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## CHANGELOG

| Rule     | Version | Change   |
|----------|---------|--|
| A 1.2.1  | 1.0     | Included CV Hybrid into CV class   |
| A 3.7    | 1.0     | Simplified and clarified protest rules   |
| A 3.8.1  | 1.0     | Defined minimum penalty for rules violation  |
| A 3.8.2  | 1.0     | Defined penalty handling for DC  |
| A 4.2.8  | 1.0     | Defined “first competition”  |
| A 4.3.8  | 1.0     | Replaced reference to HV by TS   |
| A 4.4.2  | 1.0     | Clarified total number of ESOs and ASRs  |
| A 5.3.1  | 1.0     | Simplified rule  |
| A 5.4    | 1.0     | Extended late submission handling to all deadlines   |
| A 5.6.7  | 1.0     | Re-added rule that was accidentally removed  |
| A 6.4.6  | 1.1     | Replaced APPS/brake pedal plausibility check by BSPD   |
| A 6.7    | 1.0     | Removed rule about the HVD   |
| A 6.7.7  | 1.0     | Clarified rule   |
| A 6.10   | 1.0     | Added requirements for working on an EV  |
| T 1.1.2  | 1.0     | Added definition of bodywork   |
| T 1.1.2  | 1.1     | Clarified rule   |
| T 1.1.12 | 1.0     | Harmonized impact structures under respective rule   |
| T 1.1.16 | 1.0     | Updated definition of rollover protection envelope   |
| T 1.1.18 | 1.0     | Updated definition of surface envelope   |
| T 1.1.18 | 1.1     | Clarified definition of surface envelope   |
| T 2.2.1  | 1.0     | Added restriction for active suspension  |
| T 2.3.2  | 1.0     | Added rule about the shape of the bodywork   |
| T 2.3.2  | 1.1     | Clarified rule   |
| T 2.3.4  | 1.0     | Clarified rule   |
| T 2.4.1  | 1.0     | Unified minimum radius for aerodynamic devices and bodywork  |
| T 2.4.1  | 1.1     | Clarified rule   |
| T 2.6.2  | 1.0     | Clarified rule   |
| T 2.8.9  | 1.0     | Prescribed positioning of steering rack  |
| T 2.8.9  | 1.1     | Clarified rule   |
| T 3.2.1  | 1.0     | Changed value to resolve historical discrepancy with SES and updated   |
| T 3.4.4  | 1.0     | Added thickness restriction for asymmetrical lay-ups   |
| T 3.5.4  | 1.0     | Added rule to define not quasi-isotropic laminate direction and alignment  |
| T 3.15.2 | 1.0     | Added rule to remove inconsistencies between side- and other impact structures   |
| T 3.15.3 | 1.0     | Added minimum absorbed energy requirement for two baseline steel tubes and updated rule to remove inconsistencies between side and other impact structures |
| T 3.17.1 | 1.0     | Clarified rule   |
| T 3.17.3 | 1.0     | Clarified rule   |
| T 3.17.5 | 1.0     | Redefined IA attachment requirements   |
| T 3.17.7 | 1.0     | Added minimum adhesive strength requirement for “standard” honeycomb IA  |

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| <b>Rule</b> | <b>Version</b> | <b>Change</b>  |
|-------------|----------------|--|
| T3.19.1     | 1.0            | Clarified allowance of testing mass and enforcement of rule  |
| T3.19.4     | 1.0            | Added physical testing requirement for non-crushable object(s) located in direct front view of the AIP |
| T4.8.7      | 1.1            | Require solid layer  |
| T5.5.3      | 1.0            | Clarified rule by separation of bar and bracing  |
| T6.1.8      | 1.1            | Clarified position of the brake system   |
| T6.1.10     | 1.0            | Clarified that brake pedal includes the pedal face   |
| T6.1.11     | 1.0            | Removed [EV ONLY] label, also valid for HY   |
| T6.2.3      | 1.0            | Changed requirements for BOTS  |
| T6.2.3      | 1.1            | Clarified rule   |
| T6.3.2      | 1.0            | Redefined brake light as system status light to clarify requirements                                   |
| T7.2.2      | 1.0            | Changed to accommodate HY  |
| T7.2.3      | 1.0            | Clarified wording for heat resistant cover plate positioning   |
| T7.2.7      | 1.0            | Clarified engine and motor(s) cooling specification  |
| T9.1.1      | 1.0            | Added exception for gas springs  |
| T10.1.5     | 1.0            | Added new rule about fasteners   |
| T10.2.3     | 1.0            | Changed wording for snap or retaining rings  |
| T11.1.5     | 1.0            | Added low power control signal voltage limit for HY  |
| T11.4.7     | 1.0            | Added rule that shutdown buttons must be red   |
| T11.5.4     | 1.0            | Clarified wording for inertia switch mounting  |
| T11.7.7     | 1.0            | Applied rule for all HSC, regardless of chemistry type   |
| T11.8.5     | 1.0            | Changed requirements for APPS  |
| T11.9.3     | 1.0            | Moved SCS wording to a separate rule   |
| T11.10.1    | 1.0            | Introduced definition of system status light   |
| T11.11      | 1.0            | Unified wording for electrical component mounting  |
| T12.2.1     | 1.0            | Added hybrid vehicle identification requirements   |
| T13.2.2     | 1.0            | Changed wording for positioning the jacks  |
| T13.2.3     | 1.0            | Changed size of jacks  |
| T13.3.2     | 1.0            | Removed standards that expire after 31.12.2023   |
| T13.3.3     | 1.0            | Added frontal head restraint system standards  |
| T13.3.10    | 1.0            | Added validity of fire resistant clothing  |
| T13.3.12    | 1.0            | Clarified embroidered driver's clothing  |
| T13.3.13    | 1.0            | Updated fire resistant material usage in driver's clothing   |
| T14.2.3     | 1.0            | Added new requirement concerning data logger mounting for CV   |
| T14.9.2     | 1.0            | Added additional logic to transition from AS Finished to AS Emergency                                  |
| T14.10.3    | 1.0            | Specified requirements on ASSI visibility  |
| T14.10.4    | 1.0            | Redefined ASSI as system status light to clarify requirements  |
| T14.11.3    | 1.0            | Added new requirement concerning mission selection   |
| T15.1       | 1.0            | Removed redundant rule about brake system specifications   |
| T15.1.2     | 1.0            | Clarified allowed locations for parts of ASB   |
| T15.4.2     | 1.0            | Increased requirement on EBS performance   |
| CV1.1.1     | 1.0            | Allowed hybrid powertrains   |
| CV1.3.2     | 1.0            | Harmonized impact structures   |
| CV1.3.2     | 1.1            | Clarified T3.16 reference  |
| CV2.2       | 1.0            | Removed redundant rule about fuel system parts below the chassis (already defined by EV4.4.1)          |
| CV2.4.1     | 1.0            | Added temperature rating for fuel lines  |

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| Rule       | Version | Change  |
|------------|---------|---|
| CV 2.4.2   | 1.0     | Allowed unmodified OEM fuel lines and connectors                                      |
| CV 2.4.3   | 1.0     | Clarified rule  |
| CV 3.2     | 1.0     | Moved noise test requirements to IN 10  |
| CV 4.1     | 1.0     | Changed shutdown circuit for HY integration   |
| CV 4.1.4   | 1.0     | Added HSC AIR to shutdown circuit   |
| CV 5       | 1.0     | Added section for hybrid system restrictions and requirements                         |
| EV 1.2.1   | 1.0     | Clarified test voltage, added working voltage requirement                             |
| EV 1.2.1   | 1.1     | Require working voltage only if given in the datasheet                                |
| EV 2.2.3   | 1.0     | Removed APPS / brake pedal plausibility check   |
| EV 3.1.1   | 1.0     | Require solid layer   |
| EV 3.1.2   | 1.0     | Added LVS ground measuring point  |
| EV 3.2.5   | 1.0     | Relaxed overcurrent protection of motors  |
| EV 4.3.6   | 1.0     | Removed PCB spacing exception for integrated circuits                                 |
| EV 4.4     | 1.0     | Removed redundant rule about TS parts below the chassis (already defined by EV 4.4.1) |
| EV 4.4.2   | 1.0     | Harmonized impact structures  |
| EV 4.4.2   | 1.1     | Clarified T 3.16 reference and added exception for outboard wheel motors              |
| EV 4.5.2   | 1.0     | Moved requirement to different rule   |
| EV 4.5.3   | 1.0     | Added requirement from a different rule   |
| EV 4.5.13  | 1.0     | Relaxed rule  |
| EV 4.5.14  | 1.0     | Clarified rule  |
| EV 4.7.5   | 1.0     | Clarified rule  |
| EV 4.7.7   | 1.0     | Linked bolted and soldered connections to the high current path requirements          |
| EV 4.8.1   | 1.0     | Relaxed rule  |
| EV 4.8.2   | 1.0     | Relaxed rule  |
| EV 4.10.8  | 1.0     | Defined angle per side  |
| EV 4.10.12 | 1.1     | Relaxed rule  |
| EV 4.12.1  | 1.0     | Clarified rule  |
| EV 5.4.3   | 1.0     | Limited to TSAL's green light   |
| EV 5.4.10  | 1.0     | Defined voltage indicator supply  |
| EV 5.5     | 1.0     | Removed redundant rule on joining walls and floor                                     |
| EV 5.5.1   | 1.0     | Harmonized impact structures  |
| EV 5.5.2   | 1.0     | Harmonized impact structures  |
| EV 5.5.2   | 1.1     | Clarified T 3.16 reference  |
| EV 5.5.3   | 1.0     | Require 60 °C for calculations  |
| EV 5.5.9   | 1.0     | Require $\geq 80\%$ of large surface, extended cell tab requirements                  |
| EV 5.5.9   | 1.1     | Relaxed rule, loading $\geq 80\%$ of one large surface is sufficient                  |
| EV 5.5.10  | 1.0     | Require testing of friction-based cell mounting                                       |
| EV 5.5.12  | 1.0     | Relaxed AIR and the main fuse separation  |
| EV 5.5.14  | 1.0     | Defined max. total cutout area  |
| EV 5.5.14  | 1.1     | Clarified rule  |
| EV 5.5.15  | 1.0     | Split rule, clarified cooling ducts requirements                                      |
| EV 5.6     | 1.0     | Removed redundant rule about fuse rating  |
| EV 5.6.3   | 1.0     | Shortened rule without changing the rule  |
| EV 5.7.1   | 1.0     | Changed to voltage at the vehicle side of the AIRs                                    |
| EV 5.8.4   | 1.0     | Clarified rule  |
| EV 5.8.12  | 1.0     | Require a single overview showing all values  |

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| <b>Rule</b> | <b>Version</b> | <b>Change</b>   |
|-------------|----------------|---|
| EV 6.3.2    | 1.0            | Added Bender ISOMETER® iso165C-1  |
| EV 6.3.2    | 1.1            | Added Bender A-ISOMETER® iso-F1 IR155-4203 and -4204                                |
| EV 7.1.10   | 1.0            | Added charger labeling  |
| EV 8.1.6    | 1.0            | Detailed hand cart firewall specification   |
| EV 8.1.8    | 1.0            | Added rule that hand cart must be larger than TSAC                                  |
| EV 8.1.10   | 1.0            | Require dedicated label on hand cart  |
| EV 8.1.10   | 1.1            | Clarified rule  |
| IN 1.5.1    | 1.0            | Allowed installation and removal of protective sensor covers                        |
| IN 4.1.3    | 1.0            | Move and rephrase BSPD test   |
| IN 5.1.1    | 1.0            | Require that test piece and test fixture must be presented at mechanical inspection |
| IN 5.1.1    | 1.0            | Added required items for HY   |
| IN 11.2.3   | 1.0            | Increased requirement on EBS performance  |
| IN 12.1.3   | 1.0            | Clarified rule  |
| S 1.1.1     | 1.0            | Clarified rule  |
| S 1.1.3     | 1.0            | Removed redundant information   |
| S 1.4.2     | 1.0            | Reduced penalty   |
| S 2.4.4     | 1.0            | Moved “fastener” definition to BOM and clarified they should not be listed          |
| S 3.4.6     | 1.0            | Changed condition of spare cells  |
| S 3.4.8     | 1.0            | Added separate design finals for DC   |
| S 3.7.2     | 1.0            | Changed scoring categories for engineering design event                             |
| D 2.4.1     | 1.0            | Removed distinction between autonomous and manual mode                              |
| D 2.7.6     | 1.0            | Clarified that re-runs are granted only for autonomous runs                         |
| D 2.7.6     | 1.0            | Clarified that officials must be notified before the dynamic event closes           |
| D 2.9       | 1.0            | Added new subsection on handling of Re-Runs   |
| D 4.4       | 1.0            | Changed scoring formula to refer to table 3 for maximum number of points            |
| D 4.5       | 1.0            | Changed scoring formula to refer to table 3 for maximum number of points            |
| D 4.6       | 1.0            | Changed scoring formula to refer to table 3 for maximum number of points            |
| D 5.1.1     | 1.0            | Removed restriction that cones are not marked                                       |
| D 5.4       | 1.0            | Changed scoring formula to refer to table 3 for maximum number of points            |
| D 5.5       | 1.0            | Changed scoring formula to refer to table 3 for maximum number of points            |
| D 5.6       | 1.0            | Changed scoring formula to refer to table 3 for maximum number of points            |
| D 6.1       | 1.0            | Removed rule about DC autocross using the same track as the trackdrive event        |
| D 6.1.3     | 1.1            | DC autocross layout is according to guidelines for trackdrive layout                |
| D 6.3       | 1.0            | Changed scoring formula to refer to table 3 for maximum number of points            |
| D 6.5       | 1.0            | Changed scoring formula to refer to table 3 for maximum number of points            |
| D 7.3.2     | 1.0            | Clarified rule  |
| D 7.3.3     | 1.0            | Clarified rule  |
| D 7.6.6     | 1.0            | Clarified tire change after puncture  |
| D 7.7.4     | 1.1            | Clarified rule  |
| D 7.8       | 1.0            | Changed scoring formula to refer to table 3 for maximum number of points            |
| D 7.9       | 1.0            | Changed scoring formula to refer to table 3 for maximum number of points            |
| D 8.2.2     | 1.0            | Clarified rule  |
| D 8.2.3     | 1.0            | Clarified rule  |
| D 8.4       | 1.0            | Changed scoring formula to refer to table 3 for maximum number of points            |
| D 9.1.6     | 1.0            | Added max. time to enter finish state   |
| D 9.2.4     | 1.0            | Clarified rule  |

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| <b>Rule</b> | <b>Version</b> | <b>Change</b>   |
|-------------|----------------|---|
| D9.2.4      | 1.0            | Added definition of being too slow                        |
| D9.2.6      | 1.0            | Added new rule about penalties                            |
| D9.4.2      | 1.0            | Clarified that DQ(s) apply to fastest <i>valid</i> run(s) |

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## ABBREVIATIONS

|             |                                    |             |   |
|-------------|------------------------------------|-------------|---|
| <b>AIP</b>  | Anti Intrusion Plate               | <b>EBS</b>  | Emergency Brake System                  |
| <b>AIR</b>  | Accumulator Isolation Relay        | <b>EDR</b>  | Engineering Design Report               |
| <b>AMI</b>  | Autonomous Mission Indicator       | <b>EI</b>   | Flexural Rigidity                       |
| <b>AMS</b>  | Accumulator Management System      | <b>ESF</b>  | Electrical System Form                  |
| <b>APPS</b> | Accelerator Pedal Position Sensor  | <b>ESO</b>  | Electrical System Officer               |
| <b>AS</b>   | Autonomous System                  | <b>ESOQ</b> | Electrical System Officer Qualification |
| <b>ASB</b>  | Autonomous System Brake            | <b>ETC</b>  | Electronic Throttle Control             |
| <b>ASF</b>  | Autonomous System Form             | <b>EV</b>   | Electric Vehicle                        |
| <b>ASMS</b> | Autonomous System Master Switch    | <b>HPI</b>  | High Pressure Injection                 |
| <b>ASR</b>  | Autonomous System Responsible      | <b>HSC</b>  | Hybrid Storage Container                |
| <b>ASRQ</b> | ASR Qualification                  | <b>HSF</b>  | Hybrid System Form                      |
| <b>ASSI</b> | Autonomous System Status Indicator | <b>HV</b>   | High Voltage                            |
| <b>BOM</b>  | Bill of Material                   | <b>HVD</b>  | High Voltage Disconnect                 |
| <b>BOTS</b> | Brake Over-Travel Switch           | <b>HY</b>   | Combustion Hybrid Vehicle               |
| <b>BPP</b>  | Business Plan Presentation Event   | <b>IA</b>   | Impact Attenuator                       |
| <b>BPPV</b> | Business Plan Pitch Video          | <b>IAD</b>  | Impact Attenuator Data                  |
| <b>BSPD</b> | Brake System Plausibility Device   | <b>IMD</b>  | Insulation Monitoring Device            |
| <b>CBOM</b> | Costed Bill of Material            | <b>LPI</b>  | Low Pressure Injection                  |
| <b>CRD</b>  | Cost Report Documents              | <b>LV</b>   | Low Voltage                             |
| <b>CV</b>   | Internal Combustion Engine Vehicle | <b>LVMS</b> | Low Voltage Master Switch               |
| <b>DBOM</b> | Detailed Bill of Material          | <b>LVS</b>  | Low Voltage System                      |
| <b>DC</b>   | Driverless Cup                     | <b>OC</b>   | Off-Course                              |
| <b>DI</b>   | Direct Injection                   | <b>R2D</b>  | Ready-to-drive                          |
| <b>DNA</b>  | Did Not Attempt                    | <b>RES</b>  | Remote Emergency System                 |
| <b>DNF</b>  | Did Not Finish                     | <b>SCS</b>  | System Critical Signal                  |
| <b>DOO</b>  | Down or Out                        | <b>SDC</b>  | Shutdown Circuit                        |
| <b>DQ</b>   | Disqualified                       | <b>SE3D</b> | Structural Equivalency 3D Model         |
| <b>DSS</b>  | Design Spec Sheet                  | <b>SES</b>  | Structural Equivalency Spreadsheet      |
| <b>DV</b>   | Driverless                         | <b>SESA</b> | SES Approval                            |



## Abbreviations

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|             |                                       |             |                                 |
|-------------|---------------------------------------|-------------|---------------------------------|
| <b>TPS</b>  | Throttle Position Sensor              | <b>TSMP</b> | Tractive System Measuring point |
| <b>TS</b>   | Tractive System                       | <b>TSMS</b> | Tractive System Master Switch   |
| <b>TSAC</b> | Tractive System Accumulator Container | <b>USS</b>  | Unsafe Stop                     |
| <b>TSAL</b> | Tractive System Active Light          | <b>VSV</b>  | 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) including Combustion Hybrid Vehicle (HY)
- Electric Vehicle (EV)

A 1.2.2 All vehicles must meet the requirements defined in chapters T and either EV or CV, depending on their drivetrain type.

A 1.2.3 The competition starts with a series of technical inspections described in chapter IN to check the vehicle for safety and compliance with the rules.

A 1.2.4 The competition is divided into a series of static and dynamic events described in chapters S and D.

A 1.2.5 The achievable points in each class are listed in table 3.

A 1.2.6 Vehicles of both classes can take part in an additional Driverless Cup (DC).

A 1.2.7 The maximum achievable points for the DC are listed in table 3.

A 1.2.8 The team with the most overall points will win the competition for its class or the DC, respectively.

### 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.

A 1.3.3 Every organizer of a competition based on this document bears the sole responsibility.

## A2 Vehicle Eligibility

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|                              | CV & EV     | DC         |
|------------------------------|-------------|------------|
| Static Events:               |             |            |
| Business Plan Presentation   | 75 points   | -          |
| Cost and Manufacturing       | 100 points  | -          |
| Engineering Design           | 150 points  | 150 points |
| Dynamic Events:              |             |            |
| Skidpad                      | 50 points   | -          |
| Driverless (DV) Skidpad      | 75 points   | 75 points  |
| Acceleration                 | 50 points   | -          |
| Driverless (DV) Acceleration | 75 points   | 75 points  |
| Autocross                    | 100 points  | -          |
| Driverless (DV) Autocross    | -           | 100 points |
| Endurance                    | 250 points  | -          |
| Efficiency                   | 75 points   | -          |
| Trackdrive                   | -           | 200 points |
| Overall                      | 1000 points | 600 points |

Table 3: Maximum points awarded

## A2 VEHICLE ELIGIBILITY

### A2.1 Student Competition

- A2.1.1 Vehicles entered into the competition must be conceived, designed and maintained by the student team members without direct involvement from external professional engineers, racers, machinists or related professionals.
- A2.1.2 The student team may use any information from professionals or from academics as long as the information is given as a discussion of alternatives with their pros and cons.
- A2.1.3 Professionals must not make design decisions or drawings.
- A2.1.4 Students should perform fabrication tasks where ever possible.

### A2.2 First Year Vehicles

- A2.2.1 A vehicle may only be used for one year, counting from the first day onsite of its first competition.
- A2.2.2 To be classified as new, a vehicle must have at minimum, a newly manufactured chassis with significant changes in the primary structure to its predecessor.

## **A3 Rules of Conduct**

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### **A 3 RULES OF CONDUCT**

#### **A3.1 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 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.

#### **A3.2 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 results in 25 penalty points being deducted from the team’s overall score.

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

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

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

- A 3.4.1 In the event of unsportsmanlike conduct, 25 penalty points will be deducted from the team’s overall score. A second violation results in expulsion of the team from the competition.

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

- A 3.5.1 Violation of the intent of a rule will be considered a violation of the rule itself.
- A 3.5.2 Any parts, devices or software fragments designed with the intent to violate a rule, will be considered as a violation.

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

- 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.

## **A4 General Requirements for Teams & Participants**

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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 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 3.7.2 All protests must be submitted in writing as defined in the competition handbook by the team captain within the announced protest period. 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 3.7.3 The decision of the officials regarding any protest will be in a written form and is final.

### **A 3.8 Penalties**

A 3.8.1 Rule violations result in at least 20 penalty points, unless explicitly defined otherwise. The penalty points will be deducted from the team's overall score.

A 3.8.2 Overall penalties apply to CV, EV and DC score, except for penalties concerning events which are not part of the respective class or cup.

## **A 4 GENERAL REQUIREMENTS FOR TEAMS & PARTICIPANTS**

### **A 4.1 Teams per University**

A 4.1.1 A university can register one CV team and one EV team which both can take part in the DC.

A 4.1.2 For the purposes of registering and competing, a university's CV team and EV 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 and Participants**

A 4.2.1 Each participant must provide proof of valid private liability & individual health insurance for the competition.

A 4.2.2 All onsite participants must sign a liability waiver upon registering onsite which can be found on the competition website.

A 4.2.3 A team member may only be part of one team, work on one vehicle and take part in static and dynamic events for only one team.

A 4.2.4 Each team must have one team member identified as the team captain. The team captain is the main contact person for the officials during the registration process and the competition.

A 4.2.5 Persons who have previously attended any official event as a judge are not allowed to participate as team members.

## **A4 General Requirements for Teams & Participants**

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- A 4.2.6 Team members must be enrolled as degree seeking undergraduate or graduate students in any university. Team members who have graduated within the seven month period prior to the competition remain eligible to participate.
- A 4.2.7 Students seeking a PhD degree/PhD students or equivalent are not allowed to participate.
- A 4.2.8 Counting from the year of their first competition, team members can only participate for four additional full years. First competition is defined as the first registration of a team member for a competition by the team captain, irrespective if the team or the team member actually physically participated.
- A 4.2.9 Team members must be at least 18 years of age.
- A 4.2.10 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 4.3 [EV ONLY] Electrical System Officer**

- A 4.3.1 Every participating team has to appoint one to four ESOs for the competition.
- A 4.3.2 The ESOs are responsible for all electrical work carried out on the vehicle during the competition.
- A 4.3.3 The ESOs are the only persons 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 4.3.4 The ESOs must be valid team members, i.e. they must have student status, see A 4.2.6.
- A 4.3.5 The ESOs must be contactable by phone at all times during the competition.
- A 4.3.6 An ESO must accompany the vehicle whenever it is operated or moved around at the competition site.
- A 4.3.7 If only one ESO is named by the team, this ESO must not be a driver.
- A 4.3.8 An appropriate Electrical System Officer Qualification (ESOQ) requires the proof of a practical and theoretical training for working on the TS. Regarding content, the training should be on the basis of DGUV 209-093 stage 2E/3E<sup>1</sup> and held by an external expert.

### **A 4.4 Autonomous System Responsible**

- A 4.4.1 To operate the Autonomous System (AS), every participating team must appoint at least one ASR for the competition. This person is responsible for all autonomous operations of the vehicle during the competition which includes any work on the AS as well as racing and testing.
- A 4.4.2 For vehicles with an electric drivetrain the ASR must fulfill A 4.3 and therefore replaces the ESO. The team may register additional ESOs for accumulator inspection and work on Tractive System (TS) only. The sum of registered ASRs and ESOs must not exceed four persons.

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<sup>1</sup><https://fsg.one/4i5SP>

## **A5 Documentation & Deadlines**

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- A 4.4.3 The ASR is the only person in the team who is allowed to declare the AS safe, so that the vehicle may be operated in manual or autonomous mode.
- A 4.4.4 The ASR must be a valid team member, i.e. they must have student status, see A 4.2.6.
- A 4.4.5 The ASR must accompany the vehicle whenever it is operated or moved around at the competition site.
- A 4.4.6 If only one ASR is named by the team, this ASR must not be a driver.
- A 4.4.7 The ASR must be properly qualified to handle the AS and to understand and deal with problems and failures. As ASR Qualification (ASRQ), a bachelor degree in computer science, electrical engineering, mechatronics, automation engineering, robotics or similar , i.e. comparable study content or progress, is a sufficient qualification. The qualification certificate needs to be an official university document and contain information on completed courses.

## **A 5 DOCUMENTATION & DEADLINES**

### **A 5.1 Required Documents and Forms**

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

### **A 5.2 Submission**

- A 5.2.1 Submitted documents may only be viewed by members of the submitting team, authorized judges and officials.
- A 5.2.2 By submitting documents via the competition website, the team agrees that they may be reproduced and distributed by the officials, in both complete and edited versions, for educational purpose.
- A 5.2.3 Documents or videos that are largely incomplete or not readable/viewable will be considered as not submitted.

### **A 5.3 Correction Requests**

- A 5.3.1 If the officials request a correction for a document, the corrected version has to be submitted within 168 hours (7 days) following the request.
- A 5.3.2 Separate requests for different parts within one document or form will be treated independently.
- A 5.3.3 If the corrected version of the document does not completely contain all requested corrections, the team will be de-registered from the competition.

## **A 5 Documentation & Deadlines**

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### **A 5.4 Late Submission or Non-Submission**

- A 5.4.1 For each submission later than the respective deadline 10 penalty points are deducted from the team's overall score.
- A 5.4.2 Teams that do not submit documents until 24 hours (1 day) after the respective deadline will be de-registered from the competition.

### **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 place 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 for de-registration (e.g. submission 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 20 penalty points.
- 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**

- A 5.6.1 All teams must submit a video showing the vehicle driving prior to the competition. The video must be submitted before the deadline specified in the competition handbook.
- A 5.6.2 The video must show the following sequences in the described order:
- Standing still
  - 360° video around the vehicle (close up, may overlap with the following two bullet points)
  - [EV ONLY] Activate TS
  - [CV ONLY] Start engine
  - Straight driving, minimum distance is 30 m, minimum speed is 10 km/h for vehicles with driver
  - Full stop (not needed for [DC ONLY] video)
  - 180° cornering
  - Straight driving back to start point, minimum speed is 10 km/h for vehicles with driver
  - [DC ONLY] At the end of the VSV, the vehicle must be stopped by an emergency brake maneuver (see T 15).
  - Standing still



## A5 Documentation & Deadlines

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- A5.6.3 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 under its own power
  - Driving must follow A6.4.6
  - Vehicle must be presented in ready-to-race conditions incl. body work
  - No crossing in front of the vehicle after [EV ONLY] TS activated / [CV ONLY] engine started
  - [EV ONLY] Tractive System Active Light (TSAL), [DC ONLY] Autonomous System Status Indicator (ASSI), and brake light, must be clearly visible in the video
  - [EV ONLY] Ready-to-drive (R2D) sound must be audible in the video
  - [DC ONLY] Vehicle must drive without a driver
  - [DC ONLY] In addition to the third person view, an onboard view and a visualization of the vehicle's environment perception and path planning must be shown in split screen. All parts must be time synchronized.
  - Must not exceed a length of 60 seconds. File size may be limited, see the competition handbook.
  - File format must be common e.g. avi, mpg, mp4, wmv
- A5.6.4 The VSV will be reviewed in order of submission. A review may take up to two weeks.
- A5.6.5 If a team receives a "fail" for its video prior to the VSV deadline, the video will be treated as not submitted. A new submission is possible afterwards. In all other situations A5.4 and A5.3 apply.
- A5.6.6 If a team fails only the [DC ONLY] part, it will only be de-registered from the DC.
- A5.6.7 A team which uploads a VSV with a previous year vehicle will be de-registered from the competition.

### A5.7 SES Approval

- A5.7.1 Teams using a monocoque must submit a SESA as one document, in addition to the SES deadline. The SESA template will be available on the competition website.
- A5.7.2 The Structural Equivalency Spreadsheet (SES) must be checked and approved by a graduated engineer with appropriate expertise.
- A5.7.3 Once the SES has been approved, the SESA form should be filled out, signed and submitted until the SESA deadline.
- A5.7.4 If any changes to the original SES become necessary due to the approval process, the updated final SES must be submitted again on the competition website.
- A5.7.5 The changelog with details of all changes made from the "Version History" tab of the SES form must be attached to the SESA document and must also be signed by the SES reviewer.

## **A 6 General Rules**

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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 TS 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 Briefing**

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 All ASRs are required to attend the team briefing.

#### **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 disassociate 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, before, during 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 for a testing/operating environment to qualify as safe. Following these guidelines does not guarantee safety under all circumstances:

- Driver wearing full protection gear according to T 13.3
- Working TSAL, IMD, AMS, ASSI, RES, EBS, BSPD, APPS, and ETC plausibility check if applicable
- Rules compliant chassis and mounted Impact Attenuator (IA)
- No other passenger cars, trucks etc. being parked or driven on the same premise at the same time, unless the areas are clearly separated

## A 6 General Rules

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- 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 team registered for 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 Appropriate personal protective equipment must be used.

A 6.5.3 Any operation producing litter or debris, e.g. cutting of carbon fiber, should not be performed in the pits.

A 6.5.4 When jacking up the vehicle a safe and stable support device rated for the load must be used.

### 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. A second team member being found to have an alcohol level higher than 0.0‰ results in the entire team being disqualified immediately.

### A 6.7 Vehicle Movement

A 6.7.1 Vehicles must not move under their own power anywhere other than 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 completely removed and kept by an ESO. The lockout/tagout function of the TSMS, see EV 6.2.2, must be used.

A 6.7.3 Vehicles must also have their AS, see T 14.6, deactivated when being moved around the paddock. The ASR must ensure no unauthorized activation of the Autonomous System Master Switch (ASMS) following T 14.6.8.

A 6.7.4 Vehicles must be pushed at a normal walking pace by means of a "push bar", see T 13.1, and with a team member in the cockpit wearing the required driver equipment as defined in T 13.3 except for helmet, arm restraints and balaclava.

A 6.7.5 The team member in the cockpit must have full control of steering and braking.

## **A 6 General Rules**

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- A 6.7.6 When the push bar is attached to the vehicle, the engine/TS must remain switched off.
- A 6.7.7 Vehicles with wings are required to have two team members walking on either side of the front wing whenever the vehicle is being pushed.

### **A 6.8 [CV ONLY] Engine Running**

- A 6.8.1 Running 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 using the jacks, see T 13.2.
  - A driver, wearing required driver equipment, see T 13.3, must be seated in the cockpit.
  - A fire extinguisher must be immediately available.
  - Driven wheels can only remain fitted to the vehicle if they will not rotate.
  - No one is allowed under the vehicle while the engine is running.
- A 6.8.3 Cranking engines in the pits is allowed, when the following conditions are met:
- The vehicle has passed mechanical inspection.
  - The driven axles are securely jacked up.
  - Gearbox is in neutral.
  - All driven wheels are removed.
  - Connectors to all injectors and ignition coils are detached.
  - A fire extinguisher must be placed next to the engine.

### **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.

### **A 6.10 [EV ONLY] Working on the Vehicle**

- A 6.10.1 All activities require the TSAL to be green.
- A 6.10.2 A prominent manual sign indicating the “TSAL green” state must be present whenever the LVS is switched off and the requirements for an only green TSAL according to EV 4.10 are met.
- A 6.10.3 All activities on the vehicle, except when working on an active TS, require the High Voltage Disconnect (HVD) to be removed.

## **A 6 General Rules**

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### **A 6.11 [EV ONLY] Working on the Tractive System**

A 6.11.1 Activities on the TS, except for the accumulator, see A 6.12, must take place in the pit.

A 6.11.2 All activities require the attendance of the ESO.

A 6.11.3 For activities on the inactive TS, the following procedure must be carried out:

- The vehicle must be barred from anyone not involved in the work, by using barrier tape.
- The Tractive System Master Switch (TSMS) must be switched off.
- It must be assured that the TS cannot be activated by, at a minimum, using the lockout/tag out of the TSMS.
- A check for zero-potential must be carried out.
- A sign that declares the vehicle is electrically safe must be installed. The name of the ESO who is supervising the activities must be noted on the sign. This ESO is the only person who may remove the sign and the barrier.

A 6.11.4 In case of measurements on the active TS or an activation of the TS in the pit for testing purposes, the following steps must be followed:

- The vehicle must be barred from anyone not involved in the work, by using barrier tape.
- The vehicle must be jacked up and the driven wheels removed.
- One team member must be prepared to push a shutdown button at any time.
- The TS must only be activated for as long as necessary.
- Appropriate insulated tools and equipment must be used.
- Safety glasses with side shields and compliant safety gloves must be worn by all participating team members when parts of the TS are exposed.
- No other work on the vehicle is permitted when the TS is active.

A 6.11.5 If the TSAL is flashing red or malfunctioning, the TS is considered as active.

A 6.11.6 There must be at least one team member present, who is not directly involved in the work, but who could assist in case of an incident.

### **A 6.12 [EV ONLY] Working on Tractive System Accumulators**

A 6.12.1 Opening or working on Tractive System Accumulator Containers (TSACs) is only allowed in the provided work places in the charging area, see A 6.13.

A 6.12.2 All activities require the attendance of an ESO.

A 6.12.3 Whenever the TSACs are opened, the cell segments must be separated with the maintenance plugs, see EV 5.4.4.

A 6.12.4 Appropriate insulated tools and equipment must be used.

A 6.12.5 Safety glasses with side shields and compliant safety gloves must be worn by all participating team members.

## **A 6 General Rules**

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- A 6.12.6 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.
- A 6.12.7 Moving accumulator cells and/or accumulator segment(s) around at the competition site is only permitted if they are inside a completely closed TSAC.
- A 6.12.8 All parts and modules of the TSAC that are not currently being worked on must be covered at least according to IPxxB while working on the accumulator container.
- A 6.12.9 Additional safety measures may be included in the respective competition handbook.

### **A 6.13 [EV ONLY] Charging**

- A 6.13.1 There will be a separated charging area on the competition site. Charging TS accumulators is only allowed inside this area.
- A 6.13.2 Accumulators must be removed from the vehicle and placed on the TSAC hand cart, see EV 8.1, for charging.
- A 6.13.3 The label EV 5.3.8 or an additional label according to EV 5.3.8 must be visible during charging.
- A 6.13.4 No grinding, drilling, etc. is allowed in the charging area.
- A 6.13.5 At least one team member who has knowledge of the charging process must stay with the accumulator(s) during charging.

# T GENERAL TECHNICAL REQUIREMENTS

## T 1 DEFINITIONS

### T 1.1 Chassis Definitions

- T 1.1.1 Chassis – the fabricated structural assembly that supports all functional vehicle systems. This assembly may be a single welded structure, multiple welded structures or a combination of composite and welded structures.
- T 1.1.2 Bodywork – the outermost surface of the chassis or any fairing parts and covers.
- T 1.1.3 Cockpit – the volume which accommodates the driver which is defined by the top of the vehicle, the floor closeout, the inner side of the bodywork, the front bulkhead and the firewall.
- T 1.1.4 Chassis member – a minimum representative single piece of uncut, continuous tubing or equivalent structure.
- T 1.1.5 Front bulkhead – a planar structure that defines the forward plane of the chassis and provides protection for the driver’s feet (in front view, together with the Anti Intrusion Plate (AIP), covers the driver’s feet).
- T 1.1.6 Front bulkhead support – a structure that defines the side of the chassis from the front bulkhead back to the top of the upper side impact structure and the bottom of the front hoop.
- T 1.1.7 Front hoop – a roll bar located above the driver’s legs, in proximity to the steering wheel.
- T 1.1.8 Impact Attenuator (IA) – a deformable, energy absorbing device located forward of the front bulkhead.
- T 1.1.9 Main hoop – a roll bar located alongside or just behind the driver’s torso.
- T 1.1.10 Monocoque – a chassis made of composite material.
- T 1.1.11 Node-to-node triangulation – an arrangement of chassis members projected onto a plane, where a co-planar load applied in any direction, at any node, results in only tensile or compressive forces in the chassis members as shown in figure 1.
- T 1.1.12 Primary structure – the primary structure is comprised of the following components:
- Main hoop
  - Front hoop
  - Roll hoop braces and supports
  - Impact structures as mentioned under T 3.15
  - Front bulkhead

## T1 Definitions

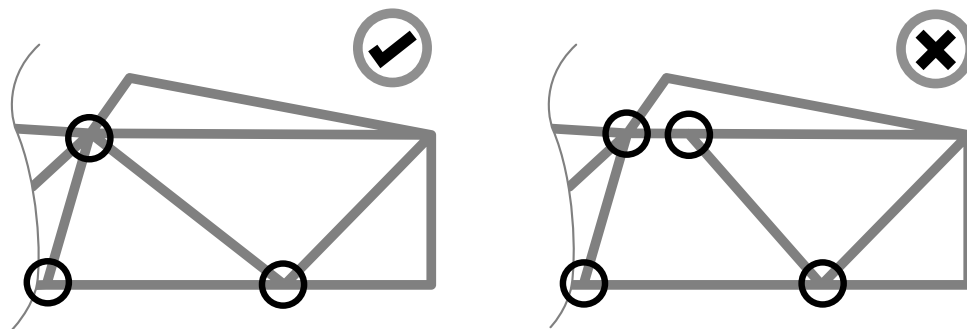


Figure 1: Node-to-node triangulation of chassis members (left correct and right incorrect).

- Front bulkhead support system
- All chassis members, guides and supports that transfer load from the driver’s restraint system into the above mentioned components of the primary structure

- T 1.1.13 Roll hoops – both the front hoop and the main hoop are classified as “roll hoops”
- T 1.1.14 Roll hoop bracing – the structure from a roll hoop to the roll hoop bracing support.
- T 1.1.15 Roll hoop bracing supports – the structure from the lower end of the roll hoop bracing back to the roll hoop(s).
- T 1.1.16 Rollover protection envelope – the union of
- the primary structure and any additional structures fixed to the primary structure which meet the minimum specification defined in T 3.2 or equivalent
  - the plane from the top of the main hoop to the top of the front hoop
  - the plane from the top of the main hoop to the rearmost structure according to T 3.2 or equivalent

Example depicted in figure 2.

- T 1.1.17 Side impact structure – the area of the side of the chassis between the front hoop and the main hoop and from the chassis floor to the height as required in T 3.15 above the lowest inside chassis point between front hoop and main hoop.
- T 1.1.18 Surface envelope – the surface envelope is the surface of the union of the rollover protection envelope, see T 1.1.16, and the volume defined by
- the top of the main hoop and the outside edges of the four tires
  - a plane from the top of the main hoop to the top of the front bulkhead
  - a plane from the top of the main hoop to the the rearmost structure according to T 3.2 or equivalent
  - a projection in side view of the lower boundaries of the rollover protection envelope

Example depicted in figure 3.



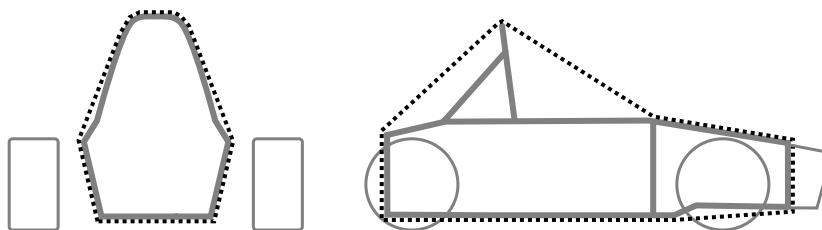


Figure 2: Rollover protection envelope T 1.1.16, thick lines are primary structure members according to T 3.2

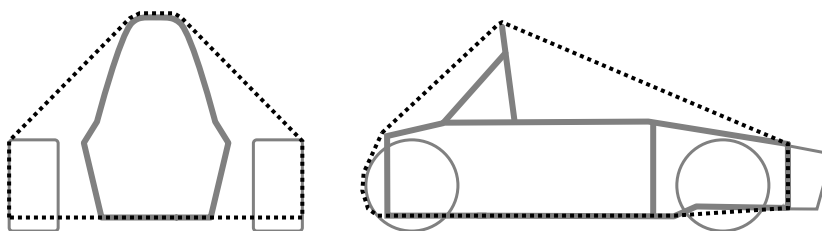


Figure 3: Surface Envelope T 1.1.18

### T1.2 Material Definitions

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

- UL94 V-0 for the minimum used material thickness
- FAR 25.853(a)(1)(i)

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

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

### T1.3 Electrical Definitions

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

### T1.4 Driving Mode Definitions

T1.4.1 Manual Mode – a vehicle is in manual mode when driven by a human driver. In this case the ASMS must be off (AS deactivated).

T1.4.2 Autonomous Mode – a vehicle is in autonomous mode when the AS is activated. When a vehicle is in autonomous mode, there must be no person inside the vehicle.

## T2 General Design Requirements

### T2 GENERAL DESIGN REQUIREMENTS

#### T2.1 Vehicle Configuration

T2.1.1 The vehicle must be designed and fabricated in accordance with good engineering practices.

T2.1.2 The vehicle must be open-wheeled, single seat and open cockpit (a formula style body) with four wheels that are not in a straight line.

T2.1.3 Open wheel vehicles must satisfy the following (see also figure 4):

- The wheel/tire assembly must be unobstructed when viewed from the side.
- No part of the vehicle may enter a keep-out-zone defined by two lines extending vertically from positions 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 steering straight ahead. This keep-out zone extends laterally from the outside plane of the wheel/tire to the inboard plane of the wheel/tire assembly.

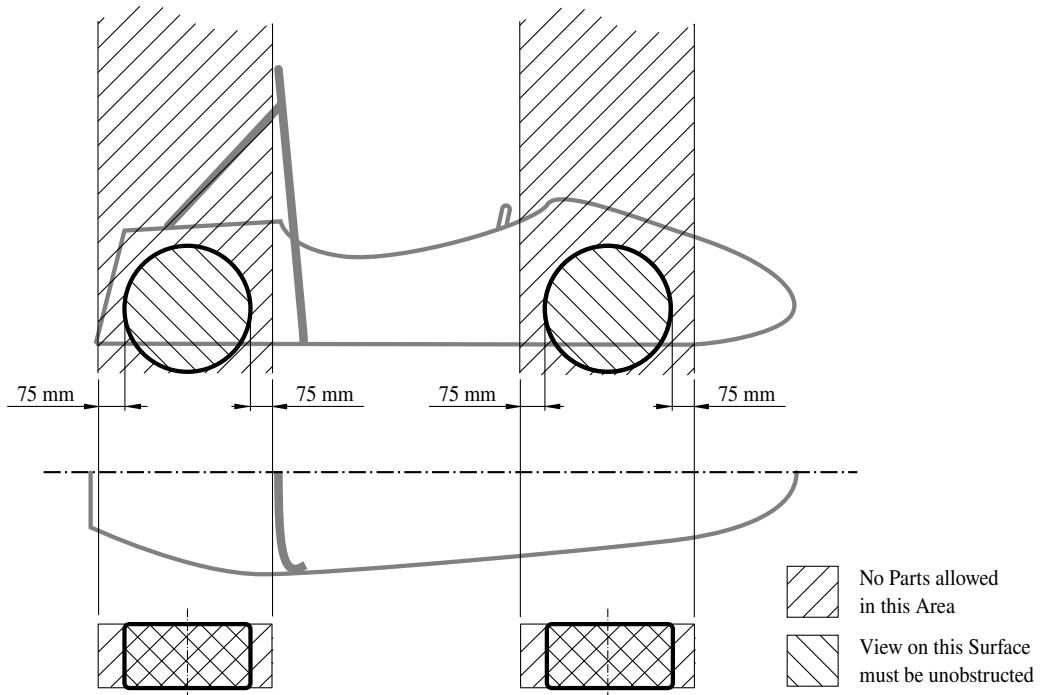


Figure 4: Keep-out-zones for the definition of an open-wheeled vehicle.

#### T2.2 Ground Clearance

T2.2.1 The minimum static ground clearance of any portion of the vehicle, other than the tires, including a driver, must be 30 mm. If an active suspension system is installed, the static ground clearance is measured in the lowest adjustable position.

T2.2.2 Sliding skirts or other aerodynamic devices that by design, fabrication or as a consequence of moving, contact the track surface are prohibited.

## **T2 General Design Requirements**

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### **T2.3 Bodywork**

- T2.3.1 There must be no openings through the bodywork into the cockpit other than that required for the cockpit opening. Minimal openings around the front suspension and steering system components are allowed.
- T2.3.2 In any side view in front of the cockpit opening and outside the area defined in T8.2 all parts of the bodywork must have no external concave radii of curvatures. Any gaps between bodywork and other parts must be reduced to a minimum.
- T2.3.3 Enclosed chassis structures and structures between the chassis and the ground must have two venting holes of at least 25 mm diameter in the lowest part of the structure to prevent accumulation of liquids. Additional holes are required when multiple local lowest parts exist in the structure.
- T2.3.4 The bodywork in front of the front wheels with the tangent of surface above 45° relative to the forward direction must have a radius of at least 38 mm along the top, sides and bottom of all affected edges.

### **T2.4 Minimum Edge Radii of Bodywork and Aerodynamic Devices**

- T2.4.1 For all edges that could come into contact with any standing pedestrian without reaching to the vehicle, the minimum radius of the bodywork and aerodynamic devices is 3 mm for all forward facing edges and 1 mm for all other edges.

### **T2.5 Suspension**

- T2.5.1 The vehicle must be equipped with fully operational front and rear suspension systems including shock absorbers and a usable wheel travel of at least 50 mm and a minimum jounce of 25 mm with driver seated.
- T2.5.2 All suspension mounting points must be visible at technical inspection, either by direct view or by removing any covers.

### **T2.6 Wheels**

- T2.6.1 Any wheel mounting system that uses a single retaining nut must incorporate a device to prevent loosening of the nut and the wheel. A second nut (“jam nut”) does not meet these requirements.
- T2.6.2 Wheel lug bolts, drive pegs and studs must be made of steel or titanium. The team must be able to show good engineering practice and providing adequate strength by calculations. Wheel lug bolts, drive pegs and studs must not be hollow.
- T2.6.3 Aluminium wheel nuts may be used, but they must be hard anodized and in pristine condition.

### **T2.7 Tires**

- T2.7.1 Vehicles must have two types of tires as follows:

## **T2 General Design Requirements**

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- Dry tires - The tires on the vehicle when it is presented for technical inspection are defined as its “dry tires”.
- Wet tires - Wet tires may be any size or type of treaded or grooved tire provided:
  - The tread pattern or grooves were molded in by the tire manufacturer or were cut by the tire manufacturer or their appointed agent. Any grooves that have been cut must have documentary proof that it was done in accordance with these rules.
  - There is a minimum tread depth of 2.4 mm.

T2.7.2 Tires on the same axle must have the same manufacturer, size and compound.

T2.7.3 Tire warmers are not allowed.

T2.7.4 Special agents that increase traction must not be added to the tires or track surface.

### **T2.8 Steering**

T2.8.1 Steering systems using cables or belts for actuation are prohibited. This does not apply for autonomous steering actuators.

T2.8.2 The steering wheel must directly mechanically actuate the front wheels.

T2.8.3 The steering system must have positive steering stops that prevent the steering linkages from locking up. The stops must be placed on the rack and must prevent the tires and rims from contacting any other parts. Steering actuation must be possible during standstill.

T2.8.4 Allowable steering system free play is limited to a total of 7° measured at the steering wheel.

T2.8.5 The steering wheel must be attached to the column with a quick disconnect. The driver must be able to operate the quick disconnect while in the normal driving position with gloves on.

T2.8.6 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.

T2.8.7 The steering wheel must have a continuous perimeter that is near circular or near oval. The outer perimeter profile may have some straight sections, but no concave sections.

T2.8.8 In any angular position, the top of the steering wheel must be no higher than the top-most surface of the front hoop.

T2.8.9 The steering rack must be mechanically attached to the primary structure and all stationary parts must be within the rollover protection envelope, see T 1.1.16.

T2.8.10 Joints between all components attaching the steering wheel to the steering rack must be mechanical and visible at technical inspection. Bonded joints are allowed in accordance with T3.2.8.

T2.8.11 Rear wheel steering, which can be electrically actuated, is permitted if mechanical stops limit the range of angular movement of the rear wheels to a maximum of 6°. This must be demonstrated with a driver in the vehicle and the team must provide the equipment for the steering angle range to be verified at technical inspection.

### T3 General Chassis Design

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#### T2.9 Wheelbase

T2.9.1 The vehicle must have a wheelbase of at least 1525 mm.

#### T2.10 Track and Rollover Stability

T2.10.1 The smaller track of the vehicle (front or rear) must be no less than 75 % of the larger track.

T2.10.2 The track and center of gravity of the vehicle must combine to provide adequate rollover stability.

### T3 GENERAL CHASSIS DESIGN

#### T3.1 General Requirements

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

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

#### T3.2 Minimum Material Requirements

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

| Item or application   | Minimum wall thickness | Minimum cross sectional area | Minimum area moment of inertia |
|---|------------------------|------------------------------|--------------------------------|
| Main and front hoops, shoulder harness mounting bar   | 2.0 mm                 | 173 mm <sup>2</sup>          | 11 320 mm <sup>4</sup>         |
| Impact structures, front bulkhead, roll hoop bracing, driver's restraint harness attachment (except as noted above) | 1.2 mm                 | 119 mm <sup>2</sup>          | 8509 mm <sup>4</sup>           |
| Front bulkhead support, main hoop bracing supports  | 1.2 mm                 | 91 mm <sup>2</sup>           | 6695 mm <sup>4</sup>           |

Table 4: Minimum Material Requirements

T3.2.2 Steel tubing has to be made from unalloyed carbon steel with a maximum content of 0.3 % carbon, 1.7 % manganese and 0.6 % of any other element. All other steel grades are considered alternative materials and require additional testing and documentation (see T3.3).

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

## T3 General Chassis Design

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

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

- Young's Modulus (E) = 200 GPa
- Yield Strength ( $S_y$ ) = 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

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

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

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

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

T3.2.8 Where bonded joints are applicable and governed by the rules, a 50 % reduction shall be applied to all nominal and tested adhesive values. Bonded joints in the primary structure must be documented in the SES.

### T3.3 Alternative Materials

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

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

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

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

## **T3 General Chassis Design**

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- Receipts and data sheets of the used tubing materials
- Documentation about welding processes and filler materials
- Documentation about heat treatments
- Tests showing adequate strength and elongation at break in the welded condition

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

- T3.4.1 If composite structures are used in the primary structure or the TSAC, the Flexural Rigidity (EI) of that structure must be calculated with the tools and formulas in the SES. The actual geometry and curvature of the panel may be taken into account for the main hoop bracing support, the front hoop bracing, the front bulkhead support structure, the shoulder harness bar, the TS and TSAC protective structure. For all other areas the EI must be calculated as the EI of a flat panel about its neutral axis. This panel must have the same composition as the structure used in the primary structure or the TSAC.
- T3.4.2 If composite materials are used in the primary structure or the TSAC the SES must include:
- Material type(s)
  - Cloth weights
  - Resin type
  - Fiber orientation
  - Number of layers
  - Core material
  - Lay-up technique
  - 3-point-bend test and shear test data
- T3.4.3 For any laminate in the primary structure or the TSAC, the maximum weight content of parallel fibers, relative to the weight of all fibers in the laminate, is 50 %. All fibers laid within any orientation +/-10° count as parallel in this case.
- T3.4.4 If an asymmetrical lay-up is used in the primary structure, the thinner skin must have a thickness of at least 40 % of the thicker skin.
- T3.4.5 Wherever backing plates are required, they must be fully supported by the structure they are attached to.
- T3.4.6 Backing plates must have a continuous perimeter that is near circular or near oval. The outer perimeter profile may have some straight sections, but no concave sections. Backing plates must not have any cut-outs within their outside perimeter except for the holes for bolts.

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

- T3.5.1 If composite materials are used for any part of the primary structure or the TSAC the team must:
- Build a representative test panel which must measure exactly 275 mm × 500 mm that has the same design, laminate and fabrication method as used for the respective part of

### T3 General Chassis Design

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the primary structure represented as a flat panel. The sides of the test panel must not be laminated (core material must be visible).

- Perform a 3-point bending test on this panel

The data from these tests and pictures of the test samples and test setup must be included in the SES. In the pictures, the following must be identifiable: distance between the two supports, dimensions of the load applicator and test sample marking as per T3.5.5. The test results must be used to derive strength and stiffness properties used in the SES formula for all laminate panels.

Representative test panels for parts of the TSAC may use smaller dimensions, provided that the panel core thickness is 5 mm or smaller. This representative test panel must then measure 150 mm × 275 mm. In this case, the distance between the two test panel supports must be at least 200 mm and the load applicator must have a radius of at least 5 mm. T3.5.6 and T3.5.7 do not apply.

- T3.5.2 If a panel represents side impact structure it must be proven that it has at least the same properties as two steel tubes meeting the requirements for side impact structure tubes for buckling modulus, yield strength and absorbed energy.
- T3.5.3 Composite structures with different core thicknesses but otherwise identical construction may use material properties derived from a single test panel. The panel with the thicker core must be tested and the structure using derived material properties must not use a core thickness of less than 66 % of the tested panel.
- T3.5.4 When a laminate is not quasi-isotropic, i.e. has equal strength and stiffness in the 0°, 90° and ±45° direction, the results from the 3 point bending test will be assigned to the 0° lay-up direction. To show equivalence in the SES, the 0° lay-up direction must be used and oriented accordingly in the chassis.
- T3.5.5 The test samples must be presented at technical inspection. All samples must be marked with the following non-removable (e.g.: permanent marker or engraving, but no sticker) information: laminated structure acronym and date of testing.
- T3.5.6 The distance between the two test panel supports must be at least 400 mm.
- T3.5.7 The load applicator used to test any panel or tube must be metallic and have a radius of 50 mm.
- T3.5.8 The load applicator must overhang the test piece to prevent edge loading.
- T3.5.9 There must be no material between the load applicator and the test piece.
- T3.5.10 Perimeter shear tests must be completed which measure the force required to push or pull a 25 mm diameter flat punch through a flat laminate sample. The sample must be at least 100 mm × 100 mm. Core and skin thicknesses must be identical to those used in the actual primary structure and be manufactured using the same materials and processes.
- T3.5.11 The test 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.



## **T3 General Chassis Design**

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

- T3.6.1 All teams must submit a Structural Equivalency Spreadsheet (SES) and Structural Equivalency 3D Model (SE3D).
- T3.6.2 The SES spreadsheet form can be downloaded from the competition website.
- T3.6.3 The SE3D must contain a three dimensional CAD model of the chassis including all members of the primary structure and all mechanical attachment details of the hoops and hoop braces in “IGES” file format not larger than 40 MB. [EV ONLY] The TSAC(s) and attachment must also be included.
- T3.6.4 Vehicles must be fabricated in accordance with the materials and processes described in the SES.
- T3.6.5 Teams must bring a copy of the approved SES to technical inspection.

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

- T3.7.1 Both roll hoops must be securely integrated to the primary structure using node-to-node triangulation or equivalent joining methods.
- T3.7.2 The minimum radius of any bend, measured at the tube 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. The minimum area moment of inertia, see T3.2, must be maintained in all areas, including the bends of the manufactured tubes.
- T3.7.3 In a plane perpendicular to the longitudinal axis of the vehicle and through the lower endpoints of the roll hoop, no part of the primary structure may lie below 30 mm of the endpoints of the roll hoop.
- T3.7.4 Roll hoops attached to a composite primary structure must be mechanically attached at the top and bottom of both sides of that structure and at intermediate locations if needed to show equivalency. The lower roll hoop tubing attachment points must be within 50 mm of the endpoints of the roll hoop.
- T3.7.5 Mounting plates welded to the roll hoops must be at least 2 mm thick steel or 3 mm thick aluminium, dependent of the roll hoop material.
- T3.7.6 Both roll hoops must have one 4.5 mm inspection hole in a non-critical straight location and its surface at this point must be unobstructed for at least 180°.

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

- T3.8.1 The main hoop must be constructed of a single piece of uncut, continuous, closed section steel tubing.
- T3.8.2 In side view the portion of the main hoop which is above its upper attachment point to the side impact structure must be inclined less than 10° from vertical.
- T3.8.3 In side view any bends in the main hoop above its upper attachment point to the primary structure must be braced to a node of the main hoop bracing support structure with tubing meeting the requirements of main hoop bracing.

## T3 General Chassis Design

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T3.8.4 In side view any portion lower than the upper attachment point to the side impact structure must be inclined either forward or not more than 10° rearward.

### T3.9 Front Hoop

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

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

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

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

T3.9.5 The front hoop requires six attachment points, two on each side connecting to the front bulkhead support structures and two connecting to the front hoop bracing, and must therefore show equivalency to 180 kN, as follows from T3.16.1 and T3.11.4.

T3.9.6 Fully laminating the front hoop to the monocoque is acceptable. Fully laminating means that the hoop has to be encapsulated with laminate around its whole circumference, see figure 5. Equivalence to T3.7.4 must be shown in the SES. The laminate encapsulating the front hoop must overlap by at least 25 mm on each side. It must have the same lay-up as the laminate that it is connecting to.

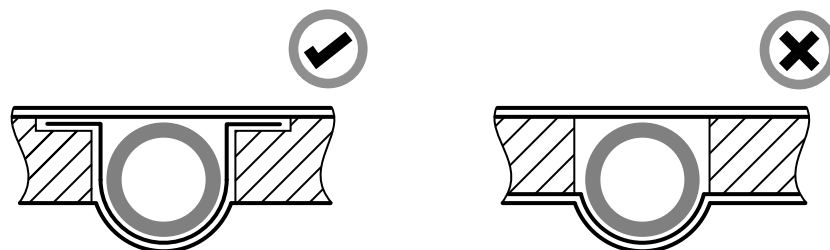


Figure 5: Front hoop laminating requirements

### T3.10 Main Hoop Bracing

T3.10.1 The main hoop must be supported to the front or the rear by bracing tubes on each side of the main hoop.

T3.10.2 In side view the main hoop and the main hoop braces must not lie on the same side of a vertical line coincident with the top of the main hoop.

T3.10.3 The main hoop braces must be attached to the main hoop no lower than 160 mm below the top-most surface of the main hoop. The included angle formed by the main hoop and the main hoop braces must be at least 30°.

### T3 General Chassis Design

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- T3.10.4 The main hoop braces must be straight.
- T3.10.5 The lower ends of the main hoop braces must be supported back to the upper attachment point of the main hoop to the side impact structure and to the lower attachment point of the main hoop to the side impact structure by a node-to-node triangulated structure or equivalent composite structure.
- T3.10.6 If any item which extends outside of the primary structure is attached to the main hoop braces, additional bracing is required to prevent bending loads in a rollover situation.

#### T3.11 Front Hoop Bracing

- T3.11.1 The front hoop bracing attaches on each side of the front hoop as well as the structure forward of the driver's feet. A minimum of two tubes without any bends must be straight on a line in side view of the frame and must have a minimum distance of 100 mm between each other at the front hoop.
- T3.11.2 The front hoop bracing structure must be attached no lower than 50 mm below the top-most surface of the front hoop, see figure 6.
- T3.11.3 If the front hoop is inclined more than 10° to the rear, additional braces extending rearwards are required.
- T3.11.4 Composite front hoop bracing structures and their attachments cannot be counted towards the front bulkhead support structures and vice-versa for the structural equivalency documentation.

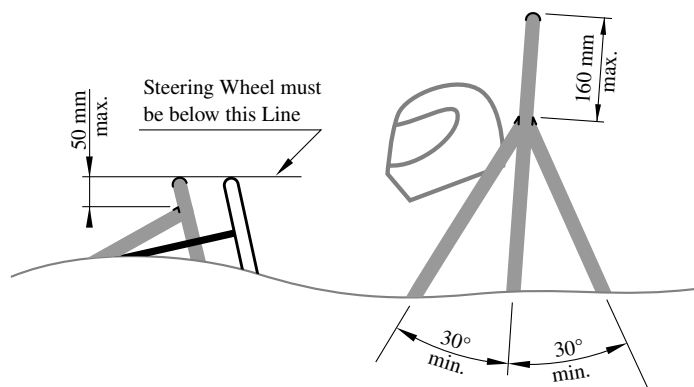


Figure 6: Front hoop bracing, main hoop bracing and steering wheel requirements

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

- T3.12.1 Any non-welded joint at either end of a bracing must be either a double-lug joint, see figure 7, or a sleeved joint, see figure 8. Spherical rod ends are prohibited.
- T3.12.2 If threaded fasteners are used, they are considered critical fasteners and must meet T 10.1.
- T3.12.3 Double lug-joints must include a capping arrangement, see figure 7.

### T3 General Chassis Design

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- T3.12.4 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 8.8 minimum. The attachment holes in the lugs and in the attached bracing must be a close fit with the pin or bolt.
- T3.12.5 For sleeved joints the sleeve must have a minimum length of 38 mm either side of the joint and be a close-fit around the base tubes. The wall thickness of the sleeve must be at least that of the bracing tubes. The bolts must be 6 mm metric grade 8.8 minimum. The holes in the sleeves and tubes must be a close-fit with the bolts.

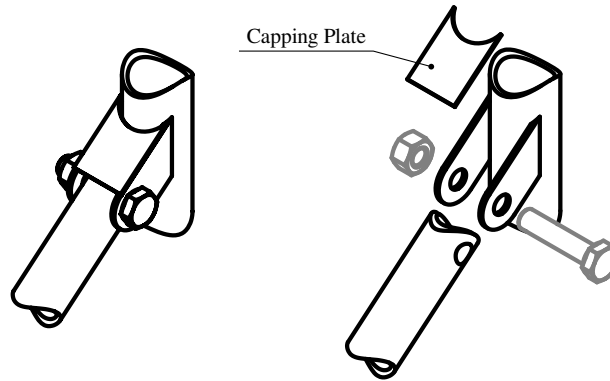


Figure 7: Double lug joint

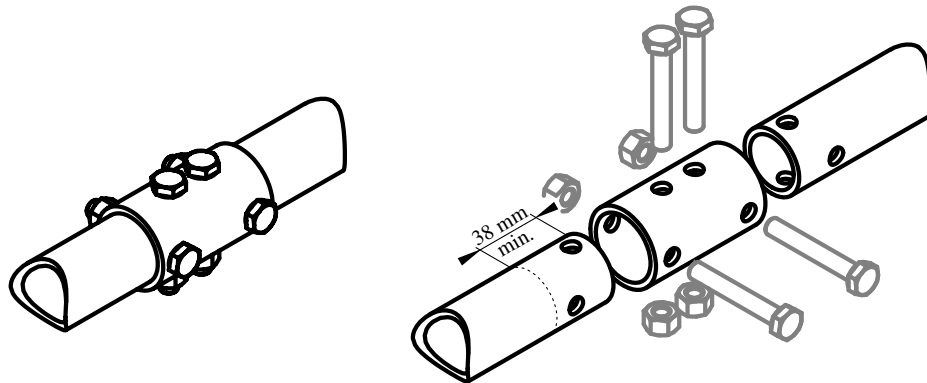


Figure 8: Sleeved joint

### T3.13 Front Bulkhead

- T3.13.1 Any alternative material used for the front bulkhead must have a perimeter shear strength equivalent to a 1.5 mm thick steel plate.
- T3.13.2 If the front bulkhead is part of a composite structure and is modeled as an “L” shape, the EI of the front bulkhead about the vertical and lateral axes must be equivalent to a steel tube meeting the requirements for the front bulkhead. The length of the section perpendicular to the bulkhead may be a maximum of 25 mm measured from the rearmost face of the bulkhead.

## T3 General Chassis Design

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### T3.14 Front Bulkhead Support

- T3.14.1 The front bulkhead must be supported back to the front hoop by a minimum of three tubes on each side; an upper member, a lower member and diagonal bracing to provide triangulation.
- The upper support member must be attached to the front bulkhead a maximum of 50 mm below the top-most surface of the front bulkhead, and attached to the front hoop a maximum of 50 mm below the upper side impact member. If the attachment point of the upper member is greater 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.
- T3.14.2 If the front bulkhead support is part of a composite structure, it must have equivalent EI to the sum of the EI of the six baseline steel tubes that it replaces and it must not be counted towards the composite front hoop bracing structures for the structural equivalency documentation (i.e. T3.11.4).
- T3.14.3 The EI of the vertical side of the front bulkhead support structure must be equivalent to at least the EI of one baseline steel tube that it replaces.
- T3.14.4 The perimeter shear strength of the monocoque laminate in the front bulkhead support structure must be at least 4 kN.

### T3.15 Impact Structures

- T3.15.1 The side impact structure must consist of at least three steel tubes, see T3.2, on each side of the cockpit, see figure 9.
- The upper member must connect the main hoop and the front hoop.
  - The upper member must be at a height between 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.
- T3.15.2 Other impact structures, see CV 1.3.2, EV 4.4.2 and EV 5.5.2, must be fully triangulated structures and consist of at least three steel tubes, see T3.2, on each side and rearward of the component that needs to be protected.
- If the component projects outwards from the roll hoops to the side, the front of the component must also be protected.
  - The upper member must not be higher than 320 mm above the lowest inside chassis point between the front and main hoop.
- T3.15.3 If the impact structure is part of a composite structure, the following is required:

### T3 General Chassis Design

- The region of the structure up to a height of 320 mm above the lowest inside chassis point between the front and main hoop must have an EI equal to the three baseline steel tubes that it replaces. An example for side impact structure is given in figure 10.
- The vertical 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 impact structure must have an absorbed energy equivalent to two baseline steel tubes, exceeding 65 J.
- The perimeter shear strength must be at least 7.5 kN.

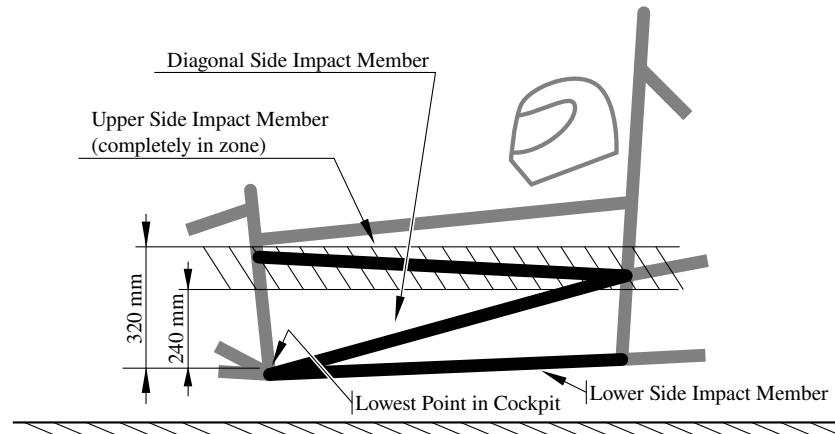


Figure 9: Side impact structure

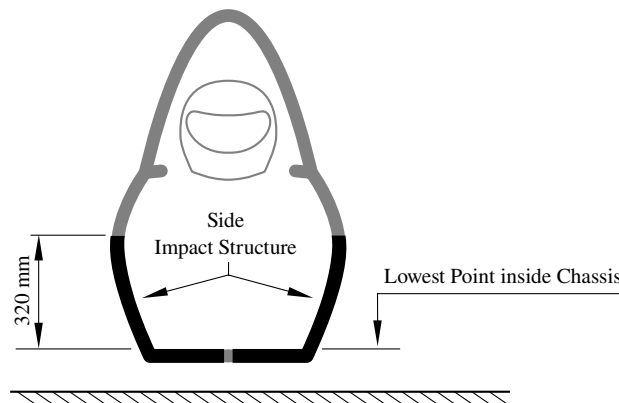


Figure 10: Side impact structure monocoque

#### T3.16 Bolted Primary Structure Attachments

- T3.16.1 If two parts of the primary structure are bolted together, each attachment point between the two parts must be able to carry a load of 30 kN in any direction.
- T3.16.2 Data obtained from the laminate perimeter shear strength test must be used to prove that adequate shear area is provided.

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- T3.16.3 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.
- T3.16.4 For the attachment of front hoop bracing, main hoop bracing and main hoop bracing support to the primary structure the use of one 10 mm metric grade 8.8 bolt is sufficient, if the bolt is on the centerline of the tube, see figure 11.

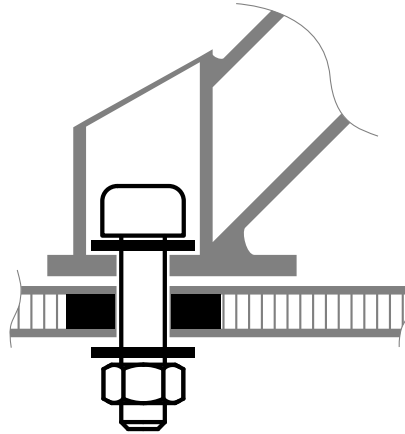


Figure 11: Bolted roll hoop bracing support

- T3.16.5 When using bolted joints within the primary structure, no crushing of the laminate core material is permitted.
- T3.16.6 For the AIP to front bulkhead attachment, and if two panels or plates of the primary structure are bolted together, for each 200 mm of reference perimeter a minimum of one 8 mm metric grade 8.8 bolt(s) must be used, rounded up to the next integer. Smaller, but more, bolts may be used, if equivalency is shown. The bolts must be evenly distributed over the circumference using good engineering practices. The reference perimeter is the outside perimeter of the attached part at the connection. The bolts are considered critical fasteners and must comply with T 10.

### T3.17 Impact Attenuator

- T3.17.1 Each vehicle must be equipped with an IA assembly consisting of an IA and AIP.
- T3.17.2 The IA must:
- Be installed forward of the front bulkhead.
  - Be at least 100 mm high and 200 mm wide for a minimum distance of 200 mm forward of the front bulkhead.
  - Not be positioned more than 350 mm above the ground, for any portion of the required  $100 \times 200 \times 200 \text{ mm}^3$  volume.
  - Not be able to penetrate the front bulkhead in the event of an impact.
  - Be attached securely and directly to the AIP.
  - Not be part of the non-structural bodywork.

## **T3 General Chassis Design**

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- Be designed with a closed front section.
  - Not be wider or higher than the AIP.
- T3.17.3 The baseline design for the AIP is a 1.5 mm solid steel or 4.0 mm solid aluminium plate.
- 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.
  - The AIP must not extend past the outside edges of the front bulkhead.
- T3.17.4 Alternative AIP designs are permissible if equivalency to T3.17.3 is proven by physical testing as in T3.19.2.
- T3.17.5 The IA may be attached to the AIP by a minimum of four 8 mm metric grade 8.8 bolts that are considered critical fasteners and must comply with T10. Attachment(s) using adhesive must be able to carry a load of 60 kN in any direction.
- T3.17.6 The attachment of the IA assembly must be designed to provide an adequate load path for transverse and vertical loads in the event of off-center and off-axis impacts. Segmented foam attenuators must have the segments bonded together to prevent sliding or parallelogramming.
- T3.17.7 A team may use one of the “standard” FSAE IAs, in order to avoid testing, provided that:
- if the front bulkhead width is larger than 400 mm and/or its height is larger than 350 mm a diagonal or X-bracing that is a front bulkhead support tube or an approved equivalent per T3.2, must be included in the front bulkhead. Or equivalent for mono-coque bulkheads.
  - must use a 1.5 mm solid steel AIP that is welded along its full perimeter to a steel bulkhead or use a 4 mm solid aluminium AIP that is bolted to any bulkhead with a minimum of eight 8 mm metric grade 8.8 bolts
  - if the “standard” honeycomb IA is used, the IA must be of pre-crushed type
  - adhesive used to mount the “standard” honeycomb IA to the AIP must have a shear strength of at least 24 MPa
- T3.17.8 If the standard IA is used, but does not comply with the requirements of T3.17.7 physical testing must be carried out to prove that the AIP does not permanently deflect more than 25 mm.

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

- T3.18.1 All teams must submit an IA data report using the Impact Attenuator Data (IAD) template provided at the competition website.

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

- T3.19.1 The IA assembly, when mounted on the front of a vehicle with a total mass of 300 kg and impacting a solid, non-yielding impact barrier with a velocity of impact of 7 m/s, must meet the following requirements:



### T3 General Chassis Design

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- 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.

Equivalent (higher) test velocities are only allowed to accommodate for a lower total testing mass, as long as the energy absorbed is 7350 J or more. If these requirements cannot be met, a team must use the standard IA.

T3.19.2 During the IA test:

- The IA must be attached to the AIP using the intended vehicle attachment method.
- The IA assembly must be attached to a test fixture that has geometry representative of the intended primary structure and equal or higher stiffness and strength. When alternative materials are used for the AIP, the test fixture must be a copy of the intended primary structure (i.e. materials, lay-up, joining methods).
- There must be at least 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.

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

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

- Physical testing of the IA assembly including any attached non-crushable object(s) or structurally representative dummies thereof in front of the AIP. When non-crushable object(s) are located in front view of the AIP, physical testing is required.
- Combining the peak force from physical testing of the IA assembly with the failure load for the mounting of the non-crushable object(s), calculated from fastener shear and/or link buckling.
- Combining the “standard” IA peak load of 95 kN with the failure load for the mounting of the non-crushable object(s), calculated from fastener shear and/or link buckling.

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

T3.19.6 When using acceleration data from the dynamic test, the average deceleration must be calculated based on the raw unfiltered data. If peaks above the 40 g limit are present in the data, a 100 Hz, 3<sup>rd</sup> order, low pass Butterworth (–3 dB at 100 Hz) filter may be applied.

## T4 Cockpit

### T3.20 Non-Crushable Objects

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

## T4 COCKPIT

### T4.1 Cockpit Opening

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

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

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

### T4.2 Cockpit Internal Cross Section

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

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

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

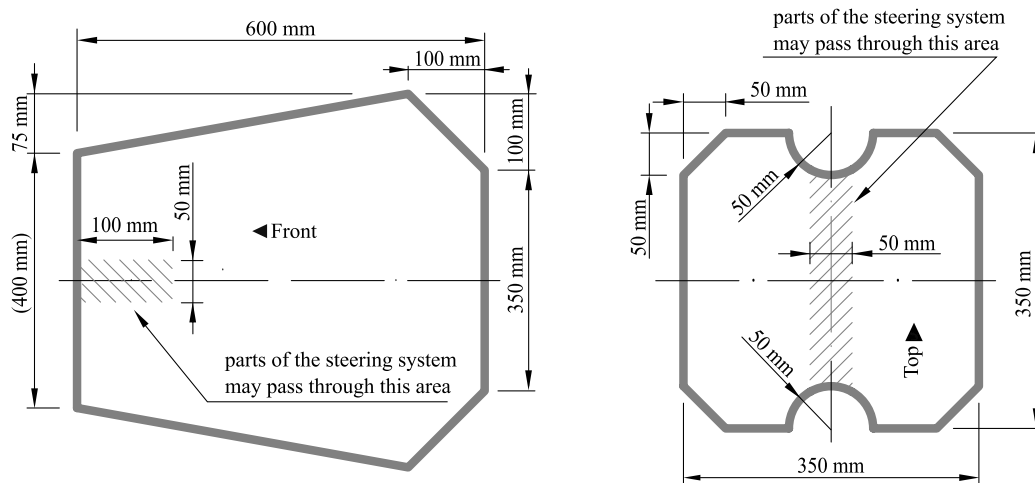


Figure 12: Cockpit opening template (left) and cockpit internal cross section template (right)

## T4 Cockpit

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

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

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

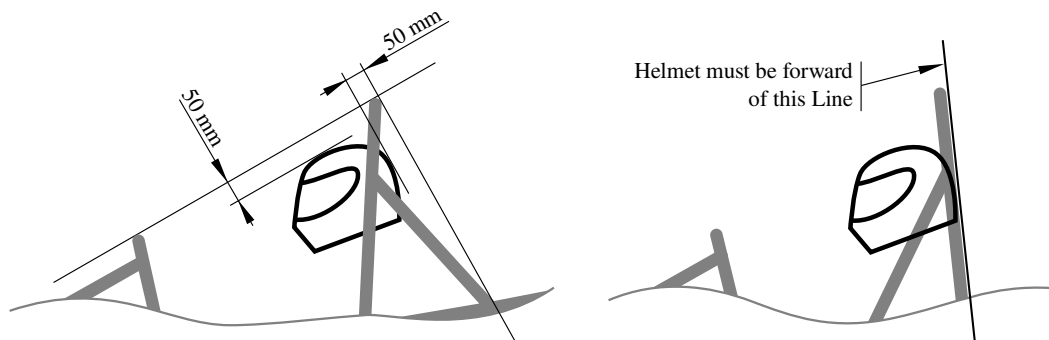


Figure 13: Minimum helmet clearance

T4.3.2 The 95<sup>th</sup> percentile male is represented by a two dimensional figure consisting of two circles of 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).

T4.3.3 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.

T4.3.4 The figure has to be positioned in the vehicle as follows, see figure 14:

- The seat adjusted to the rearmost position
- The pedals adjusted to the frontmost position
- The bottom 200 mm circle placed on the seat bottom. The distance between the center of the circle and the rearmost actuation face of the pedals must be minimum 915 mm.
- The middle circle positioned on the seat back
- The upper 300 mm circle positioned 25 mm away from the head restraint.

### T4.4 Side Tubes

T4.4.1 If there is any chassis member alongside the driver at the height of the neck of any of the drivers in the team, a metal tube or piece of sheet metal must be attached to the chassis to prevent the driver's shoulders from passing under that chassis member.



## **T4 Cockpit**

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

- T4.6.1 The lowest point of the driver's seat must in side view not extend below the upper face of the lowest side impact structure member or have a longitudinal tube (or tubes) that meets the material requirements for the side impact structure (T3.2), passing underneath the lowest point of the seat.
- T4.6.2 Adequate heat insulation must be provided to ensure that the driver is not able to contact any parts of the vehicle with a surface temperature above 60 °C. The insulation may be external to the cockpit or incorporated with the driver's seat or firewall. The design must 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 T4.6.2.a.ii.

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

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

### **T4.8 Firewall**

- T4.8.1 A firewall must separate the cockpit from all components of the fuel supply system, hydraulic fluid (except brake system and dampers), flammable liquids, the LV battery and any TS component, see EV 1.1.1.
- T4.8.2 The firewall must cover any straight line between the parts mentioned in T4.8.1 and any part of the tallest driver below a plane 100 mm above the bottom of the helmet.
- T4.8.3 The firewall must be a non-permeable surface made from a rigid, fire resistant material, see T1.2.1, which must be rigidly mounted to the vehicle's structure.
- T4.8.4 Any firewall must seal completely against the passage of fluids, especially at the sides and the floor of the cockpit.
- T4.8.5 Pass-throughs for wiring, cables, etc. are permitted if grommets are used to seal the pass-through.

## **T4 Cockpit**

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- T4.8.6 Multiple panels may be used to form the firewall but must overlap at least 5 mm and be sealed at the joints. Any sealing material must not be vital to the structural integrity of the firewall.
- T4.8.7 [EV ONLY] The TS firewall between driver and TS components must be composed of two layers:
- One solid layer, facing the TS side, must be made of aluminium with a thickness of at least 0.5 mm. This part of the TS firewall must be grounded according to EV 3.1.
  - The second layer, facing the driver, must be made of an electrically insulating and fire retardant material, see T 1.2.1. The second layer must not be made of CFRP.
  - The thickness of the second layer must be sufficient to prevent penetrating this layer with a 4 mm wide screwdriver and 250 N of force.
- A sample of the TS firewall must be presented at technical inspection.
- T4.8.8 [EV ONLY] Conductive parts, except for the chassis and firewall mounting points, must not protrude through the TS firewall or must be properly insulated on the driver's side. The driver must not be able to touch uninsulated firewall mounting points while operating the vehicle.
- T4.8.9 [EV ONLY] TS parts outside of the rollover protection envelope, see T 1.1.16 and EV 4.4.3, do not need a firewall.

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

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

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

- T4.10.1 The driver must have adequate visibility to the front and sides of the vehicle. Seated in a normal driving position, the driver must have a minimum field of vision of 100° to either side. The required visibility may be obtained by the driver turning their head and/or the use of mirrors.
- T4.10.2 If mirrors are required to meet T4.10.1, they must remain in place and be adjusted to enable the required visibility throughout all dynamic events.

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

- T4.11.1 All drivers must be able to exit to the side of the vehicle in less than 5 s with the driver in the fully seated position, hands in the driving position on the connected steering wheel (in all possible steering positions) and wearing the required driver equipment as in T 13.3. The egress time will stop when the driver has both feet on the ground.

## **T5 Driver Restraint System**

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### **T5 DRIVER RESTRAINT SYSTEM**

#### **T5.1 Definitions**

- T5.1.1 6-point system – consists of a two-piece lap belt (minimum width 50 mm), two shoulder straps (minimum width 75 mm) and two leg or anti-submarine straps (minimum width 50 mm).
- T5.1.2 7-point system – same as the 6-point system except it has three anti-submarine straps.
- T5.1.3 upright driving position – position with a seat back angled at 30° or less from the vertical as measured along the line joining the two 200 mm circles of the 95<sup>th</sup> percentile male template as defined in T4.3 and positioned per T4.3.4.
- T5.1.4 reclined driving position – position with a seat back angled at more than 30° from the vertical as measured along the line joining the two 200 mm circles of the 95<sup>th</sup> percentile male template as defined in T4.3 and positioned per T4.3.4

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

- T5.2.1 All drivers must use a 6-point or 7-point restraint harness meeting the following specifications:
- All driver restraint systems must meet SFI Specification 16.1, SFI Specification 16.5, SFI Specification 16.6 or FIA specification 8853/2016.
  - The belts must bear the appropriate dated labels.
  - The material of all straps must be in perfect condition.
  - There must be a single metal-to-metal latch type quick release for all straps.
  - All lap belts must incorporate a tilt lock adjuster (“quick adjuster”). A tilt lock adjuster in each portion of the lap belt is highly recommended. Lap belts with “pull-up” adjusters are recommended over “pull-down” adjusters.
  - Vehicles with a “reclined driving position” must have either anti-submarine belts with tilt lock adjusters (“quick adjusters”) or have two sets of anti-submarine belts installed.
  - The shoulder harness must be the “over-the-shoulder type”. Only separate shoulder straps are permitted (i.e. “Y”-type shoulder straps are not allowed). The “H”-type configuration is allowed.
  - The shoulder harness straps must be threaded through the three bar adjusters in accordance with the manufacturer’s instructions.
  - When a HANS device is used by the driver, FIA certified 50 mm wide shoulder harnesses are allowed.
- T5.2.2 SFI spec harnesses must be replaced following December 31<sup>st</sup> of the 2<sup>nd</sup> year after the date of manufacture as indicated by the label. FIA spec harnesses must be replaced following December 31<sup>st</sup> of the year marked on the label.
- T5.2.3 The restraint system must be worn tightly at all times.

## **T5 Driver Restraint System**

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

- T5.3.1 The lap belt, shoulder harness and anti-submarine strap(s) must be securely mounted to the primary structure. This structure and any guide or support for the belts must meet the minimum requirements of T3.2.
- T5.3.2 Harnesses, belts and straps must not pass through a firewall, i.e. all harness attachment points must be on the driver's side of any firewall.
- T5.3.3 The attachment of the driver's restraint system requires an approved SES per T3.6 The lap belts and anti submarine belts must not be routed over the sides of the seat. Where the belts or harness pass through a hole in the seat, the seat must be rolled or grommeted to prevent chafing of the belts.

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

- T5.4.1 The lap belt must pass around the pelvic area below the anterior superior iliac spines (the hip bones).
- T5.4.2 The lap belts must come through the seat at the bottom of the sides of the seat to maximize the wrap of the pelvic surface and continue in a straight line to the anchorage point.
- T5.4.3 In side view, the lap belt must be capable of pivoting freely by using either a shouldered bolt or an eye bolt attachment.
- T5.4.4 With an "upright driving position", in side view the lap belt must be at an angle of between 45° and 65° to the horizontal.
- T5.4.5 With a "reclined driving position", in side view the lap belt must be between an angle of 60° and 80° to the horizontal.
- T5.4.6 The centerline of the lap belt at the seat bottom must be between 0 mm to 76 mm forward of the seat back to seat bottom junction as in figure 15.

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

- T5.5.1 The shoulder harness must be mounted behind the driver to a structure that meets the requirements of the primary structure. However, it cannot be mounted to the main hoop bracing or attendant structure without additional bracing to prevent loads being transferred into the main hoop bracing.
- T5.5.2 If the harness is mounted to a tube that is not straight, the joints between this tube and the structure to which it is mounted must be reinforced in side view by triangulation tubes to prevent torsional rotation of the harness mounting tube. Supporting calculations are required. Analysis method: Use 7 kN load per attachment and the range of angles in T5.5.5, calculate that the bent shoulder harness bar triangulation stresses are less than as welded yield strength T3.2.4 for combined bending and shear and does not fail in column buckling. If the team chooses not to perform the strength analysis T3.2.6 will apply.
- T5.5.3 The strength of any shoulder harness bar and bracing tubes must be proven in the relevant tab of the team's SES submission.



## T5 Driver Restraint System

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- T5.5.4 The shoulder harness mounting points must be between 180 mm and 230 mm apart, measured center to center.
- T5.5.5 From the driver's shoulders rearwards to the mounting point or structural guide, the shoulder harness must be between 10° above the horizontal and 20° below the horizontal as in figure 15.

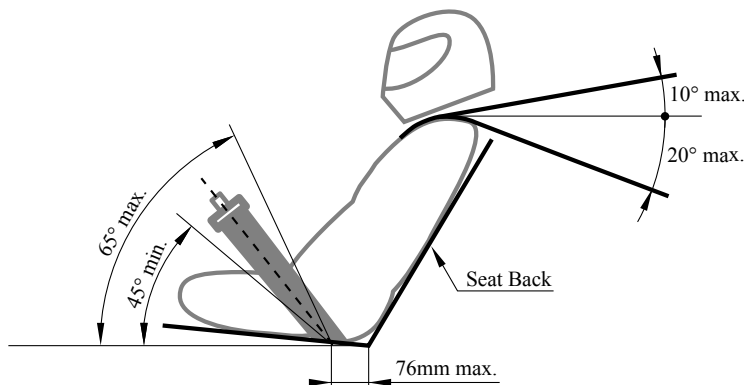


Figure 15: Lap belt and shoulder harness mounting

### T5.6 Anti-Submarine Belt Mounting

- T5.6.1 The anti-submarine belts of a 6 point harness must 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 must 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.

### T5.7 Head Restraint

- T5.7.1 A head restraint must be provided on the vehicle to limit the rearward motion of the driver's head.
- T5.7.2 The head restraint must:
- Be vertical or near vertical in side view.
  - Be padded with an energy absorbing material with a minimum thickness of 40 mm that meets either the SFI 45.2 standard, or is listed in the FIA technical list n°17 as a type B material for single seater cars.
  - Have a minimum width and height of 150 mm.
  - Be located so that for each driver:
    - 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.

## **T6 Brake System**

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- 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.

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

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

T5.8.1 Any portion of the roll bar, roll bar bracing or chassis which might be contacted by the driver’s helmet must be covered with a minimum thickness of 12 mm of padding which meets SFI spec 45.1 or FIA 8857-2001.

### **T5.9 Driver’s Leg Protection**

T5.9.1 All moving suspension and steering components and other sharp edges inside the cockpit between the front hoop and a vertical plane 100 mm rearward of the pedals, must be shielded with solid material.

T5.9.2 Covers over suspension and steering components must be removable to allow inspection of the mounting points.

## **T6 BRAKE SYSTEM**

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

T6.1.1 The vehicle must be equipped with a hydraulic brake system that acts on all four wheels and is operated by a single control.

T6.1.2 The brake system must have two independent hydraulic circuits such that in the case of a leak or failure at any point in the system, effective braking power is maintained on at least two wheels. Each hydraulic circuit must have its own fluid reserve, either by the use of separate reservoirs or by the use of a dammed reservoir.

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

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

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

T6.1.6 Unarmored plastic brake lines are prohibited.

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

T6.1.8 Any part of the brake system must be within the surface envelope, see T1.1.18.

T6.1.9 The brake pedal and its mounting must 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.

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

## **T7 Powertrain**

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T6.1.11 The first 90 % of the brake pedal travel may be used to regenerate brake energy without actuating the hydraulic brake system. The remaining brake pedal travel must directly actuate the hydraulic brake system, but brake energy regeneration may remain active.

### **T6.2 Brake Over-Travel Switch (BOTS)**

T6.2.1 A BOTS must be installed on the vehicle as part of the Shutdown Circuit (SDC), as in EV 6 or CV 4.1. This switch must be installed so that in the event of a failure in at least one of the brake circuits the brake pedal over-travel will result in the SDC being opened. This must function for all possible brake pedal and brake balance settings without damaging any part of the vehicle.

T6.2.2 Repeated actuation of the switch must not close the SDC, and it must be designed so that the driver cannot reset it.

T6.2.3 The BOTS must be a push-pull, push-rotate or flip type mechanical switch. It may consist of a series connection of switches.

### **T6.3 Brake Light**

T6.3.1 The vehicle must be equipped with one brake light that is illuminated if and only if

- the hydraulic brake system is actuated
- [EV ONLY] or the electric brake system is actuated, see EV 2.2.2

T6.3.2 The brake light must

- be a red light.
- be clearly visible from the rear.
- meet requirements according to T 11.10.

T6.3.3 In side view the brake light must be oriented vertically and mounted between the wheel centerline and driver's shoulder level. Viewed from the back it must be positioned approximately at the vehicle's centerline.

## **T7 POWERTRAIN**

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

T7.1.1 Movement of the vehicle without a person in the vehicle and with the master switch(es) in the off position must be possible.

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

T7.2.1 [CV ONLY] Water-cooled internal combustion engines must only use plain water as the coolant.

T7.2.2 Other cooling systems may only use plain water, air or oil as the coolant, see T 1.2.2.

## **T7 Powertrain**

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- T7.2.3 Cooling systems using plain water (except outboard wheel motors and their cooling hoses) must have a heat resistant (Permanently rated for at least 100 °C), rigid and rigidly mounted cover which covers any part of the tallest driver below a plane 100 mm above the bottom of the helmet.
- T7.2.4 Any cooling or lubrication system must be sealed to prevent leakage.
- T7.2.5 Separate catch cans must be employed to retain fluids other than plain water from any vents of the cooling system or combustion engine lubrication system. Each catch-can must have a minimum volume of 10 % of the fluid being contained or 900 mL whichever is greater.
- T7.2.6 Any vent for systems containing plain water must have a catch-can with a minimum volume of 10 % of the fluid being contained or 100 mL, whichever is greater.
- T7.2.7 All parts of the engine, motor(s) cooling and lubrication system, including their mountings, must be rated for at least 120 °C or the temperatures the respective fluid may reach, whichever is higher.
- T7.2.8 Catch cans must be rigidly mounted to the chassis and located rearwards of the firewall below the driver's shoulder level.
- T7.2.9 Any catch can must vent through a hose with a minimum internal diameter of 3 mm down to the bottom level of the chassis and must exit outside the bodywork.

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

- T7.3.1 The lowest point of any lubrication system can only be lower than the line between the lowest point of the main hoop and the lowest chassis member behind the lubrication system if it is protected from hitting the ground by a structure mounted directly to the chassis.
- T7.3.2 Exposed rotating drivetrain parts, such as gears, clutches, chains and belts must be fitted with scatter shields. Scatter shields and their mountings must:
- Be constructed of non-perforated 2 mm steel or 3 mm aluminium alloy 6061-T6.
  - Be attached with 6 mm metric grade 8.8 or stronger and must comply with T 10.1.
- T7.3.3 In addition to T7.3.2, scatter shields must:
- Cover chains and belts from the drive sprocket to the driven sprocket/chain wheel/belt or pulley.
  - Start and end parallel to the lowest point of the driven sprocket/chain wheel/belt or pulley.
  - Be at least three times the width of the chain or belt and be centered at the centerline of the chain or belt
- T7.3.4 The tractive electric motor(s) must have a housing or separate scatter shield from non-perforated 2 mm aluminium alloy 6061-T6 or equivalent. The scatter shield may be split into two equal sections, each 1 mm thick.
- T7.3.5 Finger guards are required to cover any parts that spin while the vehicle is stationary. Finger guards may be made of lighter material, sufficient to resist finger forces. Mesh or perforated material may be used but must prevent the passage of a 12 mm diameter object through the guard.

### T8 AERODYNAMIC DEVICES

#### T8.1 Definition Aerodynamic Device

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

#### T8.2 Restrictions for Aerodynamic Devices

T8.2.1 Height restrictions:

- All aerodynamic devices forward of a vertical plane through the rearmost portion of the front face of the driver head restraint support, excluding any padding, set to its most rearward position, must be lower than 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.

T8.2.2 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 most outboard point 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.

T8.2.3 Length restrictions:

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

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

#### T8.3 Aerodynamic Devices Stability and Strength

T8.3.1 Any aerodynamic device must be able to withstand a force of 200 N distributed over a minimum surface of 225 cm<sup>2</sup> and not deflect more than 10 mm in the load carrying direction.

T8.3.2 Any aerodynamic device must be able to withstand a force of 50 N applied in any direction at any point and not deflect more than 25 mm.

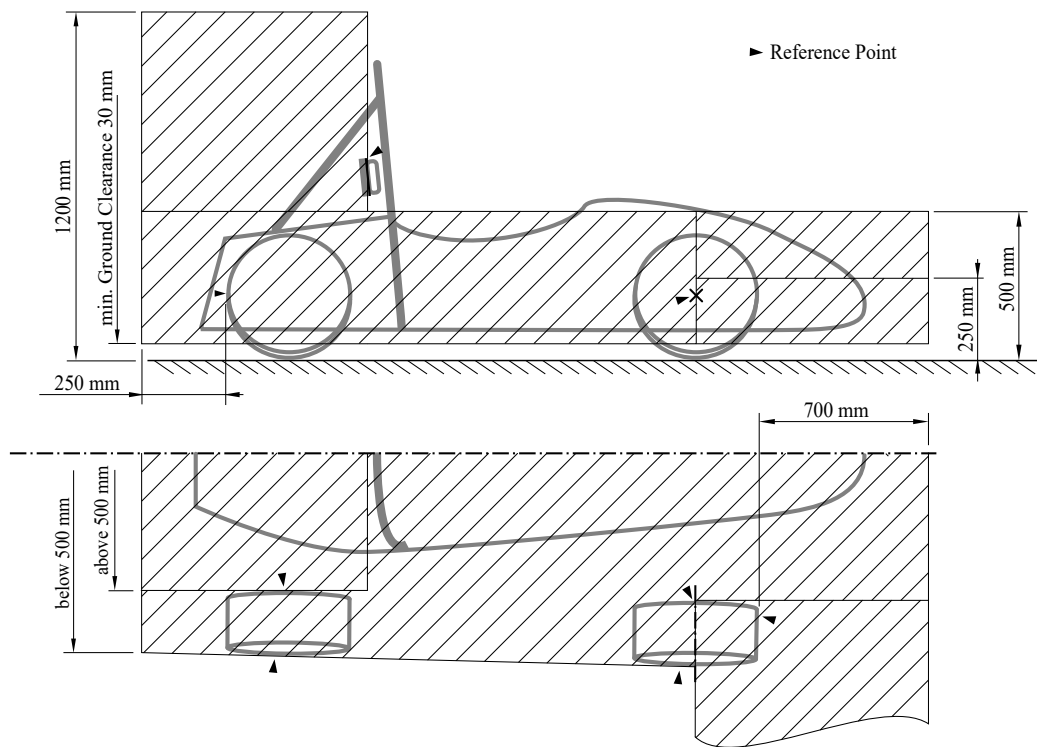


Figure 16: Maximum dimensions and positioning of aerodynamic devices. The positioning space is further restricted, see T 2.1.

## T9 COMPRESSED GAS SYSTEMS AND HIGH PRESSURE HYDRAULICS

### T9.1 Compressed Gas Systems

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

- The working gas must be nonflammable.
- The pressure inside compressed gas systems must not exceed 10 bar.
- Gas cylinders/tanks may exceed the 10 bar limit, if a pressure regulator, which limits the output pressure to a maximum of 10 bar, is mounted directly onto them.
- Gas cylinders/tanks and their pressure regulators must be of proprietary manufacture, designed and built for the pressure being used. Gas cylinders/tanks must be certified and labeled or stamped appropriately.
- The pressure in the function critical pneumatic circuits of the Autonomous System Brake (ASB) shall be limited by means of an overpressure protection, if compressed gas cylinders/tanks exceed the pressure threshold.
- Gas cylinders/tanks and lines must be protected from rollover, collision from any direction, or damage resulting from the failure of rotating equipment.
- Gas cylinders/tanks and their pressure regulators must be located within the rollover protection envelope T 1.1.16.

## **T10 Fasteners**

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- Gas cylinders/tanks and their pressure regulators, must be shielded from the driver. The shields must be steel or aluminium with a minimum thickness of 1 mm.
- Gas cylinders/tanks and their pressure regulators must be protected from damage by the driver or any moving parts.
- Gas cylinders/tanks must be securely mounted to the chassis, engine or transmission.
- The axis of gas cylinders/tanks must not point at the driver.
- Gas cylinders/tanks must be insulated from any heat sources.
- All used parts must be appropriate for the maximum possible operating pressure.

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

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

## **T10 FASTENERS**

### **T10.1 Critical Fasteners**

T10.1.1 Critical fasteners are defined as bolts, nuts, and other fasteners utilized in the primary structure, the steering, braking, driver's harness, suspension systems and those specifically designated as critical fasteners in the respective rule.

T10.1.2 All threaded critical fasteners must be at least 4 mm metric grade 8.8 (OEM parts 3 mm metric grade 8.8), equivalent size or of that specified in the referencing rule, whichever is larger.

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

T10.1.4 Any bolted joint in the primary structure and mounting of the TSAC to the chassis using either tabs or brackets, must have an edge distance ratio "e/D" of 1.5 or greater. "D" equals the hole diameter and "e" equals the distance from the hole 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.

T10.1.5 For steering and suspension systems, alternative fasteners are allowed if equivalency to T10.1.2 and T10.1.3 can be shown.

### **T10.2 Securing Fasteners**

T10.2.1 All critical fasteners must be secured from unintentional loosening by the use of positive locking mechanisms.

T10.2.2 The following methods are accepted as positive locking mechanisms:

## **T 11 Electrical Components**

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- Correctly installed safety wiring.
- Cotter pins.
- Nylon lock nuts (ISO 7040, ISO 10512, EN 1663 or an equivalent standard) for locations where no temperature rating above 80 °C is required.
- Prevailing torque lock nuts (DIN 980, ISO 7042 or an equivalent standard, and jet nuts or K-nuts).
- Locking plates.
- Tab washers.

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

- T 10.2.3 Snap or retaining rings according to DIN 471, DIN 472, or equivalent standard are permitted in OEM applications or for securing bearings or springs given that they do not bear any loads under normal driving conditions.
- T 10.2.4 A minimum of two full threads must project from any lock nut.
- T 10.2.5 All spherical rod ends and spherical bearings on the steering or suspension must be in double shear or captured by having a screw/bolt head or washer with an outer diameter that is larger than the spherical bearing housing inner diameter.
- T 10.2.6 Adjustable tie-rod ends must be constrained with a jam nut to prevent loosening.

## **T 11 ELECTRICAL COMPONENTS**

### **T 11.1 Low Voltage System**

- T 11.1.1 The Low Voltage System (LVS) is defined as
- [CV ONLY] all electrical circuits of the vehicle.
  - [EV ONLY] every electrical part that is not part of the TS, see EV 1.1.1
- T 11.1.2 The maximum permitted voltage that may occur between any two electrical connections in the LVS is 60 VDC or 50 V AC RMS.
- T 11.1.3 All LVS parts must be adequately insulated.
- T 11.1.4 [CV ONLY] The following systems are excluded from the LVS voltage limit, see T 11.1.2:
- High voltage systems for ignition
  - High voltage systems for injectors
  - Voltages internal to OEM charging systems designed for <60 VDC output.
- T 11.1.5 [CV ONLY] The maximum permitted voltage for motor controller/inverters internal low power control signals is 75 VDC
- T 11.1.6 [EV ONLY] The LVS must not use orange wiring or conduit.
- T 11.1.7 [EV ONLY] The LVS must be grounded to the chassis.



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### T11.2 Master Switches

- T11.2.1 Master switches, see T11.3, EV 6.2, and T14.6, must be a mechanical switch of the rotary type, with a red, removable handle. The handle must have a width of at least 50 mm and must only be removable in electrically open position. They must be direct acting, i.e. they must not act through a relay or logic.
- T11.2.2 Master switches must be located on the right side of the vehicle, in proximity to the main hoop, at the 95<sup>th</sup> percentile male driver's shoulder height, as defined in T4.3, and be easily actuated from outside the vehicle.
- The center of any master switch must not be mounted lower than the vertical distance of the template's, see T4.3, middle circle center to the ground surface multiplied by 0.8.
- T11.2.3 The "ON" position of the switch must be in the horizontal position and must be marked accordingly. The "OFF" position of the master switch must also be clearly marked.
- T11.2.4 Master switches must be rigidly mounted to the vehicle and must not be removed during maintenance.
- T11.2.5 Master switches must be mounted next to each other.

### T11.3 Low Voltage Master Switch

- T11.3.1 An LVMS according to T11.2 must completely disable
- [EV ONLY] power to the LVS
  - [CV ONLY] power from the Low Voltage (LV) battery and the alternator to the LVS
- T11.3.2 The LVMS must be mounted in the middle of a completely red circular area of  $\geq 50$  mm diameter placed on a high contrast background.
- T11.3.3 The LVMS must be marked with "LV" and a symbol showing a red spark in a white edged blue triangle.

### T11.4 Shutdown Buttons

- T11.4.1 A system of three shutdown buttons must be installed on the vehicle.
- T11.4.2 Each shutdown button must be a push-pull or push-rotate mechanical emergency switch where pushing the button opens the SDC, see EV 6.1 and CV 4.1.
- T11.4.3 One button must be located on each side of the vehicle behind the driver's compartment at approximately the level of the driver's head. The minimum allowed diameter of the shutdown buttons on both sides of the vehicle is 40 mm. The buttons must be easy reachable from outside the vehicle.
- T11.4.4 One shutdown button serves as a cockpit-mounted shutdown button and must:
- Have a minimum diameter of 24 mm.
  - Be located in easy reach of a belted-in driver.

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- Be alongside of the steering wheel and unobstructed by the steering wheel or any other part of the vehicle.

T 11.4.5 The international electrical symbol consisting of a red spark on a white-edged blue triangle must be affixed in close proximity to each shutdown button.

T 11.4.6 Shutdown buttons must be rigidly mounted to the vehicle and must not be removed during maintenance.

T 11.4.7 Shutdown buttons must be red.

### T 11.5 Inertia Switch

T 11.5.1 An inertia switch must be part of the SDC, see CV 4.1 and EV 6.1, such that an impact will result in the SDC being opened. The inertia switch must latch until manually reset.

T 11.5.2 The device must trigger due to an omnidirectional peak acceleration of  $\leq 8$  g for a half sine test pulse of  $\geq 50$  ms length and  $\leq 13$  g for a half sine test pulse of  $\geq 20$  ms length. The “Sensata Resettable Crash Sensor” should meet those requirements.

T 11.5.3 The device must not include any semiconductor components.

T 11.5.4 The device must be rigidly attached and installed according to manufacturer specification to the vehicle. It must be possible to demount the device so that its functionality may be tested by shaking it.

### T 11.6 Brake System Plausibility Device

T 11.6.1 A standalone non-programmable circuit, the BSPD, must open the SDC, see EV 6.1 and CV 4.1, when hard braking occurs, whilst

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

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

T 11.6.2 The action of opening the SDC must occur if the implausibility is persistent for more than 500 ms.

T 11.6.3 The BSPD must be directly supplied, see T 1.3.1, from the LVMS, see T 11.3.

T 11.6.4 Standalone is defined as there is no additional functionality implemented on all required PCBs. The interfaces must be reduced to the minimum necessary signals, i.e. power supply, required sensors and the SDC. Supply and sensor signals must not be routed through any other devices before entering the BSPD.

T 11.6.5 To detect hard braking, a brake system pressure sensor must be used. The threshold must be chosen such that there are no locked wheels and the brake pressure is  $\leq 30$  bar.

T 11.6.6 [EV ONLY] To measure power delivery, a DC circuit current sensor only must be used. The threshold must be chosen to an equivalent of  $\leq 5$  kW for maximum TS voltage.

T 11.6.7 It must be possible to separately disconnect each sensor signal wire for technical inspection.

## **T 11 Electrical Components**

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T 11.6.8 All necessary signals are System Critical Signal (SCS), see T 11.9.

T 11.6.9 [EV ONLY] The BSPD including all required sensors must not be installed inside the TSAC.

### **T 11.7 Low Voltage Batteries**

T 11.7.1 LV batteries are all batteries connected to the LVS.

T 11.7.2 LV batteries must be securely attached to the chassis and located within the rollover protection envelope, see T 1.1.16.

T 11.7.3 Any wet-cell battery located in the cockpit must be enclosed in a non-conductive, water proof (according to IPX7 or higher, IEC 60529) and acid resistant container.

T 11.7.4 LV batteries must have a rigid and sturdy casing.

T 11.7.5 Completely closed LV battery cases must have an overpressure relief. Venting gases must be separated from the driver by a firewall.

T 11.7.6 LV batteries must be protected from short circuits, not more than 100 mm from ungrounded terminals.

T 11.7.7 Battery packs based on lithium chemistry other than lithium iron phosphate (LiFePO<sub>4</sub>) and all hybrid system energy storages regardless of chemistry type:

- Must have a fire retardant casing, see T 1.2.1.
- Must include overcurrent protection that trips at or below the maximum specified discharge current of the cells.
- Must include overtemperature protection of at least 30 % of the cells, meeting EV 5.8.4, that trips when any cell leaves the allowed temperature range according to the manufacturer's datasheet, but not more than 60 °C, for more than 1 s and disconnects the battery.
- Must include voltage protection of all cells that trips when any cell leaves the allowed voltage range according to the manufacturer's datasheet for more than 500 ms and disconnects the battery.
- It must be possible to display all cell voltages and measured temperatures, e.g. by connecting a laptop.
- Must meet EV 5.8.11
- Signals needed to fulfill these requirements are SCS, see T 11.9.

### **T 11.8 Accelerator Pedal Position Sensor**

T 11.8.1 T 11.8 only applies for EVs or CVs using ETC.

T 11.8.2 The APPS must be actuated by a foot pedal.

T 11.8.3 Pedal travel is defined as percentage of travel from fully released position to a fully applied position where 0 % is fully released and 100 % is fully applied.

## T11 Electrical Components

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- T11.8.4 The foot pedal must return to the 0 % position when not actuated. The foot pedal must have a positive stop preventing the mounted sensors from being damaged or overstressed. Two springs must be used to return the foot pedal to the 0 % position and each spring must work when the other is disconnected. Springs in the APPS are not accepted as return springs.
- T11.8.5 At least two separate sensors must be used as APPSs. The sensors may share the housing.
- T11.8.6 If analog sensors are used, they must have different, non-intersecting transfer functions. A short circuit between the signal lines must always result in an implausibility according to T11.8.9.
- T11.8.7 The APPS signals are SCSs, see T11.9.
- T11.8.8 If an implausibility occurs between the values of the APPSs and persists for more than 100 ms
- [EV ONLY] The power to the motor(s) must be immediately shut down completely. It is not necessary to completely deactivate the TS, the motor controller(s) shutting down the power to the motor(s) is sufficient.
  - [CV ONLY] The power to the electronic throttle must be immediately shut down.
- T11.8.9 Implausibility is defined as a deviation of more than ten percentage points pedal travel between any of the used APPSs or any failure according to T11.9.
- T11.8.10 If three sensors are used, then in the case of an APPS implausibility, any two sensors that are plausible may be used to define the torque target and the 3rd APPS may be ignored.
- T11.8.11 It must be possible to separately disconnect each APPS signal wire to check all functionalities.
- T11.8.12 A fully released accelerator pedal in manual mode must result in:
- [EV ONLY] A wheel torque of  $\leq 0$  Nm
  - [CV ONLY] An idle position or lower throttle set-point. This may only be exceeded during a gearshift for a maximum of 500 ms.

### T11.9 System Critical Signal

- T11.9.1 SCS are defined as all electrical signals which
- Influence actions on the SDC, see CV 4.1 and EV 6.1.
  - Influence the wheel torque.
  - [EV ONLY] Influence indicators according to EV 5.8.9, EV 4.10 or EV 6.3.7.
- T11.9.2 Any of the following SCS single failures must result in a safe state of all connected systems:
- (a) Failures of signals transmitted by cable:
    - Open circuit
    - Short circuit to ground
  - (b) Failures of analog sensor signals transmitted by cable:
    - Short circuit to supply voltage
  - (c) Failures of sensor signals used in programmable devices:

## T11 Electrical Components

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

(d) Failures of digitally transmitted signals by cable or wireless:

- Data corruption (e.g. checked by a checksum)
- Loss and delay of messages (e.g. checked by transmission time outs)

Signals might be a member of multiple signal classes, e.g. analog signals transmitted by cable might be a member of T 11.9.2.a, T 11.9.2.b and T 11.9.2.c.

- T 11.9.3 If a signal failure is correctable, e.g. due to redundancy or worst case values, the safe state must be entered as soon as an additional non correctable failure occurs.
- T 11.9.4 The maximum allowed delay of messages according to T 11.9.2.d must be chosen depending on the impact of delayed messages to the connected system, but must not exceed 500 ms.
- T 11.9.5 Safe state is defined depending on the signals as follows:
- signals only influencing indicators – Indicating a failure of its own function or of the connected system
  - LV battery signals – At least one pole is electrically disconnected from the rest of the vehicle
  - [EV ONLY] For all others signals – opened SDC and opened AIRs
  - [CV ONLY] For all others signals – opened SDC and stopped engine
- T 11.9.6 Indicators according to T 11.9.1 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 LVMS.

### T 11.10 System status light

- T 11.10.1 Any system status light(s), see T 6.3 and T 14.10, must meet the following requirements:
- Black background.
  - Rectangular, triangular or near round shape.
  - Minimum illuminated surface of 15 cm<sup>2</sup> with even luminous intensity.
  - Clearly visible in very bright sunlight.
  - If LED lights are used without a diffuser, they must not be more than 20 mm apart.
  - If a single line of LED lights is used, the minimum length is 150 mm.

### T 11.11 Sensors, Cameras & Electrical Components Mounting

- T 11.11.1 All sensors, cameras and components must be securely mounted.
- T 11.11.2 Sensors, cameras and components must not come into contact with the driver’s helmet under any circumstances.
- T 11.11.3 All sensors, cameras and components must be positioned within the surface envelope, see T 1.1.18, or within the box defined in T 8.2.

## **T 12 Vehicle Identification**

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T 11.11.4 Passive antennas which do not incorporate active electronic parts, e.g. amplifiers with the longest side <100 mm may additionally to T 11.11.3 protrude from the surface envelope, see T 1.1.18, but not their mounting.

### **T 11.12 Legal & Work Safety**

T 11.12.1 All sensors must fulfill the local legislative specifications (i.e. eye-protection classification for laser sensors, power limitation for radar sensors, etc.) in the country of competition.

## **T 12 VEHICLE IDENTIFICATION**

### **T 12.1 Vehicle Number**

T 12.1.1 Each vehicle will be assigned a number at the time of its entry into a competition.

T 12.1.2 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 12.2 Hybrid Vehicle Identification**

T 12.2.1 Combustion Hybrid Vehicles have to be identified by an additional marking next to all three vehicle numbers with the capital letters “HY” in Roman Sans-Serif characters at least 75 mm high in white on a red background.

### **T 12.3 University Name**

T 12.3.1 The university name must be written fully. Only the following abbreviations in the university name are accepted, if the city name is written fully:

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

## **T13 Vehicle and Driver Equipment**

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T 12.3.2 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 12.3.3 The characters must be clearly visible at a distance and placed on a high contrast background.

### **T 12.4 Timing Equipment**

T 12.4.1 All vehicles will get timing equipment provided by the competition organizers.

## **T 13 VEHICLE AND DRIVER EQUIPMENT**

### **T 13.1 Push Bar**

T 13.1.1 Each team must have a removable device (called the push bar) that attaches to the rear of the vehicle and allows two people to push and pull the vehicle while standing erect behind the vehicle.

T 13.1.2 The push bar must have a red color.

T 13.1.3 The university name must be written on the push bar. The characters must be clearly visible and placed on a high contrast background.

T 13.1.4 The push bar must be capable of slowing and stopping the forward motion of the vehicle and pulling it rearwards.

T 13.1.5 An approved fire extinguisher, see T 13.4.1, must be mounted to the push bar such that it is quickly accessible.

T 13.1.6 [EV ONLY] Two pairs of high-voltage insulating gloves and a multimeter with two 4 mm banana plug test leads rated for 1000 V CAT III or better must be attached to the push bar. The High Voltage (HV) gloves must be protected by a case or similar means from mechanical damage, humidity and sunlight. It must be possible to open the case without using tools.

### **T 13.2 Jacks**

T 13.2.1 Each team must have one or two removable devices (jacks) that hold the vehicle, so that all driven wheels are at least 100 mm off the ground.

T 13.2.2 Positioning of the device(s) must be safe.

T 13.2.3 In lifted position:

- The vehicle must be adequately supported and stable
- It must be safe for a driver to enter and exit the vehicle
- The device(s) must not extend out of the vehicles projected surface area.

T 13.2.4 On both sides of the vehicle the devices pickup points must be indicated by orange triangles.

T 13.2.5 The university name must be written on the jacks. The characters must be clearly visible and placed on a high contrast background.

## T13 Vehicle and Driver Equipment

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### T13.3 Driver Equipment

- T13.3.1 The equipment specified below must be worn by the driver anytime while in the cockpit with the engine running or with the TS 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 Disqualified (DQ).
- T13.3.2 A well-fitting, closed face helmet that meets one of the following certifications and is labeled as such:
- Snell K2015, K2020, M2015, M2020, SA2020, EA2016 or newer
  - 31.1/2015, 31.1/2020, 41.1/2015, 41.1/2020 or newer
  - FIA 8860-2010 , FIA 8860-2018, FIA 8859-2015 or newer
- Open faced helmets and off-road helmets (helmets without integrated eye shields) are not approved. All helmets to be used in the competition must be presented during technical inspection where approved helmets will be stickered.
- T13.3.3 If Frontal Head Restraint systems (FHR, HANS) are used, they must be certified to one of the following standards and be labeled as such:
- FIA 8858-2010
  - FIA 8860-2004
  - SFI 38.1
- T13.3.4 A balaclava which covers the driver's head, hair and neck, made from acceptable fire resistant material as defined in T13.3.13, or a full helmet skirt of acceptable fire resistant material.
- T13.3.5 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)
  - SFI 3.4/5 (or higher)
  - FIA Standard 8856-2000
  - FIA Standard 8856-2018
- T13.3.6 Fire resistant underwear (long pants and long sleeve t-shirt). This fire resistant underwear must be made from acceptable fire resistant material as listed in T13.3.13 and must cover the driver's body completely from neck down to ankles and wrists.
- T13.3.7 Fire resistant socks made from acceptable fire resistant material as defined in T13.3.13, that cover the bare skin between the driver's suit and the boots or shoes.
- T13.3.8 Fire resistant shoes made from acceptable fire resistant material as defined in T13.3.13. The shoes must be certified to the standard and labeled as such:
- SFI Spec 3.3
  - FIA Standard 8856-2000
  - FIA Standard 8856-2018



## **T13 Vehicle and Driver Equipment**

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- T 13.3.9 Fire resistant gloves made from acceptable fire resistant material as defined in T 13.3.13. Gloves of all leather construction or fire resistant gloves constructed using leather palms with no insulating fire resisting material underneath are not acceptable.
- T 13.3.10 Fire resistant clothing must not be older than 10 years, recognisable since no FIA hologram label present.
- T 13.3.11 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 13.3.12 All driver equipment covered in T 13.3: must be in good condition. Specifically, it must not have any tears, rips, open seams, areas of significant wear or abrasion or stains which might compromise fire resistant performance. Teams must be able to show that the clothing still meets the requirements of T 13.3 if driver's clothing is embroidered. This requires, but is not limited to, that only the outer shell is perforated. The officials reserve the right to impound all non-approved driver equipment until the end of the competition.
- T 13.3.13 For the purpose of this section some, but not all, of the approved fire resistant materials are: Nomex, Aramid, Belcotex and Indura.
- T 13.3.14 T-shirts, socks or other undergarments made from nylon or any other synthetic material which will melt when exposed to high heat are prohibited.

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

- T 13.4.1 Each team must have at least two dry chemical/dry powder fire extinguishers with a minimum firefighting agent capacity of 0.9 kg.
- T 13.4.2 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 13.4.3 Aqueous Film Forming Foam (AFFF) fire extinguishers are prohibited. Halon extinguishers and systems are prohibited.
- T 13.4.4 All extinguishers must be equipped with a manufacturer installed pressure/charge gauge.
- T 13.4.5 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 13.4.6 Hand held fire extinguishers are not permitted to be mounted on or in the vehicle.

## **T 14 Autonomous System**

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### **T 14 AUTONOMOUS SYSTEM**

#### **T 14.1 Definitions**

T 14.1.1 Each vehicle must implement a full AS according to T 14, to run in autonomous mode.

T 14.1.2 [CV ONLY] The following definitions apply to maintain the same wording as for EVs:

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

#### **T 14.2 Data Logger**

T 14.2.1 The officials will provide a standardized data logger that must be installed during the competition. Further specifications for the data logger and required hardware and software interfaces can be found in the competition handbook.

T 14.2.2 The team needs to provide two sets of signals to the data logger:

- Basic set of signals as defined in the competition handbook
- Vehicle-individual set of signals that is monitored by the ASB to ensure redundancy and fault detection

T 14.2.3 [CV ONLY] The mounting of the data logger must be sealed during technical inspection.

#### **T 14.3 Remote Emergency System**

T 14.3.1 Every vehicle must be equipped with a standard RES specified in the competition handbook. The system consists of two parts, the remote control and the vehicle module.

T 14.3.2 The RES must be purchased by the team.

T 14.3.3 The RES has two functions:

- When the remote emergency stop button is pressed, it must open the SDC defined in T 14.4.
- When the “Go” button is pressed, the preselected autonomous mission is started.

T 14.3.4 The RES vehicle module must be directly integrated in the vehicle’s SDC with one of its relays hard-wired in series to the shutdown buttons.

T 14.3.5 The RES relay, which is integrated into the SDC, may be bypassed by a normally closed relays, when driving manually. The relay must:

- Be directly supplied by the ASMS, see T 14.6.
- Have a safety certified forcibly guided or a mirrored normally open contact which is directly connected in series to the ASMS.

## **T 14 Autonomous System**

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T 14.3.6 The antenna of the RES must be mounted unobstructed and without interfering parts in proximity (other antennas, etc.).

### **T 14.4 Shutdown Circuit**

T 14.4.1 The SDC may only be closed by the AS, if the following conditions are fulfilled:

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

### **T 14.5 Signals**

T 14.5.1 Any signal of the AS is a SCS. If failures lead to loss of environment perception and/or localization, the system must react accordingly.

### **T 14.6 Autonomous System Master Switch**

T 14.6.1 Each vehicle must be equipped with an ASMS, according to T 11.2.

T 14.6.2 The ASMS must be mounted in the middle of a completely blue circular area of  $\geq 50$  mm diameter placed on a high contrast background.

T 14.6.3 The ASMS must be marked with “AS”.

T 14.6.4 The power supply of the steering and braking actuators must be switched by

- LVMS
- ASMS

Other than stated in T 11.2.1, non-programmable logic may be used as part of the ASMS.

T 14.6.5 When the ASMS is in “Off” position, the following must be fulfilled:

- No steering, braking and propulsion actuation can be performed by request of the autonomous system.
- The sensors and the processing units can stay operational.
- The vehicle must be able to be pushed as specified in A 6.7.
- It must be possible to operate the vehicle manually as a normal CV or EV.

T 14.6.6 It is strictly forbidden to switch the ASMS to the “On” position if a person is inside the vehicle.

T 14.6.7 After switching the ASMS to the “On” position, the vehicle must not start moving, until R2D is entered (Figure 17).

T 14.6.8 The ASMS must be fitted with a “lockout/tagout” capability to prevent accidental activation of the AS. The ASR must ensure that the ASMS is locked in the off position whenever the vehicle is outside the dynamic area or driven in manual mode.

## T 14 Autonomous System

### T 14.7 Steering Actuation

- T 14.7.1 Steering system actuation (movement) must only happen if the vehicle is R2D.
- T 14.7.2 The steering system may remain active during an emergency brake maneuver while the vehicle is in movement.
- T 14.7.3 Manual steering must be possible without manual release steps (e.g. operating manual valves / (dis-) connecting mechanical elements) while the ASMS is switched “Off”.

### T 14.8 Actuator Decoupling

- T 14.8.1 It is not allowed to remove any parts of the AS for dynamic events.
- T 14.8.2 The actuators may be disconnected for manual driving if:
  - no parts including bolts, clips, etc. are removed for disconnection i.e. they must never lose the physical contact to the disconnection mechanism.
  - the disconnection mechanism cannot block manual operation in any position.
  - the disconnection mechanism is securely locked in both positions.

### T 14.9 Autonomous System Status Definitions

- T 14.9.1 The Emergency Brake System (EBS) is considered to be “activated”, if the power supply path defined in T 15.2.2 is cut after passing the initial checkup sequence (T 15.3.1). Brakes may only be released after performing manual steps.
- T 14.9.2 The status of the AS must be determined according to the flowchart in Figure 17.

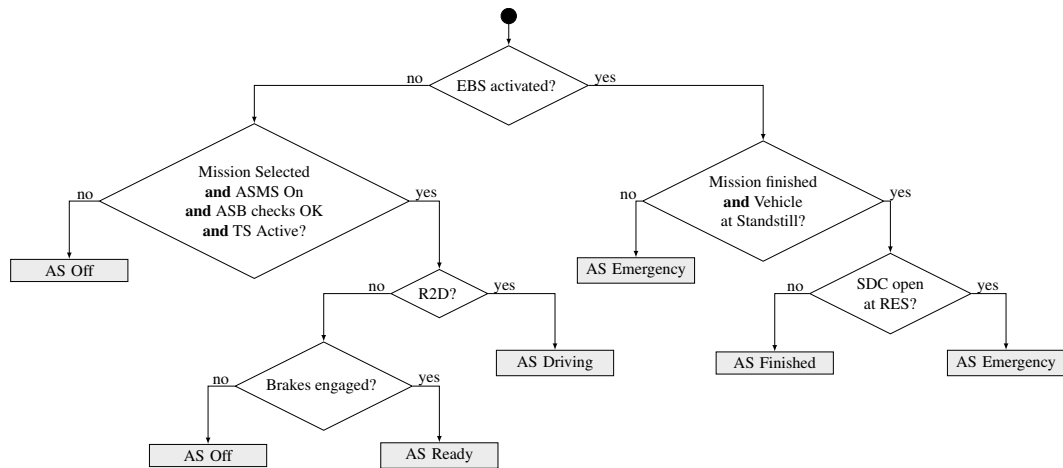


Figure 17: AS Status Flowchart

- T 14.9.3 R2D may only be activated by the “Go” signal from the RES, after the system has remained in “AS Ready” for at least 5 s.
- T 14.9.4 Performing manual steps, other than activating the TS, at the vehicle while the ASMS is switched “On” is prohibited.

## T 14 Autonomous System

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### T 14.10 Autonomous System Status Indicators

T 14.10.1 The vehicle must include three ASSIs that must indicate the status of the AS (as defined in T 14.9) correlating to illumination as shown:

| AS Off | AS Ready          | AS Driving      | AS Emergency  | AS Finished     |
|--------|-------------------|-----------------|---------------|-----------------|
| off    | yellow continuous | yellow flashing | blue flashing | blue continuous |

The ASSIs must not perform any other functions.

T 14.10.2 One ASSI must be located on each side of the vehicle behind the driver's compartment, in a region 160 mm below the top of the main hoop and 600 mm above the ground. The third ASSI must be located at the rear of the vehicle, on the vehicle centerline, in a region 160 mm below the top of the main hoop and 100 mm above the brake light.

T 14.10.3 At least one ASSI must be visible from any angle of the vehicle from a point 1.60 m vertically from ground level, within 3 m horizontal radius from the top of the main hoop.

T 14.10.4 Each ASSI must meet requirements according to T 11.10.

T 14.10.5 The status "AS Emergency" has to be indicated by an intermittent sound with the following parameters:

- on-/off-frequency: 1 Hz to 5 Hz
- duty cycle 50 %
- sound level between 80 dBA and 90 dBA, fast weighting in a radius of 2 m around the vehicle.
- duration between 8 s and 10 s after entering "AS Emergency"

### T 14.11 Autonomous Missions

T 14.11.1 The AS must at least implement the following missions:

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

T 14.11.2 The inspection mission is defined by slowly spinning the drivetrain and actuating the steering system with a sine wave while the vehicle is jacked up and all wheels are removed. After 25 s to 30 s the AS must transition to "AS Finished".

T 14.11.3 It must be possible to select any mission without the use of an external device.

T 14.11.4 The selected mission must be indicated by the Autonomous Mission Indicator (AMI).

## **T 15 Autonomous System Brake**

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T 14.11.5 The AMI must be easily readable and can either be part of the dashboard or located next to the ASMS. If an e-ink display is used, it must be visible that the shown mission is up-to-date. AMI is considered SCS!

### **T 14.12 Autonomous System Form**

T 14.12.1 Prior to the competition, all teams must submit a clearly structured documentation of their entire AS (including ASB) called ASF.

## **T 15 AUTONOMOUS SYSTEM BRAKE**

### **T 15.1 Technical Requirements**

T 15.1.1 To run in autonomous mode, the vehicle must be equipped with an ASB that features an EBS as part of it, see T 15.2.

T 15.1.2 All parts of the ASB must be located within the rollover protection envelope, see T 1.1.16.

T 15.1.3 The TS is not considered to be a brake system.

T 15.1.4 Manual braking must always be possible. In case of manual and autonomous braking simultaneously, always the highest of both pressures must be applied to the brakes.

T 15.1.5 Master brake cylinders must not be connected in series.

T 15.1.6 The ASB may be part of the hydraulic brake system. For all components inside the vehicles brake circuit T6 is applied. On all remaining pneumatic and hydraulic components T9 applies.

T 15.1.7 The ASB must be designed so that it can be easily deactivated by a maximum of two deactivation points.

T 15.1.8 All deactivation points of the ASB must:

- work without the aid of electrical power
- be in proximity to each other
- either be mounted in proximity to the ASMS or on the top side of the vehicle between front bulkhead and front hoop close to the vehicles center line
- be operable by maximum two simple push/pull and/or turning actions, the order and direction of these actions must be shown next to the deactivation points.
- be marked with “Brake release”
- have a red handle

T 15.1.9 The use of push-in fittings is prohibited in function critical pneumatic circuits of the ASB and any other system which uses the same energy storage without proper decoupling.

## **T 15 Autonomous System Brake**

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### **T 15.2 Emergency Brake System**

- T 15.2.1 The EBS must only use passive systems with mechanical energy storage. Electrical power-loss at EBS must lead to a direct emergency brake maneuver with the performance specified in T 15.4.
- T 15.2.2 The EBS must be supplied by LVMS, ASMS, RES and a relay which is supplied by the SDC (parallel to the AIRs, but must not be delayed).

### **T 15.3 Functional Safety**

- T 15.3.1 An initial check has to be performed to ensure that ASB is able to build up brake pressure as expected, before AS transitions to “AS Ready”.
- T 15.3.2 After the initial check the ASB and its SCS must be continuously monitored for failures.
- T 15.3.3 The vehicle must automatically transition to the safe state, if:
- the functionality according to T 15.2.1 cannot be ensured.
  - an (additional) single point of failure would lead to total loss of brake capability.
- T 15.3.4 The safe state is the vehicle at a standstill, brakes engaged to prevent the vehicle from rolling, and an open SDC.
- T 15.3.5 To get to the safe state, the vehicle must perform an autonomous brake maneuver described in section T 15.4 and IN 11.2.

### **T 15.4 Emergency Brake System Performance**

- T 15.4.1 The system reaction time (the time between opening of the SDC and the start of the deceleration) must not exceed 200 ms.
- T 15.4.2 The average deceleration must be greater than  $10 \text{ m/s}^2$  under dry track conditions.
- T 15.4.3 In case of a single failure the ASB should be designed to achieve at least half of the performance specified in T 15.4.2.
- T 15.4.4 Whilst decelerating, the vehicle must remain in a stable driving condition.

# CV INTERNAL COMBUSTION ENGINE VEHICLES

## CV1 INTERNAL COMBUSTION ENGINE POWERTRAINS

### CV1.1 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 with a displacement not exceeding 710 cm<sup>3</sup> per cycle. Hybrid powertrains must use a purely electrical energy storage.

### CV1.2 Starter

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

CV 1.2.2 For autonomous operation, the vehicle must be equipped with an additional engine start button next to the LVMS, see T 11.3, that can be easily actuated from outside the vehicle. Using the external engine start button, the engine may only start if

- the ASMS (see T 14.6) is switched on and
- the gearbox is in neutral.

CV 1.2.3 If CV 1.2.2 requires an additional engine start button, there must be a green light next to it, 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 The AS must not be able to (re-)start the engine.

### CV1.3 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 envelope, see T 1.1.18.

CV 1.3.2 Any portion of the air intake system that is less than 350 mm above the ground must be protected from impacts, see T 3.15. Impact protection must follow T 3.16 when having bolted attachments.

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 T 10. Rubber bushings or hoses are not considered as securely attached.



## **CV1 Internal Combustion Engine Powertrains**

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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 chassis must incorporate isolation to allow for engine movement and chassis torsion.

### **CV1.4 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 Electronic Throttle Control (ETC) system, see CV 1.6.

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

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

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

CV 1.5.1 CV 1.5 can only be used if no AS 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.

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

CV 1.6.1 CV 1.6 only applies if ETC is used.

CV 1.6.2 The team must be able to demonstrate the functionality of all safety features and error detections of the ETC system at technical inspection, see IN.

CV 1.6.3 The ETC system must be equipped with at least the following sensors:

- Accelerator Pedal Position Sensors (APPSs) as defined in T 11.8.
- Two Throttle Position Sensors (TPSs) to measure the throttle position.

## CV1 Internal Combustion Engine Powertrains

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- CV 1.6.4 All ETC signals are SCS, see T 11.9.
- CV 1.6.5 When power is removed, the electronic throttle must immediately close at least to idle position  $\pm 5\%$ . An interval of one second is allowed for the throttle to close to idle, failure to achieve this within the required interval must result in immediate disabling of power to ignition, fuel injectors and fuel pump. This action must remain active until the TPS signals indicate the throttle has returned to idle position  $\pm 5\%$  for at least one second.
- CV 1.6.6 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 11.9.  
AS must check this signal consistency on a low level itself.
- CV 1.6.7 The electronic throttle must use at least two sources of energy capable of returning the throttle to the closed position. One of the sources may be the device that normally actuates the throttle, e.g. a DC motor, but the other device(s) must be a return spring that can return the throttle to the idle position in the event of a loss of actuator power.
- CV 1.6.8 Springs in the TPSs are not acceptable as return springs.
- CV 1.6.9 The power to the electronic throttle must be immediately shut down, as defined in CV 1.6.5, if the throttle position differs by more than 10 % from the expected target TPS position for more than 500 ms.

### CV1.7 Intake System Restrictor

- CV 1.7.1 In order to limit the power capability from the engine(s), a single circular restrictor must be placed in the intake system and all engine(s) airflow must pass through this restrictor. The only allowed sequence of components are the following:
- For naturally aspirated engines, the sequence must be: throttle body, restrictor, and engine, see figure 18
  - For turbocharged or supercharged engines, the sequence must be: restrictor, compressor, throttle body, engine, see figure 19
- CV 1.7.2 The maximum restrictor diameters which must be respected at all times during the competition are:
- Gasoline fueled vehicles - 20 mm
  - E 85 fueled vehicles - 19 mm
- CV 1.7.3 The restrictor must be located to facilitate measurement during the inspection process.
- CV 1.7.4 The circular restricting cross section must 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.

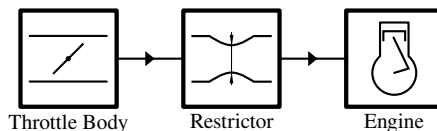


Figure 18: Intake configuration for naturally aspirated engines.

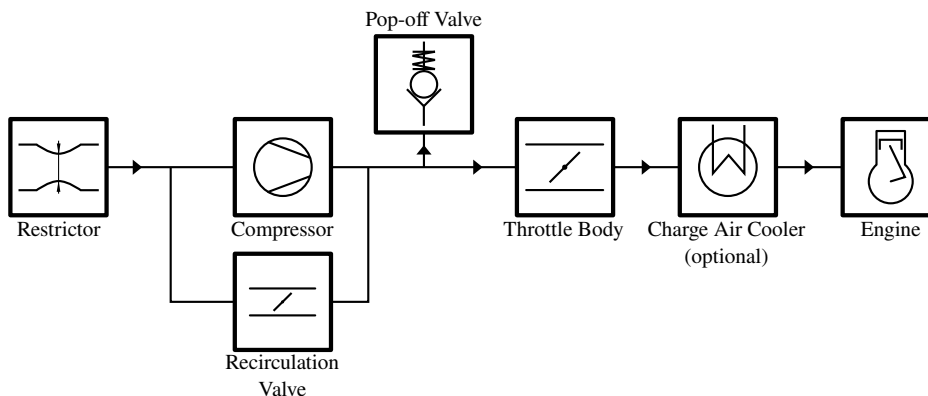


Figure 19: Intake configuration for turbocharged or supercharged engines.

### CV1.8 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 plain 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 19.
- 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<sup>2</sup> if non-circular.

### CV1.9 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.

## CV2 FUEL AND FUEL SYSTEM

### CV2.1 Fuel

- CV2.1.1 The available fuel types will be unleaded gasoline 98RON and E 85.

## **CV2 Fuel and Fuel System**

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- CV 2.1.2 The vehicles must be operated with the fuel provided at the competition.
- CV 2.1.3 No agents other than fuel and air may be induced into the combustion chamber.
- CV 2.1.4 The temperature of fuel introduced into the fuel system must not be changed with the intent to improve calculated efficiency.

### **CV 2.2 Fuel System Location Requirements**

- CV 2.2.1 The fuel tank must be located within the rollover protection envelope, see T 1.1.16, except the fuel filler neck if it is 350mm above the ground.
- CV 2.2.2 All parts of the fuel storage and supply system must lie within the surface envelope, see T 1.1.18.
- CV 2.2.3 All parts of the fuel storage and supply system must be adequately protected against any heat sources and located at least 50 mm from any exhaust system component.
- CV 2.2.4 All parts of the fuel system which can come in contact with the fuel must be rated for permanent contact with fuel.

### **CV 2.3 Fuel Tank**

- CV 2.3.1 The fuel tank is defined as the part of the fuel containment device that is in contact with the fuel. It may be made of a rigid material or a flexible material.
- CV 2.3.2 The fuel tank must be securely attached to the vehicle structure with mountings that allow some flexibility such that chassis flex cannot unintentionally load the fuel tank.
- CV 2.3.3 The fuel tank must not touch any part of the vehicle other than its mounting and parts of the fuel system at any time.
- CV 2.3.4 Any fuel tank that is made from a flexible material, for example a bladder fuel cell or a bag tank, must be enclosed within a rigid fuel tank container which is securely attached to the vehicle structure. Fuel tank containers (containing a bladder fuel cell or bag tank) may be load carrying.
- CV 2.3.5 The fuel system must have a provision for emptying the fuel tank if required.
- CV 2.3.6 The fuel tank, by design, must not have a variable capacity.

### **CV 2.4 Fuel Lines for Low Pressure Systems**

- CV 2.4.1 Fuel lines between fuel tank and fuel rail and return lines must:
- have reinforced rubber fuel lines with an abrasion protection with a fuel hose clamp which has a full 360° wrap, a nut and bolt system for tightening and rolled edges to prevent the clamp cutting into the hose, or
  - have metal braided hoses with crimped-on or reusable, threaded fittings.
  - be rated for temperatures of at least 120 °C.

## **CV2 Fuel and Fuel System**

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- CV 2.4.2 The use of unmodified OEM fuel lines and connectors, including those manufactured from plastic, is acceptable.
- CV 2.4.3 For reinforced rubber fuel lines with hose & clamp style connections beaded or barbed hose fittings must be used.
- CV 2.4.4 Fuel lines must be securely attached to the vehicle and/or engine.
- CV 2.4.5 All fuel lines must be shielded from possible rotating equipment failure or collision damage.
- CV 2.4.6 All fuel lines must be fitted in such a way that any leakage cannot result in the accumulation of fuel in the cockpit.

### **CV 2.5 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 2.5.1 The following requirements apply to LPI fuel systems:
- The fuel lines must comply with CV 2.4.
  - The fuel rail must be securely attached to the engine cylinder block, cylinder head, or intake manifold with mechanical fasteners. The threaded fasteners used to secure the fuel rail are considered critical fasteners and must comply with T 10.
  - The use of fuel rails made from plastic, carbon fiber or rapid prototyping flammable materials is prohibited. However, the use of unmodified OEM Fuel Rails manufactured from these materials is acceptable.
- CV 2.5.2 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 10.
  - 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.

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

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

- has at least an inner diameter of 35 mm at any point between the fuel tank and the top of the fuel filler cap.
- is angled at no more than 30° from the vertical
- is accompanied by a clear fuel resistant sight tube above the top of the fuel tank with a length of at least 125 mm vertical height for reading the fuel level, see figure 20.
- is made of material that is permanently rated for temperatures of at least 120 °C.

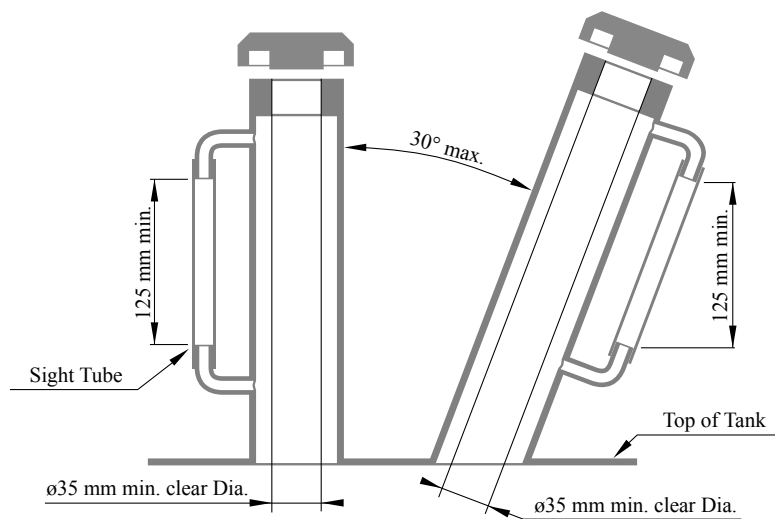


Figure 20: Minimum requirements fuel tank filler neck.

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

CV2.6.3 A permanent, non-movable, clear and easily 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 (IN 7.1), and before and after the endurance test to measure the amount of fuel used during the endurance event.

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

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

### CV2.7 Tank Filling Requirement

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

## **CV3 Exhaust System and Noise Control**

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CV2.7.2 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.

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

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

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

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

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

CV3.1.1 The exhaust outlet must be routed to the side or rear of the vehicle and so that the driver is not subjected to fumes at any speed considering the draft of the vehicle.

CV3.1.2 The exhaust outlet(s) must not extend more than 450 mm behind the centerline of the rear axle and shall be no more than 600 mm above the ground.

CV3.1.3 Any exhaust components (headers, mufflers, etc.) that protrude from the side of the chassis in front of the rear axle must be shielded to prevent contact by persons approaching the vehicle or a driver exiting the vehicle. The temperature of the outer surface must not be harmful to a person touching it.

CV3.1.4 The application of fibrous/absorbent material, e.g. “headerwrap”, to the outside of an exhaust manifold or exhaust system is prohibited.

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

CV3.2.1 The maximum sound level test speed for a given engine will be the engine speed that corresponds to an average piston speed of 15.25 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.

CV3.2.2 The idle test speed for a given engine will be up to the team and determined by their calibrated idle speed. If the idle speed varies then the vehicle will be tested across the range of idle speeds determined by the team. At idle the maximum permitted sound level is 103 dB(C), fast weighting.

## **CV4 SHUTDOWN SYSTEM**

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

CV4.1.1 The Shutdown Circuit (SDC) directly controls all electrical power to the ignition, fuel injectors and all fuel pumps. It must act through a minimum of two mechanical relays. One relay for the fuel pump and at least one relay for injection and ignition.

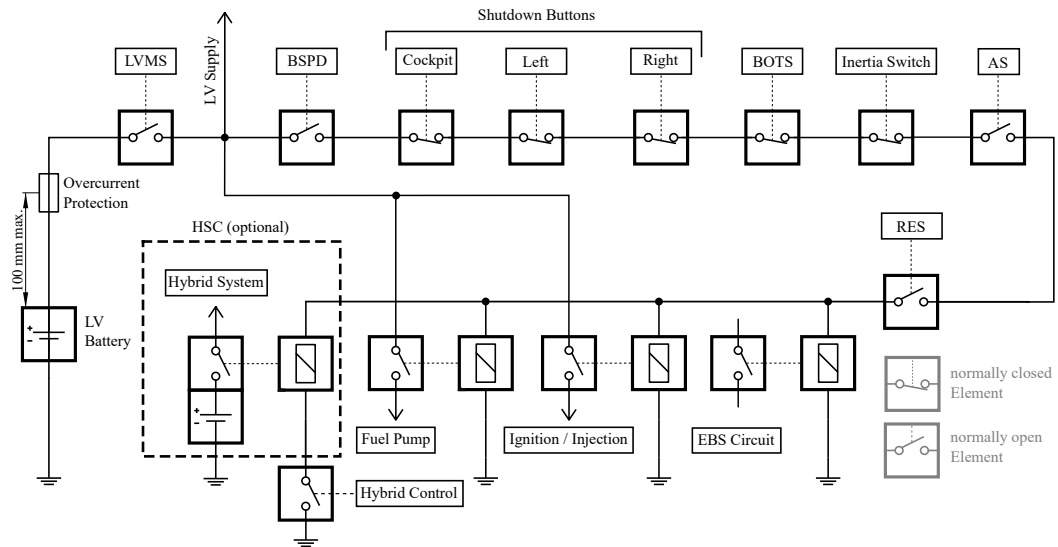


Figure 21: Explanatory example schematic of the required Shutdown Circuit (SDC)

An explanatory schematic of the required SDC, is shown in Figure 21.

- CV 4.1.2 The SDC is defined as a series connection of at least the LVMS, see T 11.3, the BSPD, see T 11.6, three shutdown buttons, see T 11.4, the BOTS, see T 6.2 and the inertia switch, see T 11.5.
- CV 4.1.3 All circuits that are part of the SDC must be designed in a way, that in the de-energized/disconnected state they open the SDC.
- CV 4.1.4 [HY ONLY] The HSC AIR as per CV 5.2.2 must be part of the SDC in such a way that one side of the relay coil is directly incorporated into the SDC and the other side is controlled by the hybrid control system.

## **CV 5 HYBRID SYSTEM**

### **CV 5.1 Hybrid System General**

- CV 5.1.1 The hybrid system must be a LVS, T 11.1 and T 11.7 are applied for all hybrid system components.
- CV 5.1.2 All electrical parts of the hybrid system except for ground terminals must be covered at least according to IPxxB when energized.
- CV 5.1.3 The Hybrid Storage Container (HSC) is defined as the electric energy storage system, including the AIR and overcurrent protection, that is used in the hybrid powertrain.
- CV 5.1.4 Moving energy into the HSC from a different electrical storage system is prohibited.
- CV 5.1.5 A firewall, see T 4.8, must be present between the HSC and the fuel tank.
- CV 5.1.6 The HSC must be positioned according to T 11.7.2, all other hybrid system components must be positioned within the surface envelope, see T 1.1.18.



## **CV5 Hybrid System**

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- CV 5.1.7 The high current path of the hybrid system must meet EV 4.5.16.
- CV 5.1.8 Motors must meet EV 2.1.
- CV 5.1.9 The hybrid system may only be activated when the combustion engine is running or during engine start.

### **CV 5.2 Hybrid Storage Container**

- CV 5.2.1 The HSC must be attached to the primary structure, see T 1.1.12, and meet EV 5.5.8.
- CV 5.2.2 A disconnection mechanism, designed as an AIR must be integrated into the HSC, disconnecting the positive pole of the HSC. The AIR must be compliant with EV 5.6.3.
- CV 5.2.3 The maximum accumulated weight of all elements in the hybrid system that store the electrical energy, e.g. battery cells or supercapacitors, including all casings and tabs that are integral to them, is 3 kg.
- CV 5.2.4 The HSC must be removable to be inspected at the mechanical inspection and it must be possible to easily check the weight limit.

### **CV 5.3 Hybrid System Form**

- CV 5.3.1 A Hybrid System Form (HSF) has to be submitted using the HSF template
- CV 5.3.2 The HSF template will be available on the competition website
- CV 5.3.3 If no HSF is submitted, the team must not use the hybrid system at the competition. A 5.4.2 will not be applied for the HSF

## **EV ELECTRIC VEHICLES**

### **EV 1 DEFINITIONS**

#### **EV 1.1 Tractive System**

EV 1.1.1 Tractive System (TS) – every part that is electrically connected to the motors and TS accumulators.

EV 1.1.2 TS enclosures – every housing or enclosure that contains parts of the TS.

#### **EV 1.2 Electric**

EV 1.2.1 Galvanic Isolation – two electric circuits are defined as galvanically isolated if all of the following conditions are true:

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

### **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 10.

EV 2.1.3 Motor casings must follow T 7.3.

EV 2.1.4 The motor(s) must be connected to the accumulator through a motor controller.

#### **EV 2.2 Power Limitation**

EV 2.2.1 The TS power at the outlet of the TSAC must not exceed 80 kW.

EV 2.2.2 Regenerating energy is allowed and unrestricted.

EV 2.2.3 Wheels must not be spun in reverse.

### EV3 GENERAL REQUIREMENTS

#### EV3.1 Grounding

EV 3.1.1 TS enclosures, see EV 1.1.2, must consist of either

- a grounded solid layer made of at least 0.5 mm thick electrically conductive material, aluminium or better, having a resistance below 300 m $\Omega$ , measured with a current of 1 A, to LVS ground and able to continuously carry at least 10 % of the TS accumulator main fuse current rating or
- be fully made out of electrically insulating materials having an isolation resistance of at least 2 M $\Omega$ , measured with a voltage of 500 V. The enclosure must be rigid and must prevent possible mechanical penetrations. Protruding electrically conductive parts, such as fasteners or connectors, must follow EV 3.1.2

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

EV 3.1.2 Electrically conductive seat, driver harness, and firewall mounting points as well as the aluminium layer of the TS firewall, see T4.8, and the LVS ground measuring point, see EV 4.7.8, must have a resistance below 300 m $\Omega$ , measured with a current of 1 A, to LVS ground and be able to continuously carry at least 10 % of the TS accumulator main fuse current rating.

EV 3.1.3 Parts of the vehicle which are or may become electrically conductive within 100 mm of any TS component must have a resistance below 100  $\Omega$  to LVS ground.

EV 3.1.4 The rotating part of the wheels does not need to be grounded.

#### EV3.2 Overcurrent Protection

EV 3.2.1 All electrical systems must have appropriate overcurrent protection.

EV 3.2.2 The continuous current rating of the overcurrent protection must not be greater than the continuous current rating of any electrical component, for example, wire, busbar, or other conductors that it protects. I.e. if multiple pins of a connector are used to carry currents in parallel, each pin must be appropriately protected.

EV 3.2.3 All used fuses must have an interrupt current rating that is higher than the theoretical short circuit current of the system that it protects.

EV 3.2.4 All overcurrent protection devices must be rated for the highest voltage in the systems they protect. All devices used must be rated for DC.

EV 3.2.5 All overcurrent protection devices that are part of the TS must not rely on programmable logic. The overcurrent protection function of motor controllers/inverters for the motor outputs may rely on programmable logic.

EV 3.2.6 The overcurrent protection must be designed for the expected surrounding temperature range but at least for 0 °C to 85 °C

EV 3.2.7 The TS high current path through the accumulator(s) must be fused.

## EV 4 Tractive System

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### EV 4 TRACTIVE SYSTEM

#### EV 4.1 General Requirements

- EV 4.1.1 The maximum permitted voltage that may occur between any two electrical connections is 600 VDC and for motor controller/inverters internal low power control signals 630 VDC.
- EV 4.1.2 All components in the TS must be rated for the maximum TS voltage.  
The TS area of a PCB, see EV 4.3.6, is considered as one component. Every input connected to the TS must be rated to the maximum TS voltage.
- EV 4.1.3 All components must be rated for the maximum possible temperature that may occur during usage.
- EV 4.1.4 Fans with  $>50$  W power must not be connected to the TS.

#### EV 4.2 Tractive System Enclosures

- EV 4.2.1 TS enclosures, see EV 1.1.2, must be labeled with (a) reasonably sized sticker(s) according to “ISO 7010-W012” (triangle with a black lightning bolt on a yellow background). The sticker must also contain the text “High Voltage” if the voltage is more than 60 VDC or 50 VACRMS.

#### EV 4.3 Separation of Traction System and Grounded Low Voltage System

- EV 4.3.1 The entire TS and LVS must be galvanically isolated, see EV 1.2.1 and IN 4.1.1.
- EV 4.3.2 All connections from a TS component to external devices, such as laptops must include galvanic isolation, see EV 1.2.1.
- EV 4.3.3 TS and LVS circuits must be physically segregated such that they are not running through the same conduit or connector, except for interlock circuit connections.
- EV 4.3.4 Where both TS and LVS are present within an enclosure, they must be separated by barriers made of moisture-resistant insulating materials or maintain the following spacing through the air, or over a surface:

| Voltage                   | Spacing |
|---------------------------|---------|
| $U < 100$ VDC             | 10 mm   |
| $100$ VDC $< U < 200$ VDC | 20 mm   |
| $U > 200$ VDC             | 30 mm   |

- EV 4.3.5 Components and cables capable of movement must be positively restrained to maintain spacing.
- EV 4.3.6 If TS and LVS are on the same PCB, they must be on separate well-defined areas of the board, meeting the spacing requirements in table 5, each area clearly marked with “TS” or “LV”. The outline of the area required for spacing must be marked.  
“Conformal coating” refers to a coating insulator, solder resist is not a coating.

## EV 4 Tractive System

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| Voltage            | Over Surface | Through Air<br>(Cut in board) | Conformal Coating |
|--------------------|--------------|-------------------------------|-------------------|
| 0 VDC to 50 VDC    | 1.6 mm       | 1.6 mm                        | 1.0 mm            |
| 50 VDC to 150 VDC  | 6.4 mm       | 3.2 mm                        | 2.0 mm            |
| 150 VDC to 300 VDC | 9.5 mm       | 6.4 mm                        | 3.0 mm            |
| 300 VDC to 600 VDC | 12.7 mm      | 9.5 mm                        | 4.0 mm            |

Table 5: Spacing required between TS and LV.

EV 4.3.7 Teams must be prepared to demonstrate spacing on team-built equipment. For inaccessible circuitry, fully assembled spare boards must be available.

### EV 4.4 Positioning of Tractive System Parts

EV 4.4.1 Except what is permitted according to EV 4.4.3, all parts belonging to the TS including cables and wiring must be located within the rollover protection envelope, see T 1.1.16. “Part” is the whole device such as the complete HVD.

EV 4.4.2 Any part of the TS that is less than 350 mm above the ground, except what is permitted according to EV 4.4.3, must be protected from impacts, see T 3.15. Impact protection must follow T 3.16 when having bolted attachments. TS wiring in front of the front hoop may alternatively be shielded by the front bulkhead support structure according to T 3.14.

EV 4.4.3 Outboard wheel motors are allowed only if

- an interlock is routed along the TS wiring such that the SDC, see EV 6, is opened before the TS wiring or its clamping fails
- an interlock is routed along a suspension member such that the SDC, see EV 6, is opened if the suspension fails
- TS wiring is not able to reach the cockpit opening or the driver regardless of where it breaks
- wiring outside of the rollover protection envelope, see T 1.1.16 is minimum length
- wiring outside of an impact structure or front bulkhead support structure, see EV 4.4.2, is minimum length
- Minimum length is the shortest distance plus extra wiring caused by bending radius.

### EV 4.5 Tractive System Insulation, Wiring, and Conduit

EV 4.5.1 All live parts of the TS must be protected from being touched. This must include team members working on or inside the vehicle. This is tested with a 100 mm long, 6 mm diameter insulated test probe when the TS enclosures are in place.

EV 4.5.2 Insulation material that is rated for the maximum TS voltage must be used. Using only insulating tape or rubber-like paint for insulation is prohibited.

EV 4.5.3 The temperature rating for TS wiring, connections, and insulation must be appropriate for the expected surrounding temperatures but at least 85 °C.

## EV4 Tractive System

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- EV 4.5.4 TS components and containers must be protected from moisture in the form of rain or puddles, see IN9.
- EV 4.5.5 It must be possible to clearly assign and prove the wire gauge, temperature rating, and insulation voltage to each used wire.
- EV 4.5.6 All TS wiring must be completed to professional standards with appropriately sized conductors and terminals and with adequate strain relief and protection from loosening due to vibration etc.
- EV 4.5.7 TS wiring must be located out of the way of possible snagging or damage.
- EV 4.5.8 All TS wiring that runs outside of TS enclosures must:
- Be enclosed in separate orange non-conductive conduit or use an orange shielded cable. The conduit must be securely anchored to the vehicle, but not to the wire, at least at each end.
  - Be securely anchored at least at each end so that it can withstand a force of 200 N without straining the cable end crimp.
- Bodywork is not sufficient to meet this enclosure requirement.
- EV 4.5.9 Any shielded cable must have the shield grounded.
- EV 4.5.10 Every TS connector outside of a housing must include a pilot contact/interlock line which is part of the SDC. Housings only used to avoid interlocks are prohibited.
- EV 4.5.11 All TS connections must be designed so that they use intentional current paths through conductors such as copper or aluminium and must not rely on steel bolts to be the primary conductor.
- EV 4.5.12 All TS connections must not include compressible material such as plastic in the stack-up or as a fastener. FR-4 is allowed.
- EV 4.5.13 TS connectors outside of TS enclosures must be designed in a way, that the TS cannot be activated, see EV 4.11, if connected in any way other than the design intent configuration.
- EV 4.5.14 All electrical connections, including bolts, nuts, and other fasteners, in the high current path of the TS must be secured from unintentional loosening. Fasteners must use positive locking mechanisms, see T 10.2, that are suitable for high temperatures, see EV 4.5.3.
- Components, e.g. inverters, certified for automotive use might be allowed without a positive locking feature if connections are completed as recommended by the manufacturers' datasheet and no positive locking is possible.
- EV 4.5.15 Teams must be prepared to demonstrate positive locking. For inaccessible connections, appropriate photographs must be available.
- EV 4.5.16 Soldered connections in the high current path are only allowed if all of the following are true:
- connections on PCBs
  - the connected devices are not cells or wires
  - the devices are additionally mechanically secured against loosening

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### EV 4.6 Data Logger

- EV 4.6.1 A calibrated data logger will be provided by the officials and must be inserted during the competition. The data logger measures TS voltage and TS current.
- EV 4.6.2 The data logger must be in an easily accessible location so that it is possible to insert, remove, or replace it within 15 min in ready-to-race condition.
- EV 4.6.3 The data logger must not be placed within the TSAC.
- EV 4.6.4 All current supplying the TS must run through the data logger. The data logger must be inserted in the negative TS supply between the most negative AIR(s) and the inverters.
- EV 4.6.5 The TS voltage sense connection of the data logger must be directly connected, see T 1.3.1, to the most positive AIR(s) on the vehicle side.
- EV 4.6.6 The data logger must be directly supplied, see T 1.3.1, from the LVMS.
- EV 4.6.7 The specification of the data logger will be available in the competition handbook.

### EV 4.7 Tractive System Measuring point

- EV 4.7.1 Two TSMPs must be installed directly next to the master switches, see EV 6.2.
- EV 4.7.2 The TSMPs must be directly connected, see T 1.3.1, to the intermediate circuit capacitors even if the HVD has been opened or the TS accumulator is disconnected.
- EV 4.7.3 4 mm shrouded banana jacks rated for 1000 V CAT III or better must be used.
- EV 4.7.4 The TSMPs must be marked “TS+” and “TS-” and exclusively mounted on an orange background.
- EV 4.7.5 The TSMPs must be protected by a non-conductive cover that can be opened without tools. The cover must always be mechanically linked to the vehicle.
- EV 4.7.6 Each TSMP must be secured with a current limiting resistor according to the following table. Fusing the TSMPs is prohibited. The resistor’s power rating must be chosen such that they can continuously carry the current if both TSMPs are short-circuited.

| Maximum TS Voltage                               | Resistor Value |
|--|----------------|
| $U_{max} < 200 \text{ VDC}$                      | 5 k $\Omega$   |
| $200 \text{ VDC} < U_{max} \leq 400 \text{ VDC}$ | 10 k $\Omega$  |
| $400 \text{ VDC} < U_{max} \leq 600 \text{ VDC}$ | 15 k $\Omega$  |

- EV 4.7.7 All electrical connections needed for TSMP, including bolts, nuts, and other fasteners, must be secured from unintentional loosening by the use of positive locking mechanisms. Bolted connections must follow T 10.2, soldered connections EV 4.5.16.
- EV 4.7.8 Next to the TSMPs an LVS ground measuring point must be installed. A 4 mm black shrouded banana jack must be connected to LVS ground and must be marked “GND”.

## EV 4 Tractive System

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### EV 4.8 High Voltage Disconnect

- EV 4.8.1 It must be possible to disconnect at least one pole of the TS accumulator by quickly removing an unobstructed and directly accessible element, fuse, or connector. It must be possible to disconnect the HVD without removing any bodywork. The HVD must be above 350 mm from the ground. Remote actuation of the HVD through a long handle, rope, or wire is not permitted.
- EV 4.8.2 Any ESO must be able to remove the HVD within 10 s when the vehicle is in ready-to-race condition.
- EV 4.8.3 A dummy connector or similar may be required to restore the system's isolation, see EV 4.5. The dummy connector must be attached to the push bar, see T 13.1, if not in use.
- EV 4.8.4 The HVD must be clearly marked with "HVD".
- EV 4.8.5 No tools must be necessary to open the HVD. An interlock is required, see EV 4.5.10.

### EV 4.9 Discharge Circuit

- EV 4.9.1 If a discharge circuit is required to meet EV 6.1.5, it must be designed to handle the maximum TS voltage permanently.
- After three subsequent discharges within 15 s in total, the discharge time specified in EV 6.1.5 may be exceeded. Full discharging functionality must be given after a reasonable time with a deactivated discharge circuit.
- EV 4.9.2 The discharge circuit must be wired in a way that it is always active whenever the SDC is open. Furthermore, the discharge circuit must be fail-safe such that it still discharges the intermediate circuit capacitors if the HVD has been opened or the TS accumulator is disconnected.
- EV 4.9.3 Fusing of the discharge main current path is prohibited.

### EV 4.10 Tractive System Active Light

- EV 4.10.1 The vehicles must include a single TSAL that must indicate the TS status. The TSAL must not perform any other functions. A TSAL with multiple LEDs in one housing is allowed.
- EV 4.10.2 The TSAL itself must have a red light, flashing continuously with a frequency between 2 Hz and 5 Hz and a duty cycle of 50 %, active if and only if the LVS is active and the voltage across any DC-link capacitor exceeds
- 60 VDC or 50 VACRMS
  - Half the nominal TS voltage
- whichever is lower.
- EV 4.10.3 The TSAL itself must have a green light, continuously on, active if and only if the LVS is active and ALL of the following conditions are true:
- All AIRs are opened.
  - The pre-charge relay, see EV 5.7.2, is opened.



## EV 4 Tractive System

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- The voltage at the vehicle side of the AIRs inside the TSAC does not exceed 60 VDC or 50 VACRMS.
- EV 4.10.4 The mentioned voltage detection must be performed inside the respective TS enclosure.
- EV 4.10.5 The mentioned states of the relays (opened/closed) are the actual mechanical states. The mechanical state can differ from the intentional state, i.e. if a relay is stuck. Any circuitry detecting the mechanical state must meet EV 5.6.2.
- EV 4.10.6 The voltage detection circuit of the red light and the relay state and voltage detection circuit of the green light must be independent. Any plausibility check between both lights is not allowed. A TSAL state with both lights simultaneously active might occur and must not be prevented.
- EV 4.10.7 The TSAL must:
- Be located lower than the highest point of the main hoop and including the mounting within the rollover protection envelope, see T 1.1.16.
  - Be no lower than 75 mm from the highest point of the main hoop.
  - Not be able to contact the driver's helmet in any circumstances.
- EV 4.10.8 The entire illuminated surface of the TSAL must be clearly visible:
- Except for angles less than 10° on each side which are blocked by the main hoop.
  - From a point 1.60 m vertically from ground level, within 3 m horizontal radius from the TSAL.
  - In direct sunlight.
- EV 4.10.9 The TSAL and all needed circuitry must be hard-wired electronics. Software control is not permitted.
- EV 4.10.10 A green indicator light in the cockpit that is easily visible even in bright sunlight and clearly marked with "TS off" must light up if TSAL green light is on, see EV 4.10.3.
- EV 4.10.11 Signals influencing the TSAL and the indicator according to EV 4.10.10 are SCS, see T 11.9. The individual safe state of each of the TSAL lights is off. The TSAL has an active indication of the absence of failures (continuous green illumination) and thus the red light must not be illuminated for a visible check, see T 11.9.6.
- EV 4.10.12 The TSAL's red light voltage detection circuit, see EV 4.10.2, does not need to detect an open circuit, as required by T 11.9. A plausibility check must not be implemented.
- EV 4.10.13 The TSAL's green light relay state detection circuit, see EV 4.10.3, does not need to detect an open circuit, as required by T 11.9, when the intentional state of the used (auxiliary) contact is opened. A plausibility check against the intentional relay state must be implemented in a way that the TSAL's green light stays off after the open circuit is detectable.
- EV 4.10.14 The TSAL's green light voltage detection circuit, see EV 4.10.3, does not need to detect an open circuit, as required by T 11.9, when no voltage is present. A plausibility check against the intentional relay states must be implemented in a way that the TSAL's green light stays off after the open circuit of the accumulator voltage detection circuit is detectable.
- EV 4.10.15 The latching required by EV 4.10.13 and EV 4.10.14 must not be triggered during normal operation conditions and must only be reset by power cycling the LVS.

## **EV 5 Tractive System Energy Storage**

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### **EV 4.11 Activating the Tractive System**

- EV 4.11.1 The TS is active if any of the AIRs or the pre-charge relay is closed.
- EV 4.11.2 The driver must be able to activate and deactivate the TS from within the cockpit without the assistance of any other person.
- EV 4.11.3 The ASR must be able to activate the TS from outside the vehicle with an external TS activation button in proximity to the TSMS if and only if the ASMS is in “On” position.
- EV 4.11.4 Closing the SDC by any part defined in EV 6.1.2 must not (re-)activate the TS. Additional action must be required.
- EV 4.11.5 The AS must not be able to (re-)activate the TS.
- EV 4.11.6 The vehicle is in Ready-to-drive (R2D) mode as soon as the motor(s) will respond to the input of the APPS.
- EV 4.11.7 After the TS has been activated, additional actions must be required by the driver to set the vehicle to R2D mode, e.g. pressing a dedicated start button. The transition to R2D mode must only be possible during the actuation of the mechanical brakes and a simultaneous dedicated additional action.
- EV 4.11.8 The R2D mode must be left immediately when the SDC is opened.

### **EV 4.12 Ready-To-Drive Sound**

- EV 4.12.1 The vehicle must make a characteristic sound, continuously for at least 1 s and a maximum of 3 s while entering R2D mode.
- EV 4.12.2 The sound level must be a minimum of 80 dBA and a maximum of 90 dBA, fast weighting in a radius of 2 m around the vehicle.
- EV 4.12.3 The used sound must be easily recognizable. No animal voices, song parts, or sounds that could be interpreted as offensive will be accepted.
- EV 4.12.4 The vehicle must not make any other sounds similar to the R2D sound.

## **EV 5 TRACTIVE SYSTEM ENERGY STORAGE**

### **EV 5.1 Definitions**

- EV 5.1.1 Cell – a battery cell or super-capacitor.
- EV 5.1.2 Cell Energy – the maximum cell voltage times the nominal capacity of the used cell.
- EV 5.1.3 TS Accumulator – all cells that store the electrical energy to be used by the TS as a whole.
- EV 5.1.4 Tractive System Accumulator Container (TSAC) – the container itself, which contains the TS accumulator.
- EV 5.1.5 TS Accumulator Segments – sub-divisions of the TS accumulator.

## **EV 5 Tractive System Energy Storage**

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### **EV 5.2 Allowed Tractive System Cells**

EV 5.2.1 All types of cells except molten salt and thermal batteries are allowed.

EV 5.2.2 Fuel cells are prohibited.

### **EV 5.3 Tractive System Energy Storage – General Requirements**

EV 5.3.1 All cells that store the TS energy must be enclosed in (a) TSAC(s).

EV 5.3.2 Each TS accumulator segment must not exceed a maximum static voltage of 120 VDC, a maximum energy of 6 MJ, see EV 5.1.2, and a maximum mass of 12 kg.

EV 5.3.3 If spare TS accumulators are used, they must be of the same size, weight, and type as those that are replaced.

EV 5.3.4 Spare cells must be stored in an electrically insulated container made of fire retardant material, see T 1.2.1. The container must be labeled according to EV 5.3.8.

EV 5.3.5 Spare accumulators and spare cells must be presented at technical inspection.

EV 5.3.6 It must be possible to open the TSAC for technical inspection.

EV 5.3.7 Each TSAC must be removable from the vehicle while still remaining rules compliant without the need to install extra components. A dummy connector or similar may be used to restore the system's isolation, see EV 4.5.

EV 5.3.8 The vehicle number, the university name, and the ESO phone number(s) must be displayed and written in Roman Sans-Serif characters of at least 20 mm high on the lid of each TSAC. The characters must be clearly visible and placed on a high-contrast background.

### **EV 5.4 Tractive System Energy Storage – Electrical Configuration**

EV 5.4.1 If the TSAC is made from an electrically conductive material, the insulation barrier must be adequately protected against conductive penetrations.

EV 5.4.2 Every TSAC must contain at least one fuse and at least two AIRs, see EV 5.6 and EV 3.2.7.

EV 5.4.3 LVS must not be included in the TSAC except where inherently required. Exceptions include the AIRs, TS DC/DC converters, the Accumulator Management System (AMS), the Insulation Monitoring Device (IMD), the TSAL's green light circuitry, and cooling fans.

EV 5.4.4 Maintenance plugs must allow electrical separation of all TS accumulator segments, see EV 5.3.2. The separation must affect both poles of all segments including the first and last segment.

EV 5.4.5 Maintenance plugs must:

- Not require tools to separate the TS accumulator segments.
- Be non-conductive on surfaces that do not provide any electrical connection.
- Be designed in a way, that it is physically impossible to electrically connect them in any way other than the design intent configuration.
- Be protected against accidental reconnection.

## **EV 5 Tractive System Energy Storage**

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- Be designed such that it is clearly visible whether the connection is open or closed. Electrically controlled switches must not be used.
- EV 5.4.6 Each TS accumulator segment must be electrically insulated by the use of suitable rigid and fire retardant material, see T 1.2.1, between the segments and on top of the segment to prevent arc flashes caused by inter-segment contact or by parts/tools accidentally falling into the TSAC during maintenance.
- EV 5.4.7 Every wire used in a TSAC, regardless of whether it is part of the LVS or TS, must be rated to the maximum TS voltage.
- EV 5.4.8 Each TSAC must have a prominent indicator, a voltmeter, or a red LED visible even in bright sunlight that will illuminate whenever a voltage greater than 60 VDC or half the maximum TS voltage, whichever is lower, is present at the vehicle side of the AIRs.
- EV 5.4.9 The indicator must be clearly visible while disconnecting the TSAC from the vehicles. The indicator must be clearly marked with “Voltage Indicator”
- EV 5.4.10 The indicator must be hard-wired electronics without software control, directly and only supplied by the TS from the vehicle side of the AIRs, and always working, even if the accumulator is disconnected from the LVS or removed from the vehicle.

### **EV 5.5 Tractive System Energy Storage – Mechanical Configuration**

- EV 5.5.1 All TSACs must lie within and be attached to the primary structure or any additional structures fixed to the primary structure that meet the minimum specification for impact structures, see T 3.2, no higher than the top of the impact structure, see T 3.15.
- EV 5.5.2 The TSAC(s) must be protected from impacts, see T 3.15. Impact protection must follow T 3.16 when having bolted attachments. The TSAC must not be part of this structure.
- EV 5.5.3 All TSAC materials as well as all structural parts used to comply with EV 5.5.8 must be fire retardant, see T 1.2.1. All calculations must be conducted for an ambient temperature of 60 °C except for metallic materials and continuous fiber-reinforced laminates.
- EV 5.5.4 The TSAC(s) must be constructed of steel or aluminium. With the following requirements:
- The bottom of the TSAC must be at least 1.25 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 T 3.3 or for composite materials per EV 5.5.5. This must be documented in the SES. When alternative materials are used, test samples must be presented at technical inspection.

- EV 5.5.5 Composite TSAC(s) must satisfy the following requirements:
- Data obtained from the laminate perimeter shear strength test and three-point bending test, see T 3.5, 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 results must be included in the SES.

## EV 5 Tractive System Energy Storage

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- EV 5.5.6 The TSAC must consist of electrically insulating internal vertical walls with a minimum of 75 % of the height of the external vertical walls, that divide the TSAC into sections of a maximum of 12 kg. These walls must not divide any accumulator segment, see EV 5.3.2.
- EV 5.5.7 The accumulator segments, see EV 5.3.2, must be separated by a rigid, electrically insulating, and fire retardant barrier, see T 1.2.1.
- EV 5.5.8 The TSAC itself, the mounting of the TSAC to the chassis, and the mounting of each cell to the TSAC must be designed to withstand the following accelerations:
- 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 documented in the SES. All considered TSAC attachment points must follow EV 5.5.13. TSAC(s) made of materials as stated in EV 5.5.4 or EV 5.5.5 may need further reinforcement to comply with this rule.
- EV 5.5.9 Pouch cells must be fixed using one or both of the large surface(s) only. Each used surface must be fixed on at least 80 %. Tabs of pouch cells must not carry mechanical loads and must not press into the pouch.
- EV 5.5.10 Friction-based cell mounting requires physical testing and must be documented in the SES. Mechanically representative test cells or cell mockups can be used for testing.
- EV 5.5.11 All fasteners used within or to mount the TSAC must comply with T 10. Fasteners within the accumulator used for non-structural accumulator parts (e.g. PCBs etc.) do not have to follow T 10.1.2. Fasteners made of electrically non-conductive material within the accumulator used for non-structural accumulator parts do not have to follow T 10.
- EV 5.5.12 The AIRs and the main fuse, see EV 3.2.7, must be separated with an electrically insulated and fire retardant material, see T 1.2.1, from the TS accumulator, see EV 5.1.3. Air is not considered to be a suitable insulation material in this case.
- EV 5.5.13 Any brackets used to mount the TSAC 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 5.5.14 Holes, both internal and external, in the TSAC, are only allowed for the wiring harness, ventilation, cooling, or fasteners. The TSAC must still be compliant with all other rules, especially the ones concerning its structural requirements. The total cutout area must be below 25 % of the area of the respective single wall. External holes must be sealed according to EV 4.5.
- EV 5.5.15 External openings in the TSAC or mounted ducts must not point toward the driver or the operator of the accumulator hand cart even though there is a firewall, see T 4.8, in between. Ducts and their mounting must be fire retardant, see T 1.2.1, and properly sealed.
- EV 5.5.16 A sticker according to “ISO 7010-W012” (triangle with a black lightning bolt on a yellow background) with the triangle side length of at least 100 mm and the text “Always Energized” must be applied on every TSAC. The sticker must also contain the text “High Voltage” if the voltage is more than 60 VDC or 50 V AC RMS.

## **EV 5 Tractive System Energy Storage**

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- EV 5.5.17 Any TS accumulators that may vent an explosive gas must have a ventilation system to prevent the vented gas from reaching an explosive concentration.
- EV 5.5.18 Every TSAC which is completely sealed must also have a pressure relief valve to prevent highpressure in the TSAC.
- EV 5.5.19 The design of the TSAC and its contents must be documented in the SES including materials used, drawings, images, fastener locations, segment weight, cell, and segment position.

### **EV 5.6 Accumulator Isolation Relays**

- EV 5.6.1 At least two AIRs must be fitted inside each TSAC.
- EV 5.6.2 The AIRs must open both poles of the TS accumulator. If the AIRs are open, no TS voltage may be present outside of the TSAC and the vehicle side of the AIRs must be galvanically isolated from the accumulator side, see EV 1.2.1.
- EV 5.6.3 The AIRs must be mechanical relays of a “normally open” type.

### **EV 5.7 Pre-Charge Circuit**

- EV 5.7.1 A circuit that ensures that the voltage at the vehicle side of the AIRs is pre-charged to at least 95 % of the actual TS accumulator voltage before closing the second AIR must be implemented.
- EV 5.7.2 The pre-charge circuit must use a mechanical, normally open relay. All pre-charge current must pass through this relay.

### **EV 5.8 Accumulator Management System**

- EV 5.8.1 Each TS accumulator must be monitored by an AMS whenever the LVS is active or the accumulator is connected to a charger.
- EV 5.8.2 Every TSAC must contain its full AMS including its own and AMS exclusive SDC power stage, see EV 6.1
- EV 5.8.3 The AMS must continuously measure
- all cell voltages
  - the TS current
  - the temperature of thermally critical cells
  - for lithium-based cells: the temperature of at least 30 % of the cells equally distributed within the TSAC(s)
- EV 5.8.4 Cell temperature must be measured at the negative terminal of the respective cell. The sensor used must be in direct contact with the electrically exposed negative terminal or less than 10 mm along the high current path away from the terminal in direct contact with the respective busbar. It is acceptable to monitor multiple cells with one sensor if this requirement is met for all cells sensed by the sensor.

## **EV 6 Shutdown Circuit and Systems**

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- EV 5.8.5 The maximum cell temperature is 60 °C or the limit stated in the cell data sheet, whichever is lower.
- EV 5.8.6 An independent cell temperature monitoring device may be provided by the officials during accumulator inspection and must be installed, see IN 3.  
The device must be placed on the warmest negative cell terminal of the TSAC and in direct contact with the terminal or less than 30 mm away from it on the busbar.
- EV 5.8.7 The AMS must switch off the TS via the SDC, if a critical voltage, temperature, or current value according to the cell manufacturer's datasheet or these rules persistently occurs for more than:
- 500 ms for voltage and current values
  - 1 s for temperature values
- The accuracy, noise, and sample rate of the measurement must be taken into account.
- EV 5.8.8 AMS cell voltage measurement inputs, temperature measurement inputs, and supply voltage of decentralized AMS slaves may be rated below the maximum TS voltage if the team has proven by calculations in the Electrical System Form (ESF), see EV 9, that the input voltage rating is reasonably chosen.
- EV 5.8.9 A red indicator light in the cockpit that is easily visible from inside and outside the cockpit even in bright sunlight and clearly marked with the lettering "AMS" must light up if and only if the AMS opens the SDC. It must stay illuminated until the error state has been manually reset, see EV 6.1.6. Signals controlling this indicator are SCS, see T 11.9.
- EV 5.8.10 AMS signals are System Critical Signals, see T 11.9.
- EV 5.8.11 It must be possible to individually disconnect the current sensor, one temperature sensor, and one cell voltage measurement wire during technical inspection if any wire is used.
- EV 5.8.12 The AMS must be able to read and display all measured values according to EV 5.8.3 in a single overview e.g. by connecting a laptop to the AMS.

## **EV 6 SHUTDOWN CIRCUIT AND SYSTEMS**

### **EV 6.1 Shutdown Circuit**

- EV 6.1.1 The Shutdown Circuit (SDC) directly carries the power driving the AIRs, see EV 5.6, and the pre-charge circuitry, see EV 5.7.
- EV 6.1.2 The SDC is defined as a series connection of at least two master switches, three shutdown buttons, the BOTS, see T 6.2, the IMD, the inertia switch, see T 11.5, the BSPD, see T 11.6, all required interlocks, and the AMS.  
An explanatory schematic of the required SDC, excluding any possible interlock circuitry, is shown in Figure 22.
- EV 6.1.3 All parts of the SDC defined in EV 6.1.2 must be on the high-side connection of the AIR coils and the pre-charge circuitry.
- EV 6.1.4 The Tractive System Master Switch (TSMS), see EV 6.2, must be the last switch before the AIRs except for pre-charge circuitry and hardwired interlocks.

## EV 6 Shutdown Circuit and Systems

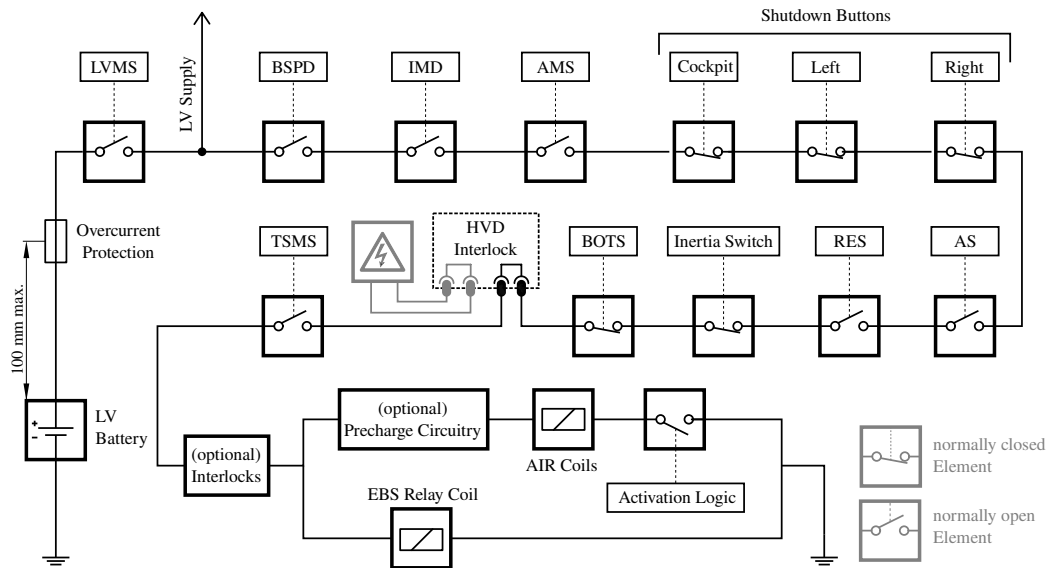


Figure 22: Explanatory example schematic of the required Shutdown Circuit (SDC)

- EV 6.1.5 If the SDC is opened the TS must be shut down by opening all AIRs and the voltage in the TS must drop to below 60 VDC and 50 V AC RMS in less than 5 s. All accumulator current flow must stop immediately.
- The action of opening the AIRs may be delayed by  $\leq 250$  ms to signal the action to the motor controllers and reduce the TS current before the AIRs are opened. The AIR supply must be abruptly switched off before reaching the minimum AIR supply voltage.
- EV 6.1.6 If the SDC is opened by the AMS or the IMD, it has to be latched open by a non-programmable logic that can only be manually reset by a person at the vehicle who is not the driver.
- EV 6.1.7 All circuits that are part of the SDC must be designed in a way, that in the de-energized/disconnected state, they open the SDC.
- EV 6.1.8 It must be possible to demonstrate that all features of the SDC function correctly. This includes all interlocks.
- EV 6.1.9 Every system that is required to or can open the SDC must have its own, non-programmable, power stage to achieve this. The respective power stages must be designed to be able to carry the SDC current, e.g. AIR inrush currents, and such that a failure cannot result in electrical power being fed back into the electrical SDC.
- EV 6.1.10 The shutdown buttons, the BOTS, the TSMS, and all interlocks must not act through any power stage.
- EV 6.1.11 All signals influencing the SDC are SCSs, see T 11.9.

### EV 6.2 Tractive System Master Switch

- EV 6.2.1 An TSMS according to T 11.2 must be part of the SDC, see EV 6.1.2.



## EV7 Chargers

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- EV 6.2.2 The TSMS must be fitted with a “lockout/tagout” capability to prevent accidental activation of the TS. The ESO must ensure that it is locked in the off position whenever work is done on the vehicle or no ESO is present.
- EV 6.2.3 The TSMS must be mounted in the middle of a completely orange circular area of  $\geq 50$  mm diameter placed on a high contrast background.
- EV 6.2.4 The TSMS must be marked with “TS” and a symbol according to “ISO 7010-W012” (triangle with a black lightning bolt on a yellow background).

### EV 6.3 Insulation Monitoring Device

- EV 6.3.1 Every vehicle must have an IMD installed in the TS system.
- EV 6.3.2 The IMD must be a Bender A-ISOMETER<sup>®</sup> iso-F1 IR155-3203, -3204, -4203, or -4204, or a Bender ISOMETER<sup>®</sup> iso165C-1, or equivalent IMD approved for automotive use. Equivalency may be approved by the officials based on the following criteria: robustness to vibration, operating temperature range, IP rating, availability of a direct output, a self-test facility, and must not be powered by the system that is monitored.
- EV 6.3.3 The response value of the IMD must be set to  $\geq 500 \Omega/V$ , related to the maximum TS voltage.
- EV 6.3.4 The IMD must be connected on the vehicle side of the AIRs.
- EV 6.3.5 One IMD chassis ground measurement line must be connected to the grounded TSAC or the respective grounded enclosure of the IMD. The other chassis ground measurement line must be connected to the main hoop. Each connection must use a separate conductor, rated for at least maximum TS voltage. An open circuit in any of these ground measurement connections must result in an opened SDC.
- EV 6.3.6 In case of an insulation failure or an IMD failure, the IMD must open the SDC. This must be done without the influence of any programmable logic. See also EV 6.1.6 regarding the re-activation of the TS after an insulation fault.
- EV 6.3.7 A red indicator light in the cockpit that is easily visible from inside and outside the cockpit even in bright sunlight and clearly marked with the lettering “IMD” must light up if and only if the IMD opens the SDC. It must stay illuminated until the error state has been manually reset, see EV 6.1.6. Signals controlling this indicator are SCS, see T 11.9.

## 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 insulated and covered. No open connections are allowed.
- EV 7.1.2 Exposed conductive parts and the TSAC must be connected to protective earth (PE).
- EV 7.1.3 All components interfacing with mains must be accredited to a recognized standard e.g. CE. All remaining parts must comply with all electrical requirements for the vehicle TS, e.g. EV 4.3, EV 3.1, and EV 4.2.

## **EV 8 Tractive System Accumulator Container Hand Cart**

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- EV 7.1.4 TS charging leads must be orange.
- EV 7.1.5 When charging, the AMS must be live and must be able to turn off the charger if a fault is detected.
- EV 7.1.6 The charger must include a push-type emergency stop button which has a minimum diameter of 24 mm and must be clearly labeled.
- EV 7.1.7 When charging the accumulator, an IMD as described in EV 6.3 must be active and must be able to shut down the charger. Either the charger must incorporate an active IMD or an active IMD must be within the accumulator. Other than stated in EV 6.3, the second chassis ground measurement line must be connected to the casing of the charger instead of the main hoop.
- EV 7.1.8 An IMD indicator light as defined in EV 6.3.7 must be available during charging.
- EV 7.1.9 The charger must include TSMPs as described in EV 4.7. Other than stated, the TSMPs must be connected to the TS output of the charger.
- EV 7.1.10 All indicators, switches, buttons, and connectors of the charger must be labeled.

### **EV 7.2 Charging Shutdown Circuit**

- EV 7.2.1 When charging, the charging Shutdown Circuit (SDC) consists of at least the charger shutdown button, see EV 7.1.6, the IMD, and the AMS.
- EV 7.2.2 If the SDC is opened the charging system must remain disabled and the SDC opened until it is manually reset.
- EV 7.2.3 The charging shutdown systems must comply with EV 6.1.1, EV 6.1.5, EV 6.1.7, EV 6.1.8 and EV 6.1.9.
- EV 7.2.4 All signals influencing the charger SDC are SCS, see T 11.9.

## **EV 8 TRACTIVE SYSTEM ACCUMULATOR CONTAINER HAND CART**

### **EV 8.1 Tractive System Accumulator Container Hand Cart**

- EV 8.1.1 A hand cart(s) must be used for transporting the TSAC(s) around the competition site.
- EV 8.1.2 The hand cart must have at least four wheels.
- EV 8.1.3 The hand cart must have a brake that is always on and only released if someone pushes the handle, or similar.
- EV 8.1.4 The brake must be capable of safely stopping the fully loaded hand cart.
- EV 8.1.5 The hand cart must be able to carry the load of the TSAC(s).
- EV 8.1.6 The hand cart must provide a firewall to protect the person while moving the hand cart. The firewall must have the same width as the hand cart, start at the lowest point of the hand cart excluding the wheels, and be at least 30 cm higher than the hand cart handle and the TSAC. The firewall must be made from a rigid, fire retardant material, see T 1.2.1, and be transparent from 1.3 m above the ground.

## **EV9 Electrical System Form**

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- EV 8.1.7 The TSAC(s) must be mechanically fixed to the hand cart to enable safe transportation.
- EV 8.1.8 The TSAC(s) must not protrude the hand cart.
- EV 8.1.9 The TSAC(s) must be protected from vibrations and shocks during normal operation of the cart, e.g. by the use of air tires.
- EV 8.1.10 The hand cart itself must have a label according to EV 5.3.8 on its firewall below the hand cart handle.
- EV 8.1.11 The overall floor space used by the fully loaded hand cart must not exceed 1200 mm x 800 mm. If the TSAC is larger than the allowed floor space, exceptions may be approved by the officials before the competition.

## **EV 9 ELECTRICAL SYSTEM FORM**

### **EV 9.1 Electrical System Form**

- EV 9.1.1 Before the competition, all teams must submit structured documentation of their entire electrical system (including control and TS) called the ESF.

# IN TECHNICAL INSPECTIONS

## IN 1 GENERAL

### IN 1.1 Technical Inspection Process

IN 1.1.1 The technical inspection is divided into the following parts:

- Pre-Inspection
- [EV ONLY] Accumulator Inspection
- [EV ONLY] Electrical Inspection
- Mechanical Inspection
- Autonomous System Inspection
- Tilt Test
- Vehicle Weighing
- [CV ONLY] Noise Test
- [EV ONLY] Rain Test
- Brake Test
- EBS Test

### IN 1.2 General Rules

IN 1.2.1 Each vehicle must pass all parts of technical inspection except Autonomous System Inspection and EBS Test before it may participate in any dynamic event.

IN 1.2.2 Each vehicle must pass Autonomous System Inspection and EBS Test before it may participate in any Driverless (DV) dynamic event.

IN 1.2.3 Passing the technical inspections is not a certification of complete rules compliance of the vehicle.

IN 1.2.4 The technical inspection sheet includes several inspection points and will be provided on the competition website prior to the competition. It must always stay with the push bar.

IN 1.2.5 The officials may inspect other points not mentioned on the technical inspection sheet to ensure compliance with the rules.

IN 1.2.6 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 1.2.7 Vehicles must be presented for technical inspection in ready-to-race condition.

## **IN1 General**

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- IN1.2.8 Safety uncritical rule violations without a benefit to the team that cannot be changed at the event may result in at least 20 penalty points for the teams, depending on officials' decision. Safety uncritical violations with a minor benefit to the team that cannot be changed at the event may result in at least 40 penalty points for the team. The penalty points will be deducted from the team's overall score.
- IN1.2.9 All items on the inspection sheet must be clearly visible for the officials without using instruments such as endoscopes or mirrors. Visible access may be provided by removing body panels or by providing removable access panels.
- IN1.2.10 The vehicle must maintain all required specifications throughout the competition.
- IN1.2.11 Officials reserve the right to ask the team for drilling of additional inspection holes to check the chassis for compliance with the rules.
- IN1.2.12 Officials will mark or seal various different approved parts. Removal of or damage to the seals will void the inspection approval.
- IN1.2.13 Once the vehicle is approved for competition, any damage to the vehicle that requires repair(s) will void the inspection approval. After completion of the repair(s), the vehicle must be re-submitted to technical inspection for re-approval.
- IN1.2.14 The officials reserve the right to prohibit the use of parts that could pose a safety risk to drivers, track marshals or the environment.

### **IN1.3 Technical Inspection Sticker**

- IN1.3.1 The competition technical inspection stickers will be placed on the nose of the vehicle.
- IN1.3.2 If a vehicle is no longer in compliance with the rules, the officials will set the vehicle's technical inspection status to fail, remove the respective inspection sticker(s) from the vehicle and note the reason for revoking the technical inspection approval in the technical inspection sheet.

### **IN1.4 Inspection Responsible Person**

- IN1.4.1 To accelerate the technical inspection process, the team must appoint one team member as inspection responsible person. [EV ONLY] For electrical inspection and accumulator inspection this has to be an ESO.
- IN1.4.2 This inspection responsible person must be:
- Familiar with the vehicle.
  - Able to show compliance of the vehicle with all points mentioned on the technical inspection sheet.
  - Able to perform the technical inspection autonomously observed by the officials, when asked.
- IN1.4.3 Should the inspection responsible person be unable to perform one of these requirements, or the vehicle and all necessary items are not ready, the technical inspection will be aborted and the team will be asked to leave the technical inspection area.

## **IN2 Pre-Inspection**

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### **IN 1.5 Modifications and Repairs**

IN 1.5.1 After technical inspection, the only modifications permitted to the vehicle are:

- Adjustment of belts, chains and clutches
- Adjustment of the brake bias
- Adjustment of the driver restraint system, head restraint, seat and pedal assembly
- Substitution of the head restraint or seat insert for different drivers
- Adjustment to engine operating parameters, e.g. fuel mixture and ignition timing
- Adjustment of mirrors
- Adjustment of the suspension where no part substitution, other than springs, sway bars and shims, is required
- Adjustment of tire pressure
- Adjustment of winglet angles, but not the position of the complete aerodynamic device in relation to the vehicle
- Replenishment of fluids
- Replacement of defective tires or brake pads. Replacement tires and brake pads must be identical in material/composition/size to those presented and approved at technical inspection.
- Changing wheels and tires for “wet” or “damp” conditions as allowed in D3.2 and D7.6
- Software calibration changes
- Recharging LV batteries
- Recharging TS accumulators
- Adjustments of AS sensors
- (De-)Coupling of actuators as allowed in T 14.8
- Installing and removing protective sensor covers, if approved during technical inspection

## **IN 2 PRE-INSPECTION**

### **IN 2.1 Pre-Inspection Required Items**

IN 2.1.1 The following items must be presented for pre-inspection:

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

## **IN3 [EV ONLY] Accumulator Inspection**

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

### **IN3 [EV ONLY] ACCUMULATOR INSPECTION**

#### **IN3.1 Accumulator Inspection General Definitions**

- IN3.1.1 Cell modules or stacks do not need to be disassembled when AIRs, fuses, pre- and discharge circuit and positive locking mechanism of the maintenance plugs are reachable and visible for the officials.
- IN3.1.2 An official temperature logging device must be installed if used by the competition, see EV 5.8.6.
- IN3.1.3 The accumulator charger will be inspected and sealed.
- IN3.1.4 The set of basic tools will be checked.

#### **IN3.2 Accumulator Inspection Required Items**

- IN3.2.1 The following items must be presented at accumulator inspection:
- All TS accumulators
  - Accumulator hand cart
  - Accumulator charger
  - Basic Tools, see IN 3.2.2
  - Tools needed for the (dis)assembly of parts
  - Samples of self designed PCBs that are part of the TS and inside the TSAC, see EV 4.3.7
  - Data sheets for all parts used in the accumulator
  - Original delivery notes for material without serial number printed on according to T 1.2.1
  - Print-outs of rule questions (if applicable)
- IN3.2.2 The following basic tools in good condition must be presented:
- Insulated cable shears
  - Insulated screw drivers
  - Multimeter with protected probe tips and two 4 mm banana plug test leads rated for 1000 V CAT III or better
  - Insulated tools, if bolted connections are used in the TS
  - Face shield
  - at least two pairs of HV insulating gloves (not expired)
  - Two HV insulating blankets of at least 1.0 m<sup>2</sup> each

## IN4 [EV ONLY] Electrical Inspection

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- Safety glasses with side shields for all team members that might work on the TS or accumulator

All electrical safety items must be rated for at least the maximum TS voltage.

## IN4 [EV ONLY] ELECTRICAL INSPECTION

### IN4.1 Electrical Inspection General Definitions

IN4.1.1 The insulation resistance between the TS and LVS ground will be measured. Vehicles with a maximum TS voltage less than or equal to 250 V will be probed with 250 V and vehicles with a maximum TS voltage greater than 250 V with 500 V.

To pass this test, the measured insulation resistance must be at least  $500 \Omega/V$  related to the maximum TS voltage of the vehicle.

IN4.1.2 The IMD will be tested by connecting a resistor between the TSMP, see EV 4.7 and LVS ground connector, see EV 4.7.8.

The test is passed if the IMD shuts down the TS within 30 s at a fault resistance of 50 % below the response value which corresponds to  $250 \Omega/V$ .

IN4.1.3 The BSPD will be tested by sending an appropriate signal that represents the current, to achieve  $\leq 5$  kW whilst pressing the brake pedal. This test must prove the functionality of the complete BSPD except for any commercially available current sensors. Ends of a current transducer's auxiliary winding must be insulated.

### IN4.2 Electrical Inspection Required Items

IN4.2.1 The following items must be presented at electrical inspection:

- One ESO
- Vehicle with mounted TS accumulator
- Jacks and push bar
- Samples of self designed PCBs that are part of the TS and are outside of the TSAC, see EV 4.3.7
- Tools needed for the BSPD check, see IN4.1.3
- Data sheets for all parts used in the TS
- Original delivery notes for material without serial number printed on according to T 1.2.1
- Tools needed for the (dis)assembly of parts for electrical inspection
- Print-outs of rule questions (if applicable)
- The connectors needed
  - to safely close the SDC while the HVD is removed and
  - to safely supply the TS using the same shrouded receptacles as used for TSMP when the TS accumulator is unconnected



## **IN5 Mechanical Inspection**

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### **IN 5 MECHANICAL INSPECTION**

#### **IN5.1 Mechanical Inspection Required Items**

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

- The vehicle in ready-to-race condition
- Jacks and push bar
- The tallest driver of the team
- Copies of any safety structure equivalency forms
- Copies of any impact attenuator data requirement
- Print-outs of rule questions (if applicable)
- IA test piece and (representative) test fixture (except for teams with “standard” IA)
- Teams with a monocoque: laminate test specimen(s)
- Teams using alloyed steel: test specimen(s)
- Only tools needed for the (dis)assembly of parts for mechanical inspection
- [HY ONLY] Copies of the HSF
- [HY ONLY] HSC and any tools and/or materials needed to determine the weight limit as per CV 5.2.3

### **IN 6 AUTONOMOUS SYSTEM INSPECTION**

#### **IN6.1 Autonomous System Inspection Required Items**

IN6.1.1 The following items are required:

- One ASR
- The vehicle in ready-to-race condition including mounted data logger, see T 14.2
- Data sheets for all perception sensors
- Documents which proof that all perception sensors meet local legislation
- RES remote control
- ASF
- Tools needed for the (dis)assembly of parts for autonomous system inspection
- Print-outs of rule questions (if applicable)

### **IN 7 TILT TEST**

#### **IN7.1 Tilt Test Procedure**

IN7.1.1 The tilt test will be conducted with the tallest driver fully strapped in normal driving position.

IN7.1.2 The tilt test will be conducted with all vehicle fluids at their maximum fill level.

## **IN8 Vehicle Weighing**

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IN7.1.3 The vehicle will be placed upon the tilt table and to an angle of 60°. There must be no fluid leaks and all wheels must remain in contact with the tilt table surface.

## **IN 8 VEHICLE WEIGHING**

### **IN8.1 Vehicle Weighing Procedure**

IN8.1.1 All vehicles must be weighed in ready-to-race condition.

IN8.1.2 All fluids must be at their maximum fill level for weighing.

## **IN 9 [EV ONLY] RAIN TEST**

### **IN9.1 Rain Test General Definitions**

IN9.1.1 Vehicles must have passed electrical inspection, see IN4, to attempt the rain test.

### **IN9.2 Rain Test Procedure**

IN9.2.1 The vehicle must be in ready-to-race condition. All components and constructions used to protect the vehicle from water during the rain test must be used during the entire competition.

IN9.2.2 The TS must be active during the rain test.

IN9.2.3 The vehicle must be jacked up using the jacks, see T 13.2, and all driven wheels must be removed.

IN9.2.4 The vehicle must not be in R2D mode, see EV 4.11.

IN9.2.5 The test will be conducted without a driver.

IN9.2.6 Water will be sprayed at the vehicle from any possible direction. The water spray is similar to a vehicle driving in rain and not a direct high-pressure stream of water.

IN9.2.7 The test is passed if the IMD is not triggered while water is sprayed at the vehicle for 120 s and 120 s after the water spray has stopped.

## **IN 10 [CV ONLY] NOISE TEST**

### **IN 10.1 Noise Test Procedure**

IN 10.1.1 The sound level will be measured during a static test.

IN 10.1.2 The vehicle must be compliant at all engine speeds up to the maximum test speed, see CV 3.2.1.

IN 10.1.3 Teams must bring a laptop to indicate the engine speed measured by the engine control unit.

## **IN11 Brake Test**

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- IN10.1.4 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.
- IN10.1.5 Where more than one exhaust outlet is present, the test will be repeated for each exhaust and the highest reading will be used.
- IN10.1.6 If the exhaust has any form of active tuning or throttling device or system, it must be compliant with the rules in all positions. Manually adjustable tuning devices must require tools to change them and must not be moved or modified after the noise test is passed. The position of the device must be visible to the officials and manually operable by the officials during the noise test.
- IN10.1.7 The test will be run with the gearbox in neutral. During this test the vehicle must be jacked up using the jacks (see T13.2).
- IN10.1.8 After passing the noise test the function of the master switch, the cockpit-mounted shutdown button and the inertia switch will be tested.
- IN10.1.9 After passing IN10.1.8 the air tightness of the intake system will be tested by closing off the inlet after which the engine must stall.

## **IN 11 BRAKE TEST**

### **IN11.1 Brake Test Procedure**

- IN11.1.1 Lock all four wheels and stop the vehicle in a straight line at the end of an acceleration run specified by the officials without stalling the engine.
- IN11.1.2 [EV ONLY] After accelerating, the TS must be switched off by the driver and the driver must brake using only the mechanical brakes. It is acceptable for the TSAL to switch to green shortly after the vehicle has come to a complete stop as the reduction of the system voltage may take up to 5 s.
- IN11.1.3 The brake light and TSAL illumination will be checked and the officials will verify if the illumination is satisfactory for external observation.
- IN11.1.4 [EV ONLY] The R2D sound will be checked and the officials will verify if the sound level is satisfactory.

### **IN11.2 EBS Test**

- IN11.2.1 The EBS performance will be tested dynamically and must demonstrate the performance described in T15.4.
- IN11.2.2 The test will be performed in a straight line marked with cones similar to acceleration.
- IN11.2.3 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 8.5 m.

## IN 12 Post Inspection

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IN 11.2.4 In case of wet track conditions, the stopping distance will be scaled by the officials dependent on the friction level of the track.

IN 11.2.5 The EBS test is conducted after all other elements of IN 11 have been passed.

## IN 12 POST INSPECTION

### IN 12.1 Post Inspection Procedure

IN 12.1.1 The officials reserve the right to impound any vehicle at any time during or after any of the dynamic events to check for compliance with the rules. If necessary, the vehicle will remain with the officials until the violation of the rule was discussed with the team.

IN 12.1.2 After the endurance and trackdrive event, the vehicle must be placed in parc fermé where no team member may access the vehicle.

IN 12.1.3 During and after any dynamic event, the vehicle must be in compliance with the rules.

IN 12.1.4 For each violation of the rules, the team receives a separate penalty as follows:

- Group A: Violation of the rules without advantage for the team
- Group B: Violation of the rules with advantage for the team (e.g. aerodynamics)

|         | Acceleration | Skidpad | Autocross | Endurance | Trackdrive |
|---------|--------------|---------|-----------|-----------|------------|
| Group A | 0.3 s        | 0.2 s   | 2 s       | 30 s      | 30 s       |
| Group B | 1 s          | 0.6 s   | 5 s       | 2 min     | 2 min      |

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

IN 12.1.5 Violation of the rules concerning safety or the environment (e.g. BOTS, safety harness issues, ground clearance, fluid leaks other than plain water, noise) results in DQ since entering the dynamic area.

IN 12.1.6 Losing a part of the vehicle on the track will result in DQ for that particular run.

IN 12.1.7 Changes in vehicle weight of more than  $\pm 5$  kg compared to the official technical inspection weight (see IN 8) results in a 20 point penalty for each kg the tolerance is exceeded by. E.g. a weight difference of  $\pm 6.2$  kg results in a 40 point penalty.

IN 12.1.8 [EV ONLY] The vehicle must be able to enter R2D mode, see EV 4.11, during post inspection process for all tests requiring this mode. Violation will result in DQ.

IN 12.1.9 [EV ONLY] Directly after endurance and leaving parc fermé, every team must come back to the charging area to disassemble the temperature logging device (if used by the competition) from the TS accumulator, see EV 5.8.6.

IN 12.1.10 Directly after the last dynamic discipline and leaving parc fermé, the data logger (if installed), see EV 4.6 or T 14.2, will be disassembled from the vehicle.

## **S            STATIC EVENTS**

### **S 1            BUSINESS PLAN PRESENTATION EVENT**

#### **S 1.1            Business Plan Presentation Objective**

S 1.1.1            The objective of the BPP is to assess the team’s ability to develop and to present a comprehensive business model. This business model must relate to the team’s specific prototype vehicle or a specific component of it. In doing so, the business must offer the vehicle or component as a product, or sell a service based on it, providing a rewarding business opportunity that creates a monetary profit.

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 quality of the actual prototype 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 10 min. The judges will stop any presentation exceeding 10 min.

S 1.2.2            The presentation 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 plan.

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

S 1.2.6            Prior to the competition a specific deep dive topic, which has to be part of the 10 min presentation, will be published on the competition website.

#### **S 1.3            Pitch Video**

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 a Business Plan Pitch Video (BPPV) is submitted before the competition. The pitch video should be considered as the first impression of the business idea and has to contain the relevant investment figures.

## S2 Cost and Manufacturing Event

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- S 1.3.2 The BPPV must be submitted online via the competition website, not later than the deadline specified in the competition handbook.
- S 1.3.3 The BPPV must not exceed a length of 30 s and must be in a common video format, e.g. avi, mpg, mp4, wmv.

### S 1.4 Business Plan Presentation Scoring

- S 1.4.1 The BPP will be evaluated on the categories specified in table 6.

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

Table 6: BPP evaluation categories

- S 1.4.2 If the business model presented does not relate to one of the areas listed within S 1.1.1, 15 penalty points will be deducted from the team's BPP scoring.
- S 1.4.3 The judging at the competition will start with an initial judging, where all teams are judged by different judging groups.
- S 1.4.4 Some teams may be chosen to participate in the BPP finals to determine the BPP winner. The BPP finals will be held separately from the initial judging and teams will be informed about their participation during the event.
- S 1.4.5 The scoring of the BPP is based on the average of the scores given by each of the judges.
- S 1.4.6 The scoring for the non-finalist is calculated as followed:

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

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

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

- S 1.4.7 The scoring of the BPP finalists will vary from 75 to 71 points and is scored immediately after the BPP finals by all judges.

## 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 construction of a prototype

## **S2 Cost and Manufacturing Event**

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vehicle. This includes trade off decisions between content and cost, make or buy decisions and understanding the differences between prototype and mass production.

### **S2.2 Cost and Manufacturing Procedure**

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

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

S2.2.3 Part 1 "Bill of Material (BOM) Discussion":  
A discussion to evaluate the team's ability to prepare an accurate engineering and manufacturing BOM for the complete vehicle. The team must prove the following:

- The specification of the vehicle in the CRD accurately reflects the vehicle brought to the competition.
- The costs within the Costed Bill of Material (CBOM) part of the BOM are correct and realistic.
- The manufacturing feasibility of the vehicle.

S2.2.4 Part 2 "Cost Understanding":  
A discussion to evaluate the general cost and manufacturing knowledge of the team.

S2.2.5 Part 3 "Real case":  
A specific task to evaluate the cost and manufacturing knowledge in a certain field. The real case task will be published on the competition website prior to the competition.

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

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

### **S2.3 Cost Report Documents**

S2.3.1 The CRD consist of the following documents:

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

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

S2.3.3 A changelog of the changes on the vehicle since the submission deadline of the CRD can be presented at the BOM discussion to the judges. Missing parts of the BOM cannot be part of the changelog.

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

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

## **S2 Cost and Manufacturing Event**

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- S2.3.6 A hard copy must be in a ring binder with DIN A4 pages (or similar).
- S2.3.7 The team must ensure that two judges are able to review the CRD independently.
- S2.3.8 The presented CRD must be identical with the submitted versions, otherwise five penalty points will be deducted from the team's cost event score.

### **S2.4 Bill of Material**

- S2.4.1 The BOM is a sorted list for every vehicle part.
- S2.4.2 The BOM must list all parts and equipment fitted to the prototype vehicle at any time during the competition.
- S2.4.3 The BOM is structured as follows:
- The BOM is broken down into “systems” (see S2.4.6), which are defined by the website tool.
  - Each “system” is broken down into “assemblies”, which are defined by the website tool.
  - Each “assembly” can optional be broken down into “sub-assemblies”, which must be defined by the team.
  - Each “assembly” or “sub-assembly” is broken down into “parts”, which must be defined by the team.
- S2.4.4 “Fasteners” are additional items necessary to assemble the “part” and should not be listed.
- S2.4.5 A self-manufactured “fastener” is considered a “part”.
- S2.4.6 The “systems” are:
- Brake System
  - Engine and Drivetrain
  - Chassis and Body
  - Electrical
  - Miscellaneous, Fit and Finish
  - Steering System
  - Suspension System
  - Wheels, Wheel Bearings and Tires
  - Autonomous system
- S2.4.7 The “assemblies” of each “system” are provided by the website tool.
- S2.4.8 When adding “parts” to the BOM, the comments section should be reviewed thoroughly. The chosen part name must clearly describe what is included. For example, if a spring is included, the “part” should not be called “damper”.
- S2.4.9 Only metric units must be used within the BOM.
- S2.4.10 Only dry tires and wheels per T2.7.1 need to be included in the BOM.



## **S2 Cost and Manufacturing Event**

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S2.4.11 Two or three systems of the BOM have to be a DBOM, see S2.5.

S2.4.12 One or two systems of the DBOM have to be a CBOM, see S2.6.

### **S2.5 Detailed Bill of Material**

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

S2.5.2 Additional to the BOM, the DBOM must:

- Include the actual associated manufacturing processes for each part as used for the prototype vehicle.
- Include tooling (e.g. welding jigs, molds, patterns and dies).
- Not include any cost, except for the “systems” described in S2.6.

S2.5.3 Additional to the structure of the BOM, the DBOM is structured as follows:

- Each “part” is broken down into “materials” and “processes”.
- Each “process” may be broken down into “tooling” and “fasteners”, if applicable.

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

S2.5.5 For each “bought part”, only fasteners must be included (if required). If the part was modified, the associated processes for this modification must to be included.

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

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

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

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

### **S2.6 Costed Bill of Material**

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

S2.6.2 The cost calculations must include the costs of materials, fabrication, bought parts and assembly to the vehicle and must be completed as realistically as possible.

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

S2.6.4 All costs must be displayed in EUR. For calculating the prices in EUR from other currencies, the team must provide the exchange rates used.

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

S2.6.6 If production tooling is associated with processes that are specific to the part geometry, it must be included. For example the dies to stamp out a chassis bracket are tooling.

## **S2 Cost and Manufacturing Event**

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

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

### **S2.7 Supporting Material File**

S2.7.1 The supporting material file is a document containing additional information which allows the judges to understand the BOM. It should include drawings, exploded view drawings and/or pictures of the vehicle and the parts included in the BOM.

### **S2.8 Cost Explanation File**

S2.8.1 The cost explanation file is a document containing additional explanations, which allow the judges to understand the costs within the CBOM part of the BOM.

S2.8.2 The cost explanation file should point out which cost model was used and which types of costs are included. It should also contain which specific cost figures were used, e.g. the cost of one machine operation hour.

### **S2.9 Cost and Manufacturing Vehicle Condition**

S2.9.1 Vehicles must be presented for cost and manufacturing judging in finished condition, fully assembled, complete and ready-to-race.

S2.9.2 The judges will not evaluate any vehicle that is presented at the cost and manufacturing event, in what they consider to be an unfinished state and will award zero points for the entire event.

S2.9.3 Vehicles may be presented for judging without having passed technical inspection, even if final tuning and setup is in progress.

S2.9.4 Covers and/or parts may be removed during the judging to facilitate access and presentation of components or concepts.

### **S2.10 Cost and Manufacturing Scoring**

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

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

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

### S3 Engineering Design Event

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

S2.10.3 A maximum of four top teams may be chosen to participate in the cost and manufacturing finals to determine the cost and manufacturing event winner. The cost and manufacturing finals will be held separately from the initial judging and teams will be informed about their participation during the event.

S2.10.4 In case of finals the scoring for the non-finalist is calculated as followed:

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

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

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

S2.10.5 The scoring of the cost and manufacturing finalists will vary from 100 to 96 points.

S2.10.6 In case of no cost finals the scoring is calculated as followed:

$$COST\_SCORE = P_{team}$$

## S3 ENGINEERING DESIGN EVENT

### S3.1 Engineering Design Objective

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

S3.1.2 Proprietary components and systems that are incorporated into the vehicle design as finished items are not evaluated as a student designed unit, but are only assessed on the team's selection and application of that unit.

S3.1.3 An evaluation concerning the capability of the vehicle to drive autonomously will also be part of this event. 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 AS.

### S3.2 Engineering Design Report

S3.2.1 The EDR should contain a brief description of the overall vehicle including the AS with a review and derivation of the team's design objectives. Any information to scope, explain or highlight design features, concepts, methods or objectives to express the value and performance of the vehicle to the judges shall be included at the teams' discretion.

S3.2.2 The EDR must not exceed ten pages, consisting of not more than seven pages of content (text, which may include pictures and graphs) and three pages of drawings.

S3.2.3 The three EDR drawings (no renderings) must show the vehicle from the front, the top and the side. Each drawing must appear on a separate page.

### **S3 Engineering Design Event**

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

#### **S3.3 Design Spec Sheet**

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

#### **S3.4 Engineering Design Procedure**

- S3.4.1 The design event starts with the submission of the DSS and the EDR and their review respectively.
- S3.4.2 At the competition, teams will present their knowledge and their vehicle to the judges, which will evaluate the teams' performance following the design objectives stated in chapter S3.1.
- S3.4.3 Some teams may be chosen to participate in the design finals to determine the engineering design event winner. The design finals will be held separately from the initial judging and teams will be informed about their participation during the event.
- S3.4.4 Teams may bring any photographs, drawings, charts, spare parts or other material that they believe are supportive to the design event, but the space provided for design judging may be limited.
- S3.4.5 [EV ONLY] Only sealed TSACs which passed the accumulator inspection may be presented or mounted in the vehicle. They must not be opened.
- S3.4.6 [EV ONLY] Only discharged, below 5 % State of Charge, accumulator cells each having all terminals electrically isolated may be presented.
- S3.4.7 [DC ONLY] There is no extra design presentation for the DC, however scoring will be adapted (see table 8) and there will be more judges during the normal presentation focusing on the AS.
- S3.4.8 [DC ONLY] There will be separate design finals for the DC.

#### **S3.5 Engineering Design Vehicle Condition**

- S3.5.1 Vehicles must be presented for design judging in finished condition, fully assembled, complete and ready-to-race.

### S3 Engineering Design Event

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

#### S3.6 Engineering Design Judging Criteria

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

#### S3.7 Engineering Design Scoring

- S3.7.1 The overall engineering design event maximum scoring is 150 points.
- S3.7.2 The maximum scores listed in table 7 apply for the engineering design event.

| Category                              | Points |
|---------------------------------------|--------|
| Overall Vehicle Concept               | 20     |
| Software                              | 10     |
| Vehicle Performance / Aerodynamics    | 30     |
| Mechanical / Structural Engineering   | 10     |
| Tractive System / Powertrain          | 20     |
| LV-Electrics / Electronics / Hardware | 10     |
| Autonomous Functionality              | 30     |
| Driver Interface                      | 10     |
| Engineering Design Report (EDR)       | 10     |

Table 7: Maximum scores in engineering design event

| Category                              | Points |
|---------------------------------------|--------|
| Overall Vehicle Concept               | 20     |
| Software                              | 20     |
| Vehicle Performance                   | 20     |
| Actuators                             | 10     |
| LV-Electrics / Electronics / Hardware | 20     |
| Autonomous Functionality              | 60     |

Table 8: [DC ONLY] Maximum scores in engineering design event

## **D DYNAMIC EVENTS**

### **D1 DYNAMIC EVENTS GENERAL**

#### **D1.1 Driver Limitations**

D 1.1.1 In total, a minimum of three and a maximum of four drivers are allowed for each team.

D 1.1.2 An individual driver must not drive in more than two dynamic events.

D 1.1.3 The endurance and efficiency event is considered a single event.

#### **D1.2 Dynamic Area and Dynamic Vests**

D 1.2.1 The technical 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 at one time.

D 1.2.4 Drivers must not wear the dynamic vest when sitting in the vehicle. The driver's vest must not be attached to the vehicle.

D 1.2.5 The number of tools that may be used in this area is restricted to those which can be safely carried by the four team members in one trip.

D 1.2.6 Engines may be run in the staging queue on the order of the officials.

### **D2 DRIVING RULES**

#### **D2.1 Flags**

D 2.1.1 Flag signals are commands that must be obeyed immediately and without question.

D 2.1.2 There will be no flag signs for vehicles 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.

## **D2 Driving Rules**

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- D2.1.6 CHECKERED FLAG – The session has been completed. The driver must exit the track at the first opportunity.
- D2.1.7 GREEN FLAG –
- The session has started, the driver may enter the track under direction of the track marshals. In case of stalling, the vehicle can be restarted, but the driver has to await another green flag as the opening in traffic may have closed.
  - The driver is clear to re-enter the track after using the slow lane to let a faster vehicle pass.
  - The driver may pick up speed again after a yellow flag was displayed.
- D2.1.8 RED FLAG – The driver must come to an immediate safe and controlled stop on the track and must follow track marshals' directions.
- D2.1.9 YELLOW FLAG – Danger, the driver must slow down, something has happened beyond the flag station, no overtaking unless directed by the track marshals.
- D2.1.10 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.

### **D2.2 Teleoperated Driving**

- D2.2.1 After the vehicle has crossed the starting line it is prohibited to change parameters, send commands or perform any software changes by wireless communication until the vehicle has crossed the finish line. Receiving information from the vehicle via one-way-telemetry is allowed.
- D2.2.2 The only device that is allowed to send commands by wireless communication at all times is the RES described in T 14.3.

### **D2.3 Driving Under Power**

- D2.3.1 During driving, the mechanical integrity of the vehicle must be maintained.
- D2.3.2 Vehicles must not be driven in reverse.
- D2.3.3 The vehicle must be capable of starting and restarting without external assistance/batteries at all times.
- D2.3.4 Push starts are prohibited.
- D2.3.5 Vehicles may only be driven under power when running in a dynamic event, on the practice track and during brake test.
- D2.3.6 Driving off-site is absolutely prohibited. Teams found to have driven their vehicle at an off-site location during the period of the competition will be excluded from the competition.
- D2.3.7 Burnouts prior to and during the events are prohibited.

## D2 Driving Rules

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D2.3.8 When driving in autonomous mode, an ASR has to be present at the race control with the RES. Additionally, one single monitoring device (laptop, tablet, ...) may be brought (no complicated antenna construction or similar!).

### D2.4 Practice Track

D2.4.1 A practice track for testing and tuning vehicles is available.

D2.4.2 To use the practice track, vehicles must have passed all technical inspections.

D2.4.3 Practice or testing at any location other than the practice track is absolutely forbidden.

### D2.5 Cones & Markings for Autonomous Running

D2.5.1 Details of the cones used and more detailed track layout figures can be found in the competition handbook.

### D2.6 Start-up Procedure for Autonomous Running

D2.6.1 No additional equipment (e.g. laptop, jack-up device, pressure tank, etc.) is allowed to start up the vehicle at the staging/starting line.

D2.6.2 If the vehicle does not enter “AS Ready” state within 1 min after being staged, the team may be sent back to the preparation area by the officials. In this case any priority is lost.

D2.6.3 The vehicle may only be staged with the steering system in straight position.

D2.6.4 The vehicle may be pushed from the preparation area to the start line with activated LVS.

D2.6.5 The ASB may be energized already in the preparation area.

D2.6.6 The ASMS may only be switched on by the ASR after approval from an official at the starting line.

### D2.7 Vehicle Break Downs and Usage of RES during Autonomous Running

D2.7.1 Stalling the engine or deactivating the TS for any reason during a dynamic event will result in Did Not Finish (DNF) as the AS is not allowed to restart the engine/reactivate the TS.

D2.7.2 If a vehicle comes to standstill for any reason, it may have up to 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.

D2.7.3 When the vehicle is driving in autonomous mode, one ASR must be present at the race control to operate the RES remote control.

D2.7.4 The ASR or the officials may stop the vehicle using the RES in any of the following cases:

- Its behavior seems to be uncontrolled, e.g. driving Off-Course (OC) without visible intention to re-enter the track immediately.
- It is mechanically or electrically damaged.



## **D3 Weather Conditions**

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- The average speed of the first three laps in trackdrive (after completing the third lap) is below 2.5 m/s or the average speed of any of the following laps is below 3.5 m/s.
- To ensure safe conditions on the track (e.g. persons or animals on the track). In this case the team will get a re-run.

D2.7.5 If a vehicle breaks down or is stopped by the use of the RES it will be removed from the track, will not be allowed to re-enter the track and scored DNF.

D2.7.6 If a traceable signal loss of the RES appears and doubtless proof can be brought by the team that it is was not self-inflicted, a re-run may be granted for the respective autonomous run, if the officials are notified before the affected dynamic event closes. The data logger data must be uploaded before notifying the officials.

D2.7.7 At the direction of the officials, team members may be instructed to retrieve broken-down vehicles. This recovery may only be done under the control of the officials.

### **D2.8 Procedure After Completing a Driverless (DV) Dynamic Event**

D2.8.1 After approval from the officials the ASR has to deactivate the vehicle using the RES.

D2.8.2 The vehicle must be collected by the ASR and an additional team member immediately after approval from the officials.

### **D2.9 Handling of Re-Runs**

D2.9.1 A re-run may be granted in following cases:

- Usage of YELLOW FLAG in Autocross.
- Usage of RED FLAG.
- Usage of RES to ensure safe conditions on the track or traceable signal loss of the RES according to D2.7.
- After official's decision due to technical or organizational issues.

D2.9.2 The team will be informed about a granted re-run either by a sign at the exit or by direct communication through an official.

D2.9.3 It is at the discretion of the team whether or not they accept the re-run. If the re-run is accepted, it must be executed immediately and the corresponding initial run is deleted.

## **D3 WEATHER CONDITIONS**

### **D3.1 Operating Conditions**

D3.1.1 The following track conditions are recognized:

- Dry
- Damp
- Wet

## D4 Skidpad Event

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- D3.1.2 The operating condition are decided by the officials and may change at any time.
- D3.1.3 The current operating condition will be prominently displayed at the dynamic area.

### D3.2 Tires Allowed

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

| Operating Condition | Tires allowed |
|---------------------|---------------|
| Dry                 | Dry           |
| Damp                | Dry or Wet    |
| Wet                 | Wet           |

- D3.2.2 When the operating condition is damp, teams may change between dry tires and wet tires:
- Any time during the acceleration, skidpad, and autocross events.
  - Any time before taking the green flag to start endurance.
- D3.2.3 If an event had varied operating conditions, the minimum performance levels to score points may be adjusted if deemed appropriate by the officials.
- D3.2.4 Only one set of tires per type (dry/wet) may be used during all the dynamic events. The brake test, practice area, [DC ONLY] driverless autocross, [DC ONLY] trackdrive and the static events are excluded from this regulation.

## D4 SKIDPAD EVENT

### D4.1 Skidpad Track Layout

- D4.1.1 The skidpad track consists of two pairs of concentric circles in a figure of eight pattern.
- D4.1.2 The 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 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 tangent to the circles where they meet.
- D4.1.6 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.

### D4.2 Manual Skidpad Procedure

- D4.2.1 Each team has two runs, driven by one driver.
- D4.2.2 The driver has the option to make the second run immediately after his/her first run.

## D4 Skidpad Event

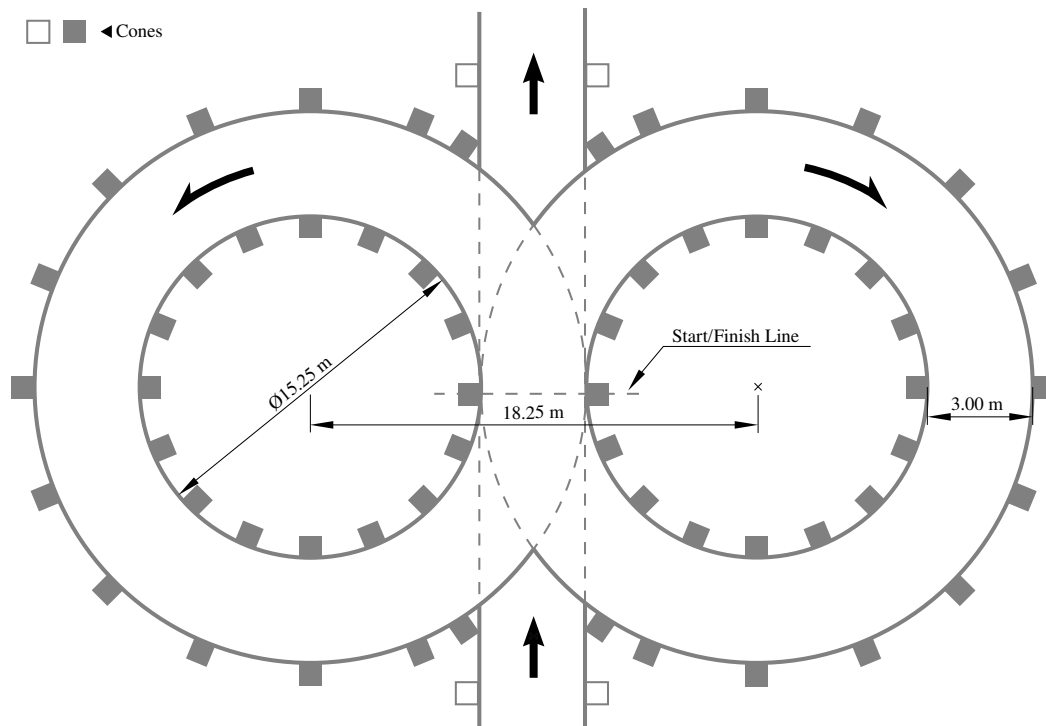


Figure 23: Skidpad Track Layout

- D4.2.3 The starting order is based on the time the team arrives at the skidpad event. Teams on their first run will receive priority.
- D4.2.4 Starting - A green flag is used to indicate that the driver may start.
- D4.2.5 The vehicle will enter perpendicular to the figure of eight and will take one full lap on the right circle to establish the turn. The next lap will be on the right circle and will be timed. Immediately following the second lap, the vehicle will enter the left circle for the third lap. The fourth lap will be on the left circle and will be timed. Immediately upon finishing the fourth lap, the vehicle will exit the track perpendicular to the figure of eight and moving in the same direction as entered.

### D4.3 Driverless Skidpad Procedure

- D4.3.1 Each team has two runs in autonomous mode.
- D4.3.2 Starting order is based upon time of arrival. Teams on their first run will receive priority.
- D4.3.3 Staging - The foremost part of the vehicle is staged 15 m in front of the timekeeping line.
- D4.3.4 Starting - A go-signal from RES is used to indicate the approval to begin.
- D4.3.5 The vehicle will enter perpendicular to the figure eight and will take one full lap on the right circle to establish the turn. The next lap will be on the right circle and will be timed. Immediately following the second lap, the vehicle will enter the left circle for the third lap.

## D4 Skidpad Event

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The fourth lap will be on the left circle and will be timed. Immediately upon finishing the fourth lap, the vehicle will exit the track.

- D4.3.6 The vehicle will exit at the intersection moving in the same direction as entered and must come to a full stop within 25 m behind the timekeeping line, inside the marked exit lane and enter the finish-state described in T 14.10.

### D4.4 Manual Skidpad Scoring

- D4.4.1 The run time is the average time of the timed left and the timed right circle plus penalties which are added after the averaging.

- D4.4.2 5 % of the maximum points for the event according to table 3 are awarded to every team that finishes at least one run without DNF or DQ.

- D4.4.3 If a team's best manual mode time including penalties is below  $T_{\max}$ , additional points based on the following formula are given:

$$M\_SKIDPAD\_SCORE = 0.95 P_{\max} \left( \frac{\left( \frac{T_{\max}}{T_{\text{team}}} \right)^2 - 1}{0.5625} \right)$$

$P_{\max}$  is the maximum points for the event according to table 3.

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

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

### D4.5 Driverless Skidpad Scoring

- D4.5.1 Run time is calculated according to D4.4.1.

- D4.5.2 Runs with a run time without penalties >25 s will be DQ.

- D4.5.3 If a team that finishes at least one DV run without a DNF or DQ, points based on the following formula are given:

$$DV\_SKIDPAD\_SCORE = P_{\max} \frac{N_{\text{all}} + 1 - R_{\text{DV,team}}}{N_{\text{all}}}$$

with

$P_{\max}$  is the maximum points for the event according to table 3

$R_{\text{DV,team}}$  is the ranking of team's best DV time including penalties within the best driverless times including penalties of all other teams

$N_{\text{all}}$  is the number of teams who finished at least one manual or DV run without DNF or DQ

### D4.6 [DC ONLY] Driverless Cup Skidpad Scoring

- D4.6.1 Run time is calculated according to D4.4.1.

- D4.6.2 The score for the DC skidpad is calculated using the runs scored for the DV skidpad.

## D5 Acceleration Event

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- D4.6.3 5 % of the maximum points for the event according to table 3 are awarded to every team that finishes at least one run without DNF or DQ.
- D4.6.4 If a team's run time including penalties is below  $T_{\max}$ , additional points based on the following formula are given:

$$DC\_SKIDPAD\_SCORE = 0.95 P_{\max} \left( \frac{\left( \frac{T_{\max}}{T_{\text{team}}} \right)^2 - 1}{1.25} \right)$$

$P_{\max}$  is the maximum points for the event according to table 3.

$T_{\text{team}}$  is the team's best DV run time including penalties.

$T_{\max}$  is 1.5 times the time of the fastest DV run of all teams including penalties.

## D5 ACCELERATION EVENT

### D5.1 Acceleration Track Layout

- D5.1.1 The acceleration track is a straight line with a length of 75 m from starting line to finish line. The track is at least 3 m wide. Cones are placed along the track at intervals of about 5 m.

### D5.2 Manual Acceleration Procedure

- D5.2.1 Each team has two runs, driven by one driver.
- D5.2.2 The driver has the option to make the second run immediately after his/her first run.
- D5.2.3 Staging - The foremost part of the vehicle is staged 0.30 m behind the starting line. Vehicles will accelerate from a standing start.
- D5.2.4 Starting - A green flag is used to indicate that the driver may start. Timing starts after the vehicle crosses the starting line and stops after it crosses the finish line.
- D5.2.5 The starting order is based on the time the team arrives at the acceleration event. Teams on their first run will receive priority.

### D5.3 Driverless Acceleration Procedure

- D5.3.1 Each team has two runs in autonomous mode.
- D5.3.2 Staging - The foremost part of the vehicle is staged at 0.30 m behind the starting line. Vehicles will accelerate from a standing start.
- D5.3.3 Starting - A go-signal from RES is used to indicate the approval to begin, timing starts only after the vehicle crosses the starting line and stops after it crosses the finish line.
- D5.3.4 After the finish line, the vehicle must come to a full stop within 75 m inside the marked exit lane and enter the finish-state described in T 14.10.
- D5.3.5 Starting order is based upon time of arrival. Teams on their first run will receive priority.

## D5 Acceleration Event

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### D5.4 Manual Acceleration Scoring

D5.4.1 5 % of the maximum points for the event according to table 3 are awarded to every team that finishes at least one manual mode run without a DNF or DQ.

D5.4.2 If a team's best manual mode time including penalties is below  $T_{\max}$ , additional points based on the following formula are given:

$$M\_ACCELERATION\_SCORE = 0.95 P_{\max} \left( \frac{\frac{T_{\max}}{T_{\text{team}}} - 1}{0.5} \right)$$

$P_{\max}$  is the maximum points for the event according to table 3.

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

$T_{\max}$  is 1.5 times the time of the fastest manual mode vehicle including penalties.

### D5.5 Driverless Acceleration Scoring

D5.5.1 Runs with a time without penalties  $>25$  s will be DQ.

D5.5.2 If a team that finishes at least one DV run without a DNF or DQ, points based on the following formula are given:

$$DV\_ACCELERATION\_SCORE = P_{\max} \frac{N_{\text{all}} + 1 - R_{\text{DV,team}}}{N_{\text{all}}}$$

with

$P_{\max}$  is the maximum points for the event according to table 3

$R_{\text{DV,team}}$  is the ranking of team's best DV time including penalties within the best DV times including penalties of all other teams

$N_{\text{all}}$  is the number of teams who finished at least one manual or DV run without DNF or DQ

### D5.6 [DC ONLY] Driverless Cup Acceleration Scoring

D5.6.1 The score for the DC acceleration is calculated using the runs scored for the DV acceleration.

D5.6.2 5 % of the maximum points for the event according to table 3 are awarded to every team that finishes at least one DV run without a DNF or DQ.

D5.6.3 If a team's best time including penalties is below  $T_{\max}$ , additional points based on the following formula are given:

$$DC\_ACCELERATION\_SCORE = 0.95 P_{\max} \left( \frac{T_{\max}}{T_{\text{team}}} - 1 \right)$$

$P_{\max}$  is the maximum points for the event according to table 3.

$T_{\text{team}}$  is the team's best DV time including penalties.

$T_{\max}$  is 2 times the time of the fastest DV vehicle including penalties.

### D6 AUTOCROSS EVENT

#### D6.1 Autocross Track Layout

D6.1.1 The autocross track layout is a handling track built to the following guidelines:

- Straights: No longer than 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 m.

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

D6.1.3 [DC ONLY] The autocross track layout is built to the guidelines defined in D8.1.

#### D6.2 Autocross Procedure

D6.2.1 Each team has up to four runs, driven by two drivers with two runs each.

D6.2.2 Each driver has the option to make the second run immediately after his/her first run.

D6.2.3 Staging - The vehicle is staged at a staging line prior to the starting line.

D6.2.4 Starting - A green flag is used to indicate that the driver may start. Timing starts only after the vehicle crosses the starting line and stops after it crosses the finish line.

D6.2.5 The starting order is based on the time the team arrives at the autocross event. Teams on their first run will receive priority.

#### D6.3 Autocross Scoring

D6.3.1 5 % of the maximum points for the event according to table 3 are awarded to every team that finishes at least one run without DNF or DQ.

D6.3.2 If a team's corrected elapsed time is below  $T_{\max}$ , points based on the following formula are given:

$$AUTOCROSS\_SCORE = 0.95 P_{\max} \left( \frac{\frac{T_{\max}}{T_{\text{team}}} - 1}{0.25} \right)$$

$P_{\max}$  is the maximum points for the event according to table 3.

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

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

## D7 Endurance and Efficiency Event

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### D6.4 [DC ONLY] Driverless Autocross Procedure

- D6.4.1 There will be a track walk prior to the autocross. During the track walk no equipment (e.g. antennas, sensors, cameras, etc) other than analog measurement devices (i.e. measurement wheel or measurement tape) is allowed.
- D6.4.2 Each team has two runs consisting of one single lap.
- D6.4.3 The starting order is based on the time the team arrives at the autocross event. Teams on their first run will receive priority.
- D6.4.4 Staging - The vehicle is staged such that the front wheels are 6 m in front of the starting line on the track.
- D6.4.5 Starting - A go-signal from RES is used to indicate the approval to begin. Timing starts after the vehicle crosses the starting line.
- D6.4.6 After the run 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 T 14.9.

### D6.5 [DC ONLY] Driverless Autocross Scoring

- D6.5.1 10 % of the maximum points for the event according to table 3 are awarded to every team that finishes at least one run without DNF or DQ.
- D6.5.2 If a team's  $T_{team,total}$  is below  $T_{max}$ , points based on the following formula are given:

$$AUTOCROSS\_SCORE = 0.9 P_{max} \left( \frac{T_{max} - T_{team,total}}{T_{max} - T_{min}} \right)$$
$$T_{team,total} = \min(T_{team,1}, \text{avg}(T_{team,1}, T_{team,2}))$$

$P_{max}$  is the maximum points for the event according to table 3.

$T_{team,1}$  is the team's time including penalties of run 1.

$T_{team,2}$  is the team's time including penalties of run 2.

$T_{max}$  is the time for driving the lap with 6 m/s.

$T_{min}$  is the fastest  $T_{team,total}$  of all teams.

For runs that are DNF or DQ and for runs with a  $T_{team,i}$  above  $T_{max}$ ,  $T_{team,i}$  is set to  $T_{max}$ .

## D7 ENDURANCE AND EFFICIENCY EVENT

### D7.1 Endurance Track Layout

- D7.1.1 The endurance track layout is a closed lap circuit built to the following guidelines:
- Straights: No longer than 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 m



## **D7 Endurance and Efficiency Event**

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D7.1.2 The length of one lap of the endurance track is approximately 1 km.

D7.1.3 The length of the complete endurance is approximately 22 km.

### **D7.2 Endurance Procedure**

D7.2.1 Before entering the event, each CV's fuel tank must be filled to the fuel level line (see CV2.6.3, "Fuel Level Line") at the 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.

D7.2.2 There is only one run for the endurance event.

D7.2.3 Staging - The vehicle is staged at a staging line prior to the starting line. The timer starts only after the vehicle crosses the start line.

D7.2.4 Starting - A green flag is used to indicate that the driver may start. Timing starts only after the vehicle crosses the starting line.

D7.2.5 The first driver will drive for 11 km and will then be signaled into the driver change area.

D7.2.6 After the driver change specified in D7.5, the second driver will drive for an additional 11 km and will be signaled to exit the track after crossing the finish line.

D7.2.7 After leaving the track, the vehicle must be powered down.

D7.2.8 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.

### **D7.3 Endurance Running Order**

D7.3.1 The running order for the endurance will be established in a way that vehicles with similar speeds shall be on the track together.

D7.3.2 The running order will be published according to the competition handbook.

D7.3.3 The procedure for handling the running order is defined in the competition handbook.

### **D7.4 Passing**

D7.4.1 During the endurance event, overtaking is only permissible in the designated passing zones and under the control of the track marshals.

D7.4.2 Passing zones have two parallel lanes, a slow lane only used by the vehicles that are being overtaken and a fast lane for the vehicles that are overtaking.

D7.4.3 Passing zones may be situated on either the left or right of the fast lane.

D7.4.4 The passing zone procedure will be as follows:

- A slower leading vehicle will be shown the blue flag and must drive into the slow lane and decelerate.
- The following faster vehicle will continue in the fast lane to pass the slow vehicle.

## **D7 Endurance and Efficiency Event**

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- The vehicle that has been overtaken may re-enter the track when the track marshal who is in charge of that passing zone is showing the green flag.

D7.4.5 The passing rules do not apply to vehicles that are stopped on track or vehicles that have spun out and are not moving. When passing a stationary vehicle, it is critical to slow down, drive cautiously and to follow the instructions from the track marshals.

### **D7.5 Endurance Driver Change Procedure**

D7.5.1 Only three team members including the driver may enter the driver change area. They may only bring the tools required to adjust the vehicle to accommodate the second driver and/or change tires.

D7.5.2 [EV ONLY] One team member must be an ESO.

D7.5.3 During the driver change, the team may:

- perform changes to accommodate the second driver
- operate the master switch(es)
- change tires as per D7.6.

No other work may be performed during the driver change.

D7.5.4 Each team is given 3 min to change their driver.

D7.5.5 The driver change time will start once the vehicle is stopped in the driver change area and the first driver has turned off the engine for CV or turned off the TS for EVs.

D7.5.6 [EV ONLY] The TSMS must be switched off by the ESO and the TSAL must have changed to green color, before anyone is allowed to touch the vehicle or to climb out the vehicle.

D7.5.7 The first driver will climb out the vehicle and any necessary adjustments will be made to the vehicle to fit the second driver (seat cushions, head restraint, pedal position, etc.). The second driver will then be secured in the vehicle.

D7.5.8 When the second driver is fully secured in the vehicle, the vehicle has restarted and is R2D again, the driver change time is stopped.

D7.5.9 If the driver change takes longer than 3 min, the extra time is included in the final time.

### **D7.6 Endurance Event Tire Changes**

D7.6.1 All tire changes after a vehicle has received the green flag to start the endurance event must take place in the driver change area.

D7.6.2 If the operating condition changes to wet during endurance, the track will be red flagged and all vehicles brought into the driver change area.

D7.6.3 If a team wants to change tires, the officials must be informed beforehand.

D7.6.4 In some cases, tire changes can be carried out directly after the driver change, for others the team must make an extra stop.

D7.6.5 The allowed tire changes and associated conditions are given in table 9.

## D7 Endurance and Efficiency Event

| 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 10 min without driver change, or 13 min 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.

Table 9: Endurance event tire change

- D7.6.6 Teams that have incurred a puncture during the endurance event due to external factors (e.g. debris on track) may change the tire with no time penalty, if the vehicle reaches the driver change area under its own power without external assistance.
- D7.6.7 The wheel will be inspected by the officials. If the deflation was not caused by external factors, the vehicle will be scored DNF.
- D7.6.8 Deflation caused by running OC or impacting barriers or other objects due to driver error will not be regarded as external factors.

### D7.7 Endurance Specific Regulations

- D7.7.1 Teams are prohibited from working on or fueling their vehicles during the run.
- D7.7.2 Wheel-to-wheel racing is prohibited.
- D7.7.3 If a vehicle stalls out on the track, it is allowed one lap by the vehicle that is following it (approximately one minute) to restart.
- D7.7.4 If a vehicle has a restart problem at the driver change or after a red flag, it is allowed 2 min to restart the engine or to enable the TS. The 2 min start from the time the driver first tries to restart the engine or to enable the TS. The time is added to the endurance time.
- D7.7.5 If restarts are not accomplished within the above times, the vehicle is scored as DNF for the run.
- D7.7.6 If a vehicle breaks down it will be removed from the track and will not be allowed to re-enter the track.
- D7.7.7 Team members may be instructed by the officials to retrieve broken down vehicles. This recovery may only be carried out under the control of the officials.

## D7 Endurance and Efficiency Event

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### D7.8 Endurance Scoring

- D7.8.1 Each lap of the endurance event is individually timed. The corrected elapsed time is determined by subtracting the extra-long lap for the driver change from the total time and adding any penalty times.
- D7.8.2 The post event technical inspection (see IN 12) must be passed to score points in the endurance event.
- D7.8.3 10 % of the maximum points for the event according to table 3 are awarded to every team that finishes endurance without DNF or DQ.
- D7.8.4 If a team's corrected elapsed time is below  $T_{\max}$ , additional points based on the following formula are given:

$$ENDURANCE\_SCORE = 0.9 P_{\max} \left( \frac{\frac{T_{\max}}{T_{\text{team}}} - 1}{0.333} \right)$$

$P_{\max}$  is the maximum points for the event according to table 3.

$T_{\text{team}}$  is the team's corrected elapsed time.

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

### D7.9 Efficiency Scoring

- D7.9.1 Efficiency is measured during the endurance event.
- D7.9.2 Only vehicles which meet all of the following requirements are considered for efficiency scoring:
- the vehicle received points for the endurance event
  - the uncorrected elapsed endurance time does not exceed 1.333 times the uncorrected elapsed time of the fastest vehicle
  - [CV ONLY] the consumed fuel mass does not exceed 15 kg/100 km 98 RON or 21.75 kg/100 km E85
- D7.9.3 [CV ONLY] Fuel pumps must be on and fuel valves must be opened during refueling.
- D7.9.4 [CV ONLY] The measured fuel mass of vehicles using E85 fuel is divided by 1.45 to be comparable to the vehicles using 98 RON.
- D7.9.5 [EV ONLY] The endurance energy is calculated as the time integrated value of the measured voltage multiplied by the measured current logged by the data logger, see EV 4.6. Regenerated energy is multiplied by 0.9 and subtracted from the used energy.
- D7.9.6 Efficiency points based on the following formula are given:

$$EFFICIENCY\_SCORE = P_{\max} \left( \frac{EF_{\max} - EF_{\text{team}}}{EF_{\max} - EF_{\min}} \right)$$

with

$P_{\max}$  is the maximum points for the event according to table 3

$EF_{\text{team}}$  the team's efficiency factor

## D8 [DC ONLY] Trackdrive Event

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

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

D7.9.7 The efficiency factor is calculated based on the following formula:

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

with

$T$  uncorrected elapsed driving time

$E$  [CV ONLY] corrected used fuel mass / [EV ONLY] used energy

## D8 [DC ONLY] TRACKDRIVE EVENT

### D8.1 Trackdrive Tracklayout

D8.1.1 The trackdrive layout is a closed loop circuit built to the following guidelines:

- Straights: No longer than 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 m

D8.1.2 The length of one lap is approximately 200 m to 500 m.

### D8.2 Trackdrive Running Order

D8.2.1 The running order will be defined by the officials, based on previous dynamic event results.

D8.2.2 The running order will be published according to the competition handbook.

D8.2.3 The procedure for handling the running order is defined in the competition handbook.

### D8.3 Trackdrive Procedure

D8.3.1 There will be one run consisting of ten laps.

D8.3.2 Staging - The vehicle is staged such that the front wheels are 6 m in front of the starting line on the track.

D8.3.3 Starting - A go-signal from RES is used to indicate the approval to begin. Timing starts after the vehicle crosses the starting line.

D8.3.4 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 T 14.9.

D8.3.5 There will be no last lap signal i.e. the vehicle should count laps itself.

## D9 Dynamic Events Penalties

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### D8.4 Trackdrive Scoring

D8.4.1 Each lap of the trackdrive event is individually timed. The corrected elapsed time is determined by adding any penalty times.

D8.4.2 If a team's corrected elapsed time is below  $T_{\max}$  and the run was not DNF or DQ, points based on the following formula are given:

$$TRACKDRIVE\_SCORE = 0.75 P_{\max} \left( \frac{T_{\max}}{T_{\text{team}}} - 1 \right)$$

$P_{\max}$  is the maximum points for the event according to table 3.

$T_{\text{team}}$  is the team's corrected elapsed time.

$T_{\max}$  is 2 times of the corrected elapsed time of the fastest vehicle.

D8.4.3 An additional 2.5 % of the maximum points for the event according to table 3 are awarded for every completed lap, independent of the corrected elapsed time. This is also applied for teams that do not finish the trackdrive i.e. get a DNF.

## D9 DYNAMIC EVENTS PENALTIES

### D9.1 General Penalties

D9.1.1 Penalties will not be assessed for accident avoidance or other reasons deemed sufficient by the officials.

D9.1.2 A cone is Down or Out (DOO) if the cone has been knocked over or the entire base of the cone lies outside the box marked around the cone in its undisturbed position.

D9.1.3 Cones that are DOO are not replaced/reset during autonomous running. There will be no re-run due to cones in the driving path or disorientation due to missing cones.

D9.1.4 The DOO penalty (see D9.1.7) is added for each DOO including entry and exit gate cones before the start and after the finish line, that occur on that particular run.

D9.1.5 Off-Course (OC)

- An OC occurs when the vehicle has all four wheels outside the track boundary as indicated by edge marking.
- Missing one or more gates of a given slalom at autocross or endurance is counted as one OC per occurrence.
- When an OC occurs, the driver must re-enter the track at the next possible point.
- When re-entering the driver needs to wait for a gap and follow the instructions of the track marshals.

D9.1.6 An Unsafe Stop (USS) is defined as not stopping within the specified area and/or not entering the finish-state described in T 14.9 within 30 s after stopping during autonomous running.

## D9 Dynamic Events Penalties

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|        |     |              |         |           |           |            |
|--------|-----|--------------|---------|-----------|-----------|------------|
| D9.1.7 |     | Acceleration | Skidpad | Autocross | Endurance | Trackdrive |
|        | DOO | 2 s          | 0.2 s   | 2 s       | 2 s       | 2 s        |
|        | OC  | DNF          | DNF     | 10 s      | 10 s      | 10 s       |
|        | USS | DNF          | DNF     | DNF       | n/a       | –50 points |

D9.1.8 DNF equals zero points for that run.

D9.1.9 DQ equals zero points for that run.

D9.1.10 If a team Did Not Attempt (DNA) an event the score is zero points.

D9.1.11 Each run with an incorrect number of laps at skidpad is classified as DNF.

D9.1.12 Failure to obey a flag: 1 min time penalty.

D9.1.13 Reckless or aggressive driving or “Over Driving”: black flag (see D2.1.3)

D9.1.14 Vehicle to vehicle contact: 2 min up to DQ depending on the nature of the incident.

D9.1.15 If a vehicle stalls before passing the finish line and cannot restart without external assistance, the vehicle is DNF for that run.

D9.1.16 If a vehicle is not able to start the run, within 30 s after receiving a green flag or go-signal, the vehicle is DQ for that run.

### D9.2 Endurance Penalties

D9.2.1 Teams that are running out-of-order as defined in the competition handbook, are penalized by 2 min and may then run at the discretion of the officials.

D9.2.2 Mechanical Problem: The time taken for mechanical inspection under a “mechanical black flag” (see D2.1.4) 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.

D9.2.3 If it is impossible to impose a penalty by a stop under a black flag, e.g. not enough laps left, the officials may add an appropriate time penalty to the team’s elapsed time.

D9.2.4 A team may be disqualified if their vehicle is too slow or being driven without proper control. A vehicle is considered to be too slow if the average speed, based on lap times, for two consecutive laps is below 8 m/s in dry conditions or below 5 m/s in wet or damp conditions.

D9.2.5 Any violation to the procedure of driver change (D7.5.3) will lead to a time penalty of up to 2 min.

D9.2.6 All rules and penalties from IN 12 are also applicable during driver change.

### D9.3 [CV ONLY] Efficiency Penalties

D9.3.1 Should the fuel level change after refueling due to effects such as described in CV2.7.1, then the difference in fuel level will be measured and twice the amount will be added to the official fuel consumption figure.

## **D9 Dynamic Events Penalties**

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### **D9.4 [EV ONLY] Power and Voltage Violation Penalties**

- D9.4.1 A violation is defined as using more than the maximum power, see EV 2.2, or exceeding the specified voltage, see EV 4.1.1, after a moving average over 500 ms is applied to the respective data logger signal, see EV 4.6.
- D9.4.2 Each violation is a DQ for the fastest valid run of the event. If a violation occurred during two runs, the two fastest valid runs will be DQ etc. .
- D9.4.3 The respective data and the resulting decision of violations may be made public.
- D9.4.4 Non-availability of data logger data will be treated as a violation.