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A 4.3.1	1.1	Team members do not need to be students of the teams's university
A 5.2.1	1.1	Two deputies may also upload team documents
A 6.1.1	1.1	Removal of tractive system accumulators prohibited
A 6.4.6	1.1	Refined requirements for testing safety
T 1.1.1	1.1	Added good engineering practices
T 1.2.1	1.1	Clarification: Minimal bodywork openings allowed around suspension system
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CV 2.6.4	1.1	Changed wording
CV 4.2.2	1.1	Changed requirement for exciter coil
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EV 3.4.10	1.1	Removed redundant mounting position requirement
EV 3.5.10	1.1	Bonding of accumulator container permitted
EV 3.5.13	1.1	Relaxed requirements for fasteners within the accumulator container
EV 3.5.18	1.1	Removed redundant parts of the rule
EV 3.7.6	1.1	Brought in-line with IMD indicator; added indicator to SCS
EV 4.1.3	1.1	Explicitly allowed BSPD to be inside the accumulator container
EV 4.5.15	1.1	Exception for soldered connections
EV 4.10.1	1.1	Removed redundancy
EV 4.12.3	1.1	Specified type of relay
EV 4.12.7	1.1	Discharge fusing is prohibited

Rule	Version	Change
EV 4.13.6	1.1	Added explicit TSAL roll-over protection requirement
EV 4.13.7	1.1	TSAL visibility for new aero rules
EV 4.13.8	1.1	Added TSAL to SCS
EV 5.1.7	1.1	Clarification of BSPD error handling
EV 5.4.6	1.1	Added indicator to SCS
EV 5.5.1	1.1	Clarification about BSPD reset
EV 6	1.1	Changed fusing requirements to more general overcurrent protection
DV 1.4.7	1.1	Remote Emergency System (RES) antenna mounting
DV 2.3	1.1	Reordered and clarified the some safety issues concerning usage of Tractive System Active Light (TSAL) and Autonomous System Status Indicator (ASSI)
DV 3.2.5	1.1	Emergency Brake System (EBS) failure indicator light added
DV 3.4.2	1.1	Clarification: No EBS trigger when in finished state
DV 3.4.3	1.1	New EBS transition
IN 6.1.1	1.1	Changed wording for clarification
IN 6.3.3	1.1	Added acceleration distance
IN 11.2.4	1.1	Added TSAL illumination check
IN 11.2.5	1.1	Added ready-to-drive sound level check
IN 12.1.1	1.1	Added trackdrive for Driverless Vehicle (DV)
IN 12.1.2	1.1	Changed wording
IN 12.2.3	1.1	Changed wording
IN 12.2.8	1.1	Disassembly of data logger added
D 7.8.9	1.1	Refer E 85 fuel volume to 98 RON fuel volume
D 7.9.7	1.1	Corrected efficiency score formula
D 9.1.3	1.1	No rerun for Down or Out (DOO)

ABBREVIATIONS

AAIR	ASF Add Item Request
ADR	Autonomous Design Report
AIP	Anti Intrusion Plate
AIR	Accumulator Isolation Relay
AMI	Autonomous Mission Indicator
AMS	Accumulator Management System
APPS	Accelerator Pedal Position Sensor
ASF	Autonomous System Form
ASMS	Autonomous System Master Switch
ASR	Autonomous System Responsible
ASRQ	ASR Qualification
ASSI	Autonomous System Status Indicator
BOM	Bill of Material
BOTS	Brake Over-Travel Switch
BPES	Business Plan Executive Summary
BPP	Business Plan Presentation Event
BSE	Brake System Encoder
BSPD	Brake System Plausibility Device
CBOM	Costed Bill of Material
CCP	Charging Connector and Power
CRD	Cost Report Documents
CV	Internal Combustion Engine Vehicle
DI	Direct Injection
DNA	Did Not Attempt
DNF	Did Not Finish
DOO	Down or Out
DSS	Design Spec Sheet
DV	Driverless Vehicle
EAIR	ESF Add Item Request
EBS	Emergency Brake System
ECU	Electronic Control Unit
EDR	Engineering Design Report
EI	Flexural Rigidity
ESF	Electrical System Form
ESO	Electrical System Officer
ESOQ	Electrical System Officer Qualification
ETC	Electronic Throttle Control
EV	Electric Vehicle
FEA	Finite Element Analysis
FMEA	Failure Modes and Effects Analysis
FTO	Fuel Type Order
GLV	Grounded Low Voltage
GLVMS	Grounded Low Voltage Master Switch
HPI	High Pressure Injection
HV	High Voltage
HVD	High Voltage Disconnect
IA	Impact Attenuator
IAD	Impact Attenuator Data
IMD	Insulation Monitoring Device
LPI	Low Pressure Injection
LV	Low Voltage
OC	Off-course
OEM	Original Equipment Manufacturer
PCB	Printed Circuit Board
R2D	Ready-to-drive
RES	Remote Emergency System
RMS	Root Mean Square
SCS	System Critical Signal

SE3D	Structural Equivalency 3D Model	**TSAL**	Tractive System Active Light
SES	Structural Equivalency Spreadsheet	**TSMP**	Tractive System Measuring point
SESA	SES Approval	**TSMS**	Tractive System Master Switch
TMD	Team Member Designation	**USS**	Unsafe Stop
TPS	Throttle Position Sensor	**VSV**	Vehicle Status Video

A ADMINISTRATIVE REGULATIONS

A 1 COMPETITION OVERVIEW

A 1.1 Competition Objective

A 1.1.1 The competition challenges teams of university students to conceive, design, fabricate, develop and compete with small, formula style, race cars.

A 1.2 Competition Procedure

A 1.2.1 The competition is split into the following classes:

- Internal Combustion Engine Vehicle (CV)
- Electric Vehicle (EV)
- Driverless Vehicle (DV) (which are either CV or EV)

A 1.2.2 All vehicles must meet the requirements defined in the chapter T and dependent on their drivetrain either EV or CV.

A 1.2.3 Vehicles from the DV class in addition, must meet the requirements defined in chapter DV.

A 1.2.4 The competition starts with a series of technical inspections described in chapter IN to check the vehicle for safety and compliance with the rules.

A 1.2.5 The competition is divided into a series of static and dynamic events described in chapter S and D.

A 1.2.6 Maximum points are awarded as described in table 3.

A 1.2.7 The team with the most total points will win the competition for its class.

A 1.3 Competition Information

A 1.3.1 The competition specific rules and information are defined in the competition handbook.

A 1.3.2 The official language of the competition is English.

	CV & EV	DV
Static Events:		
Business Plan Presentation	75 points	75 points
Cost and Manufacturing	100 points	100 points
Engineering Design	150 points	150 points
Autonomous Design	-	175 points
Dynamic Events:		
Skid Pad	75 points	75 points
Acceleration	75 points	75 points
Autocross	100 points	-
Endurance	325 points	-
Efficiency	100 points	100 points
Trackdrive	-	250 points
Total	1000 points	1000 points

Table 3: Maximum points awarded

A 2 VEHICLE ELIGIBILITY

A 2.1 Student Competition

A 2.1.1 Vehicles entered into the competition must be conceived, designed and maintained by the student team members without direct involvement from professional engineers, racers, machinists or related professionals.

A 2.1.2 The student team may use any information from professionals or from academics as long as the information is given as a discussion of alternatives with their pros and cons.

A 2.1.3 Professionals may not make design decisions or drawings.

A 2.1.4 Students should perform fabrication tasks whenever possible.

A 2.2 First Year Vehicles

A 2.2.1 A vehicle may only be used for one year, counting from the first day of its first competition.

A 2.2.2 To be classified as new, a vehicle must have significant changes in the chassis structure to its predecessor.

A 2.3 [DV ONLY] Second and Third Year Vehicles

A 2.3.1 In derogation from rule A 2.2.1 and A 2.2.2, reconfigured second and third year vehicles may participate in the DV class.

A 2.3.2 Second and third years vehicles need to be compliant to the chapters A, DV, IN, S, D and to all rules marked as [DV ONLY] in the chapters T, CV (for DV combustion vehicles) and EV (for DV electric vehicles).

A 2.3.3 For all rules that are not covered in A 2.3.2, either the actual competition rules, or the rules from the first competition year of the vehicle are applied. The teams may make this choise themselves.

A 2.3.4 All documents (SES, IAD, ESF, etc.) that have been approved by the competition officials in the past are still valid. If modifications are made to the vehicle which are not covered by the original documents, updates of the affected documents must be submitted. In this case the same deadlines as for first year vehicles apply.

A 3 RULES OF CONDUCT

A 3.1 General Officials Authority

A 3.1.1 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 the safe and efficient operation.

A 3.1.2 All team members are required to cooperate with, and follow all instructions from the officials.

A 3.1.3 Official announcements shall be considered part of these rules.

A 3.1.4 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.

A 3.1.5 Questions concerning the meaning or intent of the rules will be resolved by the officials.

A 3.2 Official Instructions

A 3.2.1 Failure of a team member to follow an instruction or command directed specifically to that team or team member will result in a twenty-five point penalty.

A 3.3 Arguments with Officials

A 3.3.1 Argument with, or disobedience to, any official will result in the team being eliminated from the competition.

A 3.4 Unsportsmanlike Conduct

A 3.4.1 In the event of unsportsmanlike conduct, the team will receive a twenty-five point penalty. A second violation will result in expulsion of the team from the competition.

A 3.5 Violations of Intent

A 3.5.1 Violation of the intent of a rule will be considered a violation of the rule itself.

A 3.6 Questions about the Rules

A 3.6.1 Questions about the rules may be asked to the officials.

A 3.6.2 The frequently asked questions (FAQ) section on the competition website must be checked before submitting a question.

A 3.6.3 The officials will only answer questions that are not already answered in the rules or FAQs or that require new or novel interpretation.

A 3.6.4 Refer to the competition website for specific directions how to submit a rules question.

A 3.7 Protests

A 3.7.1 If a team has a question about scoring, judging, policies or any official action it must be brought to the officials' attention for an informal preliminary review before a protest can be filed.

A 3.7.2 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.

A 3.7.3 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.

A 3.7.4 Protests concerning any aspect of the competition must be filed within the protest period announced by the officials.

A 3.7.5 The decision of the officials regarding any protest will be in a written form and is final.

A 4 General Requirements for Teams & Participants

A 4.1 Teams per University

A 4.1.1 A university may register a CV team, an EV team and a DV team.

A 4.1.2 For the purposes of registering and competing, a university's CV team, EV team and DV team are considered to be separate and independent entities.

A 4.1.3 Teams which are formed with members from two or more universities are treated as a single team.

A 4.2 Team Members

A 4.2.1 A team member may only be part of one team, work on one vehicle and take part in a static or dynamic event for only one team.

A 4.2.2 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.

A 4.3 Student Status

A 4.3.1 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.

A 4.3.2 Students seeking a PhD degree/PhD students or equivalent are not allowed to participate.

A 4.4 Age

A 4.4.1 Team members must be at least eighteen years of age.

A 4.5 Driver's License

A 4.5.1 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.

A 4.6 Insurance

A 4.6.1 Each participant must provide proof of valid private liability & individual health insurance for the competition.

A 4.7 Liability Waiver

A 4.7.1 All onsite participants must sign a liability waiver upon registering onsite which can be found on the competition website.

A 4.8 [EV ONLY] Electrical System Officer (ESO)

A 4.8.1 Every participating team has to appoint at least one ESO for the competition.

A 4.8.2 The ESO is responsible for all work carried out on the vehicle during the competition.

A 4.8.3 The ESO is the only person in the team who may declare the vehicle electrically safe, in order for work to be performed on any system of the vehicle by the team.

A 4.8.4 The ESO must be a valid team member, which means that he/she must have student status, see A 4.3.

A 4.8.5 The ESO must be contactable by phone at all times during the competition.

A 4.8.6 The ESO must accompany the vehicle whenever it is operated or moved around at the competition site.

A 4.8.7 If only one ESO is named by the team, this ESO may not be a driver.

A 4.8.8 The ESO must be properly qualified. The ESO must be certified or must have received appropriate practical training (formal or informal) for working with high voltage systems in

automotive vehicles. Details of the training must be provided to the officials on the Electrical System Officer Qualification (ESOQ) form.

A 4.9 [DV ONLY] Autonomous System Responsible (ASR)

A 4.9.1 Every participating team must appoint at least one ASR for the competition. This person is responsible for all autonomous operations of the vehicle during the competition which includes any kind of work on the autonomous system as well as racing and testing.

A 4.9.2 For driverless vehicles with an electric drivetrain the ASR must fulfill A 4.8.

A 4.9.3 The ASR is the only person in the team who is allowed to declare the autonomous system safe, so that work on any system of the vehicle may be performed by the team, or the vehicle may be operated in manual or autonomous mode.

A 4.9.4 The ASR must be a valid team member, which means that he/she must have student status, see A 4.3.

A 4.9.5 The ASR must accompany the vehicle whenever it is operated or moved around at the competition site.

A 4.9.6 If only one ASR is named by the team, this ASR may not be a driver.

A 4.9.7 The ASR must be properly qualified to handle the autonomous system and to understand & deal with problems and failures. A bachelor degree in computer science, electrical engineering, mechatronics, automation engineering, robotics or similar is a sufficient qualification.

A 5 DOCUMENTATION & DEADLINES

A 5.1 Required Documents and Forms

A 5.1.1 The following documents and forms must be submitted by the action deadlines defined in the competition handbook.

A 5.1.2 Group A
IAD, SE3D, SES, SESA, [EV ONLY] EAIR & ESF, [DV ONLY] AAIR & ASF

A 5.1.3 Group B
BPES, CRD, DSS, EDR, [DV ONLY] ADR

A 5.1.4 Group C
TMD, [CV ONLY] ETC & FTO, [EV ONLY] CCP & ESOQ, [DV ONLY] ASRQ

A 5.1.5 Group D
VSV

A 5.2 Submission

A 5.2.1 Only the team captain and two deputies may upload and/or replace documents in the name of the team.

A 5.2.2 Uploaded documents may only be viewed by members of the submitting team, authorized judges and officials.

A 5.2.3 By submitting documents via the competition website, the team agrees that it can be reproduced and distributed by the officials, in both complete and edited versions, for educational purpose.

A 5.2.4 Documents that are largely incomplete will count as not submitted.

A 5.3 Late Submission or Non-Submission

A 5.3.1 Submissions later than the initial deadline will be penalized with ten points for group A and B for each overdue 24 hours. These will be deducted from the team's total score up to a maximum of 70 points for each deadline independently.

A 5.3.2 Teams that submit documents that miss the initial deadlines of group A by more than 168 hours (7 days) will be de-registered from the competition.

A 5.3.3 Teams that submit documents that miss the initial deadlines of group B by more than 168 hours (7 days) will receive zero points for the related event. In that case, no additional penalty points are given.

A 5.4 Correction Requests

A 5.4.1 If the officials request a correction for a document of group A and the team has not uploaded a corrected version after 168 hours (7 days) following the request, it will be penalized with five points for each overdue 24 hours, up to a maximum of 35 points for each correction request independently. These points will be deducted from the team's total score.

A 5.4.2 The team will be de-registered from the competition if it has not uploaded a corrected version of a document of group A after 336 hours (14 days) following the request.

A 5.4.3 Simultaneous requests for different parts within one document or form will be penalized independently of each other.

A 5.5 De-registration

A 5.5.1 A team which is de-registered from the competition has a single chance to apply for a placement on the waiting list.

A 5.5.2 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 of de-registration (e.g. upload of a document)

A 5.5.3 If the application is positively confirmed by the officials, the team will be

- Placed at the end of the waiting list
- Receive the full amount of penalties for the offense

A 5.5.4 Applications will be declined if the rework is inadequate or de-registration was caused by misbehavior of the team.

A 5.6 Vehicle Status Video (VSV)

A 5.6.1 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.

A 5.6.2 The video must show the following sequences:

- Standing still (video close-up of the vehicle front left-side; min. 70 %)
- Straight driving
- 180° cornering
- Straight driving back to start point
- Standing still (video close-up of the vehicle front right-side; min. 70 %)

A 5.6.3 The video must fulfill 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 by its own power
- Driving in a clearly separated and/or protected area (rule A 6.4 applies)
- Vehicle must be presented in ready-to-race conditions incl. body work
- Driver must wear clothes as specified in the rules, incl. helmet, driver suit, gloves and arm-restraints
- [EV ONLY] TSAL must be clearly visible in the video
- [EV ONLY] Ready-to-drive sound must be audible in the video
- [DV ONLY] The vehicle must drive without a driver.
- [DV ONLY] ASSI must be clearly visible in the video
- Must not exceed a length of 45 seconds and size of 40 MB
- File format must be common like avi, mpg, mp4, wmv

A 5.6.4 The submitted VSV will be reviewed based on the specified criteria above. Fulfilling the specified criteria is the responsibility of the team. The goal of the review is to recognize if the vehicle is in ready-to-race condition for the competition.

A 5.6.5 The VSV will be reviewed in order of submission. A review may take up to two weeks.

A 5.6.6 If a team receives a “fail” for its video prior the VSV deadline, the video will be treated as not submitted. A new upload is possible afterwards.

A 5.6.7 Each team without a video upload prior to the specified deadline will receive ten penalty points. Furthermore, the team will receive three penalty points for each additional 24 hours. The last upload of a video is possible until 336 hours (14 days) after the VSV deadline (max. 49 penalty points). Teams without a video at this point will be de-registered from the competition. A re-entry will not be possible.

A 5.6.8 If a team receives a "fail" for its video after the VSV deadline, the team has 72 hours, beginning from the point of notification, to improve the video and upload it again for a new review. If the team fails the review again, the team will be de-registered from the competition. Rule A 5.5 does not apply in this case.

A 5.7 SES Approval (SESA)

A 5.7.1 All teams with a monocoque vehicle must submit a SESA as one document, in addition to the SES deadline. A template of SESA will be supplied on the competition website.

A 5.7.2 The Structural Equivalency Spreadsheet (SES) must be checked and approved by:

- University professor
- Validation/inspection organization (e.g. DEKRA, ...)
- Engineering firm for lightweight structures
- Engineering consultancy company
- Any other official competition

A 5.7.3 Once the SES has been approved by one of the listed institutions the SESA form should be filled out and signed by this institution and uploaded until the SESA deadline.

A 5.7.4 If any changes to the original SES have become necessary due to the approval process, the updated final SES must be uploaded again on the competition website.

A 5.7.5 The detailed changelog with all made changes 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.

A 5.7.6 The officials will randomly double check submitted SESA with their respective submitted SES.

A 6 GENERAL RULES

A 6.1 Removing the Vehicle from the Site

A 6.1.1 Teams who remove their vehicle ([EV ONLY] or tractive system accumulator) from the competition site after the competition has begun will be disqualified from the competition.

A 6.2 Forfeit for Non-Appearance

A 6.2.1 It is the responsibility of each team to be in the right place at the right time.

A 6.2.2 If a team is not present and ready to compete at the scheduled time, they forfeit their attempt at that event.

A 6.3 Team Briefings

A 6.3.1 All team captains and drivers on a particular day must attend the team briefing for that day.

A 6.3.2 [DV ONLY] Drivers that want to operate a DV vehicle in manual mode on the test track are required to attend the team briefing as well.

A 6.3.3 [DV ONLY] All ASR are required to attend the onsite ASR meeting.

A 6.4 Testing and Work Safety

A 6.4.1 Competition organizers are not responsible for the use of the vehicles outside of their competition.

A 6.4.2 The competition officials dissociate themselves from all activities of the teams besides their own competition and associated events.

A 6.4.3 All teams are advised to follow common practices and common sense when working on the vehicle and when operating the vehicle, also before and after a competition.

A 6.4.4 The vehicles must not participate in events not suitable for this type of vehicles like hill climbs, drag races or similar.

A 6.4.5 Teams must never use their vehicles for wheel-to-wheel races.

A 6.4.6 The following listed requirements are considered the minimum of what should be met to qualify as a safe testing/running environment. This does not mean that following these guidelines guarantees safety under all circumstances:

- Driver wearing full protection gear incl. arm restraints
- Working TSAL, IMD, AMS, ASSI, RES, EBS, APPS/brake pedal plausibility check, APPS, and ETC plausibility check if applicable
- Rules compliant frame / monocoque and mounted impact attenuator
- No other passenger cars, trucks etc. being driven on the same premise at the same time, unless the area is 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.

A 6.4.7 Organizers reserve the right to disqualify a registered team of their competition in case of unsafe driving behavior, especially if the reputation of the competition, sponsors and other teams is compromised.

A 6.5 Onsite Working Safety

A 6.5.1 Everyone in the dynamic area and everybody working on the vehicle must wear appropriate, closed-toed shoes.

A 6.5.2 When using metal cutting equipment that produces metal swarf, eye protection is required for the operator as well as any team member assisting.

A 6.5.3 When operating loud tools, hearing protection is required.

A 6.5.4 Any operation producing litter or debris, e.g. cutting of carbon fiber, should not be performed in the pits.

A 6.5.5 When jacking up the vehicle a safe, stable, load rated support device must be used.

A 6.5.6 The use of motorcycles, quads, bicycles, scooters, skateboards, rollerblades or similar person-carrying devices by team members and spectators in any part of the competition area is prohibited.

A 6.5.7 The use of self-propelled pit carts, tool boxes, tire carriers or similar motorized devices in any part of the competition site is prohibited.

A 6.6 Alcohol and Illegal Material

A 6.6.1 Alcohol, illegal drugs, weapons or other illegal material are prohibited on the competition site during the competition.

A 6.6.2 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. The second person of the same team caught with an alcohol level higher than $0.0‰$ will result in the entire team being disqualified immediately.

A 6.7 Vehicle Movement

A 6.7.1 Vehicles may not move under their own power anywhere but on the practice or competition tracks.

A 6.7.2 [EV ONLY] The detachable handle or key of the Tractive System Master Switch (TSMS) must be taken off completely and kept by a ESO. The lockout/tagout function of the TSMS, see EV 5.2.6, must be used.

A 6.7.3 [EV ONLY] In case that the vehicle has not passed electrical inspection, the High Voltage Disconnect (HVD), see EV 4.7, must be disconnected, whilst the vehicle is moved around on the competition site. This also includes taking part in static events.

A 6.7.4 [DV ONLY] Driverless vehicles must also have their autonomous system (see definition in section DV 2.2) deactivated when being moved around the paddock. The detachable handle or key of the Autonomous System Master Switch (ASMS) must be taken off completely and kept by an ASR.

A 6.7.5 Vehicles must be pushed at a normal walking pace by means of a "pushbar" (see rule T 12.1) and with a team member in the cockpit wearing the required driver equipment as defined in T 12.3.1.

A 6.7.6 The person in the cockpit must have full control of steering and braking.

A 6.7.7 When the pushbar is attached to the vehicle, the engine/tractive system must remain off.

A 6.7.8 Vehicles with wings are required to have two team members walking on either side of the vehicle whenever the vehicle is being pushed.

A 6.8 [CV ONLY] Engine Running

A 6.8.1 Running of engines is not allowed in the pits.

A 6.8.2 Engine running is allowed in the engine test area and in the dynamic area, when the following conditions are met:

- The vehicle must have passed mechanical inspection.
- The vehicle must be jacked up using the quick jack (see T 12.2.1).
- A driver, wearing required driver equipment (see T 12.3.1), must be seated in the cockpit.
- A fire extinguisher must be immediately available.
- Driven wheels can only stay attached if they will not turn during engine running.
- No one is allowed under the vehicle whilst the engine is running.

A 6.9 Fueling and Oil

A 6.9.1 Fueling may only take place at the fuel station and must be conducted by officials only.

A 6.9.2 Open fuel containers are not permitted at the competition.

A 6.9.3 Waste oil must be taken to the fuel station for disposal.

T GENERAL TECHNICAL REQUIREMENTS

T 1 GENERAL DESIGN REQUIREMENTS

T 1.1 Vehicle Configuration

T 1.1.1 The vehicle must be designed and fabricated in accordance with good engineering practices.

T 1.1.2 The vehicle must be an open-wheeled single seat and open-cockpit (a formula style body) with four wheels that are not in a straight line.

T 1.1.3 Open wheel vehicles must satisfy (see also Figure 1):

(a) The wheels/tires must be unobstructed when viewed from the side.

(b) No part of the vehicle may enter a keep-out-zone defined by two lines extending vertically from positions 75 mm in front of and 75 mm behind the outer diameter of the front and rear tires in the side view of the vehicle, with tires steered straight ahead. This keep-out zone will extend laterally from the outside plane of the wheel/tire to the inboard plane of the wheel/tire.

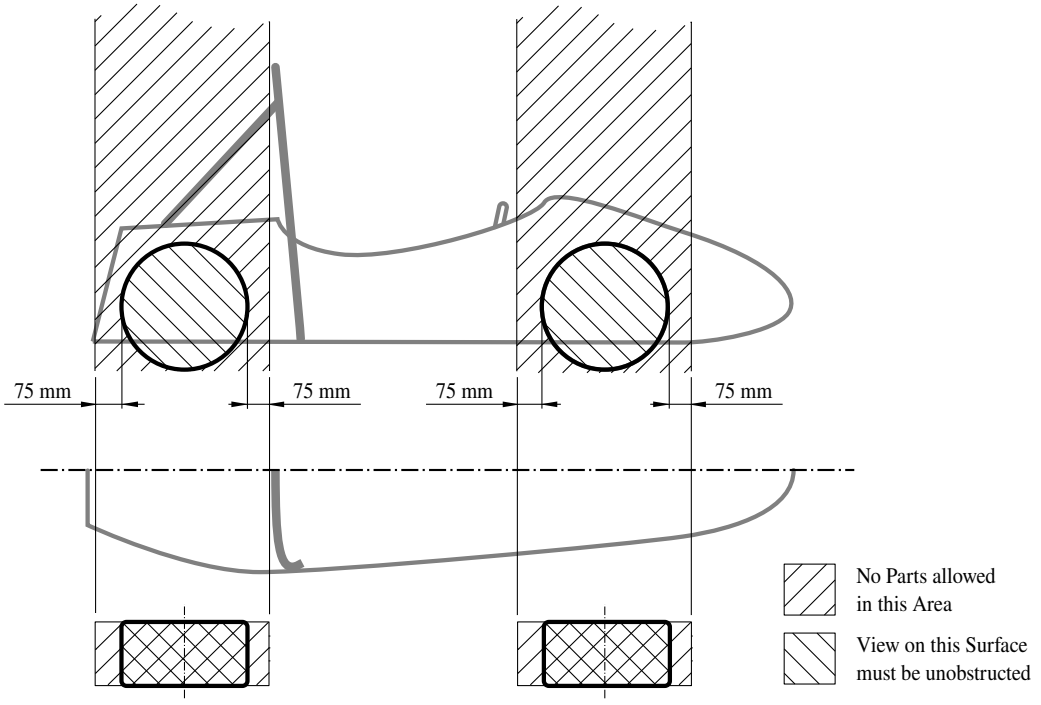

Figure 1: Keep-out-zones for the definition of an open-wheeled vehicle.

T 1.2 Bodywork

T 1.2.1 There must be no openings through the bodywork into the driver compartment other than that required for the cockpit opening. Minimal openings around the front suspension and steering system components are allowed.

T 1.2.2 All edges of the bodywork that could come into contact with a pedestrian must have a minimum radius of 1 mm. The bodywork in front of the front wheels must have a radius of at least 38 mm extending at least 45° relative to the forward direction, along the top, sides and bottom of all affected edges.

T 1.3 Suspension

T 1.3.1 The vehicle must be equipped with fully operational front and rear suspension systems including absorbers and a usable wheel travel of at least 50 mm with driver seated (25 mm jounce and 25 mm rebound).

T 1.3.2 All suspension mounting points must be visible at technical inspection, either by direct view or by removing any covers.

T 1.4 Wheels

T 1.4.1 Any wheel mounting system that uses a single retaining nut must incorporate a device to retain the nut and the wheel in the event that the nut loosens. A second nut ("jam nut") does not meet these requirements.

T 1.4.2 Standard wheel lug bolts must be made of steel and are considered engineering fasteners. Teams using modified lug bolts or custom designs will be required to provide proof that good engineering practices have been followed in their design.

T 1.4.3 Aluminum wheel nuts may be used, but they must be hard anodized and in pristine condition.

T 1.5 Tires

T 1.5.1 Vehicles must have two types of tires as follows:

(a) Dry tires - The tires on the vehicle when it is presented for technical inspection are defined as its "dry tires".

(b) Wet tires - Wet tires may be any size or type of treaded or grooved tire provided:

- The tread pattern or grooves were molded in by the tire manufacturer or were cut by the tire manufacturer or his appointed agent. Any grooves that have been cut must have documentary proof that it was done in accordance with these rules.
- There is a minimum tread depth of 2.4 mm.

T 1.5.2 Tires on the same axle must have the same manufacturer, size and compound.

T 1.5.3 Tire warmers are not allowed.

T 1.5.4 Special agents that increase traction may not be added to the tires or track surface.

T 1.6 Steering

T 1.6.1 Steering systems using cables or belts for actuation are prohibited.

T 1.6.2 The steering wheel must be mechanically connected to the front wheels.

[DV ONLY] Steer-by-wire is allowed in autonomous mode, but a mechanical connection must remain when ASMS is off.

T 1.6.3 The steering system must have positive steering stops that prevent the steering linkages from locking up. The stops must be placed on the rack and must prevent the tires and rims from contacting other parts.

T 1.6.4 Allowable steering system free play is limited to total of 7° measured at the steering wheel.

T 1.6.5 The steering wheel must be attached to the column with a quick disconnect. The driver must be able to operate the quick disconnect while in the normal driving position with gloves on.

T 1.6.6 The steering wheel must be no more than 250 mm rearward of the front hoop. This distance is measured horizontally, on the vehicle centerline, from the rear surface of the front hoop to the forward most surface of the steering wheel with the steering in any position.

T 1.6.7 The steering wheel must have a continuous perimeter that is near circular or near oval. The outer perimeter profile may have some straight sections, but no concave sections.

T 1.6.8 In any angular position, the top of the steering wheel must be no higher than the top-most surface of the front hoop.

T 1.6.9 The steering rack must be mechanically attached to the frame.

T 1.6.10 Joints between all components attaching the steering wheel to the steering rack must be mechanical and visible at technical inspection. Bonded joints without a mechanical backup are not permitted. The mechanical backup must be designed to solely uphold the functionality of the steering system.

T 1.6.11 Rear wheel steering, which can be electrically actuated, is permitted but only if mechanical stops limit the range of angular movement of the rear wheels to a maximum of 6°. This must be demonstrated with a driver in the vehicle and the team must provide the facility for the steering angle range to be verified at technical inspection.

T 1.7 Wheelbase

T 1.7.1 The vehicle must have a wheelbase of at least 1525 mm.

T 1.8 Track and Rollover Stability

T 1.8.1 The smaller track of the vehicle (front or rear) must be no less than 75 % of the larger track.

T 1.8.2 The track and center of gravity of the vehicle must combine to provide adequate rollover stability.

T 2 GENERAL CHASSIS DESIGN

T 2.1 General Requirements

T 2.1.1 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

T 2.2 Definitions

T 2.2.1 The following definitions apply throughout this document:

- Main hoop - A roll bar located alongside or just behind the driver's torso.
- Front hoop - A roll bar located above the driver's legs, in proximity to the steering wheel.
- Roll hoops - Both the front hoop and the main hoop are classified as "roll hoops"
- Roll hoop bracing - The structure from a roll hoop to the roll hoop bracing support.
- Roll hoop bracing supports - The structure from the lower end of the roll hoop bracing back to the roll hoop(s).
- Frame Member - A minimum representative single piece of uncut, continuous tubing or equivalent structure.
- Frame - The "frame" is the fabricated structural assembly that supports all functional vehicle systems. This assembly may be a single welded structure, multiple welded structures or a combination of composite and welded structures.
- Primary structure - The primary structure is comprised of the following frame components:
  - Main hoop
  - Front hoop
  - Roll hoop bracings and supports
  - Side impact structure
  - Front bulkhead
  - Front bulkhead support system
  - All frame members, guides and supports that transfer load from the driver's restraint system into the above mentioned components of the primary structure
- Front bulkhead - A planar structure that defines the forward plane of the frame structure and functions to provide protection for the driver's feet.
- Impact Attenuator (IA) - A deformable, energy absorbing device located forward of the front bulkhead.

- Side impact zone - The area of the side of the vehicle extending from the front hoop back to the main hoop and from the chassis floor to a height as required in T 2.16 above the lowest inside chassis point between the front and main hoop.
- Node-to-node triangulation - An arrangement of frame members projected onto a plane, where a co-planar load applied in any direction, at any node, results in only tensile or compressive forces in the frame members as shown in Figure 2.

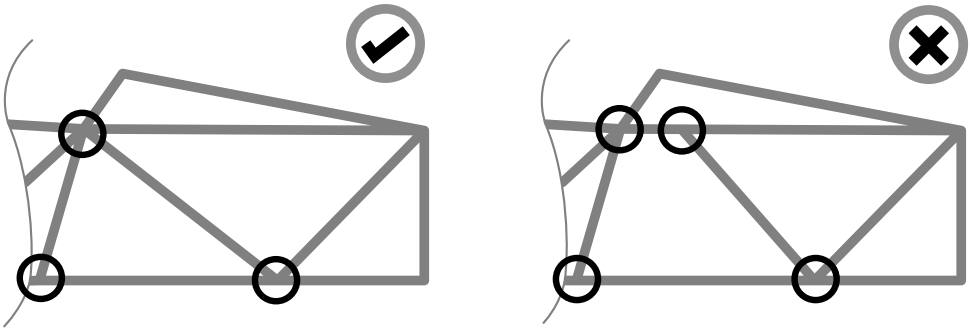

Figure 2: Node-to-node triangulation of frame members (left correct and right incorrect).

T 2.3 Minimum Material Requirements

T 2.3.1 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 area moment of inertia
Main and front hoops, shoulder harness mounting bar	2.0 mm	11 320 mm^4
Side impact structure, front bulkhead, roll hoop bracing, driver's restraint harness attachment (except as noted above) EV: Accumulator protection structure	1.2 mm	8509 mm^4
Front bulkhead support, main hoop bracing supports EV: Tractive system components	1.2 mm	6695 mm^4

Table 4: Minimum Material Requirements

T 2.3.2 Except for inspection holes (see T 2.8.4), any holes drilled in any tube which is a member of the primary structure needs proof of equivalency in the SES.

T 2.3.3 The steel properties used for the calculations in the SES must be:

Non-welded strength for continuous material calculations:

- Young's Modulus (E) = 200 GPa

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

Welded strength for discontinuous material such as joint calculations:

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

T 2.3.4 Any tubing with a wall thickness less than 1.2 mm is considered non-structural and will be ignored when assessing compliance to any rule regarding the vehicle structure.

T 2.3.5 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. The attachment point must be at the position along the tube(s) where it deviates farthest from a straight line connecting both ends. The support tube must have the same dimension as the supported tube(s), terminate at a node of the chassis and be angled no more than 30° from the plane of the supported tube(s).

T 2.4 Alternative Materials

T 2.4.1 Alternative materials may be used for all parts of the primary structure and the tractive system accumulator container with the given 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 aluminum welded structure.

T 2.4.2 If any other materials than steel tubing are used in the primary structure or the tractive system accumulator container, physical testing is required to show equivalency to the minimum requirements relative to steel with the properties given in T 2.3.3.

T 2.5 Composite Structures

T 2.5.1 If composite structures are used in the primary structure or the tractive system accumulator container, the Flexural Rigidity (EI) of that structure must be calculated as the EI of a flat panel with the same composition as the structure used in the frame about the neutral axis of the laminate. The curvature of the panel and geometric cross section of the monocoque must be ignored for these calculations.

T 2.5.2 If composite materials are used in the primary structure or the tractive system accumulator container the SES must include:

(a) Material type(s)

(b) Cloth weights

(c) Resin type

(d) Fiber orientation

(e) Number of layers

(f) Core material

(g) Lay-up technique

(h) 3-point-bend test and shear test data

T 2.6 Laminate Testing

T 2.6.1 If composite materials are used for any part of the primary structure or the tractive system accumulator container the team must

- Build a representative test panel which must measure 275 mm × 500 mm that has the same design, laminate and fabrication method as used for the respective part of the primary structure as a flat panel
- Perform a 3-point bending test on this panel

The data from these tests and pictures of the test samples must be included in the SES. The test results will be used to derive strength and stiffness properties used in the SES formula for all laminate panels.

T 2.6.2 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.

T 2.6.3 The test specimen must be presented at technical inspection.

T 2.6.4 The load applicator used to test any panel or tube must be metallic and have a radius of 50 mm.

T 2.6.5 The load applicator must overhang the test piece to prevent edge loading.

T 2.6.6 There must be no material between the load applicator and the test piece.

T 2.6.7 Perimeter shear tests must be executed to measure the force required to push or pull a 25 mm diameter flat punch through a flat laminate sample. The sample must be at least 100 mm × 100 mm. Core and skin thicknesses must be identical to those used in the actual frame structure and be manufactured using the same materials and processes.

T 2.6.8 The fixture must support the entire sample, except for a 32 mm hole aligned co-axially with the punch. The sample must not be clamped to the fixture.

T 2.7 Structural Documentation

T 2.7.1 All teams must submit a Structural Equivalency Spreadsheet (SES) and Structural Equivalency 3D Model (SE3D).

T 2.7.2 The SES spreadsheet form can be downloaded from the competition website.

T 2.7.3 The SE3D must contain a three dimensional CAD model of the frame/monocoque including all members of the primary structure in "IGES" file format not larger than 40 MB. [EV ONLY] The accumulator container(s) and attachment must also be included

T 2.7.4 Vehicles must be fabricated in accordance with the materials and processes described in the SES.

T 2.7.5 Teams must bring a copy of the approved SES to technical inspection.

T 2.8 Roll Hoops

T 2.8.1 Both roll hoops must be securely integrated to the primary structure using node-to-node triangulation or equivalent joining methods.

T 2.8.2 The minimum radius of any bend, measured at the tube centerline, must be at least three times the tube outside diameter. Bends must be smooth and continuous with no evidence of crimping or wall failure.

T 2.8.3 The roll hoops must extend from the lowest frame member on one side of the frame, up, over and down to the lowest frame member on the other side.

T 2.8.4 Both roll hoops must have one 4.5 mm hole in a non-critical location and its surface at this point must be unobstructed for at least 180°.

T 2.9 Main Hoop

T 2.9.1 The main hoop must be constructed of a single piece of uncut, continuous, closed section steel tubing.

T 2.9.2 In side view the portion of the main hoop which is higher than its upper attachment point to the side impact structure must be within 10° from vertical.

T 2.9.3 In side view any bends in the main hoop above its upper attachment point to the primary structure must be braced to a node of the main hoop bracing support structure with tubing meeting the requirements of main hoop bracing.

T 2.9.4 In side 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.

T 2.9.5 If the main hoop is attached to a composite primary structure, it must be mechanically attached at the top and bottom of the structure and at intermediate locations if needed to show equivalency.

T 2.9.6 Mounting plates welded to the main hoop must be at least 2 mm thick steel.

T 2.10 Front Hoop

T 2.10.1 If the front hoop is made from more than one piece it must be supported by node-to-node triangulation or an equivalent construction.

T 2.10.2 In side view, no part of the front hoop can be inclined more than 20° from vertical.

T 2.10.3 If the front hoop is a welded construction made from multiple aluminum 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 as to how the heat treatment process was performed.

T 2.11 Main Hoop Bracing

T 2.11.1 The main hoop must be supported by two bracings extending on both sides of the main hoop to the front or the rear.

T 2.11.2 In side view the main hoop and the main hoop bracings must not lie on the same side of the vertical line through the top of the main hoop.

T 2.11.3 The main hoop bracings must be attached to the main hoop no lower than 160 mm below the top-most surface of the main hoop. The included angle formed by the main hoop and the main hoop bracings must be at least 30°.

T 2.11.4 The main hoop bracings must be straight.

T 2.11.5 The lower ends of the main hoop bracings 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.

T 2.11.6 If any item which extends outside of the primary structure is attached to the main hoop bracings, additional bracing is required to prevent bending loads in a rollover situation.

T 2.12 Front Hoop Bracing

T 2.12.1 The front hoop must be supported by two bracings extending forward on both sides of the front hoop.

T 2.12.2 The front hoop bracings must extend to the structure forward of the driver's feet.

T 2.12.3 The front hoop bracings must be attached no lower than 50 mm below the top-most surface of the front hoop (see Figure 3).

T 2.12.4 If the front hoop is leaning more than 10° to the rear, additional bracing extending rearwards are required.

T 2.12.5 The front hoop bracings must be straight.

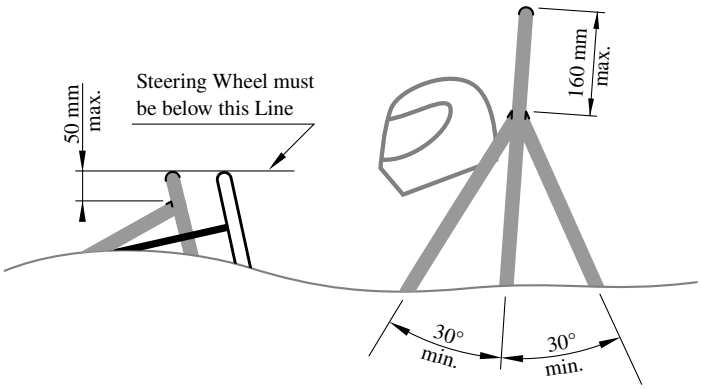

Figure 3: Front hoop bracing, main hoop bracing and steering wheel requirements

T 2.13 Mechanically Attached Roll Hoop Bracing

T 2.13.1 Any non-welded joint at either end of a bracing must be either a double-lug joint (see Figure 4) or a sleeved joint (see Figure 5).

T 2.13.2 If threaded fasteners are used they are considered critical fasteners and must comply with T 9.1.

T 2.13.3 Spherical rod ends are prohibited.

T 2.13.4 Double lug-joints must include a capping arrangement, see Figure 4.

T 2.13.5 In a double-lug joint each lug must be at least 4.5 mm thick and the pin or bolt must be 10 mm metric grade 9.8 minimum. The attachment holes in the lugs and in the attached bracing must be a close fit with the pin or bolt.

T 2.13.6 For sleeved joints the sleeve must have a minimum length of 38 mm at either side of the joint and be a close-fit around the base tubes. The wall thickness of the sleeve must be at least that of the base tubes. The bolts must be 6 mm metric grade 8.8 minimum. The holes in the sleeves and tubes must be a close-fit with the bolts.

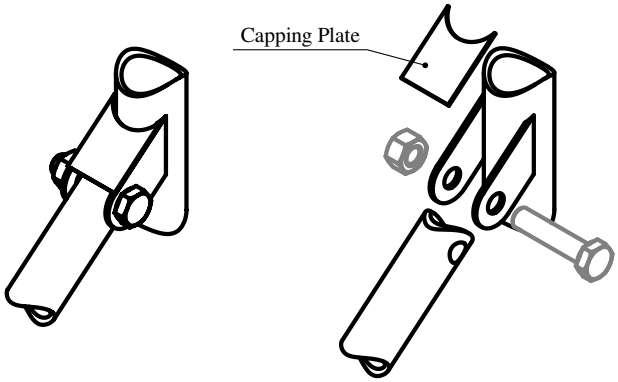

Figure 4: Double lug joint

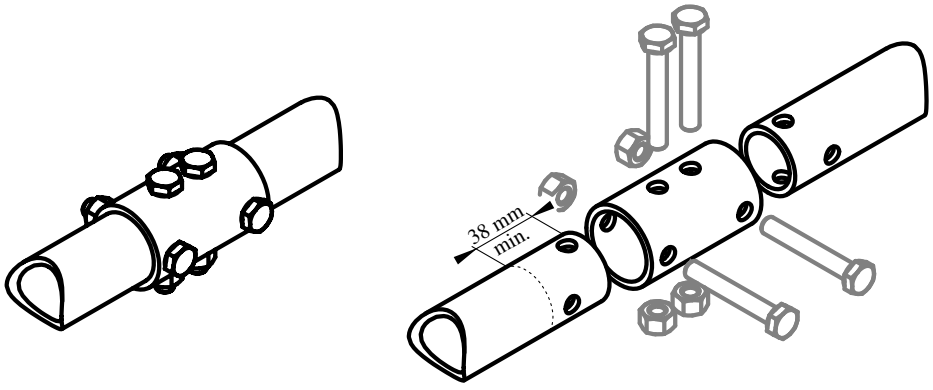

Figure 5: Sleeved joint

T 2.14 Front Bulkhead

T 2.14.1 The rear plane of the front bulkhead must be located forward of all non-crushable objects.

T 2.14.2 The soles of the driver's feet/shoes must be rearward of the rear bulkhead plane when touching but not applying the pedals for all pedal box adjustments.

T 2.14.3 Any alternative material used for the front bulkhead must have a perimeter shear strength equivalent to a 1.5 mm thick steel plate.

T 2.14.4 If the front bulkhead is part of a composite structure and is modeled as an "L" shape, the EI of the front bulkhead about vertical and lateral axis must be equivalent to a steel tube meeting the requirements for the front bulkhead. The length of the section perpendicular to the bulkhead may be max. 25 mm measured from the rearmost face of the bulkhead.

T 2.15 Front Bulkhead Support

T 2.15.1 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 a diagonal bracing to provide triangulation.

- The upper support member must be attached to the front bulkhead max. 50 mm lower than the top-most surface of the front bulkhead, and attached to the front hoop not lower than 50 mm below the upper side impact member. If the attachment point of the upper member is higher than 100 mm 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.

T 2.15.2 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.

T 2.15.3 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.

T 2.15.4 The perimeter shear strength of the monocoque laminate in the front bulkhead support structure must be at least 4 kN for a section with a diameter of 25 mm.

T 2.16 Side Impact Structure

T 2.16.1 The side impact structure must consist of at least three steel tubes (see T 2.3) at each side of the cockpit (see Figure 6).

- The upper member must connect the main hoop and the front hoop. It must be at a height between 240 mm and 320 mm 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.

T 2.16.2 If the side impact structure is part of a composite structure, the following is required:

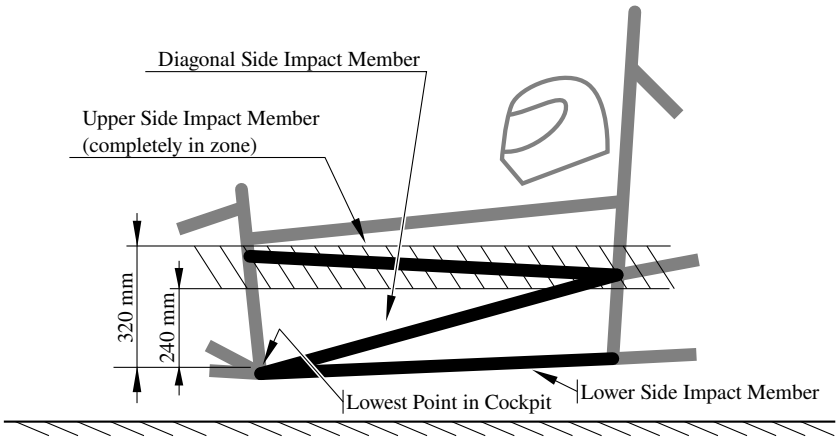

Figure 6: Side impact structure tube frame

- 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 320 mm above the lowest inside chassis point between the front and main hoop must have an EI equal to three baseline steel tubes that it replaces (see Figure 7).
- 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 7.5 kN for a section with a diameter of 25 mm.

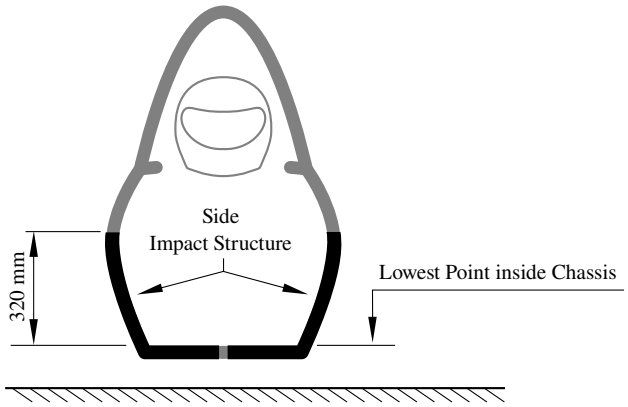

Figure 7: Side impact structure monocoque

T 2.17 Bolted Primary Structure Attachments

T 2.17.1 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 30 kN in any direction.

T 2.17.2 Data obtained from the laminate perimeter shear strength test must be used to prove that adequate shear area is provided.

T 2.17.3 Proof that the used brackets are adequately stiff must be documented in the SES. Hand calculations or Finite Element Analysis (FEA) with supporting hand calculations are acceptable. The use of FEA alone is not sufficient.

T 2.17.4 Each attachment point requires a minimum of two 8 mm metric grade 8.8 bolts and steel backing plates with a minimum thickness of 2 mm.

T 2.17.5 For the attachment of front hoop bracing, main hoop bracing and main hoop bracing support to the primary structure the use of one 10 mm metric grade 8.8 bolt is sufficient, if the bolt is on the centerline of the tube (see Figure 8).

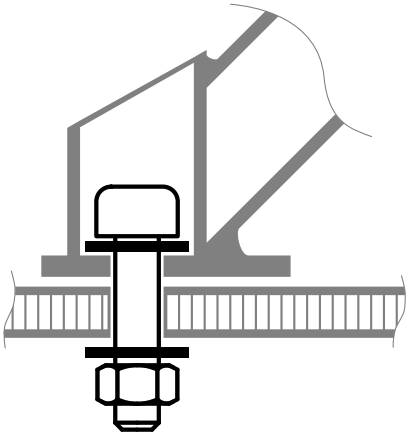

Figure 8: Bolted roll hoop bracing support

T 2.17.6 When using bolted joints within the primary structure, no crushing of the laminate core material is permitted.

T 2.18 Impact Attenuator (IA)

T 2.18.1 Each vehicle must be equipped with an IA.

T 2.18.2 The IA must be:

- Installed forward of the front bulkhead.
- At least 100 mm high and 200 mm wide for a minimum distance of 200 mm forward of the front bulkhead.
- Such that it cannot penetrate the front bulkhead in the event of an impact.
- Attached securely and directly to the front bulkhead.
- No part of the non-structural bodywork.
- Designed with a closed front section.

T 2.18.3 On all vehicles, a 1.5 mm solid steel or 4.0 mm solid aluminum Anti Intrusion Plate (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 centerline of the front bulkhead tubing in all directions.

T 2.18.4 Alternative AIP designs are permissible if equivalency to T 2.18.3 is proven, either by physical testing as in T 2.20.2 or a 3-point bending test and a perimeter shear test as in T 2.6. These tests must at least prove that:

(a) The AIP does not fail under a static bending load of 120 kN distributed over 150 mm of length.

(b) The perimeter shear strength is sufficient, such that each attachment can withstand a minimum force of 20 kN in any direction.

T 2.18.5 If the IA assembly is not integral with the frame, i.e. welded, a minimum of eight 8 mm metric grade 8.8 bolts must attach the IA assembly to the front bulkhead.

T 2.18.6 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-center and off-axis impacts. Segmented foam attenuators must have the segments bonded together to prevent sliding or parallelogramming.

T 2.18.7 The attachment of the IA assembly to a monocoque structure requires an approved "Structural Equivalency Spreadsheet" per rule T 2.7 that shows equivalency to a minimum of eight 8 mm metric grade 8.8 bolts.

T 2.18.8 If a team uses the "standard" FSAE IA, and the outside edge of the front bulkhead extends beyond the IA assembly by more than 25 mm on any side, a diagonal or X-bracing made from 25 mm $\times$ 1.5 mm steel tubing, or an approved equivalent per T 2.3, must be included in the front bulkhead.

T 2.18.9 If the standard IA is used, but does not comply with edge distance limits of rule T 2.18.8 and does not include a diagonal bracing, physical testing must be carried out to prove that the AIP does not permanently deflect more than 25.4 mm.

T 2.19 Impact Attenuator Data Requirement

T 2.19.1 All teams must submit an IA data report using the Impact Attenuator Data (IAD) template provided at the competition website.

T 2.20 Impact Attenuator Test Requirements

T 2.20.1 The IA assembly, when mounted on the front of a vehicle with a total mass of 300 kg and impacting a solid, non-yielding impact barrier with a velocity of impact of 7 $^{m}/_{s}$, must meet the following requirements:

- Decelerate the vehicle at a rate not exceeding 20 g average and 40 g peak.
- The energy absorbed in this event must meet or exceed 7350 J.
- Teams using the standard IA are not required to submit test data with their IAD report, but all other requirements must be included.

T 2.20.2 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 structurally representative section of the intended chassis. There must be at least 50 mm clearance rearwards of the AIP to the test fixture. No part of the AIP may permanently deflect more than 25 mm beyond the position of the AIP before the test. 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 120 kN (300 kg multiplied by 40 g), where the load applicator matches the minimum IA dimensions.

T 2.20.3 Vehicles with aerodynamic devices and/or environment perception sensors in front of the IA must not exceed the peak deceleration of T 2.20.1 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 120 kN:

(a) Physical testing of the IA assembly including any attached non-crushable object(s) in front of the AIP.

(b) 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.

(c) Combining the "standard" IA peak load of 95 kN with the failure load for the mounting of the non-crushable object(s), calculated from fastener shear and/or link buckling.

T 2.20.4 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.

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

If peaks above the 40 g limit are present in the data, a 100 Hz, 3rd order, low pass Butterworth (−3 dB at 100 Hz) filter may be applied.

T 2.21 Non-Crushable Objects

T 2.21.1 All non-crushable objects (e.g. batteries, master cylinders, hydraulic reservoirs) must be rearward of the front bulkhead, except for environment perception sensors, aerodynamic devices and their mountings.

T 3 COCKPIT

T 3.1 Cockpit Opening

T 3.1.1 The size of the cockpit opening needs to be sufficient for the template shown on the left in Figure 9 to pass vertically from the opening below the top bar of the side impact structure whilst being held horizontally. The template may be moved fore and aft.

T 3.1.2 If the side impact structure is not made of tubes, the template must pass until it is 320 mm above the lowest inside chassis point between the front and main hoop.

T 3.1.3 The steering wheel, steering column, 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.

T 3.2 Cockpit Internal Cross Section

T 3.2.1 The cockpit must provide a free internal cross section sufficient for the template shown on the right in Figure 9 to pass from the rear of the front hoop to a point 100 mm rearwards of the face of the rearmost pedal in inoperative position. The template may be moved up and down. Adjustable pedals have to be put in their most forward position.

T 3.2.2 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.

T 3.2.3 The driver's feet and legs must be completely contained within the primary structure whilst 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.

T 3.2.4 [DV ONLY] To allow for the steering actuator a reduced-height template (reduced by 50 mm, shown in Figure 9) may be used for a section measuring 200 mm horizontally along the template's path (compare T 3.2.1).

T 3.2.5 [DV ONLY] The additional space allowed by rule T 3.3.4 (d) and T 3.2.4 may only be used for steering, braking and clutch actuators. When the actuators are removed, the standard templates must fit into the cockpit.

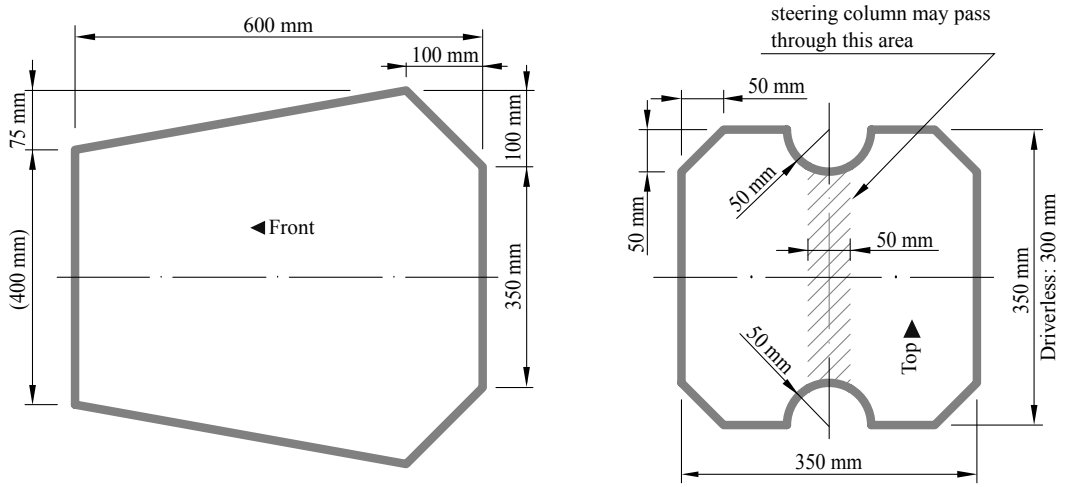

Figure 9: Cockpit opening template (left) and cockpit internal cross section template (right)

T 3.3 Percy (95th percentile male)

T 3.3.1 When seated normally and restrained by the driver's restraint system, the helmet of a 95th percentile male and all of the team's drivers must:

(a) Be a minimum of 50 mm away from the straight line drawn from the top of the main hoop to the top of the front hoop.

(b) Be a minimum of 50 mm 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.

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

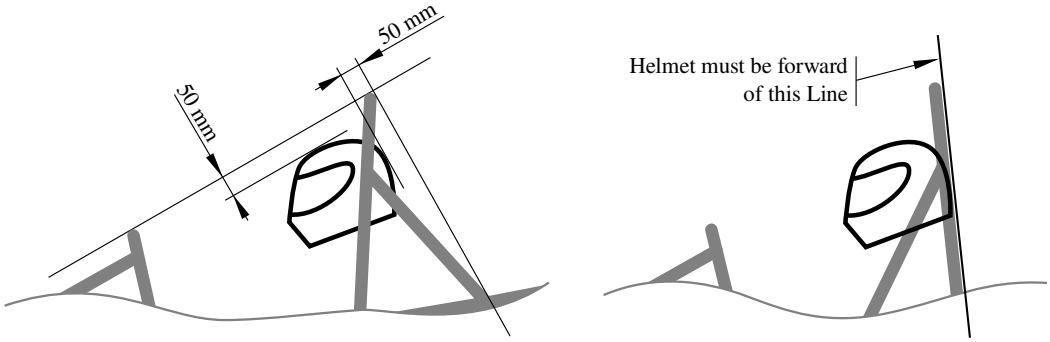

Figure 10: Minimum helmet clearance

T 3.3.2 The 95th percentile male is represented by a two dimensional figure consisting of two circles of 200 mm diameter (one representing the hips and buttocks and one representing the shoulder region) and one circle of 300 mm (representing the head with helmet).

T 3.3.3 The two 200 mm circles are connected by a straight line measuring 490 mm. The 300 mm circle is connected by a straight line measuring 280 mm with the upper 200 mm circle.

T 3.3.4 The figure has to be positioned in the vehicle as follows (see Figure 11):

(a) The seat adjusted to the rearmost position

(b) The pedals adjusted to the frontmost position

(c) The bottom 200 mm circle placed on the seat bottom. The distance between the center of the circle and the rearmost face of the pedals must be minimum 915 mm.

(d) [DV ONLY] The distance from center of circle and pedals, as mentioned above, may be reduced to 865 mm but only for placement of automated brake, steering or clutch actuators in front of the pedals.

(e) The middle circle positioned on the seat back

(f) The upper 300 mm circle positioned 25 mm away from the head restraint.

T 3.4 Side Tubes

T 3.4.1 If there is any frame 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 frame to prevent the driver's shoulders from passing under that frame member.

T 3.5 Driver's Harness Attachment

T 3.5.1 If the attachment of the drivers harness is not welded to a steel structure, it must be proven that the attachments for shoulder and lap belts can support a load of 13 kN and the attachment points of the anti-submarine belts can support a load of 6.5 kN.

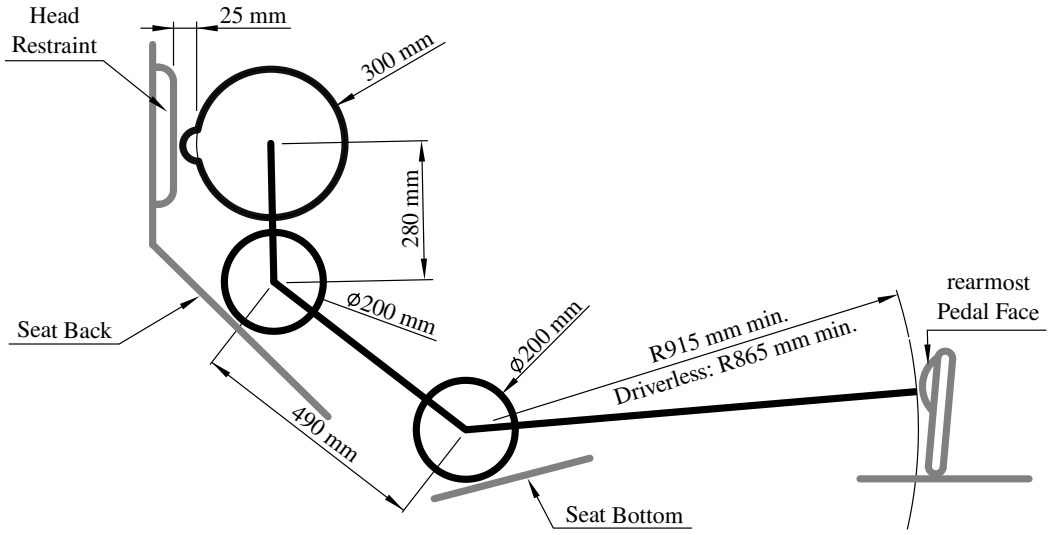

Figure 11: Percy placement

T 3.5.2 If the lap belts and anti-submarine belts are attached to the same attachment point, it must support a load of 19.5 kN.

T 3.5.3 The strength of lap belt and shoulder belt attachment must be proven by physical testing where the required load is applied to a representative attachment point with the layup and attachment brackets as in the frame. The following requirements must be met:

(a) Edges of the test fixture supporting the sample must be a minimum of 125 mm from the load application point.

(b) 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.

(c) Designs with attachments near a free edge may not support the free edge during the test.

(d) Harness loads must be tested with the worst case for the range of the angles specified for the driver's harness.

T 3.6 Driver's Seat

T 3.6.1 The lowest point of the driver's seat must in side view not extend downward of 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 (T 2.3), passing underneath the lowest point of the seat.

T 3.6.2 Adequate heat insulation must be provided to ensure that the driver will not be 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 8 mm.

(b) Convection insulation by a minimum air gap of 25 mm.

(c) Radiation insulation by:

(i) A solid metal heat shield with a minimum thickness of 0.4 mm or

(ii) reflective foil or tape when combined with T 3.6.2(a)(ii).

T 3.7 Floor Closeout

T 3.7.1 All vehicles must have a floor closeout made of one or more panels, which separate the driver from the pavement. If multiple panels are used, gaps between panels may not exceed 3 mm. The closeout must extend from the front bulkhead to the firewall. The panels must be made of a solid, non-brittle material.

T 3.8 Firewall

T 3.8.1 A firewall must separate the driver compartment from all components of the fuel supply, the engine oil, the liquid cooling systems, the low voltage battery and any high voltage system (EV 1.1). It must extend sufficiently far upwards and/or rearwards such that any point, less than 100 mm above the bottom of the helmet of the tallest driver, is not in direct line of sight with any of the above mentioned parts.

T 3.8.2 The firewall must be a non-permeable surface made from a rigid, fire resistant material, which must be rigidly mounted to the vehicle's structure.

T 3.8.3 Any firewall must seal completely against the passage of fluids, especially at the sides and the floor of the cockpit.

T 3.8.4 Pass-throughs for wiring, cables, etc. are permitted if grommets are used to seal the pass-through.

T 3.8.5 Multiple panels may be used to form the firewall but must be sealed at the joints.

T 3.8.6 [EV ONLY] The tractive system firewall between driver and tractive system components must be composed of two layers:

(a) One layer, facing the tractive system side, must be made of aluminum with a thickness of at least 0.5 mm. This part of the tractive system firewall must be grounded according to EV 4.3.

(b) The second layer, facing the driver, must be made of an electrically insulating material. The material used for the second layer must meet UL94-V0, FAR25 or equivalent. The second layer must not be made of CFRP.

(c) The thickness of second layer must be sufficient to prevent penetrating this layer with a 4 mm wide screwdriver and 250 N of force.

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

T 3.8.7 [EV ONLY] Conductive parts (except for the chassis) may not protrude through the firewall or must be properly insulated on the driver side.

T 3.8.8 [EV ONLY] High Voltage (HV) parts outside of the envelope, see EV 4.2.3, do not need a firewall.

T 3.9 Accessibility of Controls

T 3.9.1 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 planes of the side impact structure.

T 3.10 Driver Visibility

T 3.10.1 The driver must have adequate visibility to the front and sides of the vehicle. Seated in a normal driving position, the driver must have a minimum field of vision of 200° (a minimum 100° to either side). The required visibility may be obtained by the driver turning their head and/or the use of mirrors.

T 3.10.2 If mirrors are required to meet rule T 3.10.1, they must remain in place and adjusted to enable the required visibility throughout all dynamic events.

T 3.11 Driver Egress

T 3.11.1 All drivers must be able to exit to the side of the vehicle in less than 5 s with the driver in the fully seated position, hands in driving position on the connected steering wheel (in all possible steering positions) and wearing the required driver equipment as in rule T 4. Egress time will stop when the driver has both feet on the pavement.

T 4 DRIVER RESTRAINT SYSTEM

T 4.1 Definitions

(a) A 6-point system - consists of a two-piece lap belt (minimum width: 75 mm for SFI 16.1, 50 mm for SFI 16.5 or FIA 8853/98), two shoulder straps (minimum width of 75 mm) and two leg or anti-submarine straps (minimum width of 50 mm).

(b) A 7-point system - system is the same as the 6-point system except it has three anti-submarine straps.

(c) An “upright driving position” is defined as one with a seat back angled at 30° or less from the vertical as measured along the line joining the two 200 mm circles of the 95th percentile male template as defined in rule T 3.3 and positioned per rule T 3.3.4.

(d) A “reclined driving position” is defined as one with a seat back angled at more than 30° from the vertical as measured along the line joining the two 200 mm circles of the 95th percentile male template as defined in rule T 3.3 and positioned per rule T 3.3.4.

T 4.2 Belts - General

T 4.2.1 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 or FIA specification 8853/98.
- 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.
- It is mandatory that the shoulder harness, where it passes over the shoulders, be 75 mm wide, except with the use of a HANS device. 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 50 mm wide shoulder harnesses are allowed.

T 4.2.2 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.

T 4.2.3 The restraint system must be worn tightly at all times.

T 4.3 Belt, Strap and Harness Installation - General

T 4.3.1 The lap belt, shoulder harness and anti-submarine strap(s) must be securely mounted to the primary structure. Such structure and any guide or support for the belts must meet the minimum requirements of T 2.3.

T 4.3.2 The tab or bracket to which any harness is attached must have:

- A minimum cross sectional area of 60 mm^2 of steel to be sheared or failed in tension at any point of the tab, and
- A minimum thickness of 1.6 mm.
- Where lap belts and anti-submarine belts use the same attachment point, a minimum cross sectional area of 90 mm^2 of steel to be sheared if failed in tension at any point of the tab.
- Where brackets are fastened to the chassis, two fasteners of 6 mm metric grade 8.8 fasteners or stronger must be used.

T 4.3.3 Harnesses, belts and straps must not pass through a firewall, i.e. all harness attachment points must be on the driver's side of any firewall.

T 4.3.4 The attachment of the driver's restraint system to a monocoque structure requires an approved SES per rule T 2.7.

T 4.4 Lap Belt Mounting

T 4.4.1 The lap belt must pass around the pelvic area below the anterior superior iliac spines (the hip bones).

T 4.4.2 The lap belts must not be routed over the sides of the seat. 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.

T 4.4.3 Where the belts or harness pass through a hole in the seat, the seat must be rolled or grommeted to prevent chafing of the belts.

T 4.4.4 In side view, the lap belt must be capable of pivoting freely by using either a shouldered bolt or an eye bolt attachment.

T 4.4.5 With an "upright driving position", in side view the lap belt must be at an angle of between 45° and 65° to the horizontal.

T 4.4.6 With a "reclined driving position", in side view the lap belt must be between an angle of 60° and 80° to the horizontal.

T 4.4.7 The centerline of the lap belt at the seat bottom should be between 0 mm to 76 mm forward of the seat back to seat bottom junction as in Figure 12.

T 4.5 Shoulder Harness

T 4.5.1 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.

T 4.5.2 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 7 kN load per attachment and the range of angles in rule T 4.5.5, calculate that the bent shoulder harness bar triangulation stresses are less than as welded yield strength T 2.3.3 for combined bending and shear and does not fail in column buckling. If the team chooses not to perform the strength analysis rule T 2.3.5 will apply.

T 4.5.3 The strength of any shoulder harness bar bracing tubes must be proved in the relevant tab of the team's SES submission.

T 4.5.4 The shoulder harness mounting points must be between 180 mm and 230 mm apart.

T 4.5.5 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 12.

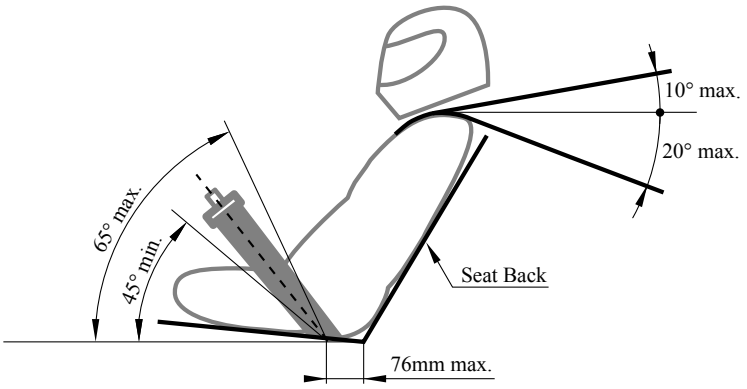

Figure 12: Lap belt and shoulder harness mounting

T 4.6 Anti-Submarine Belt Mounting

T 4.6.1 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 100 mm 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.

T 4.7 Head Restraint

T 4.7.1 A head restraint must be provided on the vehicle to limit the rearward motion of the driver's head.

T 4.7.2 The head restraint must:

(a) Be vertical or near vertical in side view.

(b) Be padded with an energy absorbing material such as Ethafoam® or Ensolite® with a minimum thickness of 40 mm.

(c) Have a minimum width and height of 150 mm and have a minimum height adjustment of 175 mm or,

(d) have a minimum width of 150 mm and a minimum height of 280 mm.

(e) Be located so that for each driver:

(i) The restraint is no more than 25 mm away from the back of the driver's helmet, with the driver in their normal driving position.

(ii) The contact point of the back of the driver's helmet on the head restraint is no less than 50 mm from any edge of the head restraint.

T 4.7.3 Head restraints must be able to accommodate different drivers.

T 4.7.4 The head restraint, its attachment and its mounting must withstand a force of 890 N applied in rearward direction at any point on its surface.

T 4.8 Roll Bar Padding

T 4.8.1 Any portion of the roll bar, roll bar bracing or frame which might be contacted by the driver's helmet must be covered with a minimum thickness of 12 mm of padding which meets SFI spec 45.1 or FIA 8857-2001.

T 4.9 Driver's Leg Protection

T 4.9.1 All moving suspension and steering components and other sharp edges inside the cockpit between the front hoop and a vertical plane 100 mm rearward of the pedals, must be shielded with solid material.

T 4.9.2 Covers over suspension and steering components must be removable to allow inspection of the mounting points.

T 5 BRAKE SYSTEM

T 5.1 Brake System - General

T 5.1.1 The vehicle must be equipped with a braking system that acts on all four wheels and is operated by a single control.

T 5.1.2 The brake system must have two independent hydraulic circuits such that in the case of a leak or failure at any point in the system, effective braking power is maintained on at least two wheels. Each hydraulic circuit must have its own fluid reserve, either by the use of separate reservoirs or by the use of a dammed reservoir.

T 5.1.3 A single brake acting on a limited-slip differential is acceptable.

T 5.1.4 "Brake-by-wire" systems are prohibited. [DV ONLY] In autonomous mode, it is allowed to use "brake-by-wire". In manual mode, T 5.1.1 applies.

T 5.1.5 Unarmored plastic brake lines are prohibited.

T 5.1.6 The braking systems must be protected from failure of the drivetrain (see T 6.4.2) and from minor collisions.

T 5.1.7 In side view any portion of the brake system that is mounted on the sprung part of the vehicle must not project below the lower surface of the frame or the monocoque, whichever is applicable.

T 5.1.8 The brake pedal shall be designed to withstand a force of 2 kN 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.

T 5.1.9 The brake pedal must be fabricated from steel or aluminum or machined from steel, aluminum or titanium.

T 5.1.10 [EV ONLY] The first 90 % of the brake pedal travel may be used to regenerate brake energy without actuating the hydraulic brake system. The remaining brake pedal travel must directly actuate the hydraulic brake system, but brake energy regeneration may remain active.

T 5.2 Brake Over-Travel Switch (BOTS)

T 5.2.1 A brake pedal over-travel switch must be installed on the vehicle as part of the shutdown circuit, as in EV 5 or CV 4.1. This switch must be installed so that in the event of brake system failure such that the brake pedal over travels it will result in the shutdown circuit being opened.

T 5.2.2 Repeated actuation of the switch must must not close the shutdown circuit, and it must be designed so that the driver cannot reset it.

T 5.2.3 The switch must be implemented with analog components, not incorporating programmable logic controllers, engine control units, or similar functioning digital controllers.

T 5.2.4 The brake over travel switch must be a mechanical single pole, single throw (commonly known as a two-position) switch (push-pull or flip type).

T 5.3 Brake Light

T 5.3.1 The vehicle must be equipped with one red brake light. The brake light itself must have a black background and a rectangular, triangular or near round shape with a minimum shining surface of 15 cm^2. The brake light must be clearly visible from the rear in very bright sunlight. When LED lights are used without a diffuser, they may not be more than 20 mm apart. If a single line of LEDs is used, the minimum length is 150 mm.

T 5.3.2 In side view the brake light must be orientated vertical or near vertical and mounted between the wheel centerline and driver's shoulder level. Viewed from the back it should be positioned approximately at the vehicle's centerline.

T 6 POWERTRAIN

T 6.1 Transmission and Drive

T 6.1.1 Any transmission and drivetrain may be used.

T 6.1.2 Movement of the vehicle without a person in the vehicle and with the primary master switch in off position must be possible.

T 6.2 Coolant Fluid Limitations

T 6.2.1 Water-cooled engines must only use pure water. Electric motors, accumulators or HV electronics may only use plain water or oil as the coolant.

T 6.3 System Sealing

T 6.3.1 Any cooling or lubrication system must be sealed to prevent leakage.

T 6.3.2 Separate catch cans must be employed to retain fluids from any vents for the coolant system or engine lubrication system. Each catch-can must have a minimum volume of 10 % of the fluid being contained or 0.9 l whichever is greater.

T 6.3.3 Any vent on other systems containing liquid lubricant or coolant must have a catch-can with a minimum volume of 10 % of the fluid being contained or 100 ml, whichever is greater.

T 6.3.4 Catch cans must be capable of containing boiling water without deformation. The mountings must be able to withstand temperatures of more than 100°.

T 6.3.5 Catch cans must be located rearwards of the firewall below the driver's shoulder level.

T 6.3.6 Any catch can on the cooling system must vent through a hose with a minimum internal diameter of 3 mm down to the bottom levels of the frame.

T 6.4 Drive Train Shields and Guards

T 6.4.1 The lowest point of any lubrication system must be no lower than the line between the lowest point of the main hoop and the lowest frame member or monocoque part behind the lubrication system. If any part of the lubrication system is lower than this line, it must be protected by a structure mounted on the chassis.

T 6.4.2 Exposed high-speed rotating final drivetrain parts, chains and belts must be fitted with non-perforated scatter shields. The scatter shields must cover chains and belts from the drive sprocket to the driven sprocket/chain wheel/belt or pulley and must start and end parallel to the lowest point of the driven sprocket/chain wheel/belt or pulley. The minimum scatter shield material requirements are 2 mm steel or 3 mm aluminum alloy 6061-T6.

T 6.4.3 Scatter shields for high-speed rotating final drivetrain parts (such as electric motors, clutches, sprockets, gears etc.) that have an OEM casing that do not comply with rule T 6.4.2 can be used, if material is added to achieve the minimum required thickness.

T 6.4.4 [EV ONLY] For the case that the electrical motor casings are rotating around the stator or the motor casing is perforated, a scatter shield must be included around the motor. This scatter shield must be at least 1 mm thick and made from aluminum alloy 6061-T6 or steel.

T 6.4.5 Scatter shields for chains and belts must be centered on the centerline of the chain or belt and remain aligned with the chain or belt under all conditions. The minimum width of the scatter shield should be at least three times the width of the chain or belt. The minimum material requirements are:

(a) For metallic chains and belts: 2 mm steel.

(b) For non-metallic chains and belts: 3 mm aluminum alloy 6061-T6.

T 6.4.6 All fasteners attaching scatter shields and guards must be 6 mm metric grade 8.8 or stronger.

T 6.4.7 Finger guards are required to cover any drivetrain parts that spin while the vehicle is stationary with the engine running. 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 12 mm diameter object through the guard.

T 7 AERODYNAMIC DEVICES

T 7.1 Definition Aerodynamic Device

T 7.1.1 A specifically designed structure mounted on the vehicle to guide the airflow around the vehicle, increasing the downforce on 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.

T 7.2 Ground Effect Devices

T 7.2.1 Power ground effects are prohibited. No power device may be used to move or remove air from under the vehicle except fans designed exclusively for cooling.

T 7.3 Restrictions for Aerodynamic Devices

T 7.3.1 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 500 mm 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 250 mm 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 1.2 m from the ground.

T 7.3.2 Width restrictions:

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

T 7.3.3 Length restrictions:

- All aerodynamic devices must not extent further rearward than 250 mm from the rearmost part of the rear tires.

T 7.3.4 All restrictions must be fulfilled with the wheels pointing straight and with any suspension setup with or without driver seated in the vehicle.

T 7.4 Minimum Edge Radii of Aerodynamic Devices

T 7.4.1 All forward facing edges of aerodynamic devices that could contact a pedestrian must have a minimum radius of 5 mm for all horizontal edges and 3 mm for vertical edges.

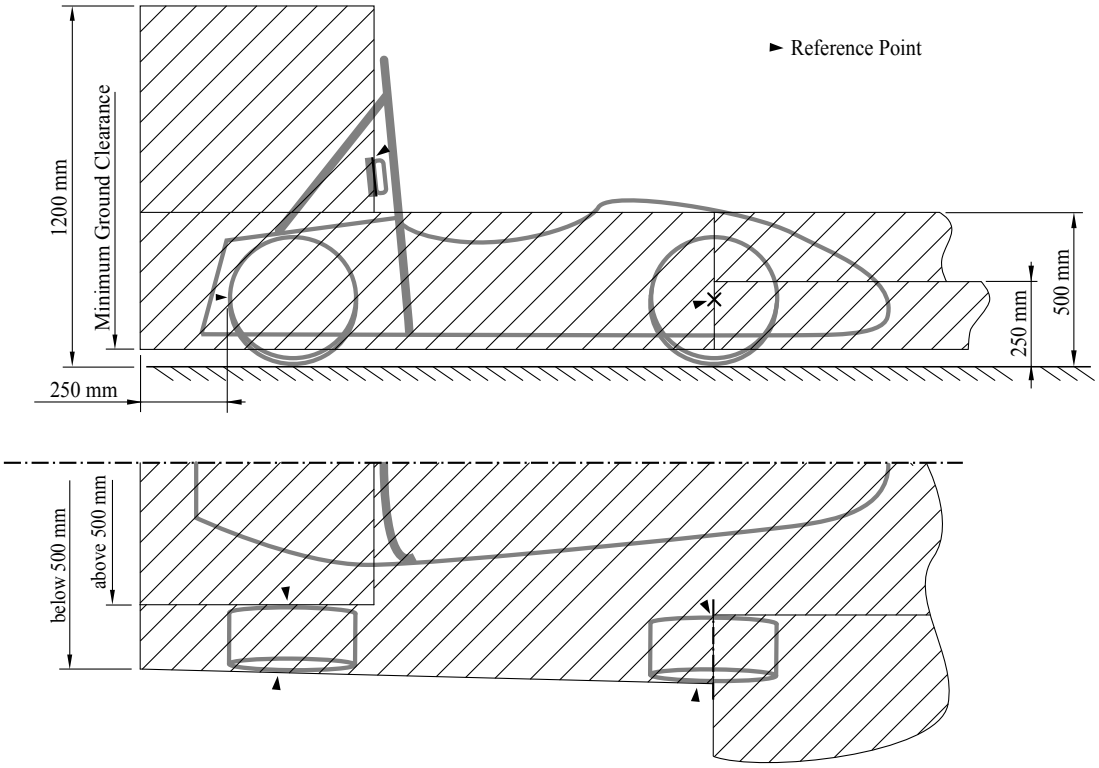

Figure 13: Maximum dimensions and positioning of aerodynamic devices. The positioning space is further restricted (see T 1.1).

T 7.5 Aerodynamic Devices Stability and Strength

T 7.5.1 Any aerodynamic device must be able to withstand a force of 200 N distributed over a minimum surface of 225 cm^2 and not deflect more than 10 mm in the load carrying direction.

T 7.5.2 Any aerodynamic device must be able to withstand a force of 50 N applied in any direction at a point and not deflect more than 25 mm.

T 8 Compressed Gas Systems and High Pressure Hydraulics

T 8.1 Compressed Gas Cylinders and Lines

T 8.1.1 Any system on the vehicle that uses a compressed gas as an actuating medium must comply with the following requirements:

- The working gas must be nonflammable.
- The gas cylinder/tank must be of proprietary manufacture, designed and built for the pressure being used, certified and labeled or stamped appropriately.
- A pressure regulator must be used and mounted directly onto the gas cylinder/tank.
- The gas cylinder/tank and lines must be protected from rollover, collision from any direction, or damage resulting from the failure of rotating equipment.

- The gas cylinder/tank and the pressure regulator must be located either rearward of the main hoop and within the envelope defined by the main hoop and the frame or in a structural side-pod. In either case it must be protected by structure that meets the requirements of rule T 2.16. It must not be located in the cockpit.
- The gas cylinder/tank must be securely mounted to the frame, engine or transmission.
- The axis of the gas cylinder/tank must not point at the driver.
- The gas cylinder/tank must be insulated from any heat sources.
- The gas lines and fittings must be appropriate for the maximum possible operating pressure of the system.

T 8.2 High Pressure Hydraulic Pumps and Lines

T 8.2.1 The driver and anyone standing outside the vehicle must be shielded from any hydraulic pumps and lines with line pressures of 2100 kPa or higher. The shields must be steel or aluminum with a minimum thickness of 1 mm. Brake lines are not considered as high pressure hydraulic lines.

T 9 FASTENERS

T 9.1 Critical Fasteners

T 9.1.1 Critical fasteners are defined as bolts, nuts, and other fasteners utilized in the primary structure, the steering, braking, driver's harness and suspension systems.

T 9.1.2 All threaded critical fasteners must meet or exceed metric grade 8.8 or equivalent.

T 9.1.3 All threaded critical fasteners must be of the type hexagon bolts (DIN 933, DIN 931) or socket head cap screws (DIN 912, DIN 7984) including their fine-pitch thread versions.

T 9.1.4 Bolts may be shortened in length as long as T 9.2.3 is fulfilled.

T 9.1.5 Any bolted joint in the primary structure using either tabs or brackets, must have an edge distance ratio "e/D" of 1.5 or greater. "D" equals the hole diameter and "e" equals the distance from the hole centerline 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.

T 9.2 Securing Fasteners

T 9.2.1 All critical fasteners must be secured from unintentional loosening by the use of positive locking mechanisms.

T 9.2.2 The following methods are accepted as positive locking mechanisms:

- Correctly installed safety wiring.
- Cotter pins.
- Nylon lock nuts (DIN 982, DIN 9626 or equivalent) for low temperature locations (80 °C or less).

- Prevailing torque lock nuts (DIN 980, DIN 6925, ISO 7042 or equivalent, and jet nuts or K-nuts).
- Locking plates.
- Tab washers.

Any locking mechanism based on pre-tensioning or an adhesive is not considered a positive locking mechanism.

T 9.2.3 A minimum of two full threads must project from any lock nut.

T 9.2.4 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.

T 9.2.5 Adjustable tie-rod ends must be constrained with a jam nut to prevent loosening.

T 10 Electrical Components

T 10.1 Low Voltage Batteries

T 10.1.1 Low voltage batteries are all batteries except tractive system batteries of electric vehicles.

T 10.1.2 Low voltage batteries must be attached securely to the frame.

T 10.1.3 Low voltage batteries must be contained within the envelope of any part of the frame which is made from any regulated tubing defined in T 2.3. and/or an additional envelope of tubing which meets the minimum specification defined in T 2.3. or equivalent, such that they are protected against being damaged in case of a crash or roll-over situation.

T 10.1.4 Any wet-cell battery located in the driver compartment must be enclosed in a non-conductive marine-type container or equivalent.

T 10.1.5 Low voltage batteries must be separated from the driver by a firewall as specified in T 3.8.

T 10.1.6 Low voltage batteries must have a rigid and sturdy casing.

T 10.1.7 The hot (ungrounded) terminal must be insulated.

T 10.1.8 Low voltage batteries must be protected for short circuits.

T 10.1.9 Battery packs based on lithium chemistry other than lithium iron phosphate ($LiFePO_4$):

(a) Must include overcurrent protection that trips at or below the maximum specified discharge current of the cells.

(b) Must have a fire retardant casing.

(c) Must have overtemperature protection of at least 30 % of the cells that trips at or below the maximum specified temperature of the cells or at 60 °C, whichever is lower and disconnects the battery.

(d) Must have voltage protection of all cells that trips at or below the maximum specified voltage of the cells and disconnects the battery.

T 10.1.10

T 10.2 Accelerator Pedal Position Sensor (APPS)

T 10.2.1 Rules T 10.2 only apply for electric vehicles, see chapter EV, or internal combustion vehicles using Electronic Throttle Control (ETC), see CV 1.6.

T 10.2.2 The APPS must be actuated by a foot pedal.

T 10.2.3 Pedal travel is defined as percent of travel from fully released position to a fully applied position where 0 % is fully released and 100 % is fully applied.

T 10.2.4 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.

T 10.2.5 At least two separate sensors must be used as APPSs. Separate is defined as not sharing supply or signal lines.

T 10.2.6 If analog sensors are used, they must have different transfer functions, each having a positive slope sense with either different gradients and/or offsets to the other(s). This will insure that even in case of a short circuit of the signal lines the APPSs will only agree at 0 % pedal position.

T 10.2.7 The APPS signal is a System Critical Signal, see T 10.3.

T 10.2.8 If an implausibility occurs between the values of the APPSs and persists for more than 100 ms

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

T 10.2.9 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 T 10.3.

T 10.2.10 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.

T 10.2.11 Each APPS must have a separate detachable connector that enables a check of these functions by unplugging it. If not, an inline switchable break-out box must be made available during technical inspection that allows disconnection of each APPS signal

T 10.2.12 A fully released accelerator pedal must result in:

- [EV ONLY] A wheel torque of ≤ 0 N m
- [CV ONLY] An idle position or lower throttle set-point. This may only be exceeded during a gearshift for maximum 500 ms.

T 10.3 System Critical Signals (SCSs)

T 10.3.1 System critical sensor signals and system critical general signals are defined as all electrical signals which

- Influence actions on the shutdown circuit, see CV 4.1 and EV 5.1.
- Influence the requested wheel torque.
- [EV ONLY] Influence indicators according to EV 3.7.6, EV 4.13 or EV 5.4.6.
- [DV ONLY] Influence indicator according to DV 3.2.5.

T 10.3.2 Any of the following signal failures must result in a safe state of all connected systems:

(a) Failures of signals transmitted by wire:

- Open circuit
- Short circuit to ground

(b) Failures of analog sensor signals:

- Short circuit to supply voltage

(c) Failures of sensor signals used in programmable logic:

- Implausibility due to out of range signals, e.g. mechanically impossible angle of an angle sensor.

(d) Failures of digitally transmitted signals by wire 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 wire might be member of (a), (b) and (c).

T 10.3.3 [EV ONLY] Indicators according to T 10.3.1 with safe state "illuminated" (e.g. absence of failures is not actively indicated) must be illuminated for 1 s to 3 s for visible check after power cycling the Grounded Low Voltage Master Switch (GLVMS).

T 10.3.4 [DV ONLY] The proper handling of SCSs is also mandatory for second and third year vehicles (as defined in A 2.3).

T 10.4 Inertia Switch

T 10.4.1 All vehicles must be equipped with an inertia switch. This must be a "Sensata Resettable Crash Sensor" or equivalent.

T 10.4.2 The inertia switch must be part of the shutdown circuit (see CV 4.1 and EV 5.1), such that an impact will result in the shutdown circuit being opened. The inertia switch must latch until manually reset.

T 10.4.3 The device must trigger due to an impact load which decelerates the vehicle at between 6 g and 11 g depending on the duration of the deceleration (see specification of the Sensata device).

T 10.4.4 The inertia switch may be reset by the driver from within the driver's cell.

T 10.4.5 The device must be rigidly attached to the vehicle; however, it must be possible to demount the device so that its functionality may be tested by shaking it.

T 11 VEHICLE IDENTIFICATION

T 11.1 Vehicle Number

T 11.1.1 Each vehicle will be assigned a number at the time of its entry into a competition.

T 11.1.2 Vehicle numbers must appear on the vehicle at the front and both sides as follows:

- Height: At least 150 mm high;
- Font: Roman Sans-Serif characters. Italic, outline, serif, or shadow numbers are prohibited.
- Stroke width and spacing between numbers: At least 20 mm.
- Color: 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 25 mm between the edge of the numbers and the edge of the background.
- Clear: The numbers must not be obscured by parts of the vehicle.

T 11.2 University Name

T 11.2.1 The university name must be written fully. Only the following abbreviations in the university name are accepted if the city name is written fully:

(a) University → Uni

(b) Technical University → TU

(c) University of Applied Sciences → UAS

(d) Berufsakademie → BA.

(e) If the university officially uses a shortcut in their proper name, this shortcut is accepted.

T 11.2.2 The university name must be displayed and written in Roman Sans-Serif characters of at least 50 mm high on both sides of the vehicle.

T 11.2.3 The characters must be clearly visible at a distance and placed on a high contrast background.

T 11.3 Timing Equipment

T 11.3.1 All vehicles will get timing equipment provided by the competition organizers.

T 12 VEHICLE AND DRIVER EQUIPMENT

T 12.1 Pushbar

T 12.1.1 Each team must have a removable device (called the pushbar) that attaches to the rear of the vehicle that allows two people to push and pull the vehicle while standing erect behind the vehicle.

T 12.1.2 The pushbar must be presented during technical inspection.

T 12.1.3 The pushbar must be capable of slowing and stopping the forward motion of the vehicle and pulling it rearwards.

T 12.1.4 An approved fire extinguisher (see T 12.4.1) must be mounted to the pushbar in a way that it is quickly accessible.

T 12.1.5 [EV ONLY] Two pairs of high-voltage insulating gloves and a multimeter must be attached to the pushbar. The HV gloves must be protected by a case or similar means from mechanical damage, humidity and sunlight. The case must also be able to be opened without using tools.

T 12.2 Quick Jack

T 12.2.1 Each team must have removable devices (called the quick jacks) that lift up the vehicle, so that all driven wheels are at least 100 mm off the ground and the vehicle is adequately supported.

T 12.2.2 The quick jacks must be presented during technical inspection.

T 12.3 Driver Equipment

T 12.3.1 The equipment specified below must be worn by the driver anytime while in the cockpit with the engine running or with the tractive system active for electric vehicles and anytime between starting a dynamic event and either finishing or abandoning a dynamic event. Removal of any driver equipment during the event will result in disqualification.

T 12.3.2 A well-fitting, closed face helmet that meets one of the following certifications and is labeled as such:

- Snell K2005, K2010, K2015, M2005, M2010, M2015, SA2005, SA2010, SAH2010, SA2015
- SFI 31.2/2005, 31.2/2010, 31.2/2015, 41.2/2005, 41.2/2010, 41.2/2015
- FIA 8860-2004, FIA 8860-2010, FIA 8859-2015
- British Standards Institution BS 6658-85 Type A/FR rating (Types A and B are not accepted)

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. The officials reserve the right to impound all non-approved helmets until the end of the competition.

T 12.3.3 A balaclava which covers the driver's head, hair and neck, made from acceptable fire resistant material as defined in T 12.3.11, or a full helmet skirt of acceptable fire resistant material.

T 12.3.4 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 labeled as such:

- SFI 3-2A/5 (or higher)
- FIA Standard 1986

- FIA Standard 8856-2000

T 12.3.5 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 T 12.3.11 and must cover the driver's body completely from neck down to ankles and wrists.

T 12.3.6 Fire resistant socks made from acceptable fire resistant material as defined in T 12.3.11, that cover the bare skin between the driver's suit and the boots or shoes.

T 12.3.7 Fire resistant shoes made from acceptable fire resistant material as defined in T 12.3.11. The shoes must be certified to the standard and labeled as such:

- SFI 3.3
- FIA 8856-2000

T 12.3.8 Fire resistant gloves made from made from acceptable fire resistant material as defined in T 12.3.11. Gloves of all leather construction or fire resistant gloves constructed using leather palms with no insulating fire resisting material underneath are not acceptable.

T 12.3.9 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.

T 12.3.10 All driver equipment covered in T 12.3.1: 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.

T 12.3.11 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.

T 12.3.12 T-shirts, socks or other undergarments made from nylon or any other synthetic material which will melt when exposed to high heat are prohibited.

T 12.4 Fire Extinguishers

T 12.4.1 Each team must have at least two dry chemical/dry powder fire extinguishers with a minimum firefighting agent capacity of 0.9 kg.

T 12.4.2 The following are the minimum accepted ratings:

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

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

T 12.4.3 Aqueous Film Forming Foam (AFFF) fire extinguishers are prohibited. Halon extinguishers and systems are prohibited.

T 12.4.4 All extinguishers must be equipped with a manufacturer installed pressure/charge gauge.

T 12.4.5 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.

T 12.4.6 Hand held fire extinguishers are not permitted to be mounted on or in the vehicle.

T 12.5 Camera Mounts

T 12.5.1 The mounts for video/photographic cameras must be of a safe and secure design:

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

[DV ONLY] Cameras used as input sensors for driverless vehicles are exempted and have to follow rule DV 4 instead.

CV INTERNAL COMBUSTION ENGINE VEHICLES

CV 1 INTERNAL COMBUSTION ENGINE POWERTRAINS

CV 1.1 Engine Limitation

CV 1.1.1 The engine(s) used to power the vehicle must be piston engine(s) using a four-stroke primary heat cycle. All waste/rejected heat from the primary heat cycle may be used. The method of conversion is not limited to the four-stroke cycle. Hybrid powertrains, such as those using electric motors running off stored energy, are prohibited.

CV 1.2 Starter

CV 1.2.1 Each vehicle must be equipped with an on-board starter, which must be used to start the vehicle at all times.

CV 1.2.2 [DV ONLY] The vehicle must be equipped with an additional engine start button next to the master switch (see CV 4.2), that can be easily actuated from outside the vehicle. Using the external engine start button, the engine may only start if

(a) the ASMS (see DV 2.2) is switched on and

(b) the gearbox is in neutral.

CV 1.2.3 [DV ONLY] There must be a green light next to the engine start button, that indicates that the gearbox is in neutral. It must be marked with the letter "N". This letter must have a minimum height of 25 mm.

CV 1.2.4 [DV ONLY] The autonomous system must not be able to (re-)start the engine.

CV 1.3 Air Intake System

CV 1.3.1 All parts of the engine air and fuel control systems (including the throttle and the complete air intake system, including the air filter and any air boxes) must lie within the surface defined by the top of the roll bar and the outside edge of the four tires. (See Figure 14).

CV 1.3.2 Any portion of the air intake system that is less than 350 mm above the ground must be shielded from side or rear impact collisions by structure built to rule T 2.16.

CV 1.3.3 The intake manifold must be securely attached to the engine block or cylinder head with brackets and mechanical fasteners. The threaded fasteners used to secure the intake manifold are considered critical fasteners and must comply with rule T 9.

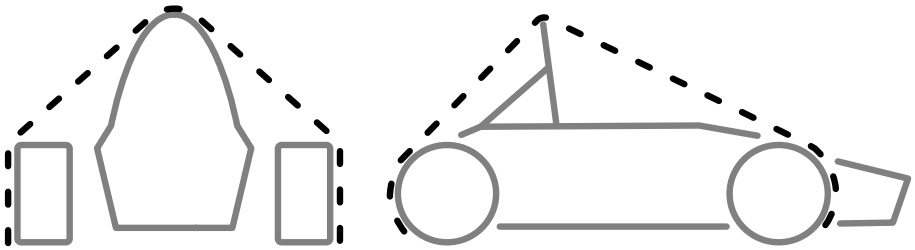

Figure 14: Air intake and fuel systems envelope

CV 1.3.4 Intake systems with significant mass or cantilever from the cylinder head must be supported to prevent stress to the intake system. Supports to the engine must be rigid. Supports to the frame or chassis must incorporate isolation to allow for engine movement and chassis torsion.

CV 1.4 Throttle

CV 1.4.1 The vehicle must be equipped with a throttle body. The throttle body may be of any size or design.

CV 1.4.2 The throttle must be actuated mechanically by a foot pedal, i.e. via a cable or a rod system, see CV 1.5, or by an ETC system, see CV 1.6.

CV 1.4.3 Throttle position is defined as percent of travel from fully closed to fully open where 0 % is fully closed and 100 % is fully open. The idle position is the average position of the throttle body while the engine is idling.

CV 1.4.4 The throttle system mechanism must be protected from debris ingress to prevent jamming.

CV 1.5 Mechanical Throttle Actuation

CV 1.5.1 The rules CV 1.5 only apply if no ETC system is used.

CV 1.5.2 The throttle actuation system must use at least two return springs located at the throttle body, so that the failure of any one of the two springs will not prevent the throttle returning to the idle position.

CV 1.5.3 Each return spring must be capable of returning the throttle to the idle position with the other disconnected.

CV 1.5.4 Springs in the Throttle Position Sensor (TPS) are not acceptable as return springs.

CV 1.5.5 Throttle cables must be located at least 50 mm from any exhaust system component and out of the exhaust stream.

CV 1.5.6 Throttle cables or rods must have smooth operation and must not have the possibility of binding or sticking. They must be protected from being bent or kinked by the driver's foot during operation or when entering the vehicle.

CV 1.5.7 A positive pedal stop must be incorporated on the accelerator pedal to prevent over-stressing the throttle cable or actuation system.

CV 1.6 Electronic Throttle Control (ETC)

CV 1.6.1 Rules CV 1.6 only apply if ETC is used.

CV 1.6.2 An ETC system that is commercially available, but does not comply with the rules CV 1.6, may be used, only if it does comply with the intent of the rules and is approved by the officials. To obtain approval, the team must:

(a) Submit an additional page in the system description of the Failure Modes and Effects Analysis (FMEA) with intent of using such a system.

(b) Include the specific ETC rule(s) that the commercial system deviates from.

(c) Include sufficient technical details of these deviations to allow the acceptability of the commercial system to be determined.

CV 1.6.3 The team must be able to demonstrate the functionality of all safety features and error detections of the ETC system at technical inspection, see IN.

CV 1.6.4 The ETC system must be equipped with at least the following sensors:

(a) Accelerator Pedal Position Sensor (APPS) as defined in T 10.2

(b) Two Throttle Position Sensor (TPS) to measure the throttle position. The TPSs may share the same supply and reference lines only if effects of supply and/or reference line voltage offsets can be detected.

(c) One Brake System Encoder (BSE) to measure brake pedal position or brake system pressure to check for plausibility.
[DV ONLY] BSE must be pressure type.

CV 1.6.5 All ETC signals are System Critical Signals (SCSs), see T 10.3.

CV 1.6.6 The encoder must have a connector that allows disconnection of each encoder signal individually.

CV 1.6.7 When power is removed, the electronic throttle must immediately close at least to idle position ± 5 %. An interval of one second is allowed for the throttle to close to idle, failure to achieve this within the required interval must result in immediate disabling of power to ignition, injection and fuel pump. This action must remain active until the TPS signals indicate the throttle return to requested position for at least one second.

CV 1.6.8 If plausibility does not occur between the values of at least two TPSs and this persists for more than 100 ms, the power to the electronic throttle must be immediately shut down. Plausibility is defined as a deviation of less than ten percentage points between the sensor values as defined in CV 1.4.3 and no detected failures as defined in T 10.3.

[DV ONLY] Autonomous system must check this signal consistency on a low level itself.

CV 1.6.9 The electronic throttle must use at least two sources of energy capable of returning the throttle closed position. One of the sources may be the device that normally actuates the throttle, e.g. a DC motor, but the other device(s) must be a throttle return spring that can return the throttle to the idle position in the event of a loss of actuator power.

CV 1.6.10 Springs in the TPSs are not acceptable as return springs.

CV 1.6.11 The power to the electronic throttle must be immediately shut down, as defined in CV 1.6.7, if one of the following conditions apply:

- The mechanical brakes are actuated and the TPS signals that the throttle is open by more than a permitted amount for more than one second. The permitted relationship between BSE and TPS may be defined by the team using a table, but the functionality must be demonstrated at technical inspection.
- The throttle position differs by more than 10 % from the expected target TPS position for more than one second.

CV 1.6.12 Teams must submit a complete FMEA of the ETC prior to the event which includes a detailed description of the system. A template including required failures to be described will be made available on the competition website. The format of the template must not be changed. Pictures, schematics and data sheets to be referenced in the FMEA must be included in the FMEA on additional table pages. The FMEA must be submitted in compliance with the procedure and by the deadline published in the competition handbook.

CV 1.6.13 Brake System Plausibility Device (BSPD) for CV with ETC
A standalone non-programmable circuit must be used on the vehicle such that when braking hard (for example >0.8 g deceleration but without locking the wheels) and when the TPS shows that the throttle is more than five percentage points over idle position, the power to the electronic throttle must be shut down and the shutdown circuit, see CV 4.1, must be opened. The action must occur if the implausibility is persistent for more than one second. This device must be provided in addition to the plausibility checks which are carried out in the Electronic Control Unit (ECU) which interprets the drivers throttle request and controls the engine throttle position. The BSPD may only be reset by power cycling the master switch (CV 4.2). All BSPD signals are System Critical Signal, see T 10.3.

CV 1.6.14 [DV ONLY] Any DV with internal combustion engine is assumed to have ETC.

CV 1.7 Intake System Restrictor

CV 1.7.1 If more than one engine is used, the air for all engines must pass through a single air intake restrictor.

CV 1.7.2 In order to limit the power capability from the engine, a single circular restrictor must be placed in the intake system and all engine airflow must pass through the restrictor. The only allowed sequence of components are the following:

(a) For naturally aspirated engines, the sequence must be: throttle body, restrictor, and engine. (See Figure 15)

(b) For turbocharged or supercharged engines, the sequence must be: restrictor, compressor, throttle body, engine. (See Figure 16)

CV 1.7.3 The maximum restrictor diameters which must be respected at all times during the competition are:

(a) Gasoline fueled vehicles - 20 mm

(b) E-85 fueled vehicles - 19 mm

CV 1.7.4 The restrictor must be located to facilitate measurement during the inspection process.

CV 1.7.5 The circular restricting cross section may not be movable or flexible in any way, e.g. the restrictor must not be part of the movable portion of a barrel throttle body.

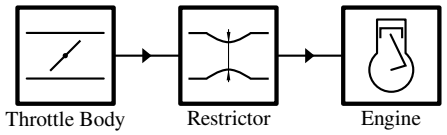

Figure 15: Intake configuration for naturally aspirated engines.

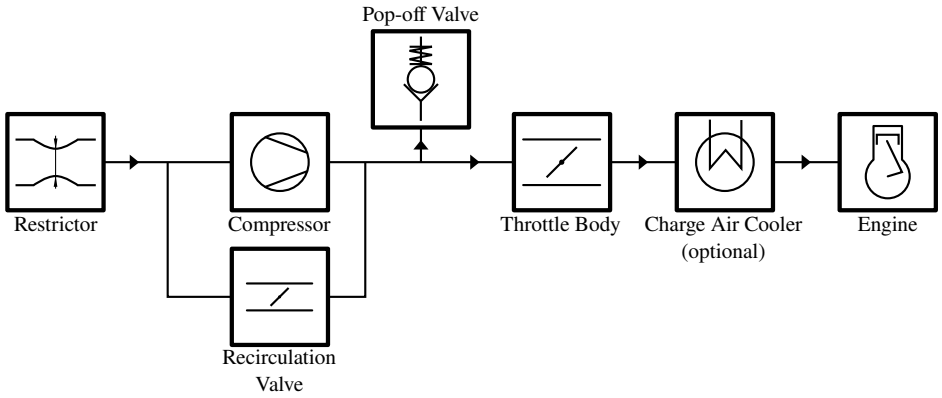

Figure 16: Intake configuration for turbocharged or supercharged engines.

CV 1.8 Turbochargers and Superchargers

CV 1.8.1 The intake air may be cooled with an intercooler. Only ambient air may be used to remove heat from the intercooler system. Air-to-air and water-to air intercoolers are permitted. The coolant of a water-to-air intercooler system must be pure water without any additives.

CV 1.8.2 If pop-off valves, recirculation valves, or heat exchangers (intercoolers) are used, they may only be positioned in the intake system as shown in Figure 16.

CV 1.8.3 Plenums anywhere upstream of the throttle body are prohibited. A “plenum” is any tank or volume that is a significant enlargement of the normal intake runner system.

CV 1.8.4 The maximum allowable internal diameter of the intake runner system between the restrictor and throttle body is 60 mm diameter, or the equivalent area of 2827 mm^2 if non-circular.

CV 1.9 Crankcase / Engine Lubrication Venting

CV 1.9.1 Any crankcase or engine lubrication vent lines routed to the intake system must be connected upstream of the intake system restrictor.

CV 1.9.2 Crankcase breathers that pass through the oil catch tank(s) to exhaust systems, or vacuum devices that connect directly to the exhaust system, are prohibited.

CV 2 FUEL AND FUEL SYSTEM

CV 2.1 Fuel

CV 2.1.1 The available fuel types will be unleaded gasoline 98RON and E85.

CV 2.1.2 The vehicles must be operated with the fuels provided at the competition.

CV 2.1.3 No agents other than fuel (gasoline or E85), and air may be induced into the combustion chamber.

CV 2.1.4 The temperature of fuel introduced into the fuel system may not be changed with the intent to improve calculated efficiency.

CV 2.2 Fuel Tanks

CV 2.2.1 The fuel tank is defined as that part of the fuel containment device that is in contact with the fuel. It may be made of a rigid material or a flexible material.

CV 2.2.2 Fuel tanks made of a rigid material cannot be used to carry structural loads and must be securely attached to the vehicle structure with mountings that allow some flexibility such that chassis flex cannot unintentionally load the fuel tank.

CV 2.2.3 Any fuel tank that is made from a flexible material, for example a bladder fuel cell or a bag tank, must be enclosed within a rigid fuel tank container which is securely attached to the vehicle structure. Fuel tank containers (containing a bladder fuel cell or bag tank) may be load carrying.

CV 2.2.4 The fuel system must have a provision for emptying the fuel tank if required.

CV 2.2.5 The fuel tank, by design, must not have a variable capacity.

CV 2.3 Fuel Lines for Low Pressure Systems

CV 2.3.1 Fuel lines between fuel tank and fuel rail and return lines must have:

- Reinforced rubber fuel lines or hoses with an abrasive protection with a fuel hose clamp which has a full 360° wrap, a nut and bolt system for tightening and rolled edges to prevent the clamp cutting into the hose, or
- Metal braided hoses with crimped-on or reusable, threaded fittings.

CV 2.3.2 Fuel lines must be securely attached to the vehicle and/or engine.

CV 2.3.3 All fuel lines must be shielded from possible rotating equipment failure or collision damage.

CV 2.4 Fuel Injection System Requirements

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

CV 2.4.1 The following requirements apply to LPI fuel systems:

- The fuel lines must comply with rule CV 2.3.

- The fuel rail must be securely attached to the engine cylinder block, cylinder head, or intake manifold with mechanical fasteners. The threaded fasteners used to secure the fuel rail are considered critical fasteners and must comply with T 9.
- The use of fuel rails made from plastic, carbon fiber or rapid prototyping flammable materials is prohibited. However, the use of unmodified Original Equipment Manufacturer (OEM) Fuel Rails manufactured from these materials is acceptable.

CV 2.4.2 The following requirements apply to HPI and DI fuel systems:

- All high pressure fuel lines must be stainless steel rigid line or Aeroquip FC807 smooth bore PTFE hose with stainless steel reinforcement and visible Nomex tracer yarn. Use of elastomeric seals is prohibited. Lines must be rigidly connected every 100 mm by mechanical fasteners to structural engine components.
- The fuel rail must be securely attached to the engine cylinder head with mechanical fasteners. The fastening method must be sufficient to hold the fuel rail in place with the maximum regulated pressure acting on the injector internals and neglecting any assistance from in-cylinder pressure acting on the injector tip. The threaded fasteners used to secure the fuel rail are considered critical fasteners and must comply with T 9.
- The fuel pump must be rigidly mounted to structural engine components.
- A fuel pressure regulator must be fitted between the high and low pressure sides of the fuel system in parallel with the DI boost pump. The external regulator must be used even if the DI boost pump comes equipped with an internal regulator.
- Prior to the tilt test specified in IN 7, engines fitted with mechanically actuated fuel pumps must be run to fill and pressure the system downstream of the high pressure pump.

CV 2.5 Fuel System Location Requirements

CV 2.5.1 All parts of the fuel storage and supply system must lie within the surface defined by the top of the roll bar and the outside edge of the four tires (see Figure 14). In side view no portion of the fuel system can project below the lower surface of the frame.

CV 2.5.2 All fuel tanks must be shielded from side or rear impact collisions. Any fuel tank which is located outside the side impact structure required by T 2.16 must be shielded by a structure built to T 2.16. Any portion of the fuel system that is less than 350 mm above the ground must be within the primary structure.

CV 2.5.3 All parts of the fuel storage and supply system must be adequately protected against any heat sources and located at least 70 mm from any exhaust system component.

CV 2.6 Fuel Tank Filler Neck and Sight Tube

CV 2.6.1 All fuel tanks must have a filler neck which is:

- At least 35 mm diameter at any point between the fuel tank and the top of the fuel filler cap.
- At least 125 mm vertical height above the top level of the tank.
- Angled at no more than thirty degrees (30°) from the vertical and

- accompanied by a clear fuel resistant sight tube with a length of at least 125 mm vertical height for reading the fuel level (see Figure 17).

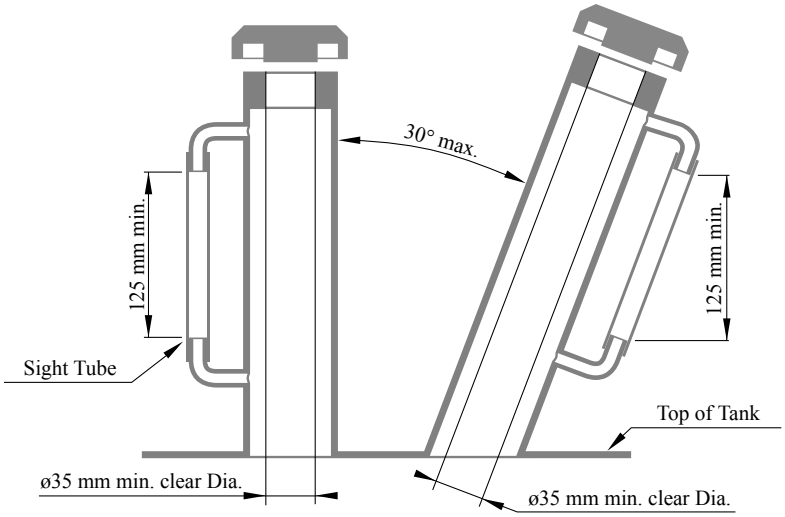

Figure 17: Minimum requirements fuel tank filler neck.

CV 2.6.2 A clear filler neck tube may be used as a sight tube.

CV 2.6.3 A permanent, non-moveable, clear and easy visible fuel level line must be located between 12 mm and 25 mm below the top of the visible portion of the sight tube. This line will be used as the fill line for the tilt test (rule IN 7.2), and before and after the endurance test to measure the amount of fuel used during the endurance event.

CV 2.6.4 The filler neck opening must be directly accessible without removing any parts of the vehicle except for the fuel filler cap.

CV 2.6.5 The filler neck must have a fuel filler cap that can withstand severe vibrations or high pressures such as could occur during a vehicle rollover event.

CV 2.7 Tank Filling Requirement

CV 2.7.1 The fuel tank must be capable of being filled to capacity without manipulating the tank or the vehicle in any manner. The fuel system must be designed in a way that during refueling of the vehicle on a level surface, the formation of air cavities or other effects that cause the fuel level observed at the sight tube to drop after movement or operation of the vehicle (other than due to consumption) is prevented.

CV 2.7.2 The fuel system must be designed such that the spillage during refueling cannot contact the driver position, exhaust system, hot engine parts, or the ignition system.

CV 2.7.3 Belly pans must be vented to prevent accumulation of fuel. At least two holes, each of a minimum diameter of 25 mm, must be provided in the lowest part of the structure in such a way as to prevent accumulation of volatile liquids.

CV 2.8 Venting Systems

CV 2.8.1 The fuel tank venting systems must be designed such that fuel cannot spill during hard cornering or acceleration.

CV 2.8.2 All fuel vent lines must be equipped with a check valve to prevent fuel leakage when the tank is inverted. All fuel vent lines must exit outside the bodywork.

CV 3 EXHAUST SYSTEM AND NOISE CONTROL

CV 3.1 Exhaust System General

CV 3.1.1 The exhaust must be routed so that the driver is not subjected to fumes at any speed considering the draft of the vehicle.

CV 3.1.2 The exhaust outlet(s) must not extend more than 450 mm behind the centerline of the rear axle and shall be no more than 600 mm above the ground.

CV 3.1.3 Any exhaust components (headers, mufflers, etc.) that protrude from the side of the body in front of the main hoop must be shielded to prevent contact by persons approaching the vehicle or a driver exiting the vehicle.

CV 3.1.4 The application of fibrous/absorbent material, e.g. “headerwrap”, to the outside of an exhaust manifold or exhaust system is prohibited.

CV 3.2 Maximum Sound Level

CV 3.2.1 The maximum sound level test speed for a given engine will be the engine speed that corresponds to an average piston speed of 15.25 $^{m}/_{s}$. The calculated speed will be rounded to the nearest 500 rpm. The maximum permitted sound level up to this calculated speed is 110 dB(C), fast weighting.

CV 3.2.2 The idle test speed for a given engine will be up to the team and determined by their calibrated idle speed. If the idle speed varies then the vehicle will be tested across the range of idle speeds determined by the team. At idle the maximum permitted sound level is 103 dB(C), fast weighting.

CV 4 ELECTRIC SYSTEM AND SHUTDOWN SYSTEM

CV 4.1 Shutdown Circuit

CV 4.1.1 The shutdown circuit directly controls all electrical current to ignition, injection and all fuel pumps. It may act through a relay.

CV 4.1.2 The shutdown circuit is defined as a series connection of at least the cockpit-mounted shutdown button, the BOTS, see T 5.2, and the inertia switch, T 10.4.

CV 4.2 Master Switch

CV 4.2.1 The vehicle must be equipped with one master switch.

CV 4.2.2 The master switch must disable power from battery and alternator to all electrical circuits, including lights, fuel pump(s), ignition, electrical controls. The master switch must be direct acting, i.e. it must not act through a relay or logic.

CV 4.2.3 The master switch 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 T 3.3, and be easily actuated from outside the vehicle.

Master switches must be mounted no lower than the vertical distance of the template's middle circle center to the ground surface multiplied by 0.8.

CV 4.2.4 The master switches must be a mechanical switch of the rotary type, with a red, removable handle. The handle must have a width of at least 50 mm and must only be removable in electrically open position.

CV 4.2.5 The international electrical symbol consisting of a red spark on a white-edged blue triangle must be affixed in close proximity to the switch.

CV 4.2.6 The master switches must be mounted so that the rotary axis of the key is near horizontal and across the vehicle. 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.

CV 4.3 Shutdown Buttons

CV 4.3.1 Shutdown buttons must be a push-pull or push-rotate mechanical emergency switch where pushing the button opens the shutdown circuit (CV 4.1).

CV 4.3.2 One shutdown button serves as a cockpit-mounted shutdown button. The minimum allowed diameter of the shutdown button in the cockpit is 24 mm. The international electrical symbol consisting of a red spark on a white-edged blue triangle must be affixed in close proximity to this switch. It must be located to provide easy actuation by the driver in an emergency or panic situation. It must be located within easy reach of the belted-in driver, alongside the steering wheel and unobstructed by the steering wheel or any other part of the vehicle.

CV 4.3.3 [DV ONLY] In addition to the cockpit mounted shutdown button, the shutdown circuit of DV with internal combustion engine must include two emergency shutdown buttons (as for electric vehicles, see rule EV 5.3 and especially EV 5.3.4). These and the RES as defined in DV 1.4 have the same functionality as the cockpit-mounted shutdown button, thus opening the shutdown circuit (see DV 1.5 for additional requirements)

CV 4.4 Voltage Limit for CV

The maximum permitted voltage between any two electrical connections is 60 V DC or 25 V AC RMS. The following systems are excluded from this voltage limit:

- High voltage systems for ignition
- High voltage systems for injectors

- Voltages internal to OEM charging systems designed for <60 V DC output.

EV ELECTRIC VEHICLES

EV 1 ELECTRIC SYSTEM DEFINITIONS

EV 1.1 High Voltage (HV) and Low Voltage (LV)

EV 1.1.1 Whenever a circuit has a potential difference where the nominal operation voltage is greater than 60 V DC or 25 V AC RMS it is defined as part of the HV system.

EV 1.1.2 LV is defined as any voltage below and including 60 V DC or 25 V AC RMS.

EV 1.1.3 The maximum permitted voltage that may occur between any two electrical connections is 600 V DC.

EV 1.2 Grounded Low Voltage (GLV) and Tractive System

EV 1.2.1 The tractive system of the vehicle is defined as every part that is electrically connected to the motor(s) and tractive system accumulators.

EV 1.2.2 The Grounded Low Voltage (GLV) system of the vehicle is defined as every electrical part that is not part of the tractive system. The tractive system must be completely isolated from the chassis and any other conductive parts of the vehicle.

EV 1.2.3 The tractive system is a HV system by definition, see EV 1.1.1.

EV 1.2.4 The GLV system must be a low voltage system, see EV 1.1.2.

EV 1.2.5 The GLV system must be grounded to the chassis.

EV 1.2.6 The entire HV and GLV system must be completely galvanically separated, see IN 4.1.2. Some components, such as the motor controller, may be part of both systems.

EV 1.2.7 All components in the tractive system must be rated for the maximum tractive system voltage.

Printed Circuit Boards (PCBs) are considered as one component. Every input of a PCB connected to the tractive system must be rated to the maximum tractive system voltage.

Accumulator Management System (AMS) cell voltage measurement inputs, temperature measurement inputs and supply voltage of decentralized AMS slaves may be rated below the maximum tractive system voltage if the team has proven by calculations in the Electrical System Form (ESF), see EV 9, that the input voltage rating is reasonably chosen.

EV 1.2.8 The tractive system motor(s) must be connected to the accumulator through a motor controller.

EV 1.2.9 It must not be possible to activate the tractive system without activation of the GLV system. A deactivation of the GLV system must immediately deactivate the tractive system.

EV 2 ELECTRIC POWERTRAIN

EV 2.1 Motors

EV 2.1.1 Only electric motors are allowed.

EV 2.1.2 Motor attachments must follow T 9.

EV 2.1.3 Motor casings must follow T 6.4.

EV 2.2 Power and Voltage Limitation

EV 2.2.1 The maximum power drawn from the battery must not exceed 80 kW.

EV 2.2.2 A violation is defined as using more than the maximum power or exceeding the specified voltage, see EV 1.1.3, after a moving average over 500 ms is applied the respective signal.

EV 2.2.3 The respective data and the resulting decision of violations will be made public.

EV 2.2.4 Non-availability of energy meter data due to the team's fault will be treated as a violation.

EV 2.2.5 Regenerating energy is allowed and unrestricted but only when the vehicle speed is $>5\,^{km}/_{h}$.

EV 2.3 Brake System Encoder (BSE)

EV 2.3.1 A BSE or switch to measure brake pedal position or brake system pressure must be fitted to check for plausibility, see EV 2.4. [DV ONLY] The BSE must be a pressure type.

EV 2.3.2 The encoder must have a connector that allows disconnection of the encoder signal during technical inspection.

EV 2.3.3 The encoder signal is a system critical signal, see T 10.3.

EV 2.4 APPS / Brake Pedal Plausibility Check

EV 2.4.1 The power to the motors must be immediately shut down completely if the mechanical brakes are actuated and the APPS (see T 10.2) signals more than 25 % pedal travel at the same time. This must be demonstrated when the motor controllers are under load.

EV 2.4.2 The motor power shut down must remain active until the APPS signals less than 5 % pedal travel, no matter whether the brakes are still actuated or not.

EV 3 TRACTIVE SYSTEM ENERGY STORAGE

EV 3.1 General Definitions

EV 3.1.1 The tractive system accumulator is defined as all the battery cells or super-capacitors that store the electrical energy to be used by the tractive system.

EV 3.1.2 Accumulator segments are sub-divisions of the accumulator. Splitting the accumulator into its segments is intended to reduce the risks associated with working on the accumulator.

EV 3.1.3 The energy of a cell is defined by the maximum cell voltage times the nominal capacity of the used cell.

EV 3.2 Allowed Tractive System Accumulators

EV 3.2.1 All types of accumulators except molten salt and thermal batteries are allowed. E.g.: Batteries, super-capacitors, etc..

EV 3.2.2 Fuel cells are prohibited.

EV 3.3 Tractive System Accumulator Container – General Requirements

EV 3.3.1 All cells or super-capacitors which store the tractive system energy will be built into accumulator segments and must be enclosed in (an) accumulator container(s).

EV 3.3.2 If spare accumulators are used, they must be of the same size, weight and type as those that are replaced. Spare accumulator packs have to be presented at technical inspection.

EV 3.3.3 It must be possible to open the accumulator container for technical inspection.

EV 3.3.4 Each accumulator container must be removable from the vehicle while still remaining rules compliant.

EV 3.4 Tractive System Accumulator Container – Electrical Configuration

EV 3.4.1 If the container is made from an electrically conductive material, then the poles of the accumulator segment(s) and/or cells must be isolated from the inner wall of the accumulator container with an insulating material that is rated for the maximum tractive system voltage. All conductive surfaces on the outside of the container must have a low-resistance connection to the GLV system ground, see EV 4.3. The insulation barrier must be adequately protected against conductive penetrations.

EV 3.4.2 Every accumulator container must contain at least one fuse and at least two accumulator isolation relays, see EV 3.6 and EV 6.

EV 3.4.3 Maintenance plugs, additional contactors or similar must allow electrical separation of the internal cell segments such that the separated cell segments contain a maximum static voltage of less than 120 V DC and a maximum energy of 6 MJ, see EV 3.1.3.

The separation must affect both poles of all segments including first and last segment.

This separation method must be used whenever the accumulator containers are opened for maintenance.

Maintenance Plugs must ensure proper current rating at all time.

EV 3.4.4 Maintenance plugs must not require tools to separate the segments. Maintenance plugs must include a positive locking feature which prevents the plug from unintentionally becoming loose. Maintenance plugs must be non-conductive on surfaces that do not provide any electrical connection.

EV 3.4.5 It must not be physically possible to connect the maintenance plugs in any way other than the design intent configuration.

EV 3.4.6 Each segment must be electrically insulated by the use of suitable material between the segments in the container and on top of the segment to prevent arc flashes caused by inter segment contact or by parts/tools accidentally falling into the container during maintenance. Air is not considered to be a suitable insulation material in this case.

EV 3.4.7 The Accumulator Isolation Relays (AIRs) and the main fuse must be separated with an electrically insulated and fireproof material to UL94-V0 from the rest of the accumulator. Air is not considered to be a suitable insulation material in this case.

EV 3.4.8 Every wire used in an accumulator container, no matter whether it is part of the GLV or tractive system, must be rated to the maximum tractive system voltage.

EV 3.4.9 Each accumulator container must have a prominent indicator, a voltmeter or a red LED visible even in bright sunlight that will illuminate whenever a voltage greater than 60 V DC or half the nominal tractive system voltage, whichever is lower, is present at the vehicle side of the AIRs.

EV 3.4.10 The indicator must be clearly visible while opening the connector. The indicator must be clearly marked with “Voltage Indicator”

EV 3.4.11 The voltage being present at the connectors must directly control the indicator using hard wired electronics without software control.

EV 3.4.12 The accumulator voltage indicator must be directly supplied by the tractive system and always working, even if the container is disconnected from the GLV system or removed from the vehicle.

EV 3.5 Tractive System Accumulator Container – Mechanical Configuration

EV 3.5.1 All accumulator containers must lie within and be attached to the primary structure no higher than the top of the side impact structure, see T 2.2.

EV 3.5.2 The container material must be fire resistant according to UL94-V0, FAR25 or equivalent.

EV 3.5.3 All accumulator containers must be protected from side or rear impact collisions by structure equivalent to that defined in T 2.3. The container must not be part of this structure.

EV 3.5.4 Design of the accumulator container must be documented in the SES including materials used, drawings, images, fastener locations, segment weight, cell and segment position.

EV 3.5.5 Accumulator containers must be constructed of steel or aluminium. With the following requirements:

- The bottom of the accumulator container must be at least 1.25 mm thick if made from steel or 3.2 mm if made from aluminium.
- The internal and external vertical walls, covers and lids must be at least 0.9 mm thick if made from steel or 2.3 mm if made from aluminium.

Alternative materials are allowed with proof of equivalency per rule T 2.4 or for composite materials per rule EV 3.5.6. This must then be documented in the SES. When alternative materials are used, test samples must be presented at technical inspection.

EV 3.5.6 Composite accumulator containers must satisfy the following requirements:

- Data obtained from the laminate perimeter shear strength test and three point bending test (T 2.6) should be used to prove adequate strength is provided.
- Each attachment point requires steel backing plates with a minimum thickness of 2 mm. Alternate materials may be used for backing plates if equivalency is approved.
- The calculations and physical test result must be included in the SES.

EV 3.5.7 Internal vertical walls must divide the accumulator container into "sections". A maximum of 12 kg is allowed in any "section".

EV 3.5.8 The accumulator segments must be separated by an electrically insulating and fire resistant barrier (according to UL94-V0, FAR25 or equivalent) and must subdivide the accumulator into segments with no more than 6 MJ capacity (see EV 3.1.3).

EV 3.5.9 Vertical walls separating cells and/or segments must be a minimum of 75 % of the height of the external vertical walls.

EV 3.5.10 The floor and walls of the accumulator container must be joined by welds, bonding and/or fasteners.

EV 3.5.11 The cells and/or segments must be appropriately secured against loosening inside the container.

EV 3.5.12 The mounting of the accumulator container must be designed to 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)

Calculations and/or tests must be included in the SES.

EV 3.5.13 All fasteners used within the accumulator or to mount the accumulator container must comply with T 9. Fasteners within the accumulator used for non-structural accumulator parts (e.g. PCBs etc.) do not have to follow T 9 if the fasteners are made of electrical non-conductive material.

EV 3.5.14 Any brackets holding the accumulator container must be made of steel 1.6 mm thick or aluminium 4 mm thick and must have gussets to carry bending loads. Each attachment point including brackets, backing plates and inserts, must be able to withstand 20 kN in any direction.

EV 3.5.15 Holes, both internal and external, in the container are only allowed for the wiring-harness, ventilation, cooling or fasteners. External holes must be sealed according to EV 4.5.

EV 3.5.16 The container must be completely closed at all times, also when dismounted from the vehicle and without the need to install extra protective covers. Openings for ventilation must be of a reasonable size. Completely open sidepods containing accumulators are not allowed.

EV 3.5.17 A sticker according to "ISO 7010-W012" (triangle with black lightning bolt on yellow background) with triangle side length of at least 100 mm and the text "Always Energized" must be applied on every accumulator container. The sticker must also contain the text "High Voltage" if the voltage is more than 60 V DC or 25 V AC.

EV 3.5.18 Any accumulators that may vent an explosive gas must have a ventilation system to prevent the vented gas from reaching an explosive concentration.

EV 3.5.19 Every accumulator container which is completely sealed must also have a pressure relief valve to prevent high-pressure in the container.

EV 3.5.20 Cell tabs must not carry mechanical loads.

EV 3.6 Accumulator Isolation Relays (AIRs)

EV 3.6.1 In every accumulator container at least two AIR must be installed.

EV 3.6.2 The AIRs must open both poles of the accumulator. If the AIRs are open, no tractive system voltage may be present outside of the accumulator container.

EV 3.6.3 The AIRs must be of a "normally open" type.

EV 3.6.4 The fuse protecting the accumulator tractive system circuit must have a rating lower than the maximum switch off current of the AIRs.

EV 3.6.5 The AIRs must not contain mercury.

EV 3.6.6 The AIRs must be mechanical relays. Solid-state relays are prohibited.

EV 3.7 Accumulator Management System (AMS)

EV 3.7.1 Each accumulator must be monitored by an AMS whenever the tractive system is active or the accumulator is connected to a charger.

EV 3.7.2 The AMS must continuously measure the cell voltage of every cell.

EV 3.7.3 The AMS must continuously measure the temperatures of critical cells of the accumulator to keep the cells below the allowed maximum cell temperature limit stated in the cell data sheet or below 60 °C, whichever is lower.

Cell temperature must be measured at the negative terminal of the respective cell and the sensor used must be in direct contact with either the negative terminal or less than 10 mm away from the terminal on the respective busbar.

EV 3.7.4 For lithium based cells, the temperature of at least 30 % of the cells must be monitored by the AMS. The monitored cells have to be equally distributed within the accumulator container(s).

It is acceptable to monitor multiple cells with one sensor, if EV 3.7.3 is met for all cells sensed by the sensor.

EV 3.7.5 An independent cell temperature monitoring device may be installed by the officials during accumulator inspection, see IN 3.

The device must be placed on the warmest negative cell terminal of the accumulator container and in direct contact with the terminal or no less then 30 mm away from it on the busbar.

EV 3.7.6 The AMS must switch off the tractive system by the shutdown circuit, if critical voltage, temperature or current values according to the cell manufacturer's datasheet or this rules are detected. The accuracy of the measurement must be taken into account for this. A red indicator light in the cockpit that is easily visible even in bright sunlight and clearly marked

with the lettering "AMS" must light up if the AMS opens the shutdown circuit. It must stay illuminated until the error state has been manually reseted, see EV 5.1.6. Signals controlling this indicator are SCS, see T 10.3.

EV 3.7.7 The action of opening the shutdown circuit may be delayed by 250 ms to signal the failure to the motor controllers and reduce the tractive system current before the AIRs are opened.

EV 3.7.8 The AMS must keep the accumulator cells within their safe operation limits with respect to charge and discharge currents according to the manufacturers data sheet.

EV 3.7.9 The AMS must be able to read and display all cell voltages e.g. by connecting a laptop to the AMS.

EV 3.7.10 All voltage, temperature and current signals are system critical signals, see T 10.3.

EV 4 TRACTIVE SYSTEM GENERAL REQUIREMENTS

EV 4.1 Separation of Traction System and Grounded Low Voltage System

EV 4.1.1 There must be no connection between the frame of the vehicle (or any other conductive surface that might be inadvertently touched) and any part of any tractive system circuits.

EV 4.1.2 Tractive system and GLV circuits must be physically segregated such that they are not run through the same conduit or connector, except for interlock circuit connections.

EV 4.1.3 GLV systems must not be included in the accumulator container except where inherently required. Exceptions include the AIRs, HV DC/DC converters, the AMS, the Insulation Monitoring Device (IMD), the BSPD and cooling fans.

EV 4.1.4 Where both tractive system and GLV are present within an enclosure, they must be separated by insulating barriers made of moisture resistant, UL recognized or equivalent insulating materials rated for 150 °C or higher (e.g. Nomex based electrical insulation), or maintain the following spacing through air, or over a surface (similar to those defined in UL1741):

Voltage	Spacing
U < 100 V DC	10 mm
100 V DC < U < 200 V DC	20 mm
U > 200 V DC	30 mm

EV 4.1.5 Components and cables capable of movement must be positively restrained to maintain spacing.

EV 4.1.6 If tractive system and GLV are on the same PCB, they must be on separate, clearly defined areas of the board. The tractive system and GLV system areas have to be clearly marked on the PCB.

The following spacing is related to the spacing between traces / board areas:

Voltage	Over Surface	Through Air (Cut in board)	Under Coating
0 V DC to 50 V DC	1.6 mm	1.6 mm	1.0 mm
50 V DC to 150 V DC	6.4 mm	3.2 mm	2.0 mm
150 V DC to 300 V DC	9.5 mm	6.4 mm	3.0 mm
300 V DC to 600 V DC	12.7 mm	9.5 mm	4.0 mm

"Under coating" is referring to a coating insulator, solder resist is not a coating. If integrated circuits are used such as opto-couplers which are rated for the respective maximum tractive system voltage, but do not fulfill the required spacing, then they may still be used and the given spacing does not apply.

EV 4.1.7 Teams must be prepared to demonstrate spacing on team-built equipment. For inaccessible circuitry, spare boards or appropriate photographs must be available.

EV 4.1.8 All connections to external devices, such as laptops, from a tractive system component must include galvanic isolation.

EV 4.2 Positioning of Tractive System Parts

EV 4.2.1 With the exception of what is permitted according to EV 4.2.3, all parts belonging to the tractive system including cables and wiring must be contained within the envelope of any part of the frame which is made from any regulated tubing defined in T 2.3. and an additional envelope of tubing which meets the minimum specification defined in T 2.3 or equivalent, such that they are protected against being damaged in case of a crash or roll-over situation.

"Part" is the whole device such as the complete HVD.

EV 4.2.2 If tractive system parts are mounted in a position where damage could occur from a rear or side impact (below 350 mm from the ground), for example motors at the rear of the vehicle, they must be protected by a fully triangulated structure with tubes meeting the minimum restrictions as described in T 2.3 for the side impact structure.

EV 4.2.3 Outboard wheel motors are allowed even if the motor, attendant cables and wiring are outside of the envelope defined in EV 4.2.1 and only if an interlock is added such that the shutdown circuit, EV 5, is activated if the wheel assembly is damaged or knocked off the vehicle. Tractive system wiring running outside of the envelope must be reduced to a minimum. The tractive system wiring must not be able to reach the cockpit opening or the driver no matter where it breaks.

EV 4.2.4 In side or front view no part of the tractive system must project below the lower surface of the frame.

EV 4.2.5 Additional regulations apply for accumulators, see EV 3.4.

EV 4.3 Grounding

EV 4.3.1 All electrically conductive parts of the vehicle (e.g. parts made of steel, (anodized) aluminum, any other metal parts, etc.) which are within 100 mm of any tractive system or GLV system component, the driver harness mounting points and the seat mounting points must have a resistance below 300 mΩ (measured with a current of 1 A) to GLV system ground.

EV 4.3.2 All parts of the vehicle which may become electrically conductive (e.g. completely coated metal parts, carbon fiber parts, etc.) which are within 100 mm of any tractive system or GLV system component, must have a resistance below 5 Ω to GLV system ground.

Carbon fiber parts may need special measures such as using copper mesh or similar to keep the ground resistance below 5 Ω.

EV 4.4 Tractive System Measuring point (TSMP)

EV 4.4.1 Two TSMPs must be installed directly next to the master switches, see EV 5.2.

EV 4.4.2 The TSMPs must be protected by a non-conductive housing that can be opened without tools.

EV 4.4.3 4 mm shrouded banana jacks of non-black color, rated for 1000 V CAT III or better must be used for the TSMPs.

EV 4.4.4 The TSMPs must be directly connected to the positive and negative motor controller/inverter supply and must be marked “HV+” and “HV-”.

EV 4.4.5 Each TSMP must be secured with a current limiting resistor according to the following table. Fusing of the TSMPs is prohibited. The resistors power rating must be chosen such that they are able to carry the current if both TSMPs are short circuited.

Maximum Tractive System Voltage	Resistor Value
Umax $<$200 V DC	5 kΩ
200 V DC $<$Umax $\leq$400 V DC	10 kΩ
400 V DC $<$Umax $\leq$600 V DC	15 kΩ

EV 4.4.6 Next to the TSMPs a GLV system ground measuring point must be installed. This measuring point must be connected to GLV system ground and must be marked “GND”.

EV 4.4.7 A 4 mm black shrouded banana jack must be used for the GLV system ground measuring point.

EV 4.5 Tractive System Insulation, Wiring and Conduit

EV 4.5.1 All parts, especially live wires, contacts, etc. of the tractive system must be isolated by non-conductive material or covers to be protected from being touched. This is tested with a 100 mm long, 6 mm diameter insulated test probe when the tractive system enclosures are in place.

EV 4.5.2 Non-conductive covers must prevent inadvertent human contact with any tractive system voltage. This must include team members working on or inside the vehicle. Covers must be secure and adequately rigid. Body panels that must be removed to access other components, etc. are not a substitute for enclosing tractive system connections.

EV 4.5.3 Tractive system components and containers must be protected from moisture in the form of rain or puddles, see IN 9.

EV 4.5.4 Insulation material that is appropriate for the expected surrounding temperatures must be used and must have a minimum temperature rating of 90 °C. Using only insulating tape or rubber-like paint for insulation is prohibited.

EV 4.5.5 All wires and terminals and other conductors used in the tractive system must be sized appropriately for the continuous tractive system current. The wires must be marked with wire gauge, temperature rating and insulation voltage rating or a serial number/norm printed on the wire if clearly bound to the wire characteristics for example by a data sheet. The minimum acceptable temperature rating for tractive system cables is 90 °C.

Sizing of the conductors for the "continuous tractive system current" may take account of the Root Mean Square (RMS) or average electrical current that will be used and the anticipated duration of time at maximum electrical current.

EV 4.5.6 All tractive system wiring must be done to professional standards with appropriately sized conductors and terminals and with adequate strain relief and protection from loosening due to vibration etc. .

EV 4.5.7 All tractive system wiring that runs outside of electrical enclosures must

- Be enclosed in separate orange non-conductive conduit or use an orange shielded cable.
- Be securely anchored at least at each end so that it can withstand a force of 200 N without straining the cable end crimp.
- Be located out of the way of possible snagging or damage.

Body work is not sufficient to meet this enclosure requirement.

EV 4.5.8 Any shielded cable must have the shield grounded.

EV 4.5.9 All tractive system connections must be designed so that they use intentional current paths through conductors such as copper or aluminum and should not rely on steel bolts to be the primary conductor. The connections must not include compressible material such as plastic in the stack-up.

EV 4.5.10 Tractive system wiring must be shielded against damage by rotating and / or moving parts.

EV 4.5.11 If external, uninsulated heat sinks are used, they must be properly grounded to the GLV system ground, see EV 4.3.

EV 4.5.12 Wiring that is not part of the tractive system must not use orange wiring or conduit.

EV 4.5.13 All electrical connections (including bolts, nuts and other fasteners) in the high current path of the tractive system must be secured from unintentional loosening by the use of positive locking mechanisms that are suitable for high temperatures, for example torque prevailing nuts, see T 9.2.

Components, e.g. inverters, certified for automotive use might be allowed without positive locking feature, if connections are done as given by the manufacturers datasheet and no positive locking is possible.

EV 4.5.14 Every tractive system 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.

EV 4.5.15 Soldered connections in the high current path are only allowed if all of the following are true:

- connections on PCBs
- the connected devices are no cells or wires
- the devices are additionally mechanically secured against loosening

EV 4.6 HV System Enclosures

EV 4.6.1 Every housing or enclosure containing parts of the HV system, except motor housings, must be labeled with (a) reasonably sized sticker(s) according to "ISO 7010-W012" (triangle with black lightning bolt on yellow background). The sticker must also contain the text "High Voltage" if the voltage is more than 60 V DC or 25 V AC.

EV 4.7 High Voltage Disconnect (HVD)

EV 4.7.1 It must be possible to disconnect at least one pole of the tractive system 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 350 mm 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.

EV 4.7.2 An untrained person must be able to remove the HVD within 10 seconds when the vehicle is in ready-to-race condition.

EV 4.7.3 EV 4.5 remains valid, therefore a dummy connector or similar may be required to restore the system's isolation.

EV 4.7.4 The HVD must be clearly marked with "HVD".

EV 4.7.5 No tools must be necessary to open the HVD. Therefore, a pilot contact/interlock must open the shutdown circuit when the HVD is removed.

EV 4.8 Wiring of the Tractive System Supply

EV 4.8.1 All accumulator containers must be wired to a single point such as the power supplying the tractive system must flow through this single point and must pass the energy meter position, see EV 4.9.

EV 4.8.2 No further energy storages except for reasonably sized intermediate circuit capacitors are allowed beyond this point.

EV 4.9 Energy Meter

EV 4.9.1 In the tractive system supply wires, see EV 4.8, a calibrated energy meter must be inserted at the competition. The energy meter is used to calculate the efficiency score by measuring the total energy being sourced by the accumulator(s).

EV 4.9.2 The energy meter must be in an easily accessible location so that the recorded data can be quickly downloaded by the officials.

EV 4.9.3 The energy meter must be directly supplied from the GLV master switch.

EV 4.9.4 The specification of the used energy meter will be available on the competition website.

EV 4.10 Activating the Tractive System

EV 4.10.1 The driver must be able to activate and deactivate the tractive system from within the cockpit without the assistance of any other person.

EV 4.10.2 [DV ONLY] The autonomous system must not be able to (re-)activate the tractive system.

EV 4.10.3 The vehicle is ready to drive as soon as the motor(s) will respond to the input of the APPS.

EV 4.10.4 Closing only the shutdown circuit must not set the vehicle to ready-to-drive mode.

EV 4.10.5 After the tractive system 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). One of these actions must include the brake pedal being pressed while ready-to-drive mode is entered.

EV 4.11 Ready-To-Drive Sound

EV 4.11.1 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.

EV 4.11.2 The sound level must be a minimum of 80 dBA, fast weighting. The sound level will be measured with a free-field microphone placed free from obstructions in a radius of 2 m around the vehicle.

EV 4.11.3 The used sound must be easily recognizable. No animal voices, song parts or sounds that could be interpreted as offensive will be accepted.

EV 4.11.4 The vehicle must not make any other sounds similar to the ready-to-drive sound.

EV 4.12 Pre-Charge and Discharge Circuits

EV 4.12.1 A circuit that is able to pre-charge the intermediate circuit to at least 90 % of the actual accumulator voltage before closing the second AIR must be implemented.

EV 4.12.2 Any pre-charge circuitry must be supplied by the shutdown circuit directly from the TSMS. The circuit must be disabled by a de-activated shutdown circuit, see EV 5.

EV 4.12.3 The pre-charge circuit must use a mechanical, normally open type relay. All pre-charge current must pass this relay.

EV 4.12.4 Pre-charging of the intermediate circuit for a conservatively calculated time is allowed before closing the second AIR. A feedback via measuring the current intermediate circuit voltage is not required.

EV 4.12.5 If a discharge circuit is required to meet EV 5.1.5, it must be designed to handle the maximum possible discharge current permanently. The discharge time exceeding the specified time in EV 5.1.5 after 15 s continuous discharge at maximum discharge current, e.g. three subsequent charges, is allowed. Full discharging functionality must be given after a reasonable time with a deactivated discharge circuit.

EV 4.12.6 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.

EV 4.12.7 Fusing of the discharge main current path is prohibited.

EV 4.13 Tractive System Active Light (TSAL)

EV 4.13.1 The vehicles must include a single TSAL that must indicate the tractive system status. The TSAL must not perform any other functions. A TSAL with multiple LEDs in one housing is allowed.

EV 4.13.2 The tractive system is active when ANY of the following conditions are true:

- An accumulator isolation relay is closed.
- The pre-charge relay, see EV 4.12.3, is closed.
- The voltage outside the accumulator containers exceeds 60 V DC or 25 V AC RMS. This implies that at least the voltage of all DC-link capacitors need to be measured even with removed HVD.

EV 4.13.3 The tractive system is deactivated when ALL of the following conditions are true:

- All accumulator isolation relays are opened.
- The pre-charge relay, see EV 4.12.3, is opened.
- The voltage outside the accumulator containers does not exceed 60 V DC or 25 V AC RMS. This implies that at least the voltage of all DC-link capacitors need to be measured even with removed HVD.

EV 4.13.4 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.

EV 4.13.5 The TSAL itself must:

- Be hard wired electronics. Software control is not permitted.
- Be in red color and flash continuously with a frequency between 2 Hz and 5 Hz if the tractive system is active, see EV 4.13.2, and the GLV system is switched on.
- Be in green color and continuously illuminated if the tractive system is deactivated, see EV 4.13.3, and the GLV system is switched on.

EV 4.13.6 The TSAL mounting location must:

- Be mounted lower than the highest point of the main hoop and according to EV 4.2.1.
- Be no lower than 150 mm from the highest point of the main hoop.
- Not allow contact with the driver's helmet in any circumstances.
- Not be in proximity to lights other than the ASSI (see DV 2.3).

EV 4.13.7 The TSAL must be clearly visible:

- Except for small angles which are blocked by the main hoop.
- From a point 1.60 m vertically from ground level, within 3 m horizontal radius from the TSAL.
- In direct sunlight.

EV 4.13.8 Signals influencing the TSAL are SCS (see T 10.3). The circuitry detecting the conditions mentioned in EV 4.13.2 and EV 4.13.3 does not need to detect open circuit or short circuit to ground of the measurement connection itself. The TSAL has an active indication of absence of failures (green light) and thus must not be illuminated for visible check, see T 10.3.3.

EV 4.13.9 [DV ONLY] Second- and third-year vehicles (A 2.3) must update their TSAL according to the above mentioned rules (EV 4.13)

EV 5 SHUTDOWN CIRCUIT AND SYSTEMS

EV 5.1 Shutdown Circuit

EV 5.1.1 The shutdown circuit directly carries the current driving the AIRs.

EV 5.1.2 The shutdown circuit is defined as a series connection of at least two master switches, three shutdown buttons, the BOTS (see T 5.2), the IMD, the inertia switch, see T 10.4, the BSPD, all required interlocks and the AMS.

EV 5.1.3 All parts of the shutdown circuit must be in the high (hot) connection of the AIR coils.

EV 5.1.4 The Tractive System Master Switch (TSMS), see EV 5.2, must be the last switch before the AIRs except for pre-charge circuitry and hardwired interlocks.

EV 5.1.5 If the shutdown circuit is opened, the tractive system must be shutdown by opening all AIRs and the voltage in the tractive system must drop to under 60 V DC and 25 V AC RMS in less than five seconds after opening the shutdown circuit. All accumulator current flow must stop immediately.

An explanatory schematic of the required shutdown circuit, excluding any possible interlock circuitry, is shown in Figure 18.

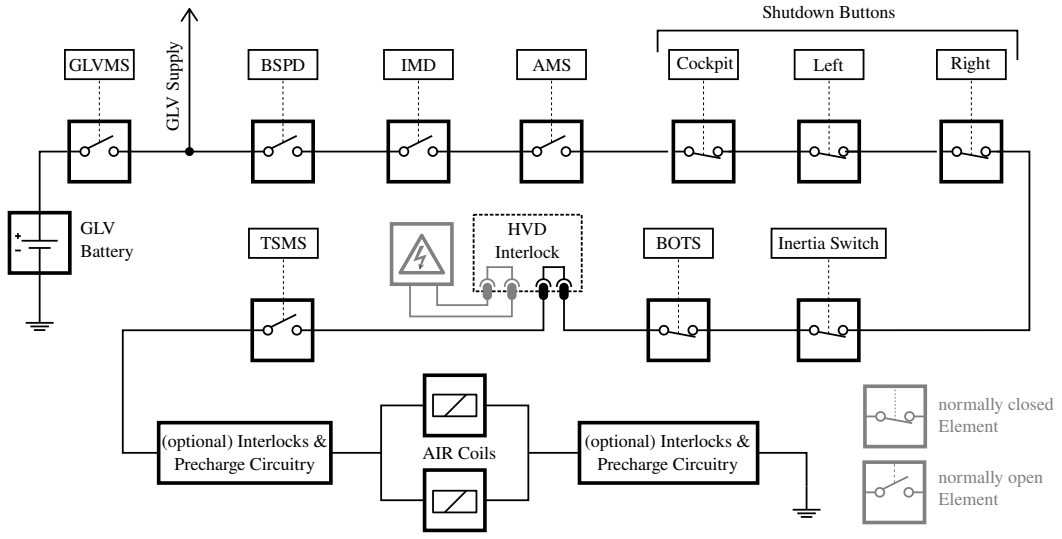

Figure 18: Explanatory example schematic of the required shutdown circuit

EV 5.1.6 If the shutdown circuit is opened by the AMS or the IMD, the tractive system must remain disabled until it is manually reset at the vehicle, by a person who is not the driver. This must be achieved by non-programmable circuits.

For example: Applying an IMD test resistor between HV+ and GLV system ground must deactivate the system. Disconnecting the test resistor must not re-activate the system.

EV 5.1.7 It must not be possible for the driver to re-activate the tractive system from within the vehicle in case of an AMS, IMD or BSPD (see EV 5.5) fault.

EV 5.1.8 All circuits that are part of the shutdown circuit must be designed in a way, that in the de-energized/disconnected state they are open such that each circuit will remove the current controlling the AIRs.

EV 5.1.9 If the tractive system is de-activated while driving, the motor(s) has/have to spin freely e.g. no brake torque may be applied to the motor(s).

EV 5.1.10 It must be possible to demonstrate that all features of the shutdown circuit function correctly. This includes all interlocks.

EV 5.1.11 Every system that is required to or is able to open the shutdown circuit must have its own, non-programmable, power stage to achieve this. The respective power stages must be designed to be able to carry the shutdown circuit current, e.g. AIR inrush currents, and such that a failure cannot result in electrical power being fed back into the electrical shutdown circuit.

EV 5.1.12 The shutdown buttons, the BOTS, the TSMS and all interlocks must not act through any power stage, but must directly carry the AIR current.

EV 5.1.13 All signals influencing the shutdown circuit are System Critical Signals, see T 10.3.

EV 5.2 Master Switches

EV 5.2.1 Each vehicle must have two master switches, the Grounded Low Voltage Master Switch (GLVMS) and the Tractive System Master Switch (TSMS).

EV 5.2.2 The GLVMS must completely disable power to the GLV system and must be direct acting, i.e. it must not act through a relay or logic.

EV 5.2.3 The TSMS must open the shutdown circuit. The TSMS must be direct acting, i.e. it cannot act through a relay or logic.

EV 5.2.4 The GLVMS must be located on the right side of the vehicle, in proximity to the main hoop, at the 95^{th} percentile male driver's shoulder height, as defined in T 3.3, and be easily actuated from outside the vehicle.

Master switches must not be mounted lower than the vertical distance of the templates middle circle center to ground measured multiplied by 0.8.

EV 5.2.5 The TSMS must be located next to the GLVMS.

EV 5.2.6 The TSMS must be fitted with a "lockout/tagout" capability to prevent accidental activation of the tractive system.

EV 5.2.7 Both master switches must be mechanical switches of the rotary type, with a red, removable handle. The handle must have a width of at least 50 mm and must only be removable in electrically open position.

EV 5.2.8 The master switches must not to be easily removable, e.g. they must not be mounted onto removable body work.

EV 5.2.9 The function of both switches must be clearly marked with "LV" and "HV". A sticker according to "ISO 7010-W012" (triangle with black lightning bolt on yellow background) must additionally mark the TSMS.

EV 5.2.10 Both master switches must be mounted so that the rotary axis of the key is near horizontal and across the vehicle.The "ON" position of both switches must be in the horizontal position and must be marked accordingly. The "OFF" position of both switches must also be clearly marked.

EV 5.3 Shutdown Buttons

EV 5.3.1 A system of three shutdown buttons must be installed on the vehicle.

EV 5.3.2 Pressing any one of the shutdown buttons must separate the tractive system from the accumulator by opening the shutdown circuit, see also EV 5.1.

EV 5.3.3 Each shutdown button must be a push-pull or push-rotate mechanical emergency switch where pushing the button opens the shutdown circuit.

EV 5.3.4 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 40 mm.

EV 5.3.5 One shutdown button serves as a cockpit-mounted shutdown button. The minimum allowed diameter of the shutdown button in the cockpit is 24 mm. It must be in easy reach of the driver, even when he/she is belted in. It must be alongside the steering wheel and unobstructed by the steering wheel and any other part of the vehicle.

EV 5.3.6 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.

EV 5.3.7 The shutdown buttons must be permanently fixed and should not be easily removable, e.g. they must not be mounted onto removable body work.

EV 5.4 Insulation Monitoring Device (IMD)

EV 5.4.1 Every vehicle must have an IMD installed in the HV system.

EV 5.4.2 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.

EV 5.4.3 The response value of the IMD must be set to 500 Ω/V, related to the maximum tractive system operation voltage.

EV 5.4.4 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 EV 5.1.6 and EV 5.1.7 regarding the re-activation of the tractive system after an insulation fault.

EV 5.4.5 The action of opening the shutdown circuit may be delayed by 250 ms to signal the failure to the motor controllers and reduce the tractive system current before the AIRs are opened.

EV 5.4.6 A red indicator light in the cockpit that is easily visible even in bright sunlight and clearly marked with the lettering "IMD" must light up if the IMD detects an insulation failure or if the IMD detects a failure in its own operation, e.g. when it loses reference ground. It must stay illuminated until the error state has been manually reseted, see EV 5.1.6. Signals controlling this indicator are SCS, see T 10.3.

EV 5.5 Brake System Plausibility Device (BSPD)

EV 5.5.1 A standalone non-programmable circuit must open the shutdown circuit when hard braking (without locking the wheels) occurs, whilst a positive current is delivered from the motor controller (a current to propel the vehicle forward). Only power cycling the GLVMS may reset this functionality and close the shutdown circuit again.

EV 5.5.2 Standalone is defined as there is no additional functionality implemented on the specific PCB(s). The interfaces must be reduced to the minimum necessary signals.

EV 5.5.3 The current limit for triggering the circuit must be set at a level where 5 kW of electrical power in the DC circuit is delivered to the motors at the nominal battery voltage.

EV 5.5.4 The action of opening the shutdown circuit must occur if the implausibility is persistent for more than 0.5 s.

EV 5.5.5 All necessary signals are system critical signals, see T 10.3.

EV 5.5.6 The team must prove the function of the BSPD during technical inspection by sending an appropriate signal to the non-programmable circuit that represents the current, in order to achieve 5 kW whilst pressing the brake pedal hard.

EV 6 Overcurrent Protection

EV 6.1 Overcurrent Protection

EV 6.1.1 All electrical systems (both LV and HV) must have appropriate overcurrent protection.

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, cell or other conductor that it protects.

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

EV 6.1.2 All overcurrent protection devices must be rated for the highest voltage in the systems they protect. Devices used for DC must be rated for DC and must carry a DC rating equal to or greater than the system voltage.

EV 6.1.3 All overcurrent protection devices must have an interrupt current rating which is higher than the theoretical short circuit current of the system that it protects.

EV 6.1.4 All overcurrent protection devices which are part of the tractive system must not rely on programmable logic.

EV 6.1.5 The tractive system high current path through the accumulator container(s) must be fused.

EV 7 CHARGERS

EV 7.1 Chargers General Requirements

EV 7.1.1 Only chargers presented and sealed at technical inspection are allowed. All connections of the charger(s) must be isolated and covered. No open connections are allowed.

EV 7.1.2 All chargers must either be accredited to a recognized standard e.g. CE, or when built by the team, they must comply with all electrical requirements for the vehicle tractive system, e.g. EV 4.1, EV 4.3 and EV 4.6.

EV 7.1.3 HV charging leads must be orange.

EV 7.1.4 When charging, the AMS must be live and must be able to turn off the charger in the event that a fault is detected.

EV 7.1.5 The charger must include a push type emergency stop button which has a minimum diameter of 25 mm and must be clearly labeled.

EV 7.1.6 When charging the accumulator, the IMD 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.

EV 7.1.7 The charger must include TSMPs as described in EV 4.4. Other than stated, the HV measuring points must be connected to the HV output of the charger.

EV 7.2 Charging Shutdown Circuit

EV 7.2.1 When charging, the charging shutdown circuit consists of at least the charger shutdown button, see EV 7.1.5, the IMD and the AMS.

EV 7.2.2 If the shutdown circuit is opened by the AMS or the IMD the charging system must remain disabled until it is manually reset.

EV 7.2.3 The charging shutdown systems must comply with EV 5.1.1, EV 5.1.5, EV 5.1.8, EV 5.1.10 and EV 5.1.11.

EV 7.2.4 All signals influencing the charger shutdown circuit are System Critical Signals (SCSs), see T 10.3.

EV 8 HIGH VOLTAGE PROCEDURES AND TOOLS

EV 8.1 Working on the Tractive System

EV 8.1.1 Activities on the tractive system, except for the accumulator container (see EV 8.2) must take place in the pit.

EV 8.1.2 All activities require the attendance of the ESO.

EV 8.1.3 For activities on the inactive tractive system, the following procedure must be carried out:

1. Barrier off the vehicle from anyone not involved in the work, by using barrier tape.
2. Make sure the Tractive System Master Switch (TSMS) is switched off.
3. Assure that the tractive system cannot by restarted, by, at a minimum, using the lockout/tag out of the TSMS.
4. Check for zero-potential.
5. Install a sign that declares the vehicle is electrically safe. Make a note of the name of the ESO who is supervising the activities on the sign. This ESO is the only person who may remove the sign and the barrier.

EV 8.1.4 In case of measurements on the active tractive system or an activation of the tractive system in the pit for testing purposes, the following steps must be followed:

- Barrier off the vehicle from anyone not involved in the work, by using barrier tape.
- The vehicle must be jacked up and the driven wheels demounted.
- One team member must be prepared to push a shutdown button at any time.
- The tractive system 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 tractive system are exposed.
- No other work on the vehicle is permitted when the tractive system is active.

EV 8.1.5 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.

EV 8.1.6 For work on tractive system accumulator container, EV 8.2 specifies additional requirements.

EV 8.2 Working on Tractive System Accumulator Containers

EV 8.2.1 Opening of or working on accumulator containers is only allowed in the provided work places in the charging area, see EV 8.3.

EV 8.2.2 All activities require the attendance of the ESO.

EV 8.2.3 Whenever the accumulator containers are opened, the cell segments must be separated with the maintenance plugs, see EV 3.4.3.

EV 8.2.4 Appropriate insulated tools and equipment must be used.

EV 8.2.5 Safety glasses with side shields and compliant safety gloves must be worn by all participating team members.

EV 8.2.6 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.

EV 8.3 Charging

EV 8.3.1 There will be a separated charging area on the competition site. Charging tractive system accumulators is only allowed inside this area.

EV 8.3.2 Accumulators must be removed from the vehicle and placed on the accumulator container hand cart, see EV 8.4, for charging.

EV 8.3.3 The accumulator containers must have a label with the following data during charging: Team name and the ESO phone number(s).

EV 8.3.4 No grinding, drilling, etc. is allowed in the charging area.

EV 8.3.5 At least one team member who has knowledge of the charging process must stay with the accumulator(s) during charging.

EV 8.3.6 Moving accumulator cells and/or accumulator segment(s) around at the event site is only permitted if they are inside a completely closed accumulator container.

EV 8.4 Accumulator Container Hand Cart

EV 8.4.1 The hand cart(s) must be used for transporting the accumulator container(s) on the event site.

EV 8.4.2 The hand cart must have a brake which is always on and only releasedif someone pushes the handle, or similar.

EV 8.4.3 The brake must be capable to stop the fully loaded accumulator container hand cart.

EV 8.4.4 The hand cart must be able to carry the load of the accumulator container(s).

EV 9 ELECTRICAL SYSTEM FORM (ESF)

EV 9.1 Electrical System Form (ESF)

EV 9.1.1 Prior to the event, all teams must submit clearly structured documentation of their entire electrical system (including control and tractive system) called ESF.

EV 9.1.2 It is the teams responsibility to create the ESF on the competition website until the deadline specified in the competition handbook.

DV DRIVERLESS VEHICLES

DV 1 VEHICLE REQUIREMENTS AND RESTRICTIONS

DV 1.1 Base Vehicle

Additions to the vehicle's general requirements and restrictions are marked and given in T, and CV or EV depending on the implemented drivetrain. Please also refer to rule A 2.3.

DV 1.2 Wireless Communication

DV 1.2.1 During dynamic events, the wireless communication is limited to ensure that the vehicle is driving autonomously. It is prohibited to change parameters, send commands or make any software changes by wireless communication.

DV 1.2.2 An exception is the RES described in DV 1.4. Receiving information from the vehicle via one-way-telemetry is allowed.

DV 1.2.3 (D)GPS may be used, but there will be no space to securely build up base stations on the event site.

DV 1.3 Data logger

DV 1.3.1 The officials will provide a standardized data logger that must be installed in any DV during the competition. Further specifications for the data logger and required hardware and software interfaces can be found in the "DV event-specific technical specification" document that can be found on the competition website.

DV 1.3.2 The intention of the data logger is to understand and reproduce the perception as well as the motion planning of the vehicle by the algorithm based on the information and data collected by the sensors implemented in the vehicle.

DV 1.3.3 A vehicle software or algorithm that bases purely on upfront loaded track data does not comply with intention or rules of DV.

DV 1.4 Remote Emergency System (RES)

DV 1.4.1 Every vehicle must be equipped with a standard RES specified by in the "DV event-specific technical specification" document that can be found on the competition website. The system consists of two parts, the remote control and the vehicle module.

DV 1.4.2 The RES must be purchased by the team.

DV 1.4.3 The RES has two functions:

(a) When the remote emergency stop button is pressed, it must trigger the DV shutdown circuit defined in DV 1.5.

(b) Race-control-to-vehicle communication:

(i) The race control can send a “Go” signal to the vehicle

(ii) The “Go” signal replaces green flags

DV 1.4.4 The RES vehicle module must be directly integrated in the vehicle’s shutdown circuit. Directly means hard-wired in series to the shutdown buttons.

DV 1.4.5 The RES remote control remains at the race control during dynamic events (see also D 2.2.8 and D 2.6).

DV 1.4.6 When the vehicle is driving in autonomous mode, one ASR must be present at the race control and may request a remote emergency stop.

DV 1.4.7 The antenna of the RES must be mounted unobstructed and without interfering parts in proximity (other antennas, etc.) on the highest point of the car.

DV 1.5 Shutdown circuit

DV 1.5.1 The drivetrain-specific requirements for the shutdown circuit (see CV 4.1 or EV 5) remain valid for DV.

DV 1.5.2 Triggering the shutdown circuit must have the following responses in addition to the drivetrain-specific behavior:

(a) The EBS (see rule DV 3) must be triggered.

(b) The autonomous steering system may remain active when the remote emergency stop button is activated.

DV 2 AUTONOMOUS SYSTEM

DV 2.1 Signals

DV 2.1.1 Any signal of the autonomous system is an SCS.

DV 2.2 Autonomous System Master Switch (ASMS)

DV 2.2.1 Each DV must be equipped with an ASMS.

DV 2.2.2 The ASMS must be located on the right side of the vehicle, in proximity to the GLVMS and TSMS (EV, EV 5.2) / master switch (CV, CV 4.2), at the driver’s shoulder height and be easily actuated from outside the vehicle.

DV 2.2.3 The ASMS must be of the rotary type, removable key, similar to the TSMS. It must be clearly distinguishable to the other switches, e.g. by color. Simple labeling is not sufficient.

DV 2.2.4 When the ASMS is switched off, it must be ensured that no steering, braking and propulsion actuation can be performed by request of the autonomous system.

DV 2.2.5 When the ASMS is in "Off" position (i.e. manual mode), the following must fulfilled:

- The sensors and the processing units can stay operational.
- The vehicle must be able to be pushed as specified in A 6.7.
- It must be possible to operate the vehicle manually as a normal CV or EV.

DV 2.2.6 It is strictly forbidden to switch the ASMS to the "On" position if a person is inside the vehicle (for safety there will be no driver in the vehicle when it is in autonomous mode).

DV 2.2.7 The ASMS may only be switched on by the ASR after approval from an official.

DV 2.2.8 After switching the ASMS to the "On" position, the vehicle may not start moving and the brakes must remain closed ("System ready" state, Table 6) until a "Go" signal is send via the RES ("Autonomous" state, Table 6).

DV 2.2.9 The ASMS must be fitted with a "lockout/tagout" capability to prevent accidental activation of the autonomous system. The ASR must ensure that the ASMS is locked in the off position whenever the vehicle is outside the dynamic area or driven in manual mode.

DV 2.2.10 The autonomous system must not start the combustion engine or activate the HV system.

DV 2.3 Autonomous System Status Indicator (ASSI)

DV 2.3.1 The vehicles must include a single ASSI that must indicate the status of the autonomous system. The ASSI may not perform any other functions.

DV 2.3.2 The ASSI must indicate the autonomous system status definitions as defined in DV 2.4.

DV 2.3.3 The ASSI mounting location must fulfill all points mentioned in EV 4.13.6.

DV 2.3.4 For the ASSI visibility the TSAL rules (EV 4.13.7) apply.

DV 2.3.5 [EV ONLY] The ASSI must be mounted directly next to the TSAL. Mounting in one case is allowed.

DV 2.3.6 [EV ONLY] The blinking pattern of RES-state must be anticyclic to the TSAL tractive system active state (see EV 4.13.5).

DV 2.3.7 [EV ONLY] The ASSI must share its green indicator light with the TSAL. The green indicator light may only light up if BOTH the conditions for finish state (see Table 6) and the tractive system deactivated state (see also EV 4.13.3) are fulfilled. Besides this, the ASSI and the TSAL must be fully electrically separated.

DV 2.4 Autonomous System Status Definitions

DV 2.4.1 The autonomous system must implement the states "Off = manual mode", "Ready", "Autonomous (mode)", "RES (triggered)" and "Finish" as listed in Table 6.

DV 2.4.2 The system must have no further states other than those listed in Table 6.

DV 2.4.3 The proof of correctness of the states is content of the Autonomous System Form (ASF).

Status	ASSI color	EBS	Engine, HV	Brake	Actuators	ASMS	R2D, Gear
off	off	deact.	-	-	deact.	removed	-
ready	blue	avail.	activate	hold	deact.	on	off/N
auton.	yellow	avail.	on	-	active	on	-
RES	blue flashing	trig.	shutd.	braking	-	on	-
finish	green	avail.	off	hold	deact.	on	off/N

Table 6: Autonomous system states

DV 2.5 Autonomous Mission Indicator (AMI)

DV 2.5.1 For safety reasons, the vehicle must be able to display its planned mission in some form before starting a dynamic discipline. This device is called AMI.

DV 2.5.2 The AMI can be part of the dashboard. The use of adequate LEDs which are clearly marked is also allowed.

DV 2.5.3 The AMI must be able to display, at minimum, the following tasks: acceleration, skidpad, trackdrive and brake test.

DV 2.5.4 The AMI will be checked before every dynamic discipline.

DV 2.6 Autonomous System Form (ASF)

DV 2.6.1 Prior to the event, all teams must submit a clearly structured documentation of their entire autonomous system (including EBS and steering system) called ASF.

DV 2.6.2 The ASF must contain at least the following items:

- All applied sensors (see also DV 4.2)
- Wiring diagrams of all SCSs of the autonomous system
- A wiring diagram of the autonomous system LV supply

DV 2.6.3 The FMEA for the EBS is part of the ASF.

DV 3 Emergency Brake System (EBS)

DV 3.1 Technical Requirements

DV 3.1.1 All specifications of the brake system from T 5 remain valid.

DV 3.1.2 When the ASMS is switched on, the brakes must be applied in a way that prevents the vehicle from moving (e.g. at a descent). The brakes must stay engaged until the vehicle receives the "Go" signal from the RES remote control.

DV 3.1.3 The vehicle must be equipped with an EBS, that is triggered when the shutdown circuit opens.

DV 3.1.4 The EBS may be part of the hydraulic brake system.

DV 3.1.5 When the EBS is part of the hydraulic brake system, the manual brake actuation (by brake pedal) may be deactivated when the ASMS is in "On" position.

DV 3.1.6 The EBS must be designed in a way such that a track marshal is able to deactivate it (e.g. by turning off the ASMS). For example, this is necessary when the vehicle is shut down by RES and needs to be moved by a track marshal. A pictographic description of the necessary steps must be clearly visible.

DV 3.2 Functional Safety

DV 3.2.1 Due to the safety critical character of the EBS, the system must either remain fully functional, or must autonomously come to the safe state in case of a single failure mode.

DV 3.2.2 The safe state is the vehicle standstill, brakes engaged to prevent the vehicle from rolling, and an opened shutdown circuit.

DV 3.2.3 To get to the safe state, the vehicle must perform an autonomous brake maneuver described in section DV 3.5 and IN 6.3.

DV 3.2.4 The functional safety of the EBS must be demonstrated by an Failure Modes and Effects Analysis (FMEA) that must be handed in prior to the event. This must describe the EBS itself, the expected failure modes and the strategy to detect and respond to those failures.

DV 3.2.5 A red indicator light in the cockpit that is easily visible even in bright sunlight and clearly marked with the lettering "EBS" must light up if the EBS detects a failure.

DV 3.3 EBS States

DV 3.3.1 The EBS has three states: deactivated, available and triggered.

DV 3.3.2 Deactivated

- It must be ensured that the EBS performs no brake actuations.
- Manual driving with all requirements must be ensured.
- This is the initial state of the EBS.

DV 3.3.3 Available

- The EBS must be fully functional and must be able to perform an emergency braking maneuver when EBS is triggered.
- If monitoring is part of the safety concept (e.g. battery voltage monitoring), all monitoring must be active.
- If a failure is detected by monitoring, the system must autonomously open the shutdown circuit.

DV 3.3.4 Triggered

- The vehicle must perform an emergency brake maneuver as described in section EBS brake performance (DV 3.5).
- After activation, the brake must remain engaged until the system is manually deactivated.

DV 3.4 EBS Transitions

DV 3.4.1 The EBS must change its state from *deactivated* to *available* for the case that the ASMS is turned on and the shutdown circuit is closed.

DV 3.4.2 The EBS must change its state from *available* to *triggered* for the case that the shutdown circuit opens or the ASMS turns off while the autonomous system is not in "Finish" state as listed in Table 6.

DV 3.4.3 The EBS must change its state from available to deactivated in case of the ASMS turns off and the autonomous state is "Finish" as listed in Table 6.

DV 3.4.4 The EBS must change its state from *triggered* to *deactivated* for the case that the ASMS turns off. Additional manual steps (see rule DV 3.1) may be performed.

DV 3.4.5 Any other transition to those mentioned above is prohibited.

DV 3.5 EBS Performance

DV 3.5.1 The system reaction time (the time between entering the triggered state and the start of the deceleration) must not exceed 200 ms.

DV 3.5.2 The average deceleration must be above 8 $^{m}/_{s^2}$ at dry track conditions.

DV 3.5.3 Whilst decelerating, the vehicle must remain in a stable driving condition (i.e. no unintended yaw movement). This can be either a controlled deceleration (steering and braking control is active) or a stable braking on a straight line with all four wheels locked.

DV 3.5.4 The performance of the system will be tested at technical inspection, see IN 6.3.

DV 4 SENSORS

DV 4.1 Mounting

DV 4.1.1 All sensors must be securely mounted.

DV 4.1.2 Sensors may not come into contact with the driver's helmet in any circumstances.

DV 4.1.3 All sensors must be positioned within the surface defined by the top of the roll bar and the outside edge of the four tires (see figure 19).

DV 4.1.4 Additionally, sensors may be mounted with a maximum distance of 500 mm above the ground and not further forward than 700 mm forward of the front of the front tires (see Figure 19). They must not exceed the width of the front axle (measured at the height of the hubs).

DV 4.2 Legal & Work Safety

DV 4.2.1 All sensors must fulfill the local legislative specifications (i.e. eye-protection classification for laser sensors, power limitation for radar sensors, etc.) in the event country.

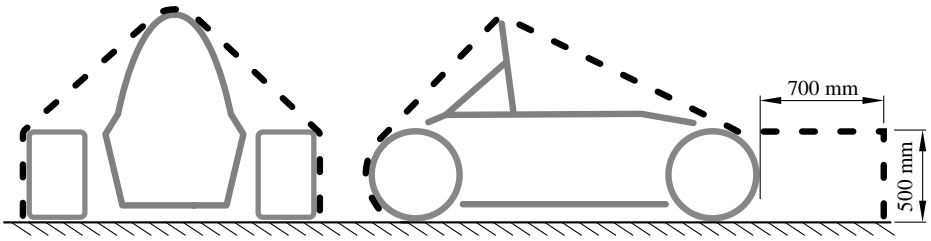

Figure 19: Envelope to mount sensor systems.

DV 4.2.2 This is to be demonstrated through the submission of the documentation of the implemented sensors prior to the competition as ASF Add Item Request (AAIR).

IN TECHNICAL INSPECTIONS

IN 1 GENERAL

IN 1.1 Technical Inspection Objective

IN 1.1.1 The technical inspections are to determine if the vehicle is able to participate in the dynamic events and is compliant to the rules.

IN 1.2 Technical Inspection Process

IN 1.2.1 The technical inspection is divided into the following parts:

- Pre-Inspection
- [EV ONLY] Accumulator Inspection
- [EV ONLY] Electrical Inspection
- Mechanical Inspection
- [DV ONLY] Driverless Inspection
- Tilt Test
- Vehicle Weighing
- [CV ONLY] Noise Test
- [EV ONLY] Rain Test
- Brake Test
- [DV ONLY] EBS Test

IN 1.3 General Rules

IN 1.3.1 Each vehicle must pass all parts of technical inspection before it may participate in any dynamic event.

IN 1.3.2 Passing the technical inspections is not a certification of complete rules compliance of the vehicle.

IN 1.3.3 The technical inspection sheet includes all inspection points and will be provided on the competition website prior to the competition. It must always stay with the vehicle. The officials may inspect other points not mentioned on the technical inspection sheet to ensure compliance with the rules.

IN 1.3.4 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.

IN 1.3.5 Vehicles must be presented for technical inspection in ready-to-race condition.

IN 1.3.6 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.

IN 1.3.7 The vehicle must maintain all required specifications throughout the competition.

IN 1.3.8 Officials will mark or seal various different approved parts. Removal of or damage to the seals will void the inspection approval.

IN 1.3.9 Once the vehicle is approved for competition, any damage to the vehicle that requires repair(s) will void the inspection approval. After the completion of the repair(s), the vehicle must be re-submitted to technical inspection for re-approval.

IN 1.3.10 Each team must present a quick jack to lift up the vehicle during technical inspection, see T 12.2.1.

IN 1.3.11 A maximum of four team members may enter the inspection area at one time.

IN 1.4 Technical Inspection Sticker

IN 1.4.1 The competition technical inspection stickers will be placed on the nose of the vehicle.

IN 1.4.2 If a vehicle is not in compliance with the rules (anymore), 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 of revoking the technical inspection approval in the technical inspection sheet.

IN 1.5 Inspection Responsible Person

IN 1.5.1 To accelerate the technical inspection process, the team must appoint one team member (for electrical inspection and accumulator inspection this has to be an ESO) as inspection responsible person.

IN 1.5.2 This inspection responsible person must be:

- Familiar with the vehicle.
- Able to show the 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.

IN 1.5.3 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.

IN 1.6 Modifications and Repairs

IN 1.6.1 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 wing angles, but not their location
- 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 of wheels and tires for "wet" or "damp" conditions as allowed in D 3.2 and D 7.5
- Software calibration changes
- Recharging low voltage batteries
- Recharging high voltage accumulators
- [DV ONLY] Adjustments of sensors

IN 2 PRE-INSPECTION

IN 2.1 Pre-Inspection Objective

At pre-inspection additional tools and driver equipment are checked for compliance with the rules.

IN 2.2 Pre-Inspection Required Items

IN 2.2.1 The following items must be presented for pre-inspection:

- All helmets
- All driver gear and other safety gear
- Two sets of four tires mounted on rims for dry and wet driving conditions
- Two unused and not overdue fire extinguishers

IN 2.2.2 [EV ONLY] Following basic tools in good condition must be presented for pre-inspection:

- Insulated cable shears
- Insulated screw drivers

- Multimeter with protected probe tips
- Insulated tools, if screwed connections are used in the tractive system
- Face shield
- HV insulating gloves (not expired)
- Two HV insulating blankets of at least 1.0 m^2 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.

IN 3 [EV ONLY] ACCUMULATOR INSPECTION

IN 3.1 Accumulator Inspection Objective

IN 3.1.1 At the accumulator inspection the accumulator charger, the accumulator container and its inner parts are checked for compliance with the rules.

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.

IN 3.1.2 An official temperature logging device will be installed, see EV 3.7.5.

IN 3.1.3 The accumulator charger will be inspected and sealed.

IN 3.2 Accumulator Inspection Required Items

IN 3.2.1 The following items must be presented at accumulator inspection:

- All accumulator containers
- Accumulator container hand cart
- Accumulator charger
- Data sheets of all parts used in the accumulator
- Tools needed for the (dis)assembly of parts
- Print-outs of rule questions (if applicable)

IN 4 [EV ONLY] ELECTRICAL INSPECTION

IN 4.1 Electrical Inspection Objective

IN 4.1.1 During the electrical inspection, all electrical parts and systems of the vehicle are checked for compliance with the rules.

IN 4.1.2 The insulation resistance between the tractive system and GLV system ground will be measured. Vehicles with a maximum tractive system voltage below or equal to 250 V will be

probed with 250 V and vehicles with a maximum tractive system voltage above 250 V with 500 V.

To pass this test, the measured insulation resistance must be at least 500 Ω/v related to the maximum tractive system voltage of the vehicle.

IN 4.1.3 The IMD will be tested by connecting a resistor between the tractive system measuring points, see EV 4.4, of the tractive system and GLV system ground connector, see EV 4.4.7.

The test is passed if the IMD shuts down the tractive system within 30 s at a fault resistance of 50 % below the response value which corresponds to 250 Ω/v.

IN 4.2 Electrical Inspection Required Items

IN 4.2.1 The following items must be presented at electrical inspection:

- One ESO
- Vehicle with mounted accumulator container
- Quick jack and push bar
- Samples of self designed PCBs that are part of the tractive system
- Tools needed for the BSPD check, see EV 5.5.6
- Data sheets of all parts used in the tractive system
- Tools needed for the (dis)assembly of parts for electrical inspection
- Print-outs of rule questions (if applicable)

IN 5 MECHANICAL INSPECTION

IN 5.1 Mechanical Inspection Objective

IN 5.1.1 During the mechanical inspection, all mechanical parts of the vehicle are checked for compliance with the rules.

IN 5.2 Mechanical Inspection Tire and Rim Combination

IN 5.2.1 Each team must present one set of tires for dry conditions and one set of tires for wet conditions mounted on rims.

IN 5.2.2 The tire type/rim type combination presented during technical inspection must be the same during the whole competition. The rims for dry tires and wet tires may be different.

IN 5.3 Mechanical Inspection Required Items

IN 5.3.1 The following items must be presented at mechanical inspection:

- The vehicle
- Quick jack 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)
- Only tools needed for the (dis)assembly of parts for mechanical inspection
- Set of tires on rims for wet conditions
- Set of tires on rims for dry conditions

IN 6 [DV ONLY] DRIVERLESS INSPECTION

IN 6.1 Driverless Inspection Objective

IN 6.1.1 The objective of the DV inspection is to approve that:

- All implemented sensors, including their mounting and location, are compliant with the rules.
- RES, ASMS, EBS, ASSI and the datalogging system are working as specified.

IN 6.2 Driverless Inspection Required Items

IN 6.2.1 The following items are required:

- One ASR
- The vehicle (in fully assembled , ready-to-race condition including mounted datalogger (see DV 1.3)
- Data sheets for all perception sensors
- Documents to proof that all perception sensors meet local legislations
- RES remote control
- System description and FMEA of the EBS
- Tools needed for the (dis)assembly of parts for DV inspection
- Print-outs of rule questions (if applicable)

IN 6.3 Driverless Inspection EBS Test

IN 6.3.1 The EBS performance will be dynamically tested and must demonstrate the performance described in rule DV 3.5.

IN 6.3.2 The test will be performed in a straight line marked with cones similar to acceleration.

IN 6.3.3 During the brake test, the vehicle must accelerate in autonomous mode up to at least 40 $^{km}/_{h}$ within 20 m. From the point where the RES is triggered, the vehicle must come to a safe stop within a maximum distance of 10 m.

IN 6.3.4 In case of wet track conditions, the stopping distance will be scaled by the officials dependent on the friction level of the track.

IN 7 TILT TEST

IN 7.1 Tilt Test Objective

IN 7.1.1 The tilt test is to evaluate the rollover stability of the vehicle and the fluid leakage.

IN 7.2 Tilt Test Procedure

IN 7.2.1 The tilt test will be conducted with the tallest driver fully strapped in normal driving position.

IN 7.2.2 The tilt test will be conducted with the vehicle containing the maximum amount of fluids it can carry.

IN 7.2.3 The vehicle will be placed upon the tilt table and then be tilted to an angle of 45°. No fluid leakage must be detected at this angle.

IN 7.2.4 If the vehicle passes this test, the angle is increased to 60° representing a cornering force of 1.7 g. All wheels must remain in contact with the tilt table surface at this angle.

IN 7.2.5 The tilt test is passed if the four wheels remained in contact with the tilt table surface and at a 45° angle there was no fluid leakage.

IN 8 VEHICLE WEIGHING

IN 8.1 Vehicle Weighing Objective

At the vehicle weighing, the the vehicle's official technical inspection weight is determined.

IN 8.2 Vehicle Weighing Procedure

IN 8.2.1 All vehicles must be weighed in ready-to-race condition.

IN 8.2.2 All parts containing fluids must be fully filled before weighing.

IN 9 [EV ONLY] RAIN TEST

IN 9.1 Rain Test Objective an General Definitions

IN 9.1.1 The rain test checks for protection of the electrical system from moisture in the form of rain or puddles.

IN 9.1.2 Vehicles must have passed electrical inspection, see IN 4, to attempt the rain test.

IN 9.2 Rain Test Procedure

IN 9.2.1 The vehicle must be in ready-to-race condition. All components and constructions used to protect the vehicle against water during rain test must be used during the complete competition.

IN 9.2.2 The tractive system must be active during the rain test.

IN 9.2.3 The vehicle must be jacked up using the quick jack (see T 12.2.1) and all four wheels need to be removed.

IN 9.2.4 The vehicle must not be in ready-to-drive mode, see EV 4.10.

IN 9.2.5 The test will be conducted without a driver.

IN 9.2.6 Water will be sprayed at the vehicle from any possible direction. The water spray is similar to rain and not a direct high-pressure water stream.

IN 9.2.7 The test is passed if the IMD is not triggered while water is sprayed for 120 s at the vehicle and 120 s after the water spray has stopped.

IN 10 [CV ONLY] NOISE TEST

IN 10.1 Noise Test Objective

IN 10.1.1 The vehicle will be checked for compliance with the sound level restrictions, see CV 3.2.

IN 10.2 Noise Test Procedure

IN 10.2.1 The sound level will be measured during a static test.

IN 10.2.2 The vehicle must be compliant at all engine speeds up to the maximum test speed, see CV 3.2.1.

IN 10.2.3 Teams must bring a laptop to indicate the engine rpm measured by the ECU.

IN 10.2.4 Measurements will be made with a free-field microphone placed free from obstructions at the exhaust outlet level, 0.5 m from the end of the exhaust outlet, at an angle of 45° with the outlet in the horizontal plane.

IN 10.2.5 Where more than one exhaust outlet is present, the test will be repeated for each exhaust and the highest reading will be used.

IN 10.2.6 If the exhaust has any form of active tuning or throttling device or system, it must be compliant with the rules in all positions. Manually adjustable tuning devices must require tools to change and must not be moved or modified after the noise test is passed. The position of the device must be visible to the officials and manually operable by the officials during the noise test.

IN 10.2.7 The test will be run with the gearbox in neutral. During this test the vehicle must be jacked up using the quick jack (see T 12.2.1).

IN 10.2.8 After passing the noise test the function of the master switch and cockpit-mounted shutdown button will be tested.

IN 10.2.9 After passing the test of the master switch and shutdown button the air tightness of the intake system will be tested by closing of the inlet after which the engine must stall.

IN 10.2.10 If the vehicle is unable to pass in three attempts, the vehicle must be repaired and then brought back for a retest.

IN 11 BRAKE TEST

IN 11.1 Brake Test Objective

IN 11.1.1 The brake system will be dynamically tested and must demonstrate the capability of locking all four wheels and stopping the vehicle in a straight line.

IN 11.2 Brake Test Procedure

IN 11.2.1 Locking of all four wheels and stopping the vehicle in a straight line at the end of an acceleration run specified by the officials without stalling the engine.

IN 11.2.2 [EV ONLY] After accelerating, the tractive system must be switched off by the driver and the driver must brake using only the mechanical brakes. It is acceptable for the TSAL to switch off shortly after the vehicle has come to a complete stop as the reduction of the system voltage may take up to 5 s.

IN 11.2.3 [DV ONLY] The procedure is described in IN 6.3

IN 11.2.4 The brake light and TSAL illumination will be checked and the officials will verify if the illumination is satisfactory for external observation.

IN 11.2.5 The ready-to-drive sound will be checked and the officials will verify if the sound level is satisfactory.

IN 11.2.6 If the vehicle is unable to pass the test in three attempts, the vehicle must be repaired and then brought back for retesting.

IN 12 POST EVENT INSPECTION

IN 12.1 Post Event Inspection Objective

IN 12.1.1 After finishing the endurance event ([DV ONLY] trackdrive), every vehicle is re-inspected to check for compliance with the rules.

IN 12.1.2 The vehicle may be re-inspected at any time during or after any of the dynamic events.

IN 12.2 Post Event Inspection Procedure

IN 12.2.1 After the endurance event, the vehicle must be placed in the parc fermé where no team member may access the vehicle.

IN 12.2.2 After a dynamic event, the vehicle must be in the same condition as required by the rules (except for normal wear).

IN 12.2.3 The officials reserve the right to impound any vehicle at any time during or after any of the dynamic events.

IN 12.2.4 If there is any violation of the rules, the team can receive a penalty given by the officials as follows:

- Violating the rules without any benefit to the team: -10 pts for each violation
- Violation of the rules with advantage for the team (e.g. wing): -30 pts for each violation
- Violation of the rules concerning safety or the environment (e.g. BOTS, harness issues, leaking, noise): Did Not Finish (DNF)

IN 12.2.5 Changes in vehicle weight of more than ± 5 kg compared to the official technical inspection weight (see IN 8) lead to -20 pts for the design event score per each additional kg or portion of a kg. Example: A weight difference of 6.2 kg (no matter if lighter or heavier) will lead to -40 pts.

IN 12.2.6 [EV ONLY] The vehicle must be able to enter ready-to-drive mode, see EV 4.10, during post inspection process for all tests requiring this mode. Violation will result in DNF.

IN 12.2.7 [EV ONLY] Directly after endurance and leaving parc fermé, every team must come back to the charging area to disassemble the temperature logging device from the accumulator container (see EV 3.7.5).

IN 12.2.8 [DV ONLY] Directly after endurance and leaving parc fermé, the data logger (see DV 1.3) will be disassembled from the vehicle.

S STATIC EVENTS

S 1 BUSINESS PLAN PRESENTATION EVENT (BPP)

S 1.1 Business Plan Presentation Objective

S 1.1.1 The objective of the BPP is to evaluate the team's ability to develop and deliver a comprehensive business model how their product – a prototype race car – could become a rewarding business opportunity.

S 1.1.2 The judges should be treated as if they were potential investors or partners for the presented business model.

S 1.1.3 The business plan must relate to the specific prototype race car entered in the competition. The actual quality of the prototype itself will not be considered as part of the BPP judging.

S 1.2 Business Plan Presentation Procedure

S 1.2.1 Presentations are limited to a maximum of ten minutes. The judges will stop any presentation exceeding ten minutes.

S 1.2.2 The presentation itself will not be interrupted by questions. Immediately following the presentation there will be a question and answer session.

S 1.2.3 One or more team members may present the business concept.

S 1.2.4 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.

S 1.2.5 Data projectors or screens with VGA input connectors will be provided. Teams planning to use other presentation equipment are responsible for bringing it themselves.

S 1.2.6 Teams that fail to make their presentation during their assigned time period will receive zero points for the BPP.

S 1.2.7 Prior to the competition a specific deep dive topic, which has to be part of the ten minute presentation, will be published on the competition website.

S 1.3 Executive Summary

S 1.3.1 To convince the potential investors or partners that the team's presentation is worthy of their time, it is required that an executive summary has to be submitted before the competition. The executive summary should contain a brief description of the team's business plan.

S 1.3.2 The executive summary must not exceed one page. The vehicle number must be written on this page.

S 1.3.3 The executive summary must be submitted online via the competition website, no later than the deadline specified in the competition handbook.

S 1.3.4 In case that the executive summary is not complaint with the rules, 5 penalty points are deducted from the final BPP score.

S 1.4 Business Plan Presentation Scoring

S 1.4.1 The BPP will be evaluated on the categories specified in the following table:

Category	Points
Executive Summary	10
Novelty	10
Content	20
Finances	10
Deep Dive Topic	10
Demonstration and Structure	15
Delivery	10
Questions	10
General Impression	5
Total	100

S 1.4.2 The judging at the competition will start with an initial judging, where all teams are judged by different judging groups. The top three to five teams are judged by all business judges in the BPP finals.

S 1.4.3 The scoring of the BPP is based on the average of the scores given by each of the judges.

S 1.4.4 The scoring for the non-finalist is calculated as followed:

$$BPPSCORE = 70\left(\frac{Pteam}{Pmax}\right)$$

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

S 1.4.5 The scoring of the BPP finalists will vary from 75 to 71 points and is scored immediately after the BPP finals by all judges. Possible penalties from A 5 could affect the final scoring.

S 2 Cost and Manufacturing Event

S 2.1 Cost and Manufacturing Objective

S 2.1.1 The objective of the cost and manufacturing event is to evaluate the team's understanding of the manufacturing processes and costs associated with the build 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.

S 2.2 Cost and Manufacturing Procedure

S 2.2.1 Prior to the competition, three Cost Report Documents (CRD) (see S 2.3) must be submitted to the competition website by the deadline specified in the competition handbook.

S 2.2.2 During the competition, a discussion with the judges will take place, next to the team's vehicle . The discussion is split into two parts:

S 2.2.3 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.

S 2.2.4 Part 2 "Cost Understanding":
A discussion to evaluate the general cost and manufacturing knowledge of the team. The following topics might be judged:

- Differences between prototype and mass production
- Resource and cost planning
- Financial and production risk management
- Make or buy decisions
- Environmental influence of the vehicle production
- Effectiveness of financial planning

S 2.2.5 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.

S 2.2.6 Teams are allowed to bring electronic, handwritten, or printed handouts, flip charts or similar to the event, but the given space may be limited.

S 2.2.7 If the team takes too long, blocks the bay or does not show up on-time, five penalty points will be deducted from the team's cost event score.

S 2.3 Cost Report Documents (CRD)

S 2.3.1 The CRD consist of the following documents:

- The BOM 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

S 2.3.2 An addendum for the CRD is not possible and changes will not be permitted after the deadline.

S 2.3.3 All CRD documents must be printed by the team and brought as a hard copy to the event discussion.

S 2.3.4 The website tool will provide a printable pdf version of the BOM.

S 2.3.5 The hard copy must be in a ring binder with DIN A4 pages (or similar).

S 2.3.6 The hard copy must be identical to the uploaded version.

S 2.4 Bill of Material (BOM)

S 2.4.1 The BOM is a sorted list for every vehicle part including the associated manufacturing processes.

S 2.4.2 The BOM must:

- List every part and equipment fitted on the prototype vehicle at any time during the competition.
- Be based on the actual manufacturing processes used for the prototype.
- Include tooling (e.g. welding jigs, molds, patterns and dies).
- Not include any cost, except for the "systems" described in S 2.5.

S 2.4.3 The BOM is structured as follows:

- The BOM is broken down into "systems" (see S 2.4.4), which are defined by the website tool.
- Each "system" is broken down into "assemblies", which are defined by the website tool.
- Each "assembly" is broken down into "parts", which must be defined by the team.
- Each "part" is broken down into "materials" and "processes".
- Each "process" may be broken down into "tooling" and "fasteners", if applicable.

S 2.4.4 The "systems" are:

- Brake System
- Engine and Drivetrain
- Frame and Body
- Electrical
- Miscellaneous, Fit and Finish
- Steering System
- Suspension System
- Wheels, Wheel Bearings and Tires
- [DV ONLY] Autonomous system

S 2.4.5 The "assemblies" of each "system" are given by the website tool.

S 2.4.6 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”.

S 2.4.7 Each “part” of an “assembly” must be classified as “bought” or “made”.

S 2.4.8 For each “bought part”, only fasteners must be included (if required). If the part was modified, the associated processes for this modification must to be included.

S 2.4.9 For each “made part” the raw material, all production processes, tooling and all required fasteners must be included.

S 2.4.10 “Processes” are the necessary operations to produce the “part” out of the “material”.

S 2.4.11 “Material” is the used raw material of a part, eg. aluminium.

S 2.4.12 “Tooling” are the necessary tools used for transforming the “material” into the desired shape.

S 2.4.13 “Fasteners” are additional items necessary to assemble the “part”.

S 2.4.14 Within the BOM, only metric units must be used.

S 2.4.15 Only the dry tires and wheels per rule T 1.5.1 need to be included and must be mounted on the vehicle during judging.

S 2.4.16 One or two systems of the BOM have to be a CBOM, see S 2.5.

S 2.5 Costed Bill of Material (CBOM)

S 2.5.1 The actual costs of the prototype vehicle as presented must be included for one or two BOM system(s) specified in the competition handbook.

S 2.5.2 The cost calculations must include the costs of materials, fabrication, bought parts and assembly to the vehicle and must be done as realistic as possible.

S 2.5.3 The cost calculations must exclude research, development and capital expenditures for real estates (e.g. plant or development hours of the team).

S 2.5.4 All costs must be displayed in EUR. For calculating the prices in EUR from other currencies, the team must provide the exchange rates used.

S 2.5.5 There is no maximum cost. Receipts are not required for any items.

S 2.5.6 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.

S 2.5.7 The costs of hand or power tools must not be included.

S 2.5.8 The estimations for machining rates, hourly rates, included overheads etc. must be shown.

S 2.6 Supporting Material File

S 2.6.1 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.

S 2.7 Cost Explanation File

S 2.7.1 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.

S 2.7.2 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.

S 2.8 Cost and Manufacturing Vehicle Condition

S 2.8.1 Vehicles must be presented for cost and manufacturing judging in finished condition, fully assembled, complete, ready-to-race and with its dry tires (see T 1.5.1) mounted.

S 2.8.2 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.

S 2.8.3 Vehicles may be presented for judging without having passed technical inspection, even if final tuning and setup is in progress.

S 2.8.4 Covers and/or parts may be removed during the judging to facilitate access and presentation of components or concepts.

S 2.9 Cost and Manufacturing Scoring

S 2.9.1 The following maximum scores apply for the cost and manufacturing event:

Category	Points
Format and Accuracy of Documents	5
Knowledge of Documents and Vehicle	5
Content and Completeness of the BOM	30
Realism of the CBOM	10
Discussion Part 2 “Cost Understanding”	50
Total	100

S 2.9.2 In case of missing items within the BOM, points are deducted up until zero points scoring for “Content and Completeness of the BOM”:

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

S 3 Engineering Design Event

S 3.1 Engineering Design Objective

S 3.1.1 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.

S 3.1.2 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.

S 3.2 Engineering Design Report (EDR)

S 3.2.1 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.

S 3.2.2 The EDR must not exceed eight pages, consisting of not more than five pages of content (text, which may include pictures and graphs) and three pages of drawings.

S 3.2.3 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.

S 3.2.4 Any measures to facilitate reviewing the drawings (e.g. measurements, details, colors) may be utilized on the teams' discretion.

S 3.2.5 Any portions of the EDR that exceed five pages of content and/or three pages of drawings will not be evaluated.

S 3.2.6 If included, cover sheets and tables of contents will count as text pages.

S 3.2.7 The EDR will be used to sort the teams into appropriate design queues based on the quality of its review.

S 3.2.8 Evidence of information mentioned in the EDR should be brought to the competition and be available, on request, for review by the judges.

S 3.3 Design Spec Sheet (DSS)

S 3.3.1 A completed DSS must be submitted online on the competition website.

S 3.4 Engineering Design Procedure

S 3.4.1 The design event starts with the submission of the EDR and the DSS and their review respectively.

S 3.4.2 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 S 3.1.

S 3.4.3 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.

S 3.4.4 Teams may bring any photographs, drawings, charts, spare parts or other material that they believe are supportive to the design event, but the given space for design judging may be limited.

S 3.5 Engineering Design Vehicle Condition

S 3.5.1 Vehicles must be presented for design judging in finished condition, fully assembled, complete and ready-to-race.

S 3.5.2 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.

S 3.5.3 Vehicles may be presented for design judging without having passed technical inspection, even if final tuning and setup is in progress.

S 3.5.4 Covers and/or parts may be removed during the design judging to facilitate access and presentation of components or concepts.

S 3.6 Engineering Design Judging Criteria

S 3.6.1 The judges will evaluate the engineering effort based upon the team's EDR and DSS, responses to questions and an inspection of the vehicle.

S 3.6.2 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).

S 3.6.3 The judges may deduct points if the team cannot adequately explain the engineering and construction of the vehicle.

S 3.7 Engineering Design Scoring

S 3.7.1 The overall engineering design event maximum scoring is 150 points.

S 3.7.2 The following maximum scores apply for the engineering design event:

Category	Points
Overall Vehicle Concept	25
Vehicle Perfomance	35
Mechanical / Structural Engineering	25
Drivetrain	35
LV-Electrics / Electronic	10
Driver Interface	15
Engineering Design Report (EDR)	5
Total	150

S 4 [DV ONLY] AUTONOMOUS DESIGN EVENT

S 4.1 Autonomous Design Objective

S 4.1.1 The purpose of this event is to evaluate the capability of the vehicle to drive autonomously. Therefore, all systems that are required to drive autonomously will be investigated. This also includes a discussion about the hardware and the software used in the autonomous system. Since the autonomous design event takes place after the dynamic disciplines, the vehicle's movements of the trackdrive are also taken into account.

S 4.1.2 The autonomous design consists of three parts: the Autonomous Design Report (ADR), the autonomous design presentation + discussion and the race review.

S 4.2 Autonomous Design General Specifications

S 4.2.1 The autonomous design event starts with the submission of the ADR and respectively with its review.

S 4.2.2 There will be no autonomous design finals.

S 4.2.3 The autonomous design event takes place without the vehicle itself.

S 4.3 Autonomous Design Report (ADR)

S 4.3.1 The ADR will be used to sort the teams into appropriate design queues, based on the quality of its review.

S 4.3.2 The ADR should contain a description of the autonomous system 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 autonomous system to the judges shall be included at the team's discretion.

S 4.3.3 Evidence of information mentioned in the ADR should be brought to the competition and be available, on request, for review by the judges.

S 4.3.4 The ADR must not exceed five pages of content (text, which may include pictures and graphs).

S 4.3.5 Any portions of the ADR that exceed five pages of content will not be evaluated.

S 4.3.6 The ADR must be written as a scientific paper.

S 4.3.7 The penalties for late-submission or non-submission are equal to the ones that are used for the engineering design report.

S 4.4 Autonomous Design Presentation

S 4.4.1 At the competition teams will present themselves, their knowledge and their autonomous system to the judges, who will evaluate the team's performance following the design objectives stated in rule S 4.1. This will be done in the form of a presentation of the team.

S 4.4.2 An open discussion is appended to the team's presentation.

S 4.4.3 Teams may bring any photographs, drawings, charts, spare parts, sensors, actuators or other material that they believe are supportive to the presentation and the discussion, but the given space for design judging may be limited.

S 4.5 Autonomous Design Race Review

S 4.5.1 The race review takes place after the discussion.

S 4.5.2 Based on the data gained during the trackdrive, the movements and decisions of the vehicle are discussed. Therefore, the software and the algorithms of the vehicle are investigated in detail.

S 4.5.3 If the vehicle was not able to compete in the trackdrive, the team may show some simulation test data, where the judges can see how the algorithms work.

S 4.6 Autonomous Design Judging Criteria

S 4.6.1 The judges will evaluate the engineering effort based upon the team's ADR, the presentation and the discussion afterwards.

S 4.6.2 The presentation itself is part of the judging.

S 4.6.3 The judges will inspect the autonomous system to determine if the design concepts are adequate and appropriate for the application.

S 4.6.4 It is the responsibility of the judges to deduct points if the team cannot adequately explain the engineering and construction of the autonomous system.

S 4.7 Autonomous Design Scoring

S 4.7.1 The overall autonomous design event scoring may range from 0 to 175 points.

S 4.7.2 The judges may, at their discretion, award the highest placing team less than 175 points.

S 4.7.3 The ADR is awarded 25 out of 175 points.

S 4.7.4 The presentation of the autonomous system and subsequent discussion is awarded 100 out of 175 points.

S 4.7.5 The race review is awarded 50 out of 175 points.

D DYNAMIC EVENT REGULATIONS

D 1 DYNAMIC EVENTS GENERAL

D 1.1 Driver Limitations

D 1.1.1 In total, a minimum of four and a maximum of six drivers are allowed for each team.

D 1.1.2 An individual driver may not drive in more than two dynamic events.

D 1.1.3 The endurance and efficiency event is considered a single event.

D 1.1.4 [DV ONLY] DV teams are not required to register drivers but may register up to three drivers for testing in manual mode.

D 1.2 Dynamic Area and Dynamic Vests

D 1.2.1 The tech inspections and all dynamic events are held in the dynamic area.

D 1.2.2 Four dynamic vests are handed out to each team by the officials and must be worn in the dynamic area.

D 1.2.3 Only four members per team, including the driver, may enter the dynamic area.

D 1.2.4 Drivers must not wear the dynamic vest when sitting in the vehicle. The driver's vest must not be fixed on the vehicle.

D 1.2.5 The number of tools that may be used in this area is restricted to an amount which can be safely carried by these four team members in one trip.

D 1.2.6 Engines may be run in the staging queue on the order of the officials.

D 2 DRIVING RULES

D 2.1 Flags

D 2.1.1 Flag signals are commands that must be obeyed immediately and without question.

D 2.1.2 [DV ONLY] There will be no flag signs for DV in autonomous mode.

D 2.1.3 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.

D 2.1.4 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.

D 2.1.5 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.

D 2.1.6 CHECKERED FLAG – The session has been completed. The driver must exit the course at the first opportunity.

D 2.1.7 GREEN FLAG –

(a) The session has started, the driver may enter the course 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.

(b) The driver is clear to re-enter the track after using the slow lane to let a faster vehicle pass.

(c) The driver may pick up speed again after a yellow flag was displayed.

D 2.1.8 RED FLAG – The driver must come to an immediate safe and controlled stop on the course and must follow track marshals directions.

D 2.1.9 YELLOW FLAG – Danger, the driver must slow down, something has happened beyond the flag station, no overtaking unless directed by the track marshals.

D 2.1.10 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 maneuvers to avoid the situation.

D 2.2 Driving Under Power

D 2.2.1 During driving, the mechanical integrity of the vehicle must be maintained.

D 2.2.2 Vehicles must not be driven in reverse.

D 2.2.3 The vehicle must be capable of starting and restarting without external assistance/batteries at all times.

D 2.2.4 Push starts are prohibited.

D 2.2.5 Vehicles may only be driven under power when running in an dynamic event, on the practice track and during brake test.

D 2.2.6 Driving off-site is absolutely prohibited. Teams found to have driven their vehicle at an off-site location during the period of the competition are excluded from the competition.

D 2.2.7 Burnouts prior and during the events are prohibited.

D 2.2.8 [DV ONLY] When driving autonomously, an ASR has to be present at the race control with the RES. Additionally, one single monitoring device (laptop, tablet, ...) may be brought (no complicated antenna construction or comparable!).

D 2.3 Ground Clearance

D 2.3.1 The minimum static ground clearance of any portion of the vehicle, other than the tires, including a driver, must be a minimum of 30 mm.

D 2.3.2 Sliding skirts or other aerodynamic devices that by design, fabrication or as a consequence of moving, contact the track surface are prohibited. Any violation may be penalized by a mechanical black flag.

D 2.3.3 The ground clearance may be tested at any time at the exit of a dynamic event / parc fermé. Any offense will lead to a DNF in the last run prior the check.

D 2.4 Practice Track

D 2.4.1 A practice track for testing and tuning vehicles is available.

D 2.4.2 [DV ONLY] A practice track for DV will be available (autonomous/manual).

D 2.4.3 To use the practice track, vehicles must have passed all technical inspections.

D 2.4.4 Practice or testing at any location other than the practice track is absolutely forbidden.

D 2.5 [DV ONLY] Cones & Markings

D 2.5.1 [DV ONLY] Details on used cones and more detailed track layout figures can be found in the "DV event-specific technical specification" document .

D 2.6 [DV ONLY] Vehicle Break Downs and Usage of RES

D 2.6.1 Stalling the engine or deactivating the tractive system for any reason during a dynamic event will result in DNF as the autonomous system is not allowed to restart the engine/reactivate the tractive system.

D 2.6.2 If a vehicle comes to standstill for any reason, it may have up to 30 s to attempt to continue to drive. If the vehicle doesn't restart within 30 s, it will be deactivated using the RES, deemed disabled and scored as DNF for the run.

D 2.6.3 The officials may stop the vehicle using the RES in any of the following cases:

(a) Its behavior seems to be uncontrolled (e.g. driving off-course).

(b) It is mechanically or electrically damaged.

(c) It is driving too slow.

(d) The stop is requested by the team's ASR.

(e) To ensure safe conditions on the track (e.g. persons or animals on the track). In this case the team will get a re-run.

D 2.6.4 If a vehicle breaks down or is stopped by the use of the RES it will be removed from the course, will not be allowed to re-enter the course and scored DNF.

D 2.6.5 If a traceable signal loss of the RES appears and the doubtless proof can be brought by the team that it is was not self-inflicted, a re-run may be granted.

D 2.6.6 At the direction of the officials, team members may be instructed to retrieve broken-down vehicles. This recovery may only be done under the control of the officials.

D2.7 [DV ONLY] Procedure After Completing a Dynamic Event

D2.7.1 The vehicle must be picked up by the ASR and an additional team member immediately after approval from the officials.

D2.7.2 After leaving the marked area, the vehicle may only be moved using the pushbar and a driver sitting in the vehicle.

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 In case an event was carried out in different 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 course consists of two pairs of concentric circles in a figure of eight pattern.

D4.1.2 The centers of these circles are 18.25 m apart. The inner circles are 15.25 m in diameter and the outer circles are 21.25 m 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 A cone will be placed in the middle of the exit gate to prevent unintended exits until the last lap (not for DV).

D4.1.6 The driving path is the 3 m wide path between the inner and outer circles. The vehicles enter and exit through gates on a 3 m wide path that is at a tangent to the circles where they meet.

D4.1.7 The line between the centers 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.

D4.1.8 Independent of the weather, the track conditions will be made artificially “wet” (not for DV).

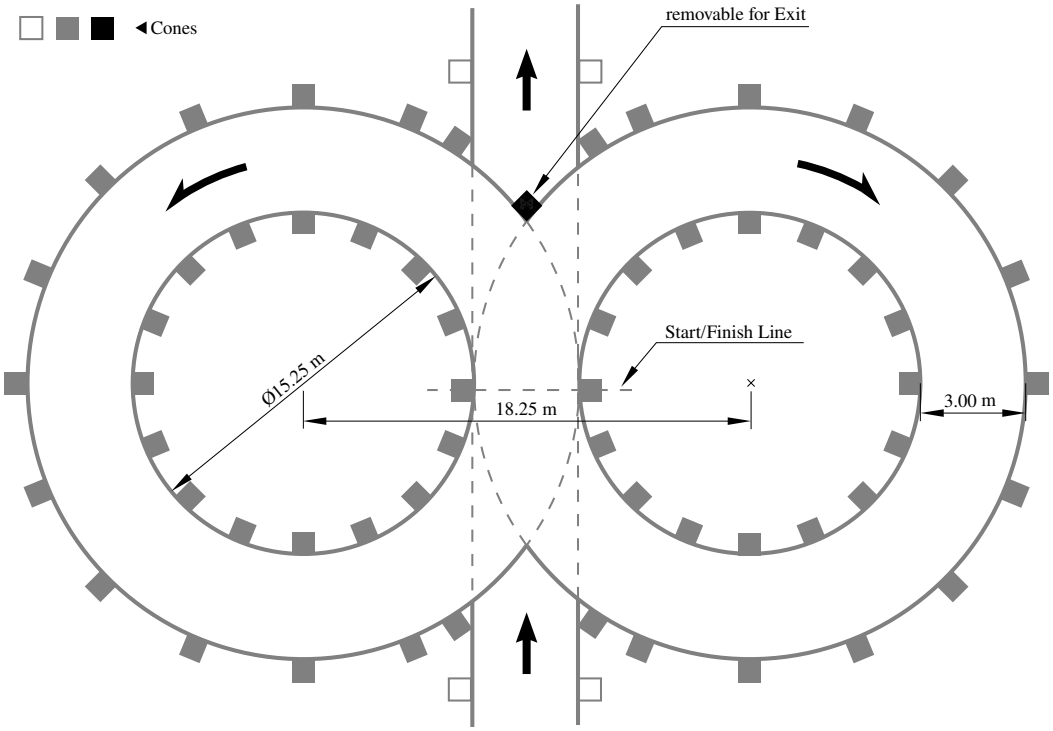

Figure 20: Skidpad Track Layout

D4.2 Skidpad Procedure

D4.2.1 Each team has four runs, driven by two drivers with two runs each.

D4.2.2 Each driver has the option to make a second run immediately after their first run.

D4.2.3 The starting order is based on the time the team arrives at the skidpad event. Teams on their first run will receive priority.

D4.2.4 Starting - A green flag is used to indicate that the driver may start.

D 4.2.5 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.

D 4.3 [DV ONLY] Skidpad Procedure

D 4.3.1 Staging - The foremost part of the vehicle is staged at 15 m in front of the timekeeping line.

D 4.3.2 Each team has two runs.

D 4.3.3 Starting order is based upon time of arrival. Teams on their first run will receive priority.

D 4.3.4 Starting - A go-signal from RES is used to indicate the approval to begin.

D 4.3.5 The vehicle will enter perpendicular to the figure eight and will take one full lap on the right circle to establish the turn. The next lap will be on the right circle and will be timed. Immediately following the second lap, the vehicle will enter the left circle for the third lap. The fourth lap will be on the left circle and will be timed. Immediately upon finishing the fourth lap, the vehicle will exit the track.

D 4.3.6 The vehicle will exit at the intersection moving in the same direction as entered and must come to a full stop within 25 m behind the timekeeping line, inside the marked exit lane and enter the finish-state described in DV 2.3 .

D 4.4 Skidpad Scoring

D 4.4.1 The run time is the average time of the timed left and the timed right circle plus penalties.

D 4.4.2 3.5 points are awarded to every team that finishes at least one run without DNF.

D 4.4.3 If a team's run time including penalties is below T_{max}, additional points based on the following formula are given:

$$SKIDPADSCORE = 71.5 \left(\frac{\left(\frac{T_{\max}}{T_{\text{team}}} \right)^2 - 1}{0.5625} \right)$$

T_{team} is the team's best run time including penalties.
T_{max} is 1.25 times the time of the fastest vehicle including penalties.

D 5 ACCELERATION EVENT

D 5.1 Acceleration Track Layout

D 5.1.1 The acceleration course is a straight line with a length of 75 m from starting line to finish line. The course is at least 5 m wide. Cones are placed along the course at intervals of about 5 m. Cone locations are not marked on the pavement.

D 5.2 Acceleration Procedure

D 5.2.1 Each team has four runs, driven by two drivers with two runs each.

D 5.2.2 Each driver has the option to make a second run immediately after their first run.

D 5.2.3 Staging - The foremost part of the vehicle is staged at 0.30 m behind the starting line. Vehicles will accelerate from a standing start.

D 5.2.4 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.

D 5.2.5 The starting order is based on the time the team arrives at the acceleration event. Teams on their first run will receive priority.

D 5.3 [DV ONLY] Acceleration Procedure

D 5.3.1 Each team has two runs.

D 5.3.2 Staging - The foremost part of the vehicle is staged at 0.30 m behind the starting line. Vehicles will accelerate from a standing start.

D 5.3.3 Starting - A go-signal from RES is used to indicate the approval to begin, timing starts only after the vehicle crosses the starting line and stops after it crosses the finish line.

D 5.3.4 After the finish line, the vehicle must come to a full stop within 100 m inside the marked exit lane and enter the finish-state described in DV 2.3.

D 5.3.5 Starting order is based upon time of arrival. Teams on their first run will receive priority.

D 5.4 Acceleration Scoring

D 5.4.1 3.5 points are awarded to every team that finishes at least one run without a DNF.

D 5.4.2 If a team's best time including penalties is below T_{max}, additional points based on the following formula are given:

$$ACCELERATIONSCORE = 71.5 \left(\frac{\frac{T_{max}}{T_{team}} - 1}{0.5} \right)$$

T_{team} is the team's best time including penalties.
T_{max} is 1.5 times the time of the fastest vehicle including penalties.

D 6 AUTOCROSS EVENT

D 6.1 Autocross Track Layout

D 6.1.1 The autocross track layout is a handling course built with the following guidelines:

- Straights: No longer than 80 m
- Constant Turns: up to 50 m diameter

- Hairpin Turns: Minimum of 9 m outside diameter (of the turn)
- Slaloms: Cones in a straight line with 7.5 m to 12 m spacing
- Miscellaneous: Chicanes, multiple turns, decreasing radius turns, etc. The minimum track width is 3.5 m.

D 6.1.2 The length of the autocross track is less than 1.5 km.

D 6.2 Autocross Procedure

D 6.2.1 Each team has up to four runs, driven by two drivers with two runs each.

D 6.2.2 Each driver has the option to make a second run immediately after their first run.

D 6.2.3 Staging - The vehicle is staged at a staging line prior to the starting line.

D 6.2.4 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.

D 6.2.5 The starting order is based on the time the team arrives at the autocross event. Teams on their first run will receive priority.

D 6.3 Autocross Scoring

D 6.3.1 4.5 points are awarded to every team that finishes at least one run without DNF.

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

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

T_{team} is the team's best time including penalties.
T_{max} is 1.25 times the time of the fastest vehicle including penalties.

D 7 Endurance and Efficiency Event

D 7.1 Endurance Track Layout

D 7.1.1 The endurance track layout is a closed lap circuit built with the following guidelines:

- Straights: No longer than 80 m
- Constant Turns: up to 50 m diameter
- Hairpin Turns: Minimum of 9 m outside diameter (of the turn)
- Slaloms: Cones in a straight line with 9 m to 15 m spacing
- Miscellaneous: Chicanes, multiple turns, decreasing radius turns, etc.
- The minimum track width is 3.5 m

D 7.1.2 The length of one lap of the endurance track is approximately 1 km.

D 7.1.3 The length of the complete endurance is approximately 22 km.

D 7.2 Endurance Procedure

D 7.2.1 Before entering the event, each CV's fuel tank must be filled to the fuel level line (see rule CV 2.6.3, "Fuel Level Line") at the fueling station. During fueling, once filled to the scribe line, no shaking or tilting of the tank, the fuel system or the entire vehicle is allowed.

D 7.2.2 There is only one run for the endurance event.

D 7.2.3 A driver change must be made during a three minute period at the midpoint of the run.

D 7.2.4 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.

D 7.2.5 Starting - A green flag is used to indicate that the driver may start. Timing starts only after the vehicle crosses the starting line.

D 7.2.6 The first driver will drive for 11 km and will then be signaled into the driver change area.

D 7.2.7 After the driver change specified in D 7.4, the second driver will drive for an additional 11 km and will be signaled to exit the track after crossing the finish line.

D 7.2.8 After leaving the track, the vehicle must be powered down.

D 7.2.9 For CV, the second driver will proceed directly to the fueling station. The tank will be filled to the refill mark and the amount of fuel will be recorded.

D 7.2.10 For EVs, the second driver will proceed directly to the energy meter download area, where the data will be downloaded.

D 7.2.11 The starting order is defined by the officials so that vehicles of similar speed potential are on track together, to reduce the need for overtaking.

D 7.3 Passing

D 7.3.1 During the endurance event, overtaking may only be done in the designated passing zones and under the control of the track marshals.

D 7.3.2 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.

D 7.3.3 Passing zones may be situated on either the left or right of the fast lane.

D 7.3.4 The passing zone procedure will be as follows:

- A slower leading vehicle will be shown the blue flag and must drive into the slow lane and decelerate
- The following faster vehicle will continue in the fast lane to pass the slow vehicle
- The vehicle that has been overtaken may re-enter the track when the track marshal who is in charge of that passing zone is showing the green flag.

D 7.3.5 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.

D 7.4 Endurance Driver Change Procedure

D 7.4.1 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.

D 7.4.2 For electric vehicles, the three team members must consist of an ESO and two drivers.

D 7.4.3 During the driver change, the team may:

- perform changes to accommodate the second driver
- operate the master switch(es)
- change tires as per D 7.5.

No other work may be performed during the driver change.

D 7.4.4 Each team is given three minutes to change their driver.

D 7.4.5 The driver change time will start once the vehicle is stopped in the driver change area and the first driver has turned off the engine for CV or turned off the tractive system for EVs.

D 7.4.6 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.

D 7.4.7 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.

D 7.4.8 If the driver change takes longer than three minutes, the extra time is included in the final time.

D 7.5 Endurance Event Tire Changes

D 7.5.1 All tire changes after a vehicle has received the green flag to start the endurance event must take place in the driver change area.

D 7.5.2 If the operating condition changes to wet during endurance, the track will be red flagged and all vehicles brought into the driver change area.

D 7.5.3 In case a team wants to change tires, the officials need to be informed beforehand.

D 7.5.4 In some cases, tire changes can be carried out directly after the driver change, for others the team must make an extra stop.

D 7.5.5 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 in excess of ten minutes without driver change, or thirteen minutes with driver change, is added to the team's total time for endurance.
Note 2: The time used to change to dry tires is added to the team's total time for endurance.

D 7.5.6 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.

D 7.5.7 The wheel will be inspected by the officials. If the deflation was not caused by external factors, the vehicle will be scored DNF.

D 7.5.8 Deflation caused by running off course or impacting barriers or other objects due to driver error will not be regarded as external factors.

D 7.6 Endurance Specific Regulations

D 7.6.1 Teams are prohibited to work on their vehicles or fuel the vehicles during the run.

D 7.6.2 Wheel-to-wheel racing is prohibited.

D 7.6.3 Passing another vehicle may only be done per D 7.3.

D 7.6.4 If a vehicle stalls out on the track, it is allowed one lap by the vehicle that is following it (approximately one minute) to restart.

D 7.6.5 If a vehicle has a restart problem at the driver change or after a red flag, it is allowed two minutes to restart the engine or to enable the tractive system. The two minutes start from the time the driver first tries to restart the engine or to enables the tractive system. The time is counted towards the endurance time.

D 7.6.6 If restarts are not accomplished within the above times, the vehicle is scored a DNF for the run.

D 7.6.7 If a vehicle breaks down it will be removed from the course and will not be allowed to re-enter the course.

D 7.6.8 Team members may be instructed by the officials to retrieve broken down vehicles. This recovery may only be done under the control of the officials.

D7.7 Endurance Scoring

D7.7.1 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.

D7.7.2 The post event technical inspection (see IN12) must be passed to score points in the endurance event.

D7.7.3 25 points are awarded to every team that finishes endurance without DNF.

D7.7.4 If a team's corrected elapsed time is below T_{max}, additional points based on the following formula are given:

$$ENDURANCESCORE = 300 \left(\frac{\frac{T_{max}}{T_{team}} - 1}{0.333} \right)$$

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

D7.8 [CV ONLY] Efficiency Scoring

D7.8.1 Energy efficiency is measured during the endurance event.

D7.8.2 Only vehicles which score points in the endurance event will receive points for efficiency.

D7.8.3 Teams whose fuel volume used during the endurance event exceeds $26 l/100$km receive zero points for fuel efficiency.

D7.8.4 Teams whose corrected elapsed endurance time exceeds T_{max} as defined in D7.7.4 receive zero points for efficiency.

D7.8.5 After finishing the endurance the vehicle is guided to to fuel station and filled up by an official.

D7.8.6 Fuel pumps will be turned on and fuel valves will be opened to ensure complete refueling.

D7.8.7 If a team finishes the endurance event, efficiency points based on the following formula are given:

$$EFFICIENCYSCORE = 100 \left(\frac{\frac{E_{min}}{E_{team}} - 1}{\frac{E_{min}}{E_{max}} - 1} \right)$$

E_{team} is the team's efficiency factor.
E_{max} is the highest efficiency factor of all teams who are able to score point in efficiency.
E_{min} is the lowest efficiency factor of all teams who are able to score point in efficiency.

D7.8.8 The efficiency factor is calculated based on the following formula:

$$EFFICIENCYFACTOR = \frac{T_{min} \cdot V_{min}}{T_{team} \cdot V_{team}}$$

T_{team} is the team's corrected elapsed time.
T_{min} is the fastest corrected elapsed time of all teams who are able to score point in efficiency.

V_{team} is the team's corrected used fuel volume.
V_{min} is the lowest corrected used fuel volume of all teams who are able to score point in efficiency.

D7.8.9 The measured fuel volume of vehicles using E 85 fuel is divided by 1.4 to be comparable to the vehicles using 98 RON.

D7.9 [EV ONLY] Efficiency Scoring

D7.9.1 Energy efficiency is measured during the endurance event.

D7.9.2 Before the endurance event, energy meter memory storage may be cleared by an official.

D7.9.3 The energy meter data is read out when the vehicle is in parc fermé.

D7.9.4 The endurance energy is calculated as the time integrated value of the measured voltage multiplied by the measured current logged by the energy meter. Regenerated energy is multiplied with 0.9 and subtracted from the used energy.

D7.9.5 Only vehicles which score points in the endurance event will receive points for efficiency.

D7.9.6 Teams whose corrected elapsed endurance time exceeds T_{max} as defined in D7.7.4 receive zero points for efficiency.

D7.9.7 If a team finishes the endurance event, efficiency points based on the following formula are given:

$$EFFICIENCYSCORE = 100 \left(\frac{\frac{0.1}{E_{\text{team}}} - 1}{\frac{0.1}{E_{\text{max}}} - 1} \right)$$

E_{team} is the team's efficiency factor.
E_{max} is the highest efficiency factor of all teams who are able to score point in efficiency.

D7.9.8 The efficiency factor is calculated based on the following formula:

$$EFFICIENCYFACTOR = \frac{T_{\text{min}} \cdot {EN_{\text{min}}}^2}{T_{\text{team}} \cdot {EN_{\text{team}}}^2}$$

T_{team} is the team's corrected elapsed time.
T_{min} is the fastest corrected elapsed time of all teams who are able to score point in efficiency.
EN_{team} is the team's corrected used energy.
EN_{min} is the lowest corrected used energy of all teams who are able to score point in efficiency.

D8 [DV ONLY] TRACKDRIVE AND EFFICIENCY EVENT

D8.1 Trackdrive Tracklayout

D8.1.1 The trackdrive layout is a closed loop circuit built with the following guidelines:

- Straights: No longer than 80 m

- Constant Turns: up to 50 m diameter
- Hairpin Turns: Minimum of 9 m outside diameter (of the turn)
- Miscellaneous: Chicanes, multiple turns, decreasing radius turns, etc.
- The minimum track width is 3.5 m

D 8.1.2 The length of one lap is approximately 200 m to 500 m.

D 8.2 Trackdrive Procedure

D 8.2.1 Starting order is defined by the officials, based on acceleration and skidpad results.

D 8.2.2 Before entering the event, each DV, with a fuel tank (CV), must be filled to the fuel level line (see rule CV 2.6.3, "Fuel Level Line") at the fueling station. During fueling, once filled to the scribe line, no shaking or tilting of the tank, the fuel system or the entire vehicle is allowed.

D 8.2.3 There will be one run consisting of ten laps only.

D 8.2.4 Staging - The vehicle is staged such that the front wheels are 6 m in front of the starting line on the track.

D 8.2.5 Starting - A go-signal from RES is used to indicate the approval to begin. Timing starts after the vehicle crosses the starting line.

D 8.2.6 After ten laps the vehicle must come to a full stop within 30 m behind the finish line on the track and enter the finish-state described in DV 2.4.

D 8.2.7 There will be no last lap signal i.e. the vehicle need to count laps on its own.

D 8.2.8 The team must proceed directly to the fueling station (DV with internal combustion engine) or the energy meter download area (electric DV) respectively after finishing trackdrive.

D 8.3 Trackdrive Course Walk

D 8.3.1 There will be a course walk prior to the trackdrive to allow teams to collect track data. Trolleys, handcarts, scooters, drones etc. are not allowed for the course walk. Measurement wheels or other devices (e.g. a monopod to guide a camera) using one single wheel are allowed.

D 8.4 Trackdrive Scoring

D 8.4.1 Each lap of the trackdrive event is individually timed. The corrected elapsed time is determined by adding any penalty times.

D 8.4.2 If a team's corrected elapsed time is below T_{max} and the run was no DNF, points based on the following formula are given:

$$TRACKDRIVESCORE = 150 \left(\frac{\frac{T_{\max}}{T_{\text{team}}} - 1}{0.5} \right)$$

T_{team} is the team's corrected elapsed time.
T_{max} is 1.5 times of the corrected elapsed time of the fastest vehicle.

D 8.4.3 An additional ten points are awarded for every completed lap, independent of the corrected elapsed time. This is also applied for teams that do not finishing the trackdrive i.e. get a DNF.

D 8.5 Efficiency Scoring

D 8.5.1 Energy efficiency is measured during the trackdrive event.

D 8.5.2 Only vehicles which complete the trackdrive event will receive points for efficiency.

D 8.5.3 [EV ONLY] Rules D 7.9.2 to D 7.9.6 are applied.

D 8.5.4 [CV ONLY] Rules D 7.8.3 to D 7.8.6 and D 7.8.9 are applied.

D 8.5.5 [CV ONLY] The trackdrive energy is calculated based on following formula:

$$E_{team} = V_{team} \cdot 3.55\,{}^{\mathrm{kWh}}/_{\mathrm{l}}$$

V_{team} is the team's corrected used fuel volume.

D 8.5.6 The team's efficiency is calculated based on D 7.9.7 and D 7.9.8.

D 9 Dynamic Events Penalties

D 9.1 General Penalties

D 9.1.1 Penalties will not be assessed for accident avoidance or other reasons deemed sufficient by the officials.

D 9.1.2 A cone is 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.

D 9.1.3 [DV ONLY] Cones that are DOO are not replaced/reset during the run. There will be no rerun due to cones in the driving path or disorientation due to missing cones.

D 9.1.4 The DOO penalty (see D 9.1.8) is added for each DOO including entry and exit gate cones before the start and after the finish line, that occur on that particular run.

D 9.1.5 [DV ONLY] The DOO penalty for any cone is applied for any Lap in which a cone isDOO (e.g. if a cone was hit in Lap 7, the DOO penalty is applied for laps 7-10)

D 9.1.6 Off-course (OC)

- An OC occurs when the vehicle has all four wheels outside the course 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.

D 9.1.7 [DV ONLY] An Unsafe Stop (USS) is defined as not stopping within the specified area and/or not entering the finish-state described in DV 2.4.

D 9.1.8

	Acceleration	Skidpad	Autocross	Endurance	Trackdrive
DOO	2 s	0.2 s	2 s	2 s	2 s
OC	DNF	DNF	10 s	10 s	DNF
USS	DNF	DNF	n/a	n/a	−50 points

D 9.1.9 DNF equals zero points on that run.

D 9.1.10 If a team Did Not Attempt (DNA) an event the score is zero points.

D 9.1.11 Each run with an incorrect number of laps at skidpad is classified as DNF.

D 9.1.12 Failure to obey a flag: one minute time penalty.

D 9.1.13 Reckless or aggressive driving or "Over Driving": black flag (see D 2.1.3)

D 9.1.14 Vehicle to vehicle contact: Two minutes up to disqualification depending on the nature of the incident.

D 9.1.15 If a vehicle stalls and cannot restart without external assistance, the vehicle is DNF for that run.

D 9.1.16 [EV ONLY] Each power or voltage violation, see EV 2.2, is DNF for the fastest run. If a violation occured during two runs, the two fastest runs will be DNF etc.

D 9.2 Endurance Penalties

D 9.2.1 Out of order running: Teams that are not ready-to-race when their turn arrives for endurance are penalized two minutes and may then run at the discretion of the officials.

D 9.2.2 Mechanical Problem: The time taken for mechanical inspection under a "mechanical black flag" (see D 2.1.4) 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.

D 9.2.3 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.

D 9.2.4 A team may receive a DNF if their vehicle is too slow or being driven without proper control.

D 9.2.5 Any violation to the procedure of driver change (D 7.4.3) lead to a time penalty of up to two minutes.

D 9.3 [CV ONLY] Efficiency Penalties

D 9.3.1 Should the fuel level change after refueling due to effects such as described in CV 2.7.1, then the difference in fuel level will be measured and twice the amount will be added to the official fuel consumption figure.