.
- EV5.5.2 Any portion of the TSAC(s) that is less than 350mm above the ground must be shielded from front, side or rear impact collisions by structure equivalent to that defined in T3.15 for a side impact structure. The TSAC must not be part of this structure.
- EV5.5.3 The TSAC (including internal walls, see EV5.5.7) and all elements attaching it to the Primary Structure must be fire retardant, see T1.2.1. Where materials are used within the TSAC which do not meet the requirements of T1.2.1 the team must be able to justify why they were used in preference to a fire retardant material.
- EV5.5.4 The TSAC(s) must be constructed of steel or aluminium. With the following requirements:
- The floor of the TSAC must be at least 1.25mm thick if made from steel or 3.2mm if made from aluminium,
  - The internal and external vertical walls, covers and lids must be at least 0.9mm thick if



made from steel or 2.3mm if made from aluminium.

Alternative materials are allowed with proof of equivalency per T3.3 or for composite materials per EV5.5.5. This must be documented in the SES. When alternative materials are used, test samples must be presented at technical inspection.

EV5.5.5 Composite TSAC(s) must satisfy the following requirements:

- Data obtained from the laminate perimeter shear strength test and three point bending test, see T3.5, should be used to prove adequate strength is provided,
- Each attachment point requires steel backing plates with a minimum thickness of 2mm. Alternate materials may be used for backing plates if equivalency is approved,
- The calculations and physical test results must be included in the SES.

EV5.5.6 The floor and walls of the TSAC must be joined by welds, bonding and/or fasteners.

- Fastened connections between the floor and any vertical wall of each section must have at least 2 fasteners,
- Fastened connections between internal vertical walls and external vertical walls must be located in the top half of the internal vertical wall,
- Sections containing 8kg or less must have a minimum of 2 fasteners connecting any two vertical walls,
- Sections containing between 8kg and 12kg must have a minimum of 3 fasteners connecting any two vertical walls.

EV5.5.7 The TSAC must include electrically insulating internal vertical walls with a minimum of 75% of the height of the external vertical walls, which divide the TSAC into section of a maximum of 12kg.

EV5.5.8 The accumulator segments, see EV5.3.2, must be separated by a rigid, electrically insulating and fire-retardant barrier, see T1.2.1.

EV5.5.9 The TSAC itself, the mounting of the TSAC to the chassis and the mounting of each segment to the TSAC must be designed to withstand the following accelerations:

- 40g in the longitudinal direction (forward/aft),
- 40g in the lateral direction (left/right),
- 20g in the vertical direction (up/down).

Calculations and/or tests must be documented in the SES. All considered TSAC attachment points must follow EV5.5.13. TSAC(s) made of materials as stated in EV5.5.4 or EV5.5.5 may need further reinforcement in order to comply with this rule.

EV5.5.10 Tabs of pouch cells must not carry mechanical loads. Pouch cells must only carry mechanical loads on the large surface areas.

EV5.5.11 All fasteners used within or to mount the TSAC must comply with T10. Fasteners within the accumulator used for non-structural accumulator parts (e.g. PCBs etc.) do not have to follow T10 if the fasteners are made of electrically non-conductive material or other than

stated in T10.1.2, may be of any diameter. Non-structural fasteners used to mount tabs of pouch cells must comply with T10 with the exception of T10.1.2.

- EV5.5.12 The AIRs and the main fuse, see EV3.2.7, must be separated with an electrically insulated and fire-retardant material, see T1.2.1, from the rest of the TS accumulator. Air is not considered to be a suitable insulation material in this case.
- EV5.5.13 Any brackets used to mount the TSAC must be made of steel 1.6mm thick or aluminium 4mm thick and must have gussets to carry bending loads. Each attachment point including brackets, backing plates and inserts, must be able to withstand 20kN in any direction.
- EV5.5.14 Holes, both internal and external, in the TSAC are only allowed for the wiring-harness, ventilation, cooling or fasteners. The TSAC must still be compliant with all other rules, especially the ones concerning its structural requirements. External holes must be sealed according to EV4.5. Openings for cooling and connected cooling ducts must not point towards the driver, or if the accumulator is out of the car, towards the operator of the accumulator hand cart.
- EV5.5.15 A sticker according to “ISO 7010-W012” (triangle with black lightning bolt on yellow background) with triangle side length of at least 100mm and the text “Always Energized” must be applied on every TSAC. The sticker must also contain the text “High Voltage” if the voltage is more than 60VDC or 25VAC.
- EV5.5.16 Every TSAC must be able to vent gas to prevent high-pressure in the TSAC.
- EV5.5.17 Where there are liquid cooling elements within the accumulator container, teams must demonstrate how they have been designed, manufactured and tested to ensure that cooling liquid cannot leak into the accumulator.
- EV5.5.18 The design of the TSAC and its contents must be documented in the SES including materials used, drawings, images, fastener locations, segment weight, cell and segment position.

## **EV5.6 Accumulator Isolation Relays**

- EV5.6.1 At least two AIRs must be fitted inside each TSAC.
- EV5.6.2 The AIRs must open both poles of the TS accumulator. If the AIRs are open, no TS voltage may be present outside of the TSAC and the vehicle side of the AIRs must be galvanically isolated from the accumulator side, see EV1.2.1.
- EV5.6.3 The AIRs must be mechanical relays of a “normally open” type. Solid-state relays are prohibited.
- EV5.6.4 The fuse protecting the accumulator TS circuit must have a rating lower than the maximum switch off current of the AIRs.

## **EV5.7 Pre-Charge Circuit**

- EV5.7.1 A circuit that ensures that the intermediate circuit is pre-charged to at least 95 % of the actual TS accumulator voltage before closing the second AIR must be implemented. Therefore the intermediate circuit voltage must be measured.
- EV5.7.2 The pre-charge circuit must use a mechanical, normally open type relay. All pre-charge current must pass through this relay.

## **EV5.8 Accumulator Management System**

- EV5.8.1 Each TS accumulator must be monitored by an AMS whenever the LVS is active, or the accumulator is connected to a charger.
- EV5.8.2 Every TSAC must contain its full AMS including its own and AMS exclusive SDC power stage, see EV 6.1
- EV5.8.3 The AMS must continuously measure
- All cell voltages,
  - The TS current,
  - The temperature of thermally critical cells,
  - For lithium based cells: the temperature of at least 30 % of the cells equally distributed within the TSAC(s).
- EV5.8.4 Cell temperature must be measured at the negative terminal of the respective cell and the sensor used must be in direct contact with the negative terminal or less than 10mm along the high current path away from the terminal in direct contact with the respective busbar. It is acceptable to monitor multiple cells with one sensor if this requirement is met for all cells sensed by the sensor.
- EV5.8.5 The maximum cell temperature is 60°C or the limit stated in the cell data sheet, whichever is lower.
- EV5.8.6 An independent cell temperature monitoring device may be provided by the officials during accumulator inspection and must be installed.
- The device must be placed on the warmest negative cell terminal of the TSAC and in direct contact with the terminal or less than 30mm away from it on the busbar.
- EV5.8.7 The AMS must switch off the TS via the shutdown circuit, if critical voltage, temperature or current values according to the cell manufacturer's datasheet or these rules persistently occurs for more than:
- 500ms for voltage and current values,
  - 1s for temperature values.
- The accuracy, noise and sample rate of the measurement must be taken into account.
- EV5.8.8 AMS cell voltage measurement inputs, temperature measurement inputs and supply voltage of decentralized AMS slaves may be rated below the maximum TS voltage if the team has proven by calculations in the Electrical System Form (ESF), see EV9, that the input voltage rating is reasonably chosen.
- EV5.8.9 A red indicator light in the cockpit that is easily visible from inside and outside the cockpit even in bright sunlight and clearly marked with the lettering "AMS" must light up if the AMS opens the shutdown circuit. It must stay illuminated until the error state has been manually reset, see EV6.1.6. Signals controlling this indicator are SCS, see T11.9.
- EV5.8.10 AMS signals are System Critical Signals, see T11.9.

- EV5.8.11 It must be possible to individually disconnect the current sensor, one temperature sensor and one cell voltage measurement wire during technical inspection, if any wire used.
- EV5.8.12 The AMS must be able to read and display all measured values according to EV5.8.2 e.g. by connecting a laptop to the AMS.

## EV6 EV SHUTDOWN CIRCUIT AND SYSTEMS

### EV6.1 Shutdown Circuit

EV6.1.1 The shutdown circuit directly carries the power driving the AIRs, see EV5.6, and the pre-charge circuitry, see EV5.7.

EV6.1.2 The shutdown circuit is defined as a series connection of at least two master switches, three shutdown buttons, the BOTS, see T6.2, the IMD, the inertia switch, see T11.5, the BSPD, see T11.6, all required interlocks and the AMS.

An explanatory schematic of the required shutdown circuit, excluding any possible interlock circuitry, is shown in Figure 29.

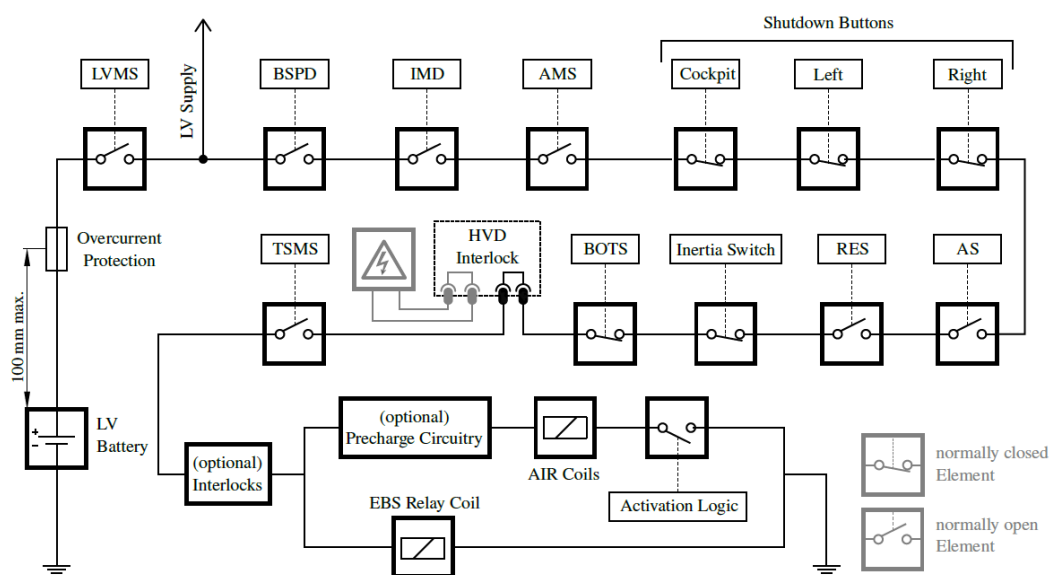


Figure 29: Explanatory example schematic of the required shutdown circuit

EV6.1.3 All parts of the shutdown circuit defined in EV6.1.2 must be on the high-side connection of the AIR coils and the pre-charge circuitry.

EV6.1.4 The Tractive System Master Switch (TSMS), see EV6.2, must be the last switch before the AIRs except for pre-charge circuitry and hardwired interlocks.

EV6.1.5 If the shutdown circuit is opened, the TS must be shutdown by opening all AIRs and the voltage in the TS must drop to below 60VDC and 25VACRMS in less than five seconds. All accumulator current flow must stop immediately.

The action of opening the AIRs may be delayed by  $\leq 250\text{ms}$  to signal the action to the motor controllers and reduce the TS current before the AIRs are opened. The AIR supply must be abruptly switched off before reaching the minimum AIR supply voltage.

EV6.1.6 If the shutdown circuit is opened by the AMS or the IMD, it has to be latched open by a non-programmable logic that can only be manually reset by a person at the vehicle who is not the driver.

EV6.1.7 All circuits that are part of the shutdown circuit must be designed in a way, that in the de-energized/disconnected state they open the shutdown circuit.

- EV6.1.8 It must be possible to demonstrate that all features of the shutdown circuit function correctly. This includes all interlocks.
- EV6.1.9 Every system that is required to or is able to open the shutdown circuit must have its own, non-programmable, power stage to achieve this. The respective power stages must be designed to be able to carry the shutdown circuit current, e.g. AIR inrush currents, and such that a failure cannot result in electrical power being fed back into the electrical shutdown circuit.
- EV6.1.10 The shutdown buttons, the BOTS, the TSMS and all interlocks must not act through any power stage.
- EV6.1.11 All signals influencing the shutdown circuit are SCSs, see T11.9.

#### **EV6.2 Traction System Master Switch**

- EV6.2.1 An TSMS according to T11.2 must be part of the shutdown circuit, see EV6.1.2.
- EV6.2.2 The TSMS must be fitted with a “lockout/tagout” capability to prevent accidental activation of the TS. The ESO must ensure that it is locked in the off position whenever work is done on the vehicle or no ESO is present.
- EV6.2.3 The TSMS must be mounted in the middle of a completely orange circular area of  $\geq 50\text{mm}$  diameter placed on a high contrast background.
- EV6.2.4 The TSMS must be marked with “TS” and a symbol according to “ISO 7010-W012” (triangle with black lightning bolt on yellow background).

#### **EV6.3 Insulation Monitoring Device**

- EV6.3.1 Every vehicle must have an IMD installed in the TS system.
- EV6.3.2 The IMD must be a Bender A-ISOMETER® iso-F1 IR155-3203 or -3204, -4203, or -4204, or a Bender ISOMETER® iso165C-1, or equivalent IMD approved for automotive use. Equivalency may be approved by the officials based on the following criteria: robustness to vibration, operating temperature range, IP rating, availability of a direct output, a self-test facility and must not be powered by the system which is monitored.
- EV6.3.3 The response value of the IMD must be set to  $\geq 500 \Omega/\text{V}$ , related to the maximum TS voltage.
- EV6.3.4 The IMD must be connected on the vehicle side of the AIRs.
- EV6.3.5 One IMD chassis ground measurement line must be connected to the grounded TSAC. The other chassis ground measurement line must be connected to the main hoop. Each connection must use a separate conductor, rated for at least maximum TS voltage. An open circuit in any of this ground measurement connections must result in an opened shutdown circuit.
- EV6.3.6 In case of an insulation failure or an IMD failure, the IMD must open the shutdown circuit. This must be done without the influence of any programmable logic. See also EV6.1.6 regarding the re-activation of the TS after an insulation fault.
- EV6.3.7 A red indicator light in the cockpit, that is easily visible from inside and outside the cockpit in bright sunlight and clearly marked with the lettering “IMD”, must light up if the IMD opens the shutdown circuit. It must stay illuminated until the error state has been manually reset, see EV6.1.6. Signals controlling this indicator are SCS, see T11.9.

**EV7 CHARGERS****EV7.1 Chargers General Requirements**

- EV7.1.1 Only chargers presented and sealed at technical inspection are allowed to be used. All connections of the charger(s) must be insulated and covered. No open connections are allowed.
- EV7.1.2 Exposed conductive parts and the TSAC must be connected to protective earth (PE).
- EV7.1.3 All chargers must either be accredited to a recognized standard e.g. CE, or when built by the team, must comply with all electrical requirements for the vehicle TS, e.g. EV4.3, EV3.1 and EV4.2.
- EV7.1.4 TS charging leads must be orange.
- EV7.1.5 When charging, the AMS must be live and must be able to turn off the charger in the event that a fault is detected.
- EV7.1.6 The charger must include a push type emergency stop button which has a minimum diameter of 24mm and must be clearly labelled.
- EV7.1.7 When charging the accumulator, an IMD as described in EV6.3 must be active and must be able to shut down the charger. Either the charger must incorporate an active IMD or an active IMD must be within the accumulator. Other than stated in EV6.3, the second chassis ground measurement line must be connected to the casing of the charger instead of the main hoop.
- EV7.1.8 An IMD indicator light as defined in EV6.3.7 must be available during charging.
- EV7.1.9 The charger must include TSMPs as described in EV4.7. Other than stated, the TSMPs must be connected to the TS output of the charger.

**EV7.2 Charging Shutdown Circuit**

- EV7.2.1 When charging, the charging shutdown circuit consists of at least the charger shutdown button, see EV7.1.6, the IMD and the AMS.
- EV7.2.2 If the shutdown circuit is opened the charging system must remain disabled and the shutdown circuit opened until it is manually reset.
- EV7.2.3 The charging shutdown systems must comply with EV6.1.1, EV6.1.5, EV6.1.7, EV6.1.8 and EV6.1.9.
- EV7.2.4 All signals influencing the charger shutdown circuit are SCS, see T11.9.

## **EV8 TRACTIVE SYSTEM ACCUMULATOR CONTAINER HAND CART**

### **EV8.1 Tractive System Accumulator Container Hand Cart**

- EV8.1.1 A hand cart(s) must be used for transporting the TSAC(s) around the competition site.
- EV8.1.2 The hand cart(s) must have at least four wheels.
- EV8.1.3 The hand cart(s) must have a brake that is always on and only released if someone pushes the handle, or similar.
- EV8.1.4 The brake must be capable of safely stopping the fully loaded hand cart.
- EV8.1.5 The hand cart(s) must be able to carry the load of the TSAC(s).
- EV8.1.6 The hand cart must provide a vertical firewall (see T4.8) to protect anyone moving the hand cart. The firewall must be the same width as the hand cart, start at the lowest point of the hand cart and be at least 30 cm higher than the hand cart handle and the TSAC.
- EV8.1.7 The TSAC(s) must be mechanically fixed to the hand cart(s) to enable safe transportation.
- EV8.1.8 The TSAC(s) must be protected from vibrations and shocks during normal operation of the cart(s), e.g. by using pneumatic tyres.
- EV8.1.9 The label on the TSAC or an additional label according to EV5.3.8 must be clearly visible if the TSAC is on the hand cart.
- EV8.1.10 The overall floor space used by the fully loaded hand cart must not exceed 1200mm x 800mm. If the TSAC is larger than the allowed floor space, exceptions may be approved by the officials prior to the competition.



## **EV9 ELECTRICAL SYSTEM FORM**

### **EV9.1 Electrical System Form**

- EV9.1.1 Prior to the competition, all teams must submit clearly structured documentation of their entire electrical system (including control and TS) called the ESF.
- EV9.1.2 The ESF must follow the template provided on the Formula Student website, must not exceed one hundred and ten (110) pages and be submitted in pdf format. Submissions that do not meet these requirements may be rejected by the judges and considered as a non-submission.
- EV9.1.3 Datasheet values and manufacturer recommendations must be adhered to for all items in the ESF, unless prior permission is sought and approved by submitting a rules question to the Formula Student Question Database.

## **SECTION AFV – ALTERNATIVE FUEL VEHICLES**

### **AFV1 ALTERNATIVE FUEL VEHICLES**

#### **AFV1.1 Alternative Fuels and Powertrains Overview**

AFV1.1.1 Formula Student would like to promote alternative powertrains and fuels such that vehicles built with alternative powertrains can compete fairly at the competition.

AFV1.1.2 If a team wishes to use an alternative fuel, then the process in AFV1.2 must be followed.

AFV1.1.3 There are additional rules for alternative fuels. It will be necessary to work with the Formula Student Technical Committee to develop a satisfactory design; some of the additional rules are presented in AFV1.3 to AFV1.5.

AFV1.1.4 During the endurance event the fuel efficiency of all vehicles will be measured in terms of the production of CO<sub>2</sub> measured in kg. The quantity of CO<sub>2</sub> released to the atmosphere by the consumption of each allowable fuel is specified in rule D7.9.2 and is intended to represent the UK average number for the type of fuel under consideration.

AFV1.1.5 The fuel efficiency of any AFV using on-board electrical energy storage will be calculated on a State of Charge (SOC) neutrality basis using the Energy Meter described in EV4.6.

#### **AFV1.2 Alternative Fuel Report**

AFV1.2.1 Any team intending to submit an alternative fuel entry must submit a short report (5 A4 pages maximum) by the date defined by the Key Dates Document outlining the fuel or combination of fuels that the team intends to use, how the fuel will be transported and stored at the event, details of how the powertrain will work and any possible risks and how these might be mitigated. Subsequent discussions with the Formula Student Technical Committee will determine whether an entry can be accepted and what additional regulations the entry must respect.

AFV1.2.2 Once an alternatively fuelled vehicle's entry is accepted, the team must complete reports equivalent to those required by EVs, namely the FMEA and ESF before the vehicle will be allowed to run at the competition.

#### **AFV1.3 Fuel**

AFV1.3.1 The allowable forms of power in addition those covered by the Formula Student rules (Gasoline, E85 and Electric) are specified as Diesel, Hydrogen, Hydrogen fuel cell and combinations of all the above forms of power to create a hybrid but the organising committee will consider requests for other fuels such as Liquid Petroleum Gas (LPG) and Compressed Natural Gas (CNG) to be added to this list.

AFV1.3.2 For alternative powertrains, in addition to the fuel that is available for cars built to the CV rules, the organisers will seek to secure the supply of appropriate fuels to support alternative powertrains, but this cannot currently be guaranteed.

AFV1.3.3 Entrants requiring alternative fuels should have a back-up plan in mind for fuel supply.

#### **AFV1.4 Location of Fuel System**

AFV1.4.1 Any fuel, compressed gasses, other energy storage media must be contained within the Primary Structure Envelope and when located less than 350mm from the ground must be shielded from front, side or rear impacts with a structure built to T3.2.

#### **AFV1.5 Powertrain Limitations**

AFV1.5.1 Any alternatively fuelled combustion engine, whether the sole prime mover or part of a hybrid powertrain, must use a reciprocating 4 stroke cycle internal combustion engine with a maximum capacity of 710cc.

AFV1.5.2 The engine can be modified within the restrictions of the rules.

AFV1.5.3 If more than one engine is used, the total displacement cannot exceed the maximum displacement described in AFV1.3.1 and the air for all engines must pass through a single air intake restrictor (see CV1.7, "Intake System Restrictor.")

AFV1.5.4 HV hybrid powertrains utilising on-board energy storage are allowed.

AFV1.5.5 Electric only or hybrid vehicles which use Electric as their prime means of propulsion e.g. electric / hydraulic and series hybrids as well as parallel hybrids are allowed.

AFV1.5.6 Any HV electric hybrid vehicles must follow the EV regulations for the Electrical System unless a change is agreed with the Formula Student Technical Committee.

AFV1.5.7 Any car using a diesel engine with mechanical fuel injection must incorporate a throttle which is mechanically closed when the throttle pedal is released. Diesel engines with electronic fuel injection do not require a throttle if the team follows the principles of the electronic throttle control rules to control and monitor the supply of fuel to the engine and satisfies the technical inspection team that their design is safe.

## **SECTION IN – TECHNICAL INSPECTIONS**

### **IN1 GENERAL**

#### **IN1.1 Technical Inspection Process**

IN1.1.1 The technical inspection is divided into the following parts:

- Motorsport UK Safety Inspection (SAFETY)
- Mechanical Inspection (CHASSIS and TECH)
- [EV Only] Accumulator Inspection (EV BATTERY)
- [EV Only] Electrical Inspection (EV VEHICLE)
- [EV Only] Rain Test
- Noise Test (NOISE)
- Tilt Test (TILT)
- Brake Test (BRAKE)
- Vehicle Weighing
- Driver Egress Tests
- [DV Only] Driverless Inspection
- [DV Only] EBS Test

#### **IN1.2 General Rules**

- IN1.2.1 Each vehicle must pass all parts of technical inspection before it may participate in any dynamic event.
- IN1.2.2 Passing the technical inspections is not a certification of complete rules compliance of the vehicle.
- IN1.2.3 The technical inspection sheet includes several inspection points and will be provided on the competition website prior to the competition. It must always stay with the vehicle.
- IN1.2.4 The officials may inspect other points not mentioned on the technical inspection sheet to ensure compliance with the rules.
- IN1.2.5 Teams are responsible for confirming that their vehicle and the required equipment satisfies the requirements and restrictions of the rules before presenting it for technical inspection.
- IN1.2.6 Vehicles must be presented for technical inspection in ready-to-race condition.
- IN1.2.7 All items on the inspection sheet must be clearly visible for the officials without using instruments such as endoscopes or mirrors. Visible access may be provided by removing body panels or by providing removable access panels.
- IN1.2.8 The vehicle must maintain all required specifications throughout the competition.
- IN1.2.9 Officials reserve the right to ask the team for drilling of additional inspection holes to check the chassis for compliance with the rules.

IN1.2.10 Officials will mark or seal various different approved parts. Removal of or damage to the seals will void the inspection approval.

IN1.2.11 Once the vehicle is approved for competition, any damage to the vehicle that requires repair(s) will void the inspection approval. After completion of the repair(s), the vehicle must be re-submitted to technical inspection for re-approval.

IN1.2.12 The officials reserve the right to prohibit the use of parts that could pose a safety risk to drivers, track marshals or the environment.

IN1.2.13 The event organisers reserve the right to re-inspect the vehicle at any time during the event after passing technical inspection. If any non-compliances are identified, then the team may be disqualified from the run in the dynamic event that immediately preceded the re-inspection.

### **IN1.3 Technical Inspection Sticker**

IN1.3.1 Technical inspection stickers will be placed on the upper nose of the vehicle. Cars must have a clear and unobstructed area at least 125 mm diameter on the upper front surface of the nose along the vehicle centreline, which will be used to record the car weight and identify the sections of scrutineering that have been completed.

IN1.3.2 If a vehicle is no longer in compliance with the rules, the officials will set the vehicle's technical inspection status to fail, remove the respective inspection sticker(s) from the vehicle and note the reason for revoking the technical inspection approval in the technical inspection sheet.

IN1.3.3 Each car will be required to append a sticker on the car 8cm x 8cm, which identifies which drivers have completed which event. The location of the sticker must be on the left-hand side of the car above 350mm from the ground such that the marshals can record the driver's letter on the sticker at each event.

### **IN1.4 Inspection Responsible Person**

IN1.4.1 To accelerate the technical inspection process, the team must appoint one team member as inspection responsible person. [EV ONLY] For electrical inspection and accumulator inspection this has to be an ESO.

IN1.4.2 This inspection responsible person must be:

- Familiar with the vehicle,
- Able to show compliance of the vehicle with all points mentioned on the technical inspection sheet,
- Able to perform the technical inspection autonomously observed by the officials, when asked.

IN1.4.3 Should the inspection responsible person be unable to perform one of these requirements, or the vehicle and all necessary items are not ready, the technical inspection will be aborted, and the team will be asked to leave the technical inspection area.

### **IN1.5 Modifications and Repairs**

IN1.5.1 After technical inspection, the only modifications permitted to the vehicle are:

- Adjustment of belts, chains and clutches,
- Adjustment of the brake bias,
- Adjustment of the driver restraint system, head restraint, seat and pedal assembly,
- Substitution of the head restraint or seat insert for different drivers,
- Adjustment to engine operating parameters, e.g. fuel mixture and ignition timing,
- Adjustment of mirrors,
- Adjustment of the suspension where no part substitution, other than springs, sway bars and shims, is required,
- Adjustment of tyre pressure,
- Adjustment of winglet angles, but not the position of the complete aerodynamic device in relation to the vehicle,
- Replenishment of fluids,
- Replacement of defective tyres or brake pads. Replacement tyres and brake pads must be identical in material/composition/size to those presented and approved at technical inspection,
- Changing wheels and tyres for “wet” or “damp” conditions as allowed in D3.2 and D7.6,
- Software calibration changes,
- Recharging low voltage batteries,
- Recharging TS accumulators,
- Adjustments of AS sensors.

## **IN2      MOTORSPORT UK SAFETY INSPECTION**

### **IN2.1      Motorsport UK Safety Inspection Objective**

IN2.1.1      At the Motorsport UK Safety Inspection the driver's equipment and various aspects of the vehicle are checked for compliance with the rules.

### **IN2.2      Motorsport UK Safety Inspection Required Items**

IN2.2.1      The following items must be presented:

- All helmets,
- All driver's equipment and other safety gear,
- Two unused and in date fire extinguishers,
- The vehicle.

**IN3 [EV ONLY] ACCUMULATOR INSPECTION****IN3.1 Accumulator Inspection General Definitions**

IN3.1.1 Cell modules or stacks do not need to be disassembled when AIRs, fuses, pre- and discharge circuit and positive locking mechanism of the maintenance plugs are reachable and visible for the officials.

IN3.1.2 The accumulator charger and the accumulator will be inspected and sealed. If either are disassembled and the seals broken or removed, they must be reinspected and resealed before they can be used again.

IN3.1.3 The set of basic tools will be checked.

**IN3.2 Accumulator Inspection Required Items**

IN3.2.1 The following items must be presented at accumulator inspection:

- All TS accumulators,
- Accumulator hand cart,
- Accumulator charger,
- Basic Tools, see IN3.2.2,
- Tools needed for the (dis)assembly of parts,
- Samples of self-designed PCBs that are part of the tractive system and inside the TSAC, see EV4.3.7,
- Data sheets for all parts used in the accumulator,
- Original delivery notes for material without serial number printed on according to T1.2.1,
- Printouts of rule questions (if applicable).

IN3.2.2 The following basic tools in good condition must be presented:

- Insulated cable shears,
- Insulated screw drivers,
- Multimeter with protected probe tips and two 4mm banana plug test leads rated for 1000V CAT III or better,
- Insulated tools, if screwed connections are used in the tractive system,
- Face shield,
- at least two pairs of HV insulating gloves (not expired),
- Two HV insulating blankets of at least 1.0m<sup>2</sup> each,
- Safety glasses with side shields for all team members that might work on the tractive system or accumulator.

All electrical safety items must be rated for at least the maximum tractive system voltage.



## **IN4 [EV ONLY] ELECTRICAL INSPECTION**

### **IN4.1 Electrical Inspection General Definitions**

IN4.1.1 The insulation resistance between the TS and LVS ground will be measured. Vehicles with a maximum TS voltage less than or equal to 250V will be probed with 250V and vehicles with a maximum TS voltage greater than 250V with 500V.

To pass this test, the measured insulation resistance must be at least 500  $\Omega/V$  related to the maximum TS voltage of the vehicle.

IN4.1.2 The IMD will be tested by connecting a resistor between the TSMP, see EV4.7 and LVS ground connector, see EV4.7.8.

The test is passed if the IMD shuts down the TS within 30s at a fault resistance of 50 % below the response value which corresponds to 250  $\Omega/V$ .

### **IN4.2 Electrical Inspection Required Items**

IN4.2.1 The following items must be presented at electrical inspection:

- One ESO,
- Vehicle with the TS Accumulator removed,
- Quick jack, stands and push bar,
- Samples of self-designed PCBs that are part of the tractive system,
- Tools needed for the BSPD check, see T11.6.9,
- Equipment needed for the brake light check for regenerative braking, see T261250.32896.1988739072,
- Data sheets for all parts used in the tractive system,
- Tools needed for the (dis)assembly of parts for electrical inspection,
- Printouts of any relevant Rules questions.

## **IN5 MECHANICAL INSPECTION**

### **IN5.1 Mechanical Inspection Required Items**

IN5.1.1 The following items must be presented at mechanical inspection:

- The vehicle fitted with tyres for dry conditions,
- Quick jack, stands and push bar,
- The tallest driver of the team with their helmet,
- Copy of SES,
- Copies of any impact attenuator data requirement,
- Printouts of any relevant Rules questions,
- Impact attenuator test piece (except for teams with “standard” IA),
- Teams with a monocoque: laminate test specimen(s),
- Only tools needed for the (dis)assembly of parts for mechanical inspection,
- Data sheets for the headrest foam, LV Battery(s) and any other item with a material specification required by the rules,
- Photographic evidence demonstrating that the chassis is new for the year of entry.
- [LV HY ONLY] Copy of HSF
- [LV HY ONLY] HSC and any tools and/or materials required to confirm compliance with CV5.2.3.

## **IN6 [DV ONLY] AUTONOMOUS SYSTEM INSPECTION**

### **IN6.1 Autonomous System Inspection Required Items**

IN6.1.1 The following items are required:

- One ASR,
- The vehicle (in fully assembled, ready-to-race condition including mounted datalogger (see T14.3),
- Data sheets for all perception sensors,
- Documents which proof that all perception sensors meet local legislation,
- RES remote control
- ASF,
- Tools needed for the (dis)assembly of parts for autonomous system inspection,
- Printouts of rule questions (if applicable),

### **IN6.2 Autonomous System Inspection EBS Test**

IN6.2.1 The EBS performance will be tested dynamically and must demonstrate the performance described in T15.4.

IN6.2.2 The test will be performed in a straight line marked with cones similar to acceleration.

IN6.2.3 During the brake test, the vehicle must accelerate in autonomous mode up to at least 40km/h within 20m. From the point where the RES is triggered, the vehicle must come to a safe stop within a maximum distance of 10m.

IN6.2.4 In case of wet track conditions, the stopping distance will be scaled by the officials dependent on the friction level of the track.

IN6.2.5 The EBS test is conducted after all other elements of IN11 have been passed.

**IN7      TILT TEST**

**IN7.1      Tilt Test Procedure**

- IN7.1.1    The tilt test will be conducted with the tallest driver fully strapped in normal driving position.
- IN7.1.2    The tilt test will be conducted with all vehicle fluids at their maximum fill level.
- IN7.1.3    The vehicle will be placed upon the tilt table and to an angle of 60°. There must be no fluid leaks and all wheels must remain in contact with the tilt table surface.

## **IN8 VEHICLE WEIGHING**

### **IN8.1 Vehicle Weighing Procedure**

IN8.1.1 All vehicles must be weighed in ready-to-race condition.

IN8.1.2 All oil and coolant circuits must be at their maximum fill level. The fuel tank(s) must be empty [CV & AFR Only].

## **IN9 [EV ONLY] RAIN TEST**

### **IN9.1 Rain Test General Definitions**

- IN9.1.1 Vehicles must have passed electrical inspection, see IN4, to attempt the rain test.
- IN9.1.2 Prior to commencing the rain test the team must present their procedures (as described in the EV Safety Protocols document) for investigating an IMD activation to the satisfaction of the scrutineers.

### **IN9.2 Rain Test Procedure**

- IN9.2.1 The vehicle must be in ready-to-race condition. All components and constructions used to protect the vehicle from water during the rain test must be used during the entire competition.
- IN9.2.2 The tractive system must be active during the rain test.
- IN9.2.3 The vehicle must be jacked up using the quick jack, see T13.2.
- IN9.2.4 The vehicle must not be in ready-to-drive mode, see EV4.11.
- IN9.2.5 The test will be conducted without a driver.
- IN9.2.6 Water will be sprayed at the vehicle from any possible direction. The water spray is similar to a vehicle driving in rain and not a direct high-pressure stream of water.
- IN9.2.7 The test is passed if the IMD is not triggered while water is sprayed at the vehicle for 120s and 120s after the water spray has stopped.

## **IN10 NOISE TEST**

### **IN10.1 Noise Test Procedure [CV ONLY]**

IN10.1.1 The sound level will be measured during a static test.

IN10.1.2 The vehicle must be compliant at all engine speeds up to the maximum test speed, see CV3.2.1.

IN10.1.3 Teams must bring a laptop to indicate the engine speed measured by the Electronic Control Unit (ECU).

IN10.1.4 Measurements will be made with a free-field microphone placed free from obstructions at the exhaust outlet level, 0.5m from the end of the exhaust outlet, at an angle of 45° with the outlet in the horizontal plane.

IN10.1.5 Where more than one exhaust outlet is present, the test will be repeated for each exhaust and the highest reading will be used.

IN10.1.6 If the exhaust has any form of active tuning or throttling device or system, it must be compliant with the rules in all positions. Manually adjustable tuning devices must require tools to change them and must not be moved or modified after the noise test is passed. The position of the device must be visible to the officials and manually operable by the officials during the noise test.

IN10.1.7 The test will be run with the gearbox in neutral. During this test the vehicle must be jacked up using the quick jack (see T13.2).

IN10.1.8 After passing the noise test the function of the master switch, the cockpit-mounted shutdown button and the inertia switch will be tested.

IN10.1.9 After passing IN10.1.8 the air tightness of the intake system will be tested by closing off the inlet after which the engine must stall.

### **IN10.2 Noise Test Procedure [EV ONLY]**

IN10.2.1 The ready-to-drive sound level will be measured during a static test.

IN10.2.2 Measurements will be made with a free-field microphone placed free from obstructions in a radius of 2m around the vehicle.

## **IN11 BRAKE TEST**

### **IN11.1 Brake Test Procedure**

IN11.1.1 Lock all four wheels and stop the vehicle in a straight line at the end of an acceleration run specified by the officials.

Whilst at some point during the run all 4 wheels must be locked at the same time, it is acceptable for the front wheels to lock before the rear wheels.

IN11.1.2 [EV ONLY] After accelerating, the tractive system must be switched off by the driver and the driver must brake using only the mechanical brakes. It is acceptable for the TSAL to switch to green shortly after the vehicle has come to a complete stop as the reduction of the system voltage may take up to 5s.

IN11.1.3 The brake light and TSAL illumination will be checked, and the officials will verify if the illumination is satisfactory for external observation.



## IN12 POST EVENT INSPECTION

### IN12.1 Post Event Inspection Procedure

IN12.1.1 The officials reserve the right to impound any vehicle at any time during or after any of the dynamic events to check for compliance with the rules. If necessary, the vehicle will remain with the officials until the violation of the rule was discussed with the team.

IN12.1.2 After the endurance and trackdrive event, the vehicle must be placed in parc fermé where no team member may access the vehicle.

IN12.1.3 After any dynamic event, the vehicle must be in compliance with the rules.

IN12.1.4 For each violation of the rules, the team receives a separate penalty as follows:

- Group A: Violation of the rules without advantage for the team
- Group B: Violation of the rules with advantage for the team (e.g. aerodynamic device)

	Acceleration	Skidpad	Autocross	Endurance	Trackdrive
Group A	0.3s	0.3s	2s	30s	30s
Group B	1s	1s	5s	2min	2min

Table 7: Post Event Inspection Penalties

The penalty applies to all runs since the vehicle entered the dynamic area the last time.

IN12.1.5 Violation of the rules concerning safety or the environment (e.g. BOTS, safety harness issues, ground clearance, fluid leaks, noise) results in DQ for that particular run.

IN12.1.6 Losing a part of the vehicle on the track will result in DQ for that particular run.

IN12.1.7 Changes in vehicle weight of more than  $\pm 5\text{kg}$  compared to the official technical inspection weight (see IN8) results in a 20-point penalty for each kg the tolerance is exceeded by. E.g. a weight difference of  $\pm 6.2\text{ kg}$  results in a 40-point penalty.

IN12.1.8 [EV ONLY] The vehicle must be able to enter ready-to-drive mode, see EV4.11, during post inspection process for all tests requiring this mode. Violation will result in DQ.

IN12.1.9 [EV ONLY] Directly after endurance and leaving parc fermé, every team must come back to the charging area to disassemble the temperature logging device (if used by the competition) from the TS accumulator, see EV5.8.6.

IN12.1.10 Directly after the last dynamic discipline and leaving parc fermé, the Energy Meter (if installed), see EV4.6 or T14.3, will be disassembled from the vehicle.

## **IN13 DRIVER EGRESS TEST**

### **IN13.1 Driver Egress Test Objectives**

IN13.1.1 All of the drivers will be tested to prove they meet the requirements of:

- T4.3.1 – Minimum Helmet Clearance,
- T5 – Driver Restraint System.

### **IN13.2 Driver Egress Test Procedure**

IN13.2.1 The vehicle must have passed SAFETY, CHASSIS, TECH, [EV ONLY] EV BATTERY, [EV ONLY] EV VEHICLE and [EV ONLY] RAIN TEST before attempting the Driver Egress Test.

IN13.2.2 A Driver Egress Test will be completed for the tallest driver only at first to allow the vehicle to attempt the later stages of Inspection.

IN13.2.3 When all other aspects of Inspection are passed the remaining drivers can be tested.

IN13.2.4 The following vehicle and driver with helmet, gloves and shoes must be presented at the Driver Egress Test.

IN13.2.5 The three other team members allowed in the Inspection Area must strap the driver into the car in the normal driving position and make any required adjustments to the Driver Restraint System (harnesses and head restraint).

IN13.2.6 If there are any non-compliances these will be noted and must be corrected before the driver is allowed to attempt the Driver Egress Test.

IN13.2.7 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 ground.

## **SECTION S – STATIC EVENTS**

### **S1      STATIC EVENT NO-SHOW PENALTY**

**S1.1.1**      Where a team fails to notify officials, by the date and time specified in the competition handbook, that they are unable to attend their scheduled static event session, the organisers shall apply a points penalty of a maximum of (negative) 100 points per absent notification.

This will be applied to a team's overall event score. For the avoidance of doubt, this is additional to any specified penalty applicable for non-attendance at a scheduled static event session.

This penalty may be waived if extenuating circumstances are presented to and accepted by the officials.

## **S2 BUSINESS PLAN PRESENTATION (BPP) – FS CLASS AND CONCEPT CLASS**

### **S2.1 Business Plan Presentation Objective**

- S2.1.1 The objective of the BPP is to evaluate the team's ability to develop and deliver a comprehensive business model which demonstrates that selling their vehicle could become a rewarding business opportunity.
- S2.1.2 Given the quality of the competitor's car is not considered within the BPP event, Formula Student Class and Concept Class teams compete directly against each other
- S2.1.3 The BPP event is a role play and teams should present themselves as employees of a company rather than as students.
- S2.1.4 The judges should be treated as if they were potential investors or partners for the presented business model. Teams should assume that the "executives" represent different areas of a corporate organisation, including engineering, production, marketing and finance, and thus may not all be engineers.
- S2.1.5 The business plan must relate to the specific prototype race car entered in the competition. The quality of the actual prototype will not be considered as part of the BPP judging.
- S2.1.6 The Business presentations must consider a "special condition" set prior to the event.
- S2.1.7 Teams are free to suggest their own manufacturing volume / production rate targets, within their Business Presentations.
- S2.1.8 Teams may choose to use Pounds Sterling, US Dollars, or Euros as currency within their presentation.

### **S2.2 Business Presentation Schedule**

- S2.2.1 The Business Plan Presentation Judging will take place in two parts:
  - Initial judging of all teams,
  - Final judging of up to the 5 top teams.
- S2.2.2 Initial judging of Business Presentations will be made on the static events days. Presentation times will be published in the event schedule. Teams are reminded that the Business Presentations will be held in the Business Presentation judging rooms, NOT at your display area.
- S2.2.3 All initial judging sessions may be recorded by the BPP judging team.
- S2.2.4 Teams arriving more than eleven (11) minutes late to their assigned BPP judging slot will be deemed to have missed their assigned time period.
- S2.2.5 Final judging of up to the 5 top teams will take place during the BPP Final. Qualifying teams will be notified in advance of the final.

### **S2.3 Business Presentation Format**

- S2.3.1 One or more team members may participate in the presentation.
- S2.3.2 All team members who will give any part of the presentation, or who will respond to the judges' questions, must be listed on the first slide. Team members who are part of this "presentation group" may answer the judge's questions even if they did not speak during

the presentation itself.

- S2.3.3 Presentations are limited to a maximum of ten (10) minutes. Penalties will be imposed if the presentation is less than nine (9) minutes or exceeds eleven (11) minutes. Teams will be asked to rapidly conclude their presentation and may be stopped by the judges if they significantly overrun.
- S2.3.4 The presentation itself will not be interrupted by questions. Immediately following the presentation there will be a question and answer session of up to five (5) minutes.
- S2.3.5 Only team members who are part of the “presentation group” may answer the judges’ questions.
- S2.3.6 Teams are required to provide an electronic copy of their slide pack and any supporting documentation to the BPP judging team during their presentation slot. Submissions must be in the below file formats and transfer will be conducted via USB pen drive, supplied by the judges:
- Presentation slide pack: \*.pptx or \*.pdf,
  - Supporting document(s): \*.pdf.
- S2.3.7 The format of the final judging will be the same as for the initial judging including Questions & Answers. The “presentation group” for the final must consist of the same team members as the initial judging.
- S2.3.8 Access to an internet connection during the initial or final judging cannot be guaranteed.

## **S2.4 Data Projection Equipment**

- S2.4.1 LCD TV-style screens or video projectors will be provided by the organisers, but teams should bring their own laptop computers and may use their own projectors if they wish. The screens/projectors will have HDMI and VGA Input Connectors. Teams are responsible for the compatibility of their computer equipment and setting up of the screens. Overseas teams should ensure they have UK compatible power leads/adaptors.

## **S2.5 Evaluation Criteria**

- S2.5.1 The presentation will be evaluated against the following categories:
- Content,
  - Visual Aids,
  - Delivery,
  - Q&A.
- S2.5.2 The criteria are applied only to the team’s presentation itself. The team that makes the best presentation, regardless of the quality of their car, will win the event.
- S2.5.3 Content marks will only be awarded for the information presented to the judges. Printed material to support this is allowable but must:
- Be referred to within the presentation,
  - Be limited to a maximum of eight (8) sides of A4 paper. Decorative covers are excluded from this page count.

## S2.6 Scoring Formula

S2.6.1 To ensure judging allows an acceptable separation between teams, the BPP event is marked out of 460 marks – please note: this number may change due to modifications of the marking scheme between the rules being published and the competition taking place, but any changes will be consistent to all teams. A team’s mark out of 460 will be converted into a maximum of one hundred and fifteen (115) points that count towards the Formula Student competition as described below.

S2.6.2 Up to 5 teams will be invited to participate in the BPP final, finalists will be required to deliver their presentation live to a single judging panel. The presentation must not be changed from the initial judging and must be delivered by the same members of the “presentation group”. Points will be allocated to top six teams will be as shown in Table 8 below.

Teams in Final	Points assigned					
	1st	2nd	3rd	4th	5th	6th
2	115	105	103*	pro-rata	pro-rata	pro-rata
3			103	101*	pro-rata	pro-rata
4				101	100*	pro-rata
5					100	99*

Table 8: BPP Finalist Scores

S2.6.3 The BPP scores for non-finalists will be normalised and awarded on a pro-rata basis using the following formula:

$$BUSINESS\ PLAN\ PRESENTATION\ SCORE = HFNS \left( \frac{P_{your}}{P_{max}} \right)$$

Where:

- HNFS is the highest non-finalist score (as indicated with a \*) shown in Table 2,
- $P_{max}$  is the mark achieved out of 460 by the highest non-finalist,
- $P_{your}$  is the mark achieved out of 460 by your team.

S2.6.4 The BPP Event Captain may at their discretion; normalise the scores of different judging teams.

## S2.7 Business Plan Presentations without a Completed Car

S2.7.1 Given the quality of the competitor’s car isn’t considered within the BPP event, Formula Student and Concept Class teams compete directly against each other.

S2.7.2 Formula Student Teams that are unable to bring a vehicle to the competition may participate in the BPP event and will receive a score for that event.

S2.7.3 Participating in the BPP event without bringing a vehicle to the competition will not affect vehicle eligibility as per Rule A2.

### **S3 COST AND MANUFACTURING EVENT – FORMULA STUDENT CLASS**

#### **S3.1 Cost and Manufacturing Objective**

S3.1.1 The objective of the cost and manufacturing event is to evaluate the team’s understanding of the manufacturing processes and costs associated with the construction of a prototype race car. This includes trade off decisions between content and cost, make or buy decisions and understanding the differences between prototype and mass production.

#### **S3.2 Cost and Manufacturing Procedure**

S3.2.1 Prior to the competition, three Cost Report Documents (CRD) (see S3.3) must be submitted to the competition website by the deadline specified on the website.

S3.2.2 During the competition, a discussion with the judges will take place, next to the team’s vehicle. The discussion is split into two parts:

S3.2.3 Part 1 “BOM Discussion”:

A discussion to evaluate the team’s ability to prepare an accurate engineering and manufacturing BOM for the complete vehicle. The team must prove the following:

- The specification of the vehicle in the CRD accurately reflects the vehicle brought to the competition,
- The costs within the Costed Bill of Material (CBOM) (part of the BOM) are correct and realistic,
- The manufacturing feasibility of the vehicle.

S3.2.4 Part 2 “Cost Understanding”:

A discussion to evaluate the general cost and manufacturing knowledge of the team.

S3.2.5 The teams must present their vehicle at the designated time to the judges. Teams that miss their time slot will lose all points for the cost event.

S3.2.6 Teams are allowed to bring electronic, handwritten, or printed handouts, flip charts, or similar to the event, but the space available may be limited.

#### **S3.3 Cost Report Documents**

S3.3.1 The CRD consists of the following documents:

- The Bill of Material file (BOM) uploaded as a PDF in A4 landscape format
- The Supporting Material file uploaded as a PDF in A4 portrait format
- The Cost Explanation file uploaded as a PDF in A4 portrait format

S3.3.2 Changes to the CRD will not be permitted after the deadline.

S3.3.3 A changelog of the changes on the vehicle since the submission deadline of the CRD can be presented at the BOM discussion to the judges. Missing parts of the BOM cannot be part of the changelog.

S3.3.4 All CRD must be brought as a hard copy to the event and must match exactly the submitted documents.

S3.3.5 The BOM shall be created utilising the online BOM tool, any other format will not be

- scored. The website tool will provide a printable pdf version of the BOM.
- S3.3.6 The hard copy must be in a ring binder with DIN A4 pages (or similar).
- S3.3.7 The team must ensure that two judges are able to review the CRD independently.
- S3.3.8 The presented CRD must be identical with the uploaded versions, otherwise five penalty points will be deducted from the team's cost event score.
- S3.4 Bill of Material**
- S3.4.1 The BOM is a sorted list for every vehicle part.
- S3.4.2 The BOM must list all parts and equipment fitted to the prototype vehicle at any time during the competition.
- S3.4.3 The BOM is structured as follows:
- The BOM is broken down into “systems” (see S3.4.6), which are defined by the website tool,
  - Each “system” is broken down into “assemblies”, which are defined by the website tool,
  - Each “assembly” can optional be broken down into “sub-assemblies”, which must be defined by the team,
  - Each “assembly” or “sub-assembly” is broken down into “parts”, which must be defined by the team.
- S3.4.4 “Fasteners” are additional items necessary to assemble to “part” and should not be listed.
- S3.4.5 A self-manufactured “fastener” is considered a “part”.
- S3.4.6 The “systems” are:
- Brake System,
  - Engine and Drivetrain,
  - Chassis and Body,
  - Electrical,
  - Miscellaneous, Fit and Finish,
  - Steering System,
  - Suspension System,
  - Wheels, Wheel Bearings and Tyres,
  - [DV ONLY] Autonomous system.
- S3.4.7 The “assemblies” of each “system” are provided by the website tool.
- S3.4.8 When adding “parts” to the BOM, the comments section should be reviewed thoroughly. The chosen part name must clearly describe what is included. For example, if a spring is included, the “part” should not be called “damper”.
- S3.4.9 Only metric units must be used within the BOM.



- S3.4.10 Only dry tyres and wheels per T2.5.1 need to be included and must be mounted on the vehicle during judging.
- S3.4.11 Two or three systems of the BOM must have a DBOM e.g. list all parts/assembly, materials, and processes. (See S3.5).
- S3.4.12 One or two systems of the DBOM must be a CBOM e.g. list all parts/assembly, materials, processes, and costs. (See S3.6).

### **S3.5 Detailed Bill of Material**

- S3.5.1 The manufacturing processes of all parts from two or three BOM systems, specified prior to the event, must be listed in the DBOM.
- S3.5.2 Additional to the BOM, the DBOM must:
- Include the actual associated manufacturing processes for each part as used for the prototype vehicle,
  - Include tooling (e.g. welding jigs, moulds, patterns and dies),
  - Not include any cost, except for the “systems” described in S3.6.
- S3.5.3 Additional to the structure of the BOM, the DBOM is structured as follows:
- Each “part” is broken down into “materials” and “processes”,
  - Each “process” may be broken down into “tooling” and “fasteners”, if applicable.
- S3.5.4 Each constituent “part” of an “assembly” must be classified as “bought” or “made”.
- S3.5.5 For each “bought part”, only fasteners must be included (if required). If the part was modified, the associated processes for this modification must be included.
- S3.5.6 For each “made part” the raw material, all production processes, tooling and all required fasteners must be included.
- S3.5.7 “Processes” are the necessary operations to produce the “part” out of the “material”.
- S3.5.8 “Material” is the raw material of a part, e.g. aluminium.
- S3.5.9 “Tooling” is the necessary tools used for transforming the “material” into the desired shape.

### **S3.6 Costed Bill of Material**

- S3.6.1 The actual costs of the prototype vehicle as presented must be included for two BOM systems, which will be specified prior to the competition.
- S3.6.2 The cost calculations must include the costs of materials, fabrication, bought parts, and assembly to the vehicle, and must be completed as realistically as possible.
- S3.6.3 The cost calculations must exclude research, development and capital expenditures for real estates (e.g. plant or development hours of the team).
- S3.6.4 All costs must be displayed in EUR. For calculating the prices in EUR from other currencies, the team must provide the exchange rates used.

- S3.6.5 There is no maximum cost. Receipts are not required for any items.
- S3.6.6 If production tooling is associated with processes that are specific to the part geometry, it must be included. For example, the dies to stamp out a chassis bracket are tooling.
- S3.6.7 The costs of hand or power tools must not be included.
- S3.6.8 The estimations for machining rates, hourly rates, included overheads etc. must be shown.

### **S3.7 Supporting Material File**

- S3.7.1 The Supporting Material File is a document containing additional information which allows the judges to understand the BOM. It should include drawings, exploded view drawings and/or pictures of the vehicle and the parts included in the BOM.

### **S3.8 Cost Explanation File**

- S3.8.1 The Cost Explanation File is a document containing additional explanations which allow the judges to understand the costs within the CBOM part of the BOM.
- S3.8.2 The Cost Explanation File should point out which cost model was used, and which types of costs are included. It should also contain which specific cost figures were used, e.g. the cost of one machine operation hour.

### **S3.9 Cost and Manufacturing Vehicle Condition**

- S3.9.1 Vehicles must be presented for cost and manufacturing judging in finished condition, fully assembled, complete, ready-to-race and with its dry tyres (see T2.5.1) mounted.
- S3.9.2 The judges may not evaluate any vehicle, that is presented at the cost and manufacturing event, in what they consider to be an unfinished state and may apply a penalty in line with standard tariff (e.g. not attending Cost Judging session or a documentation fault).
- S3.9.3 Vehicles may be presented for judging without having passed technical inspection, even if final tuning and setup is in progress.
- S3.9.4 Covers and/or parts may be removed during the judging to facilitate access and presentation of components or concepts.
- S3.9.5 [EV ONLY] Only sealed TSACs which passed the accumulator inspection may be presented or mounted in the vehicle. They must not be opened.
- S3.9.6 [IC ONLY] Only cars that have successfully pass the Tilt Test may be fuelled during the event.

### S3.10 Cost and Manufacturing Scoring

S3.10.1 The cost and manufacturing event will be evaluated on the categories specified in the following table:

Category	Points
Format and Accuracy of Documents	5
Knowledge of Documents and Vehicle	5
Content and Completeness of the BOM	20 (2x10)
Realism of the CBOM	30
Discussion Part 2 "Cost Understanding"	45
Cost Final	10
Total	115

Table 9: FS Class Cost event scoring

S3.10.2 If items are missing from the BOM, points are deducted and reported up to a maximum - 100 points:

Missing Item	Points
Assembly	-5
Part	-3
Process/Material	-1

Table 10: Cost event BOM penalties

S3.10.3 A maximum of four top teams will be chosen to participate in the Cost and Manufacturing finals to determine the Cost and Manufacturing Event winner. The Cost and Manufacturing finals will be held separately from the initial judging and teams will be informed about their participation during the event.

S3.10.4 The scoring for the non-finalist is calculated as followed:

$$COST\ SCORE = 105 \left( \frac{P_{team}}{P_{max}} \right)$$

- $P_{team}$  is the score awarded to the team,
- $P_{max}$  is the highest score awarded to any team not participating in the finals.

S3.10.5 The scoring of the cost and manufacturing finalists will vary from 115 to 105 points.

S3.10.6 The maximum penalty for the Cost and Manufacturing Event is capped at 115 penalty points.

S3.10.7 Teams that submit incorrectly formatted documentation, completed not as prescribed or one of the three required pieces of documentation is missing from the upload/submission may be subject to a penalty of up to 30 points per failed document on top of any late penalties incurred.

S3.10.8 Teams that submit their Cost Report Documents after the Final Deadline published in the Key Dates document are expected to attend the Cost event with the correct documentation for judging. Failure to supply documentation at your cost judging slot will result in penalties in line with S3.9.2 in addition to those received for missing the Final Deadline.

## **S4 COST AND MANUFACTURING EVENT – CONCEPT CLASS**

### **S4.1 Cost and Manufacturing Objective**

- S4.1.1 The objective of the cost and manufacturing event is to evaluate the team’s understanding of the manufacturing processes and costs associated with the construction of a theoretical prototype race car. This includes trade off decisions between content and cost, make or buy decisions and understanding the differences between prototype and mass production.

### **S4.2 Cost and Manufacturing Procedure**

- S4.2.1 Prior to the competition, three Cost Report Documents (CRD) must be submitted to the competition website by the deadline specified in the competition handbook.
- S4.2.2 During the competition, a 30 min discussion with the judges will take place. Followed by a 10 -15-minute presentation by the team on the real-world task.
- S4.2.3 The discussion is split into two parts:
- (a) Part 1 “Costed Bill of Material (CBOM) Discussion”:
- A discussion to evaluate the team’s ability to prepare an accurate engineering and manufacturing Costed Bill of Material (CBOM), evaluating both for correctness and manufacturing feasibility.
- (b) Part 2 “Cost Understanding”:
- A discussion to evaluate the general cost and manufacturing knowledge of the team.
- S4.2.4 The teams must present their CRD at the designated time to the judges. Teams that miss their time slot will lose all cost points for that day.
- S4.2.5 Real World Task. Details will be announced to the teams early in 2024 relating to what this task will be.

### **S4.3 Cost Report Documents (CRD)**

- S4.3.1 The CRD consists of the following documents.
- (a) Costed Bill of Materials (CBOM) of the frame and Body uploaded as a PDF in A4 landscape format. e.g. list all parts/assembly, materials, and processes and associated costs (No other BOMs (DBOMs or CBOMs) for any other part or section of your car are required for this event).
- (b) The Supporting Material file uploaded as a PDF in A4 portrait format for your frame and body (only).
- (c) The Cost Explanation file uploaded as a PDF in A4 portrait format for your frame and body (only).
- S4.3.2 The BOM shall be created utilising the online BOM tool, any other format will not be scored.
- S4.3.3 Changes to the CRD will not be permitted after the deadline.
- S4.3.4 All CRD must be brought as a hard copy to the event and must match exactly the submitted documents.

#### **S4.4 Costed Bill of Material (CBOM)**

- S4.4.1 The cost calculations must include the costs of materials, fabrication, bought parts and assembly to the vehicle and must be completed as realistically as possible.
- S4.4.2 The cost calculations must exclude consider research, development and capital expenditures for real estates (e.g. plant or development hours of the team).
- S4.4.3 All costs must be displayed in EUR. For calculating the prices in EUR from other currencies, the team must provide the exchange rates used.
- S4.4.4 There is no maximum cost. Receipts are not required for any items.
- S4.4.5 If production tooling is associated with processes that are specific to the part geometry, it must be included. For example, the dies to stamp out a chassis bracket are tooling.

#### **S4.5 Supporting Material File**

- S4.5.1 The supporting material file is a document containing additional information which allows the judges to understand the CBOM. It should include drawings, exploded view drawings and/or pictures of the vehicle and the parts included in the CBOM.

#### **S4.6 Cost Explanation File**

- S4.6.1 The cost explanation file is a document containing additional explanations, which allow the judges to understand the costs within the CBOM.
- S4.6.2 The cost explanation file should point out which cost model was used, and which types of costs are included. It should also contain which specific cost figures were used, e.g., the cost of one machine operation hour, labour rate per hour etc.
- S4.6.3 The estimations for machining rates, hourly rates, included overheads etc. must be shown.

#### **S4.7 Cost and Manufacturing Scoring**

- S4.7.1 The cost and manufacturing event will be evaluated on the categories specified in the following table:

Category	Points
Format and Accuracy of Documents	5
Knowledge of Documents and Vehicle	5
Content and Completeness of the CBOM	20
Realism of the CBOM	30
Discussion Part 2 "Cost Understanding"	50
Real world task	30
Cost Final	10
Total	150

Table 11: Concept Class Cost event scoring

S4.7.2 Teams that submit incorrectly formatted documentation, completed not as prescribed or one of the three required pieces of documentation is missing from the upload/submission may be subject to a penalty of up to 30 points per failed document on top of any late penalties incurred.

S4.7.3 A maximum of four top teams will be chosen to participate in the cost and manufacturing finals to determine the Concept Class cost and manufacturing event winner. The cost and manufacturing finals will be held separately from the initial judging and teams will be informed about their participation during the event.

S4.7.4 The scoring for the non-finalist is calculated as followed:

$$COST\ SCORE = 140 \left( \frac{P_{team}}{P_{max}} \right)$$

- $P_{team}$  is the score awarded to the team,
- $P_{max}$  is the highest score awarded to any team not participating in the finals.

S4.7.5 The scoring of the cost and manufacturing finalists will vary from 140 to 150 points.

## **S5 ENGINEERING DESIGN EVENT – FORMULA STUDENT CLASS**

### **S5.1 Engineering Design Objective**

S5.1.1 The concept of the design event is to evaluate the student's engineering process, understanding and effort that went into the design of a vehicle, meeting the intent of the competition.

S5.1.2 Proprietary components and systems that are incorporated into the vehicle design as finished items are not evaluated as a student designed unit but are only assessed on the team's selection and application of that unit.

### **S5.2 Engineering Design Report (EDR)**

S5.2.1 The EDR should contain a brief description of the overall vehicle with a review and derivation of the team's design objectives. Any information to scope, explain or highlight design features, concepts, methods or objectives to express the value and performance of the vehicle to the judges shall be included at the teams' discretion.

S5.2.2 The EDR must not exceed eight (8) pages, consisting of not more than five (5) pages of content (text, which may include pictures and graphs) and three pages of drawings.

TIP: Do not use newspaper style twin columns of text or wrap text around images or graphs as reading and evaluating such Reports is hard for Judges using a laptop.

S5.2.3 The three EDR drawings (no renderings) must show the vehicle from the front, the top and the side. Each drawing must appear on a separate page.

S5.2.4 Any measures to facilitate reviewing the drawings (e.g. measurements, details, colours) may be utilized at the teams' discretion.

S5.2.5 Any portions of the EDR that exceeds five pages of content and/or three pages of drawings will not be evaluated.

S5.2.6 If included, cover sheets and tables of contents will count as text pages.

S5.2.7 The EDR shall be used to sort the teams into appropriate Design Judging Groups based on the quality of the information and understanding of the event objectives contained in the Report.

S5.2.8 Evidence of information mentioned in the EDR should be brought to the competition and be available, on request, for review by the judges.

### **S5.3 Design Spec Sheet**

S5.3.1 A completed DSS must be submitted online on the competition website.

### **S5.4 Engineering Design Procedure**

S5.4.1 The design event starts with the submission of the DSS and the EDR and their review respectively.

S5.4.2 At the competition, teams will present their knowledge and their vehicle to the judges, who will evaluate the teams' performance following the design objectives stated in S5.1.

S5.4.3 Some teams may be chosen to participate in a Design Final to determine the Engineering

Design event winner. The Design Final will be held separately from the initial judging and teams will be informed about their participation during the event.

To be considered for the Design Final, the vehicle must have passed all elements of scrutineering. In exceptional circumstances the Organisers may relax this requirement so long as it is applied equitably across all potential Design Finalists.

S5.4.4 Teams may bring any photographs, drawings, charts, spare parts or other material that they believe are supportive to the design event, but the space provided for design judging may be limited.

S5.4.5 [EV ONLY] Only sealed TSACs which passed the accumulator inspection may be presented or mounted in the vehicle. They must not be opened.

S5.4.6 [IC ONLY] Only cars that have successfully pass the Tilt Test may be fuelled during the event.

## **S5.5 Engineering Design Vehicle Condition**

S5.5.1 Vehicles must be presented for design judging in finished condition, fully assembled, complete and ready-to-race.

S5.5.2 The judges may not evaluate any vehicle that is presented at the design event in what they consider to be an unfinished state and may, at their sole discretion, award a substantially reduced score for the entire design event.

S5.5.3 Vehicles may be presented for design judging without having passed technical inspection, even if final tuning and setup is in progress.

S5.5.4 Covers and/or parts may be removed during the design judging to facilitate access and presentation of components or concepts.

## **S5.6 Engineering Design Judging Criteria**

S5.6.1 The judges shall inspect the vehicle and discuss the vehicle design with the team to determine if the design concepts are adequate and appropriate for the application (relative to the objectives set forth in the rules). The judges may sit in the vehicle to ascertain the ergonomics and the driver environment.

S5.6.2 The judges may deduct points if the team cannot adequately explain the engineering and construction of the vehicle.

## **S5.7 Engineering Design Scoring**

S5.7.1 The overall engineering design event maximum scoring is 150 points for FS Class.

S5.7.2 Up to 50 penalty points may be given to teams that demonstrate a fundamental lack of engineering knowledge and are unable to provide justification for their designs, including the use of 'carry-over parts' from previous competition vehicles.

The Universal Design Judging Score Sheet for both FS and Concept Class will be available at:

<https://www.imeche.org/events/formula-student/team-information/forms-and-documents>



## **S6 ENGINEERING DESIGN EVENT – CONCEPT CLASS**

- S6.1.1 The concept of the design event is to evaluate the student’s engineering process, understanding and effort that went into the design of a vehicle, meeting the intent of the competition.
- S6.1.2 The maximum points awarded for the Concept Class Engineering Design Event are 150 points.
- S6.1.3 Prior to the event, teams will submit an Engineering Design Report and Engineering Design Spec Sheet. These documents should reflect the current state of development of the designs and outline plans for resolution of outstanding issues/manufacture. As per the Formula Student regulations, late submission of documents will be penalised. For the Engineering Design event documents, penalties will be awarded as per Formula Student but note that Concept Class entrants are not required to submit an Impact Attenuator Report. The requirement for pre-judging submissions of individual Score Sheet Category presentations may be added. If required, teams will be informed via email and the Key Dates spreadsheet will be updated. We aim to inform teams of this requirement no later than April for a June submission deadline.
- S6.1.4 Understanding that the vehicle design/manufacture is incomplete, i.e. a non-running vehicle, the judges will be looking at the project planning as well as the design process and will be looking to see evidence of understanding of proposed manufacturing methods and their implications (e.g. costs, tooling requirements, etc).
- S6.1.5 Judges expect to see proof of reasoning for key design and concept choice decisions. Given that Formula Student accommodates alternative powertrain technology possibilities it is expected that teams will outline their basic conceptual choice in this regard in some detail. In recognition of the “real world” it is further expected that teams will consider fully the costs of manufacture, service and safety of innovative design choices in addition to the usual parameters of mass and performance and customer appeal. You should note that there is an increased link between the information provided to Cost & Manufacturing, Engineering Design and Business Plan Presentation static event judges.
- S6.1.6 Although the Concept Class does not require manufacture of a vehicle, and may be judged online, it is in your interests to have manufactured or procured some real parts before the competition. You will be able to then demonstrate greater understanding of how you progress from “paper” to “part”.
- S6.1.7 Points will be awarded according to the Universal Engineering Design Scoring Sheet. <https://www.imeche.org/events/formula-student/team-information/forms-and-documents>.
- S6.1.8 There is no Design Final for Concept Class entrants: the only potential exception is if under “force majeure” the Organisers decide to run a fully virtual/online event where all entries effectively become Concept Class. All entries will be notified in such circumstances.

## **S7 LAP TIME SIMULATION (LTS)**

IPG Automotive provides virtual test-driving software, hardware and web application tools to the automotive industry, this enables early testing of designs to ensure design confidence prior to physical build and enables data driven Conceptual Design choices to be made.

The Lap Time Simulation event was created to help students get started with using virtual test-driving software (CarMaker) and to provide less experienced teams with a baseline vehicle to adapt to match their intended vehicle.

The 2024 virtual vehicles and parameter sets will be released by the deadline in the Key Dates document on the FS website.

Teams are reminded that they may register for their free CarMaker license at any time to familiarise themselves with how to use the software package.

### **S7.1 Software and User Documentation**

**S7.1.1** All CarMaker license requests must be submitted no later than 8 weeks before and Web Tools registration must be requested no later than 4 weeks before the final submission deadline published in the Key Dates document on the FS website.

It is not guaranteed that IPG Automotive will process your requests after these dates which may prevent your team from participating in the LTS event. It is recommended teams submit their requests well in advance of the deadlines above.

**S7.1.2** Registration for LTS requires the three steps to be completed at the links below:

- Register your team for the Formula CarMaker program:  
<https://ipg-automotive.com/en/company/research-teaching/registration-formula-carmaker/>
- Register for a Formula CarMaker license:  
<https://ipg-automotive.com/en/support/licenses/formula-carmaker/>
- Register for the web-application tool suite (VVB and NGD):  
<https://fcm.ipg-automotive.uk/>

**S7.1.3** The CarMaker software and the Formula CarMaker package can be downloaded from the Formula CarMaker customer area on the IPG Automotive website:

<https://ipg-automotive.com/en/support/customer-area/>

Log in credentials will be provided with your Formula CarMaker license file.

**S7.1.4** A Formula CarMaker tutorial can be found within the “FCM Tutorial” folder in the install directory file path:

[...\formula-carmaker-R022.1\FCM\\_Tutorial](#)

Support is also available on the IPG Automotive forum:

<https://forums.ipg-automotive.com/> and by email as per **Error! Reference source not found..**

S7.1.5 Help documentation for the Virtual Vehicle Build (VVB) & Non-Geometric Database (NGD) can be found in the side menu of the web applications. This documentation includes:

- How to get started with the LTS competition using the web application tools
- Competition guidelines
- How to submit your final model

S7.1.6 It is recommended that teams review the previous LTS webinars available here:

[LTS Webinar Playlist](#)

S7.1.7 Upon the start of the LTS event, there will be a 4-week window where the software may be updated in response to any bugs flagged by teams. There will be no updates to the software after this 4-week window unless any critical issues are identified.

S7.1.8 Any requests for support for questions not captured in the tutorials, webinars or documentation, or to flag a potential bug should be sent by email with **“FS LTS” in the Subject Line** to: [FormulaCarMaker@ipg-automotive.com](mailto:FormulaCarMaker@ipg-automotive.com)

Please ensure you provide sufficient detail for the support team to understand and recreate the problem(s) you are facing.

## **S7.2 Event Format and Scoring**

S7.2.1 The LTS event aims to simulate the real-world scenario where you “the team” are using LTS to evaluate the relative performance of four different Formula Student powertrain types and two aerodynamic configurations.

It consists of two major elements:

- LTS Vehicle Evaluation – completed using the CarMaker software and LTS specific download files, this element is administered by IPG Automotive.

Any questions on this element should be raised by sending an email with **“FS LTS” in the Subject Line** to: [FormulaCarMaker@ipg-automotive.com](mailto:FormulaCarMaker@ipg-automotive.com)

- Model Validation Test Plan – a short report submission, this element is administered by the IMechE.

Any questions on this element should be raised on the FSQD (See Rule A3.6)

S7.2.2 The LTS event is a stand-alone competition and does not require any relation to the team’s FS Class or Concept Class vehicle.

S7.2.3 Submission deadlines and associated lateness penalties are detailed in the Key Dates document on the Formula Student website.

S7.2.4 Any incomplete submissions will be treated as non-submissions and attract lateness penalties as per the Key Dates document.

S7.2.5 Teams are reminded that Rule A4.2.3 applies to the LTS Event. FS Class and Concept Class team from the same university are classed as separate teams. Any suspicion of collaboration between teams will be reported to the Chief Judge and may result in both teams being disqualified.

S7.2.6 The maximum possible event scores for FS Class and Concept Class are:

	<b>FS Class</b>	<b>Concept Class</b>
LTS Vehicle Evaluation	15 points	30 points
Model Validation Test Plan	5 points	10 points
<b>Total</b>	<b>20 points</b>	<b>40 points</b>

Table 12: LTS Scoring

S7.2.7 The main “LTS Vehicle Evaluation” task requires teams to develop the optimal setup from the matrix of possible vehicle and parameter combinations, deriving a vehicle configuration that achieves the highest combined event score for simulated Acceleration, Skid-Pad and Sprint events.

S7.2.8 The maximum points available for each simulated event will be as per the normal FS rules:

- Acceleration – 75 points
- Skid-Pad – 75 points
- Sprint – 100 points

The scoring for each of these events will be identical to those used in the real-world dynamic events, please see Part D1 of this Rulebook for details

S7.2.9 The number of simulation iterations is unlimited, but only one final vehicle model must be built and submitted using the Virtual Vehicle Builder (VVB) web application tool:

<https://fcm.fleet.ipg-automotive.uk/>

S7.2.10 All submissions will be checked to ensure they comply with the restrictions detailed in the User Documentation. Any submission that deviates from these will result in disqualification and zero points will be scored for each of the affected events.

S7.2.11 The secondary task is to submit a Model Validation Test Plan report. It is to be treated as a high-level summary to be presented to your Chief Engineer, giving an overview of your proposed vehicle model validation process.

The report should detail the series of tests you intend to complete (at vehicle and sub-system level), including the instrumentation required to capture the necessary data, and how you intend to account for real world variability and environmental conditions when post-processing the experimental results.

S7.2.12 The Model Validation Test Plan must be a maximum of two (2) pages, in Arial font with a minimum size of 10pt. If included, cover sheets and tables of contents will count as text pages.

S7.2.13 Points will be awarded for covering the expected topics, in a logical, clear and concise manner, with adequate engineering rationale and graded as per Table 13.

Grade	Grading Notes	FS Class	Concept Class
A	Excellent report, all expected topics covered with sound engineering rationale for all points, presented in a logical, clear and concise manner.	5 pts	10 pts
B	As Grade A but lacking in some of the required areas	4 pts	8 pts
C	As Grade A but lacking in several of the required areas	3 pts	6 pts
D	As Grade C but poor quality report	2 pts	4 pts
E	As Grade C but very poor quality report	1 pts	2 pts
F	Report does not address any aspects of the brief / non-submission.	0 pts	0 pts

Table 13: Model Validation Test Plan scoring

### S7.3 LTS Vehicle Evaluation Parameters

- S7.3.1 Please see the “LTS Documentation” within the web application tools suite for full details and limits for the tuneable parameters. Should there be any discrepancies the User Documentation prevails as the correct requirement.
- S7.3.2 All tuneable parameters must be set to values which are realistically achievable in a real-world scenario. This should be automatically restricted within the software; exploitation of any loopholes may result in disqualification from the LTS event. Any queries on the legality of a setting should be raised on the FSQD as per A3.6.
- S7.3.3 The four powertrain types are:
- NA Gasoline,
  - Turbo-Charged Gasoline,
  - Single Motor Electric Vehicle,
  - Four Motor Electric Vehicle.
- S7.3.4 The two aerodynamic configurations are:
- Minimal Aerodynamic Package,
  - High Downforce Aerodynamic Package.
- S7.3.5 The mass of the vehicle is dependent on the powertrain type and aerodynamic configuration.
- S7.3.6 The selected powertrain type and aerodynamic configuration must be the same for all three of the Virtual Dynamic Events in the submitted final virtual vehicle model.
- S7.3.7 The tyre model is fixed and may not be adjusted.
- S7.3.8 The tuneable vehicle parameters must be identical for all three of the Virtual Dynamic Events in the submitted final virtual vehicle model.

S7.3.9 The following parameters are available to tune:

DRIVER

Driver Aggression: Five tuneable parameters, see User Documentation for details

SUSPENSION

Spring Rates: Any linear rate

ARB Rates: Any linear rate

Bump Stop Gap: Any value within limited range

Rebound Spring Gap: Any value within limited range

Damping Rates: Various Force vs Velocity curves in a 1-D table

Kinematics: 5 configurations per axle with camber and toe options

BRAKE SYSTEM

Front Braking Torque Any value within limited range

Rear Braking Torque Any value within limited range

VEHICLE DRIVELINE

Differential Type Open, spool (locked) or torque sensing (three options, N/A for Four Motor EV)

Gear Ratios Max 6 ratios, discrete ratio values not limited (Gasoline vehicles only)

Final Drive Ratio Any value within limited range

## SECTION D – DYNAMIC EVENTS

### **D1 DYNAMIC EVENTS GENERAL**

The Dynamic Section Rules have been made in collaboration with the Motorsport UK Yearbook and are in compliance with their issued permit for the FSUK Event.

#### **D1.1 D1.1 Driver Limitations**

D1.1.1 In total, a minimum of four and a maximum of six drivers are allowed for each team.

D1.1.2 An individual driver may not drive in more than two dynamic events.

D1.1.3 The endurance and efficiency event are considered a single event.

#### **D1.2 Dynamic Area and Dynamic Vests**

D1.2.1 The technical inspections and all dynamic events are held in the dynamic area.

D1.2.2 Four dynamic vests are handed out to each team by the officials and must be worn in the dynamic area.

D1.2.3 Only four members per team, including the driver, may enter the dynamic area at one time.

D1.2.4 The respective competition organizers may choose to specify areas of the event such as the area immediately prior to the start line for dynamic events where no team members except the driver in the car may enter. The marshals may grant permission for team members at their discretion to recover cars from this area in the event that a car stalls or breaks down however it is likely that no tools including auxiliary starter batteries may be used in this area. Please check the respective event websites or event handbooks to understand the specific restrictions for any competition.

D1.2.5 Drivers must not wear the dynamic vest when sitting in the vehicle. The driver's vest must not be attached to the vehicle.

D1.2.6 The number of tools that may be used in this area is restricted to those which can be safely carried by the four team members in one trip.

D1.2.7 Engines may be run in the staging queue on the order of the officials.

**D2 DRIVING RULES****D2.1 Flags**

D2.1.1 Flag signals are commands that must be obeyed immediately and without question.

D2.1.2 There will be no flag signs for vehicles in autonomous mode.

**D2.1.3 GREEN FLAG –**

- The session has started, the driver may enter the track under direction of the track marshals. In case of stalling, the vehicle can be restarted, but the driver has to await another green flag as the opening in traffic may have closed,
- The driver is clear to re-enter the track after using the slow lane to let a faster vehicle pass,
- The driver may pick up speed again after a yellow flag was displayed.

D2.1.4 YELLOW FLAG (Stationary) – Danger, the driver must slow down, something has happened beyond the flag station, no overtaking unless directed by the track marshals.

D2.1.5 YELLOW FLAG (Waved) – greater danger. The driver must be prepared to move off the track or stop due track blockage.

D2.1.6 RED AND YELLOW STRIPED FLAG – The track is slippery, or something is on the racing surface that should not be there. The driver must be prepared for evasive manoeuvres to avoid the situation.

D2.1.7 BLUE FLAG (and/or blue lights) – The driver must pull into the designated passing zone to be passed by a faster competitor. The driver must obey the track marshals' signals at the end of the passing zone.

D2.1.8 RED FLAG – The driver must come to an immediate safe and controlled stop on the track and must follow track marshals' directions.

D2.1.9 BLACK FLAG – the driver must pull into the driver change area, at the end of the lap when the flag is shown, for discussion. The time penalty is the discussion time with the Official, which may be re-assessed.

D2.1.10 BLACK FLAG WITH ORANGE DOT – Mechanical black flag. The driver must pull into the driver change area for a mechanical inspection of the vehicle, something has been observed that requires a closer inspection.

D2.1.11 CHECKERED FLAG – The session has been completed. The driver must exit the track at the first opportunity.

D2.1.12 There is no Last Lap Board/Flag for Endurance Event.

**D2.2 Driving Under Power**

D2.2.1 During driving, the mechanical integrity of the vehicle must be maintained.

D2.2.2 Vehicles must not be driven in reverse.

D2.2.3 The vehicle must be capable of always starting and restarting without external assistance/batteries.



- D2.2.4 Push starts are prohibited.
- D2.2.5 Vehicles may only be driven under power when running in a dynamic event, on the practice track and during brake test.
- D2.2.6 Driving off-site is absolutely prohibited. Teams found to have driven their vehicle at an off-site location during the period of the competition will be excluded from the competition.
- D2.2.7 Burnouts prior to and during the events are prohibited.
- D2.2.8 When driving in autonomous mode, an ASR has to be present at the race control with the RES. Additionally, one single monitoring device (laptop, tablet, ...) may be brought (no complicated antenna construction or similar!).
- D2.3 Ground Clearance**
- D2.3.1 Sliding skirts or other aerodynamic devices that by design, fabrication or as a consequence of moving, contact the track surface are prohibited. Any violation may be penalized by a mechanical black flag.
- D2.4 Practice Track**
- D2.4.1 A practice track for testing and tuning vehicles (autonomous/manual mode) is available.
- D2.4.2 To use the practice track, vehicles must have passed all technical inspections.
- D2.4.3 Practice or testing at any location other than the practice track is absolutely forbidden.
- D2.5 Cones & Markings DV Running**
- D2.5.1 Details of the cones used, and more detailed track layout figures can be found in the competition handbook.
- D2.6 Start-up Procedure DV Running**
- D2.6.1 No additional equipment (e.g. laptop, jack-up device, pressure tank, etc.) is allowed to start up the vehicle at the staging/starting line.
- D2.6.2 If the vehicle does not enter “AS Ready” state within 1 min after being staged, the team may be sent back to the preparation area by the officials.
- D2.6.3 The vehicle may only be staged with the steering system in straight position.
- D2.6.4 The vehicle may be pushed from the preparation area to the start line with activated LVS.
- D2.6.5 The ASB may be energized already in the preparation area.
- D2.6.6 The ASMS may only be switched on by the ASR after approval from an official at the starting line.
- D2.7 Vehicle Break Downs and Usage of RES during DV Running**
- D2.7.1 Stalling the engine or deactivating the TS for any reason during a dynamic event will result in Did Not Finish (DNF) as the autonomous system is not allowed to restart the engine/reactivate the TS.
- D2.7.2 If a vehicle comes to standstill for any reason, it may have up to 30s to attempt to continue to drive. If the vehicle doesn’t restart within 30s, it will be deactivated using the RES, deemed disabled and scored as DNF for the run.

- D2.7.3 When the vehicle is driving in autonomous mode, one ASR must be present at the race control to operate the RES remote control.
- D2.7.4 The ASR or the officials may stop the vehicle using the RES in any of the following cases:
- Its behaviour seems to be uncontrolled (e.g. driving off-course without visible intention to re-enter the track immediately),
  - It is mechanically or electrically damaged,
  - The average speed of the first three laps in trackdrive (after completing the third lap) is below 2.5m/s or the average speed of any of the following laps is below 3.5m/s,
  - To ensure safe conditions on the track (e.g. persons or animals on the track). In this case the team will get a re-run.
- D2.7.5 If a vehicle breaks down or is stopped by the use of the RES it will be removed from the track, will not be allowed to re-enter the track and scored DNF.
- D2.7.6 If a traceable signal loss of the RES appears and doubtless proof can be brought by the team that it is was not self-inflicted, a re-run may be granted.
- D2.7.7 At the direction of the officials, team members may be instructed to retrieve broken-down vehicles. This recovery may only be done under the control of the officials.

## **D2.8 Procedure After Completing an DV Dynamic Event**

- D2.8.1 The vehicle must be collected by the ASR and an additional team member immediately after approval from the officials.

## **D3 WEATHER CONDITIONS**

### **D3.1 Operating Conditions**

- D3.1.1 The following track conditions are recognized:
- Dry,
  - Damp,
  - Wet.
- D3.1.2 The operating conditions are decided by the officials and may change at any time.
- D3.1.3 The current operating condition will be prominently displayed at the dynamic area.

### **D3.2 Tyres Allowed**

- D3.2.1 Teams must run the tyres allowed for each operating condition:

Operating Condition	Tyres allowed
Dry	Dry
Damp	Dry or Wet
Wet	Wet

- D3.2.2 When the operating condition is damp, teams may change between dry tyres and wet tyres:
- Any time during the acceleration, skidpad, and autocross events.
  - Any time before taking the green flag to start endurance.
- D3.2.3 If an event had varied operating conditions, the minimum performance levels to score points may be adjusted if deemed appropriate by the officials.
- D3.2.4 Only one set of tyres per type (dry/wet) may be used during all the dynamic events. The brake test, practice area and the static events are excluded from this regulation.

## D4 SKIDPAD EVENT

### D4.1 Skidpad Track Layout

- D4.1.1 The skidpad track consists of two pairs of concentric circles in a figure of eight pattern, as shown in Figure 30.
- D4.1.2 The centres of these circles are 18.25m apart. The inner circles are 15.25m in diameter and the outer circles are 21.25m in diameter.
- D4.1.3 16 cones are placed around the inside of each inner circle. 13 cones are positioned around the outside of each outer circle, in the pattern shown in the skidpad layout diagram.
- D4.1.4 Each circle is marked with a line, outside the inner circle and inside the outer circle.
- D4.1.5 The driving path is the 3m wide path between the inner and outer circles. The vehicles enter and exit through gates on a 3m wide path that is tangent to the circles where they meet.
- D4.1.6 The line between the centres of the circles defines the start/finish line. A lap is defined as traveling around one of the circles, starting and ending at the start/finish line.

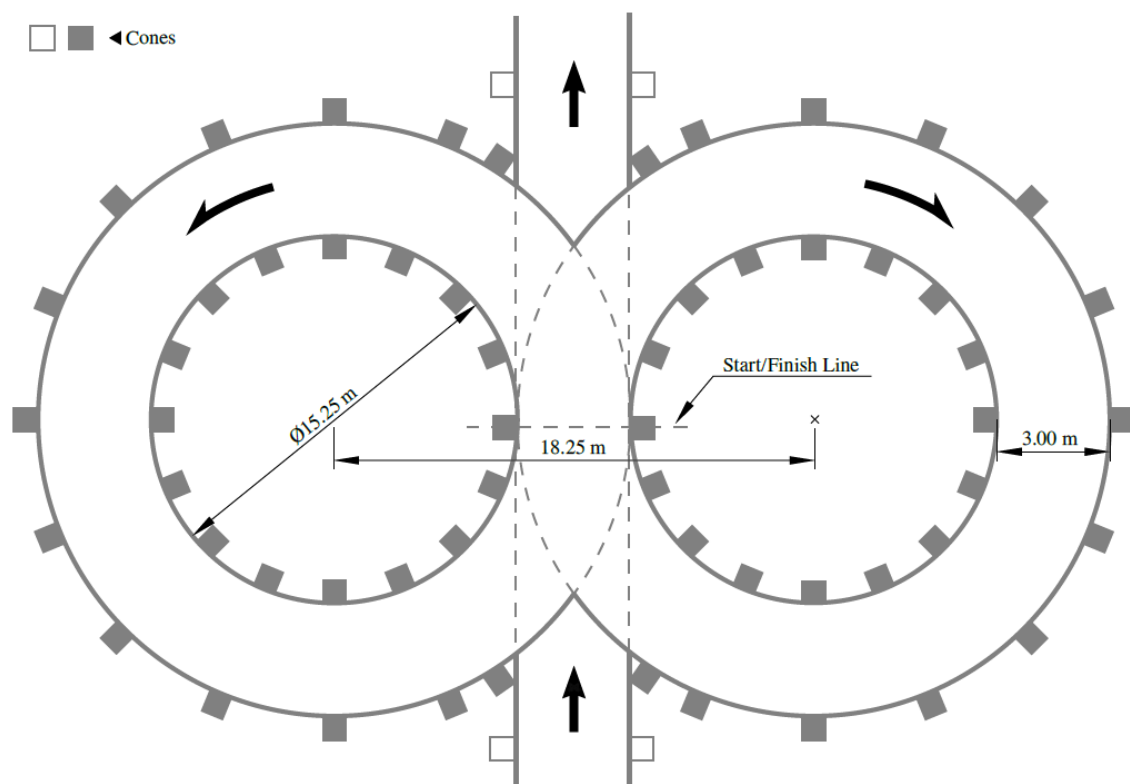


Figure 30: Skidpad Track Layout

### D4.2 Manual Skidpad Procedure

- D4.2.1 Each team has up to four runs, driven by two drivers with two runs each.
- D4.2.2 The driver has the option to make a second run immediately after their first run.

- D4.2.3 The starting order is based on the time the team arrives at the skidpad event. Teams on their first run will receive priority.
- D4.2.4 Staging – The car will be staged before the timing line by a line or pair of cones, this will be between 15-20m approximately and subject to the available space to allow marshals to stand clear of the Skidpad.
- D4.2.5 Starting - A green flag is used to indicate that the driver may start.
- D4.2.6 The vehicle will enter perpendicular to the figure of eight and will take one full lap on the right circle to establish the turn. The next lap will be on the right circle and will be timed. Immediately following the second lap, the vehicle will enter the left circle for the third lap. The fourth lap will be on the left circle and will be timed. Immediately upon finishing the fourth lap, the vehicle will exit the track perpendicular to the figure of eight and moving in the same direction as entered.

#### **D4.3 Driverless Skidpad Procedure**

- D4.3.1 Each team has two runs in autonomous mode.
- D4.3.2 Starting order is based upon time of arrival. Teams on their first run will receive priority.
- D4.3.3 Staging - The foremost part of the vehicle is staged 15m in front of the timekeeping line.
- D4.3.4 Starting - A go-signal from RES is used to indicate the approval to begin.
- D4.3.5 The vehicle will enter perpendicular to the figure eight and will take one full lap on the right circle to establish the turn. The next lap will be on the right circle and will be timed. Immediately following the second lap, the vehicle will enter the left circle for the third lap. The fourth lap will be on the left circle and will be timed. Immediately upon finishing the fourth lap, the vehicle will exit the track.
- D4.3.6 The vehicle will exit at the intersection moving in the same direction as entered and must come to a full stop within 25 m behind the timekeeping line, inside the marked exit lane and enter the finish-state described in T14.10.

#### **D4.4 Manual Skidpad Scoring**

- D4.4.1 The run time is the average time of the timed left and the timed right circle plus penalties which are added after the averaging.
- D4.4.2 5 points are awarded to every team that finishes at least one run without DNF or DQ.
- D4.4.3 If a team's best manual mode time including penalties is below  $T_{max}$ , additional points based on the following formula are given:

$$M-SKIDPADSCORE = 70 \left( \frac{\left( \frac{T_{max}}{T_{team}} \right)^2 - 1}{\left( \frac{T_{max}}{T_{min}} \right)^2 - 1} \right)$$

- $T_{team}$  is the team's best run time including penalties,
- $T_{min}$  is the fastest vehicle run time including penalties,
- $T_{max}$  is 125% of the fastest vehicle time including penalties.

**D4.5 Driverless Skidpad Scoring**

D4.5.1 Runs >25s will be DQ.

D4.5.2 If a team that finishes at least one driverless run without a DNF or DQ, points based on the following formula are given:

$$DV\ SKIDPAD\ SCORE = 75 \left( \frac{N_{all} + 1 - R_{DV,team}}{N_{all}} \right)$$

- $R_{DV,team}$  is the ranking of team's best driverless time including penalties within the best driverless times including penalties of all other teams,
- $N_{all}$  is the number of teams who finished at least one manual or driverless run without DNF or DQ

## **D5 ACCELERATION EVENT**

### **D5.1 Acceleration Track Layout**

- D5.1.1 The acceleration track is a straight line with a length of 75m from starting line to finish line. The track is at least 3 m wide. Cones are placed along the track at intervals of about 5m. Cone locations are not marked on the pavement.

### **D5.2 Manual Acceleration Procedure**

- D5.2.1 There will be two (2) heats. Each heat must have a different driver and each driver can have two (2) runs.
- D5.2.2 The driver has the option to make a second run immediately after their first run.
- D5.2.3 Staging - The foremost part of the vehicle is staged 0.30m behind the starting line. Vehicles will accelerate from a standing start.
- D5.2.4 Starting - A green flag is used to indicate that the driver may start. Timing starts after the vehicle crosses the starting line and stops after it crosses the finish line.
- D5.2.5 The starting order is based on the time the team arrives at the acceleration event. Teams on their first run will receive priority.
- D5.2.6 The six (6) fastest cars in the heats qualify to compete in the "Top Six Runoff". The runoff will be run as an additional heat for the fastest driver from each qualifying team.
- D5.2.7 The driver has one (1) run, this additional run does not count as competing in another dynamic event.
- D5.2.8 The starting order will be reversed from the fastest times in the heats, i.e. the slowest team runs first, and the fastest team runs last.

### **D5.3 Driverless Acceleration Procedure**

- D5.3.1 Each team has two runs in autonomous mode.
- D5.3.2 Staging - The foremost part of the vehicle is staged at 0.30m behind the starting line. Vehicles will accelerate from a standing start.
- D5.3.3 Starting - A go-signal from RES is used to indicate the approval to begin, timing starts only after the vehicle crosses the starting line and stops after it crosses the finish line.
- D5.3.4 After the finish line, the vehicle must come to a full stop within 50m inside the marked exit lane and enter the finish-state described in T14.10.
- D5.3.5 Starting order is based upon time of arrival. Teams on their first run will receive priority.

### **D5.4 Manual Acceleration Scoring**

- D5.4.1 5 points are awarded to every team that finishes at least one manual mode run without a DNF or DQ.
- D5.4.2 If a team's best manual mode time including penalties is below  $T_{max}$ , additional points based on the following formula are given:

$$M\_ACCELERATION\_SCORE = 65 \left( \frac{\frac{T_{max}}{T_{team}} - 1}{\frac{T_{max}}{T_{min}} - 1} \right)$$

- $T_{team}$  is the team's best time including penalties,
- $T_{min}$  is the fastest vehicle time,
- $T_{max}$  is 150% of the fastest vehicle time.

D5.4.3 The score for the Top Six Runoff is spread between zero (0) and five (5) based upon the elapsed time, additional points will be awarded as per the below:

Top Six Runoff Placing	Points
First	5
Second	4
Third	3
Fourth	2
Fifth	1
Sixth	0

Table 14: Acceleration run-off scoring

## D5.5 Driverless Acceleration Scoring

D5.5.1 Runs >25s will be DQ.

D5.5.2 If a team that finishes at least one DV run without a DNF or DQ, points based on the following formula are given:

$$DV\_ACCELERATION\_SCORE = 75 \left( \frac{N_{all} + 1 - R_{DV,team}}{N_{all}} \right)$$

- $R_{DV,team}$  is the ranking of team's best driverless time including penalties within the best driverless times including penalties of all other teams,
- $N_{all}$  is the number of teams who finished at least one manual or driverless run without DNF or DQ.

## D5.6 [DC ONLY] Driverless Cup Acceleration Scoring

D5.6.1 There are no extra runs for DV acceleration for the DC, however a separate formula is used to calculate the score for DC based on the DV runs.

D5.6.2 3.5 points are awarded to every team that finishes at least one DV run without a DNF or DQ.



D5.6.3 If a team's best time including penalties is below  $T_{\max}$ , additional points based on the following formula are given:

$$DC \text{ ACCELERATION SCORE} = 71.5 \left( \frac{T_{\max}}{T_{\text{team}}} - 1 \right)$$

- $T_{\text{team}}$  is the team's best DV time including penalties.
- $T_{\max}$  is 2 times the time of the fastest DV vehicle including penalties.

## **D6 AUTOCROSS EVENT**

### **D6.1 Autocross Track Layout**

D6.1.1 The autocross track layout is a handling track built to the following guidelines:

- Straights: No longer than 80m,
- Constant Turns: up to 50m diameter,
- Hairpin Turns: Minimum of 9m outside diameter (of the turn),
- Slaloms: Cones in a straight line with 7.5m to 12m spacing,
- Miscellaneous: Chicanes, multiple turns, decreasing radius turns, etc. The minimum track width is 3 m.

D6.1.2 The length of the autocross track is less than 1.5km.

D6.1.3 [DC ONLY] The autocross is using the same track as the trackdrive event (see D8.1).

D6.1.4 The organisers reserve the right to deviate from the parameters specified when they determine it is appropriate given the characteristics of the particular competition site.

### **D6.2 Autocross Procedure**

D6.2.1 Each team has up to four runs, driven by two drivers with two runs each.

D6.2.2 Each driver has the option to make a second run immediately after their first run.

D6.2.3 Staging - The vehicle is staged at a staging line prior to the starting line. The staging line will be a minimum of 2m from the start line and a maximum of 6m, cars will be positioned on this line by the marshals

D6.2.4 Starting - A green flag is used to indicate that the driver may start. Timing starts only after the vehicle crosses the starting line and stops after it crosses the finish line.

D6.2.5 The starting order is based on the time the team arrives at the autocross event. Teams on their first run will receive priority.

D6.2.6 If a stalled or broken-down vehicle is blocking the track, then all other vehicles on track will be shown the red flag and allowed another run.

### **D6.3 [DC ONLY] Driverless Autocross Procedure**

D6.3.1 There will be a track walk prior to the autocross. During the track walk no equipment (e.g. antennas, sensors, cameras, etc) other than analogue measurement devices (i.e. measurement wheel or measurement tape) is allowed.

D6.3.2 Using data collected in a previous run is not permitted for the autocross event.

D6.3.3 Each team has at least two runs consisting of one single lap. The final number of runs will be published before the start of the event.

D6.3.4 The starting order is based on the time the team arrives at the autocross event. Teams on their first run will receive priority.

- D6.3.5 Staging - The vehicle is staged such that the front wheels are 6m in front of the starting line on the track.
- D6.3.6 Starting - A go-signal from RES is used to indicate the approval to begin. Timing starts after the vehicle crosses the starting line.
- D6.3.7 After the run, the vehicle must come to a full stop within 30m behind the finish line on the track and enter the finish-state described in T14.10.

#### **D6.4 Autocross Scoring**

- D6.4.1 5 points are awarded to every team that finishes at least one run without DNF or DQ.
- D6.4.2 If a team's corrected elapsed time is below  $T_{max}$ , points based on the following formula are given:

$$ASPRINT\_SCORE = 95 \left( \frac{\frac{T_{max}}{T_{team}} - 1}{\frac{T_{max}}{T_{min}} - 1} \right)$$

- $T_{team}$  is the team's best time including penalties.
- $T_{min}$  is the fastest vehicle time including penalties.
- $T_{max}$  is 145% of the fastest vehicle time including penalties.

#### **D6.5 [DC ONLY] Driverless Autocross Scoring**

- D6.5.1 10 points are awarded to every team that finishes at least one run without DNF or DQ.
- D6.5.2 If a team's corrected elapsed time is below  $T_{max}$ , points based on the following formula are given:

$$AUTOCROSS\_SCORE_i = 90 \left( \frac{T_{max} - T_{team,i}}{T_{max} - T_{min}} \right)$$

$$AUTOCROSS\_SCORE_{total} = \max(AUTOCROSS\_SCORE_1, \text{avg}(AUTOCROSS\_SCORE_1..AUTOCROSS\_SCORE_n))$$

- $T_{team,i}$  is the team's time including penalties of run i.
- $T_{max}$  is the time for driving the lap with 4m/s.
- $T_{min}$  is the fastest corrected elapsed time of all teams.

**D7 ENDURANCE AND EFFICIENCY EVENT****D7.1 Endurance Track Layout**

D7.1.1 The endurance track layout is a closed lap circuit built to the following guidelines:

- Straights: No longer than 80m
- Constant Turns: up to 50m diameter
- Hairpin Turns: Minimum of 9m outside diameter (of the turn)
- Slaloms: Cones in a straight line with 9m to 15m spacing
- Miscellaneous: Chicanes, multiple turns, decreasing radius turns, etc.
- The minimum track width is 3m

D7.1.2 The length of one lap of the endurance track is approximately 1km.

D7.1.3 The length of the complete endurance is approximately 22km.

D7.1.4 The organisers reserve the right to deviate from the parameters specified, when they determine it is appropriate given the characteristics of the particular competition site.

**D7.2 Endurance Procedure**

D7.2.1 Before entering the event, each CV's fuel tank must be filled to the fuel level line (see CV2.6.3, "Fuel Level Line") at the fuelling station. During fuelling, once filled to the scribe line, no shaking or tilting of the tank, the fuel system or the entire vehicle is allowed.

D7.2.2 There is only one run for the endurance event.

D7.2.3 A driver change must be made at the midpoint of the run.

D7.2.4 Staging - The vehicle is staged at a staging line prior to the starting line. If the vehicle is unable to proceed across the timing line from the staging line due to a vehicle issue, then a DNS (Did Not Start) will be applied, it has failed the endurance event and will not be allowed to be repaired and re-start

D7.2.5 Starting - A green flag is used to indicate that the driver may start. Timing starts only after the vehicle crosses the starting line.

D7.2.6 The first driver will drive for 11km and will then be signalled into the driver change area.

D7.2.7 After the driver change specified in D7.5, the second driver will drive for an additional 11km and will be signalled to exit the track after crossing the finish line.

D7.2.8 After leaving the track, the vehicle must be powered down.

D7.2.9 For CV, the second driver will proceed directly to the fuelling station. The tank will be filled to the refill mark and the amount of fuel will be recorded.

**D7.3 Endurance Running Order**

D7.3.1 The running order for the endurance will be established in a way that vehicles with similar speeds shall be on the track together.

D7.3.2 The running order will be published as announced in the competition handbook.

D7.3.3 The procedure for handling the running order will be defined in the competition handbook.

#### **D7.4 Passing**

D7.4.1 During the endurance event, overtaking is only permissible in the designated passing zones and under the control of the track marshals.

D7.4.2 Passing zones have two parallel lanes, a slow lane only used by the vehicles that are being overtaken and a fast lane for the vehicles that are overtaking.

D7.4.3 Passing zones may be situated on either the left or right of the fast lane.

D7.4.4 The passing zone procedure will be as follows:

- A slower leading vehicle will be shown the blue flag and must drive into the slow lane and decelerate,
- The following faster vehicle will continue in the fast lane to pass the slow vehicle,
- The vehicle that has been overtaken may re-enter the track when the track marshal who is in charge of that passing zone is showing the green flag.

D7.4.5 The passing rules do not apply to vehicles that are stopped on track or vehicles that have spun out and are not moving. When passing a stationary vehicle, it is critical to slow down, drive cautiously and to follow the instructions from the track marshals.

#### **D7.5 Endurance Driver Change Procedure**

D7.5.1 Only three team members including the driver may enter the driver change area. They may only bring the tools required to adjust the vehicle to accommodate the second driver and/or change tyres.

D7.5.2 For electric vehicles one of the team members must be an ESO.

D7.5.3 During the driver change, the team may:

- perform changes to accommodate the second driver,
- operate the master switch(es),
- change tyres as per D7.6.

No other work may be performed during the driver change, external jumper batteries may not be used to restart the car

D7.5.4 Each team is given three minutes to change their driver and one minute to restart the car.

D7.5.5 The driver change time will start once the vehicle is stopped in the driver change area and the first driver has turned off the engine for CV or turned off the tractive system for EVs.

D7.5.6 [EV ONLY] The TSMS must be switched off by the ESO and the TSAL must have changed to green colour, before anyone is allowed to touch the vehicle or to climb out the vehicle.

D7.5.7 The first driver will climb out the vehicle and any necessary adjustments will be made to the vehicle to fit the second driver (seat cushions, head restraint, pedal position, etc.). The second driver will then be secured in the vehicle.

D7.5.8 When the second driver is fully secured in the vehicle, the driver change time ends.

Marshalls will check that the driver is securely fastened into the vehicle and complies with all regulations.

- D7.5.9 The driver will be given the signal to start the engine/tractive system. The moment the signal is given, the driver is given one minute to restart the car.
- D7.5.10 Once the vehicle has restarted and is ready-to-drive again, the restart time is stopped.
- D7.5.11 If the driver change and vehicle starting takes longer than three minutes and one minute, respectively, the extra time is included in the final time.

## **D7.6 Endurance Event Tyre Changes**

- D7.6.1 All tyre changes after a vehicle has received the green flag to start the endurance event must take place in the driver change area.
- D7.6.2 If the operating condition changes to wet during endurance, the track will be red flagged, and all vehicles brought into the driver change area.
- D7.6.3 If a team wants to change tyres, the officials must be informed beforehand.
- D7.6.4 In some cases, tyre changes can be carried out directly after the driver change, for others the team must make an extra stop.
- D7.6.5 The allowed tyre changes and associated conditions are given in the following tables.

	Existing Operating Condition	Currently running on	Condition changes to Dry	Condition changes to Damp	Condition changes to Wet
	Dry	Dry Tyres	–	A	B
	Damp	Dry Tyres	–	A	B
	Damp	Wet Tyres	C	C	–
	Wet	Wet Tyres	C	C	–
	Requirement		Allowed at Driver Change?		Time Allowed
A	may change from dry to wet		yes		Note 1
B	must change from dry to wet		yes		Note 1
C	may change from wet to dry		no		Note 2

Table 15: Allowed tyre changes

Note 1: Any time in excess of ten minutes without driver change, or thirteen minutes with driver change, is added to the team's total time for endurance.

Note 2: The time used to change to dry tyres is added to the team's total time for endurance.

- D7.6.6 Teams that have incurred a puncture during the endurance event due to external factors (e.g. debris on track) may change the tyre with no time penalty.
- D7.6.7 The wheel will be inspected by the officials. If the deflation was not caused by external factors, the vehicle will be scored DNF.
- D7.6.8 Deflation caused by running off-course or impacting barriers or other objects due to driver error will not be regarded as external factors.

- D7.6.9 If a vehicle is unable to maintain lap times within one hundred forty-five percent (145%) of the fastest lap time for the course, then it must exit immediately.
- D7.6.10 Disqualification for failure to maintain the minimum speed will be made at the discretion of the Dynamic Event Captain / Clerk of the Course.

### **D7.7 Endurance Specific Regulations**

- D7.7.1 Teams are prohibited from working on or fuelling their vehicles during the run.
- D7.7.2 Wheel-to-wheel racing is prohibited.
- D7.7.3 Passing another vehicle must be completed as per D7.4.
- D7.7.4 If a vehicle stalls out on the track, it is allowed one lap by the vehicle that is following it (approximately one minute) to restart.
- D7.7.5 If a vehicle has a restart problem at the driver change or after a red flag, it is allowed two minutes to restart the engine or to enable the tractive system. The two minutes start from the time the driver first tries to restart the engine or to enable the tractive system. The time is counted towards the endurance time.
- D7.7.6 If restarts are not accomplished within the above times, the vehicle is scored as DNF for the run.
- D7.7.7 If a vehicle breaks down, it will be removed from the track and will not be allowed to re-enter the track.
- D7.7.8 Team members may be instructed by the officials to retrieve broken down vehicles. This recovery may only be carried out under the control of the officials.

### **D7.8 Endurance Scoring**

- D7.8.1 Each lap of the endurance event is individually timed. The corrected elapsed time is determined by subtracting the extra-long lap for the driver change from the total time and adding any penalty times.
- D7.8.2 The post event technical inspection (see IN12) must be passed to score points in the endurance event.
- D7.8.3 25 points are awarded to every team that finishes endurance without DNF or DQ.
- D7.8.4 If a team's corrected elapsed time is below  $T_{max}$ , additional points based on the following formula are given:

$$ENDURANCE\ SCORE = 225 \left( \frac{\frac{T_{max}}{T_{team}} - 1}{\frac{T_{max}}{T_{min}} - 1} \right)$$

- $T_{team}$  is the team's best time including penalties.
- $T_{min}$  is the fastest vehicle time including penalties.
- $T_{max}$  is 145% of the fastest vehicle time including penalties.

D7.8.5 If a team DNFs then:

$$ENDURANCE\ SCORE = \text{Number of Laps Completed}$$

D7.8.6 If a driver's run is interrupted by a red flag, the recorded lap time for their red-flagged lap will be replaced by the average lap time from their preceding laps. The number of laps used for the averaging will be at the discretion of the Dynamic Event Captain.

## D7.9 Efficiency Scoring

D7.9.1 The Efficiency is based on a metric of the amount of fuel consumed or energy used and the lap time on the endurance course, averaged over the length of the event. Teams are advised that the Efficiency score is based only on the distance cars run on the course during the Endurance event. Although the starting line, exit line and the driver change zone increase the actual distance a car must drive during the event, those distances are not factored into the fuel calculations. Additionally, fuel consumption adjustments will not be made for engine running in the entry/exit lines, during driver change, in the penalty box or for any on-course incidents. The Organisers may use either the corrected Endurance lap times or the scored Endurance lap times for the Efficiency event.

D7.9.2 The mass of CO<sub>2</sub> released to the atmosphere will be assessed by using the conversion factors below from quantity of fuel used to CO<sub>2</sub> released. The factors are intended to represent the average supply of the appropriate commodity and the Organisers will not take account of where the actual fuel used came from.

Fuel Type		Conversion Factor	
Unleaded petrol		2.31kg CO <sub>2</sub> per litre	
I.	Electric	II.	0.45kg CO <sub>2</sub> per kWh
E85		1.65kg CO <sub>2</sub> per litre	

Table 16: Fuel Conversion Factors

The conversion factor for Alternative Fuels will be determined by the organisers upon receipt and review of the Alternative Fuel Report.

*Note: These factors are currently under review to account for the use of sustainable fuels and the current UK grid energy mix. They will be updated in a later version of these rules.*

D7.9.3 Full credit will be given for energy recovered through regenerative braking.

D7.9.4 Efficiency will be scored using the following formulas:

$$EFFICIENCY\ SCORE = 100 \frac{(Efficiency\ Factor_{min}/Efficiency\ Factor_{team}) - 1}{(Efficiency\ Factor_{min}/Efficiency\ Factor_{max}) - 1}$$

Where:

$$EFFICIENCY\ FACTOR = \frac{T_{min}/LapTotal_{Tmin}}{T_{team}/Laps_{team}} * \frac{CO_{2min}/LapTotal_{CO2min}}{CO_{2team}/Laps_{team}}$$



- $CO_{2min}$  is the smallest mass of  $CO_2$  used by any competitor whose endurance time  $T_{team}$  is less than 145% of the average lap time of the fastest team that completes the endurance event.
  - $CO_{2team}$  is the mass of  $CO_2$  used by the team being scored.
  - $T_{min}$  is the lowest Endurance time of the fastest team whose fuel consumption does not exceed 26 litres/100km or energy equivalent of 60.06 kg $CO_2$ /100km.
  - $T_{team}$  is the combined Endurance times of the drivers in your heat.
  - $Laps_{team}$  is the number of laps driven by the team being scored.
  - $LapTotal_{Tmin}$  and  $LapTotal_{CO2min}$  are the number of laps completed by the teams which set  $T_{min}$  and  $CO_{2min}$  respectively.
  - $EfficiencyFactor_{min}$  is calculated using  $CO_{2team}$  equivalent to 60.06kg  $CO_2$ /100km and  $T_{team}$  set to 145% of the average laptime of the fastest team that completes the Endurance event.
- D7.9.5 Vehicles whose average Endurance lap time exceeds 1.45 times the average Endurance lap time of the fastest team that completes the Endurance event, will receive zero (0) points for efficiency.
- D7.9.6 Vehicles whose corrected average fuel consumption per lap exceeds 26 litres/100 km or energy equivalent of 60.06 kg $CO_2$ /100 km, will receive zero (0) points for Efficiency.
- D7.9.7 The minimum Efficiency Factor is determined from the maximum allowable  $CO_2$ /100km and 145% of the corrected average Endurance lap time of the fastest team that completes the Endurance event.
- D7.9.8 Efficiency scores can range from zero points (0) to positive one hundred (100) points.
- D7.9.9 Vehicles which cross the start line following driver change are eligible for Efficiency points. Other vehicles will receive a score of zero points (0) for Efficiency.
- D7.9.10 Should the fuel level change after refuelling due to effects such as described in CV2.7.1 then the difference in fuel level will be measured and twice the amount will be added to the official fuel consumption figure.

## **D8 [DV ONLY] TRACKDRIVE EVENT**

### **D8.1 Trackdrive Tracklayout**

D8.1.1 The trackdrive layout is a closed loop circuit built to the following guidelines:

- Straights: No longer than 80m,
- Constant Turns: up to 50m diameter,
- Hairpin Turns: Minimum of 9m outside diameter (of the turn),
- Miscellaneous: Chicanes, multiple turns, decreasing radius turns, etc,
- The minimum track width is 3m.

D8.1.2 The length of one lap is approximately 200m to 500m.

### **D8.2 Trackdrive Procedure**

D8.2.1 Starting order may be defined by the officials, based on previous dynamic event results.

D8.2.2 Before starting a run, each vehicle with a fuel tank (CV), must be filled to the fuel level line (see CV2.6.3, "Fuel Level Line") at the fuelling station. During fuelling, once filled to the scribe line, no shaking or tilting of the tank, the fuel system or the entire vehicle is allowed.

D8.2.3 There will be a maximum of two runs, each run consisting of ten laps. The number of runs and the starting order procedure will be announced before the start of the event.

D8.2.4 Staging - The vehicle is staged such that the front wheels are 6 m in front of the starting line on the track.

D8.2.5 Starting - A go-signal from RES is used to indicate the approval to begin. Timing starts after the vehicle crosses the starting line.

D8.2.6 After ten laps the vehicle must come to a full stop within 30m behind the finish line on the track and enter the finish-state described in T14.10.

D8.2.7 There will be no last lap signal i.e. the vehicle should count laps itself.

D8.2.8 The team must proceed directly to the fuelling station (vehicles with internal combustion engine only).

### **D8.3 Trackdrive Scoring**

D8.3.1 If there is more than one run per vehicle, the run with the highest score of trackdrive is scored.

D8.3.2  $T_{max}$  and  $T_{min}$  for the trackdrive score is calculated based on all valid runs.

D8.3.3 Each lap of the trackdrive event is individually timed. The corrected elapsed time is determined by adding any penalty times.

D8.3.4 If a team's corrected elapsed time is below  $T_{max}$  and the run was not DNF or DQ, points based on the following formula are given:

$$TRACKDRIVE\_SCORE = 150 \left( \frac{T_{max}}{T_{min}} \right)$$

- $T_{\text{team}}$  is the team's corrected elapsed time.
- $T_{\text{max}}$  is 2 times of the corrected elapsed time of the fastest vehicle over all runs.

D8.3.5 An additional five points are awarded for every completed lap, independent of the corrected elapsed time. This is also applied for teams that do not finish the trackdrive i.e. get a DNF.

## D9 DYNAMIC EVENTS PENALTIES

### D9.1 General Penalties

D9.1.1 Penalties will not be assessed for accident avoidance or other reasons deemed sufficient by the officials.

D9.1.2 A cone is Down or Out (DOO) if the cone has been knocked over or the entire base of the cone lies outside the box marked around the cone in its undisturbed position.

D9.1.3 Cones that are DOO are not replaced/reset during a DV run. There will be no re-run due to cones in the driving path or disorientation due to missing cones.

D9.1.4 The DOO penalty (see D9.1.7) is added for each DOO including entry and exit gate cones before the start and after the finish line, which occur on that particular run.

D9.1.5 Off-course (OC)

- An OC occurs when the vehicle has all four wheels outside the track boundary as indicated by edge marking,
- Missing one or more gates of a given slalom at autocross or endurance is counted as one OC per occurrence,
- When an OC occurs, the driver must re-enter the track at the next possible point,
- When re-entering the driver needs to wait for a gap and follow the instructions of the track marshals.

D9.1.6 An Unsafe Stop (USS) is defined as not stopping within the specified area and/or not entering the finish-state described in T14.10 during autonomous running.

D9.1.7

	Acceleration	Skidpad	Autocross	Endurance	Trackdrive
DOO	2s	0.2s	2s	2s	2s
OC	DNF	DNF	10s	10s	10s
USS	DNF	DNF	DNF	N/A	-50 points

Table 17: Dynamic event penalties

D9.1.8 DNF equals zero points for that run.

D9.1.9 DQ equals zero points for that run.

D9.1.10 If a team Did Not Attempt (DNA) an event the score is zero points.

D9.1.11 Each run with an incorrect number of laps at skidpad is classified as DNF.

D9.1.12 Failure to obey a flag: one minute time penalty.

D9.1.13 Reckless or aggressive driving or "Over Driving": black flag (see D2.1.9)

D9.1.14 Vehicle to vehicle contact: Two minutes up to disqualification depending on the nature of the incident.

D9.1.15 If a vehicle stops and cannot restart without external assistance, the vehicle is DNF for that run.

D9.1.16 If a vehicle is not able to start the run, after being called to the staging/starting line, the vehicle is DQ for that run.

## **D9.2 Endurance Penalties**

D9.2.1 Teams that are running out-of-order as defined in the competition handbook, are penalized by two minutes and may then run at the discretion of the officials.

D9.2.2 Mechanical Problem: The time taken for mechanical inspection under a “mechanical black flag” (see D2.1.10) is considered officials’ time and is not included in the team’s total time. If the inspection reveals a mechanical integrity problem the vehicle is scored DNF.

D9.2.3 If it is impossible to impose a penalty by a stop under a black flag, e.g. not enough laps left, the officials may add an appropriate time penalty to the team’s elapsed time.

D9.2.4 A team may receive a DNF if their vehicle is too slow or being driven without proper control.

D9.2.5 Any violation to the procedure of driver change (D7.5.3) will lead to a time penalty of up to two minutes.

## **D9.3 [CV ONLY] Efficiency Penalties**

D9.3.1 Should the fuel level change after refuelling due to effects such as described in CV2.7.1, then the difference in fuel level will be measured and twice the amount will be added to the official fuel consumption figure.

## **D9.4 [EV ONLY] Power and Voltage Violation Penalties**

D9.4.1 A violation is defined as using more than the maximum power, see EV2.2, or exceeding the specified voltage, see EV4.1.1, after a moving average over 500ms is applied to the respective Energy Meter signal, see EV4.6.

D9.4.2 Each violation is a DQ for the fastest run of the event. If a violation occurred during two runs, the two fastest runs will be DQ etc.

D9.4.3 The respective data and the resulting decision of violations may be made public.

D9.4.4 Non-availability of Energy Meter data will be treated as a violation.

## **SECTION FC – FUTURE CHANGES**

### **FC1 FUTURE RULE CHANGES**

#### **FC1.1 General**

- FC1.1.1 This section contains rules proposed to be introduced in the 2025 rules and will be updated in a later release of the 2024 rules.