

SUPRA SAE INDIA REGULATIONS FOR EV

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ABBREVIATIONS

AIP	Anti Intrusion Plate	EBS	Emergency Brake System
AIR	Accumulator Isolation Relay	ECU	Electronic Control Unit
AMS	Accumulator Management System	EDR	Engineering Design Report
APPS	Accelerator Pedal Position Sensor	EI	Flexural Rigidity
BOM	Bill of Material	ESF	Electrical System Form
BOTS	Brake Over-Travel Switch	ESO	Electrical System Officer
BPP	Business Plan Presentation Event	ESQ	Electrical System Officer Qualification
BPPV	Business Plan Pitch Video	ETC	Electronic Throttle Control
BSPD	Brake System Plausibility Device	EV	Electric Vehicle
CBOM	Costed Bill of Material	HPI	High Pressure Injection
CRD	Cost Report Documents	HV	High Voltage
DBOM	Detailed Bill of Material	HVD	High Voltage Disconnect
DI	Direct Injection	IA	Impact Attenuator
DNA	Did Not Attempt	IAD	Impact Attenuator Data
DNF	Did Not Finish	IMD	Insulation Monitoring Device
DOO	Down or Out	LPI	Low Pressure Injection
DQ	Disqualified	LV	Low Voltage
DSS	Design Spec Sheet	LVMS	Low Voltage Master Switch
TPS	Throttle Position Sensor	LVS	Low Voltage System
TSMP	Tractive System Measuring point	OC	Off-course
USS	Unsafe Stop	OEM	Original Equipment Manufacturer
TSMS	Tractive System Master Switch	PCB	Printed Circuit Board
TS	Tractive System	R2D	Ready-to-drive
TSAC	Tractive System Accumulator Con Tainer	RES	Remote Emergency System
TSAL	Tractive System Active Light	SCS	System Critical Signal
VSV	Vehicle Status Video	SDC	Shutdown Circuit
SESA	SES Approval	SE3D	Structural Equivalency 3D Model
SES	Structural Equivalency Spreadsheet		

SUPRA SAE INDIA REGULATIONS FOR EV

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1.1	5/Dec/2023	First Release
1.2	11/Dec/2023	Revision marked with Δ^1
1.3	24/Jan/2024	Revision marked with Δ^2

Administrative Regulations

Vehicle Eligibility

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.

A1.2 Competition Procedure

A1.2.1 The competition is for Electric Vehicle (EV)

A1.2.2 All vehicles must meet the requirements defined in chapters T and EV

A1.2.3 The competition starts with a series of technical inspections described in chapter 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 chapters S and D.

A1.2.5 The achievable points in each class are listed in table 3.

A1.2.6 The team with the most overall points will win the competition for its class.

A1.3 Competition Information

A1.3.1 The competition specific rules and information are defined in the competition handbook.

A1.3.2 The official language of the competition is English.

A1.3.3 Every organizer of a competition based on this document bears the sole responsibility.

Static Events:	
Business Plan Presentation	75 points
Cost and Manufacturing	100 points
Engineering Design	150 points
Dynamic Events:	
Skidpad	50 points
Acceleration	50 points
Autocross	100 points
Endurance	250 points
Efficiency	75 points
Track drive	-
Overall,	850 Points

Table 3: Maximum points awarded.

A2 VEHICLE ELIGIBILITY

A2.1 Student Competition

A2.1.1 Vehicles entered the competition must be conceived, designed, and maintained by the student team members without direct involvement from external professional engineers, racers, machinists, or related professionals.

A2.1.2 The student team may use any information from professionals or from academics if the information is given as a discussion of alternatives with their pros and cons.

A2.1.3 Professionals may not make design decisions or drawings. The Faculty Advisor may be required to sign a statement of compliance with this restriction.

A2.1.4 Students should perform fabrication tasks wherever possible.

A2.2 First Year Vehicles

A2.2.1 A vehicle may only be used for one year, counting from the first day onsite of its first competition.

A2.2.2 To be classified as new, a vehicle must have at minimum, a newly manufactured chassis with significant changes in the primary structure to its predecessor.

A3 RULES OF CONDUCT

A3.1 General Officials Authority

A3.1.1 The officials reserve the right to revise the schedule 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 these 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 these 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 25penaltypoints 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 eliminated from the competition.

A3.4 Unsportsmanlike Conduct

A3.4.1 In the event of unsportsmanlike conduct, 25penaltypoints will be deducted from the team’s overall score. A second violation will result in expulsion of the team 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 new or novel interpretation.

A3.6.4 Refer to the competition website for specific directions how to submit a rules question.

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

A4 GENERAL REQUIREMENTS FOR TEAMS & PARTICIPANTS

A4.1 Teams per University

A4.1.1 A university can register one EV team.

A4.1.2 Teams which are formed with members from two or more universities are treated as a single team.

A4.1.3 In the case where multiple colleges located in multiple cities or districts are grouped under a common University, either autonomous or through affiliation, the team must register under their college name. (Δ^1)

A4.2 Team Members and Participants

- A4.2.1 Each participant must provide proof of valid private liability & individual health insurance for the competition.
- A4.2.2 All onsite participants must sign a liability waiver upon registering onsite which can be found on the competition website.
- 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.
- 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 Each team is also required to identify two additional team members during the registration process who will serve as communication liaisons between the team and the competition, should the team captain not be available. These additional team members must have a 'current' student status at the attended College or University, at the time of the competition. (Δ^1)
- A4.2.6 Persons who have previously attended any official event as a judge are not allowed to participate as team members.
- A4.2.7 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.
- A4.2.8 Students seeking a PhD degree/PhD students or equivalent are not allowed to participate.
- A4.2.9 Counting from the year of their first competition, team members can only participate for four additional full years.
- A4.2.10 Team members must be at least 18 years of age.
- A4.2.11 Team members who will drive a competition vehicle at any time during a competition must present a valid, government issued driver's license for passenger cars, containing a photograph.
- A4.2.9 Counting from the year of their first competition, team members can only participate for four additional full years.
- A4.2.10 Team members must be at least 18 years of age.
- A4.2.11 Team members who will drive a competition vehicle at any time during a competition must present a valid, government issued driver's license for passenger cars, containing a photograph.

A4.3 Electrical System Officer

- A4.3.1 Every participating team must appoint one to four ESOs for the competition.
- A4.3.2 The ESOs are responsible for all electrical work carried out on the vehicle during the competition.

- A4.3.3 The ESOs are the only persons in the team who may declare the vehicle electrically safe, for work to be performed on any system of the vehicle by the team.
- A4.3.4 The ESOs must be valid team members, which means that they must have student status, see A4.2.6.
- A4.3.5 The ESOs must be always contactable by phone during the competition.
- A4.3.6 An ESO must accompany the vehicle whenever it is operated or moved around at the competition site.
- A4.3.7 If only one ESO is named by the team, this ESO may not be a driver.
- A4.3.8 An appropriate Electrical System Officer Qualification (ESOQ) requires the proof of a practical and theoretical training for working with HV power systems. Regarding content, the training should be based on DGUV 209-093 stage 2E/3E¹ and held by an external expert.
- A4.3.9 Each team must have a minimum of two ESOs trained in 3E and a minimum of one ESO trained in 2E. Only ESOs with 3E training are allowed to work on live high voltage systems. (Δ^1)
- A4.3.10 It is recommended that all other team members receive an 1E training instruction. This can be provided by an external provider or from one of the team's certified ESO itself. (Δ^1)

A4.4 Electric System Advisor (Δ^2)

- A4.4.1 The Electrical System Advisor (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. The faculty advisor may also be the ESA if all the requirements below are met.
- A4.4.2 The ESA must supply details of their experience of electrical and/or control systems engineering as used in the vehicle on the ESO/ESA form for approval by the organizers.
- A4.4.3 The ESA must be sufficiently qualified to advise the team on their proposed electrical and control system designs based on significant experience of the technology being developed and its implementation into vehicles or other safety critical systems. More than one person may be needed.
- A4.4.4 The ESA must advise the team on the merits of any relevant engineering solutions. Solutions should be discussed, questioned and approved before they are implemented into the final vehicle design.
- A4.4.5 The ESA should advise the students on any required training to work with the systems on the vehicle.
- A4.4.6 The ESA must review the Electrical System Form and to confirm that in principle the vehicle has been designed using good engineering practices.

- A4.4.7 The ESA must ensure that the team communicates any unusual aspects of the design to the organizers to reduce the risk of exclusion or significant changes being required to pass Technical Inspection.

A5 DOCUMENTATION & DEADLINES

A5.1 Required Documents and Forms

- A5.1.1 Several documents and forms must be submitted by the action deadlines defined in the competition handbook.

A5.2 Submission

- A5.2.1 Uploaded documents may only be viewed by members of the submitting team, authorized judges, and officials.
- A.5.2.2 Only persons designated Team Members or Team Captains are able to upload documents to the website. (Δ^2)
- A.5.2.3 Prior to the Submission Deadline: (Δ^2)
- a. Documents may be uploaded at any time. (Δ^2)
 - b. Uploads may be replaced with new uploads without penalty (Δ^2)
- A5.2.4 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 purpose.
- A5.2.5 Documents or videos that are largely incomplete or not readable/viewable will be considered as not submitted.

A5.3 Late Submission or Non-Submission

- A5.3.1 For each submission later than the initial deadline 10penaltypoints are deducted from the team's overall score.
- A5.3.2 Teams that do not submit documents until 24 hours (1 day) after the initial deadline will be de-registered from the competition.

A5.4 Correction Requests

- A5.4.1 If the officials request a correction for a document and the team has not uploaded a corrected version after 168 hours (7 days) following the request, the team will be de-registered from the competition. In case the team re-joins the competition according to A5.5, 10 additional penalty points will be deducted from its overall score.
- A5.4.2 Separate requests for different parts within one document or form will be treated independently.
- A5.4.3 If the corrected version of the document does not completely contain all requested corrections, the team will be de-registered from the competition.

A5.5 De-registration

- A5.5.1 A team which is de-registered from the competition has a single chance to apply for a place on the waiting list.

A5.5.2 To apply, the team must complete the following within 24 hours after the de-registration notification.

- Submit an informal application to the officials.
- Correct the reason for de-registration (e.g., upload of a document)

A5.5.3 If the application is positively confirmed by the officials, the team will:

- Be placed at the end of the waiting list.
- Receive 20 penalty points

A5.5.4 Applications will be declined if the rework is inadequate or de-registration was caused by misbehaviour of the team.

A5.6 Vehicle Status Video

A5.6.1 All teams must upload a video showing the vehicle driving prior to the competition. The video must be uploaded before the deadline specified in the competition handbook.

A5.6.2 The video must show the following sequences in the described order:

- Standing still
- 360° video around the vehicle (close, may overlap with the following two bullet points)
- Activate TS
- Straight driving, minimum distance is 30m, minimum speed is 10^{km}/h.
- Full stop
- 180° cornering²
- Straight driving back to start point, minimum speed is 10^{km}/h.
- Standing still

A5.6.3 The video must fulfil the following criteria:

- Continuous video from a third person view - no assembled sequences
- Vehicle must be clearly visible (light, video resolution, frames, and frequency)
- Vehicle must run under its own power.
- Driving must follow A6.4.6
- Vehicle must be presented in ready-to-race conditions incl. body work.
- No crossing in front of the vehicle after TS activated.
- Tractive System Active Light (TSAL) and brake light must be clearly visible in the video.
- Ready-to-drive sound must be audible in the video.
- Must not exceed a length of 60 seconds. File size may be limited, see the competition handbook.
- File format must be common e.g., Avi, mpg, mp4, wmv

A5.6.4 The VSV will be reviewed in order of submission. A review may take up to two weeks

A5.6.5 If a team receives a “failure” for its video prior to the VSV deadline, the video will be treated as not submitted. A new upload is possible afterwards. In all other situations A5.3 and A5.4 apply.

A5.7 SES Approval

A5.7.1 Teams using a monocoque must submit a SESA as one document, in addition to the SES deadline. The SESA template will be available on the competition website.

A5.7.2 The Structural Equivalency Spreadsheet (SES) must be checked and approved by a graduated engineer with appropriate expertise.

A5.7.3 Once the SES has been approved, the SESA form should be filled out, signed, and uploaded until the SESA deadline.

A5.7.4 If any changes to the original SES become necessary due to the approval process, the updated final SES must be uploaded again on the competition website.

A5.7.5 The changelog with details of all changes made from the “Version History” tab of the SES form must be attached to the SESA document and must also be signed by the SES reviewer.

A5.7.6 The officials will randomly double check submitted SESA with their respective submitted SES.

A6 GENERAL RULES

A6.1 Removing the Vehicle from the Site

A6.1.1 Teams who remove their vehicle 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 All team captains, designated team representatives and drivers on a particular day must attend the team briefing for that day. (Δ^1)

A6.4 Testing and Work Safety

A6.4.1 Competition organizers are not responsible for the use of the vehicles outside of their competition.

A6.4.2 The competition officials disassociate themselves from all activities of the teams besides their own competition and associated events.

A6.4.3 All teams are advised to follow common practices and common sense when working on the vehicle and when operating the vehicle, before, during and after a competition.

A6.4.4 The vehicles must not participate in events not suitable for this type of vehicles like hill climbs, drag races or similar.

A6.4.5 Teams must never use their vehicles for wheel-to-wheel races.

A6.4.6 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, 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.

A6.4.7 Organizers reserve the right to disqualify a team registered for their competition in case of unsafe driving behaviour, especially if the reputation of the competition, sponsors and other teams is compromised. This includes any questionable material posted on social media by registered participating team under the competition. (Δ^1)

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, should 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 Alcohol, illegal drugs, weapons, or other illegal material are prohibited on the competition site during the competition.

A6.6.2 If any team member is tested with an alcohol level higher than 0.0‰, he or she 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 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 If the vehicle has not passed electrical inspection, the HVD, see EV4.8, must be disconnected, while the vehicle is moved around on the competition site. This also includes taking part in static events.

A6.7.4 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.

A6.7.5 The team member in the cockpit must have full control of steering and braking.

A6.7.6 When the push bar is attached to the vehicle, the tractive system must remain switched off.

A6.7.7 Vehicles with wings are required to have two team members walking on either side of the vehicle whenever the vehicle is being pushed.

A6.8 Working on the Tractive System

- A6.8.1 Activities on the TS, except for the accumulator (see A6.9) must take place in the pit.
- A6.8.2 All activities require the attendance of the ESO.
- A6.8.3 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 activated 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.
- A6.8.4 In case of measurements on the active TS or an activation of the TS in the pit for testing purposes, the following steps must be followed:
- 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.
- A6.8.5 If the TSAL is flashing red or malfunctioning, the TS is considered as active.
- A6.8.6 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.
- A6.8.7 Turning on the TS inside pit is restricted. Working on the vehicle with TS ON is only allowed in the designated areas specified by the officials. (Δ^1)
- ## **A6.9 Working on Tractive System Accumulators**
- A6.9.1 Opening or working on TSACs is only allowed in the provided workplaces in the charging area, see A6.10.

- A6.9.2 All activities require the attendance of an ESO.
- A6.9.3 Whenever the TSACs are opened, the cell segments must be separated with the maintenance plugs, see EV5.4.4.
- A6.9.4 Appropriate insulated tools and equipment must be used.
- A6.9.5 Safety glasses with side shields and compliant safety gloves must be worn by all participating team members.
- A6.9.6 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.
- A6.9.7 Moving accumulator cells and/or accumulator segment(s) around at the competition site is only permitted if they are inside a completely closed TSAC.
- A6.9.8 All parts and modules of the TSAC that are not currently being worked on must be covered at least according to IPxxB while working on the accumulator container.
- A6.9.9 Additional safety measures may be included in the respective competition handbook.
- A6.9.10 The TSAC and any spare cells must be stored in a designated area specified by competition officials. (Δ^1)
- A6.9.11 The TSAC must be stored in designated areas specified by competition officials after the competition's daily operational hours, even after a vehicle passes technical inspections. The TSAC shall not be stored in the team's pit. (Δ^1)

A6.10 Charging

- A6.10.1 There will be a separated charging area on the competition site. Charging TS accumulators is only allowed inside this area.
- A6.10.2 Accumulators must be removed from the vehicle and placed on the TSAC hand cart, see EV8.1, for charging.
- A6.10.3 The label EV5.3.8 or an additional label according to EV5.3.8 must be visible during charging.
- A6.10.4 No grinding, drilling, etc. is allowed in the charging area.
- A6.10.5 At least one team member who has knowledge of the charging process must stay with the accumulator(s) during charging.

T1 TGENERAL TECHNICAL REQUIREMENTS

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 Cockpit – The volume which accommodates the driver, which is defined by the top of the vehicle, the floor closeout, the inner side of the bodywork, the front bulkhead, and the firewall.
- T1.1.3 Chassis member – A minimum representative single piece of uncut, continuous tubing or equivalent structure.
- T1.1.4 Front bulkhead – A planar structure that defines the forward plane of the chassis and provides protection for the driver’s feet (in front view, together with the AIP, covers the driver’s feet).
- T1.1.5 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.
- T1.1.6 Front hoop – A roll bar located above the driver’s legs, in proximity to the steering wheel.
- T1.1.7 Impact Attenuator (IA) – A deformable, energy absorbing device located forward of the front bulkhead.
- T1.1.8 Main hoop – A roll bar located alongside or just behind the driver’s torso.
- T1.1.9 Monocoque – A chassis made of composite material.
- T1.1.10 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.
- T1.1.11 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.
- structures mentioned under EV4.4.2 and EV5.5.2

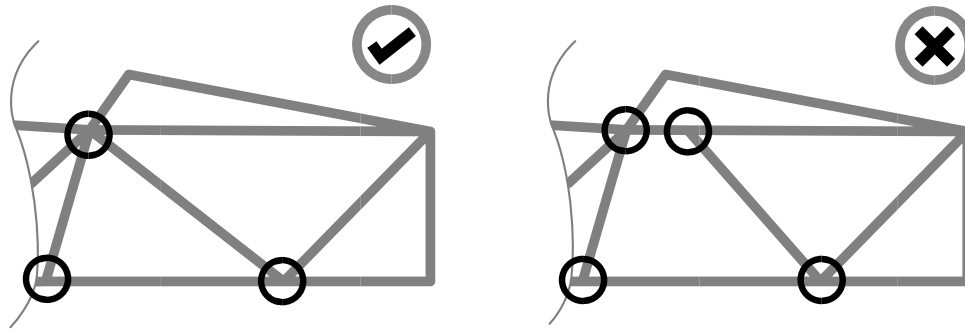


Figure 1: Node-to-node triangulation of chassis members (left correct and right incorrect).

- T1.1.12 Roll hoops – Both the front hoop and the main hoop are classified as “roll hoops”
- T1.1.13 Roll hoop bracing – The structure from a roll hoop to the roll hoop bracing support.
- T1.1.14 Roll hoop bracing supports – The structure from the lower end of the roll hoop bracing back to the roll hoop(s).
- T1.1.15 Rollover protection envelope – Envelope of the primary structure and any additional structures fixed to the primary structure which meet the minimum specification defined in T3.2 or equivalent, see Figure 3.
- T1.1.16 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.
- T1.1.17 Surface envelope – The surface envelope is the surface of the union of the rollover protection envelope, see T1.1.15, and the volume defined by top of the roll bar and the outside edges of the four tires, see Figure 2.

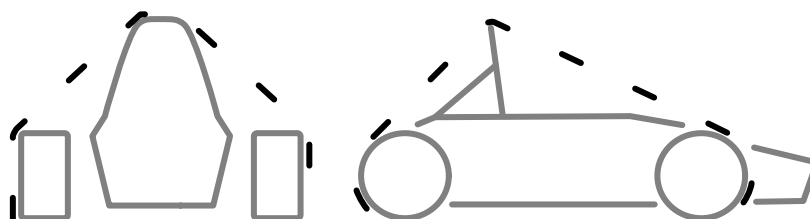


Figure 2: Surface Envelope without the rollover protection envelope, see T1.1.15

T1.2 Material Definitions

T1.2.1 Fire Retardant – A material meeting one of the following standards:

- UL94V-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.

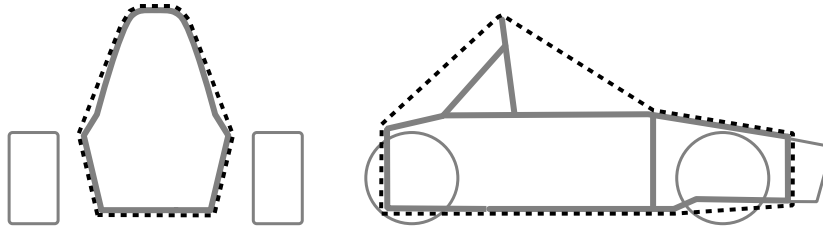


Figure 3: Rollover protection envelope T1.1.15, thick lines are primary structure members according to T3.2

T1.2.2 Coolant – A substance used for heat transfer by convection.

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 or connectors.

T1.4 Driving Mode Definitions

T1.4.1 Manual Mode – A vehicle is in manual mode when driven by a human driver.

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/tire 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 75mm in front of and 75mm behind the outer diameter of the front and rear tires in the side view of the vehicle, with steering straight ahead. This keep-out zone extended laterally from the outside plane of the wheel/tire to the inboard plane to the wheel/tire assembly

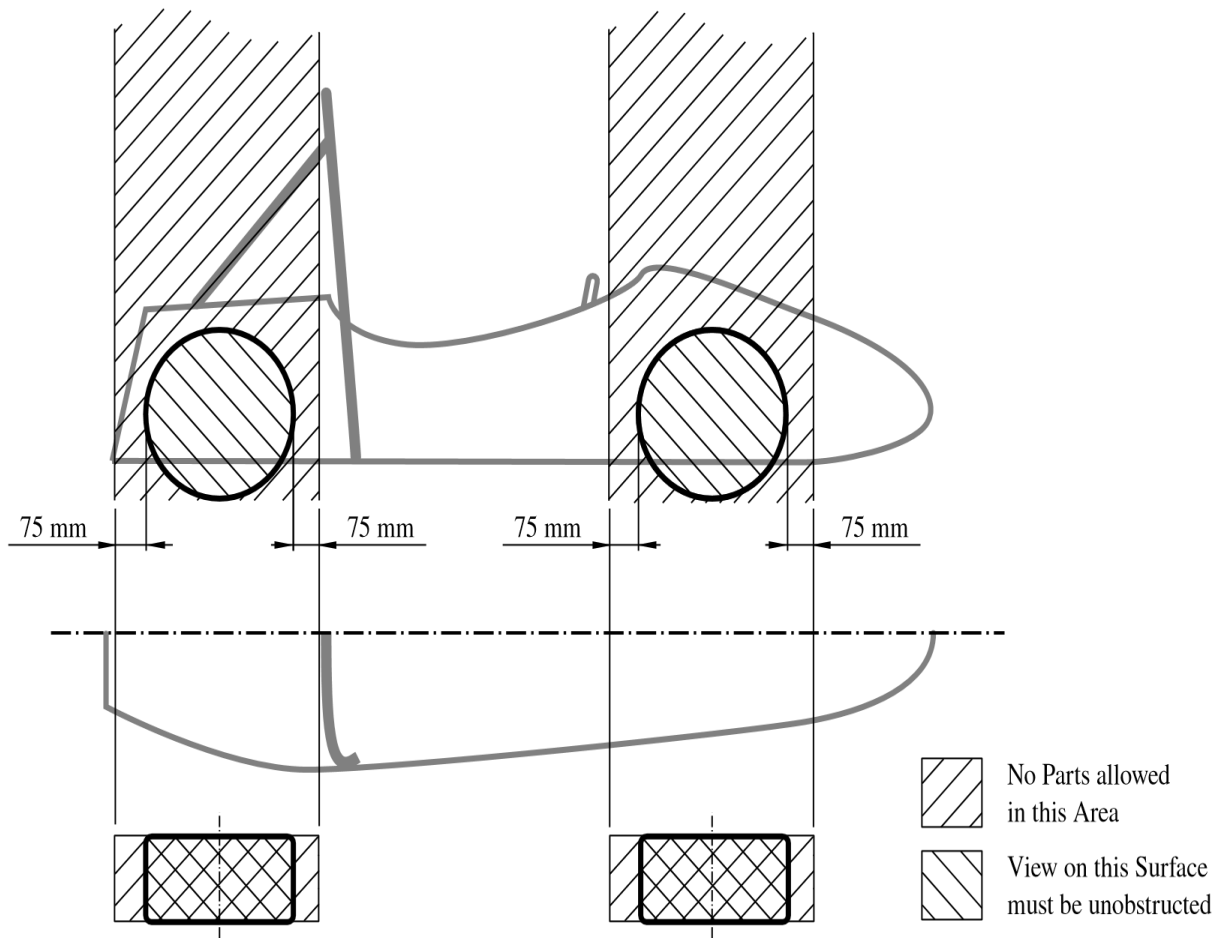


Figure 4: Keep-out-zones for the definition of an open-wheeled vehicle.

T2.2 Ground Clearance

- T2.2.1 The minimum static ground clearance of any portion of the vehicle, other than the tires, including a driver, must be 30mm.
- T2.2.2 Sliding skirts or other aerodynamic devices that by design, fabrication or because of moving, contact the track surface are prohibited.

T2.3 Bodywork

- T2.3.1 There must be no openings through the bodywork into the cockpit other than that required for the cockpit opening. Minimal openings around the front suspension and steering system components are allowed.
- T2.3.2 Enclosed chassis structures and structures between the chassis and the ground must have two venting holes of at least 25mm 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.
- T2.3.3 All edges of the bodywork that could come into contact with a pedestrian must have a minimum radius of 1mm.

T2.3.4 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.

T2.4 Suspension

T2.4.1 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 25mm with driver seated.

T2.4.2 All suspension mounting points must be visible at technical inspection, either by direct view or by removing any covers.

T2.5 Wheels

T2.5.1 Any wheel mounting system that uses a single retaining nut must incorporate a device to prevent loosening of the nut and the wheel. A second nut (“jam nut”) does not meet these requirements.

T2.5.2 Wheel lug bolts and studs must be made of steel or titanium. The team must be able to show good engineering practice and providing adequate strength by calculations. Wheel lug bolts and studs must not be hollow.

T2.5.3 Aluminium wheel nuts may be used, but they must be hard anodized and in pristine condition.

T2.6 Tires

T2.6.1 Vehicles must have two types of tires as follows:

- Dry tires - The tires on the vehicle when it is presented for technical inspection are defined as its “dry tires”.
- Wet tires - Wet tires may be any size or type of treaded or grooved tire provided:
 - The tread pattern or grooves were moulded in by the tire manufacturer or were cut by the tire manufacturer or their appointed agent. Any grooves that have been cut must have documentary proof that it was done in accordance with these rules.

There is a minimum tread depth of 2.4mm.

T2.6.2 Tire Set (Δ^2)

- All four Dry Tires and Wheels or all four Wet Tires and Wheels do not have to be identical.
- Once each tire set has been presented for Technical Inspection, any tire compound or size, or wheel type or size must not be changed

T2.6.3 Tire Pressure (Δ^2)

- Tire Pressure must be in the range allowed by the manufacturer at all times.
- Tire Pressure may be inspected at any time

T2.6.4 Tires on the same axle must have the same manufacturer, size and compound.

T2.6.5 Tire warmers are not allowed.

T2.6.6 Special agents that increase traction may not be added to the tires or track surface.

T2.7 Steering

T2.7.1 Steering systems using cables or belts for actuation are prohibited.

T2.7.2 The steering wheel must directly mechanically actuate the front wheels.

T2.7.3 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 tires and rims from contacting any other parts. Steering actuation must be possible during standstill.

T2.7.4 Allowable steering system free play is limited to a total of 7° measured at the steering wheel.

T2.7.5 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.

T2.7.6 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.

T2.7.7 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.

T2.7.8 In any angular position, the top of the steering wheel must be no higher than the top-most surface of the front hoop.

T2.7.9 The steering rack must be mechanically attached to the primary structure.

T2.7.10 Joints between all components attaching the steering wheel to the steering rack must be mechanical and visible at technical inspection. Bonded joints are allowed in accordance with T3.2.8.

T2.7.11 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.

T2.8 Wheelbase

T2.8.1 The vehicle must have a wheelbase of at least 1525mm.

T2.9 Track and Rollover Stability

- T2.9.1 The smaller track of the vehicle (front or rear) must be no less than 75% of the larger track.
- T2.9.2 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 IA
 - Side impact structures

T3.2 Minimum Material Requirements

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

Item or application	Minimum wall thickness	Minimum cross-sectional area	Minimum area moment of inertia
Main and front hoops, shoulder harness mounting bar	2.0mm	173mm ² (Δ^2)	11320mm ⁴
Side impact structure, front bulkhead, roll hoop bracing, driver’s restraint harness attachment (except as noted above)	1.2mm	114mm ² (Δ^2)	8509mm ⁴
Front bulkhead support, Main hoop bracing supports	1.2mm	91mm ²	6695mm ⁴

Table 4: Minimum Material Requirements

- T3.2.2 Steel tubing has to be made from unalloyed carbon steel with a maximum content of 0.3% carbon, 1.7% manganese and 0.6% of any other element. All other steel grades are considered alternative materials and require additional testing and documentation (see T3.3).
- T3.2.3 Except for inspection holes, any holes drilled in any part which is a member of the primary structure must be considered 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) = 200GPa

- Yield Strength (S_y) = 305MPa
- Ultimate Strength (S_u) = 365MPa

Welded strength for discontinuous material such as joint calculations:

- Yield Strength (S_y) = 180MPa
- Ultimate Strength (S_u) = 300MPa

T3.2.5 Any tubing with a wall thickness less than 1.2mm or a minimum area moment of inertia less than 6695mm^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 primary structure.
- Be angled no more than 30° 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 nominal and tested adhesive values. 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 other materials 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.

T3.3.3 If alloyed steel as defined by T3.2.2 is used, the team must include tests and documentation in the SES to show structural equivalency. This may include, but is not limited to:

- Receipts and data sheets of the used tubing materials
- Documentation about welding processes and filler materials
- Documentation about heat treatments

Tests showing adequate strength and elongation at break in the welded condition

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 considered for the main hoop bracing support, the front hoop bracing, the front bulkhead support structure, the shoulder harness bar, the TS and TSAC protective structure. 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 primary structure or the TSAC.

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
- Fiber 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.

T3.4.5 Backing plates 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. Backing plates must not have any cut-outs within their outside perimeter except for the holes for bolts.

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 275mm \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.

Representative test panels for parts of the TSAC may use smaller dimensions, provided that the panel core thickness is 5mm or smaller. This representative test panel must then measure 150mm×275mm. In this case, the distance between the two-test panel supports must be at least 200mm and the load applicator must have a radius of at least 5mm. T3.5.5 and T3.5.6 do not apply.

- 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 66% 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 (e.g.: permanent marker or engraving, but no sticker) information: laminated structure acronym and date of testing.
- T3.5.5 The distance between the two-test panel supports must be at least 400mm.
- 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 25mm 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 primary 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) and Structural Equivalency 3D Model (SE3D).

- T3.6.2 The SES spreadsheet form can be downloaded from the competition website.
- T3.6.3 The SE3D must contain a three-dimensional CAD model of the chassis including all members of the primary structure and all mechanical attachment details of the hoops and hoop braces in “IGES” file format not larger than 40MB. The TSAC(s) and attachment must also be included.
- 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.

T3.7 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. The minimum area moment of inertia, see T3.2, must be maintained in all areas, including the bends of the manufactured tubes.
- 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 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 3mm thick aluminium, dependent of the roll hoop material.
- T3.7.6 Both roll hoops must have one 4.5mm 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 Inside 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 Inside 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 Inside view any portion lower than the upper attachment point to the side impact structure must be inclined either forward or not more 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 Inside 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 The front hoop requires six attachment points, two on each side connecting to the front bulkhead support structures and two connecting to the front hoop bracing, and must therefore show equivalency to 180kN, as follows from T3.16.1 and T3.11.4.
- T3.9.6 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.

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.

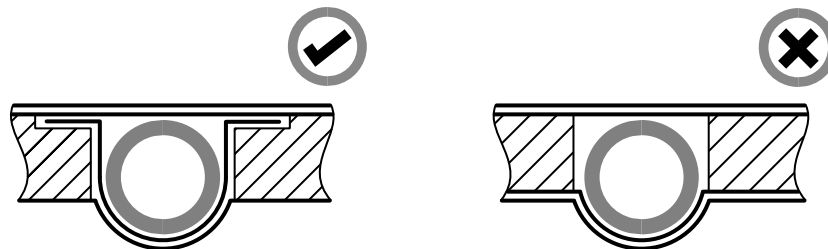


Figure 5: Front hoop laminating requirements.

- T3.10.2 Inside 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 inside view of the frame and must have a minimum distance of 100mm 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.

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.

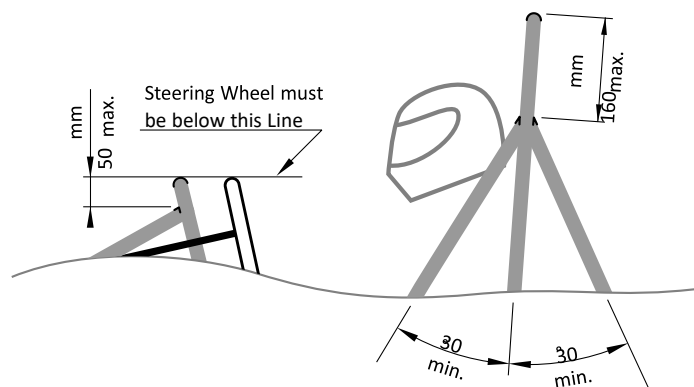


Figure 6: Front hoop bracing, main hoop bracing and steering wheel requirements.

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

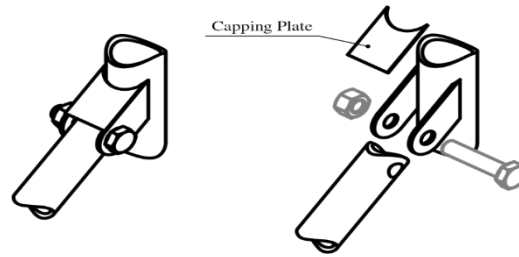


Figure 7: Double lug joint

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

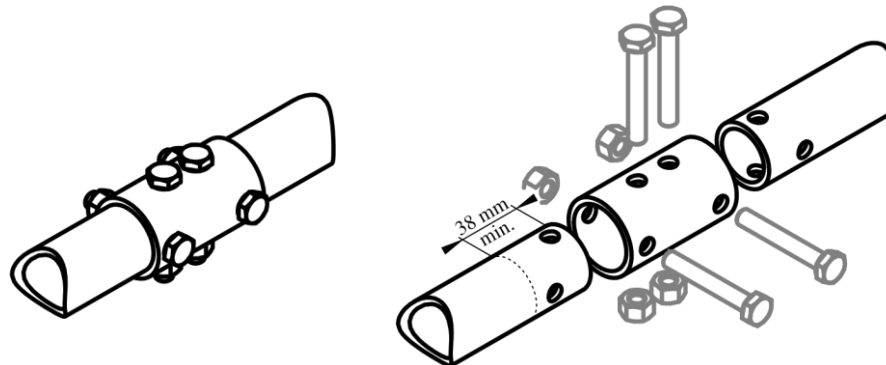


Figure 8: Sleeved joint

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.

T3.14 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 to the front bulkhead a maximum of 50mm below the top-most surface of the front bulkhead and attached to the front hoop a maximum of 50mm below the upper side impact member. If the attachment point of the upper 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 and it must not be counted towards the composite front hoop bracing structures for the structural equivalency documentation (i.e., T3.11.4).

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.
- The upper member 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.

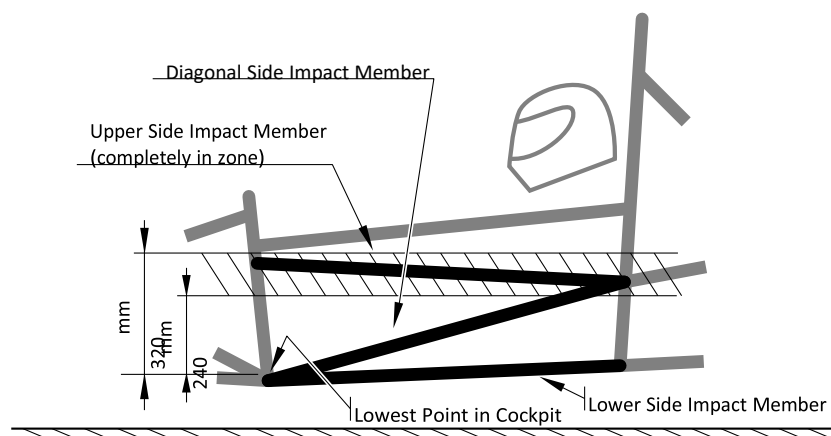


Figure 9: Side impact structure

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.

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.

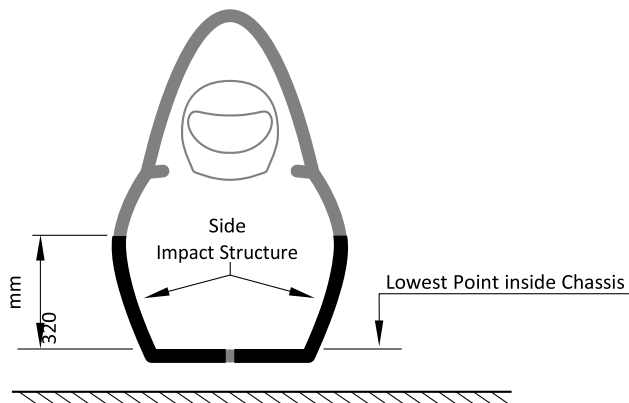


Figure 10: Side impact structure monocoque

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.

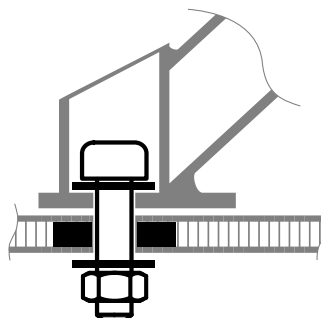


Figure 10: Side impact structure monocoque

- T3.16.5 When using bolted joints within the primary structure, no crushing of the laminate core material is permitted.
- T3.16.6 For the AIP to front bulkhead attachment, and if two panels or plates of the primary structure are bolted together, for each 200mm of reference perimeter a minimum of one 8mm metric grade 8.8 bolt(s) must be used, rounded up to the next integer. Smaller, but more, bolts may be used, if equivalency is shown. The bolts must be evenly distributed over the circumference using good engineering practices. 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 IA.

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 required 100×200×200mm³ volume of the IA can be positioned more than 350mm above the ground.
- Not able to penetrate the front bulkhead in the event of an impact.
- Attached securely and directly to the AIP.
- Not part of the non-structural bodywork.
- Designed with a closed front section.

Cannot be wider or higher than the AIP.

T3.17.3 On all vehicles, a 1.5mm solid steel or 4.0mm solid aluminium AIP must be integrated into the IA.

- If the IA and AIP (IA assembly) are bolted to the front bulkhead, it must be the same size as the outside dimensions of the front bulkhead.
- 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 AIP designs are permissible if equivalency to T3.17.3 is proven by physical testing as in T3.19.2.

T3.17.5 The IA may be attached to the AIP by a minimum of four 8mm metric grade 8.8 bolts. The bolts are considered critical fasteners and must comply with T10.

T3.17.6 The attachment of the IA assembly 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 parallelograming.

T3.17.7 A team may use one of the “standards” FSAE IAs, to avoid testing, provided that:

- if the front bulkhead width is larger than 400mm and/or its height is larger than 350mm a diagonal or X-bracing that is a front bulkhead support tube or an approved equivalent per T3.2, must be included in the front bulkhead. Or equivalent for monocoque bulkheads.
- must use a 1.5mm solid steel AIP that is welded along its full perimeter to a steel bulkhead or use a 4mm solid aluminium AIP that is bolted to any bulkhead with a minimum of eight 8mm metric grade 8.8 bolts.

if the “standard” honeycomb IA is used, the IA must be of pre-crushed type

T3.17.8 If the standard IA is used but does not comply with the requirements of T3.17.7 physical testing must be carried out to prove that the AIP does not permanently deflect more than 25mm.

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 at the competition website.

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 300kg 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 7350J.

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 representative of the intended primary structure and equal or higher stiffness and strength. When alternative materials are used for the AIP, the test fixture must be a copy of the intended primary structure (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 front bulkhead 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 thereof 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 100Hz, 3rd order, low pass Butterworth (–3dB 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.

T4.3 Percy (95th percentile male)

- T4.3.1 When seated normally and restrained by the driver’s restraint system, the helmet of a 95th 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.

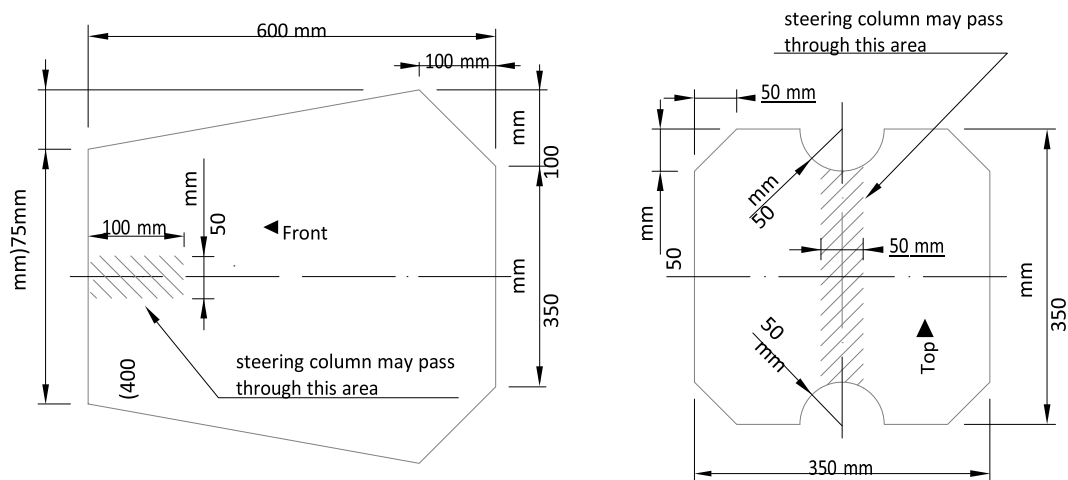


Figure 12: Cockpit opening template (left) and cockpit internal cross section template (right)

- Be no further rearwards than the rear surface of the main hoop if the main hoop bracing extends forwards.

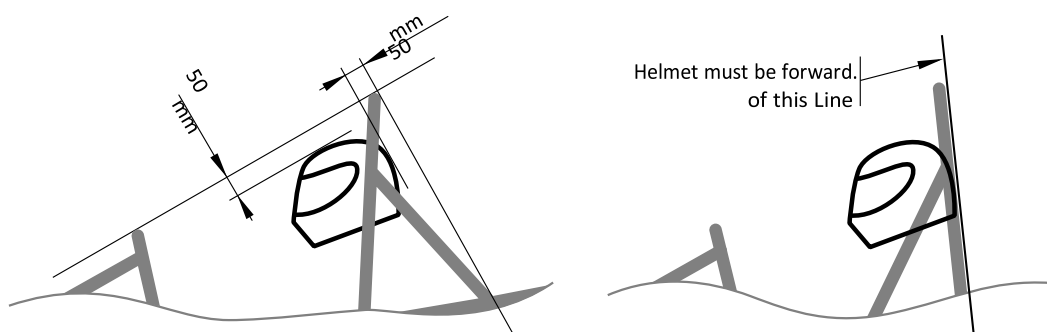


Figure 13: Minimum helmet clearance

- T4.3.2 The 95th 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 490mm. 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 frontmost 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 25mm away from the head restraint.

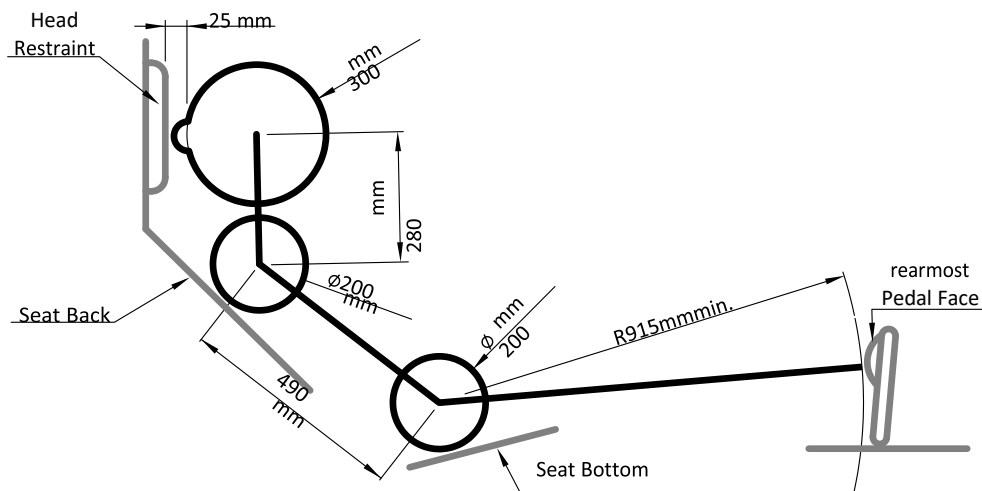


Figure 14: Percy placement

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 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 8mm metric grade 8.8 bolts (or bolts of an equivalent standard) and steel backing plates with a minimum thickness of 2mm.
- T4.5.2 Any harness that is fastened to the primary structure using brackets must use two 8mm 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 If the belts are attached to a laminated structure or the mounting brackets and tabs are not made from steel at least 1.6mm or aluminium at least 4.0mm thick, physical testing is required. The following requirements must be met:
- Load is applied to a test sample representing the tubular or laminated structure and must use the same brackets and tabs.
 - 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 does 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 address all three types of heat transfer with the following minimum requirements between the heat source and the part that the driver could contact:
- (a) Conduction insulation by:
 - (i) No direct contact, or
 - (ii) a heat resistant, conduction insulation material with a minimum thickness of 8mm.
 - (b) Convection insulation by a minimum air gap of 25mm.

(c) Radiation insulation by:

(i) A solid metal heat shield with a minimum thickness of 0.4mm or reflective foil or tape when combined with T4.6.2.a.ii.

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 cockpit from all components of the hydraulic fluid (except brake system and dampers), flammable liquids, the low voltage battery, and any TS component, see EV1.1.1.

T4.8.2 The firewall must cover any straight line between the parts mentioned in T4.8.1 and 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-resistant material, see T1.2.1, which must be rigidly mounted to the vehicle's structure.

T4.8.4 Any 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 passthrough.

T4.8.6 Multiple panels may be used to form the 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 The TS firewall between driver and TS components must be composed of two layers:

- One layer, facing the TS side, must be made of aluminium with a thickness of at least 0.5mm. This part of the TS 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 TS firewall must be presented at technical inspection.

T4.8.8 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 TS parts outside of the envelope, see 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 plane's tangent to the outermost surface of the side impact structure.

T4.10 Accommodation (Δ^2)

T4.10.1 The vehicle must be able to accommodate drivers of sizes ranging from 5th percentile female up to 95th percentile male. (Δ^2)

- Accommodation includes driver position, driver controls, and driver equipment.
- Anthropometric data may be found on the FSAE Online Website.

T4.10.2 The driver's head and hands must not contact the ground in any rollover attitude. (Δ^2)

T4.11 Driver Visibility

T4.11.1 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.

T4.11.2 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.

T4.12 Driver Egress

T4.12.1 All drivers must be able to exit to the side of the vehicle in less than 5s with the driver 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 as in T13.3. 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 (minimum width 50mm), two shoulder straps (minimum width 75mm) and two leg or anti-submarine straps (minimum width 50mm).

T5.1.2 7-point system – Same as the 6-point system except it has three anti-submarine straps.

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 95th 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 95th 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 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 HANS device is used by the driver, FIA certified 50mm wide shoulder harnesses are allowed.

T5.2.2 SFI spec harnesses must be replaced following December 31st of the 2nd year after the date of manufacture as indicated by the label. FIA spec harnesses must be replaced following December 31st of the year marked on the label.

T5.2.3 The restraint system must be always worn tightly.

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 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.

- T5.3.3 The attachment of the driver's restraint system 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", Inside view the lap belt must be at an angle of between 45° and 65° to the horizontal.
- T5.4.5 With a "reclined driving position", Inside view the lap belt must be between an angle of 60° and 80° 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 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.

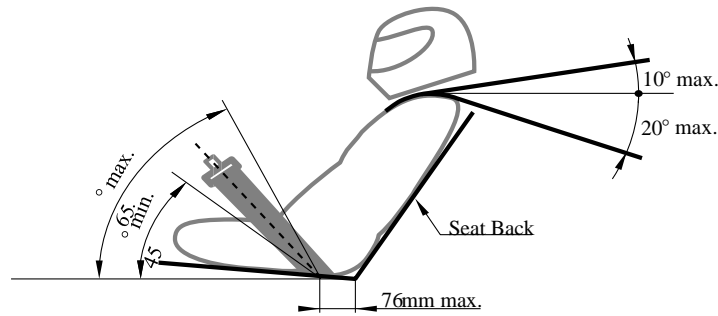


Figure 15: Lap belt and shoulder harness mounting

T5.6 Anti-Submarine Belt Mounting

T5.6.1 The anti-submarine belts of a 6-point harness should be mounted in one of the following setups:

- With the belts going vertically down from the groin or angled up to 20° rearwards. The anchorage points should be approximately 100mm apart.
- With the anchorage points on the primary structure at or near the lap belt anchorages, the driver sitting on the anti-submarine belts and the belts coming up around the groin to the release buckle.

T5.7 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 must:

- Be vertical or near vertical in side view.
- Be padded with an energy absorbing material with a minimum thickness of 40mm that meets either the SFI 45.2 standard or is listed in the FIA technical list n°17 as a type B material for single seater cars.
- Have a minimum width and height of 150mm.
- Be located so that for each driver.
 - The 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.

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's 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.

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 using separate reservoirs or by the use of a dammed reservoir.

T6.1.3 The brake system must be sealed to prevent leakage.

T6.1.4 A single brake acting on a limited-slip differential is acceptable.

T6.1.5 "Brake-by-wire" systems are prohibited in manual mode.

T6.1.6 Unarmoured plastic brake lines are prohibited.

T6.1.7 The brake system must be protected from failure of the drivetrain, see T7.3.2, from touching any movable part and from minor collisions.

T6.1.8 Inside 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.

T6.1.9 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.

T6.1.10 The brake pedal must be fabricated from steel or aluminium or machined from steel, aluminium, or titanium.

T6.1.11 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.

T6.2 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. 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.
- the hydraulic brake system is actuated.
 - the electric brake system is actuated, see EV2.2.2
- 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 15cm² 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 150mm.
- T6.3.3 Inside 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 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 TS components may only use plain water, air or oil as the coolant, see T1.2.2.
- T7.2.2 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 T4.8.2.
- T7.2.3 Any cooling or lubrication system must be sealed to prevent leakage.

- T7.2.4 Separate catch cans must be employed to retain fluids other than plain water from any vents of the cooling system. Each catch-can must have a minimum volume of 10% of the fluid being contained or 900ml whichever is greater.
- T7.2.5 Any vent for systems containing plain water must have a catch-can with a minimum volume of 10% of the fluid being contained or 100ml, whichever is greater.
- T7.2.6 All parts of the lubrication system, including their mountings, must be rated for at least 120°C or the temperatures the respective fluid may reach, whichever is higher.
- T7.2.7 Catch cans must be rigidly mounted to the chassis and located rearwards of the firewall below the driver's shoulder level.
- T7.2.8 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, such as gears, clutches, chains and belts must be fitted with scatter shields. Scatter shields and their mountings must:
- Be constructed of non-perforated 2mm steel or 3mm aluminium alloy 6061-T6.
- Be attached with 6mm metric grade 8.8 or stronger and must comply with T10.1.
- T7.3.3 In addition to T7.3.2, scatter shields 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 at least three times the width of the chain or belt and be centred at the centreline of the chain or belt
- T7.3.4 The tractive electric motor(s) must have a housing or separate scatter shield from nonperforated 2mm aluminium alloy 6061-T6 or equivalent. The scatter shield may be split into two equal sections, each 1mm thick.
- T7.3.5 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.

T8.2 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 tire/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/tire.
- All aerodynamic devices higher than 500mm from the ground, must not extend outboard of the most inboard point of the rear wheel/tire.

T8.2.3 Length restrictions:

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

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

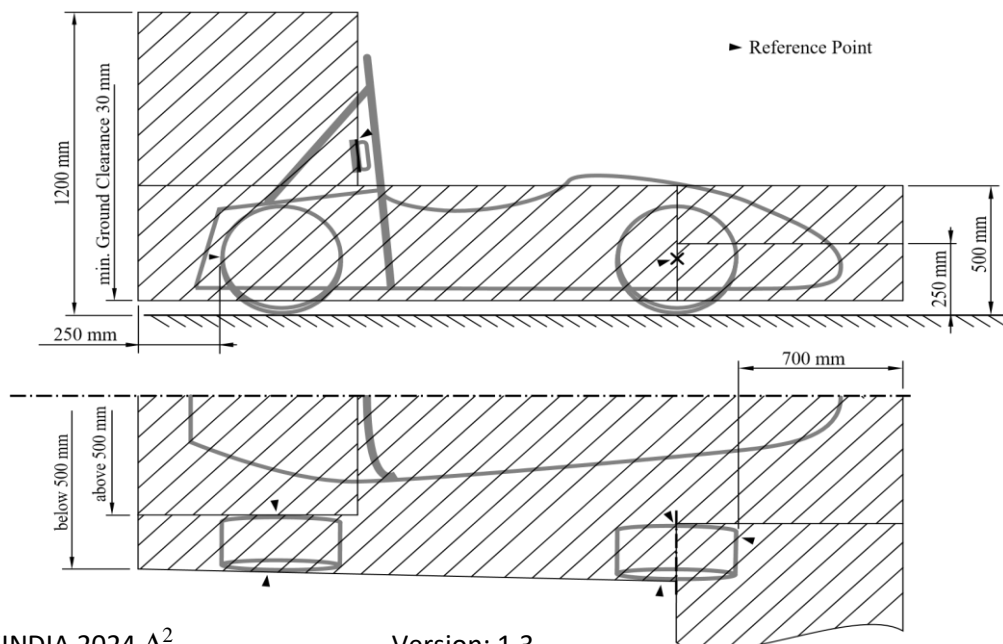


Figure 16: Maximum dimensions and positioning of aerodynamic devices. The positioning space is further restricted, see T2.1.

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 225cm² 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.

T9 HIGH PRESSURE HYDRAULICS

T9.1 High Pressure Hydraulic Pumps and Lines

T9.1.1 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.

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 3mm metric grade 8.8), equivalent size or of that specified in the referencing rule, whichever is larger.

T10.1.3 All threaded critical fasteners must be of the type hexagon bolts (ISO 4017, ISO 4014 or an equivalent standard.) or socket head cap screws (ISO 4762, DIN 7984, ISO 7379 or an equivalent standard.) including their fine-pitch thread versions.

T10.1.4 Any bolted joint in the primary structure and mounting of the TSAC to the chassis 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 an equivalent standard) for locations where no temperature rating above 80°C is required.
- Prevailing torque lock nuts (DIN 980, ISO 7042 or an equivalent standard, 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 given that they do not bear any loads under normal driving conditions.

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 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 60VDC or 25VACRMS. (Δ^2)

T11.1.3 All LVS parts must be adequately insulated.

T11.1.4 The LVS must not use orange wiring or conduit.

T11.1.5 The LVS must be grounded to the chassis.

T11.2 Master Switches

T11.2.1 Master switches, see T11.3, EV6.2, and T14.6, 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 95th 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 power to the LVS

T11.3.2 The LVMS must be mounted in the middle of a completely red circular area of ≥ 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.

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 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.

T11.5 Inertia Switch

T11.5.1 An inertia switch must be part of the shutdown circuit, see EV6.1, 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 $\leq 8g$ for a half sine test pulse of $\geq 50ms$ length and $\leq 13g$ for a half sine test pulse of $\geq 20ms$ 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, when hard braking occurs, whilst.

- $\geq 5kW$ power is delivered to the motors.

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 $\leq 30bar$.

T11.6.6 To measure power delivery, a DC circuit current sensor only must be used. The threshold must be chosen to an equivalent of $\leq 5kW$ 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 The team must prove the function of the BSPD during technical inspection by sending an appropriate signal that represents the current, to achieve $\leq 5kW$ 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 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 T1.1.15.

- T11.7.3 Any wet-cell battery located in the cockpit 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 Completely closed LV battery cases must have an overpressure relief. Venting gases must be separated from the driver by a firewall.
- T11.7.6 LV batteries must be protected from short circuits, not more than 100mm from ungrounded terminals.
- T11.7.7 Battery packs based on lithium chemistry other than lithium iron phosphate (LiFePO₄):
- Must have a fire-retardant casing, see T1.2.1.
 - Must include overcurrent protection that trips at or below the maximum specified discharge current of the cells.
 - 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.
 - Must meet EV5.8.11

Signals needed to fulfil these requirements are SCS, see T11.9.

T11.8 Accelerator Pedal Position Sensor

- T11.8.1 T11.8 only apply for electric vehicles, see chapter EV.
- 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 analog 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
- 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.
- 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 wire to check all functionalities.
- T11.8.12 A fully released accelerator pedal in manual mode must result in:
A wheel torque of ≤ 0 Nm

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.
 - Influence the wheel torque.
- Influence indicators according to EV5.8.9, EV4.10 or EV6.3.7.
- T11.9.2 Any of the following SCS single failures must result in a safe state of all connected systems:
- (a) Failures of signals transmitted by cable:
 - Open circuit
 - Short circuit to ground.
 - (b) Failures of analog sensor signals transmitted by cable:
 - Short circuit to supply voltage.
 - (c) Failures of sensor signals used in programmable devices:
 - Implausibility due to out-of-range signals, e.g., mechanically impossible angle of an angle sensor.
 - (d) Failures of digitally transmitted signals by cable or wireless:
 - Data corruption (e.g., checked by a checksum)
 - Loss and delay of messages (e.g., checked by transmission time outs)

Signals might be a member of multiple signal classes, e.g., analog 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 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 state is defined depending on the signals as follows:

- 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.

For all other signals – opened shutdown circuit and opened AIRs.

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.

T11.10 Sensors & Electrical Components Mounting

T11.10.1 All sensors and components must be securely mounted. For all mounts, T2.3.3 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 T1.1.17, or within the box defined in T8.2.

T11.10.4 Passive antennas which do not incorporate active electronic parts, e.g., amplifiers with the longest side <100mm may additionally to T11.10.3 protrude from the surface envelope, see T1.1.17, but not their mounting.

T11.11 Legal & Work Safety

T11.11.1 All sensors must fulfil the local legislative specifications (i.e. eye-protection classification for laser sensors, power limitation for radar sensors, etc.) in the country of competition.

T12 VEHICLE IDENTIFICATION

T12.1 Vehicle Number

T12.1.1 Each vehicle will be assigned a number at the time of its entry into a 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.

T12.2 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
- 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.

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 university name must be written on the push bar. The characters must be clearly visible and placed on a high contrast background.

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 T13.4.1, must be mounted to the push bar such that it is quickly accessible.

T13.1.6 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 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 Jacks

T13.2.1 Each team must have one or two removable devices (jacks) that hold the vehicle, so that all driven wheels are at least 100mm off the ground.

T13.2.2 Positioning of the device(s) must be safe (e.g., without reaching under the vehicle).

T13.2.3 In lifted position:

- The vehicle must be adequately supported and stable.
- It must be safe for a driver to enter and exit the vehicle.
- The device(s) must not extend out of the area defined by the footprint of the four tires

T13.2.4 On both sides of the vehicle the devices pickup points must be indicated by orange triangles.

T13.2.5 The university name must be written on the jacks. The characters must be clearly visible and placed on a high contrast background.

T13.3 Driver Equipment

T13.3.1 The equipment specified below must be worn by the driver anytime while in the cockpit 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 K2010, K2015, K2020, M2010, M2015, M2020, SA2010, SAH2010, SA2015, SA2020, EA2016 or newer
- SFI 31.1/2010, 31.1/2015, 31.1/2020, 41.1/2010, 41.1/2015, 41.1/2020 or newer. FIA8860-2010, FIA 8860-2018, FIA 8859-2015 (with SA 2015), FIA 8858-2010 (with SA(H) 2010) or newer

Open faced helmets and off-road helmets (helmets without integrated eye shields) are not approved. All helmets to be used in the competition must be presented during technical inspection where approved helmets will be stickered.

T13.3.3 A Ski mask 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 A fire-resistant one-piece suit, made from a minimum of two layers that covers the body from the neck down to the ankles and the wrists. The suit must be certified to one of the following standards and be labelled as such:

- SFI 3.2A/5 (or higher)
- SFI 3.4/5 (or higher)

- FIA Standard 8856-2000
- FIA Standard 8856-2018

- 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. Teams must be able to show that the clothing still meets the requirements of T13.3 if driver's clothing is embroidered. 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.

T13.4 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

- India: Dry chemical or dry powder ABC fire extinguishers are acceptable. (Δ^1)

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 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.
- T13.4.6 Handheld fire extinguishers are not permitted to be mounted on or in the vehicle.

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 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 250V, whichever is higher.
- the isolation voltage RMS, AC for 1min, between both circuits is higher than three times the maximum TS voltage or 750V, whichever is higher.

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 at the outlet of the TSAC must not exceed 80kW.

EV2.2.2 Regenerating energy is allowed and unrestricted.

EV2.2.3 Wheels must not be spun in reverse.

EV2.3 APPS / Brake Pedal Plausibility Check

EV2.3.1 The commanded motor torque must be 0Nm, if hard braking, see T11.6.5, and the APPS, see T11.8, signals pedal travel equivalent to $\geq 25\%$ desired motor torque or $\geq 5kW$, whichever is lower, at the same time for more 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 layer made of at least 0.5mm thick electrically conductive material, aluminium or better, having a resistance below 300m Ω , measured with a current of 1A, to LVS ground and able to continuously carry at least 10% of the TS accumulator main fuse current rating or
- be fully made of electrically insulating materials having an isolation resistance of at least 2M Ω , measured with a voltage of 500V. 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

The TSAC might use at least 0.9mm thick steel layer as the grounded layer.

EV3.1.2 Electrically conductive seat, driver harness, and firewall mounting points as well as the TS firewall must have a resistance below 300m Ω , measured with a current of 1A, 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 are or may become electrically conductive within 100mm of any TS component must have a resistance below 100 Ω 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 conductors that it protects.

I.e., if multiple pins of a connector are used to carry currents in parallel, each pin must be appropriately protected.

EV3.2.4 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 which 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 630VDC.

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 which may occur during usage.

EV4.1.4 Fans with >50W power must not be connected to the TS.

EV4.2 Tractive System Enclosures

EV4.2.1 TS enclosures, see EV1.1.2, must be labelled with (a) reasonably sized sticker(s) according to “ISO 7010-W012” (triangle with a black lightning bolt on yellow background). The sticker must also contain the text “High Voltage” if the voltage is more than 60VDC or 25VACRMS. (Δ^2)

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 <100VDC	10mm
100VDC < U <200VDC	20mm
U >200VDC	30mm

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 Air (Cut in board)	Conformal Coating
0VDC to 50VDC	1.6mm	1.6mm	1.0mm

50VDC to 150VDC	6.4mm	3.2mm	2.0mm
150VDC to 300VDC	9.5mm	6.4mm	3.0mm
3 00VDC to 600VDC	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. If integrated circuits are used such as optocouplers which are rated for the respective maximum TS voltage, see EV1.2.1, but do not fulfil the required spacing, then they may still be used and the given spacing does not apply to this integrated circuit.

EV4.3.7 Teams must be prepared to demonstrate spacing on team-built equipment. For inaccessible circuitry, fully assembled spare boards must be available.

EV4.4 Positioning of Tractive System Parts

EV4.4.1 Except for 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 T1.1.15. “Part” is the whole device such as the complete HVD.

EV4.4.2 Any part of the TS that is less than 350mm above the ground must be shielded from side and rear impact collisions by structure according to T3.15(with exception of the first point under T3.15.1) and must follow T3.16 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

- an interlock is routed along the TS wiring such that the shutdown circuit, see EV6, is opened before the TS wiring or its clamping fails.
- an interlock is routed along a suspension member such that the shutdown circuit, see EV6, is opened if the suspension fails.
- 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 T1.1.15 is minimum length.

wiring outside of an impact structure or front bulkhead support structure, see EV4.4.2, is minimum length.

EV4.4.4 Inside 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 EV5.4.

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 appropriate for the expected surrounding temperatures and 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 at least 85°C.
- EV4.5.4 TS components and containers must be protected from moisture in the form of rain or puddles, see IN8.
- 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 the 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.
- Bodywork 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 it is physically impossible to electrically connect them 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 using 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.

- 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 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 Data Logger

- EV4.6.1 A calibrated data logger will be provided by the officials and must be inserted during competition. The data logger measures TS voltage and TS current.
- EV4.6.2 The data logger must be in an easily accessible location so that it is possible to insert, remove or replace it within 15min in ready to race condition.
- EV4.6.3 The data logger must not be placed within the TSAC.
- EV4.6.4 All current supplying the TS must run through the data logger. The data logger 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 data logger must be directly connected, see T1.3.1, to the most positive AIR(s) on vehicle side.
- EV4.6.6 The data logger must be directly supplied, see T1.3.1, from the LVMS.
- EV4.6.7 The specification of the data logger will be available in the competition handbook.

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 rated for 1000V CAT III or better must be used.
- EV4.7.4 The TSMPs must be marked “TS+” and “TS-” and exclusively mounted on orange background.
- EV4.7.5 The TSMPs must be protected by a non-conductive housing that can be opened without tools. The housing must always be mechanically linked to the vehicle.
- EV4.7.6 Each TSMP must be secured with a current limiting resistor according to the following table. Fusing the TSMPs is prohibited. The resistor’s 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 Ω
$200\text{VDC} < U_{max} \leq 400\text{VDC}$	10k Ω
$400\text{VDC} < U_{max} \leq 600\text{VDC}$	15k Ω

- EV4.7.7 All electrical connections needed for TSMP, including bolts, nuts, and other fasteners, must be secured from unintentional loosening using positive locking mechanisms.
- EV4.7.8 Next to the TSMPs an 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 attached to the push bar, see T13.1, 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 discharge main current path is prohibited.

EV4.10 Tractive System Active Light

- EV4.10.1 The vehicles 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 if and only if the LVS is active and the voltage across any DC-link capacitor exceeds.

- 60VDC or 25VACRMS (Δ^2)

Half the nominal TS voltage whichever is lower.

EV4.10.3 The TSAL itself must have a green light, continuously on, active if and only if the LVS is active and ALL 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 25VACRMS. (Δ^2)

EV4.10.4 The mentioned voltage detection must be performed inside the respective TS enclosure.

EV4.10.5 The mentioned 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 T1.1.15.
- 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° 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 needed circuitries must be hard-wired electronics. Software control is not permitted.

EV4.10.10 A green indicator light in the cockpit that is easily visible even in bright sunlight and clearly marked with "TS off" must light up if TSAL green light is on, see EV4.10.3.

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 T11.9.5.

- 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, when no voltage is present. 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.

EV4.11 Activating the Tractive System

- EV4.11.1 The TS is active if any of the AIRs or the pre-charge relay is 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 Closing the shutdown circuit by any part defined in EV6.1.2 must not (re-)activate the TS. Additional action must be required.
- EV4.11.4 The vehicle is ready-to-drive as soon as the motor(s) will respond to the input of the APPS.
- EV4.11.5 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.
- EV4.11.6 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 when it enters ready-to-drive mode.
- EV4.12.2 The sound level must be a minimum of 80dBA and a maximum of 90dBA, fast weighting in a radius of 2m around the vehicle.
- EV4.12.3 The used sound must be easily recognizable. No animal voices, song parts, or sounds that could be interpreted as offensive will be accepted.
- EV4.12.4 The vehicle must not make any other sounds like 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.
- 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.
- EV5.1.3 TS Accumulator – all cells that store the electrical energy to be used by the TS.
- 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 which store the TS energy must be enclosed in (an) TSAC(s).
- EV5.3.2 Each TS accumulator segment must not exceed a maximum static voltage of 120VDC, a maximum energy of 6MJ, see EV5.1.2, and 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 must 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 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.

EV5.4 Tractive System Energy Storage – Electrical Configuration

EV5.4.1 If the TSAC is made from an electrically conductive material, the insulation barrier must be adequately protected against conductive penetrations.

EV5.4.2 Every TSAC must contain at least one fuse and at least two AIRs, see EV5.6 and EV3.2.7.

EV5.4.3 LVS must not be included in the TSAC except where inherently required. Exceptions include the AIRs, TS DC/DC converters, the AMS, the Insulation Monitoring Device (IMD), parts of the TSAL, and cooling fans.

EV5.4.4 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 the first and last segment.

EV5.4.5 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.
- protected against accidental reconnection.
- be designed such that it is clearly visible whether the connection is open or closed. Electrically controlled switches must not be used.
 - Upon removal of all maintenance plugs, no voltage should be present at the accumulator side of AIR. ($\Delta 1$)

EV5.4.6 Each TS accumulator segment must be electrically insulated by the use of suitable rigid and fire-retardant material, see T1.2.1, 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.

EV5.4.7 Every wire used in a TSAC, regardless of whether it is part of the LVS or TS, must be rated to the maximum TS voltage.

EV5.4.8 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 60VDC or half the maximum TS voltage, whichever is lower, is present at the vehicle side of the AIRs.

EV5.4.9 The indicator must be clearly visible while disconnecting the TSAC from the vehicles. The indicator must be clearly marked with “Voltage Indicator”

EV5.4.10 The indicator must be hard-wired electronics without software control and 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 lie within and be attached to the primary structure, or any additional structures fixed to the primary structure which meets the minimum specification for side impact structures, see table 4, no higher than the top of the side impact structure, see T1.1.16.

EV5.5.2 The TSAC(s) must be protected from side and rear impact collisions by structure equivalent to that defined in T3.15 (with exception of the first point under T3.15.1) and must follow T3.16 when having bolted attachments. The TSAC must not be part of this structure.

EV5.5.3 All TSAC materials as well as all structural parts must be fire retardant, see T1.2.1.

EV5.5.4 The TSAC(s) must be constructed of steel or aluminium. With the following requirements:

- The bottom 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.

EV5.5.7 The TSAC must consist of electrically insulating internal vertical walls with a minimum of 75% of the height of the external vertical walls, that divide the TSAC into sections of a maximum of 12kg. These walls must not divide any accumulator segment, see EV5.3.2.

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 cell 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 to comply with this rule.

EV5.5.10 Tabs of pouch cells must not carry mechanical loads. Pouch cells must only carry mechanically 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 T10.1.2. Fasteners made of electrically non-conductive material within the accumulator used for non-structural accumulator parts do not have to follow T10.

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. External openings for cooling or mounted 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 a black lightning bolt on yellow background) with the 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 25VACRMS. (Δ^2)

EV5.5.16 Any TS accumulators that may vent an explosive gas must have a ventilation system to prevent the vented gas from reaching an explosive concentration.

EV5.5.17 Every TSAC which is completely sealed must also have a pressure relief valve to prevent high-pressure in the TSAC.

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 EV6.1

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, see IN3.
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 and only 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 is used.
- EV5.8.12 The AMS must be able to read and display all measured values according to EV5.8.3 e.g., by connecting a laptop to the AMS.

EV6 SHUTDOWN CIRCUIT AND SYSTEMS

EV6.1 Shutdown Circuit

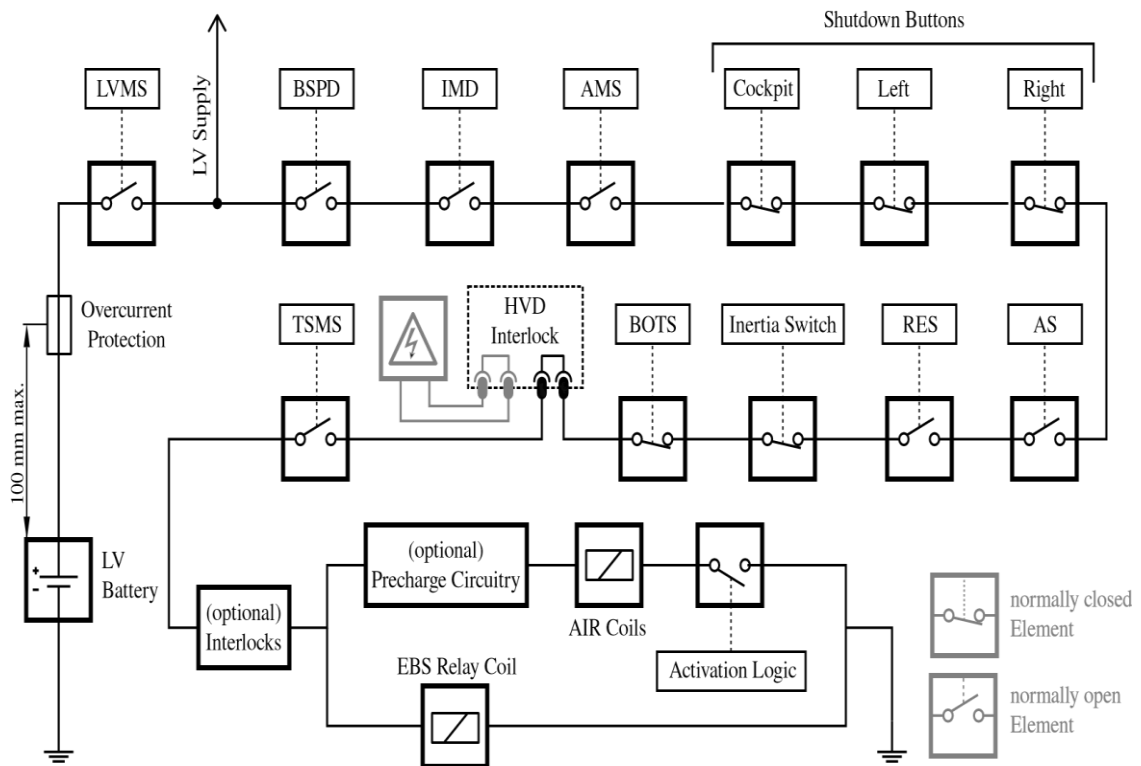


Figure 22: Explanatory example schematic of the required shutdown circuit

- 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 22.
- 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 shut down 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. (Δ^2)

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 must 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 can 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 Tractive 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 a 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 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 or the respective grounded enclosure of the IMD. 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 these 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 even in bright sunlight and clearly marked with the lettering “IMD” must light up if and only 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. 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 components interfacing to mains must be accredited to a recognized standard e.g. CE. All remaining parts 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 if 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 AND HAND CART

EV8.1 Accumulator Container (Δ^2)

EV8.1.1 General Requirement

- EV8.1.1.1 All Accumulator Containers must be:
 - a. Designed to withstand forces from deceleration in all directions.
 - b. Made from a Non-flammable Material
- EV8.1.1.2 Design of the Accumulator Container must be documented in the SES. Documentation includes materials used, drawings/images, fastener locations, cell/segment weight and cell/segment position
- EV8.1.1.3 The Accumulator Containers and mounting systems are subject to approval during SES review and Technical Inspection.
- EV8.1.2 External Structure
 - EV8.1.2.1 The Floor or Bottom must be made from one of the three:
 - a. Steel 1.25 mm minimum thickness
 - b. Aluminum 3.2 mm minimum thickness
 - c. Equivalent Alternate / Composite materials
 - EV8.1.2.2 Vertical Walls, Covers and Lids must be made from one of the three:
 - a. Steel 0.9 mm minimum thickness
 - b. Aluminum 2.3 mm minimum thickness
 - c. Equivalent Alternate / Composite materials
 - EV8.1.2.3 The accepted methods of joining walls to walls and walls to floor are:
 - a. Welding
 - Welds may be continuous or interrupted.
 - If interrupted, the weld/space ratio must be 1:1 or greater
 - All weld lengths must be greater than 25 mm
 - b. Fasteners Combined strength of the fasteners must be Equivalent to the strength of the welded joint.

c. Bonding

- Bonding must meet requirement
- Strength of the bonded joint must be Equivalent to the strength of the welded joint
- Bonds must run the entire length of the join

EV8.1.2.4 Covers and Lids must be attached with a minimum of one fastener for each external vertical wall per section

EV8.1.3 Internal Structur

EV8.1.3.1 Walls

a. Construction of Internal walls (vertical or horizontal) separating cells and/or segments must meet EV8.1.2.2

b. Internal vertical walls separating cells and/or segments must have minimum height of the full height of the Accumulator Segments

c. Fastened connections between the floor and any vertical wall of each Section must have minimum of two fasteners.

d. Removable horizontal interior walls must be fastened with a minimum of one fastener for each external vertical wall per section.

Folding or bending plate material to create flanges or to eliminate joints between walls is recommended.

EV8.2.3.2 Sections

a. Internal vertical walls divide the Accumulator Container into “Sections”.

b. A maximum of 12 kg is allowed in any Section.

c. Fastened connections between vertical walls around Sections containing 8kg or less must have a minimum of two fasteners.

d. Fastened connections between vertical walls around sections containing between 8 kg and 12 kg must have a minimum of three fasteners.

Example: An Accumulator Container with 2 internal walls has 3 Sections. Each Section contains less than 8 kg. Therefore 18 floors to wall joints are required in total with minimum two fasteners per joint

EV8.1.3.3 If segments are arranged vertically above other segments, each layer of segments must have a load path to the Chassis attachments that does not pass through another layer of segments

EV8.1.3.4 Cells and Segments

a. The cells and/or segments must be appropriately secured against moving inside the Container.

b. This mounting system design must withstand the following accelerations: 40 g in the longitudinal direction (forward/aft) 40 g in the lateral direction (left/right) 20 g in the vertical direction (up/down)

c. Calculations and/or tests proving these requirements are met must be included in the SES.

d. Any fasteners must be 6 mm or 1/4" minimum diameter

EV8.1.4 Holes and Openings

EV8.1.4.1 The Accumulator Container(s) exterior or interior walls may contain holes or openings

EV8.1.4.2 Any Holes and Openings must be the minimum area necessary

EV8.1.4.3 Exterior and interior walls must cover a minimum of 75% of each face of the battery segments

EV8.1.4.4 Holes and Openings for airflow:

a. Must be round. Slots are prohibited.

b. Should be maximum 10 mm diameter.

c. Must not have line of sight to the driver, with the Firewall installed or removed

EV8.1.5 Attachment

EV8.1.5.1 Attachment of the Accumulator Container must be documented in the SES

EV8.1.5.2 Accumulator Containers must:

a. Attach to the Major Structure of the chassis A maximum of two attachment points may be on a chassis tube between two triangulated nodes.

b. Not attach to the Shoulder Harness Mounting

EV8.1.5.3 Any fasteners used to attach Accumulator Container(s) are Critical Fasteners

EV8.1.5.4 Each attachment point to a composite Accumulator Container requires backing plates that are one of the two: a. Steel with a thickness of 2 mm minimum b. Alternate materials Equivalent to 2 mm thickness steel

EV8.1.5.5 Teams may justify the Accumulator Container attachment using one of:

- Corner Attachments and Analysis per EV8.1.5.6

- Load Based Analysis per EV8.1.5.7

EV8.1.5.6 Accumulator Attachment – Corner Attachments

a. Eight or more attachments are required for any configuration.

- One attachment for each corner of a rectangular structure of multiple Accumulator Segments

- More than the minimum number of fasteners may be required for non-rectangular arrangements

Examples: If not filled in with additional structure, an extruded L shape would require attachments at 10 convex corners (the corners at the inside of the L are not convex); an extruded hexagon would require 12 attachments

- b. The mechanical connections at each corner must be:
 - 50 mm or less from the corner of the Segment
 - Spaced minimum 50 mm from the mechanical connection of any other corner
 - The same fastener diameter and grade c. Each attachment point must be able to withstand a Test Load.
 - The Test Load is equal to 1/4 of total mass of the container accelerating at 40 g
 - Every fastener must withstand the Test Load in pure shear, using the minor diameter if any threads are in shear.
 - Every Accumulator bracket, chassis bracket, or monocoque attachment point must withstand the Test Load in bending, in pure tearout, pure pullout, pure weld shear if welded, and pure bond shear and pure bond tensile if bonded

EV8.1.5.7 Accumulator Attachment – Load Based

- a. The minimum number of attachment points depends on the total mass of the container:

Accumulator Weight	Minimum Attachment Points
< 20 kg	4
20 – 30 kg	6
30 – 40 kg	8
> 40 kg	10

- b. Any brackets which attach the Accumulator Container to the chassis must:
 - Be made of steel 1.6 mm minimum thickness or aluminum 4 mm minimum thickness
 - Have gussets to carry bending loads.
- c. Each attachment point, including any brackets, backing plates and inserts, must be able to withstand 15 kN in any direction.
- c. Fasteners must spaced minimum 50 mm apart to be counted as separate attachment points.

EV8.2 Tractive System Accumulator Container Hand Cart

- EV8.2.1 A hand cart(s) must be used for transporting the TSAC(s) around the competition site.
- EV8.2.2 The hand cart must have at least four wheels.
- EV8.2.3 The hand cart must have a brake that is always on and only released if someone pushes the handle, or similar.
- EV8.2.4 The brake must be capable of safely stopping the fully loaded hand cart.
- EV8.2.5 The hand cart must be able to carry the load of the TSAC(s).
- EV8.2.6 The hand cart must provide a firewall to protect the person while moving the hand cart. The firewall must have the same width as the hand cart, start at the lowest

point of the hand cart excluding the wheels and be at least 30cm higher than the hand cart handle and the TSAC.

- EV8.2.7 The TSAC(s) must be mechanically fixed to the hand cart to enable safe transportation.
- EV8.2.8 The TSAC(s) must be protected from vibrations and shocks during normal operation of the cart, e.g., by the use of air tires.
- EV8.2.9 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.
- EV8.2.10 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 Submission and approval of the ESF does not mean that the vehicle will automatically pass Electrical Technical Inspection with the described items / parts. (Δ^2)
- EV9.1.2 Templates of the ESF shall be made available on the competition website. (Δ^1)

EV9.2 Failure Modes and Effects Analysis (FMEA) (Δ^1)

- EV9.2.1 Teams must submit a complete failure modes and effects analysis (FMEA) of the TS by the deadline published on the competition website. (Δ^1)
- EV9.2.2 A template including required failures to be described will be made available online. Pictures, schematics and data sheets referenced in the FMEA must be included in the FMEA on additional table pages. (Δ^1)

EV9.3 [EV ONLY] Accumulator Pre-Tech Inspection (ACC-PT) (Δ^1)

- EV9.3.1 Teams will be required to participate in a pre-technical inspection for the accumulator system, prior to the competition, by the deadline highlighted on the competition website. (Δ^1)
- EV9.3.2 A document will be required to be submitted prior to this inspection. A checklist of views required, including the method of submission shall be specified on the competition website. (Δ^1)

IN TECHNICAL INSPECTION

IN1 GENERAL

IN1.1 Technical Inspection Process

IN1.1.1 The technical inspection is divided into the following parts:

- Pre-Inspection
- Accumulator Inspection
- Electrical Inspection
- Mechanical Inspection
- Tilt Test
- Vehicle Weighing
- Rain Test
- Brake Test
- 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 push bar.
- 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 Safety uncritical rule violations without a benefit to the team that cannot be changed at the event may result in at least 20 penalty points for the teams, depending on officials' decision. Safety uncritical violations with a minor benefit to the team that cannot be changed at the event may result in at least 40 penalty points for the team. The penalty points will be deducted from the team's overall score.

- IN1.2.8 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.
- IN1.2.9 The vehicle must maintain all required specifications throughout the competition.
- IN1.2.10 Officials reserve the right to ask the team for drilling of additional inspection holes to check the chassis for compliance with the rules.
- IN1.2.11 Officials will mark or seal various approved parts. Removal of or damage to the seals will void the inspection approval.
- IN1.2.12 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.
- IN1.2.13 The officials reserve the right to prohibit the use of parts that could pose a safety risk to drivers, track marshals or the environment.

IN1.3 Technical Inspection Sticker

- IN1.3.1 The competition technical inspection stickers will be placed on the nose of the vehicle.
- 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.

IN1.4 Inspection Responsible Person

- IN1.4.1 To accelerate the technical inspection process, the team must appoint one team member as inspection responsible person. 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

- IN 1.5.1 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 tire 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 tires or brake pads. Replacement tires and brake pads must be identical in material/composition/size to those presented and approved at technical inspection.
- Changing wheels and tires for “wet” or “damp” conditions as allowed in D 3.2 and D 7.6 • Software calibration changes
- Recharging low voltage batteries
- Recharging TS accumulators
- Adjustments of AS sensors
- (De-)Coupling of actuators as allowed in T 14.8

IN2 PRE-INSPECTION

IN2.1 Pre-Inspection Required Items

IN2.1.1 The following items must be presented for pre-inspection:

- All helmets
- All driver’s equipment and other safety gear
- Two unused and in date fire extinguishers
- One set of four tires on rims for wet conditions
- One set of four tires on rims for dry conditions

The tire type/rim type combination presented during pre-inspection must be the same during the whole competition. The rims for dry tires and wet tires may be different.

IN3 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 An official temperature logging device must be installed if used by the competition, see EV5.8.6.
- IN3.1.3 The accumulator charger will be inspected and sealed.
- IN3.1.4 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.
 - Multi meter 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 1.0m² 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 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 mounted TS accumulator
- Jacks and push bar
- Samples of self-designed PCBs that are part of the tractive system and are outside of the TSAC, see EV4.3.7
- Tools needed for the BSPD check, see T11.6.9
- Data sheets for all parts used in the tractive system.
- Original delivery notes for material without serial number printed on according to T1.2.1
- Tools needed for the (dis)assembly of parts for electrical inspection.
- Printouts of rule questions (if applicable)
- The connectors needed.
 - to safely close the SDC while the HVD is removed and
 - to safely supply the TS using the same shrouded receptacles as used for TSMP when the TS accumulator is unconnected

IN5 MECHANICAL INSPECTION

IN5.1 Mechanical Inspection Required Items

IN5.1.1 The following items must be presented at mechanical inspection:

- The vehicle in ready-to-race condition
- Jacks and push bar
- The tallest driver of the team
- Copies of any safety structure equivalency forms
- Copies of any impact attenuator data requirement

- Print-outs of rule questions (if applicable)
- Impact attenuator test piece (except for teams with “standard” IA)
- Teams with a monocoque: laminate test specimen(s)
- Teams using alloyed steel: test specimen(s)
- Only tools needed for the (dis)assembly of parts for mechanical inspection

IN6 TILT TEST

IN6.1 Tilt Test Procedure

- IN6.1.1 The tilt test will be conducted with the tallest driver fully strapped in normal driving position.
- IN6.1.2 The tilt test will be conducted with all vehicle fluids at their maximum fill level.
- IN6.1.3 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.

IN7 VEHICLE WEIGHING

IN7.1 Vehicle Weighing Procedure

- IN7.1.1 All vehicles must be weighed in ready-to-race condition.
- IN7.1.2 All fluids must be at their maximum fill level for weighing.

IN8 RAIN TEST

IN8.1 Rain Test General Definitions

- IN8.1.1 Vehicles must have passed electrical inspection, see IN4, to attempt the rain test.

IN8.2 Rain Test Procedure

- IN8.2.1 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.
- IN8.2.2 The tractive system must be active during the rain test.
- IN8.2.3 The vehicle must be jacked up using the jacks, see T13.2, and all driven wheels must be removed.
- IN8.2.4 The vehicle must not be in ready-to-drive mode, see EV4.11.
- IN8.2.5 The test will be conducted without a driver.
- IN8.2.6 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.
- IN8.2.7 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.

IN9 BRAKE TEST

IN9.1 Brake Test Procedure

- IN9.1.1 Lock all four wheels and stop the vehicle in a straight line at the end of an acceleration run specified by the officials without stalling the engine.
- IN9.1.2 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.
- IN9.1.3 The brake light and TSAL illumination will be checked, and the officials will verify if the illumination is satisfactory for external observation.
- IN9.1.4 The ready-to-drive sound will be checked, and the officials will verify if the sound level is satisfactory.

IN10 POST EVENT INSPECTION

IN10.1 Post Event Inspection Procedure

- IN10.1.1 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.
- IN10.1.2 After the endurance and track drive event, the vehicle must be placed in Closed Park where no team member may access the vehicle.
- IN10.1.3 After any dynamic event, the vehicle must follow the rules.
- IN10.1.4 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., aerodynamics)

	Acceleration	Skidpad	Autocross	Endurance	Track drive
Group A	0.3s	0.2s	2s	30s	30s
Group B	1s	0.6s	5s	2min	2min

The penalty applies to all runs since the vehicle entered the dynamic area the last time

- IN10.1.5 Violation of the rules concerning safety or the environment (e.g., BOTS, safety harness issues, ground clearance, fluid leaks other than plain water, noise) results in Disqualified (DQ) since entering the dynamic area.
- IN10.1.6 Losing a part of the vehicle on the track will result in DQ for that particular run.
- IN10.1.7 Changes in vehicle weight of more than ±5kg compared to the official technical inspection weight (see IN7) results in a 20-point penalty for each kg the tolerance is exceeded by. E.g., a weight difference of ±6.2kg results in in a 40-point penalty.

- IN10.1.8 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.
- IN10.1.9 Directly after endurance and leaving Closed Park, 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.
- IN10.1.10 Directly after the last dynamic discipline and leaving Closed Park, the data logger (if installed), see EV4.6 or T14.2, will be disassembled from the vehicle.

S STATIC EVENTS

S1 BUSINESS PLAN PRESENTATION EVENT

S1.1 Business Plan Presentation Objective

S1.1.1 The objective of the BPP is to evaluate the team's ability to develop and deliver a comprehensive business model. This business model must refer to the team's specific prototype race car or a specific component of it. In doing so, the business must offer the car or component as a product or sell a service that relates to it providing a rewarding business opportunity that creates a monetary profit.

S1.1.2 The judges should be treated as if they were potential investors or partners for the presented business model.

S1.1.3 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

S1.2 Business Plan Presentation Procedure

S1.2.1 Presentations are limited to a maximum of ten minutes. The judges will stop any presentation exceeding ten minutes.

S1.2.2 The presentation will not be interrupted by questions. Immediately following the presentation there will be a question-and-answer session

S1.2.3 One or more team members may present the business plan.

S1.2.4 All team members involved in the BPP must be in the podium area and must be introduced to the judges at the beginning of the presentation. The team members who have been introduced may answer the judges' questions even if they were not actually presenting

S1.2.5 Teams that fail to make their presentation within their assigned time will receive zero points for the BPP

S1.2.6 Prior to the competition a specific deep dive topic, which has to be part of the ten minutes Presentation, will be published on the competition's website

S1.3 Pitch Video

S1.3.1 To convince the potential investors or partners that the team's presentation is worthy of their time, it is required that a Business Plan Pitch Video (BPPV) is submitted before the competition The pitch video should be considered as the first impression of the business idea and must contain the relevant investment figures

S1.3.2 The BPPV must be submitted online via the competition website, not later than the deadline specified in the competition handbook.

S1.3.3 The BPPV must not exceed a length of 30s and must be in a common video format, e.g., Avi, mpg, mp4, wmv.

S1.4 Business Plan Presentation Scoring

S1.4.1 The BPP will be evaluated on the categories specified in the following table

Category	Points
Pitch Video	10
Content	20
Finances	10
Deep Dive Topic	10
Demonstration and Structure	15
Delivery	10
Questions	10
General Impression	15
Total	100

S1.4.2 If the business model presented does not relate to one of the areas listed within S1.1.1, 25penaltypoints will be deducted from the team’s BPP scoring.

S1.4.3 The judging at the competition will start with an initial judging, where all teams are judged by different judging groups.

S1.4.4 Some teams may be chosen to participate in the BPP finals to determine the BPP winner. The BPP finals will be held separately from the initial judging and teams will be informed about their participation during the event.

S1.4.5 The scoring of the BPP is based on the average of the scores given by each of the judges.

S1.4.6 The scoring for the non-finalist is calculated as followed:

$$BPP_SCORE = 70 \left(\frac{P_{team}}{P_{max}} \right)$$

P_{team} is the score awarded to the team.

P_{max} is the highest score awarded to any team not participating in the finals.

S1.4.7 The scoring of the BPP finalists will vary from 75 to 71 points and is scored immediately after the BPP finals by all judges.

S2 COST AND MANUFACTURING EVENT

S2.1 Cost and Manufacturing Objective

S2.1.1 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.

S2.2 Cost and Manufacturing Procedure

S2.2.1 Prior to the competition, three Cost Report Documents (CRD) (see S2.3) must be submitted to the competition website by the deadline specified in the competition handbook.

S2.2.2 During the competition, a discussion with the judges will take place, next to the team's vehicle. The discussion is split into three parts:

S2.2.3 Part 1 "Bill of Material (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.

S2.2.4 Part 2 "Cost Understanding":

A discussion to evaluate the general cost and manufacturing knowledge of the team.

S2.2.5 Part 3 "Real case":

A specific task to evaluate the cost and manufacturing knowledge in a certain field. The real case task will be published on the competition website prior to the competition.

S2.2.6 The teams must present their vehicle at the designated time to the judges. Teams that miss their time slot will lose all cost points for that day.

S2.2.7 Teams are allowed to bring electronic, handwritten, or printed handouts, flip charts or like the event, but the space available may be limited.

S2.3 Cost Report Documents

S2.3.1 The CRD consist of the following documents:

- The BOM including DBOM and CBOM created online on the competition website.
- The supporting material file uploaded as a pdf file to the competition website.
- The cost explanation file uploaded as a pdf file to the competition website.

S2.3.2 Changes to the CRD will not be permitted after the deadline.

S2.3.3 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.

S2.3.4 All CRD must be brought either as hard copy or digital version to the event discussion.

S2.3.5 The website tool will provide a printable pdf version of the BOM.

S2.3.6 A hard copy must be in a ring binder with DIN A4 pages (or similar).

S2.3.7 The team must ensure that two judges are able to review the CRD independently.

S2.3.8 The presented CRD must be identical with the uploaded versions, otherwise five penalty points will be deducted from the team's cost event score

S2.4 Bill of Material

S2.4.1 The BOM is a sorted list for every vehicle part.

S2.4.2 The BOM must list all parts and equipment fitted to the prototype vehicle at any time during the competition.

S2.4.3 The BOM is structured as follows.

- The BOM is broken down into “systems” (see S2.4.4), 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.

S2.4.4 The “systems” are:

- Brake System
- Drivetrain
- Chassis and Body
- Electrical
- Miscellaneous, Fit and Finish
- Steering System
- Suspension System
- Wheels, Wheel Bearings and Tires

S2.4.5 The “assemblies” of each “system” are provided by the website tool.

S2.4.6 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”.

S2.4.7 Only metric units must be used within the BOM.

S2.4.8 Only dry tires and wheels per T2.6.1 need to be included in the BOM.

S2.4.9 Two or three systems of the BOM must be a DBOM, see S2.5.

S2.4.10 One or two systems of the DBOM must be a CBOM, see S2.6.

S2.5 Detailed Bill of Material

S2.5.1 The manufacturing and assembly processes of all parts from two or three BOM systems specified in the competition handbook must be listed in the DBOM.

S2.5.2 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 S2.6.

S2.5.3 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.

S2.5.4 Each constituent “part” of an “assembly” must be classified as “bought” or “made”.

S2.5.5 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.

S2.5.6 For each “made part” the raw material, all production processes, tooling and all required fasteners must be included.

S2.5.7 “Processes” are the necessary operations to produce the “part” out of the “material”.

S2.5.8 “Material” is the raw material of a part, e.g., aluminium.

S2.5.9 “Tooling” is the necessary tools used for transforming the “material” into the desired shape.

S2.5.10 “Fasteners” are additional items necessary to assemble the “part”.

S2.6 Costed Bill of Material

S2.6.1 The actual costs of the prototype vehicle as presented must be included for one or two BOM system(s) specified in the competition handbook.

S2.6.2 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.

S2.6.3 The cost calculations must exclude research, development, and capital expenditures for real estates (e.g., plant or development hours of the team).

S2.6.4 All costs must be displayed in INR.

S2.6.5 There is no maximum cost. Receipts are not required for any items.

S2.6.6 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.

S2.6.7 The costs of hand or power tools must not be included.

S2.6.8 The estimations for machining rates, hourly rates, included overheads etc. must be shown.

S2.7 Supporting Material File

S2.7.1 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.

S2.8 Cost Explanation File

- S2.8.1 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.
- S2.8.2 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.

S2.9 Cost and Manufacturing Vehicle Condition

- S2.9.1 Vehicles must be presented for cost and manufacturing judging in finished condition, fully assembled, complete and ready-to-race.
- S2.9.2 The judges will not evaluate any vehicle that is presented at the cost and manufacturing event, in what they consider to be an unfinished state and will award zero points for the entire event.
- S2.9.3 Vehicles may be presented for judging without having passed technical inspection, even if final tuning and setup is in progress.
- S2.9.4 Covers and/or parts may be removed during the judging to facilitate access and presentation of components or concepts.

S2.10 Cost and Manufacturing Scoring

- S2.10.1 The cost and manufacturing event will be evaluated on the categories specified in the following table:

Category	Points
Format and Accuracy of Documents of Documents and Vehicle	-5 Knowledge -5
BOM and BOM discussion	-35
Discussion Part 2 “Cost Understanding”	-35
Part 3 “Real Case”	-20
Total	-100

- S2.10.2 If items are missing from the BOM, points are deducted until zero points are scored for “BOM and BOM discussion”:

Missing Item	Points
Assembly	-5
Part	-3
Process/Material	-1

- S2.10.3 A maximum of four top teams may 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.
- S2.10.4 In case of finals the scoring for the non-finalist is calculated as followed:

$$COST_SCORE = 95 \left(\frac{P_{team}}{P_{max}} \right)$$

S3 ENGINEERING DESIGN EVENT

S3.1 Engineering Design Objective

- S3.1.1 The concept of the design event is to evaluate the student's engineering process and effort that went into the design of a vehicle, meeting the intent of the competition.
- S3.1.2 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.

S3.2 Engineering Design Report

- S3.2.1 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.
- S3.2.2 The EDR must not exceed ten pages, consisting of not more than seven pages of content (text, which may include pictures and graphs) and three pages of drawings.
- S3.2.3 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.
- S3.2.4 Any measures to facilitate reviewing the drawings (e.g., measurements, details, colours) may be utilized at the teams' discretion.
- S3.2.5 Any portions of the EDR that exceeds seven pages of content and/or three pages of drawings will not be evaluated.
- S3.2.6 If included, cover sheets and tables of contents will count as text pages.
- S3.2.7 The EDR will be used to sort the teams into appropriate design queues based on the quality of its review.
- S3.2.8 Evidence of information mentioned in the EDR should be brought to the competition and be available, on request, for review by the judges.

S3.3 Design Spec Sheet

- S3.3.1 A completed DSS must be submitted online on the competition website.

S3.4 Engineering Design Procedure

- S3.4.1 The design event starts with the submission of the DSS and the EDR and their review respectively.
- S3.4.2 At the competition, teams will present their knowledge and their vehicle to the judges, which will evaluate the teams' performance following the design objectives stated in chapter S3.1.
- S3.4.3 Some teams may be chosen to participate in the design finals to determine the engineering design event winner. The design finals will be held separately from the initial judging and teams will be informed about their participation during the event.
- S3.4.4 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.
- S3.4.5 Only sealed TSACs which passed the accumulator inspection may be presented or mounted in the vehicle. They must not be opened.
- S3.4.6 Only fully discharged and electrically shortened spare accumulator cells or spare stacks may be presented

S3.5 Engineering Design Vehicle Condition

- S3.5.1 Vehicles must be presented for design judging in finished condition, fully assembled, complete and ready-to-race
- S3.5.2 The judges will not evaluate any vehicle that is presented at the design event in what they consider to be an unfinished state and will award zero points for the entire design event
- S3.5.3 Vehicles may be presented for design judging without having passed technical inspection, even if final tuning and setup is in progress.
- S3.5.4 Covers and/or parts may be removed during the design judging to facilitate access and presentation of components or concepts.

S3.6 Engineering Design Judging Criteria

- S3.6.1 The judges will evaluate the engineering effort based upon the teams’ DSS and EDR, responses to questions and an inspection of the vehicle.
- S3.6.2 The judges will inspect the vehicle to determine if the design concepts are adequate and appropriate for the application (relative to the objectives set forth in the rules).
- S3.6.3 The judges may deduct points if the team cannot adequately explain the engineering and construction of the vehicle.

S3.7 Engineering Design Scoring

- S3.7.1 The overall engineering design event maximum scoring is 150 points.
- S3.7.2 The maximum scores listed in table 6 apply for the engineering design event.

Category	EV Points
Overall Vehicle Concept	35
Vehicle Performance	20
Mechanical / Structural Engineering	10
Tractive System / Powertrain	20
LV-Electrics / Electronics / Hardware	15
Driver Interface	10
Engineering Design Report (EDR)	10

Table 6: Maximum scores in engineering design event

D DYNAMIC EVENTS

D1 DYNAMIC EVENTS GENERAL

D1.1 Driver Limitations

- D1.1.1 In total, a minimum of three and a maximum of four 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 is 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 Drivers must not wear the dynamic vest when sitting in the vehicle. The driver's vest must not be attached to the vehicle.
- D1.2.5 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.
- D1.2.6 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 **BLACK FLAG** – The driver must pull into the driver change area for discussion with the officials concerning an incident. A time penalty may be assessed.
- D2.1.3 **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.
- D2.1.4 **BLUE FLAG** – 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.
- D2.1.5 **CHECKERED FLAG** – The session has been completed. The driver must exit the track at the first opportunity.
- D2.1.6 **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.

- D2.1.7 RED FLAG – The driver must come to an immediate safe and controlled stop on the track and must follow track marshals' directions.
- D2.1.8 YELLOW FLAG – Danger, the driver must slow down, something has happened beyond the flag station, no overtaking unless directed by the track marshals.
- D2.1.9 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.

D2.2 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.

D2.3 Practice Track

- D2.3.1 A practice track for testing and tuning vehicles is available.
- D2.3.2 To use the practice track, vehicles must have passed all technical inspections.
- D2.3.3 Practice or testing at any location other than the practice track is absolutely forbidden.

D3 WEATHER CONDITIONS

D3.1 Operating Conditions

- D3.1.1 The following track conditions are recognized:
 - Dry
 - Damp
 - Wet

- D3.1.2 The operating condition 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 Tires Allowed

- D3.2.1 Teams must run the tires allowed for each operating condition:

Operating Condition Tires allowed.

Dry

Dry

Damp	Dry or Wet
Wet	Wet

D3.2.2 When the operating condition is damp, teams may change between dry tires and wet tires:

- 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 tires 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.

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.

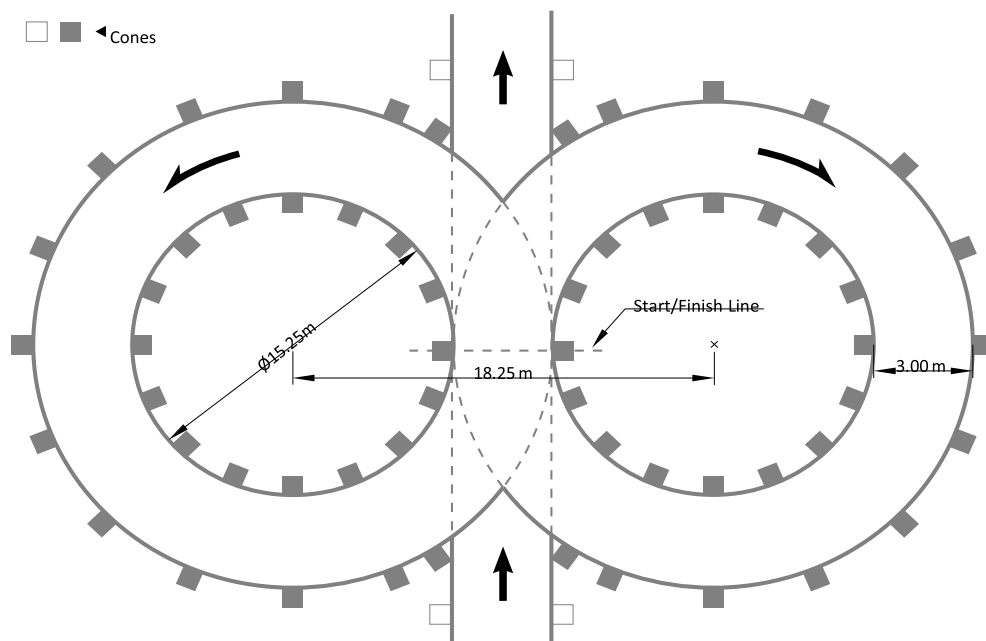


Figure 23: Skidpad Track Layout

D4.2 Manual Skidpad Procedure

- D4.2.1 Each team has two runs, driven by one driver.
- D4.2.2 The driver has the option to make the second run immediately after his/her 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 Starting - A green flag is used to indicate that the driver may start.
- D4.2.5 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 Manual Skidpad Scoring

- D4.3.1 The run time is the average time of the timed left and the timed right circle plus penalties which are added after the averaging.
- D4.3.2 3.5 points are awarded to every team that finishes at least one run without DNF or DQ.
- D4.3.3 If a team's best manual mode time including penalties is below T_{\max} , additional points based on the following formula are given:

$$M\text{-SKIDPAD-SCORE} = 46.5 \left(\frac{\left(\frac{T_{\max}}{T_{\text{team}}} \right)^2 - 1}{0.5625} \right)$$

T_{team} is the team's best manual mode time including penalties.

T_{\max} is 1.25 times the time of the fastest manual mode vehicle including penalties.

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 3m 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 Each team has two runs, driven by one driver.
- D5.2.2 The driver has the option to make the second run immediately after his/her 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.

D5.3 Manual Acceleration Scoring

- D5.3.1 3.5 points are awarded to every team that finishes at least one manual mode run without a DNF or DQ.

- D5.3.2 If a team's best manual mode time including penalties is below T_{max} , additional points based on the following formula are given:

$$M_ACCELERATION_SCORE = 46.5 \left(\frac{T_{max} - 1}{T_{team} \cdot 0.5} \right)$$

T_{team} is the team's best manual mode time including penalties.

T_{max} is 1.5 times the time of the fastest manual mode 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 3m.

- D6.1.2 The length of the autocross track is less than 1.5km.

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 the second run immediately after his/her first run.
- D6.2.3 Staging - The vehicle is staged at a staging line prior to the starting line.
- 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.

D6.3 Autocross Scoring

- D6.3.1 4.5 points are awarded to every team that finishes at least one run without DNF or DQ.

- D 6.3.2 If a team's corrected elapsed time is below T_{max} , points based on the following formula are given:

$$AUTOCROSS_SCORE = 95.5 \left(\frac{T_{max} - 1}{T_{team} \cdot 0.25} \right)$$

T_{team} is the team's best time including penalties.

T_{max} is 1.25 times the time of the fastest vehicle including penalties.

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.

D7.2 Endurance Procedure

D7.2.1 There is only one run for the endurance event.

D7.2.2 Staging - The vehicle is staged at a staging line prior to the starting line. The timer starts only after the vehicle crosses the start line.

D7.2.3 Starting - A green flag is used to indicate that the driver may start. Timing starts only after the vehicle crosses the starting line.

D7.2.4 The first driver will drive for 11km and will then be signalled into the driver change area.

D7.2.5 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.

D7.2.6 After leaving the track, the vehicle must be powered down.

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 oversees 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 tires.
 - 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 tires as per D7.6.
- No other work may be performed during the driver change.
- D7.5.4 Each team is given three minutes to change their driver.
 - 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 tractive system for EVs.
 - D7.5.6 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 vehicle has restarted and is ready-to-drive again, the driver change time is stopped.
 - D7.5.9 If the driver change takes longer than three minutes, the extra time is included in the final time.

D7.6 Endurance Event Tire Changes

- D7.6.1 All tire changes after a vehicle have 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 tires, the officials must be informed beforehand.
- D7.6.4 In some cases, tire changes can be carried out directly after the driver change, for others the team must make an extra stop.
- D7.6.5 The allowed tire 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 Tires	–	A	B
Damp	Dry Tires	–	A	B
Damp	Wet Tires	C	C	–
Wet	Wet Tires	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

Note 1: Any time more than 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 tires 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 tire 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.

D7.7 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 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.

D7.7.4 If a vehicle has a restart problem at the driver change or after a red flag, it is allowed two minutes to enable the tractive system. The two minutes start from the time the driver first tries to enable the tractive system. The time is counted towards the endurance time.

D7.7.5 If restarts are not accomplished within the above times, the vehicle is scored as DNF for the run.

D7.7.6 If a vehicle breaks down, it will be removed from the track and will not be allowed to re-enter the track.

D7.7.7 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 IN10) 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:

$$ENDURANCE_SCORE = 225 \left(\frac{T_{max} - 1}{T_{team} \cdot 0.333} \right)$$

T_{team} is the team’s corrected elapsed time.

T_{max} is 1.333 times of the corrected elapsed time of the fastest vehicle.

D7.9 Efficiency Scoring

D7.9.1 Efficiency is measured during the endurance event.

D7.9.2 Only vehicles which meet all of the following requirements are considered for efficiency scoring:

- the vehicle received points for the endurance event.
- the uncorrected elapsed endurance time does not exceed 1.333 times the uncorrected elapsed time of the fastest vehicle.

D7.9.3 The endurance energy is calculated as the time integrated value of the measured voltage multiplied by the measured current logged by the data logger, see EV4.6.

Regenerated energy is multiplied by 0.9 and subtracted from the used energy.

D7.9.4 Efficiency points based on the following formula are given:

$$EFFICIENCY_SCORE = 75 \left(\frac{EF_{max} - EF_{team}}{EF_{max} - EF_{min}} \right)$$

with

EF_{team} the team's efficiency factor

EF_{min} the lowest efficiency factor of all teams which were considered for efficiency.

EF_{max} is defined as $1.5 \cdot EF_{min}$

D7.9.5 The efficiency factor is calculated based on the following formula:

$$EF = T^2 \cdot E$$

with

T uncorrected elapsed driving time

E used energy

D8 DYNAMIC EVENTS PENALTIES**D8.1 General Penalties**

D8.1.1 Penalties will not be assessed for accident avoidance or other reasons deemed sufficient by the officials.

D8.1.2 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.

D8.1.3 Cones that are DOO are not replaced/reset. There will be no re-run due to cones in the driving path or disorientation due to missing cones.

D8.1.4 The DOO penalty (see D8.1.7) is added for each DOO including entry and exit gate cones before the start and after the finish line, that occur on that run.

D8.1.5 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.

D8.1.6 An Unsafe Stop (USS) is defined as not stopping within the specified area and/or not entering the finish-state described in T14.9

D8.1.7	Acceleration	Skidpad	Autocross	Endurance	Track drive
DOO	2s	0.2s	2s	2s	2s
OC	DNF	DNF	10s	10s	10s
USS	DNF	DNF	DNF	n/a	-50 points

D8.1.8 DNF equals zero points for that run.

D8.1.9 DQ equals zero points for that run.

D8.1.10 If a team Did Not Attempt (DNA) an event the score is zero points.

D8.1.11 Each run with an incorrect number of laps at skidpad is classified as DNF.

D8.1.12 Failure to obey a flag: one minute time penalty.

D8.1.13 Reckless or aggressive driving or “Over Driving”: black flag (see D2.1.2)

D8.1.14 Vehicle to vehicle contact: Two minutes up to disqualification depending on the nature of the incident.

D8.1.15 If a vehicle stalls before passing the finish line and cannot restart without external assistance, the vehicle is DNF for that run.

D8.1.16 If a vehicle is not able to start the run, within 30s after receiving a green flag or go-signal, the vehicle is DQ for that run.

D8.2 Endurance Penalties

D8.2.1 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.

D8.2.2 Mechanical Problem: The time taken for mechanical inspection under a “mechanical black flag” (see D2.1.3) 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.

D8.2.3 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.

D8.2.4 A team may receive a DNF if their vehicle is too slow or being driven without proper control.

D8.2.5 Any violation to the procedure of driver change (D7.5.3) will lead to a time penalty of up to two minutes.

D8.3 Power and Voltage Violation Penalties

D8.3.1 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 data logger signal, see EV4.6.

D8.3.2 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..

D8.3.3 Violations during the Endurance event: (Δ^2)

- Each Violation: 60 second penalty

D8.3.3 The respective data and the resulting decision of violations may be made public.

D8.3.4 Non-availability of data logger data will be treated as a violation.