

# FORMULA SAE®

## Rules 2019

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## **GR - GENERAL REGULATIONS**

### **GR.1 FORMULA SAE COMPETITION OBJECTIVE**

#### **GR.1.1 Formula SAE Concept**

The Formula SAE® competitions challenge teams of university undergraduate and graduate students to conceive, design, fabricate, develop and compete with small, formula style vehicles.

#### **GR.1.2 Engineering Competition**

Formula SAE® is an engineering education competition that requires performance demonstration of vehicles in a series of events, both off track and on track against the clock. Each competition gives teams the chance to demonstrate their creativity and engineering skills in comparison to teams from other universities around the world.

#### **GR.1.3 Vehicle Design Objectives**

- GR.1.3.1 Teams are to assume that they work for an engineering firm that is designing, fabricating, testing and demonstrating a prototype vehicle.
- GR.1.3.2 The vehicle should have high performance and be sufficiently durable to successfully complete all the events at the Formula SAE competitions.
- GR.1.3.3 Additional design factors include: aesthetics, cost, ergonomics, maintainability, and manufacturability.
- GR.1.3.4 Each design will be judged and evaluated against other competing designs in a series of Static and Dynamic events to determine the vehicle that best meets the design goals and may be profitably built and marketed.

#### **GR.1.4 Good Engineering Practices**

Vehicles entered into Formula SAE competitions should be designed and fabricated in accordance with good engineering practices.

#### **GR.1.5 Restriction on Vehicle Use**

SAE International and competition organizer(s) are not responsible for use of vehicles designed in compliance with these Formula SAE Rules outside of the official Formula SAE competitions.

### **GR.2 FORMULA SAE RULES AND ORGANIZER AUTHORITY**

#### **GR.2.1 Rules Authority**

The Formula SAE Rules are the responsibility of the Formula SAE Rules Committee and are issued under the authority of the SAE International Collegiate Design Series.

#### **GR.2.2 Rules Validity**

- GR.2.2.1 The Formula SAE Rules posted on the website and dated for the calendar year of the competition are the rules in effect for the competition.
- GR.2.2.2 Rules appendices or supplements may be posted on the website and incorporated into the rules by reference.
- GR.2.2.3 Additional guidance or reference documents may be posted on the website.
- GR.2.2.4 Any rules, questions, or resolutions from previous years are not valid for the current competition year.

### **GR.2.3 Rules Alterations**

- GR.2.3.1 The Formula SAE rules may be revised, updated, or amended at any time during the competition season.
- GR.2.3.2 Official designated announcements from the Formula SAE Rules Committee, SAE International or the other organizing bodies are to be considered part of, and have the same validity as, these rules.
- GR.2.3.3 Draft rules or proposals may be issued for comments, however they are a courtesy, are not valid for any competitions, and may or may not be implemented in whole or in part.

### **GR.2.4 Rules Compliance**

- GR.2.4.1 By entering a Formula SAE competition, the team, members of the team as individuals, faculty advisors and other personnel of the entering university agree to comply with, and be bound by, these rules and all rule interpretations or procedures issued or announced by SAE International, the Formula SAE Rules Committee and the other organizing bodies.
- GR.2.4.2 All participants must comply with the latest issue of the rules. Check the Event Website to verify the current version.
- GR.2.4.3 Teams and team members must comply with the general rules and any specific rules for each competition they enter.
- GR.2.4.4 Any regulations pertaining to the use of the competition site by teams or individuals and which are posted, announced and/or otherwise publicly available are incorporated into the Formula SAE Rules by reference. As examples, all competition site waiver requirements, speed limits, parking and facility use rules apply to Formula SAE participants.

### **GR.2.5 Violations on Intent**

The violation of the intent of a rule will be considered a violation of the rule itself.

### **GR.2.6 Understanding the Rules**

- GR.2.6.1 Teams, team members as individuals and faculty advisors, are responsible for reading and understanding the rules in effect for the competition in which they are participating.

### **GR.2.7 Participating in the Competition**

- GR.2.7.1 Teams, individual team members, faculty advisors and other representatives of a registered university who are present onsite at a competition are “participating in the competition” from the time they arrive at the competition site until they depart the site at the conclusion of the competition or earlier by withdrawing.
- GR.2.7.2 All team members, faculty advisors and other university representatives are required to cooperate with, and follow all instructions from, competition organizers, officials and judges.

### **GR.2.8 Forfeit for Non Appearance**

- GR.2.8.1 It is the responsibility of each team to be in the right place at the right time.
- GR.2.8.2 If a team is not present and ready to compete at the scheduled time, they forfeit their attempt at that event.
- GR.2.8.3 There are no makeups for missed appearances.

### **GR.2.9 Right to Impound**

- GR.2.9.1 SAE and other competition organizing bodies may impound any onsite registered vehicle at any time during a competition.

GR.2.9.2 Team access to a vehicle in impound may be restricted.

#### **GR.2.10 Problem Resolution**

Any problems that arise during the competition will be resolved through the onsite organizers and the decision will be final.

#### **GR.2.11 General Authority**

SAE and the competition organizing bodies reserve the right to revise the schedule of any competition and/or interpret or modify the competition rules at any time and in any manner that is, in their sole judgment, required for the efficient operation of the event or the Formula SAE series as a whole.

### **GR.3 RULES OF CONDUCT**

#### **GR.3.1 Unsportsmanlike Conduct**

In the event of unsportsmanlike conduct, the team will receive a warning from an official. A second violation will result in expulsion of the team from the competition.

#### **GR.3.2 Official Instructions**

Failure of a team member to follow an instruction or command directed specifically to that team or team member will result in a 25 point penalty.

#### **GR.3.3 Arguments with Officials**

Argument with, or disobedience of, any official may result in the team being eliminated from the competition.

All members of the team may be immediately escorted from the grounds.

#### **GR.3.4 Alcohol and Illegal Material**

GR.3.4.1 Alcohol, illegal drugs, weapons or other illegal material are prohibited on the competition site during the entire competition.

GR.3.4.2 Any violation of this rule by any team member or faculty advisor will cause immediate disqualification and expulsion of the entire team.

GR.3.4.3 Any use of drugs, or the use of alcohol by an underage individual will be reported to the local authorities.

#### **GR.3.5 Smoking – Prohibited**

Smoking and e-cigarette use is prohibited in all competition areas.

### **GR.4 RULES FORMAT AND USE**

#### **GR.4.1 Definition of Terms**

- **Must** - designates a requirement
- **Must NOT** - designates a prohibition or restriction
- **Should** - gives an expectation
- **May** - gives permission, not a requirement and not a recommendation

#### **GR.4.2 Capitalized Terms**

Items or areas which have specific definitions or are covered by specific rules are capitalized. For example, “Rules Questions” or “Primary Structure”

### **GR.4.3 Headings**

The article, section and paragraph headings in these rules are provided only to facilitate reading: they do not affect the paragraph contents.

### **GR.4.4 Applicability**

GR.4.4.1 Unless otherwise designated, all rules apply to all vehicles at all times

GR.4.4.2 Rules specific to vehicles based on their powertrain will be designated as such in the rule text:

- Internal Combustion “IC” or “IC Only”
- Electric Vehicle “EV” or “EV Only”

### **GR.4.5 Change Identification**

Any summary of changed rules and changed portions marked within the rules themselves are provided for courtesy, and may or may not include all changes.

## **GR.5 RULES QUESTIONS**

### **GR.5.1 Question Types**

The Committee will answer questions that are not already answered in the rules or FAQs or that require new or novel rule interpretations.

Rules Questions may also be used to request approval, as designated within these rules.

### **GR.5.2 Question Format**

GR.5.2.1 All Rules Questions must include:

- Full name and contact information of the person submitting the question
- University name – no abbreviations
- The specific competition your team has, or is planning to, enter.
- Number of the applicable rule(s)

GR.5.2.2 Response Time

- Please allow a minimum of two weeks for a response
- Do not resubmit questions

GR.5.2.3 Submission Addresses

- a. Teams entering Formula SAE competitions: Follow the link and instructions published on the FSAE Online Website to "Submit a Rules Question"
- b. Teams entering other competitions please visit those respective competition websites for further instructions.

### **GR.5.3 Question Publication**

Any submitted question and the official answer may be reproduced and freely distributed, in both complete and edited versions.

## **GR.6 PROTESTS**

### **GR.6.1 Cause for Protest**

A team may protest any rule interpretation, score or official action (unless specifically excluded from protest) which they feel has caused some actual, non trivial, harm to their team, or has had a substantive effect on their score.

### **GR.6.2 Preliminary Review – Required**

Questions about scoring, judging, policies or any official action must be brought to the attention of the organizer or SAE International staff for an informal preliminary review before a protest may be filed.

### **GR.6.3 Protest Format**

- All protests must be filed in writing
- The completed protest must be presented to the organizer or SAE International staff by the team captain.
- Team video or data acquisition will not be reviewed as part of a protest.

### **GR.6.4 Protest Point Bond**

A team must post a 25 point protest bond which will be forfeited if their protest is rejected.

### **GR.6.5 Protest Period**

Protests concerning any aspect of the competition must be filed within the protest period announced by the competition organizers or 30 minutes of the posting of the scores of the event to which the protest relates.

### **GR.6.6 Decision**

The decision regarding any protest is final.

## **GR.7 VEHICLE ELIGIBILITY**

### **GR.7.1 Student Developed Vehicle**

GR.7.1.1 Vehicles entered into Formula SAE competitions must be conceived, designed, fabricated and maintained by the student team members without direct involvement from professional engineers, automotive engineers, racers, machinists or related professionals.

#### **GR.7.1.2 Information Sources**

The student team may use any literature or knowledge related to design and information from professionals or from academics as long as the information is given as a discussion of alternatives with their pros and cons.

#### **GR.7.1.3 Professional Assistance**

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

#### **GR.7.1.4 Student Fabrication**

Students should perform all fabrication tasks

### **GR.7.2 Definitions**

#### **GR.7.2.1 Competition Year**

The period beginning at the event of the Formula SAE series where the vehicle first competes and continuing until the start of the corresponding event held approximately 12 months later.

#### **GR.7.2.2 First Year Vehicle**

A vehicle which has, at minimum, a new Chassis and is within its initial Competition Year

#### **GR.7.2.3 Second Year Vehicle**

A vehicle which has competed in a previous Competition Year



**GR.7.2.4 Third Year Vehicle**

A vehicle which has competed in more than one previous Competition Year

**GR.7.3 Formula SAE Competition Eligibility**

GR.7.3.1 Only First Year Vehicles may enter the Formula SAE Competitions.

GR.7.3.2 Second Year Vehicles must not enter Formula SAE Competitions, unless permitted by the organizer of the specific competition.

GR.7.3.3 Third Year Vehicles must not enter any Formula SAE Competitions

GR.7.3.4 If there is any question about the status as a First Year Vehicle, the team must provide additional information and/or evidence.

## AD - ADMINISTRATIVE REGULATIONS

### AD.1 THE FORMULA SAE SERIES

#### AD.1.1 Rule Variations

All competitions in the Formula SAE Series may post rule variations specific to the operation of the events in their countries. Vehicle design requirements and restrictions will remain unchanged. Any rule variations will be posted on the websites specific to those competitions.

#### AD.1.2 Official Announcements and Competition Information

Teams must read the published announcements by SAE International and the other organizing bodies and be familiar with all official announcements concerning the competitions and any released rules interpretations.

#### AD.1.3 Official Languages

The official language of the Formula SAE series is English. Document submissions, presentations and discussions in English are acceptable at all competitions in the series.

### AD.2 OFFICIAL INFORMATION SOURCES

The following websites are referenced in these rules. Refer to the websites for additional information and resources.

#### AD.2.1 Event Website

The Event Website for Formula SAE is specific to each competition, refer to:

<https://www.sae.org/attend/student-events>

#### AD.2.2 FSAE Online Website

The FSAE Online website is at: <http://fsaeonline.com/>

AD.2.2.1 Documents, forms, and information are accessed from the “Series Resources” link

AD.2.2.2 Each registered team must have an account on the FSAE Online Website.

AD.2.2.3 Each team must have one or more persons as Team Captain. The Team Captain must accept Team Members.

AD.2.2.4 Only persons designated Team Members or Team Captains are able to upload documents to the website.

#### AD.2.3 Contacts

Contact [collegiatecompetitions@sae.org](mailto:collegiatecompetitions@sae.org) with any problems/comments/concerns

Consult the specific website for the other competitions requirements.

### AD.3 INDIVIDUAL PARTICIPATION REQUIREMENTS

#### AD.3.1 Eligibility

AD.3.1.1 Team members must be enrolled as degree seeking undergraduate or graduate students in the college or university of the team with which they are participating.

AD.3.1.2 Team members who have graduated during the seven month period prior to the competition remain eligible to participate.

AD.3.1.3 Teams which are formed with members from two or more universities are treated as a single team. A student at any university making up the team may compete at any competition where the team participates. The multiple universities are treated as one university with the same eligibility requirements.

AD.3.1.4 Each team member may participate at a competition for only one team. This includes competitions where the University enters both IC and EV teams.

**AD.3.2 Age**

Team members must be at least 18 years of age.

**AD.3.3 Driver's License**

Team members who will drive a competition vehicle at any time during a competition must hold a valid, government issued driver's license.

**AD.3.4 Society Membership**

Team members must be members of at least one of the following societies: SAE International, SAE Australasia, SAE Brazil, ATA, IMechE, VDI, or JSAE. Proof of membership, such as membership card, is required at the competition.

**AD.3.5 Medical Insurance**

Individual medical insurance coverage is required and is the sole responsibility of the participant.

**AD.4 INDIVIDUAL REGISTRATION REQUIREMENTS**

**AD.4.1 Preliminary Registration**

AD.4.1.1 All students and faculty must be affiliated to your respective school /college/university on the Event Website by January 31 of the year of the competition.

AD.4.1.2 International student participants (or unaffiliated Faculty Advisors) who are not SAE International members must create a free customer account profile on [www.sae.org](http://www.sae.org). Upon completion, please email [collegiatecompetitions@sae.org](mailto:collegiatecompetitions@sae.org) the assigned customer number stating also the event and university affiliation.

**AD.4.2 Onsite Registration**

AD.4.2.1 All team members and faculty advisors must register at the competition site

AD.4.2.2 All onsite participants, including students, faculty and volunteers, must sign a liability waiver upon registering onsite.

AD.4.2.3 Onsite registration must be completed before the vehicle may be unloaded, uncrated or worked upon in any manner.

**AD.5 TEAM ADVISORS AND OFFICERS**

**AD.5.1 Faculty Advisor**

AD.5.1.1 Each team must have a Faculty Advisor appointed by their university.

AD.5.1.2 The Faculty Advisor must accompany the team to the competition and will be considered by the officials to be the official university representative.

AD.5.1.3 Faculty Advisors:

- a. May advise their teams on general engineering and engineering project management theory.

- b. Must not design, build or repair any part of the vehicle
- c. Must not develop any documentation or presentation

#### **AD.5.2 Electrical System Officer (EV Only)**

The Electrical System Officer (ESO) is responsible for all electrical operations of the vehicle during the event.

AD.5.2.1 Every participating team must appoint one or more ESO for the event

AD.5.2.2 The ESO must meet the following:

- a. Is a valid team member, see **AD.3 Individual Participation Requirements**
- b. At least one ESO must not be a driver.
- c. Is certified or has received appropriate practical training whether formal or informal for working with high voltage systems in automotive vehicles. Details of the training must be provided to the organizers on the ESO/ESA form for approval.

AD.5.2.3 Duties of the ESO:

- a. The only person in the team that may declare the vehicle electrically safe to allow work on any system
- b. Must accompany the vehicle whenever operated or moved at the competition site
- c. Must be contactable by phone at all times during the event

#### **AD.5.3 Electric System Advisor (EV Only)**

AD.5.3.1 The Electrical System Advisor (ESA) must be a professionally competent person(s) nominated by the team who can advise on the electrical and control systems that will be integrated into the vehicle. The faculty advisor may also be the ESA if all the requirements below are met.

AD.5.3.2 The ESA must supply details of their experience of electrical and/or control systems engineering as employed in the vehicle on the ESO/ESA form for approval by the organizers.

AD.5.3.3 The ESA must have significant experience of the technology that is being developed and its implementation into vehicles or other safety critical systems such that they are adequately qualified to advise the team on their proposed electrical and control system designs. More than one person may be needed.

AD.5.3.4 The ESA must advise the team such that the merits of any relevant engineering solutions can be discussed, questioned and approved before being implemented into the final vehicle design.

AD.5.3.5 The ESA should advise the students on the required training such that they are competent to work with the systems on the vehicle.

AD.5.3.6 The ESA must review the Electrical System Form and FMEA documents to confirm that in principle the vehicle has been designed using good engineering practices.

AD.5.3.7 The ESA must ensure that the team communicates any unusual aspects of the design to the organizers to reduce the risk of exclusion or significant changes being required to pass technical inspection.

## **AD.6 COMPETITION REGISTRATION**

### **AD.6.1 General Information**

AD.6.1.1 Registration for Formula SAE competitions must be completed on the Event Website.

AD.6.1.2 Refer to the individual competition websites for registration requirements for other competitions

### **AD.6.2 Registration Details**

AD.6.2.1 Refer to the Event Website for specific registration requirements and details.

- Registration limits and waitlist limits will be posted on the Event Website.
- Registration will open at the date and time posted on the Event Website.

AD.6.2.2 When registration opens, a team may enter either Formula SAE Michigan or Formula SAE Lincoln, but not both.

AD.6.2.3 Registration into Formula SAE Electric is separate and is not affected by registration into Formula SAE Michigan or Formula SAE Lincoln.

AD.6.2.4 Once a competition reaches the registration limit, a waitlist will open.

AD.6.2.5 Beginning on the date and time posted on the Event Website, any remaining slots will be available to any team on a first come, first serve basis.

AD.6.2.6 Registration and the waitlist will close at the date and time posted on the Event Website or when all available slots have been taken, whichever occurs first.

### **AD.6.3 Registration Fees**

AD.6.3.1 Registration fees must be paid to the organizer by the deadline specified on the respective competition website.

AD.6.3.2 Registration fees are not refundable and not transferrable to any other competition.

### **AD.6.4 Waitlist**

AD.6.4.1 Waitlisted teams must submit all documents by the same deadlines as registered teams to remain on the waitlist.

AD.6.4.2 Once a team withdraws from the competition, the organizer will inform the next team on the waitlist by email (the individual who registered the team to the waitlist) that a spot on the registered list has opened.

AD.6.4.3 The team will then have 24 hours to accept or reject the position and an additional 24 hours to have the registration payment completed or in process.

### **AD.6.5 Withdrawals**

Registered teams that will not attend the competition must inform the organizer, as posted on the Event Website.

## **AD.7 COMPETITION SITE**

### **AD.7.1 Personal Vehicles**

Personal cars and trailers must be parked in designated areas only. Only authorized vehicles will be allowed in the track areas.

**AD.7.2 Motorcycles, Bicycles, Rollerblades, etc. - Prohibited**

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

**AD.7.3 Self-propelled Pit Carts, Tool Boxes, etc. - Prohibited**

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

**AD.7.4 Trash Cleanup**

AD.7.4.1 Cleanup of trash and debris is the responsibility of the teams.

- The team's work area should be kept uncluttered
- At the end of the day, each team must clean all debris from their area and help with maintaining a clean paddock

AD.7.4.2 Teams are required to remove all of their material and trash when leaving the site at the end of the competition.

AD.7.4.3 Teams that abandon furniture, or that leave a paddock that requires special cleaning, will be billed for removal and/or cleanup costs.

## DR - DOCUMENT REQUIREMENTS

### DR.1 DOCUMENTATION

#### DR.1.1 Requirements

- DR.1.1.1 The documents supporting each vehicle must be submitted by the deadlines posted on the Event Website or otherwise published by the organizer.
- DR.1.1.2 The procedures for submitting documents are published on the Event Website or otherwise identified by the organizer.

#### DR.1.2 Definitions

##### DR.1.2.1 Submission Date

The date and time of upload to the website

##### DR.1.2.2 Submission Deadline

The date and time by which the document must be uploaded or submitted

##### DR.1.2.3 No Submissions Accepted After

The last date and time that documents may be uploaded or submitted

##### DR.1.2.4 Late Submission

- Uploaded after the Submission Deadline and prior to No Submissions Accepted After
- Submitted largely incomplete prior to or after the Submission Deadline

##### DR.1.2.5 Not Submitted

- Not uploaded prior to No Submissions Accepted After
- Not in the specified form or format

##### DR.1.2.6 Amount Late

The number of days between the Submission Deadline and the Submission Date.

Any partial day is rounded up to a full day. Examples: submitting a few minutes late would be one day penalty; submitting 25 hours late would be two days penalty

##### DR.1.2.7 Reviewer

A designated event official who is assigned to review and accept a Submission

### DR.2 SUBMISSION DETAILS

#### DR.2.1 Submission Location

Teams entering Formula SAE Michigan, Formula SAE Lincoln, and Formula SAE Electric must upload the required documents to the team account on the FSAE Online Website, see [AD.2.2](#)

#### DR.2.2 Submission Format Requirements

Refer to Table DR-1 Submission Information

- DR.2.2.1 Template files with the required format must be used when specified in Table DR-1
- DR.2.2.2 Template files are available on the FSAE Online Website, see [AD.2.2.1](#)
- DR.2.2.3 Do Not alter the format of any provided template files
- DR.2.2.4 Each submission must be one single file in the specified format (PDF - Portable Document File, XLSX - Microsoft Excel Worksheet File)

### DR.3 LATE SUBMISSION PENALTIES

DR.3.1.1 Each team is responsible for confirming that their documents have been properly uploaded or submitted and that the deadlines have been met.

DR.3.1.2 Prior to the Submission Deadline:

- a. Documents may be uploaded at any time
- b. Uploads may be replaced with new uploads without penalty

DR.3.1.3 If a Submitted Document revision is requested by the Reviewer, a new Submission Deadline for the revised document may apply

DR.3.1.4 Teams will not be notified if a document is submitted incorrectly.

#### DR.3.2 Penalty Detail

DR.3.2.1 Late Submissions will receive a point penalty as shown in Table DR-2, subject to official discretion.

DR.3.2.2 Additional penalties will apply if **Not Submitted**, subject to official discretion

#### DR.3.3 Removal of Team Entry

DR.3.3.1 The organizer may withdraw the team entry if the identified documents are **Not Submitted** within 10 days of the deadline.

- a. The team will be notified prior to cancelling registration.
- b. No refund of entry fees will be given.

DR.3.3.2 This elimination will take place after each round of required document deadlines.

#### DR.3.4 Submission Penalty Specifics

DR.3.4.1 Electronic Throttle Control (ETC)

- a. There is no point penalty for ETC documents.
- b. The team will not be allowed to run ETC on their vehicle and must use mechanical throttle actuation when:
  - The ETC Notice of Intent is **Not Submitted**
  - The ETC FMEA is **Not Submitted**, or is not accepted

DR.3.4.2 Fuel Type

There is no point penalty for a late fuel type order. Once the deadline has passed, the team will be allocated the basic fuel type.

DR.3.4.3 Program Submissions

Please submit material requested for the Event Program by the published deadlines.



**Table DR-1 Submission Information**

Submission	Refer to:	Required Format:	Submit in File Format:	Penalty Group
Structural Equivalency Spreadsheet (SES)	<b>T.2.4, Section T.2</b>	see below	XLSX	Tech
Impact Attenuator Data (IAD)	<b>T.2.24</b>	see below	PDF	Tech
ETC - Notice of Intent	<b>IC.4.3</b>	see below	PDF	ETC
ETC - Failure Modes and Effects Analysis (FMEA)	<b>IC.4.3</b>	see below	XLSX	ETC
EV – Electrical Systems Officer and Electrical Systems Advisor Form	<b>AD.5.2, AD.5.3</b>	see below	PDF	Tech
EV - Electrical System Form (ESF)	<b>EV.10.1</b>	see below	PDF	Tech
EV - Failure Modes and Effects Analysis (FMEA)	<b>EV.10.2</b>	see below	XLSX	Tech
Presentation	<b>S.2.4</b>	see <b>S.2.4</b>	see <b>S.2.4</b>	Present
Cost Report eBOM	<b>S.3.5</b>	see below see <b>S.3.5</b>	XLSX	Cost
Cost Report Supporting Documents	<b>S.3.6</b>	see <b>S.3.6</b>	PDF	Cost
Cost Addendum	<b>S.3.10</b>	see below	see <b>S.3.10</b>	none
Design Report	<b>S.4.3</b>	see <b>S.4.3</b>	PDF	Design
Design Spec Sheet	<b>S.4.4</b>	see below	XLSX	Design

Template files and forms are available on the FSAE Online Website see **AD.2.2.1**

**Table DR-2 Submission Penalty Information**

Penalty Group	Penalty Points per Day	Maximum Point Penalty	<b>Not Submitted</b> within 10 Days after the Deadline
Tech	-10	-50	Removal of Team Entry - see <b>DR.3.3</b>
ETC	Not Approved to use ETC - see <b>DR.3.4.1</b>		
Present	-10	-50	Removed from Presentation Event Score 0 points in Presentation Event
Cost	-10	-80	Removed from Cost Event Score -100 points in Cost Event
Design	-10	-100	Removed from Design Event Score 0 points in Design Event

## T - TECHNICAL REQUIREMENTS

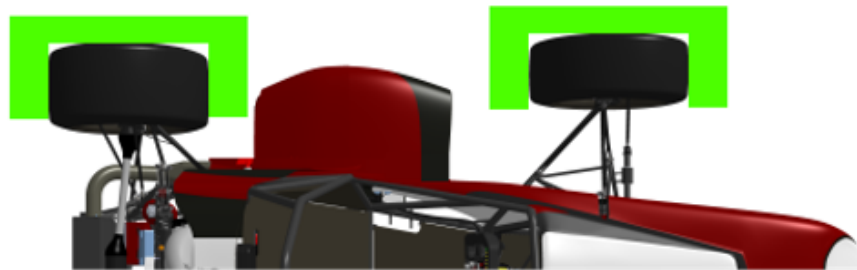
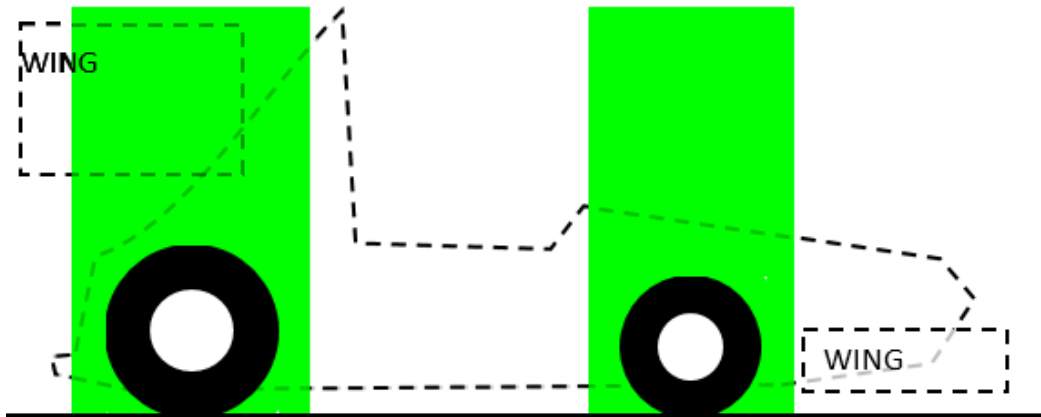
### T.1 GENERAL DESIGN

#### T.1.1 Vehicle Configuration

T.1.1.1 The vehicle must be open wheeled and open cockpit (a formula style body) with four wheels that are not in a straight line.

T.1.1.2 Open Wheel vehicles must satisfy all of the following criteria:

- a. The top 180° of the wheels/tires must be unobstructed when viewed from vertically above the wheel.
- b. The wheels/tires must be unobstructed when viewed from the side.
- c. No part of the vehicle may enter a keep out zone defined by two lines extending vertically from positions 75 mm in front of and 75 mm behind, the outer diameter of the front and rear tires in the side view elevation of the vehicle, with tires steered straight ahead. This keep out zone will extend laterally from the outside plane of the wheel/tire to the inboard plane of the wheel/tire.



#### T.1.2 Wheelbase

T.1.2.1 The vehicle must have a wheelbase of at least 1525 mm. The wheelbase is measured from the center of ground contact of the front and rear tires with the wheels pointed straight ahead.

#### T.1.3 Vehicle Track

T.1.3.1 The track and center of gravity must combine to provide adequate rollover stability. See [IN.9.2](#)

T.1.3.2 The smaller track of the vehicle (front or rear) must be no less than 75% of the larger track.

#### **T.1.4 Ground Clearance**

- T.1.4.1 Ground clearance must be sufficient to prevent any portion of the vehicle except the tires from touching the ground during dynamic events.
- T.1.4.2 Intentional or excessive ground contact of any portion of the vehicle other than the tires will forfeit a run or an entire dynamic event.

*The intent is that sliding skirts or other devices that by design, fabrication or as a consequence of moving, contact the track surface are prohibited and any unintended contact with the ground which either causes damage, or in the opinion of the Dynamic Event Officials could result in damage to the track, will result in forfeit of a run or an entire dynamic event*

#### **T.1.5 Suspension**

- T.1.5.1 The vehicle must be equipped with a fully operational suspension system with shock absorbers, front and rear, with usable wheel travel of at least 50 mm, with a driver seated.
- T.1.5.2 Officials may disqualify vehicles which do not represent a serious attempt at an operational suspension system or which demonstrate handling inappropriate for an autocross circuit.
- T.1.5.3 All suspension mounting points must be visible at Technical Inspection, either by direct view or by removing any covers.
- T.1.5.4 Fasteners in the Suspension system are **Critical Fasteners**, see **T.10.2** and **T.10.3**
- T.1.5.5 All spherical rod ends and spherical bearings on the suspension and steering must be EITHER :
  - Mounted in double shear
  - Captured by having a screw/bolt head or washer with an outside diameter that is larger than spherical bearing housing inside diameter.

#### **T.1.6 Steering**

- T.1.6.1 The steering wheel must be mechanically connected to the front wheels.
- T.1.6.2 Electrically actuated steering of the front wheels is prohibited.
- T.1.6.3 Steering systems using cables or belts for actuation are not permitted
- T.1.6.4 The steering system must have positive steering stops that prevent the steering linkages from locking up (the inversion of a four bar linkage at one of the pivots). The stops may be placed on the uprights or on the rack and must prevent the wheels and tires from contacting suspension, body, or frame members during the track events.
- T.1.6.5 Allowable steering system free play is limited to seven degrees (7°) total measured at the steering wheel.
- T.1.6.6 The steering wheel must be attached to the column with a quick disconnect. The driver must be able to operate the quick disconnect while in the normal driving position with gloves on.
- T.1.6.7 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. "H", "Figure 8", or cutout wheels are not allowed.
- T.1.6.8 In any angular position, the top of the steering wheel must be no higher than the top-most surface of the Front Hoop. See **T.2.13.4**
- T.1.6.9 The steering rack must be mechanically attached to the frame
- T.1.6.10 Joints between all components attaching the steering wheel to the steering rack must be mechanical and be visible at Technical Inspection. Bonded joints without a mechanical backup are not permitted.

- T.1.6.11 Fasteners in the steering system are **Critical Fasteners**, see **T.10.2** and **T.10.3**
- T.1.6.12 Spherical rod ends and spherical bearings in the steering must meet **T.1.5.5 above**
- T.1.6.13 Rear wheel steering may be used.
- Rear wheel steering must incorporate mechanical stops to limit the range of angular movement of the rear wheels to a maximum of six degrees (6°).
  - The team must provide the ability for the steering angle range to be verified at Technical Inspection with a driver in the vehicle.
  - Rear wheel steering may be electrically actuated.

### **T.1.7 Wheels**

- T.1.7.1 Wheels must be 203.2 mm (8.0 inches) or more in diameter.
- T.1.7.2 Any wheel mounting system that uses a single retaining nut must incorporate a device to retain the nut and the wheel in the event that the nut loosens.
- A second nut (jam nut) does not meet this requirement*
- T.1.7.3 Teams using modified lug bolts or custom designs must provide proof that good engineering practices have been followed in their design.
- T.1.7.4 If used, aluminum wheel nuts must be hard anodized and in pristine condition.

### **T.1.8 Tires**

Vehicles may have two types of tires:

- T.1.8.1 Dry Tires
- The tires on the vehicle when it is presented for Technical Inspection.
  - May be any size or type, slicks or treaded.
- T.1.8.2 Wet Tires
- Any size or type of treaded or grooved tire where:
- The tread pattern or grooves were molded in by the tire manufacturer, or were cut by the tire manufacturer or appointed agent. Any grooves that have been cut must have documented proof that it was done in accordance with this requirement.
  - There is a minimum tread depth of 2.4 mm
- T.1.8.3 Teams must not perform any hand cutting, grooving or modification of the tires.
- T.1.8.4 Tire warmers are not allowed.
- T.1.8.5 No traction enhancers may be applied to the tires at any time onsite at the competition.
- T.1.8.6 Within each tire set, the tire compound or size, or wheel type or size must not be changed.

### **T.1.9 Driver**

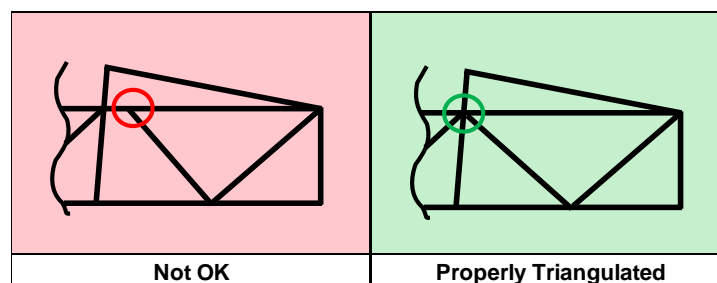
The vehicle must be able to accommodate drivers of sizes ranging from 5th percentile female up to 95th percentile male.

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

## T.2 CHASSIS

### T.2.1 Definitions

- T.2.1.1 Chassis - The fabricated structural assembly that supports all functional vehicle systems. This assembly may be a single fabricated structure, multiple fabricated structures or a combination of composite and welded structures.
- T.2.1.2 Frame Member - A minimum representative single piece of uncut, continuous tubing.
- T.2.1.3 Monocoque – A type of Chassis where loads are supported by the external panels
- T.2.1.4 Main Hoop - A roll bar located alongside or just behind the driver’s torso.
- T.2.1.5 Front Hoop - A roll bar located above the driver’s legs, in proximity to the steering wheel.
- T.2.1.6 Roll Hoops – Referring to both the Front Hoop AND the Main Hoop
- T.2.1.7 Roll Hoop Bracing Supports – The structure from the lower end of the Roll Hoop Bracing back to the Roll Hoop(s).
- T.2.1.8 Front Bulkhead – A planar structure that provides protection for the driver’s feet.
- T.2.1.9 Impact Attenuator – A deformable, energy absorbing device located forward of the Front Bulkhead.
- T.2.1.10 Side Impact Zone – The area of the side of the vehicle extending from the top of the floor to 350 mm above the ground and from the Front Hoop back to the Main Hoop.
- T.2.1.11 Primary Structure – The combination of the following components:
- Main Hoop
  - Front Hoop
  - Roll Hoop Braces and Supports
  - Side Impact Structure
  - Front Bulkhead
  - Front Bulkhead Support
  - Any Frame Members, guides, or supports that transfer load from the Driver Restraint System
- T.2.1.12 Primary Structure Envelope – A volume enclosed by multiple planes, each of which are tangent to the outermost surface of all the Primary Structure frame members.
- T.2.1.13 Major Structure– The portion of the Chassis that lies within the Primary Structure Envelope, excluding the Main Hoop Bracing and the portion of the Main Hoop above a horizontal plane located at the top of the upper side impact bar.
- T.2.1.14 Triangulation – An arrangement of frame members projected onto a plane, where a coplanar load applied in any direction, at any node, results in only tensile or compressive forces in the frame members. This is also what is meant by “properly triangulated”.



## T.2.2 General Chassis

- T.2.2.1 The driver's head and hands must not contact the ground in any rollover attitude.
- T.2.2.2 The driver's feet and legs must be completely contained within the Major Structure of the Chassis. While 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 the Major Structure of the Chassis.

## T.2.3 General Structural

- T.2.3.1 The Primary Structure must be constructed from one or a combination of the following:
- Baseline Tubing and Material
  - Alternate Steel Tubing
  - Alternative Tubing Materials
  - Composite Material
- T.2.3.2 Any chassis design that is a hybrid of the Frame, Monocoque, tubing and/or composite types must meet all relevant requirements. For example, a sandwich panel Side Impact Structure in a tube frame chassis

## T.2.4 Structural Documentation

- T.2.4.1 All teams must submit a Structural Equivalency Spreadsheet (SES) as described in section **DR - Document Requirements**.
- T.2.4.2 Any equivalency calculations must prove equivalency relative to Baseline Steel Material
- T.2.4.3 The properties of tubes and laminates may be combined to prove equivalence. For example, in a Side Impact Structure consisting of one tube as per **T.2.5** and a laminate panel, the panel only needs to be equivalent to two side impact tubes.
- T.2.4.4 Any holes drilled in any regulated tubing (other than inspection holes) must be addressed on the SES.
- T.2.4.5 Vehicles completed under an approved SES must be fabricated in accordance with the materials and processes described in the SES.

## T.2.5 Baseline Tubing and Material

### T.2.5.1 Minimum Dimensions – Steel Tubing

Application	Outside Diameter and Wall Thickness Options
Main Hoop, Front Hoop, Shoulder Harness Mounting Bar	Round 1.0 inch x 0.095 inch, Round 25.0 mm x 2.50 mm
Side Impact Structure, Front Bulkhead, Roll Hoop Bracing, Driver Restraint Harness Attachment (other than Shoulder Harness Mounting Bar), (EV) Accumulator Protection Structure	Round 1.0 inch x 0.065 inch, Round 25.0 mm x 1.75 mm, Square 1.0 inch x 1.0 inch x 0.047 inch, Square 25.0 mm x 25.0 mm x 1.20 mm
Front Bulkhead Support, Main Hoop Bracing Supports, Shoulder Harness Mounting Bar Bracing, (EV) Tractive System Component Protection	Round 1.0 inch x 0.047 inch, Round 25.0 mm x 1.5 mm
Bent Upper Side Impact Member	Round 1.375 inch x 0.047 inch Round 35.0 mm x 1.2 mm

T.2.5.2 Tubing that differs from the above minimum dimensions may be used without additional approval when:

- Tubing of the specified outside diameter but with greater wall thickness
- Tubing of the specified wall thickness and a greater outside diameter
- Replacing round tubing with square tubing of the same or larger outside diameter and wall thickness

T.2.5.3 Properties for ANY steel material for calculations submitted in an SES must be:

a. Non Welded Properties for continuous material calculations:

Young's Modulus (E) = 200 GPa (29.0 ksi)

Yield Strength (Sy) = 305 MPa (44.2 ksi)

Ultimate Strength (Su) = 365 MPa (52.9 ksi)

b. Welded Properties for discontinuous material such as joint calculations:

Yield Strength (Sy) = 180 MPa (26 ksi)

Ultimate Strength (Su) = 300 MPa (43.5 ksi)

T.2.5.4 Any tubing with Outside Diameter less than 25.0 mm or wall thickness less than 1.2 mm (0.047 inch) is not considered structural and will be ignored when assessing compliance to any rule

T.2.5.5 Where welded tubing reinforcements are required (such as inserts for bolt holes or material to support suspension cutouts), the tubing must retain the Non Welded Properties while using the Welded Properties for the additional reinforcement material.

## T.2.6 Alternate Steel Tubing

T.2.6.1 Alternate Steel Tubing geometry may be used.

T.2.6.2 If Alternate Steel Tubing geometry is used, the SES must include calculations demonstrating equivalent to or better than the minimum requirements found in **T.2.5** for yield and ultimate strengths in bending, buckling and tension, for buckling modulus and for energy dissipation.

*The Buckling Modulus is defined as  $EI$ , where,  $E$  = modulus of Elasticity, and  $I$  = area moment of inertia about the weakest axis.*

T.2.6.3 Minimum Wall Thickness - Steel Tubing

Application	Minimum Wall Thickness
Main Hoop, Front Hoop, Shoulder Harness Mounting Bar	2.0 mm (0.079 inch)
Roll Hoop Bracing, Main Hoop Bracing Supports, Side Impact Structure, Front Bulkhead, Front Bulkhead Support, Driver Restraint Harness Attachment (other than Shoulder Harness Mounting Bar), Shoulder Harness Mounting Bar Bracing, (EV) Accumulator Protection Structure, (EV) Tractive System Component Protection	1.2 mm (0.047 inch)

*To maintain  $EI$  with a thinner wall thickness, the outside diameter MUST be increased.*

*To maintain the equivalent yield and ultimate tensile strength the same cross sectional area of steel as the Baseline Tubing MUST be maintained.*

T.2.6.4 Properties for ANY steel material for calculations submitted in an SES must be per **T.2.5.3 above**

T.2.6.5 Any tubing with wall thickness less than 1.2 mm (0.047 inch) is not considered structural and will be ignored when assessing compliance to any rule

### **T.2.7 Alternative Tubing Materials**

T.2.7.1 Alternative Materials may be used for areas other than the Main Hoop and Main Hoop Bracing.

T.2.7.2 If any Alternative Materials are used, the SES must include calculations demonstrating equivalent to or better than the minimum requirements found in **T.2.5** for yield and ultimate strengths in bending, buckling and tension, for buckling modulus and for energy dissipation.

*The Buckling Modulus is defined as  $EI$ , where,  $E$  = modulus of Elasticity, and  $I$  = area moment of inertia about the weakest axis.*

T.2.7.3 Aluminum Tubing

- a. Minimum Wall Thickness: Aluminum Tubing 3.0 mm (0.118 inch)
- b. The equivalent yield strength must be considered in the “as welded” condition, (Reference: WELDING ALUMINUM (latest Edition) by the Aluminum Association, or THE WELDING HANDBOOK, Volume 4, 7th Ed., by The American Welding Society), unless the team provides detailed proof that the frame has been properly solution heat treated and artificially aged.
- c. If aluminum tubing was solution heat treated and age hardened to increase its strength after welding, the team must supply evidence as to how the process was performed. This includes, but is not limited to, the heat treating facility used, the process applied, and the fixturing used.

T.2.7.4 Titanium and Magnesium Tubing

- a. Minimum Wall Thickness: Titanium Tubing 1.2 mm
- b. Minimum Wall Thickness: Magnesium Tubing 3.0 mm
- c. Titanium or magnesium on which any welding has been utilized must not be used for any part of the Primary Structure.

### **T.2.8 Bent Tubes or Multiple Tubes**

T.2.8.1 The minimum radius of any bend, measured at the tube centerline, must be at least three times the tube outside diameter (3 x OD).

T.2.8.2 Bends must be smooth and continuous with no evidence of crimping or wall failure.

T.2.8.3 If a bent tube (or member consisting of multiple tubes that are not in a line) is used anywhere in the Primary Structure other than the Roll Hoops, an additional tube must be attached to support it.

- a. The attachment point must be the position along the tube where it deviates farthest from a straight line connecting both ends.
- b. The support tube must have the same diameter and thickness as the bent tube, terminate at a node of the chassis, and be angled no more than 30° from the plane of the bent tube.
- c. Braces for a bent Upper Side Impact Member are not required to meet the 30° from the plane of the bent tube requirement.



## T.2.9 Composite Materials

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

- Present documentation of material type, (purchase receipt, shipping document or letter of donation) and the material properties.
- Submit details of the composite layup technique as well as the structural material used (cloth type, weight, and resin type, number of layers, core material, and skin material if metal).
- Submit calculations demonstrating equivalence of their composite structure to one of similar geometry made to the minimum requirements found in **T.2.5**. Equivalency calculations must be submitted for energy dissipation, yield and ultimate strengths in bending, buckling, and tension.

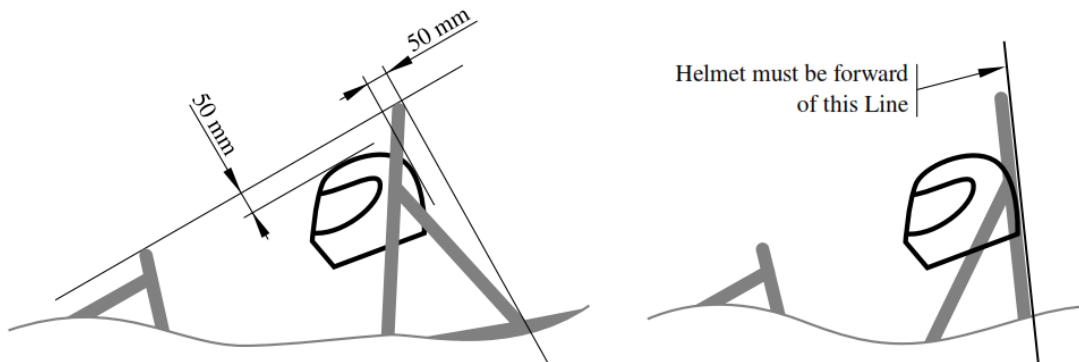
## T.2.10 Roll Hoops

T.2.10.1 The Frame must include both a Main Hoop and a Front Hoop.

T.2.10.2 The Main Hoop and Front Hoop must be securely integrated into the Primary Structure using proper Triangulation.

T.2.10.3 When seated normally and restrained by the Driver Restraint System, the helmet of a 95th percentile male (anthropometrical data) and all of the team's drivers must:

- Be a minimum of 50 mm 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 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.



## T.2.10.4 Driver Template

A two dimensional template used to represent the 95th percentile male is made to the following dimensions (see figure in next step):

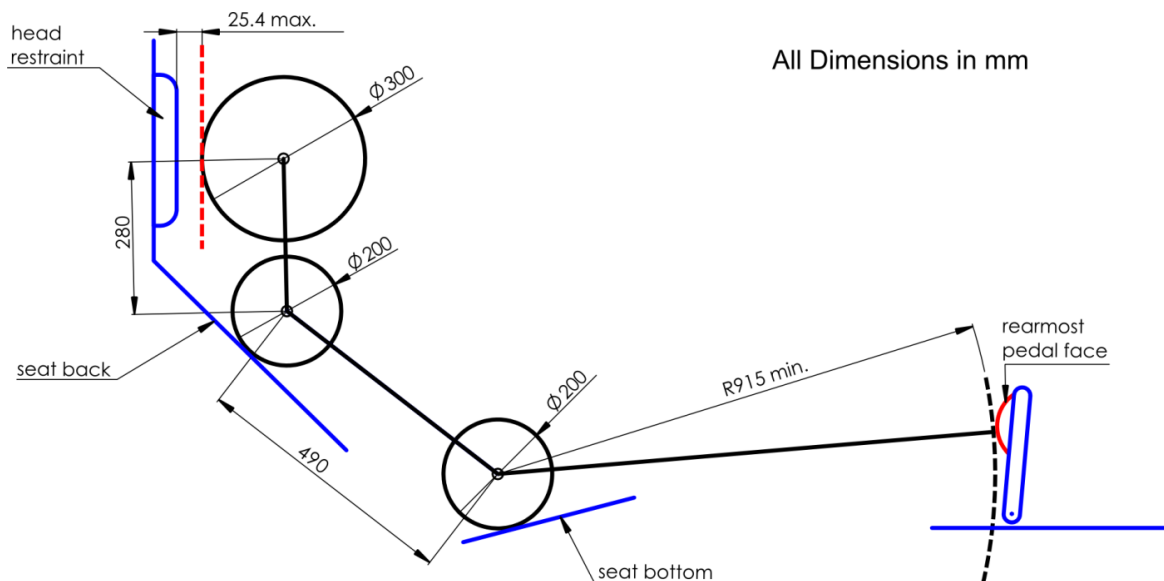
- A circle of diameter 200 mm will represent the hips and buttocks.
- A circle of diameter 200 mm will represent the shoulder/cervical region.
- A circle of diameter 300 mm will represent the head (with helmet).
- A straight line measuring 490 mm will connect the centers of the two 200 mm circles.
-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

### T.2.10.5 Driver Template Position

The Driver Template will be positioned as follows:

- The seat will be adjusted to the rearmost position
- The pedals will be placed in the most forward position
- The bottom 200 mm circle will be placed on the seat bottom such that the distance between the center of this circle and the rearmost face of the pedals is no less than 915 mm
- The middle 200 mm circle, representing the shoulders, will be positioned on the seat back
- The upper 300 mm circle will be positioned no more than 25 mm away from the head restraint

**Figure - Driver Template and Position**



### T.2.11 Main Hoop

T.2.11.1 The Main Hoop must be constructed of a single piece of uncut, continuous, closed section steel tubing per **T.2.5 Baseline Tubing** OR **T.2.6 Alternate Steel Tubing**

T.2.11.2 The Main Hoop must extend from the lowest Frame Member on one side of the Frame, up, over and down the lowest Frame Member on the other side of the Frame.

T.2.11.3 In the side view of the vehicle,

- The portion of the Main Hoop that lies above its attachment point to the upper Side Impact Tube must be within 10° of the vertical.
- Any bends in the Main Hoop above its attachment point to the Major Structure of the Frame must be braced to a node of the Main Hoop Bracing Support structure with tubing meeting the requirements of Roll Hoop Bracing per **T.2.5 Baseline Tubing** OR **T.2.6 Alternate Steel Tubing**
- The portion of the Main Hoop that lies below the upper side impact member attachment point may be inclined at any angle to the vertical in the forward direction but, it must be inclined rearward no more than 10° of the vertical.

T.2.11.4 In the front view of the vehicle, the vertical members of the Main Hoop must be at least 380 mm apart (inside dimension) at the location where the Main Hoop is attached to the bottom tubes of the Major Structure of the Frame.

### T.2.12 Front Hoop

T.2.12.1 The Front Hoop must be constructed of closed section metal tubing per **T.2.5 Baseline Tubing** OR **T.2.6 Alternate Steel Tubing** OR **T.2.7 Alternative Tubing Materials**

T.2.12.2 The Front Hoop must extend from the lowest Frame Member on one side of the Frame, up, over and down to the lowest Frame Member on the other side of the Frame.

T.2.12.3 With proper triangulation, the Front Hoop may be fabricated from more than one piece of tubing.

T.2.12.4 The top-most surface of the Front Hoop must be no lower than the top of the steering wheel in any angular position. See figure in **T.2.13.4 below**

T.2.12.5 The Front Hoop must be no more than 250 mm forward of the steering wheel.

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 rim with the steering in the straight ahead position.

T.2.12.6 In side view, the Front Hoop or any part of it must be inclined no more than 20° from the vertical.

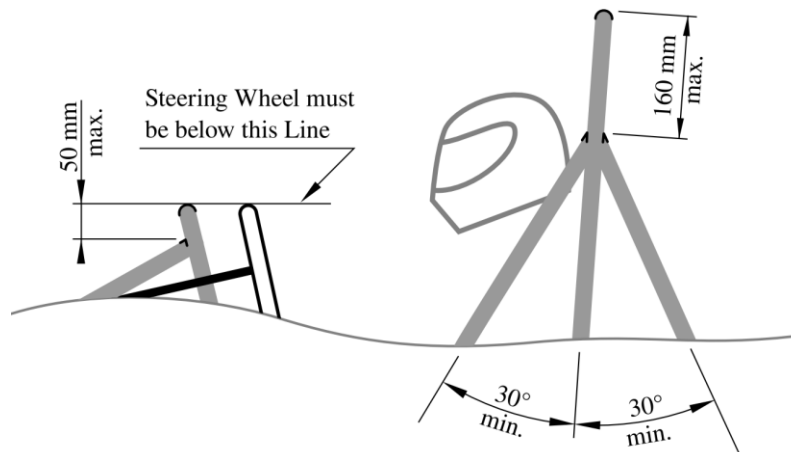
### T.2.13 Main Hoop Bracing

T.2.13.1 Main Hoop braces must be constructed of closed section steel tubing per **T.2.5 Baseline Tubing** OR **T.2.6 Alternate Steel Tubing**

T.2.13.2 The Main Hoop must be supported by two braces extending in the forward or rearward direction, one on each of the left and right sides of the Main Hoop.

T.2.13.3 In the side view of the Frame, the Main Hoop and the Main Hoop braces must not lie on the same side of the vertical line through the top of the Main Hoop. (If the Main Hoop leans forward, the braces must be forward of the Main Hoop, and if the Main Hoop leans rearward, the braces must be rearward of the Main Hoop)

T.2.13.4 The Main Hoop braces must be attached as near as possible to the top of the Main Hoop but not more than 160 mm 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°.



T.2.13.5 The Main Hoop braces must be straight, without any bends.

- T.2.13.6 The Main Hoop Braces must be securely integrated into the Frame and be capable of transmitting all loads from the Main Hoop into the Major Structure of the Frame without failing.
- T.2.13.7 The lower end of the Main Hoop Braces must be supported back to the Main Hoop by a minimum of two Frame Members on each side of the vehicle: an upper member and a lower member in a properly Triangulated configuration.
  - a. The upper support member must attach to the node where the upper Side Impact Member attaches to the Main Hoop.
  - b. The lower support member must attach to the node where the lower Side Impact Member attaches to the Main Hoop.
  - c. Each of the above members may be multiple or bent tubes provided the requirements of **T.2.8** are met.
  - d. Examples of acceptable configurations of members may be found on the FSAE Online Website.
- T.2.13.8 All the Frame Members of the Main Hoop Bracing Support system listed above must be constructed of closed section tubing per **T.2.5 Baseline Tubing** OR **T.2.6 Alternate Steel Tubing**
- T.2.13.9 If any item which is outside the envelope of the Primary Structure is attached to the Main Hoop braces, then additional bracing must be added to prevent bending loads in the braces in any rollover attitude

#### **T.2.14 Front Hoop Bracing**

- T.2.14.1 Front Hoop braces must be constructed of material per **T.2.5 Baseline Tubing** OR **T.2.6 Alternate Steel Tubing** OR **T.2.7 Alternative Tubing Materials**
- T.2.14.2 The Front Hoop must be supported by two braces extending in the forward direction, one on each of the left and right sides of the Front Hoop.
- T.2.14.3 The Front Hoop braces must be constructed such that they protect the driver's legs and should extend to the structure in front of the driver's feet.
- T.2.14.4 The Front Hoop braces must be attached as near as possible to the top of the Front Hoop but not more than 50 mm below the top-most surface of the Front Hoop. See Figure in **T.2.13.4**
- T.2.14.5 If the Front Hoop leans rearwards by more than 10° from the vertical, it must be supported by additional Front Hoop braces to the rear.
- T.2.14.6 The Front Hoop braces must be straight, without any bends

#### **T.2.15 Other Bracing Requirements**

- T.2.15.1 Where the braces are not welded to steel Frame Members, the braces must be securely attached to the Frame using 8 mm or 5/16" minimum diameter **Critical Fasteners**, see **T.10.2** and **T.10.3**.
- T.2.15.2 Mounting plates welded to the Roll Hoop braces must be 2.0 mm (0.080 in) minimum thickness steel.

#### **T.2.16 Other Side Tube Requirements**

- T.2.16.1 If there is a Roll Hoop brace or other frame tube alongside the driver, at the height of the neck of any of the team's drivers, a metal tube or piece of sheet metal must be firmly attached to the Frame to prevent the drivers' shoulders from passing under the roll hoop brace or frame tube, and his/her neck contacting this brace or tube.

**T.2.17 Fasteners in Primary Structure**

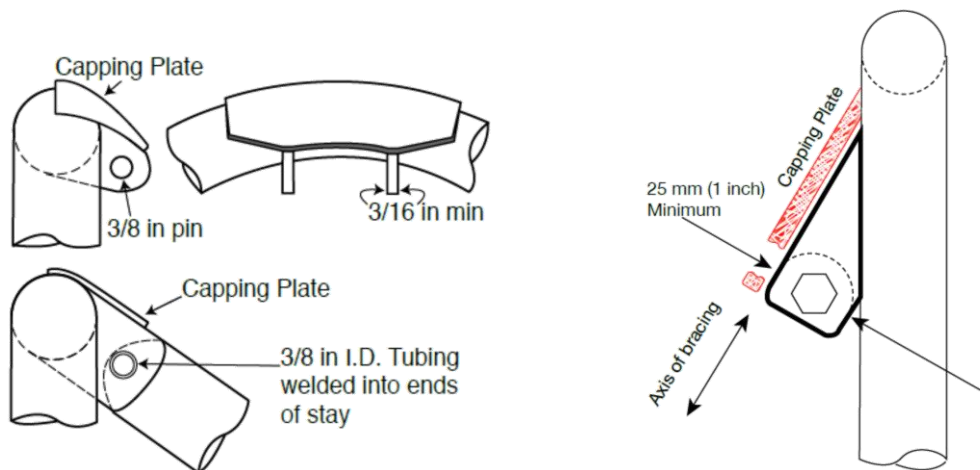
- T.2.17.1 Bonded and blind nuts and bolts are prohibited in the Primary Structure. These must use a removable bolt and nut.
- T.2.17.2 Threaded fasteners used in Primary Structure are **Critical Fasteners**, see **T.10.2** and **T.10.3**
- T.2.17.3 Any bolted joint in the Primary Structure using either tabs or brackets (other than tabs attaching suspension to the primary structure), must have an edge distance ratio “e/D” of 1.5 or greater.

*“D” equals the hole diameter. “e” equals the distance from the edge of the hole to the nearest free edge.*

**T.2.18 Mechanically Attached Roll Hoop Bracing**

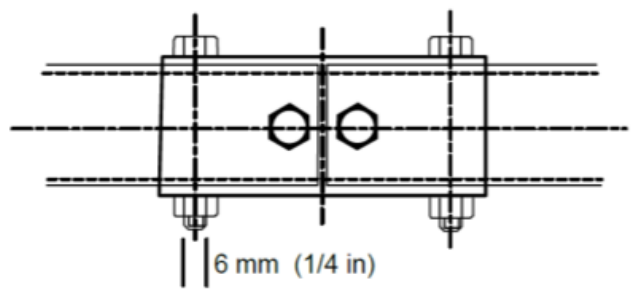
- T.2.18.1 Roll Hoop bracing may be mechanically attached.
  - a. The threaded fasteners used to secure non permanent joints are **Critical Fasteners**, see **T.10.2** and **T.10.3**. Additional requirements apply in **T.2.18.5** and **T.2.18.7 below**
  - b. No spherical rod ends are allowed.
  - c. The attachment holes in the lugs, the attached bracing and the sleeves and tubes must be a close fit with the pin or bolt.
- T.2.18.2 Any non permanent joint at either end must be either a double lug joint or a sleeved butt joint

**Figure – Double Lug Joint**



- T.2.18.3 For double lug joints, each lug must:
  - a. Be at least 4.5 mm (0.177 in) minimum thickness steel
  - b. Measure 25 mm minimum perpendicular to the axis of the bracing
  - c. Be as short as practical along the axis of the bracing.
- T.2.18.4 All double lug joints, whether fitted at the top or bottom of the tube, must include a capping arrangement
- T.2.18.5 In a double lug joint the pin or bolt must be **10 mm Metric Grade 9.8 or 3/8 in. SAE Grade 8** minimum diameter and grade. See **T.2.18.1 above**

**Figure – Sleeved Butt Joint**



T.2.18.6 For sleeved butt joints, the sleeve must:

- a. Have a minimum length of 75 mm; 37.5 mm either side of the joint
- b. Be a close fit around the base tubes.
- c. Have a wall thickness at least that of the base tubes.

T.2.18.7 In a sleeved butt joint, the bolts must be **6 mm Metric Grade 9.8** or **1/4 inch SAE Grade 8** minimum diameter and grade. See **T.2.18.1** above

#### **T.2.19 Front Bulkhead**

T.2.19.1 The Front Bulkhead must be constructed of closed section tubing per **T.2.5** OR **T.2.6** OR **T.2.7**

#### **T.2.20 Front Bulkhead Support**

T.2.20.1 The Front Bulkhead must be securely integrated into the Frame.

T.2.20.2 The Front Bulkhead must be supported back to the Front Hoop by a minimum of three Frame Members on each side of the vehicle; an upper member; lower member and diagonal brace to provide triangulation.

- a. The upper support member must be attached within 50 mm of the top surface of the Front Bulkhead, and attach to the Front Hoop within a zone extending 100 mm above and 50 mm below the Upper Side Impact member.
- b. If the upper support member is further than 100 mm above the Upper Side Impact member, then properly triangulated bracing is required to transfer load to the Main Hoop, either via the Upper Side Impact member, or an additional member transmitting load from the junction of the Upper Support Member with the Front Hoop.
- c. The lower support member must be attached to the base of the Front Bulkhead and the base of the Front Hoop.
- d. The diagonal brace must properly triangulate the upper and lower support members

T.2.20.3 Each of the above members may be multiple or bent tubes provided the requirements of **T.2.8** are met.

T.2.20.4 All the Frame Members of the Front Bulkhead Support system must be constructed of closed section tubing per **T.2.5** OR **T.2.6** OR **T.2.7**

T.2.20.5 Examples of acceptable configurations of members may be found on the FSAE Online Website

#### **T.2.21 Front Chassis Protection**

T.2.21.1 Forward of the Front Bulkhead there must be an Impact Attenuator and an Anti Intrusion Plate, with the Anti Intrusion Plate between the Impact Attenuator and the Front Bulkhead.

T.2.21.2 All methods of attachment of the Impact Attenuator to the Anti Intrusion Plate, and of the Anti Intrusion Plate to the Front Bulkhead must provide adequate load paths for transverse and vertical loads in the event of off-axis impacts.

### T.2.22 Anti Intrusion Plate (AIP)

T.2.22.1 The Anti Intrusion Plate must be one of the following:

- 1.5 mm (0.060 in) minimum thickness solid steel
- 4.0 mm (0.157 in) minimum thickness solid aluminum plate
- an approved alternative as per **T.2.39**

T.2.22.2 The outside profile requirement of the Anti Intrusion Plate depends on the method of attachment to the Front Bulkhead:

- a. For welded joints the profile must extend at least to the centerline of the Front Bulkhead tubes on all sides.
- b. For bolted joints the profile must match the outside dimensions of the Front Bulkhead around the entire periphery.

T.2.22.3 For tube frame Front Bulkheads, the attachment of the Anti Intrusion Plate directly to the Front Bulkhead must be documented in the team's SES submission. The accepted methods of attachment are:

- a. Welding, where the welds are either continuous or interrupted. If interrupted, the weld/space ratio must be at least 1:1. All weld lengths must be greater than 25 mm.
- b. Bolted joints, using no less than eight 8 mm or 5/16" minimum diameter **Critical Fasteners**, see **T.10.2** and **T.10.3**. The distance between any two bolt centers must be at least 50 mm.

T.2.22.4 For Monocoque Front Bulkheads, the attachment of the Anti Intrusion Plate directly to the Monocoque structure must be documented in the SES submission. This must prove the attachment method is equivalent to the bolted joints described in **T.2.22.3.b** and that these bolted joints will fail before any other part of the Monocoque.

### T.2.23 Impact Attenuator (IA)

T.2.23.1 Teams may either:

- Use the approved Standard Impact Attenuator from the FSAE Online Website
- Build and test an Impact Attenuator of their own design

T.2.23.2 The Impact Attenuator must meet the following:

- a. At least 200 mm long, with its length oriented along the fore/aft axis of the Frame.
- b. At least 100 mm high and 200 mm wide for a minimum distance of 200 mm forward of the Front Bulkhead.
- c. Attached securely to the Anti Intrusion Plate or directly to the Front Bulkhead.
- d. Segmented foam attenuators must have all segments bonded together to prevent sliding or parallelogramming.

T.2.23.3 The attachment of the Impact Attenuator to the Anti Intrusion Plate must be documented in the IAD submission. The accepted methods of attachment are:

- a. Welding, where the welds are either continuous or interrupted. If interrupted, the weld/space ratio must be at least 1:1. All weld lengths must be greater than 25 mm.

- b. Bolted joints, using no less than four 8 mm or 5/16" minimum diameter **Critical Fasteners**, see **T.10.2** and **T.10.3**, where the distance between any two bolt centers must be at least 50 mm. Foam IA's must not be solely attached by the bolted method.
- c. By the use of a structural adhesive. The adhesive must be appropriate for use with both substrate types. The appropriate adhesive choice, substrate preparation, and the equivalency of this bonded joint to the bolted joint in **T.2.23.3b above** must be documented in the team's IAD report.

T.2.23.4 If a team uses the Standard Impact Attenuator, and the outside profile of the Anti Intrusion Plate extends beyond the Standard Impact Attenuator by more than 25 mm on any side, then one of the following must be met:

- a. The Front Bulkhead must include a diagonal or X-brace meeting the requirements for a Front Bulkhead Support tube per **T.2.5**, or an approved equivalent per **T.2.6 OR T.2.7**, must be included in the Front Bulkhead.
- b. Physical testing must be performed to prove that the Anti Intrusion Plate does not permanently deflect more than 25 mm.

## **T.2.24 Non Crushable Objects**

### T.2.24.1 Inside Primary Structure

All non crushable objects (such as batteries, master cylinders, hydraulic reservoirs) inside the Primary Structure must have a minimum 25 mm clearance to the rear face of the Anti Intrusion Plate.

### T.2.24.2 Outside Primary Structure

All non crushable objects outside the Primary Structure must be addressed by either of the following:

- a. Objects must be mounted rearwards of an imaginary transverse vertical plane, offset forwards from the Impact Attenuator Anti Intrusion Plate by a distance equal to the height of the crushed Impact Attenuator.
- b. Prove the combination of the Impact Attenuator Assembly and non crushable object(s) does not exceed the peak deceleration specified in **T.2.25.2**

Any of the following methods may be used to prove the design does not exceed 120 kN:

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

## **T.2.25 Impact Attenuator Data (IAD)**

T.2.25.1 All teams must submit an Impact Attenuator Data (IAD) report as described in section **DR - Document Requirements**.



#### T.2.25.2 Impact Attenuator Functional Requirements

*These are not test requirements*

- a. Decelerates the vehicle at a rate not exceeding 20 g average and 40 g peak
- b. Energy absorbed must meet or exceed 7350 J

When:

- Total mass of Vehicle is 300 kg
- Impact velocity is 7.0 m/s

#### T.2.25.3 When using the standard Impact Attenuator, the IAD Report must meet the following:

- a. Test data will not be submitted
- b. All other requirements of this section must be included.
- c. Photos of the actual attenuator must be included
- d. Evidence that the Standard IA meets the design criteria provided in the Standard Impact Attenuator specification must be appended to the report. This may be a receipt or packing slip from the supplier.

#### T.2.25.4 The Impact Attenuator Data Report when NOT using the Standard Impact Attenuator must include:

- a. Test data that proves that the Impact Attenuator Assembly meets the functional requirements
- b. Calculations showing how the reported absorbed energy and decelerations have been derived.
- c. A schematic of the test method.
- d. Photos of the attenuator, annotated with the height of the attenuator before and after testing.

#### T.2.25.5 Impact Attenuator Test Setup

- a. During any test, the Impact Attenuator must be attached to the Anti Intrusion Plate using the intended vehicle attachment method.
- b. The Impact Attenuator Assembly must be attached to a structurally representative section of the intended chassis.  
  
The test fixture must have equivalent strength and stiffness to a baseline front bulkhead. A solid block of material in the shape of the front bulkhead is not “structurally representative”.
- c. There must be at least 50 mm clearance rearwards of the Anti Intrusion Plate to the test fixture.
- d. No part of the Anti Intrusion Plate may permanently deflect more than 25 mm beyond the position of the Anti Intrusion Plate before the test.

*The 25 mm spacing represents the front bulkhead support and insures that the plate does not intrude excessively into the cockpit.*

#### T.2.25.6 Test Conduct

- a. Dynamic testing (sled, pendulum, drop tower, etc.) of the Impact Attenuator must be conducted at a dedicated test facility. This facility may be part of the University, but must

be supervised by professional staff or the University faculty. Teams must not construct their own dynamic test apparatus.

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

#### T.2.25.7 Test Analysis

- a. When using acceleration data from the dynamic test, the average deceleration must be calculated based on the raw unfiltered data.
- b. If peaks above the 40 g limit are present in the data, a Channel Filter Class (CFC) 60 (100Hz) filter per SAE Recommended Practice J211 "Instrumental for Impact Test", or a 100 Hz, 3rd order, low pass Butterworth (-3dB at 100 Hz) filter may be applied.

T.2.25.8 Teams using Impact Attenuators (typically structural noses) directly attached to the Front Bulkhead, which shortcut the load path through the bulk of the Anti Intrusion Plate, must conduct an additional test.

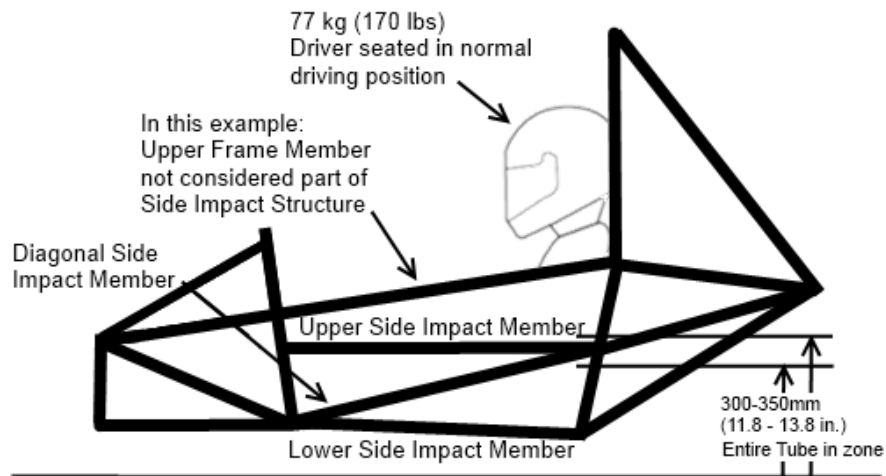
This test must prove that the Anti Intrusion Plate can withstand a load of 120 kN (300 kg multiplied by 40 g), where the load applicator matches the minimum Impact Attenuator dimensions.

### T.2.26 Side Impact Structure for Tube Frame Designs

T.2.26.1 The Side Impact Structure must be comprised of at least three tubular members located on each side of the driver while seated in the normal driving position

T.2.26.2 The required tubular members must be constructed of material per **T.2.5** OR **T.2.6** OR **T.2.7**

T.2.26.3 With proper Triangulation, Side Impact Structure members may be fabricated from more than one piece of tubing.



T.2.26.4 The Upper Side Impact Structure member must:

- a. Connect the Main Hoop and the Front Hoop.
- b. Be located so that all of the member must be at a height between 300 mm and 350 mm above the ground with a 77 kg driver seated in the normal driving position.

*The upper frame rail may be used as this member if it meets the height, diameter and thickness requirements.*

T.2.26.5 The Lower Side Impact Structure member must connect the bottom of the Main Hoop and the bottom of the Front Hoop.

*The lower frame rail/frame member may be this member if it meets the diameter and wall thickness requirements.*

T.2.26.6 The Diagonal Side Impact Member must:

- a. Connect the Upper Side Impact Member and Lower Side Impact Member forward of the Main Hoop and rearward of the Front Hoop
- b. Completely triangulate the bays created by the Upper and Lower Side Impact Members.

### **T.2.27 Inspection Holes**

T.2.27.1 Technical Inspectors may check the compliance of all tubes. This may be done by the use of ultrasonic testing or by the drilling of inspection holes on request.

### **T.2.28 Monocoque General Requirements**

T.2.28.1 All sections of the rules apply to monocoque structures except for the following sections which supplement or supersede other rule sections.

T.2.28.2 Composite and metallic monocoques have the same requirements.

T.2.28.3 The Structural Equivalency Spreadsheet must demonstrate that the design is equivalent to a welded frame in terms of energy dissipation, yield and ultimate strengths in bending, buckling and tension.

T.2.28.4 All equivalency calculations must prove equivalency relative to **T.2.5 Baseline Tubing**

T.2.28.5 The Structural Equivalency Spreadsheet must address each of the items in the following subsections.

### **T.2.29 Composite Monocoques**

T.2.29.1 Composite monocoques must meet the materials requirements in **T.2.9 Composite Materials**

T.2.29.2 Data from the laminate testing results must be used as the basis for any strength or stiffness calculations.

T.2.29.3 The SES for composite monocoques must include:

- a. Material type(s), cloth weights, resin type, fiber orientation, number of layers, core material, and layup technique.
- b. The 3 point bend test and shear test data and pictures must also be included as per **T.2.31 Monocoque Laminate Testing**

T.2.29.4 Quasi-isotropic layups are defined as having no more than two plies biased from an equal distribution in either the +/-45 or 0/90 directions per laminate skin

### **T.2.30 Monocoque Buckling Modulus – Equivalent Flat Panel Calculation**

T.2.30.1 When specified, the EI of the monocoque must be calculated as the EI of a flat panel with the same composition as the monocoque about the neutral axis of the laminate.

T.2.30.2 The curvature of the panel and geometric cross section of the monocoque must be ignored for these calculations.

T.2.30.3 Calculations of EI that do not reference this section **T.2.30** may take into account the actual geometry of the monocoque.

## T.2.31 Monocoque Laminate Testing

### T.2.31.1 Primary Structure Laminates

Teams must build representative test panels for each ply schedule used in the regulated regions of the monocoque as a flat panel and perform a 3 point bending test on these panels.

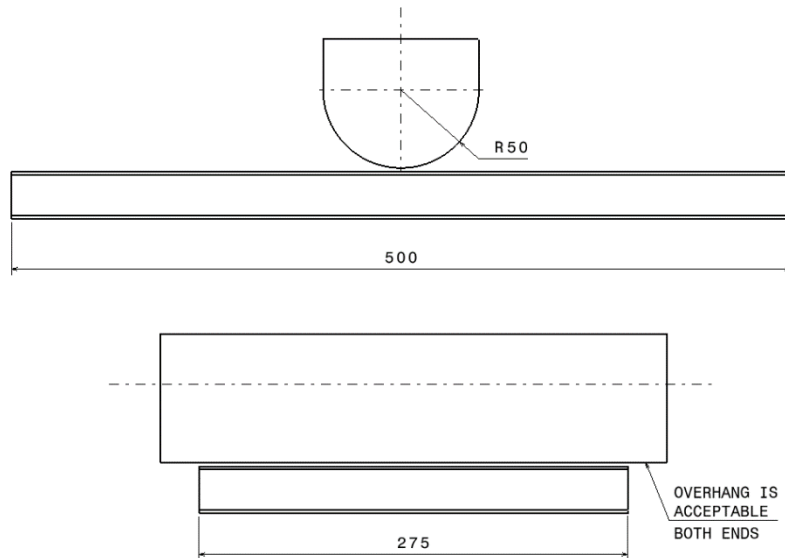
- a. Test panels must:
  - Measure 275 mm x 500 mm
  - Be supported by a span distance of 400 mm
  - Have equal surface area for the top and bottom skin.
  - Have bare edges, without skin material.
- b. The SES must include:
  - Data from the 3 point bending tests
  - Pictures of the test samples
  - A picture of the test sample and test setup showing a measurement documenting the supported span distance used in the SES.
- c. Test panel results must be used to derive stiffness, yield strength, ultimate strength and absorbed energy properties by the SES formula for the purpose of calculating laminate panels equivalency corresponding to Primary Structure regions of the chassis.
- d. Test panel results for the Side Impact Laminate must show by calculation, using the embedded SES formula, equivalence to two (2) Side Impact tubes (**T.2.5**) tested per **T.2.31.2 below**, for buckling modulus, ultimate strength and absorbed energy.

### T.2.31.2 Comparison Test

- a. Teams must make an equivalent test with two Side Impact Baseline Steel tubes (**T.2.5**) such that any compliance in the test rig can be accounted for and to establish an absorbed energy value of the baseline tubes.
- b. Baseline tubes must be tested to a minimum displacement of 19.0 mm
- c. The calculation of absorbed energy will use the integral of force times displacement from the initiation of load to a displacement of 19.0 mm.

### T.2.31.3 Test Conduct

- a. The load applicator used to test any panel/tubes as required within this section **T.2.31** must be metallic and have a radius of 50 mm.
- b. The load applicator must overhang the test piece to prevent edge loading.
- c. Any other material must not be placed between the load applicator and the items on test.



#### T.2.31.4 Perimeter Shear Test

- a. The Perimeter Shear Test must be completed by measuring the force required to push or pull a 25 mm diameter flat punch through a flat laminate sample.
- b. The sample must:
  - Measure at least 100 mm x 100 mm
  - Have core and skin thicknesses identical to those used in the actual monocoque
  - Be manufactured using the same materials and processes
- c. The fixture must support the entire sample, except for a 32 mm hole aligned coaxially with the punch.
- d. The sample must not be clamped to the fixture.
- e. The edge of the punch and hole in the fixture may include an optional fillet up to a maximum radius of 1 mm.
- f. The force and displacement data and photos of the test setup must be included in the SES.
- g. The first peak in the load-deflection curve must be used to determine the skin shear strength; this may be less than the minimum force required by **T.2.33.3 / T.2.34.5**
- h. The maximum force recorded must meet the requirements of **T.2.33.3 / T.2.34.5**

#### T.2.31.5 Additional Testing

- a. Laminate schedules that deviate from a quasi-isotropic layup must be tested in each orthogonal direction. Two bending and shear test samples are required for each unique layup.
- b. All material properties in the weaker test direction must be at least 50% of those in the stronger test direction.

### T.2.32 Monocoque Front Bulkhead

- T.2.32.1 When modeled as an “L” shaped section the EI of the front bulkhead about both vertical and lateral axis must be equivalent to that of the tubes specified for the Front Bulkhead per **T.2.19**

- T.2.32.2 The length of the section perpendicular to the Front Bulkhead may be a maximum of 25 mm measured from the rearmost face of the Front Bulkhead.
- T.2.32.3 Any Front Bulkhead which supports the IA plate must have a perimeter shear strength equivalent to a 1.5 mm thick steel plate.

### T.2.33 Monocoque Front Bulkhead Support

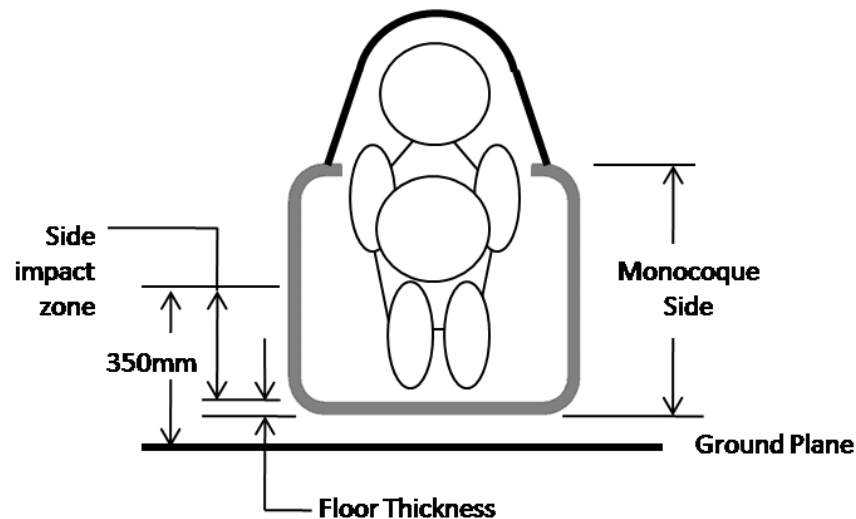
- T.2.33.1 In addition to proving that the strength of the monocoque is adequate, the monocoque must have equivalent EI to the sum of the EI of the six baseline steel tubes that it replaces.
- T.2.33.2 The EI of the vertical side of the Front Bulkhead support structure must be equivalent to at least the EI of one baseline steel tube that it replaces when calculated as per **T.2.30 Monocoque Buckling Modulus**.
- T.2.33.3 The perimeter shear strength of the monocoque laminate in the Front Bulkhead support structure should be at least 4 kN for a section with a diameter of 25 mm.

This must be proven by a physical test completed per **T.2.31.4** and the results included in the SES.

### T.2.34 Monocoque Side Impact

- T.2.34.1 In the region longitudinally forward of the Main Hoop and aft of the Front Hoop and vertically from 350 mm above the ground to the bottom surface of the floor of the monocoque must have a Buckling Modulus ( $E*I$ ) equal to three (3) Baseline Steel Tubes (**T.2.5**) that it replaces.
- T.2.34.2 The vertical side impact zone between the upper surface of the floor and 350 mm above the ground must have a Buckling Modulus ( $E*I$ ) equivalent to two (2) Baseline Steel Tubes (**T.2.5**).
- T.2.34.3 Half the horizontal floor must have a Buckling Modulus ( $E*I$ ) equivalent to one Baseline Steel Tube per **T.2.30 Monocoque Buckling Modulus**.
- T.2.34.4 The vertical side impact zone between the upper surface of the floor and 350 mm above the ground must have an absorbed energy equivalent to two (2) Baseline Steel Tubes (**T.2.5**).

Proof of equivalent absorbed energy is determined by physical testing per **T.2.31.1** and **T.2.31.2**



- T.2.34.5 The perimeter shear strength of the monocoque laminate should be at least 7.5 kN for a section with a diameter of 25 mm. This must be proven by physical test completed as per **T.2.31.4** and the results included in the SES.

### **T.2.35 Monocoque Main Hoop**

- T.2.35.1 The Main Hoop must be constructed of a single piece of uncut, continuous, closed section steel tubing per **T.2.5 Baseline Tubing** OR **T.2.6 Alternate Steel Tubing**
- T.2.35.2 The Main Hoop must extend down to the bottom of the monocoque.
- T.2.35.3 The Main Hoop must be mechanically attached to the monocoque and must meet **T.2.40**.
  - a. If three attachments on each side are used, they must be located at the bottom, top, and an intermediate location corresponding to the Upper Side Impact Member as defined in **T.2.26.4** Each attachment must meet the load requirements specified in **T.2.40.1**
  - b. Designs that combine the top of monocoque attachment and the Upper Side Impact attachment must show attachment load strength of 45 kN in all directions (1.5 times the requirements of **T.2.40.1**) for both the combined upper attachment and the lower attachment on each side.
- T.2.35.4 Mounting plates welded to the Roll Hoop must be 2.0 mm (0.080 inch) minimum thickness steel.

### **T.2.36 Monocoque Front Hoop**

- T.2.36.1 The Front Hoop must be constructed of closed section metal tubing per **T.2.5 Baseline Tubing** OR **T.2.6 Alternate Steel Tubing** OR **T.2.7 Alternative Tubing Materials**
- T.2.36.2 The Front Hoop must be mechanically attached at the top and bottom of the monocoque and at an intermediate location corresponding to the Upper Side Impact Member as defined in **T.2.26.4**
- T.2.36.3 Attachment of the Front Hoop to the monocoque must comply with **T.2.40**.
- T.2.36.4 The Front Hoop may be fully laminated into the monocoque
  - a. Fully laminating means encapsulating the Front Hoop with an appropriate number and arrangement of plies.
  - b. Equivalence to at least six mounts compliant with **T.2.40** must be shown in the SES.
- T.2.36.5 Adhesive must not be the sole method of attaching the Front Hoop to the monocoque.

### **T.2.37 Monocoque Front and Main Hoop Bracing**

- T.2.37.1 Attachment of tubular Front or Main Hoop Bracing to the monocoque must comply with **T.2.40**.

### **T.2.38 Monocoque Impact Attenuator and Anti Intrusion Plate Attachment**

- T.2.38.1 The SES for attachment of the Impact Attenuator and the Anti Intrusion Plate to a monocoque structure must show the equivalency to no less than:
  - a. Eight 8 mm or 5/16" minimum diameter **Critical Fasteners** for the Anti Intrusion Plate
  - b. Four bolts to the same minimum specification for the Impact Attenuator.

### **T.2.39 Monocoque Impact Attenuator Anti Intrusion Plate**

- T.2.39.1 Composite AIP must not fail in a frontal impact.
- T.2.39.2 Strength of the AIP must be verified by one of the following methods. All physical test results and any analysis completed must be included in the SES.
  - a. Physical testing of the Anti Intrusion plate as part of the Impact Attenuator dynamic test per **T.2.25.5** and **T.2.25.6**

- b. Laminate material testing and calculations of 3 point bending and perimeter shear analysis.

T.2.39.3 Composite laminate materials must be tested under **T.2.31.4** and **T.2.31.2**

T.2.39.4 Analysis of the AIP under 3 point bending must show the AIP does not fail under a static load of 120 kN distributed over 150 mm of length

T.2.39.5 Perimeter shear analysis must show each attachment can hold 20 kN in any direction.

#### **T.2.40 Monocoque Attachments**

T.2.40.1 Each attachment point between the monocoque and the other Primary Structure must be able to carry a minimum load of 30 kN in any direction.

A higher load may apply for Main Hoop attachment, see **T.2.35.3**

T.2.40.2 The laminate, brackets, backing plates and inserts must have sufficient stiffness, shear area, bearing area, weld area and strength to carry the load specified in **T.2.40.1** in any direction.

Data obtained from the laminate perimeter shear strength test (**T.2.31.4**) must be used to prove adequate shear area is provided.

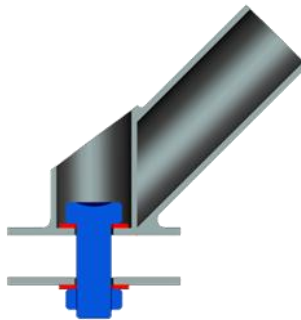
T.2.40.3 Proof that the brackets are adequately stiff must be documented in the SES, by EITHER:

- a. Hand calculations
- b. FEA with supporting hand calculations. Use of FEA alone is not acceptable.

T.2.40.4 Each attachment point requires no less than two 8 mm or 5/16" minimum diameter **Critical Fasteners**, see **T.10.2** and **T.10.3**

T.2.40.5 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.

T.2.40.6 The Front Hoop Bracing, Main Hoop Bracing and Main Hoop Bracing Supports may use only one 10 mm or 3/8" minimum diameter **Critical Fasteners**, see **T.10.2** and **T.10.3** as an alternative to **T.2.40.4 above** if the bolt is on the centerline of tube similar to the figure below.



T.2.40.7 No crushing of the core is permitted

T.2.40.8 Main Hoop bracing attached to a monocoque (not welded to a rear space frame) is considered mechanically attached and must comply with **T.2.18**



## T.2.41 Monocoque Driver Harness Attachment Points

### T.2.41.1 Required Loads

- a. The monocoque attachment points for the shoulder and lap belts must support a load of 13 kN before failure.
- b. The monocoque attachment points for the anti submarine belts must support a load of 6.5 kN before failure.
- c. If the lap belts and anti submarine belts are attached to the same attachment point, then this point must support a load of 19.5 kN before failure.

### T.2.41.2 Load Testing

The strength of lap belt, shoulder belt, and anti submarine belt attachments must be proven by physical tests where the required load is applied to a representative attachment point where the proposed layup and attachment bracket are used.

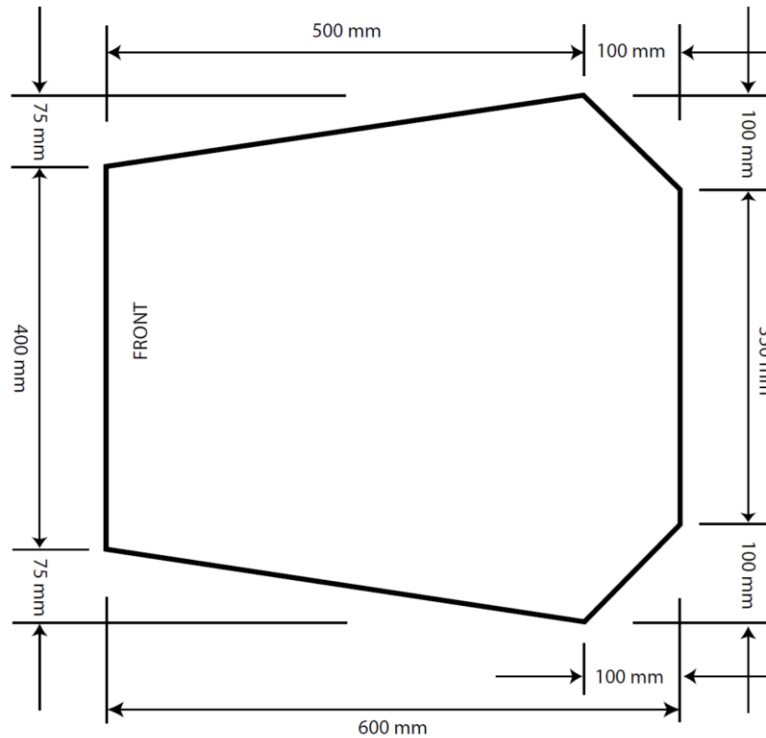
- a. Edges of the test fixture supporting the sample must be a minimum of 125 mm from the load application point (load vector intersecting a plane).
- b. Test load application:
  - Must be representative of the harness direction as installed in the cockpit
  - May be normal or parallel to the test sample
- c. The width of the shoulder harness test sample must not be any wider than the shoulder harness "panel height" (see Structural Equivalency Spreadsheet) used to show equivalency for the shoulder harness mounting bar.
- d. Designs with attachments near a free edge must not support the free edge during the test.

*The intent is that the test specimen, to the best extent possible, represents the vehicle as driven at competition. Teams are expected to test a panel that is manufactured in as close a configuration to what is built in the vehicle as possible*

### T.3 COCKPIT

#### T.3.1 Cockpit Opening

T.3.1.1 The template shown below must fit into the cockpit opening



T.3.1.2 The template will be held horizontally, parallel to the ground, and inserted vertically from a height above any Primary Structure or bodywork that is between the Front Hoop and the Main Hoop until it:

- Has passed below the top bar of the Side Impact Structure
- Is 350 mm above the ground for monocoque designs

T.3.1.3 Fore and aft translation of the template is permitted during insertion.

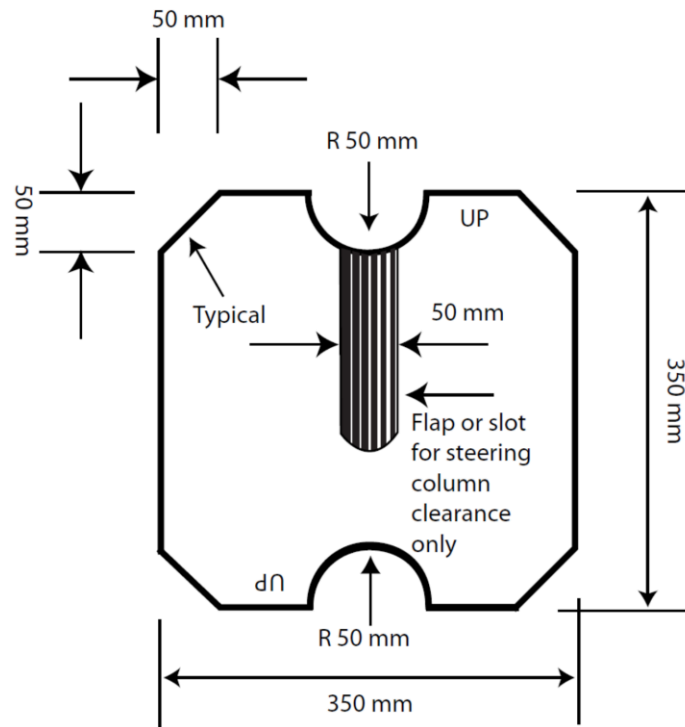
T.3.1.4 During this test:

- The steering wheel, steering column, seat and all padding may be removed.
- The shifter or shift mechanism may not be removed unless it is integral with the steering wheel and is removed with the steering wheel.
- The firewall must not be moved or removed.
- Cables, wires, hoses, tubes, etc. must not impede the template

*During inspection, the steering column, for practical purposes, will not be removed. The template may be maneuvered around the steering column shaft, but not the steering column supports.*

### T.3.2 Internal Cross Section

T.3.2.1 A free internal cross section to allow the template shown below to pass through must be maintained through the cockpit.



Template maximum thickness: 7 mm

T.3.2.2 Conduct of the test:

- The template will be held vertically and inserted into the cockpit opening rearward of the rearmost portion of the steering column.
- The template will then be passed horizontally through the cockpit to a point 100 mm rearwards of the face of the rearmost pedal when in the inoperative position

T.3.2.3 During this test:

- If the pedals are adjustable, they must be in their most forward position.
- The steering wheel may be removed
- Padding may be removed if it can be easily removed without the use of tools with the driver in the seat
- The seat must remain in the cockpit
- Cables, wires, hoses, tubes, etc. must not impede the template

### T.3.3 Driver's Seat

T.3.3.1 The driver's seat must be protected by one of the following:

- In side view, the lowest point of the driver's seat must be no lower than the bottom surface of the lower frame rails
- A longitudinal tube (or tubes) that meets the requirements for Side Impact tubing, passing underneath the lowest point of the seat.

- T.3.3.2 When seated in the normal driving position, adequate heat insulation must be provided to ensure that the driver will not contact any metal or other materials which may become heated to a surface temperature above 60°C.
- T.3.3.3 Insulation may be external to the cockpit or incorporated with the driver's seat or firewall.
- T.3.3.4 The design must address all three types of heat transfer between the heat source (exhaust pipe, coolant hose/tube) and the panel that the driver could contact (seat or floor):
- a. Conduction Isolation by one of the following:
    - No direct contact between the heat source and the panel
    - A heat resistant, conduction isolation material with a minimum thickness of 8 mm between the heat source and the panel.
  - b. Convection Isolation by a minimum air gap of 25 mm between the heat source and the panel
  - c. Radiation Isolation by one of the following:
    - A solid metal heat shield with a minimum thickness of 0.4 mm (0.015 in)
    - Reflective foil or tape when combined with conduction insulation.

#### **T.3.4 Floor Closeout**

- T.3.4.1 All vehicles must have a floor closeout to prevent track debris from entering
- T.3.4.2 The closeout must extend from the foot area to the firewall
- T.3.4.3 The panel(s) must be made of a solid, non brittle material.
- T.3.4.4 If multiple panels are used, gaps between panels must not to exceed 3 mm.

#### **T.3.5 Firewall**

- T.3.5.1 A firewall must separate the driver compartment from all components of the fuel supply, the engine oil, the liquid cooling systems, any lithium batteries and any high voltage system.
- T.3.5.2 The firewall must meet the following:
- a. A non permeable surface made from a rigid, fire resistant material.
  - b. Extend sufficiently far upwards and/or rearwards such that any point less than 100 mm above the bottom of the helmet of the tallest driver must not be in direct line of sight with any part of the fuel system, the cooling system or the engine oil system.
  - c. Seal completely against the passage of fluids (the firewall itself and edges)
  - d. Pass through for wiring, cables, etc. may be used if grommets are used to seal the pass through.
  - e. Seat belts must not pass through the firewall
  - f. Multiple panels may be used to form the firewall but must be sealed at the joints.

#### **T.3.6 Tractive System Firewall (EV only)**

- T.3.6.1 A firewall must separate the driver compartment from all tractive system components, including any HV wiring.
- T.3.6.2 The tractive system firewall must be composed of two layers as described below.
- T.3.6.3 One layer, facing the tractive system side, must be:
- a. Made of aluminum with a thickness between 0.5 and 0.7 mm
  - b. Grounded according to [EV.6.3 Grounding](#)

- T.3.6.4 Second layer, facing the driver, must be:
- Made of an electrically insulating material, which meets UL94-V0, FAR25 or equivalent. The second layer must not be made of CFRP.
  - Sufficient thickness to prevent penetrating this layer with a 4 mm wide screwdriver and 250 N of force.

T.3.6.5 The firewall must be rigidly mounted.

T.3.6.6 Conductive parts (except for the chassis) must not protrude through the firewall or must be properly insulated on the driver side.

### **T.3.7 Controls Accessibility**

All vehicle controls, including the shifter, must be operated from inside the cockpit without any part of the driver, including hands, arms or elbows, being outside the planes of the Side Impact Structure defined in [T.2.26](#) / [T.2.34](#)

### **T.3.8 Visibility**

T.3.8.1 The driver must have adequate visibility to the front and sides of the vehicle

T.3.8.2 When seated in a normal driving position, the driver must have a minimum field of vision of 100° to either side

T.3.8.3 If mirrors are required to meet this rule, they must remain in place and adjusted to enable the required visibility throughout all dynamic events.

## **T.4 DRIVER ACCOMMODATION**

### **T.4.1 Harness – General**

T.4.1.1 Definitions

- 5 point system – consists of two lap belts, two shoulder straps and one anti submarine strap.
- 6 point system – consists of two lap belts, two shoulder straps and two leg or anti submarine straps.
- 7 point system – consists of two lap belts, two shoulder straps , two leg or anti submarine straps and a negative g or Z belt.
- Upright Driving 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 template of the 95th percentile male as defined in [T.2.10.4](#) and positioned per [T.2.10.5](#)
- Reclined Driving 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 template of the 95th percentile male as defined in [T.2.10.4](#) and positioned per [T.2.10.5](#)
- Chest to groin line - the straight line that in side view follows the line of the shoulder belts from the chest to the release buckle.

### **T.4.2 Harness Requirements**

T.4.2.1 The vehicle must use a 5, 6 or 7 point restraint harness meeting at least one of the following specifications:

- [SFI Specification 16.1](#)
- [SFI Specification 16.5](#)
- [FIA specification 8853/98](#)

d. [FIA specification 8853/2016](#)

- T.4.2.2 The belts must have the original manufacturers labels showing the specification and expiration date
- T.4.2.3 The harness must be within the year of expiration shown on the labels. Harnesses expiring on or before Dec 31 of the competition year are permitted.
- T.4.2.4 The harness must be in new or like new condition, with no signs of wear, cuts, chaffing or other issues.
- T.4.2.5 Vehicles with a Reclined Driving Position must have:
- A 6 point or 7 point harness
  - Anti submarine belts with tilt lock adjusters (“quick adjusters”) OR two sets of anti submarine belts installed.
- T.4.2.6 All lap belts must incorporate a tilt lock adjuster (“quick adjuster”).
- Lap belts with “pull-up” adjusters are recommended over “pull-down” adjusters.*
- T.4.2.7 The shoulder harness must be the over the shoulder type. Only separate shoulder straps are permitted. “Y” type shoulder straps are not allowed. The “H” type configuration is allowed.
- T.4.2.8 All harness hardware must be threaded in accordance with manufacturer’s instructions.
- T.4.2.9 All harness hardware must be used as received from the manufacturer. No modification (including drilling, cutting, grinding, etc) is permitted.

**T.4.3 Belt, Strap and Harness Installation - General**

- T.4.3.1 The lap belt, shoulder harness and anti submarine strap(s) must be securely mounted to the Primary Structure.
- T.4.3.2 Any guide or support for the belts must meet the minimum requirements of **T.2.5** OR **T.2.6** OR **T.2.7**
- T.4.3.3 The tab or bracket to which any harness is attached must:
- Have a minimum cross sectional area of 60 sq mm of steel to be sheared or failed in tension at any point of the tab
  - Be 1.6 mm (0.063 inch) minimum thickness
  - Be aligned such that it is not put in bending when the attached part of the harness is put under load.
  - Where lap belts and anti submarine belts use the same attachment point, there must be a minimum cross sectional area of 90 sq mm of steel to be sheared or failed in tension at any point of the tab.
  - Not cause abrasion to the belt webbing
- T.4.3.4 Attachment of tabs or brackets must meet the following:
- Where brackets are fastened to the chassis, no less than two 6 mm or 1/4” minimum diameter **Critical Fasteners**, see **T.10.2** and **T.10.3** or stronger must be used to attach the bracket to the chassis.
  - Where a single shear tab is welded to the chassis, the tab to tube welding must be on both sides of the base of the tab.

*Double shear attachments are preferred. Tabs and brackets for double shear mounts should be welded on both sides.*

T.4.3.5 Harnesses, belts and straps must not pass through a firewall. All harness attachment points must be on the driver's side of any firewall.

#### T.4.4 Lap Belt Mounting

T.4.4.1 The lap belts must pass around the pelvic area below the Anterior Superior Iliac Spines (the hip bones).

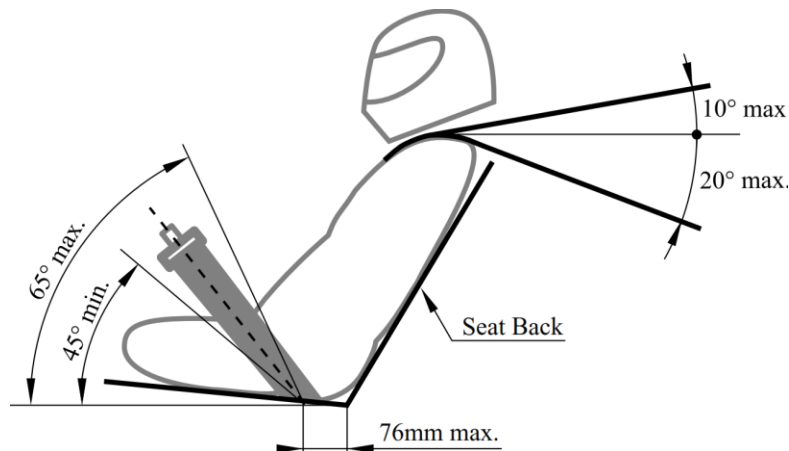
T.4.4.2 The lap belts must not be routed over the sides of the seat. The belts must come through the seat at the bottom of the sides of the seat and continue in a straight line to the anchorage point.

T.4.4.3 The seat must be rolled or grommeted where the belts or harness pass through a hole in the seat

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

T.4.4.5 Lap belts must not be mounted by wrapping them around frame tubes.

T.4.4.6 With an Upright Driving Position, in side view the lap belt must be at an angle of between 45° and 65° to the horizontal. The centerline of the lap belt at the seat bottom should be between 0 – 75 mm forward of the seat back to seat bottom junction.



T.4.4.7 With a Reclined Driving Position, in side view the lap belt must be between an angle of 60° and 80° to the horizontal.

T.4.4.8 Any bolt used to attach a lap belt, either directly to the chassis or to an intermediate bracket, is a **Critical Fasteners**, see **T.10.2** and **T.10.3**, with a minimum diameter that is the smaller of:

- The bolt diameter specified by the manufacturer
- 10 mm or 3/8"

#### T.4.5 Shoulder Harness

T.4.5.1 The shoulder harness must be mounted behind the driver to a single piece of uncut, continuous, closed section steel tubing per **T.2.5** OR **T.2.6**.

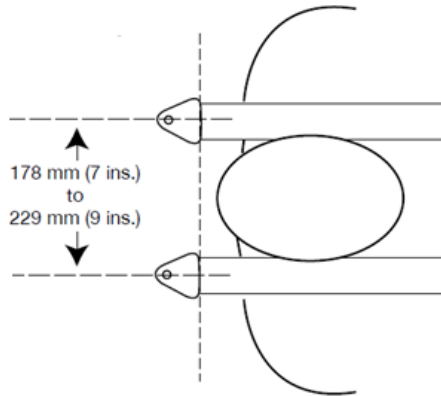
T.4.5.2 The Shoulder Harness Mounting Bar must attach to the Main Hoop on both sides of the chassis.

T.4.5.3 Bent Shoulder Harness Mounting Bars must:

- a. Meet **T.2.8.1** and **T.2.8.2**
- b. Have bracing members attached at the bend(s) and to the Main Hoop.

- Material for this Shoulder Harness Mounting Bar Bracing must meet the requirements of **T.2.5 OR T.2.6 OR T.2.7**
- The included angle in side view between the Shoulder Harness Bar and the braces must be no less than 30°.

T.4.5.4 The shoulder harness mounting points must be between 178 mm and 229 mm apart.



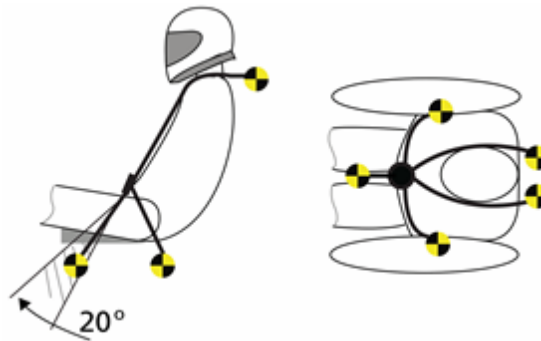
T.4.5.5 From the driver's shoulders rearwards to the mounting point or structural guide, the shoulder harness must be between 10° above the horizontal and 20° below the horizontal.

T.4.5.6 Any bolt used to attach a shoulder harness belt, either directly to the chassis or to an intermediate bracket, is a **Critical Fasteners**, see **T.10.2** and **T.10.3**, with a minimum diameter that is the smaller of:

- The bolt diameter specified by the manufacturer
- 10 mm or 3/8"

#### T.4.6 Anti Submarine Belt Mounting

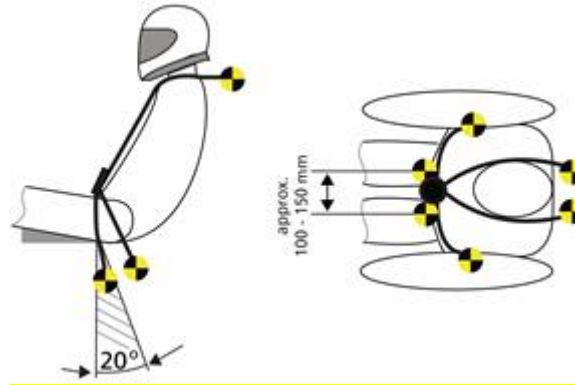
T.4.6.1 The anti submarine belt of a 5 point harness must be mounted so that the mounting point is in line with, or angled slightly forward (up to 20°) of, the driver's chest to groin line.



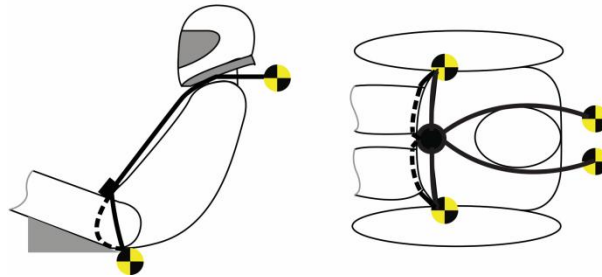
T.4.6.2 The anti submarine belts of a 6 point harness must be mounted in one of the following ways:

- With the belts going vertically down from the groin, or angled up to 20° rearwards. The anchorage points should be approximately 100 mm apart.





- b. With the anchorage points on the Primary Structure at or near the lap belt anchorages, the driver sitting on the anti submarine belts, and the belts coming up around the groin to the release buckle.



T.4.6.3 All anti submarine belts must be installed so that they go in a straight line from the anchorage point(s) without touching any hole in the seat or any other intermediate structure until they reach:

- The harness release buckle for the 5 point mounting per **T.4.6.1**
- The first point where the belt touches the driver's body for the 6 point mounting per **T.4.6.2** without touching any hole in the seat or any other intermediate structure

T.4.6.4 Any bolt used to attach an anti submarine belt, either directly to the chassis or to an intermediate bracket, is a **Critical Fasteners**, see **T.10.2** and **T.10.3**, with a minimum diameter that is the smaller of:

- The bolt diameter specified by the manufacturer
- 8 mm or 5/16"

#### **T.4.7 Head Restraint**

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

T.4.7.2 The head restraint must be vertical or near vertical in side view.

T.4.7.3 The head restraint padding must:

- Be an energy absorbing material that meets either [SFI Spec 45.2](#), or is listed in the [FIA Technical List No. 17](#) as a "Type B Material for single seater cars": CONFOR M foam CF-42 (pink) or CF-42M (pink). CF-42AC (pink) is acceptable.
- Have a minimum thickness of 38 mm
- Have a minimum width of 15 cm

- d. Have a minimum area of 235 sq cm AND have a minimum height adjustment of 17.5 cm, OR have a minimum height of 28 cm

T.4.7.4 For all drivers, the head restraint must be located and adjusted so that:

- a. 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.
- b. 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.

*Approximately 100 mm of longitudinal adjustment should accommodate range of specified drivers. Several head restraints with different thicknesses may be used*

T.4.7.5 The head restraint, its attachment and mounting must be strong enough to withstand a force of 890 N applied in a rearward direction.

#### **T.4.8 Roll Bar Padding**

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

#### **T.4.9 Driver Leg Protection**

T.4.9.1 All moving suspension and steering components and other sharp edges inside the cockpit between the Front Hoop and a vertical plane 100 mm rearward of the pedals, must be covered by a shield made of a solid material.

*Moving components include, but are not limited to springs, shock absorbers, rocker arms, anti-roll/sway bars, steering racks and steering column CV joints.*

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

### **T.5 BRAKE SYSTEM**

#### **T.5.1 General**

T.5.1.1 The vehicle must be equipped with a braking system that:

- a. Acts on all four wheels
- b. Is operated by a single control
- c. Must be capable of locking all four wheels

T.5.1.2 The braking 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.

T.5.1.3 Each hydraulic circuit must have its own fluid reserve, either by the use of separate reservoirs or by the use of an OEM style reservoir.

T.5.1.4 A single brake acting on a limited slip differential may be used.

T.5.1.5 "Brake by Wire" systems are prohibited.

T.5.1.6 Unarmored plastic brake lines are prohibited.

T.5.1.7 The braking systems must be protected with scatter shields from failure of the drive train (see [T.7.2](#)) or from minor collisions.

T.5.1.8 In side view any portion of the brake system that is mounted on the sprung part of the vehicle must not project below the lower surface of the chassis

T.5.1.9 Fasteners in the Brake system are **Critical Fasteners**, see **T.10.2** and **T.10.3**

T.5.1.10 The brake pedal must be:

- a. Fabricated from steel or aluminum OR machined from steel, aluminum or titanium.
- b. Designed to withstand a force of 2000 N without any failure of the brake system or pedal box.

*This may be tested by pressing the pedal with the maximum force that can be exerted by any official when seated normally.*

T.5.1.11 (EV only) Additional requirements for Electric Vehicles:

- a. The first 90% of the brake pedal travel may be used to regenerate brake energy without actuating the hydraulic brake system.
- b. The remaining brake pedal travel must directly actuate the hydraulic brake system. Brake energy regeneration may remain active.
- c. Any strategy to regenerate energy while coasting or braking must be covered by the FMEA

## **T.5.2 Brake Over Travel Switch - BOTS**

T.5.2.1 A Brake Over Travel Switch (BOTS) must be installed such that brake pedal travel exceeding the normal range will actuate the switch

T.5.2.2 The BOTS must be a mechanical single pole, single throw (commonly known as a two position) switch (push-pull or flip type).

T.5.2.3 Actuation of the BOTS to the OFF position must:

- a. (IC) Shutdown the engine(s) and fuel pump(s) **IC.8**
- b. (EV) Shutdown the Tractive System **EV.7.2**

T.5.2.4 Repeated actuation of the switch must not reset or restore power

T.5.2.5 The BOTS must be designed so that the driver cannot reset it.

T.5.2.6 The switch must be implemented with analog components, and not using programmable logic controllers, engine control units, or similar functioning digital controllers.

## **T.5.3 Brake Light**

T.5.3.1 The vehicle must be equipped with a brake light that is clearly visible from the rear in very bright sunlight.

T.5.3.2 The brake light must be:

- a. Red in color on a Black background
- b. Rectangular, triangular or near round shape with a minimum shining surface of at least 15 sq cm
- c. Mounted between the wheel centerline and driver's shoulder level vertically and approximately on vehicle centerline laterally.

T.5.3.3 When LED lights are used without a diffuser, they must not be more than 20 mm apart.

T.5.3.4 If a single line of LEDs is used, the minimum length is 150 mm.

## T.6 ELECTRONIC THROTTLE COMPONENTS

### T.6.1 Applicability

This section applies only for:

- IC vehicles using Electronic Throttle Control (ETC)
- EV vehicles

*Differences between IC and EV applications are noted in the rule text*

### T.6.2 Accelerator Pedal Position Sensor - APPS

T.6.2.1 The APPS must be actuated by a foot pedal.

- a. Pedal travel is defined as percent of travel from a fully released position to a fully applied position where 0% is fully released and 100% is fully applied.
- b. The foot pedal must return to its original position when not actuated.
- c. The foot pedal must have a positive stop preventing the mounted sensors from being damaged or overstressed.
- d. Two springs must be used to return the foot pedal to the off position
- e. Each spring must be capable of returning the pedal to the fully released position with the other disconnected. The springs in the APPS are not acceptable pedal return springs.

T.6.2.2 At least two entirely separate sensors have to be used as APPSs. The sensors must have different transfer functions which meet either:

- Each sensor has a positive slope sense with either different gradients and/or offsets to the other(s).
- An OEM pedal sensor with opposite slopes. Non OEM opposite slope sensor configurations require prior approval.

*The intent is that in a short circuit the APPSs will only agree at 0% pedal position.*

T.6.2.3 Implausibility is defined as a deviation of more than 10% pedal travel between the sensors or other failure as defined in this Section T.6.2. Use of values larger than 10% require justification in the FMEA and may not be approved

T.6.2.4 If an implausibility occurs between the values of the APPSs and persists for more than 100msec, the power to the (IC) electronic throttle / (EV) motor(s) must be immediately shut down completely.

(EV only) It is not necessary to completely deactivate the Tractive System, the motor controller(s) shutting down the power to the motor(s) is sufficient.

T.6.2.5 If three sensors are used, then in the case of an APPS failure, any two sensors that agree within 10% pedal travel may be used to define the (IC) throttle position / (EV) torque target and the 3rd APPS may be ignored.

T.6.2.6 Each APPS must be able to be checked during Technical Inspection by having either:

- A separate detachable connector that enables a check of functions by unplugging it
- An inline switchable breakout box available that allows disconnection of each APPS signal.

T.6.2.7 The APPS signals must be sent directly to a controller using an analogue signal or via a digital data transmission bus such as CAN or FlexRay.

- T.6.2.8 Any failure of the APPS or APPS wiring must be detectable by the controller and must be treated like an implausibility, see **T.6.2.3 above**
- T.6.2.9 When an analogue signal is used, the APPS will be considered to have failed when they achieve an open circuit or short circuit condition which generates a signal outside of the normal operating range, for example  $<0.5\text{ V}$  or  $>4.5\text{ V}$ .  
The circuitry used to evaluate the sensor must use pull down or pull up resistors to ensure that open circuit signals result in a failure being detected.
- T.6.2.10 When any kind of digital data transmission is used to transmit the APPS signal,
- The FMEA study must contain a detailed description of all the potential failure modes that can occur, the strategy that is used to detect these failures and the tests that have been conducted to prove that the detection strategy works.
  - The failures to be considered must include but are not limited to the failure of the APPS, APPS signals being out of range, corruption of the message and loss of messages and the associated time outs.
- T.6.2.11 The current rules are written to only apply to the APPS (pedal), but the integrity of the torque command signal is important in all stages.
- T.6.3 Brake System Encoder - BSE**
- T.6.3.1 A Brake System Encoder or switch to measure brake pedal position or brake system pressure must be fitted to check for plausibility
- T.6.3.2 The BSE must be able to be checked during Technical Inspection by having either:
- A separate detachable connector that enables detection of error states and the response of the ECU to be checked by unplugging it
  - An inline switchable breakout box available that allows disconnection of each BSE signal.
- T.6.3.3 The BSE or switch signals must be sent directly to a controller using an analogue signal or via a digital data transmission bus such as CAN or FlexRay. Any failure of the BSE or BSE wiring that persists more than 100 msec must be detectable by the controller and treated like an implausibility such that power to the (IC) electronic throttle / (EV) motor(s) is immediately and completely shut down.  
(EV only) It is not necessary to completely deactivate the Tractive System, the motor controller(s) shutting down the power to the motor(s) is sufficient.
- T.6.3.4 When an analogue signal is used, the BSE sensors will be considered to have failed when they achieve an open circuit or short circuit condition which generates a signal outside of the normal operating range, for example  $<0.5\text{ V}$  or  $>4.5\text{ V}$ .  
The circuitry used to evaluate the sensor must use pull down or pull up resistors to ensure that open circuit signals result in a failure being detected.
- T.6.3.5 When any kind of digital data transmission is used to transmit the BSE signal:
- The FMEA study must contain a detailed description of all the potential failure modes that can occur, the strategy that is used to detect these failures and the tests that have been conducted to prove that the detection strategy works.
  - The failures to be considered must include but are not limited to the failure of the sensor, sensor signals being out of range, corruption of the message and loss of messages and the associated time outs.

- c. In all cases a sensor failure must result in power to the motor(s) being immediately shutdown.

## T.7 POWERTRAIN

### T.7.1 Transmission and Drive

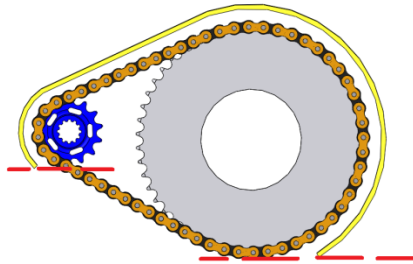
Any transmission and drivetrain may be used.

### T.7.2 Drivetrain Shields and Guards

T.7.2.1 Exposed high speed final drivetrain equipment such as Continuously Variable Transmissions (CVTs), sprockets, gears, pulleys, torque converters, clutches, belt drives, clutch drives and electric motors, must be fitted with scatter shields intended to contain drivetrain parts in case of failure.

T.7.2.2 The final drivetrain shield must:

- a. Be made with solid material (not perforated)
- b. Cover the chain or belt from the drive sprocket to the driven sprocket/chain wheel/belt or pulley.
- c. Start and end parallel to the lowest point of the chain wheel/belt/pulley:



T.7.2.3 Body panels or other existing covers are not acceptable unless constructed per [T.7.2.5](#) / [T.7.2.6](#)

T.7.2.4 If equipped, the engine drive sprocket cover may be used as part of the scatter shield system.

T.7.2.5 Chain Drive - Scatter shields for chains must:

- a. Be made of 2.66 mm (0.105 inch) minimum thickness steel (no alternatives are allowed)
- b. Have a minimum width equal to three times the width of the chain
- c. Be centered on the center line of the chain and
- d. Remain aligned with the chain under all conditions

T.7.2.6 Non-metallic Belt Drive - Scatter shields for belts must:

- a. Be made from 3.0 mm (0.120 inch) minimum thickness aluminum alloy 6061-T6
- b. Have a minimum width that is equal to 1.7 times the width of the belt.
- c. Be centered on the center line of the belt
- d. Remain aligned with the belt under all conditions.

T.7.2.7 Attachment Fasteners - All fasteners attaching scatter shields and guards must be 6mm or 1/4" minimum diameter **Critical Fasteners**, see [T.10.2](#) and [T.10.3](#)

#### T.7.2.8 Finger Guards

- a. Must cover any drivetrain parts that spin while the vehicle is stationary with the engine running.
- b. Must be made of material sufficient to resist finger forces.
- c. Mesh or perforated material may be used but must prevent the passage of a 12 mm diameter object through the guard.

#### T.7.3 Coolant Fluid

T.7.3.1 Water cooled engines must use only plain water with no additives of any kind.

T.7.3.2 Electric motors, accumulators or HV electronics may use plain water with no additives or oil as the coolant.

#### T.7.4 System Sealing

T.7.4.1 Any cooling or lubrication system must be sealed to prevent leakage.

T.7.4.2 The vehicle must be capable of being tilted to a 45° angle without leaking fluid of any type.

T.7.4.3 Flammable liquid leaks must not be allowed to accumulate.

T.7.4.4 At least 2 holes, each of a minimum diameter of 25 mm, must be provided in the lowest part of the structure or belly pan in such a way as to prevent accumulation of volatile liquids and/or vapours.

T.7.4.5 Absorbent material and open collection devices (regardless of material) are prohibited in compartments containing engine, drivetrain, exhaust and fuel systems below the highest point on the exhaust system.

#### T.7.5 Catch Cans

T.7.5.1 Separate catch cans must be employed to retain fluids from any vents for the engine coolant system and engine lubrication system.

Each catch can must have a minimum volume of 10% of the fluid being contained or 0.9 liter, whichever is greater.

T.7.5.2 Any vent on other systems containing liquid lubricant or coolant, including a differential, gearbox, or electric motor, must have a catch can with a minimum volume of 10% of the fluid being contained or 0.5 liter, whichever is greater.

T.7.5.3 Catch cans must be:

- a. Capable of containing boiling water without deformation
- b. Located rearwards of the firewall below the driver's shoulder level
- c. Positively retained, using no tie wraps or tape

T.7.5.4 Any catch can on the cooling system must vent through a hose with a minimum internal diameter of 3 mm down to the bottom levels of the Frame.

### T.8 PRESSURIZED SYSTEMS

#### T.8.1 Compressed Gas Cylinders and Lines

Any system on the vehicle that uses a compressed gas as an actuating medium must meet the following:

T.8.1.1 Working Gas - The working gas must be nonflammable

- T.8.1.2 Cylinder Certification - The gas cylinder/tank must be commercially manufactured, designed and built for the pressure being used, certified by an accredited testing laboratory in the country of its origin, and labeled or stamped appropriately.
- T.8.1.3 Pressure Regulation - The pressure regulator must be mounted directly onto the gas cylinder/tank.
- T.8.1.4 Protection – The gas cylinder/tank and lines must be protected from rollover, collision from any direction, or damage resulting from the failure of rotating equipment.
- T.8.1.5 Cylinder Location - The gas cylinder/tank and the pressure regulator must be:
  - a. Located either rearward of the Main Hoop and within the Primary Structure Envelope aft of the Main Hoop, or in a structural side-pod
  - b. Located outside the cockpit.
  - c. Protected by structure that meets **T.2.26 / T.2.34**
- T.8.1.6 Cylinder Mounting - The gas cylinder/tank must be securely mounted to the Frame, engine or transmission.
- T.8.1.7 Cylinder Axis - The axis of the gas cylinder/tank must not point at the driver.
- T.8.1.8 Insulation - The gas cylinder/tank must be insulated from any heat sources, such as the exhaust system.
- T.8.1.9 Lines and Fittings - The gas lines and fittings must be appropriate for the maximum possible operating pressure of the system.

## **T.8.2 High Pressure Hydraulic Pumps and Lines**

*This section T.8.2 does not apply to Brake lines or hydraulic clutch lines*

- T.8.2.1 The driver and anyone standing outside the vehicle must be shielded from any hydraulic pumps and lines with line pressures of 2100 kPa or higher.
- T.8.2.2 The shields must be steel or aluminum with a minimum thickness of 1 mm (0.039 inch).

## **T.9 BODYWORK AND AERODYNAMIC DEVICES**

### **T.9.1 Bodywork and Components**

- T.9.1.1 There must be no openings through the bodywork into the driver compartment from the front of the vehicle back to the roll bar main hoop or firewall other than that required for the cockpit opening. Minimal openings around the front suspension components are allowed.
- T.9.1.2 All forward facing edges on the bodywork that could impact people, including the nose, must have forward facing radii of at least 38 mm. This minimum radius must extend to at least 45° relative to the forward direction, along the top, sides and bottom of all affected edges.
- T.9.1.3 All forward facing wing edges including wings, end plates, Gurney flaps, wicker bills and undertrays that could contact a pedestrian must have a minimum radius of 5 mm for all horizontal edges and 3 mm for vertical edges (end plates).

If the edges themselves do not meet this requirement, additional permanently attached pieces designed to meet this requirement must be used.



**T.9.2 General Aerodynamics**

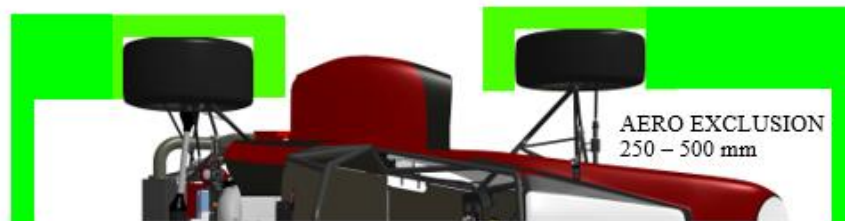
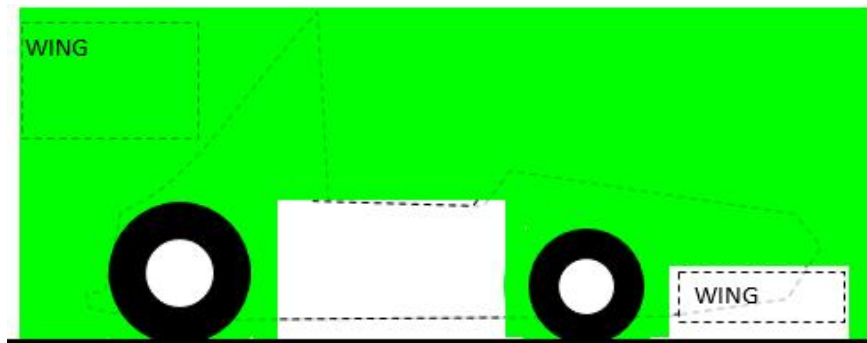
T.9.2.1 Aerodynamic Device

A part on the vehicle intended to guide airflow for generation of downforce and reduction of drag. Examples include wings, undertray, splitter, endplates, vanes

T.9.2.2 No power device may be used to move or remove air from under the vehicle except fans designed exclusively for cooling. Power ground effects are prohibited.

T.9.2.3 All aerodynamic devices must be designed such that the mounting system provides adequate rigidity in the static condition and such that the aerodynamic devices do not oscillate or move excessively when the vehicle is moving. Refer to **IN.8.2**

T.9.2.4 All aerodynamic device limitations apply with the wheels pointing in the straight ahead position



### **T.9.3 Front Mounted**

- T.9.3.1 In plan view, any part of any aerodynamic device must be:
- No more than 700 mm forward of the fronts of the front tires
  - Within a vertical plane parallel to the centerline of the chassis touching the outside of the front tires at the height of the hubs.
- T.9.3.2 When viewed from the front of the vehicle, the part of the front wheels/tires that are more than 250 mm above ground level must be unobstructed when measured without a driver in the vehicle.

### **T.9.4 Rear Mounted**

- T.9.4.1 In plan view, any part of any aerodynamic device must be:
- No more than 250 mm rearward of the rear of the rear tires
  - No further forward than a vertical plane through the rearmost portion of the front face of the driver head restraint support, excluding any padding, set (if adjustable) in its fully rearward position (excluding undertrays).
  - Inboard of two vertical planes parallel to the centerline of the chassis touching the inside of the rear tires at the height of the hub centerline.
- T.9.4.2 In side elevation, any part of an aerodynamic device must be no higher than 1.2 meters above the ground when measured without a driver in the vehicle

### **T.9.5 Between Wheels**

- T.9.5.1 Between the centerlines of the front and rear wheel axles, an aerodynamic device may extend outboard in plan view to a line drawn connecting the outer surfaces of the front and rear tires at the height of the wheel centers
- T.9.5.2 Except as permitted under **T.9.4.1 above**, any aerodynamic devices, or other bodywork, located between the transverse vertical planes positioned at the front and rear axle centerlines must not exceed a height of 500 mm above the ground when measured without a driver in the vehicle.
- Bodywork within vertical fore and aft planes set at 400 mm outboard from the centerline on each side of the vehicle is excluded from this requirement.

## **T.10 FASTENERS**

### **T.10.1 Critical Fasteners**

A threaded fastener (bolt, screw) used in a location designated as such in the applicable rule

### **T.10.2 Critical Fastener Requirements**

- T.10.2.1 Any Critical Fastener must meet, at minimum, one of the following:
- SAE Grade 5
  - Metric Grade 8.8
  - AN/MS Specifications
- T.10.2.2 All Critical Fasteners must be one of the following:
- Hex head
  - Hexagonal recessed drive (Socket Head Cap Screws or Allen screws/bolts)

T.10.2.3 Some Critical Fastener applications have additional requirements that are provided in the applicable section.

### **T.10.3 Securing Fasteners**

T.10.3.1 All Critical Fasteners must be secured from unintentional loosening by the use of Positive Locking Mechanisms.

T.10.3.2 Positive Locking Mechanisms are defined as those which:

- a. The Technical Inspectors (and the team members) are able to see that the device/system is in place (visible).
- b. The Positive Locking Mechanism does not rely on the clamping force to apply the locking or anti vibration feature. (If it loosens a bit, it still prevents the nut or bolt coming completely loose)

T.10.3.3 Acceptable Positive Locking Mechanisms include:

- a. Correctly installed safety wiring
- b. Cotter pins
- c. Nylon lock nuts (where temperature does not exceed 80°C)
- d. Prevailing torque lock nuts

*Lock washers, bolts with nylon patches and thread locking compounds (Loctite®), DO NOT meet the positive locking requirement.*

### **T.10.4 Requirements for All Fasteners**

T.10.4.1 A minimum of two full threads must project from any lock nut.

T.10.4.2 Adjustable tie rod ends must be constrained with a jam nut to prevent loosening.

## **T.11 ELECTRICAL EQUIPMENT**

### **T.11.1 Low Voltage Batteries**

T.11.1.1 All batteries and onboard power supplies must be attached securely to the frame.

T.11.1.2 All Low Voltage batteries must have overcurrent protection that trips at or below the maximum specified discharge current of the cells.

T.11.1.3 The hot (ungrounded) terminal must be insulated.

T.11.1.4 Any wet cell battery located in the driver compartment must be enclosed in a nonconductive marine type container or equivalent.

T.11.1.5 Battery packs based on Lithium Chemistry must:

- a. Have a rigid, sturdy and fire retardant casing
- b. Be separated from the driver by a firewall as specified in **T.3.5**

T.11.1.6 All batteries using chemistries other than lead acid must be presented at technical inspection with markings identifying it for comparison to a datasheet or other documentation proving the pack and supporting electronics meet all rules requirements

## VE - VEHICLE AND DRIVER EQUIPMENT

### VE.1 VEHICLE IDENTIFICATION

#### VE.1.1 Vehicle Number

VE.1.1.1 The assigned vehicle number must appear on the vehicle as follows:

- a. Locations: in three places, on the front of the chassis and both sides
- b. Height: 150 mm minimum
- c. Font: Block numbers (sans serif characters without italic, outline, shadow, or cursive numbers)
- d. Stroke Width and Spacing between numbers: 18 mm minimum
- e. Color: White numbers on a black background OR black numbers on a white background
- f. Background: round, oval, square or rectangular
- g. Spacing: 25 mm minimum between the edge of the numbers and the edge of the background
- h. The numbers must not be obscured by parts of the vehicle

VE.1.1.2 (EV only) Vehicle numbers must be preceded by a capital letter “E” in the same size and font as the numerals. Example: E211

#### VE.1.2 School Name

Each vehicle must clearly display the school name.

- a. Abbreviations are allowed if unique and generally recognized
- b. The name must be in Roman characters at least 50 mm high on both sides of the vehicle.
- c. The characters must be placed on a high contrast background in an easily visible location.
- d. The school name may also appear in non Roman characters, but the Roman character version must be uppermost on the sides.

#### VE.1.3 SAE Logo

The SAE International Logo must be displayed on the front and/or both sides of the vehicle in a prominent location.

#### VE.1.4 Inspection Sticker

VE.1.4.1 Space for the inspection sticker(s) must be provided.

VE.1.4.2 The space must be clear and unobstructed area at least 25 cm wide x 20 cm high on the upper front surface of the nose along the vehicle centerline.

#### VE.1.5 Transponder

VE.1.5.1 Each vehicle must have a functional, properly mounted transponder of the specified type.

VE.1.5.2 Vehicles without a transponder may not be allowed to compete in any event for which a transponder is used.

VE.1.5.3 The approved transponder type(s) and mounting details will be provided on the FSAE Online Website or by the organizer

## VE.2 VEHICLE EQUIPMENT

### VE.2.1 Jacking Point

VE.2.1.1 A jacking point must be provided at the rear of the vehicle

VE.2.1.2 The jacking point must be:

- a. Capable of supporting the vehicle weight and of engaging the organizer Quick Jacks
- b. Visible to a person standing 1 m behind the vehicle
- c. Color: Orange
- d. Oriented horizontally and perpendicular to the centerline of the vehicle
- e. Made from round, 25 - 30 mm OD aluminum or steel tube
- f. Minimum length: 300 mm
- g. Exposed around the lower 180° of its circumference over a minimum length of 280 mm
- h. Access from the rear of the tube must be unobstructed for at least 300 mm of its length
- i. The height of the tube must allow 75 mm minimum clearance from the bottom of the tube to the ground
- j. When the vehicle is raised to where the bottom of the tube is 200 mm above ground, the wheels do not touch the ground when they are in full rebound

### VE.2.2 Push Bar

VE.2.2.1 Each vehicle must have a removable device which attaches to the rear of the vehicle that:

- a. Allows two people, standing erect behind the vehicle, to push the vehicle around the competition site
- b. Is capable of slowing and stopping the forward motion of the vehicle and pulling it rearwards

### VE.2.3 Fire Extinguisher

VE.2.3.1 Each team must have at least two fire extinguishers.

- a. One extinguisher must readily be available in the team's paddock area
- b. One extinguisher must accompany the vehicle when moved using the push bar  
A commercially available on board fire system may be used instead of the fire extinguisher that accompanies the vehicle

VE.2.3.2 Hand held fire extinguishers must NOT be mounted on or in the vehicle

VE.2.3.3 Each fire extinguisher must meet the following:

- a. Capacity: 0.9 kg (2 lbs)
- b. Working Medium: Dry chemical/dry powder. Aqueous Film Forming Foam (AFFF) and Halon extinguishers and systems are prohibited.
- c. Equipped with a manufacturer installed pressure/charge gauge.
- d. Minimum acceptable ratings:
  - USA, Canada & Brazil: 10BC or 1A 10BC
  - Europe: 34B or 5A 34B
  - Australia: 20BE or 1A 10BE
- e. Extinguishers of larger capacity (higher numerical ratings) are acceptable.

#### VE.2.4 Electrical Equipment (EV only)

The following items must accompany the vehicle at all times:

- Two pairs of High Voltage insulating gloves
- A multimeter

#### VE.2.5 Camera Mounts

VE.2.5.1 The mounts for video/photographic cameras must be of a safe and secure design.

VE.2.5.2 All camera installations must be approved at Technical Inspection.

VE.2.5.3 Helmet mounted cameras and helmet camera mounts are prohibited.

VE.2.5.4 The body of a camera or recording unit that weighs more than 0.25 kg must be secured at a minimum of two points on different sides of the camera body.

VE.2.5.5 If a tether is used to restrain the camera, the tether length must be limited so that the camera cannot contact the driver.

### VE.3 DRIVER EQUIPMENT

#### VE.3.1 General

VE.3.1.1 Any Driver Equipment:

- a. Must be in good condition with no tears, rips, open seams, areas of significant wear, abrasions or stains which might compromise fire resistant performance.
- b. Must fit properly
- c. Is subject to inspection at any time.

VE.3.1.2 Fire Resistant Material

For the purpose of this section some, but not all, of the approved fire resistant materials are: Carbon X, Indura, Nomex, Polybenzimidazole (common name PBI) and Proban.

VE.3.1.3 Synthetic Material – Prohibited

Shirts, socks or other undergarments (not to be confused with fire resistant underwear) made from nylon or any other synthetic material which could melt when exposed to high heat are prohibited.

VE.3.1.4 Officials may impound any non approved Driver Equipment until the end of the competition.

#### VE.3.2 Helmet

VE.3.2.1 The driver must wear a helmet which:

- a. Is closed face with an integral, immovable chin guard
- b. Contains an integrated visor/face shield supplied with the helmet
- c. Meets an approved standard
- d. Is properly labeled for that standard

VE.3.2.2 Acceptable helmet standards are:

- a. [Snell](#) K2005, K2010, K2015, M2005, M2010, M2015, SA2005, SA2010, SAH2010, SA2015, EA2016
- b. [SFI Specs](#) 31.1/2005, 31.1/2010, 31.1/2015, 41.1/2005, 41.1/2010, 41.1/2015
- c. [FIA Standards](#) FIA 8860-2004, FIA 8860-2010, FIA 8860-2018, FIA 8859-2015

### VE.3.3 Driver Gear

#### VE.3.3.1 Suit

A fire resistant one piece suit, made from a minimum of two layers that covers the body from the neck to the ankles and the wrists.

Each suit must meet an approved standard and be labeled as such:

- [SFI 3.2A/5](#) (or higher ex: /10, /15, /20)
- FIA Standard 1986
- [FIA Standard 8856-2000](#)

#### VE.3.3.2 Underclothing

All competitors should wear fire resistant underwear (long pants and long sleeve shirt) under their approved driving suit.

#### VE.3.3.3 Balaclava

A balaclava (head sock) which covers the driver's head, hair and neck, made from Fire Resistant Material.

#### VE.3.3.4 Socks

Socks made from Fire Resistant Material, that cover the bare skin between the driver's suit and the boots or shoes.

#### VE.3.3.5 Shoes

Shoes made from Fire Resistant Material that meet an approved standard and be labeled as such:

- [SFI Spec 3.3](#)
- [FIA Standard 8856-2000](#)

#### VE.3.3.6 Gloves

Gloves made from Fire Resistant Material. Gloves of all leather construction or fire resistant gloves constructed using leather palms with no insulating Fire Resisting Material underneath are not acceptable.

#### VE.3.3.7 Arm Restraints

- a. Arm restraints must be worn such that the driver can release them and exit the vehicle unassisted regardless of the vehicle's position.
- b. Arm restraints must be commercially manufactured. Arm restraints certified to [SFI Spec 3.3](#) and labeled as such meet this requirement.

## IC - INTERNAL COMBUSTION ENGINE VEHICLES

### IC.1 GENERAL REQUIREMENTS

#### IC.1.1 Engine Limitations

IC.1.1.1 The engine(s) used to power the vehicle must:

- a. Be a piston engine(s) using a four stroke primary heat cycle
- b. Have a total combined displacement less than or equal to **710 cc** per cycle.

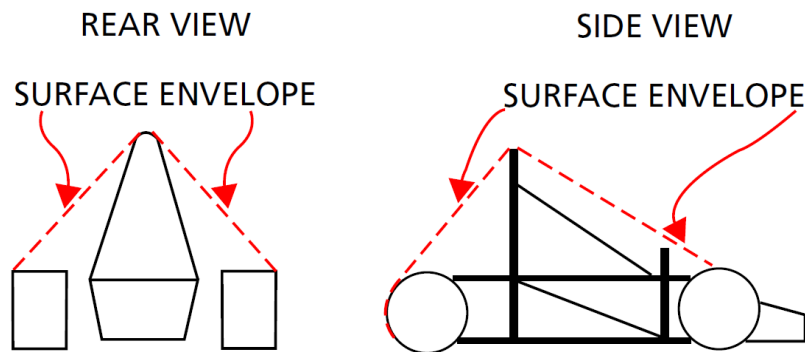
IC.1.1.2 Hybrid powertrains, such as those using electric motors running off stored energy, are prohibited.

IC.1.1.3 All waste/rejected heat from the primary heat cycle may be used. The method of conversion is not limited to the four stroke cycle.

IC.1.1.4 The engine may be modified within the restrictions of the rules.

#### IC.1.2 Air Intake and Fuel System Location

All parts of the engine air system and fuel control, delivery and storage systems (including the throttle or carburetor, and the complete air intake system, including the air cleaner and any air boxes) must lie within the surface defined by the top of the roll bar and the outside edge of the four tires.



### IC.2 AIR INTAKE SYSTEM

#### IC.2.1 General

#### IC.2.2 Intake System Location

IC.2.2.1 The Intake System must meet **IC.1.2**

IC.2.2.2 Any portion of the air intake system that is less than 350 mm above the ground must be shielded from side or rear impact collisions by structure built per **T.2.26** / **T.2.34** as applicable.

#### IC.2.3 Intake System Mounting

IC.2.3.1 The intake manifold must be securely attached to the engine block or cylinder head with brackets and mechanical fasteners. Hose clamps, plastic ties, or safety wires do not meet this requirement.

The use of rubber bushings or hose is acceptable for creating and sealing air passages, but is not a structural attachment.



IC.2.3.2 Threaded fasteners used to secure the intake manifold must have a positive locking feature, see **T.10.3**, or be an OEM fastener.

IC.2.3.3 Intake systems with significant mass or cantilever from the cylinder head must be supported to prevent stress to the intake system.

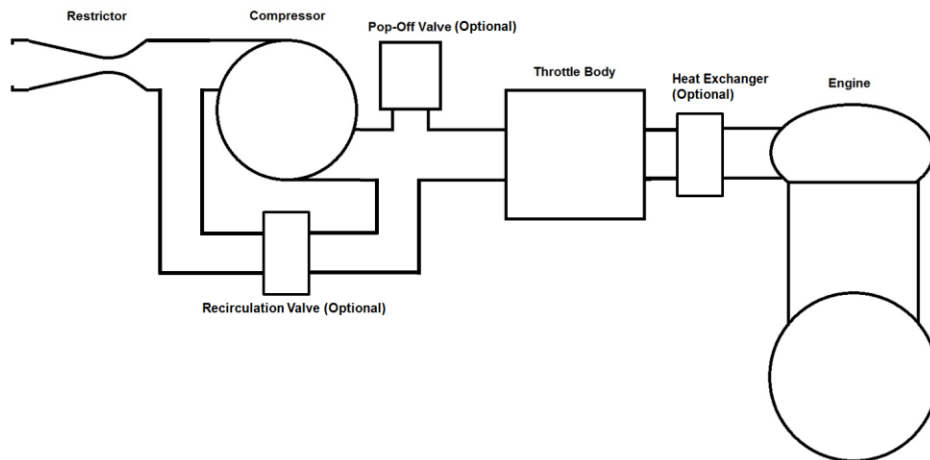
- a. Supports to the engine must be rigid.
- b. Supports to the frame or chassis must incorporate some isolation to allow for engine movement and chassis flex.

#### IC.2.4 Intake System Restrictor

IC.2.4.1 All airflow to the engine(s) must pass through a single circular restrictor placed in the intake system.

IC.2.4.2 The only allowed sequence of components are the following:

- a. For naturally aspirated engines, the sequence must be: throttle body, restrictor, and engine.
- b. For turbocharged or supercharged engines, the sequence must be: restrictor, compressor, throttle body, engine.



IC.2.4.3 The maximum restrictor diameters at any time during the competition are:

- a. Gasoline fueled vehicles            20.0 mm
- b. E85 fueled vehicles                 19.0 mm

IC.2.4.4 The restrictor must be located to facilitate measurement during Technical Inspection

IC.2.4.5 The circular restricting cross section must NOT be movable or flexible in any way

IC.2.4.6 The restrictor must not be part of the movable portion of a barrel throttle body.

#### IC.2.5 Turbochargers & Superchargers

IC.2.5.1 The intake air may be cooled with an intercooler (a charge air cooler).

- a. It must be located downstream of the throttle body
- b. Only ambient air may be used to remove heat from the intercooler system
- c. Air to air and water to air intercoolers are permitted
- d. The coolant of a water to air intercooler system is engine coolant and must meet **T.7.3.1**

IC.2.5.2 If pop-off valves, recirculation valves, or heat exchangers (intercoolers) are used, they must be positioned in the intake system as shown in **IC.2.4.2b**

IC.2.5.3 Plenums must not be located anywhere upstream of the throttle body

*For the purpose of definition, a plenum is any tank or volume that is a significant enlargement of the normal intake runner system. Teams may submit their designs via a Rules Question for review prior to competition if the legality of their proposed system is in doubt.*

IC.2.5.4 The maximum allowable area of the inner diameter of the intake runner system between the restrictor and throttle body is 2825 sq mm.

### **IC.2.6 Connections to Intake**

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

## **IC.3 THROTTLE**

### **IC.3.1 General**

IC.3.1.1 The vehicle must be equipped with a carburetor or throttle body.

- a. The carburetor or throttle body may be of any size or design.
- b. Carburetors must not be used on boosted applications.

IC.3.1.2 The foot pedal must return to its original position when not actuated

IC.3.1.3 A positive pedal stop must be incorporated on the throttle pedal to prevent over stressing the throttle cable or actuation system.

IC.3.1.4 If the throttle system contains any mechanism that could become jammed, for example a gear mechanism, then this must be covered to prevent ingress of any debris.

### **IC.3.2 Throttle Actuation Method**

IC.3.2.1 The throttle may be actuated either mechanically by a cable or rod system, or by Electronic Throttle Control.

### **IC.3.3 Throttle Actuation – Mechanical**

IC.3.3.1 The throttle cable or rod must:

- a. Have smooth operation
- b. Have no possibility of binding or sticking.
- c. Be at least 50 mm from any exhaust system component and out of the exhaust stream.
- d. Be protected from being bent or kinked by the driver's foot when it is operated by the driver or when the driver enters or exits the vehicle.

IC.3.3.2 The throttle actuation system must use at least two return springs located at the throttle body, so that the failure of any component of the throttle system will not prevent the throttle returning to the closed position.

Throttle Position Sensors (TPS) are NOT acceptable as return springs.

## IC.4 ELECTRONIC THROTTLE CONTROL

*This section IC.4 applies only when Electronic Throttle Control is used*

An Electronic Throttle Control (ETC) system may be used. This is a device or system which may change the engine throttle setting based on various inputs.

### IC.4.1 General Design

- IC.4.1.1 The electronic throttle must automatically close (return to idle) when power is removed.
- IC.4.1.2 The electronic throttle must use at least two sources of energy capable of returning the throttle to the idle position.
  - a. One of the sources may be the device (such as a DC motor) that normally actuates the throttle
  - b. The other device(s) must be a throttle return spring that can return the throttle to the idle position in the event of a loss of actuator power.
  - c. Springs in the TPS are not acceptable throttle return springs
- IC.4.1.3 The ETC system may blip the throttle during downshifts when the control strategy and its possible failure modes, including all signals used to determine that the driveline state is open and unable to transmit propulsive torque when the blipping function is active are properly documented in the FMEA and demonstrated at Technical Inspection.

### IC.4.2 Commercial ETC System

- IC.4.2.1 An ETC system that is commercially available, but does not comply with the regulations, may be used, if approved prior to the event.
- IC.4.2.2 To obtain approval, submit a Rules Question which includes:
  - Which ETC system the team is seeking approval to use.
  - The specific ETC rule(s) that the commercial system deviates from.
  - Sufficient technical details of these deviations to allow the acceptability of the commercial system to be determined.

### IC.4.3 Documentation

- IC.4.3.1 The ETC Notice of Intent:
  - Must be submitted to inform the organizer of the intent to run ETC
  - May be used to screen which teams are allowed to use ETC
- IC.4.3.2 The Failure Modes and Effects Analysis – FMEA must be submitted in order to use ETC
- IC.4.3.3 Submit the ETC Notice of Intent and ETC - FMEA as described in section **DR - Document Requirements**
- IC.4.3.4 Late or non submission will prevent use of ETC, see **DR.3.4**

### IC.4.4 Throttle Position Sensor - TPS

- IC.4.4.1 The TPS must measure the position of the throttle or the throttle actuator.

Throttle position is defined as percent of travel from fully closed to wide open where 0% is fully closed and 100% is fully open.
- IC.4.4.2 At least two separate sensors must be used as TPSs. The TPSs may share the same supply and reference lines only if effects of supply and/or reference line voltage offsets can be detected.

- IC.4.4.3 Implausibility is defined as a deviation of more than 10% throttle position between the sensors or other failure as defined in Section **IC.4**. Use of larger values may be considered on a case by case basis and require justification in the FMEA.
- IC.4.4.4 If an implausibility occurs between the values of the two TPSs and persists for more than 100 msec, the power to the electronic throttle must be immediately shut down.
- IC.4.4.5 If three sensors are used, then in the case of a TPS failure, any two TPSs that agree within 10% throttle position may be used to define the throttle position target and the 3rd TPS may be ignored.
- IC.4.4.6 Each TPS must be able to be checked during Technical Inspection by having either:
  - a. A separate detachable connector that enables a check of these functions by unplugging it
  - b. An inline switchable breakout box available that allows disconnection of each TPS signal.
- IC.4.4.7 The TPS signals must be sent directly to the throttle controller using an analogue signal or via a digital data transmission bus such as CAN or FlexRay. Any failure of the TPSs or TPS wiring must be detectable by the controller and must be treated like implausibility.
- IC.4.4.8 When an analogue signal is used, the TPSs will be considered to have failed when they achieve an open circuit or short circuit condition which generates a signal outside of the normal operating range, for example  $<0.5\text{ V}$  or  $>4.5\text{ V}$ . The circuitry used to evaluate the sensor must use pull down or pull up resistors to ensure that open circuit signals result in a failure being detected.
- IC.4.4.9 When any kind of digital data transmission is used to transmit the TPS signal,
  - a. The FMEA study must contain a detailed description of all the potential failure modes that can occur, the strategy that is used to detect these failures and the tests that have been conducted to prove that the detection strategy works.
  - b. The failures to be considered must include but are not limited to the failure of the TPS, TPS signals being out of range, corruption of the message and loss of messages and the associated time outs.

#### **IC.4.5 Accelerator Pedal Position Sensor - APPS**

Refer to **T.6.2** for specific requirements of the APPS

#### **IC.4.6 Brake System Encoder - BSE**

Refer to **T.6.3** for specific requirements of the BSE

#### **IC.4.7 Plausibility Checks**

##### **IC.4.7.1 Brakes and Throttle Position**

- a. The power to the electronic throttle must be shut down if the mechanical brakes are actuated and the TPS signals that the throttle is open by more than a permitted amount for more than one second.
- b. An interval of one second is allowed for the throttle to close (return to idle). Failure to achieve this within the required interval must result in immediate shut down of fuel flow and the ignition system.
- c. The permitted relationship between BSE and TPS may be defined by the team using a table, but the functionality must be demonstrated at Technical Inspection.

#### IC.4.7.2 Throttle Position vs Target

- a. The power to the electronic throttle must be immediately shut down, if throttle position differs by more than 10% from the expected target TPS position for more than one second.
- b. An interval of one second is allowed for the difference to reduce to less than 10%, failure to achieve this within the required interval must result in immediate shut down of fuel flow and the ignition system.
- c. An error in TPS position and the resultant system shutdown must be demonstrated at Technical Inspection.

IC.4.7.3 The electronic throttle and fuel injector/ignition system shutdown must remain active until the TPS signals indicate the throttle is at or below the unpowered default position for at least one second.

#### IC.4.8 Brake System Plausibility Device (BSPD)

IC.4.8.1 A standalone nonprogrammable circuit must be used that will check for any of the following conditions:

- a. Both of the following for more than one second:
  - Hard braking (for example  $>0.8$  g deceleration but without locking the wheels)
  - Throttle greater than 10% open
- b. Loss of signal from the braking sensor(s)
- c. Loss of signal from the throttle sensor(s)
- d. Removal of power from the BSPD circuit

IC.4.8.2 When any of the above conditions exist, the following must happen:

- Shut off power to the electronic throttle
- Shut off fuel flow
- Close the throttle to the idle position

IC.4.8.3 The BSPD may only be reset by power cycling the Primary Master Switch.

IC.4.8.4 This device must be provided in addition to the plausibility checks which are carried out in the ETC which interprets the drivers throttle request and controls the engine throttle position.

IC.4.8.5 The team must devise a test to prove these required functions during Technical Inspection.

*It should be possible to achieve this by sending an appropriate signal to the nonprogrammable circuit that represents a throttle position of more than 10% while pressing the brake pedal to a position or with a force that represents hard braking.*

### IC.5 FUEL AND FUEL SYSTEM

#### IC.5.1 General

IC.5.1.1 The fuel system must be designed so that:

- a. The fuel tank is capable of being filled to capacity without manipulating the tank or the vehicle in any manner.
- b. During refueling 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) are prevented.

- c. Spillage during refueling cannot contact the driver position, exhaust system, hot engine parts, or the ignition system.

#### **IC.5.2 Fuel**

- IC.5.2.1 Vehicles must be operated with the fuels provided by the organizer at the competition.
- IC.5.2.2 Fuels provided are expected to be Gasoline and E85. Consult the individual competition websites for fuel specifics and other information.
- IC.5.2.3 No agents other than the provided fuel and air may be induced into the combustion chamber.

#### **IC.5.3 Fuel System Location**

- IC.5.3.1 The Fuel System must meet **IC.1.2**
- IC.5.3.2 In side view any portion of the fuel system must not project below the lower surface of the chassis
- IC.5.3.3 All fuel tanks must be shielded from side or rear impact collisions.
  - a. Any fuel tank which is located laterally outside the Side Impact Structure must be shielded by structure built per **T.2.26 / T.2.34**
  - b. Any portion of the fuel system that is less than 350 mm above the ground, and all parts of the fuel tank, must be within the Primary Structure.
- IC.5.3.4 A firewall must separate the fuel tank from the driver, per **T.3.5**

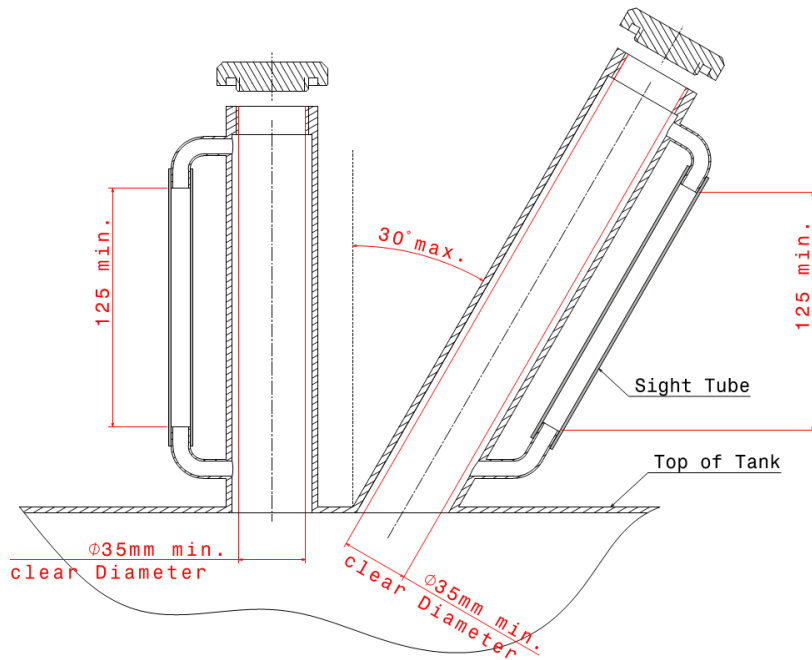
#### **IC.5.4 Fuel Tanks**

- IC.5.4.1 The fuel tank is defined as that part of the fuel containment device that is in contact with the fuel.
- IC.5.4.2 Fuel tanks made of a rigid material must:
  - a. Be securely attached to the vehicle structure with mountings that allow some flexibility such that chassis flex cannot unintentionally load the fuel tank.
  - b. Not be used to carry any structural loads; from roll hoops, suspension, engine or gearbox mounts
- IC.5.4.3 Any fuel tank that is made from a flexible material, for example a bladder fuel cell or a bag tank:
  - a. Must be enclosed within a rigid fuel tank container which is securely attached to the vehicle structure.
  - b. The fuel tank container may be load carrying
- IC.5.4.4 Any size fuel tank may be used.
- IC.5.4.5 The fuel system must have a provision for emptying the fuel tank if required.
- IC.5.4.6 The fuel tank, by design, must not have a variable capacity.

#### **IC.5.5 Fuel Tank Filler Neck & Sight Tube**

- IC.5.5.1 All fuel tanks must have a filler neck which must be:
  - a. Minimum 35 mm inner diameter at any point between the fuel tank and the fuel filler cap
  - b. Minimum 125 mm vertical height above the top level of the fuel tank
  - c. Angled no more than 30° from the vertical

- IC.5.5.2 The fuel filler neck must be accompanied by a clear fuel resistant sight tube for reading the fuel level which must be:
- Visible vertical height: 125 mm minimum
  - Inside diameter: 6 mm minimum
  - Above the top surface of the fuel tank
- IC.5.5.3 A clear filler neck tube may be used as a sight tube, subject to approval by a Rules Question or technical inspectors at the event.



- IC.5.5.4 Fuel Level Line - A permanent, non movable 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, and before and after the Endurance Test to measure the amount of fuel used during the Endurance Event.*
- IC.5.5.5 The sight tube and fuel level line must be clearly visible to two individuals (one to fill the tank, the other to visually verify fill) without the need of assistance (artificial lighting, magnifiers, etc) or the need to remove any parts (body panels, etc).
- IC.5.5.6 The individual filling the tank must have complete direct access to the filler neck opening with a standard two gallon gas can assembly.
- The gas can is at least 25 cm wide x 25 cm deep x 35 cm high, with a 25 cm spout at the top*
- IC.5.5.7 The filler neck must have a fuel cap that can withstand severe vibrations or high pressures such as could occur during a vehicle rollover event
- IC.5.6 Tank Filling Requirement**
- IC.5.6.1 During fueling or refueling the vehicle may only be touched by the fuel crew and officials.
- IC.5.6.2 The tank will be filled to the fill line, or if a filling system is used, to the automatic stop point.
- IC.5.6.3 If, for any reason, the fuel level changes after the team have moved the vehicle, then no additional fuel will be added, unless fueling after Endurance, see **D.12.2.5**

### IC.5.7 Venting Systems

- IC.5.7.1 Venting systems for the fuel tank and fuel delivery system must be designed such that fuel cannot spill during hard cornering or acceleration.
- IC.5.7.2 All fuel vent lines must be equipped with a check valve to prevent fuel leakage when the tank is inverted.
- IC.5.7.3 All fuel vent lines must exit outside the bodywork.

### IC.5.8 Fuel Lines

- IC.5.8.1 Fuel lines must be securely attached to the vehicle and/or engine.
- IC.5.8.2 All fuel lines must be shielded from possible rotating equipment failure or collision damage.
- IC.5.8.3 Plastic fuel lines between the fuel tank and the engine (supply and return) are prohibited.
- IC.5.8.4 Any rubber fuel line or hose used must meet the following:
  - a. The components over which the hose is clamped must have annular bulb or barbed fittings to retain the hose
  - b. Clamps specifically designed for fuel lines must be used.  
These clamps have three features: a full 360° wrap, a nut and bolt system for tightening, and rolled edges to prevent the clamp cutting into the hose
- IC.5.8.5 Worm gear type hose clamps must not be used on any fuel line.

## IC.6 FUEL INJECTION

### IC.6.1 Low Pressure Injection (LPI)

Low Pressure fuel injection systems are those functioning at a pressure below 10 Bar. Most Port Fuel Injected (PFI) fuel systems are low pressure.

- IC.6.1.1 Any Low Pressure flexible fuel lines must be either:
  - Metal braided hose with either crimped on or reusable, threaded fittings
  - Reinforced rubber hose with some form of abrasion resistant protection
- IC.6.1.2 Fuel rail and mounting requirements:
  - a. Unmodified OEM Fuel Rails are acceptable, regardless of material.
  - b. Non OEM fuel rails made from plastic, carbon fiber or rapid prototyping flammable materials are prohibited.
  - c. The fuel rail must be securely attached to the manifold, engine block or cylinder head with brackets and mechanical fasteners.  
Hose clamps, plastic ties, or safety wires do not meet this requirement.
  - d. Threaded fasteners used to secure the fuel rail are **Critical Fasteners**, see **T.10.2** and **T.10.3**

### IC.6.2 High Pressure Injection (HPI) / Direct Injection (DI)

- IC.6.2.1 Definitions
  - a. High Pressure fuel systems - those functioning at 10 Bar pressure or above
  - b. Direct Injection fuel systems - where the injection occurs directly into the combustion system



*Direct Injection systems often utilize a low pressure electric fuel pump and high pressure mechanical “boost” pump driven off the engine.*

- c. High Pressure Fuel Lines - those between the boost pump and injectors
- d. Low Pressure Fuel Lines - from the electric supply pump to the boost pump

IC.6.2.2 All High Pressure Fuel Lines must:

- a. Be stainless steel rigid line or Aeroquip FC807 smooth bore PTFE hose with stainless steel reinforcement and visible Nomex tracer yarn. Equivalent products may be used with prior approval.
- b. Not incorporate elastomeric seals
- c. Be rigidly connected every 100 mm by mechanical fasteners to structural engine components such as cylinder heads or block

IC.6.2.3 Any Low Pressure Fuel Lines must be either:

- a. Metal braided hose with either crimped on or reusable, threaded fittings
- b. Reinforced rubber hose with some form of abrasion resistant protection

IC.6.2.4 Fuel rail mounting requirements:

- a. The fuel rail must be securely attached to the engine block or cylinder head with brackets and mechanical fasteners. Hose clamps, plastic ties, or safety wires do not meet this requirement.
- b. 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 cylinder pressure acting on the injector tip.
- c. Threaded fasteners used to secure the fuel rail are **Critical Fasteners**, see **T.10.2** and **T.10.3**

IC.6.2.5 High Pressure Fuel Pump – must be rigidly mounted to structural engine components such as the cylinder head or engine block.

IC.6.2.6 Pressure Regulator – must be fitted between the High Pressure 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.

## **IC.7 EXHAUST AND NOISE CONTROL**

### **IC.7.1 Exhaust Protection**

IC.7.1.1 The exhaust system must be separated from any of the following components by means described in **T.3.3.4**:

- a. Flammable materials, including the fuel and fuel system, the oil and oil system
- b. Thermally sensitive components, including brake lines, composite materials, and batteries

### **IC.7.2 Exhaust Outlet**

IC.7.2.1 The exhaust must be routed so that the driver is not subjected to fumes at any speed considering the draft of the vehicle

IC.7.2.2 The exhaust outlet(s) must be:

- a. No more than 45 cm behind the centerline of the rear axle
- b. No more than 60 cm above the ground.

IC.7.2.3 Any exhaust components (headers, mufflers, etc.) that protrude from the side of the body in front of the Main Hoop must be shielded to prevent contact by persons approaching the vehicle or a driver exiting the vehicle

IC.7.2.4 Use of any fibrous/absorbent material, (such as header wrap), on the outside of an exhaust manifold or exhaust system is prohibited.

### **IC.7.3 Variable Exhaust**

IC.7.3.1 Adjustable tuning or throttling devices are permitted.

IC.7.3.2 Manually adjustable tuning devices must require tools to change

IC.7.3.3 Refer to **IN.10.2** for additional requirements during the Noise Test

### **IC.7.4 Connections to Exhaust**

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.

### **IC.7.5 Noise Level and Testing**

IC.7.5.1 The vehicle must remain below the permitted sound level at all times.

IC.7.5.2 Sound level will be verified during Technical Inspection, refer to **IN.10**

## **IC.8 ELECTRICAL**

### **IC.8.1 Starter**

Each vehicle must start the engine using an onboard starter at all times

### **IC.8.2 Batteries**

Refer to **T.11.1** for specific requirements of GLV batteries

### **IC.8.3 Voltage Limit for IC**

IC.8.3.1 The maximum permitted voltage between any two electrical connections is 60 V DC or 25 V AC RMS.

IC.8.3.2 This voltage limit does not apply to the following systems:

- High Voltage systems for ignition
- High Voltage systems for injectors
- Voltages internal to OEM charging systems designed for <60 V DC output.

### **IC.8.4 Master Switches**

IC.8.4.1 Each vehicle must have two Master Switches:

- Primary Master Switch
- Cockpit Mounted Master Switch

IC.8.4.2 Actuating either Master Switch must:

- a. Stop the engine
- b. Disable any alternator field wire

IC.8.4.3 The Primary Master Switch must meet the following:

- a. Disable power to ALL electrical circuits, including the battery, alternator, lights, fuel pump(s), ignition and electrical controls.
- b. Be direct acting, not act through a relay or logic.
- c. All battery current must flow through this switch
- d. Be located on the right side of the vehicle, in proximity to the Main Hoop, at the driver's shoulder height
- e. Be easily actuated from outside the vehicle
- f. Be of the rotary mechanical type. A removable key may only be removable in the electrically open position.
- g. Not be easily removable or mounted onto removable body work.
- h. Mounted so that the rotary axis of the key is near horizontal and across the vehicle
- i. The ON position must be in the horizontal position and must be marked accordingly.
- j. The OFF position must be clearly marked

IC.8.4.4 The Cockpit Mounted Master Switch must meet the following:

- a. Disable power to the ignition and fuel pump(s) in the OFF position
- b. May act through a relay
- c. Located within easy reach of the belted in driver, alongside the steering wheel, and unobstructed by the steering wheel or any other part of the vehicle
- d. Must be a push-pull or push-rotate emergency switch where pushing the button is the OFF position
- e. Have a minimum diameter of 24 mm.

IC.8.4.5 Both Master Switches must have the international electrical symbol consisting of a red spark on a white edged blue triangle affixed in close proximity.

## EV - ELECTRIC VEHICLES

### EV.1 GENERAL REQUIREMENTS

#### EV.1.1 Definitions

- EV.1.1.1 **High Voltage (HV) System** - circuit with a potential difference where the nominal operation voltage is greater than 60V DC or 25V AC RMS
- EV.1.1.2 **Low Voltage (LV)** - any voltage below and including 60 V DC or 25 V AC RMS
- EV.1.1.3 **Tractive System** - every part that is electrically connected to the motor(s) and Tractive System Accumulators.
- EV.1.1.4 **Grounded Low Voltage (GLV)** - every electrical part that is not part of the Tractive System.
- EV.1.1.5 **Accumulator** - all the battery cells or super capacitors that store the electrical energy to be used by the Tractive System.

#### EV.1.2 Overall Requirements

- EV.1.2.1 The Tractive System:
    - a. Is a High Voltage System
    - b. Must be completely isolated from the chassis and any other conductive parts of the vehicle
    - c. Must contain components that are rated for the maximum Tractive System voltage
  - EV.1.2.2 The GLV system must be:
    - a. A Low Voltage system
    - b. Grounded to the chassis
    - c. Powered up using a specified procedure before it is possible to activate the Tractive System, see [EV.6.11](#)
  - EV.1.2.3 Specific requirements of GLV batteries are given in [T.11.1](#)
  - EV.1.2.4 Separation of Tractive System and GLV system:
    - a. The entire Tractive System and GLV system must be completely galvanically separated.
    - b. The border between Tractive and GLV system is the galvanic isolation between both systems. Therefore, some components, such as the motor controller, may be part of both systems.
  - EV.1.2.5 The Tractive System motor(s) must be connected to the Accumulator through a motor controller. No direct connections between motor(s) and Accumulator.
  - EV.1.2.6 Regenerating energy is allowed and unrestricted when the vehicle speed is > 5 km/hr.
  - EV.1.2.7 Supplying power to the motor such that the vehicle is driven in reverse is prohibited.
- #### EV.1.3 Power and Voltage Limitation
- EV.1.3.1 The maximum power drawn from the Accumulator must not exceed **80 kW**.
  - EV.1.3.2 The maximum permitted voltage that may occur between any two points must not exceed **600 V DC**
- #### EV.1.4 Energy Meter
- EV.1.4.1 All electric vehicles must run with the Energy Meter provided by the organizer.
  - EV.1.4.2 The Energy Meter must be installed in an easily accessible location

- EV.1.4.3 Power and voltage limits will be checked by evaluating the Energy Meter data.  
Energy is calculated as the time integrated value of the measured voltage multiplied by the measured current logged by the Energy Meter.
- EV.1.4.4 A violation is defined as using more than the specified maximum power OR exceeding the maximum voltage EITHER:
- Continuously for 100 ms or more
  - After a moving average over 500 ms is applied
- EV.1.4.5 Non availability of Energy Meter data due to the team's fault, tampering, or attempting to tamper with the Energy Meter will be treated as a violation.
- EV.1.4.6 Tampering, or attempting to tamper may result in Disqualification (DQ)
- EV.1.4.7 Violations during the Acceleration, Skidpad, Autocross Events:
- Each violation will Disqualify (DQ) the best run of the team
  - Multiple violations will DQ multiple runs, ex two violations DQ the two best runs
- EV.1.4.8 Violations during the Endurance event:
- Each violation will receive a 60 second penalty
- EV.1.4.9 Repeated violations may void Inspection Approval or receive additional penalties up to and including Disqualification.
- EV.1.4.10 The respective data of each run in which a team has a violation and the resulting decision may be made public.

## EV.2 COMPONENTS

### EV.2.1 Motors

- EV.2.1.1 Only electrical motors are allowed. Any type of electrical motor is allowed. The number of motors is not limited.
- EV.2.1.2 The rotating part of the motor must be contained within a structural casing.
- EV.2.1.3 The motor casing may be the original motor casing, a team built motor casing or the original casing with additional material added to achieve the minimum required thickness.
- Minimum thickness is 3.0 mm (0.120 inch) for aluminum alloy 6061-T6. If lower grade aluminum alloy is used, then the material must be thicker to provide an equivalent strength.
  - Minimum thickness 2.0 mm (0.080 inch) for steel
- EV.2.1.4 If the motor casing rotates around the stator, or the motor case is perforated, then a scatter shield must be included around the motor. This scatter shield must be 1.0mm (0.040 inch) minimum thickness and made from aluminum alloy 6061-T6 or steel.

### EV.2.2 Accelerator Pedal Position Sensor - APPS

- EV.2.2.1 Refer to **T.6.2** for specific requirements of the APPS
- EV.2.2.2 Drive by wire control of wheel torque is permitted.
- EV.2.2.3 Any algorithm or electronic control unit that can manipulate the APPS signal, for example for vehicle dynamic functions such as traction control, may only lower the total driver requested torque and must not increase it.

### **EV.2.3 Brake System Encoder - BSE**

- EV.2.3.1 Refer to **T.6.3** for specific requirements of the BSE
- EV.2.3.2 The BSE may be used to control regenerative braking

### **EV.2.4 APPS / Brake Pedal Plausibility Check**

- EV.2.4.1 The power to the motors must be immediately shut down completely, if the mechanical brakes are actuated and the APPS signals more than 25% pedal travel at the same time. This must be demonstrated when the motor controllers are under load.
- EV.2.4.2 The motor power shut down must remain active until the APPS signals less than 5% pedal travel, whether the brakes are still actuated or not.

## **EV.3 TRACTIVE SYSTEM - ENERGY STORAGE**

### **EV.3.1 Tractive System Accumulator Container – General Requirements**

- EV.3.1.1 All cells or super capacitors which store the Tractive System energy will be built into accumulator segments and must be enclosed in (an) accumulator container(s).

- EV.3.1.2 Each accumulator segment must contain:

- Maximum static voltage of less than 120 V DC
- Maximum energy of 6 MJ

*The contained energy of a stack is calculated by multiplying the maximum stack voltage with the nominal capacity of the used cell(s).*

*Splitting the accumulator into its segments is intended to reduce the risks associated with working on the accumulator.*

- EV.3.1.3 Each accumulator container must be removable from the vehicle while still remaining rules compliant.
- EV.3.1.4 If spare accumulators are to be used then they all must be of the same size, weight and type as those that are replaced.

### **EV.3.2 Tractive System Accumulator Container - Electrical Configuration**

- EV.3.2.1 If the container is made from an electrically conductive material:

- a. The poles of the accumulator segment(s) and/or cells must be isolated from the inner wall of the accumulator container with an insulating material that is rated for the maximum tractive system voltage.
- b. All conductive surfaces on the outside of the container must have a low resistance connection to the GLV system ground, see **EV.6.3**
- c. Special care must be taken to ensure that conductive penetrations, such as mounting hardware, are adequately protected against puncturing the insulating barrier.

- EV.3.2.2 Every accumulator container must contain at least one fuse and at least two accumulator isolation relays, see **EV.5** and **EV.8.1**.

- EV.3.2.3 Each segment must be electrically insulated by the use of suitable material between the segments in the container and on top of the segment to prevent arc flashes caused by inter segment contact or by parts/tools accidentally falling into the container during maintenance for example. Air is not considered to be a suitable insulation material in this case.

- EV.3.2.4 All Tractive System connectors outside of a housing must include a pilot contact/interlock line which activates the shutdown.
- EV.3.2.5 Contacting / interconnecting the single cells by soldering in the high current path is prohibited. Soldering wires to cells for the voltage monitoring input of the AMS is allowed, these wires are not part of the high current path.
- EV.3.2.6 Every wire used in an accumulator container, no matter whether it is part of the GLV or Tractive System, must be rated to the maximum Tractive System voltage.
- EV.3.2.7 Each accumulator container must have a prominent indicator, such as an LED that will illuminate, whenever a voltage greater than 60 V DC is present at the vehicle side of the AIRs.
  - a. The voltage being present at the connectors must directly control the indicator using hard wired electronics (no software control is permitted). Activating the indicator with the control signal which closes the AIRs is not sufficient.
  - b. The accumulator voltage indicator must always work, even if the container is disconnected from the GLVS or removed from the vehicle.

### **EV.3.3 Tractive System Accumulator Container – Maintenance Plugs**

- EV.3.3.1 Maintenance plugs must allow electrical separation of the internal cell segments such that
  - a. The separated cell segments meet voltage and energy limits of **EV.3.1.2**
  - b. The separation must affect both poles of the segment
- EV.3.3.2 This separation method must be used whenever the accumulator containers are opened for maintenance and whenever accumulator segments are removed from the container.
- EV.3.3.3 Maintenance plugs must require the physical removal or separation of a component. Contactors or switches are not acceptable maintenance plugs.
- EV.3.3.4 Maintenance plug physical requirements:
  - a. Must not be possible to connect in any way other than the design intended configuration
  - b. Must not require tools to install or remove
  - c. Must include a positive locking feature which prevents the plug from unintentionally becoming loose
  - d. Must be nonconductive on surfaces that do not provide any electrical connection

### **EV.3.4 Accumulator Isolation Relay(s) (AIR)**

- EV.3.4.1 At least two isolation relays must be installed in every accumulator container.
- EV.3.4.2 The Accumulator Isolation Relays must open both poles of the accumulator.
- EV.3.4.3 If these relays are open, no HV may be present outside of the accumulator container.
- EV.3.4.4 The isolation relays must be of a “normally open” type.
- EV.3.4.5 The fuse protecting the accumulator tractive system circuit must have a rating lower than the maximum switch off current of the Accumulator Isolation Relays.

## **EV.4 TRACTIVE SYSTEM - MECHANICAL**

### **EV.4.1 General Accumulator**

- EV.4.1.1 All accumulator containers must lie within the Primary Structure (**T.2.1.11**).
- EV.4.1.2 Accumulator container(s) must be built of mechanically robust material.
- EV.4.1.3 The container material must be fire resistant according to UL94-V0, FAR25 or equivalent.

- EV.4.1.4 All accumulator containers must be protected from side or rear impact by structure equivalent to that per **T.2.26** / **T.2.34** and must be included in the SES. The container must not form part of the equivalent structure.
- EV.4.1.5 All accumulator containers must be designed to withstand forces from deceleration in all directions
- EV.4.1.6 The accumulator containers and mounting systems are subject to approval during SES review and Technical Inspection.
- EV.4.1.7 A sticker according to ISO 7010-W012 (triangle with black lightning bolt on yellow background) with triangle side length of at least 100mm and the text “Always Energized” must be applied on every accumulator container.
- The sticker must also contain the text “High Voltage” if the voltage is more than 60 V DC or 25 V AC.

#### **EV.4.2 Accumulator Container - Design**

- EV.4.2.1 Teams may use the following design guidelines or utilize a standard accumulator container.
- Design of the accumulator container must be documented in the SES.
  - Documentation includes materials used, drawings/images, fastener locations, cell/segment weight and cell/segment position.
- EV.4.2.2 Accumulator container design guidelines:
- The floor or bottom of the accumulator container must be constructed of steel 1.25 mm (0.049 inch) minimum thickness or aluminum 3.2 mm (0.125 inch) minimum thickness.
  - The external vertical walls must be constructed of steel 0.9mm (0.035 inch) minimum thickness or aluminum 2.3 mm (0.090 inch) minimum thickness.
  - Internal vertical walls separating cells and/or segments must be:
    - Minimum of 75 percent of the height of the external vertical walls
    - Constructed of steel 0.9 mm (0.035 inch) minimum thickness or aluminum 2.3 mm (0.090 inch) minimum thickness
  - Covers and lids must be constructed of steel 0.9 mm (0.035 inch) minimum thickness or aluminum 2.3 mm (0.090 inch) minimum thickness.
  - The floor and walls of the accumulator container must be joined by welds and/or fasteners. Any fasteners must be 6 mm or 1/4” minimum diameter **Critical Fasteners**, see **T.10.2** and **T.10.3**
  - Internal vertical walls divide the accumulator container into “sections”
    - A maximum of 12 kg is allowed in any section of the accumulator container
    - Fastened connections between the floor and any vertical wall of each section must have at least two fasteners.
    - Fastened connections between internal vertical walls and external vertical walls must be located in the top half of the internal vertical wall.
    - Sections containing 8 kg or less must have a minimum of two fasteners connecting any two vertical walls.
    - Sections containing between 8 kg and 12 kg must have a minimum of three fasteners connecting any two vertical walls.



*Example: An accumulator container with 2 internal walls has 3 sections. Each section contains less than 8 kg. Therefore 18 floor to wall joints are required in total with at least two fasteners per joint.*

- g. Folding or bending plate material to create flanges or to eliminate joints between walls is recommended.
- h. Covers and lids must be fastened with a minimum of one fastener for each external vertical wall per section.
- i. Alternate materials are allowed with proof of equivalency per **T.2.31**. Proof of equivalency must be documented in the SES and test samples must be available at technical inspection.
- j. Substituting one 6 mm or 1/4" bolt with two 5 mm or #12 bolts or three 4 mm or #10 bolts is allowed.

*The accumulator design guidelines are intended to generate a structure that does not fail under 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)*

EV.4.2.3 The cells and/or segments must be appropriately secured against moving inside the container.

- a. This mounting system 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)
- b. Calculations and/or tests proving these requirements are met must be included in the SES.
- c. Any fasteners must be 6 mm or 1/4" minimum diameter **Critical Fasteners**, see **T.10.2** and **T.10.3**

EV.4.2.4 The accumulator segments contained within the accumulator must be separated by an electrically insulating and fire resistant barrier (according to UL94-V0, FAR25 or equivalent)

- Documentation of segment separation must be provided in the ESF.

EV.4.2.5 Composite accumulator containers must satisfy the following requirements:

- a. Data obtained from laminate perimeter shear strength and 3 point bending tests (**T.2.31**) must be used for any strength calculations.
- b. The calculations and physical test results must be included in the SES.

### **EV.4.3 Accumulator Container – Attachment**

EV.4.3.1 Accumulator containers must be attached to the Major Structure of the chassis

EV.4.3.2 Attachment of the accumulator container must be documented in the SES

EV.4.3.3 Any fasteners used to attach accumulator container(s) are **Critical Fasteners**, see **T.10.2** and **T.10.3**

EV.4.3.4 Each attachment point to a composite accumulator container requires steel backing plates with a thickness of 2 mm minimum.

Alternate materials may be used for backing plates if equivalency is proven

EV.4.3.5 Teams may justify the accumulator container attachment using either:

- Corner Attachments and Analysis per **EV.4.3.6**
- Load Based Analysis per **EV.4.3.7**

EV.4.3.6 Accumulator Attachment – Corner Attachments

- a. At least eight attachments are required for any configuration.
  - One attachment for each corner of a rectangular arrangement of multiple accumulator segments
  - More than the minimum number of fasteners may be required for non rectangular arrangements

Examples: an extruded L shape would require attachments at 10 convex corners (the corners at the inside of the L are not convex); an extruded hexagon would require 12 attachments

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

EV.4.3.7 Accumulator Attachment – Load Based

- a. The number of attachment points that must be used depends on the total mass of the container:

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

- b. Any brackets which attach the accumulator container to the chassis must:
  - Be made of steel 1.6 mm (0.063 inch) minimum thickness or aluminum 4 mm (0.157 inch) minimum thickness
  - Have gussets to carry bending loads.

- c. Each attachment point, including any brackets, backing plates and inserts, must be able to withstand 15 kN in any direction

#### **EV.4.4 Accumulator Container – Holes and Venting**

EV.4.4.1 Holes, both internal and external, in the container are only allowed for the wiring harness, ventilation, cooling or fasteners. External holes must be sealed per **EV.6.5.1** and **EV.6.5.2**

EV.4.4.2 The container must be completely closed at all times when mounted to the vehicle and also when dismantled from the vehicle without the need to install extra protective covers.

Openings for ventilation should be of a reasonable size, completely open sidepods containing accumulators are not allowed.

EV.4.4.3 Any accumulators that may vent an explosive gas must have a ventilation system or pressure relief valve to prevent the vented gas from reaching an explosive concentration.

EV.4.4.4 Every accumulator container which is completely sealed must have a pressure relief valve to prevent high pressure in the container.

### **EV.5 TRACTIVE SYSTEM - MONITORING**

#### **EV.5.1 Accumulator Management System (AMS)**

EV.5.1.1 Each accumulator must be monitored by an Accumulator Management System whenever the Tractive System is active or the accumulator is connected to a charger.

*For battery systems this is generally referred to as a battery management system (BMS) however other electrical energy storage systems are allowed and therefore AMS will be the terminology used in this document.*

EV.5.1.2 The AMS must continuously measure the cell voltage of every cell, in order to keep the cells inside the allowed minimum and maximum cell voltage levels stated in the cell data sheet. If single cells are directly connected in parallel, only one voltage measurement is needed.

EV.5.1.3 The AMS must continuously measure the temperatures of critical points of the accumulator to keep the cells below the allowed maximum cell temperature limit stated in the cell data sheet or 60°C, whichever is lower.

EV.5.1.4 Cell temperature must be measured at the negative terminal of the respective cell and the sensor used must be in direct contact with either the negative terminal or its busbar. If the sensor is on the busbar, it must be less than 10 mm away from the cell terminal.

*A special device may be used to check the conformance to the temperature limits. Please check the Event Website for further information.*

EV.5.1.5 For centralized AMS systems (two or more cells per AMS board), all voltage sense wires to the AMS must be protected by 'fusible link wires' or fuses so that any the sense wiring cannot exceed its current carrying capacity in the event of a short circuit. The fusing must occur in the conductor, wire or PCB trace which is directly connected to the cell tab.

EV.5.1.6 Any distributed AMS system (one cell measurement per board) where the sense wire connections at the board are <25 mm does not need additional fusing if the board is protected from short circuit and the connection to the AMS is also protected. If these conditions are not met, then the positive cell terminal must be protected with a fusible link wire.

- EV.5.1.7 Where required, the fusible link wire may form the entire sense wire or a section of the sense wire.
- If the fusible link wire forms a section of the sense wire, then the gauge of the fusible link wire must be sized appropriately to protect the remaining part of the voltage sense wire from currents above its continuous current rating.
  - If any of these fusible link wires are blown or if the connection to measure the cell voltage is interrupted in any other way, then this must be detected by the AMS and must be reported as a critical voltage problem.

*If a 'fusible link wire' is required and the resistance of the connection from the AMS board to the cell for the voltage measurement is too high, then this can affect the AMS voltage measurement especially during cell balancing and charging, therefore an appropriately large gauge wire would have to be used.*

*A fusible link wire works such that when an over current event occurs, the conductor within the link is melted while the ensuing flame and spark is contained within the link's insulation. Specific products can be purchased which perform this function.*

- EV.5.1.8 For lithium based cells,
- The temperature of at least 20% of the cells must be monitored by the AMS.
  - The monitored cells must be equally distributed within the accumulator container(s).
- EV.5.1.9 It is acceptable to monitor multiple cells with one sensor, if **EV.5.1.4** is met for all cells sensed by the sensor.

*Every cell temperature should be monitored*

- EV.5.1.10 The AMS must shutdown the tractive system by opening the AIRs, if critical voltage or temperature values according to the cell manufacturer's datasheet and taking into account the accuracy of the measurement system are detected.
- EV.5.1.11 If the AMS does perform a shutdown, then a red LED marked AMS must light up in the cockpit

## **EV.6 TRACTIVE SYSTEM - GENERAL REQUIREMENTS**

### **EV.6.1 Separation of Traction System and Grounded Low Voltage System**

- EV.6.1.1 The layout of electrical devices designed by the team must be documented accurately in the ESF.
- EV.6.1.2 There must be no connection between the frame of the vehicle (or any other conductive surface that might be inadvertently touched by a crew member or spectator), and any part of any Tractive System circuits.
- EV.6.1.3 Tractive System and GLV circuits must be physically segregated such that they are not run through the same conduit or connector, except for interlock circuit connections.
- EV.6.1.4 GLV systems must not be included in the accumulator container except for required purposes. Exceptions include the AIRs, HV DC/DC converters, the AMS and the IMD.
- The galvanic isolation of any LV wiring within the accumulator container, and where appropriate elsewhere, must be described within the ESF.

- EV.6.1.5 Where both Tractive System and GLV are present within an enclosure, they must EITHER:
- Be separated by insulating barriers made of moisture resistant, UL recognized or equivalent insulating materials rated for 150° C or higher (such as Nomex based electrical insulation)
  - Maintain the following spacing through air, or over a surface (similar to those defined in UL1741):

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

EV.6.1.6 Spacing must be clearly defined. Components and cables capable of movement must be positively restrained to maintain spacing.

EV.6.1.7 If Tractive System and GLV are on the same circuit board:

- They must be on separate, clearly defined areas of the board
- The Tractive System and GLV areas must be clearly marked on the PCB.
- Required spacing related to the spacing between traces / board areas are as follows:

Voltage	Over Surface	Thru Air (cut in board)	Under Conformal Coating
0-50 V DC	1.6 mm	1.6 mm	1 mm
50-150 V DC	6.4 mm	3.2 mm	2 mm
150-300 V DC	9.5 mm	6.4 mm	3 mm
300-600 V DC	12.7 mm	9.5 mm	4 mm

- If integrated circuits are used such as opto-couplers which are rated for the respective maximum tractive system voltage, but do not fulfill the required spacing, then they may still be used and the given spacing do not apply.

EV.6.1.8 Teams must be prepared to demonstrate spacing on team built equipment. Information on this must be included in the Electrical System Form (**EV.10.1**).

For inaccessible circuitry, spare boards or appropriate photographs must be available for inspection.

EV.6.1.9 All connections to external devices such as laptops from a Tractive System component must include galvanic isolation.

## EV.6.2 Positioning of Tractive System Parts

EV.6.2.1 All parts belonging to the Tractive System (other than outboard wheel motors) including cables and wiring must be contained within the Primary Structure Envelope and/or an additional envelope of tubing which meets the minimum specification defined per **T.2.5** OR **T.2.6** OR **T.2.7** OR **T.2.34** OR equivalent, such that they are protected against being damaged in case of a crash or rollover situation.

EV.6.2.2 Outboard wheel motors (where the motor, attendant cables and wiring are outside of the frame) are allowed only if an interlock is added such that the Shutdown Circuit, **EV.7.1**, is activated and the AIRs are opened if the wheel assembly is damaged or knocked off the vehicle. The activation of the Shutdown Circuit must occur before the failure of the TS wiring.

EV.6.2.3 If Tractive System parts are mounted in a position where damage could occur from a rear or side impact (below 350 mm from the ground), for example motors at the rear of the vehicle,

they must be protected by a fully triangulated structure with tubes for “Tractive System Component Protection” – see **T.2.5 OR T.2.6 OR T.2.7 OR T.2.34**.

EV.6.2.4 In side or front view, no part of the Tractive System must project below the lower surface of the frame or the monocoque, whichever is applicable.

EV.6.2.5 Additional regulations apply for accumulators, see **EV.4.1**

### **EV.6.3 Grounding**

EV.6.3.1 All electrically conductive parts of the vehicle (parts made of steel, (anodized) aluminum, any other metal parts, etc.) which are within 100 mm of any tractive system component must have a resistance below 300 mOhms (measured with a current of 1 A) to GLV system ground.

EV.6.3.2 All parts of the vehicle which may become electrically conductive (completely coated metal parts, carbon fiber parts, etc.) which are within 100 mm of any tractive system, must have a resistance below 5 Ohm to GLV system ground.

EV.6.3.3 Electrical conductivity of any part may be tested by checking any point which is likely to be conductive, for example the Driver Harness attachment bolt, but where no convenient conductive point is available then an area of coating may be removed.

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

### **EV.6.4 Tractive System Measuring Points (TSMP)**

The Tractive System Measuring Points will be used to check during Electrical Tech Inspection that the Tractive System is shut down properly in the given time. They are also needed to ensure the isolation of the Tractive System of the vehicle for possible rescue operations after an accident or when work on the vehicle is to be done.

EV.6.4.1 Two TSMP must be installed which are:

- a. Connected to the positive and negative motor controller/inverter supply lines
- b. Next to the master switches
- c. Protected by a nonconductive housing that can be opened without tools
- d. Protected from being touched with bare hands / fingers once the housing is opened

EV.6.4.2 The TSMP must be:

- a. 4 mm shrouded banana jacks rated to an appropriate voltage level
- b. Color: Red
- c. Marked HV+ and HV-

EV.6.4.3 Each TSMP must be secured with a current limiting resistor according to the following table.

Maximum TS Voltage (Vmax)	Resistor Value
Vmax <= 200 V DC	5 kOhm
200 V DC < Vmax <= 400 V DC	10 kOhm
400 V DC < Vmax <= 600 V DC	15 kOhm

EV.6.4.4 Direct measurement of the value of the resistor must be possible during Electrical Tech Inspection.

EV.6.4.5 Fusing of any TSMP is prohibited.

EV.6.4.6 A GLV system ground measuring point must be installed which is:

- a. Connected to GLV system ground
- b. Next to the TSMP
- c. 4 mm shrouded banana jack
- d. Color: Black
- e. Marked GND

#### **EV.6.5 Tractive System Insulation, Wiring and Conduit**

EV.6.5.1 All parts, especially live wires, contacts, etc. of the tractive system must be isolated by nonconductive material or covers to be protected from being touched.

It must not be possible to touch any tractive system connections with a 100 mm long, 6 mm diameter insulated test probe when the tractive system enclosures are in place.

EV.6.5.2 Nonconductive covers must prevent inadvertent human contact with any Tractive System voltage.

- This must include crew members working on or inside the vehicle.
- Covers must be secure and adequately rigid.
- Body panels that must be removed to access other components, etc. are not a substitute for enclosing Tractive System connections.

EV.6.5.3 Tractive system components and containers must be protected from moisture in the form of rain or puddles.

*A rating of IP65 is recommended*

EV.6.5.4 Insulation material that is appropriate for the expected surrounding temperatures must be used and this must have a minimum temperature rating of 90°C. Using only insulating tape or rubber-like paint for insulation is prohibited.

EV.6.5.5 All wires and terminals and other conductors used in the Tractive System:

- a. Must be sized appropriately for the continuous tractive system current
- b. Wires must be marked with wire gauge, temperature rating and insulation voltage rating. A serial number or a norm printed on the wire is sufficient if this serial number or norm is clearly bound to the wire characteristics for example by a data sheet.
- c. The minimum acceptable temperature rating for tractive system cables is 90°C.

Sizing of the conductors for the 'continuous tractive system current' may take account of the RMS or average electrical current that will be used and the anticipated duration of time at maximum electrical current.

EV.6.5.6 All Tractive System wiring must be done to professional standards with appropriately sized conductors and terminals and with adequate strain relief and protection from loosening due to vibration etc.

EV.6.5.7 All Tractive System wiring that runs outside of electrical enclosures

- a. Must either be enclosed in separate orange nonconductive conduit or use an orange shielded cable.
- b. Except in the case where the Tractive System wiring runs in a fully enclosed container, the conduit or shielded cable must be securely anchored at least at each end so that it can withstand a force of 200 N without straining the cable end crimp, and must be

located out of the way of possible snagging or damage. Body work is not sufficient to meet this enclosure requirement.

- c. Any shielded cable must have the shield grounded.

#### EV.6.5.8 All Tractive System connections:

- a. Must be designed so that they use intentional current paths through conductors such as copper or aluminum
- b. Should not rely on steel bolts to be the primary conductor.
- c. Must not include compressible material such as plastic in the stack-up.

EV.6.5.9 Tractive System wiring must be shielded against damage by rotating and / or moving parts.

EV.6.5.10 If external, uninsulated heat sinks are used, they must be properly grounded to the GLV System ground, see **EV.6.3**

EV.6.5.11 Wiring that is not part of the Tractive System must not use orange wiring or conduit.

EV.6.5.12 All electrical connections, including bolts, nuts, and other fasteners, in the high current path of the Tractive System must be secured from unintentional loosening by the use of positive locking mechanisms that are suitable for high temperatures, for example torque prevailing nuts.

*Lock washers and thread locking compounds (Loctite®), DO NOT meet the positive locking requirement. Nyloc nuts do not meet the temperature requirements.*

EV.6.5.13 In the case that a locking Helicoil or an approved positive locking mechanism is required that cannot easily be inspected at Electrical Technical Inspection, information about this item must be included in the ESF.

EV.6.5.14 Custom locking features that prevent fasteners from coming loose may be constructed if they can be seen to be in place and do not rely on the clamping force for the locking feature.

### EV.6.6 Tractive System Enclosures

EV.6.6.1 Every housing or enclosure containing parts of the Tractive System, except motor housings, must be labeled with (a) reasonably sized sticker(s) according to ISO 7010-W012 (triangle with black lightning bolt on yellow background). The sticker must also contain the text “High Voltage” if the voltage is more than 60 V DC or 25 V AC.

EV.6.6.2 If the housing material is electrically conductive or possibly electrically conductive, it must have a low resistance connection to GLV system ground, see **EV.6.3**

### EV.6.7 HV Disconnect (HVD)

EV.6.7.1 It must be possible to disconnect at least one pole of the Tractive System Accumulator by quickly removing an unobstructed and directly accessible element, fuse or connector, in case of (a) stuck Accumulator Isolation Relay(s) for example.

- a. It must be possible to disconnect the HVD without removing any bodywork.
- b. The HVD must be above 350 mm from the ground and easily visible when standing behind the vehicle.
- c. Remote actuation of the HVD through a long handle, rope or wire is not acceptable.

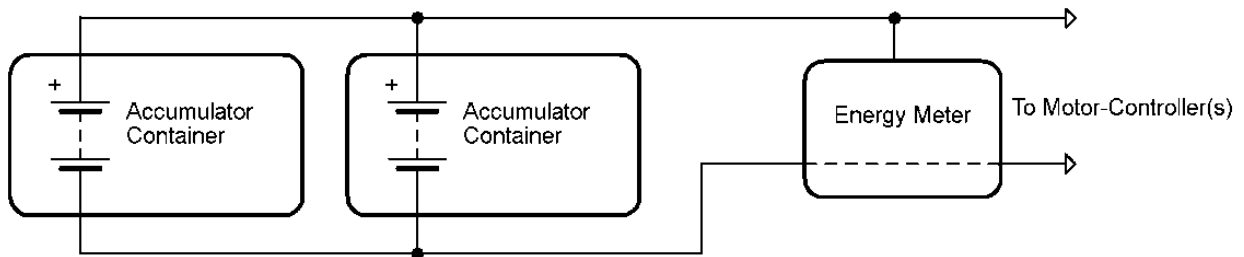
EV.6.7.2 An untrained person must be able to remove the HVD within 10 seconds in ready to race condition. Being able to quickly disconnect the Accumulator(s) from the rest of the tractive system by its connector(s) will satisfy this requirement.



- EV.6.7.3 A dummy connector or similar may be needed to restore the system's isolation.
- EV.6.7.4 The HV Disconnect must be clearly marked with "HVD".
- EV.6.7.5 No tools must be needed to open the HVD.
- EV.6.7.6 An interlock must activate the shutdown circuit and open the AIRs when the HVD is removed

#### EV.6.8 Wiring of the Tractive System Supply

- EV.6.8.1 All accumulator containers must be wired to a single point. They may be wired in series or parallel, but all the power supplying the Tractive System must flow through this single point and must pass the Energy Meter position.
- EV.6.8.2 No further energy storages except for reasonably sized intermediate circuit capacitors are allowed beyond this point.



#### EV.6.9 Pre-Charge and Discharge Circuits

- EV.6.9.1 A circuit that is able to pre charge the intermediate circuit to at least 90% of the current accumulator voltage before closing the second AIR must be implemented.
 

This circuit must be disabled by a deactivated shutdown circuit, see [EV.7.1](#). Therefore, if the shutdown circuit is open, the pre charge circuit must not be able to pre charge the system.
- EV.6.9.2 Any pre charge circuitry must be supplied directly from the TSMS
- EV.6.9.3 It is allowed to pre charge the intermediate circuit for a conservatively calculated time, before closing the second AIR. A feedback via measuring the current intermediate circuit voltage is not required.
- EV.6.9.4 If a discharge circuit is needed to meet [EV.7.2.3](#), it must be designed to handle the maximum discharge current for at least 15 seconds. The calculation proving this must be part of the ESF.
- EV.6.9.5 The discharge circuit must be wired in a way that it is always active whenever the shutdown circuit is open. Furthermore, the discharge circuit must be fail safe such that it still discharges the intermediate circuit capacitors if the HVD has been opened.
- EV.6.9.6 The pre charge and discharge circuits must not be fused.

#### EV.6.10 Tractive System Active Light (TSAL)

- EV.6.10.1 The vehicle must include a Tractive Systems Active Light (TSAL) that must:
  - a. Illuminate whenever the GLVS is energized to indicate the status of the Tractive System
  - b. Be directly controlled by the voltage present within the tractive system using hard wired electronics. Software control is not permitted.
  - c. Not perform any other functions.
- EV.6.10.2 The TSAL may be composed of multiple lights within a single housing

EV.6.10.3 When the voltage outside the accumulator container(s) exceeds 60 V DC or 25 V AC RMS, the TSAL must:

- a. Be Color: Red
- b. Flash continuously with a frequency between 2 Hz and 5 Hz

EV.6.10.4 When the voltage outside the accumulator container(s) is below the voltages listed in EV.6.10.3 above, the TSAL must:

- a. Be Color: Green
- b. Remain continuously illuminated

EV.6.10.5 The TSAL mounting location must:

- a. Be near the Main Hoop at the highest point of the vehicle.
- b. Be mounted lower than the highest point of the Main Hoop.
- c. Be no lower than 150 mm from the highest point of the Main Hoop.
- d. Not allow contact with the driver's helmet in any circumstances.
- e. Not be in proximity to other lights.

EV.6.10.6 The TSAL must be visible:

- a. From every horizontal direction, except small angles which are blocked by the Main Hoop
- b. From a point 1.6 m vertically from ground level, within a 3 m horizontal radius from the TSAL
- c. In direct sunlight

### **EV.6.11 Ready to Drive**

EV.6.11.1 The vehicle is Ready to Drive as soon as the motor(s) will respond to the input of the APPS.

EV.6.11.2 Closing only the shutdown circuit must not set the vehicle to Ready to Drive mode.

EV.6.11.3 Additional actions must be performed by the driver to set the vehicle to Ready to Drive mode, such as pressing a dedicated start button after the Tractive System has been activated.

- One of these actions must include the brake pedal being pressed as Ready to Drive mode is entered.

EV.6.11.4 The vehicle must make a characteristic sound when it is Ready to Drive

EV.6.11.5 The Ready to Drive Sound must be:

- a. Sounded continuously for at least 1 second and a maximum of 3 seconds.
- b. A minimum sound level of 80 dBA, fast weighting.
- c. Easily recognizable. No animal voices, song parts or sounds that could be interpreted as offensive will be accepted.

EV.6.11.6 The vehicle must not make sounds similar to the Ready to Drive sound.

## **EV.7 SHUTDOWN CIRCUIT AND SYSTEMS**

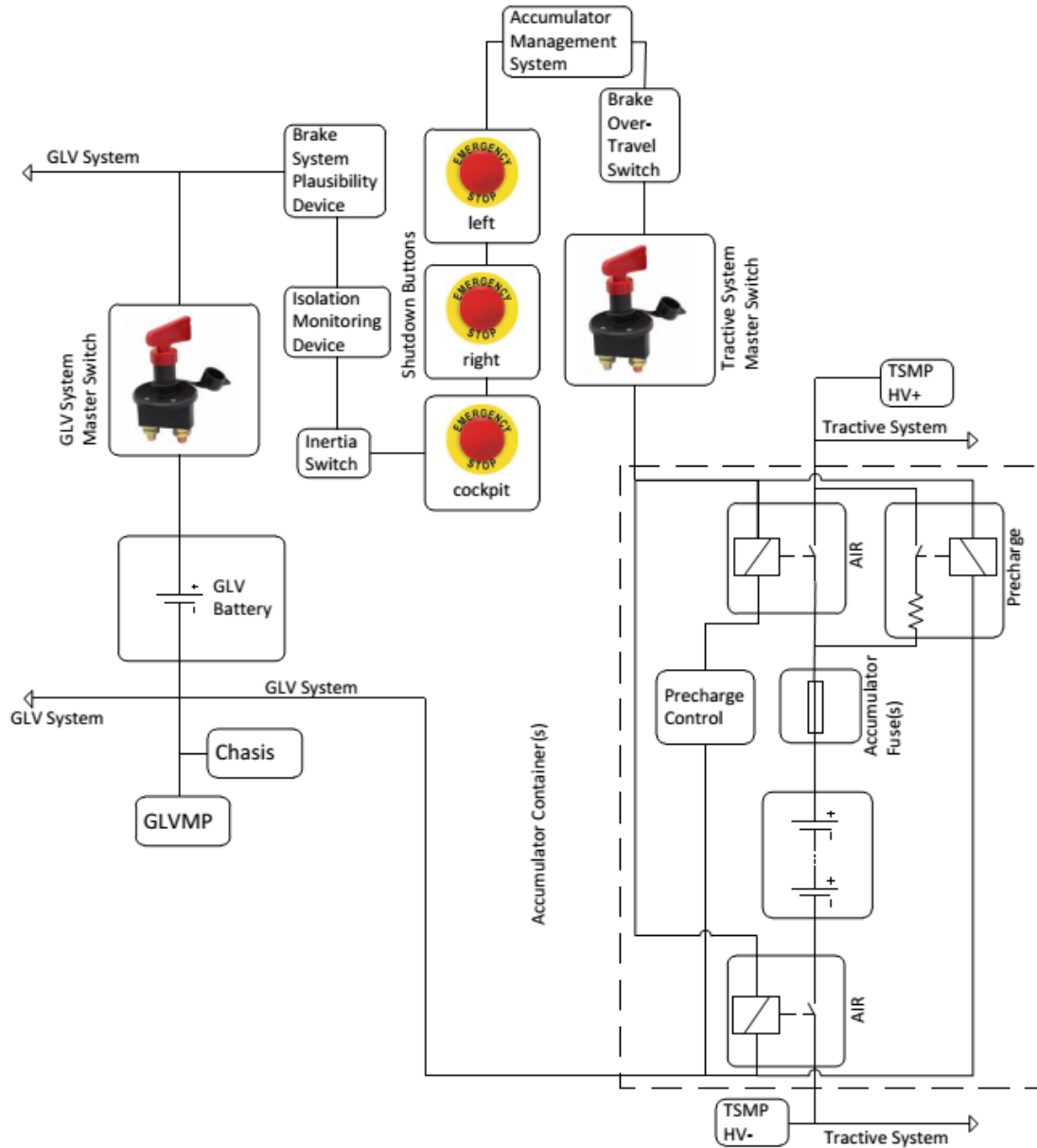
### **EV.7.1 Activating the Tractive System**

EV.7.1.1 The driver must be able to activate or reset the Tractive System from within the cockpit without external assistance except for situations in which the AMS, IMD or BSPD have shut down the Tractive System.

## EV.7.2 Shutdown Circuit

*An explanatory schematic of the required Shutdown Circuit, excluding possibly needed interlock circuitry, is shown on the next page.*

- EV.7.2.1 The shutdown circuit directly carries the current driving the Accumulator Isolation Relays (AIRs).
- EV.7.2.2 The shutdown circuit consists of at least two (2) master switches, three (3) shutdown buttons, the Brake Over Travel Switch, the Insulation Monitoring Device (IMD), the Inertia Switch, the Brake System Plausibility Device, all required interlocks and the Accumulator Management System (AMS).
- EV.7.2.3 A failure causing the GLV system to shut down must immediately deactivate the Tractive System
- EV.7.2.4 If the shutdown circuit is opened/interrupted the Tractive System must be shut down by opening all Accumulator Isolation Relay(s) and the voltage in the Tractive System must drop to under 60 V DC or 25 V AC RMS in less than five seconds after opening the shutdown circuit. All accumulator current flow must stop immediately.
- EV.7.2.5 Cell balancing when the Accumulator Isolation Relays are open is not permitted.
- EV.7.2.6 If the shutdown circuit is opened by the AMS, the IMD or the BSPD the Tractive System must remain disabled until being manually reset by a person directly at the vehicle which is not the driver.  
  
Remote reset, for example via WLAN or use of the three shutdown buttons or the TS master switch to reset the AMS, IMD or BSPD is not permitted.
- EV.7.2.7 It must not be possible for the driver to reactivate the tractive system from within the vehicle in case of an AMS, IMD or BSPD fault.  
  
*For example: Applying an IMD test resistor between HV+ and GLV system ground must deactivate the system. Disconnecting the test resistor must not reactivate the system. The tractive system must remain inactive until it is manually reset.*
- EV.7.2.8 All circuits that are part of the shutdown circuit must be designed in a way, that in the deenergized/disconnected state they are open such that each circuit will remove the current controlling the AIRs.
- EV.7.2.9 If the Tractive System is deactivated while driving, the motor(s) must spin free. No brake torque must be applied to the motor(s).
- EV.7.2.10 In order to offer additional protection to the AIRs, a capacitor may be used to hold the AIRs closed for up to 250 ms after removing the current source that keeps them closed, such that the motor controller has some opportunity to reduce the tractive current before the AIRs isolate the accumulator from the rest of the tractive system.
- EV.7.2.11 It must be possible to demonstrate that all features of the shutdown circuit function correctly, including all interlocks.
- EV.7.2.12 Every system required or able to open the shutdown circuit must have its own, nonprogrammable power stage. The respective power stages must be designed such that a failure cannot result in electrical power being fed back into the electrical shutdown circuit.
- EV.7.2.13 The shutdown buttons, the brake over travel switch, the TSMS and all interlocks must directly carry the AIR current, and not act through any power stage.



### EV.7.3 Master Switches

EV.7.3.1 Each vehicle must have two master switches.

EV.7.3.2 The Grounded Low Voltage Master Switch (GLVMS) must:

- a. Completely disable power to the GLV System
- b. Be direct acting and must not act through a relay or logic.
- c. Be in the center of a completely red circular area of >50 mm in diameter
- d. Be labeled "LV".

EV.7.3.3 The Tractive System Master Switch (TSMS) must:

- a. Open the shutdown circuit.

- b. Be direct acting, not through a relay or logic, and must be the last switch before the AIRs except for precharge circuitry and hardwired interlocks. Interlocks between the TSMS and AIR's must not be in the low (ground) connection to the AIR coils.
- c. Be in the center of a completely orange circular area of >50 mm in diameter
- d. Be labeled "HV" or "TS" and a symbol according to ISO 7010-W012 (triangle with black lightning bolt on yellow background).
- e. Be fitted with a "lockout/tagout" capability to prevent accidental activation of the Tractive System.

EV.7.3.4 Both Master Switches must:

- a. Be located on the right side of the vehicle, in proximity to the Main Hoop, at the driver's shoulder height
- b. Be easily actuated from outside the vehicle
- c. Be of the rotary mechanical type, with a red removable key that may only be removable in the electrically open position.
- d. Not be easily removable and not mounted onto removable body work.
- e. Mounted so that the rotary axis of the key is near horizontal and across the vehicle
- f. The ON position of both switches must be in the horizontal position and must be marked accordingly.
- g. The OFF position of both switches must also be clearly marked

EV.7.3.5 The Electrical System Officer must ensure that the TSMS is locked in the off position whenever work is done on the vehicle.

**EV.7.4 Shutdown Buttons**

EV.7.4.1 A system of three shutdown buttons must be installed on the vehicle.

EV.7.4.2 Pressing any one of the shutdown buttons must separate the Tractive System from the accumulator block by opening the shutdown circuit.

EV.7.4.3 Each shutdown button must be a push-pull or push-rotate emergency switch where pushing the button opens the shutdown circuit.

EV.7.4.4 The shutdown buttons must not act through programmable logic.

EV.7.4.5 Two buttons must be installed, on the sides of the vehicle which:

- a. Are located on each side of the vehicle behind the driver's compartment at approximately the level of the driver's head
- b. Have diameter of 40 mm minimum
- c. Have the international electrical symbol consisting of a red spark on a white edged blue triangle affixed in close proximity
- d. Must not be easily removable or mounted onto removable body work

EV.7.4.6 One shutdown button must be a cockpit mounted Master Switch which:

- a. Is located within easy reach of the belted in driver, alongside the steering wheel, and unobstructed by the steering wheel or any other part of the vehicle
- b. Has diameter of 24 mm minimum
- c. Has the international electrical symbol consisting of a red spark on a white edged blue triangle affixed in close proximity

### **EV.7.5 Insulation Monitoring Device (IMD)**

- EV.7.5.1 Every vehicle must have an Insulation Monitoring Device (IMD) installed in the Tractive System.
- EV.7.5.2 The IMD must be a Bender A-ISOMETER<sup>®</sup> iso-F1 IR155-3203 or -3204 or equivalent IMD approved for automotive use.

*Equivalency may be approved by a Rules Question based on the following criteria: robustness to vibration, operating temperature range, IP rating, availability of a direct output, a self-test facility and must not be powered by the system which is monitored.*

- EV.7.5.3 The response value of the IMD must be set to 500 Ohm / Volt, related to the maximum Tractive System operation voltage.
- EV.7.5.4 In case of an insulation failure or an IMD failure, the IMD must open the shutdown circuit. This must be done without the influence of any programmable logic. See [EV.7.2.6](#) and [EV.7.2.7](#) regarding the reactivation of the Tractive System after an insulation fault.
- EV.7.5.5 The status of the IMD must be shown to the driver by an indicator light which must illuminate when
  - a. The IMD detects an insulation failure
  - b. The IMD detects a failure in its own operation, when it loses reference ground for example.
- EV.7.5.6 The IMD indicator light must be
  - a. Color: Red
  - b. Clearly visible to the seated driver in bright sunlight
  - c. Clearly marked with the lettering "IMD".

### **EV.7.6 Brake System Plausibility Device (BSPD)**

- EV.7.6.1 A standalone nonprogrammable circuit must be used on the vehicle such that when braking hard (without locking the wheels) and when a positive current is delivered from the motor controller (a current to propel the vehicle forward), the AIRs will be opened.
  - a. The current limit for triggering the circuit must be set at a level where 5 kW of electrical power in the DC circuit is delivered to the motors at the nominal battery voltage.
  - b. The action of opening the AIRs must occur if the implausibility is persistent for more than 0.5 sec.
  - c. The circuit must also include open/short circuit detection for sensor inputs such that the shutdown circuit is opened.
- EV.7.6.2 This device must be provided in addition to the plausibility checks which are carried out by the controller which interprets the drivers torque request and delivers torque to the wheels. See [EV.7.2.6](#) and [EV.7.2.7](#) regarding the reactivation of the tractive system after triggering of the BSPD.
- EV.7.6.3 The team must devise a test to prove this required function during Electrical Tech Inspection. It is suggested that it should be possible to achieve this by sending an appropriate signal to the nonprogrammable circuit that represents the current to achieve 5 kW while pressing the brake pedal to a position or with a force that represents hard braking.

### **EV.7.7 Inertia Switch**

- EV.7.7.1 All vehicles must be equipped with an inertia switch. This must be a Sensata Resettable Crash Sensor or equivalent.
- EV.7.7.2 The device must trigger due to an impact load which decelerates the vehicle at between 8 g and 11 g depending on the duration of the deceleration (see spec sheet of the Sensata device).
- EV.7.7.3 The inertia switch must be part of the shutdown circuit and must be wired in series with the shutdown buttons such that an impact will result in the shutdown circuit being activated and the AIRs being opened.
- EV.7.7.4 The inertia switch must latch until manually reset.
- EV.7.7.5 The inertia switch may be reset by the driver from within the driver's cell.
- EV.7.7.6 The device must be mechanically attached to the vehicle; however, it must be possible to demount the device so that its functionality may be tested by shaking it.

### **EV.7.8 Charging Shutdown Circuit**

- EV.7.8.1 The Charging Shutdown Circuit when charging consists of at least the charger shutdown button, the Insulation Monitoring Device (IMD) and the accumulator management system (AMS).
- EV.7.8.2 If the Shutdown Circuit is opened by the AMS or the IMD the Tractive System must remain disabled until it is manually reset.
- EV.7.8.3 The charging shutdown systems must comply with [EV.7.2.1](#), [EV.7.2.3](#), [EV.7.2.9](#), [EV.7.2.10](#), [EV.7.2.11](#), and [EV.7.2.12](#)
- EV.7.8.4 The charger must include a push type emergency stop button which has a minimum diameter of 25 mm and must be clearly labeled.

## **EV.8 FUSING**

### **EV.8.1 Overcurrent Protection**

- EV.8.1.1 All electrical systems (both low and high voltage) must have appropriate overcurrent protection.
- EV.8.1.2 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, cell or other conductor that it protects.

*Fuses are the most common form of overcurrent protection.*

- EV.8.1.3 All overcurrent protection devices must be rated for the highest voltage in the systems they protect.  
Overcurrent protection devices used for DC must be rated for DC, and must carry a DC rating equal to or greater than the system voltage.
- EV.8.1.4 All overcurrent protection devices must have an interrupt current rating which is higher than the theoretical short circuit current of the system that it protects.
- EV.8.1.5 If multiple parallel battery cells, capacitors, strings of battery cells, strings of capacitors, or conductors are used then each parallel element must have individual overcurrent protection.

Any conductors, for example wires, busbars, etc. conducting the entire pack current must be appropriately sized for the total current that the individual overcurrent protection devices could transmit or additional overcurrent protection must be used to protect the conductors.

- EV.8.1.6 Battery packs with low or non voltage rated fusible links for cell connections may be used when:
- An overcurrent protection device rated at a current three times lower than the sum of the parallel fusible links and complying with **EV.8.1.2 above** is connected in series.
  - The AMS can detect an open fusible link, and will shut down the electrical system by opening the AIRs if a fault is detected.
  - Fusible link current rating is specified in manufacturer's data or suitable test data is provided.

- EV.8.1.7 Cells with internal overcurrent protection may be used without external overcurrent protection if suitably rated.

*Most cell internal overcurrent protection devices are low or non voltage rated and conditions of **EV.8.1.6 above** will apply.*

- EV.8.1.8 The ESF must include all details of internal and external over current protection including documentation from manufacturer for the particular series and parallel configuration, and string voltage.

## **EV.9 HIGH VOLTAGE PROCEDURES AND TOOLS**

### **EV.9.1 Working on Tractive System Accumulator Containers**

- EV.9.1.1 Opening or working on accumulator containers is only allowed in the charging area and during Electrical Tech Inspection.
- EV.9.1.2 Whenever the accumulator containers are opened the cell segments must be separated by using the Maintenance Plugs, see **EV.3.3**
- EV.9.1.3 Whenever the Accumulator or Tractive System is being worked on, appropriate insulated tools must be used.
- EV.9.1.4 Safety glasses with side shields must be worn by all participating team members any time when:
- Parts of the Tractive System are exposed while it is active
  - Work is being done on the accumulators

### **EV.9.2 Charging**

- EV.9.2.1 Charging tractive system accumulators is only allowed inside the designated area.
- EV.9.2.2 Accumulators must be removed from the vehicle for charging within a removable accumulator container and placed on the accumulator container hand cart for charging.
- EV.9.2.3 Each accumulator container(s) must have a label with the following data during charging: Team name and Electrical System Officer phone number(s).
- EV.9.2.4 At least one team member who has knowledge of the charging process must stay with the accumulator(s) during charging.
- EV.9.2.5 Moving accumulator cells and/or accumulator segment(s) around at the competition site is only allowed inside a completely closed accumulator container.



### EV.9.3 Chargers

EV.9.3.1 Only chargers presented and sealed at Electrical Tech Inspection are allowed.

EV.9.3.2 All chargers must meet EITHER:

- Accredited to a recognized standard (such as CE)
- Team built chargers must meet all electrical requirements for the vehicle Tractive System.

EV.9.3.3 All connections of the charger(s) must be isolated and covered.

EV.9.3.4 The charger connector must incorporate an interlock such that neither side of the connector become live unless it is correctly connected to the accumulator.

EV.9.3.5 HV charging leads must be orange

EV.9.3.6 When charging, the AMS must be live and must be able to turn off the charger in the event that a fault is detected.

EV.9.3.7 When charging the accumulator, the IMD must be active and must be able to shut down the charger. Either the charger must incorporate an active IMD or an active IMD must be within the accumulator.

### EV.9.4 Accumulator Container Hand Cart

EV.9.4.1 Teams must have a hand cart to transport their accumulators.

EV.9.4.2 The hand cart(s) must be used whenever the accumulator container(s) are transported on the competition site.

EV.9.4.3 The hand cart must be able to carry the load of the accumulator container(s).

EV.9.4.4 The hand cart must have a brake that must:

- a. Only be released using a dead man type switch (where the brake is always on except when released by pushing and holding a handle)
- b. Be capable to stop the fully loaded accumulator container hand cart.

## EV.10 ELECTRICAL SYSTEM DOCUMENTATION

### EV.10.1 Electrical System Form (ESF)

EV.10.1.1 Prior to the event all teams must submit clearly structured documentation of their entire electrical system (including control and Tractive System) on the Electrical System Form (ESF).

*Passing the ESF does not mean that you automatically pass Electrical Technical Inspection with the described items / parts.*

EV.10.1.2 The ESF must visualize the interconnection of all electric components including the voltage level, the topology, the wiring in the vehicle and the construction and build of the accumulator(s).

EV.10.1.3 Teams must present data sheets with rated specifications for all Tractive System parts used and show that none of these ratings are exceeded (including wiring components). This includes stress caused by the environment (high temperatures, vibration, etc)

EV.10.1.4 Use the format provided and submit the ESF as described in section **DR - Document Requirements**

- Small pictures and small schematics should be put inside the text for easy reference
- Data sheets and large schematics should be put in the appendix

## **EV.10.2 Failure Modes and Effects Analysis (FMEA)**

EV.10.2.1 Teams must submit a complete Failure Modes and Effects Analysis (FMEA) of the Tractive System

EV.10.2.2 Use the format provided and submit the FMEA as described in section **DR - Document Requirements**

- Pictures, schematics and data sheets to be referenced in the FMEA must be included in the FMEA on additional pages

## **EV.10.3 Penalty for Late Submission or Non-Submission**

EV.10.3.1 Penalties for Late Submission of the ESF or FMEA will be imposed as described in section **DR - Document Requirements**.

## **IN - TECHNICAL INSPECTION**

The objective of Technical Inspection is to determine if the vehicle meets the Formula SAE Rules requirements and restrictions and if, considered as a whole, it satisfies the intent of the Rules.

### **IN.1 INSPECTION REQUIREMENTS**

#### **IN.1.1 Inspection Required**

Each vehicle must pass all parts of inspection and testing, and bear the inspection stickers, before it is permitted to participate in any Dynamic event.

#### **IN.1.2 Team Responsibility**

IN.1.2.1 Teams are responsible for confirming that their vehicle, and the required equipment, satisfies the requirements and restrictions of the Formula SAE Rules before presenting it for Technical Inspection.

IN.1.2.2 Presenting a vehicle for Technical Inspection constitutes a declaration by the team that they have determined by self inspection that the vehicle complies with the Rules.

#### **IN.1.3 Technical Inspection Procedure**

Technical inspection will examine all items included on the Tech Inspection Form plus any other items the inspectors may wish to examine to ensure conformance with the Rules.

The exact procedures and instruments employed for inspection and testing are entirely at the discretion of the Chief Technical Inspector.

#### **IN.1.4 Technical Inspection Authority**

Decisions of the Technical Inspectors and the Chief Technical Inspector concerning vehicle compliance are final and may not be appealed.

#### **IN.1.5 Inspection Condition**

Vehicles must be presented for technical inspection in finished condition, fully assembled, complete and ready to run. Technical inspectors will not inspect any vehicle presented for inspection in an unfinished state.

#### **IN.1.6 Visible Access**

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

#### **IN.1.7 Marked Items**

IN.1.7.1 Officials may mark, seal, or designate items or areas which have been inspected to document the inspection and reduce the chance of tampering

IN.1.7.2 Damage or lost marks or seals require Reinspection.

#### **IN.1.8 Correction**

If any part of a vehicle does not comply with the rules, or is otherwise deemed to be a concern, the team must correct the problem and have the vehicle reinspected.

#### **IN.1.9 Reinspection**

Officials may reinspect any vehicle at any time during the competition.

## **IN.2 INSPECTION PROCESS**

### **IN.2.1 Inspection Areas**

Inspection will consist of the following parts:

- Initial Inspection
- Electrical Technical Inspection (EV only)
- Driver Cockpit Checks
- Mechanical Technical Inspection
- Tilt Test
- Ready to Drive Sound Test (EV only)
- Rain Test (EV only)
- Noise and Master Switch Test (IC only)
- Brake Test

## **IN.3 INITIAL INSPECTION**

### **IN.3.1 Inspection Items**

The following must be brought to Initial Inspection:

- Technical Inspection Form
- All Driver Equipment per **VE.3** to be used by each driver
- Fire Extinguishers (for paddock and vehicle)
- Wet Tires

## **IN.4 ELECTRICAL TECHNICAL INSPECTION (EV ONLY)**

### **IN.4.1 Inspection Items**

The following must be brought to Electrical Technical Inspection:

- Chargers for the Accumulator(s)
- Hand cart to transport the Accumulators
- Spare accumulator packs
- ESF, FMEA, and Component Data Sheets
- Copies of any submitted Rules Questions with the received answer

The following basic tools in good condition:

- Insulated cable shears
- Insulated screw drivers
- Multimeter with protected probe tips
- Insulated tools, if screwed connections are used in the Tractive System
- Face Shield
- HV insulating gloves which are within test date
- Two HV insulating blankets of at least 1.0 m<sup>2</sup> each

- Safety glasses with side shields for all team members that might work on the Tractive System or Accumulator

#### **IN.4.2 Accumulator Inspection**

The Accumulator(s) and associated equipment (hand cart, chargers, etc) may be inspected during Electrical Technical Inspection, or separately prior to the rest of Electrical Technical Inspection.

#### **IN.4.3 Accumulator Access**

IN.4.3.1 If the accumulator container(s) is not easily accessible during Electrical Tech Inspection, detailed pictures of the internals taken during assembly must be provided.

IN.4.3.2 Tech inspectors may require access to check any Accumulators for rules compliance.

#### **IN.4.4 Insulation Monitoring Device Test**

IN.4.4.1 The Insulation Monitoring Device will be tested by connecting a resistor between the Tractive System Measuring Points (**EV.6.4**), and several electrically conductive vehicle parts while the Tractive System is active.

IN.4.4.2 The test is passed if the IMD shuts down the Tractive System within 30 seconds at a fault resistance of 50% below the response value corresponding to 250 Ohm / Volt.

#### **IN.4.5 Insulation Measurement Test**

IN.4.5.1 The insulation resistance between the Tractive System and GLV system ground will be measured.

IN.4.5.2 The available measurement voltages are 250 V and 500 V. All vehicles with a maximum nominal operation voltage below 500 V will be measured with the next available voltage level. All teams with a system voltage of 500 V or more will be measured with 500 V.

IN.4.5.3 To pass the Insulation Measurement Test the measured insulation resistance must be at least 500 Ohm/Volt related to the maximum nominal Tractive System operation voltage.

#### **IN.4.6 Ready to Drive Sound**

IN.4.6.1 The sound level will be measured with a free field microphone placed free from obstructions in a radius of 2 m around the vehicle against the criteria in **EV.6.11**

#### **IN.4.7 Electrical Inspection Completion**

IN.4.7.1 All or portions of the Tractive System may be sealed

IN.4.7.2 Electric Vehicles must pass Electrical Technical Inspection before being allowed to attempt Mechanical Technical Inspection.

IN.4.7.3 Electric Vehicles may only be moved around the competition site or participate in Static events with the HVD disconnected until they have passed Electrical Technical Inspection.

### **IN.5 DRIVER COCKPIT CHECKS**

The Clearance Checks and Egress Test will be performed in conjunction with other parts of Technical Inspection

#### **IN.5.1 Driver Clearance**

Helmet clearance per **T.2.10.2** and head restraint positioning per **T.4.7.4** will be verified for each driver while in the normal driving position.

## **IN.5.2 Egress Test Requirement**

Each driver must be able to exit to the side of the vehicle in no more than 5 seconds.

## **IN.5.3 Conduct**

IN.5.3.1 The egress test will be conducted for each driver as follows:

- a. The driver must wear the specified equipment
- b. Egress time begins with the driver in the fully seated position, with hands in driving position on the connected steering wheel.
- c. Egress time may include the driver simulating actuating the cockpit master switch
- d. Egress time will stop when the driver has both feet on the pavement.

## **IN.5.4 Driver Clearance and Egress Test Completion**

IN.5.4.1 In order to drive the vehicle, each team driver must:

- a. Meet the Driver Clearance requirements
- b. Successfully complete the Egress Test

IN.5.4.2 At least one driver must complete the Driver Cockpit Checks in order to pass Mechanical Inspection

## **IN.6 DRIVER TEMPLATE INSPECTIONS**

The Driver Template Inspection will be conducted as part of the Mechanical Inspection

### **IN.6.1 Conduct**

The Driver Template shown in **T.2.10.4** will be positioned as described in **T.2.10.5**

### **IN.6.2 Driver Template Clearance Criteria**

To pass Mechanical Technical Inspection, the specified clearance to the Driver Template must be met.

## **IN.7 COCKPIT TEMPLATE INSPECTIONS**

The Cockpit Template Inspections will be conducted as part of the Mechanical Inspection

### **IN.7.1 Conduct**

IN.7.1.1 The Cockpit Opening will be checked using the template and procedure described in **T.3.1**

IN.7.1.2 The Internal Cross Section will be checked using the template and procedure described in **T.3.2**

### **IN.7.2 Cockpit Template Criteria**

To pass Mechanical Technical Inspection, both templates must fit as described.

## **IN.8 MECHANICAL TECHNICAL INSPECTION**

### **IN.8.1 Inspection Items**

The following items must be brought to Mechanical Technical Inspection:

- Vehicle on Dry tires
- Technical Inspection Form
- Push Bar

- Structural Equivalency Spreadsheet (SES) copies
- Monocoque Laminate Test Specimens (if applicable)
- Impact Attenuator Report copies
- The Impact Attenuator that was tested (if applicable)
- Accumulator Container samples (EV only) (if applicable)
- Tractive System Firewall sample (EV only)
- Copies of any submitted Rules Questions with the received answer

## **IN.8.2 Aerodynamic Devices Stability and Strength**

IN.8.2.1 Any aerodynamic devices may be checked by pushing on the device in any direction and at any point.

*The following is guidance but actual conformance will be up to technical inspectors at the respective competitions. The intent is to reduce the likelihood of wings detaching*

IN.8.2.2 If any deflection is significant, then a force of approximately 200 N may be applied and the resulting deflection should not be more than 25 mm and any permanent deflection less than 5 mm.

IN.8.2.3 If any vehicle on track is observed to have large, uncontrolled movements of aerodynamic devices, then officials may Black Flag the vehicle for **IN.15 Reinspection**.

## **IN.8.3 Monocoque Inspections**

IN.8.3.1 Inspection Scope

The following items may be confirmed during inspection:

- a. Main hoop outer diameter and thickness where it protrudes above the monocoque
- b. Main hoop extends to the lowest part of the tub
- c. Mechanical attachment of main hoop to tub exists and matches the SES, at all points shown on the SES
- d. Front Hoop is installed, visually or by feel and that the mechanical attachment (if included) agrees with the SES

IN.8.3.2 When the Front Hoop is integrally bonded to the monocoque, the size and composition of the Front Hoop must be proven with:

- a. Documentation that shows dimensions on the tubes
- b. Pictures of the dimensioned tube being included in the layup

IN.8.3.3 For items which cannot be verified by an inspector, the team must provide documentation, visual and/or written, that the requirements have been met.

IN.8.3.4 A team found to be improperly presenting any evidence of the manufacturing process may be barred from competing with a monocoque.

## **IN.8.4 Engine Inspection (IC Only)**

The organizer may measure or tear down engines to confirm conformance to the rules.

## **IN.8.5 Mechanical Inspection Completion**

Mechanical Technical Inspection must be passed before a vehicle may attempt any further inspections.

## **IN.9 TILT TEST**

### **IN.9.1 Tilt Test Requirements**

- a. The vehicle must contain the maximum amount of fluids it may carry
- b. The tallest driver must be seated in the normal driving position
- c. Tilt tests may be conducted in either or both directions in order to pass
- d. (IC only) Engines fitted with mechanically actuated fuel pumps must be run to fill and pressure the system downstream of the High Pressure pump. See **IC.6.2**

### **IN.9.2 Tilt Test Criteria**

- IN.9.2.1 No fluid leakage of any type when the vehicle is tilted to a 45° angle to the horizontal
- IN.9.2.2 The vehicle does not roll when tilted at an angle of 60° to the horizontal, corresponding to 1.7 g.

### **IN.9.3 Tilt Test Completion**

Tilt Tests must be passed before a vehicle may attempt any further inspections

## **IN.10 NOISE AND MASTER SWITCH TEST (IC ONLY)**

### **IN.10.1 Sound Level Measurement**

- IN.10.1.1 The sound level will be measured during a stationary test, with the vehicle gearbox in neutral at the defined test speed
- IN.10.1.2 Measurements will be made with a free field microphone placed:
- free from obstructions
  - at the exhaust outlet vertical level
  - 0.5 m from the end of the exhaust outlet
  - at an angle of 45° with the outlet in the horizontal plane

### **IN.10.2 Special Configurations**

- IN.10.2.1 Where more than one exhaust outlet is present, the test will be repeated for each exhaust and the highest reading will be used.
- IN.10.2.2 If the exhaust has any form of active tuning or throttling device or system, the exhaust must meet all requirements with the device or system in all positions.
- IN.10.2.3 Manually adjustable tuning devices must not be moved or modified after the noise test is passed. The position of the device must be visible to the officials for the noise test and must be manually operable by the officials during the noise test.

### **IN.10.3 Industrial Engine**

- IN.10.3.1 Defined as an engine which, according to the manufacturers' specifications and without the required restrictor, is capable of producing 5 hp per 100 cc or less.
- IN.10.3.2 Submit a Rules Question to request approval of an industrial engine.

### **IN.10.4 Test Speeds**

- IN.10.4.1 The maximum test speed for a given engine will be the engine speed that corresponds to an average piston speed of 914.4 m/min (3,000 ft/min) for automotive or motorcycle engines, and 731.5 m/min (2,400 ft/min) for "industrial engines". The calculated speed will be rounded



to the nearest 500 rpm. Test speeds for typical engines will be published on the event website.

IN.10.4.2 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.

IN.10.4.3 The vehicle must be compliant at all engine speeds up to the maximum defined test speed.

#### **IN.10.5 Maximum Permitted Sound Level**

- a. At idle 103 dBC, fast weighting
- b. At all other speeds 110 dBC, fast weighting

#### **IN.10.6 Noise Level Retesting**

IN.10.6.1 Noise levels may be monitored at any time.

IN.10.6.2 The noise test may be repeated at any time.

IN.10.6.3 If a vehicle fails the noise test, it will be withheld from the competition until it has been corrected and passes the noise test.

#### **IN.10.7 Master Switch**

The Master Switch function will be tested during the Noise test

#### **IN.10.8 Noise Test Completion**

Noise Tests must be passed before a vehicle may attempt any further inspections

### **IN.11 RAIN TEST (EV ONLY)**

#### **IN.11.1 Rain Test Requirements**

- Tractive System must be active
- The vehicle must not be in Ready to Drive mode (**EV.6.11**)
- Any driven wheels must not touch the ground
- A driver must not be seated in the vehicle

#### **IN.11.2 Rain Test Conduct**

*The water spray will be rain like, not a direct high pressure water jet*

- a. Water will be sprayed at the vehicle from any possible direction for 120 seconds
- b. The water spray will stop
- c. The vehicle will be observed for 120 seconds

#### **IN.11.3 Rain Test Completion**

The test is passed if the Insulation Monitoring Device does not react during the entire 240 seconds duration

### **IN.12 BRAKE TEST**

#### **IN.12.1 Objective**

The brake system will be dynamically tested and must demonstrate the capability of locking all four wheels when stopping the vehicle in a straight line at the end of an acceleration run specified by the brake inspectors

### **IN.12.2 Brake Test Conduct (IC Only)**

#### **IN.12.2.1 Brake Test procedure:**

- a. Accelerate to speed (typically getting into 2nd gear) until reaching the designated area
- b. Apply the brakes with force sufficient to demonstrate full lockup of all four wheels

#### **IN.12.2.2 The Brake Test is passed when:**

- All four wheels lock up
- The engine remains running during the complete test

### **IN.12.3 Brake Test Conduct (EV Only)**

#### **IN.12.3.1 Brake Test procedure:**

- a. Accelerate to speed until reaching the designated area
- b. Switch off the Tractive System
- c. Apply the brakes with force sufficient to demonstrate full lockup of all four wheels

#### **IN.12.3.2 The Brake Test is passed when all four wheels lock while the Tractive System is shut down**

#### **IN.12.3.3 The Tractive System Active Light may switch shortly after the vehicle has come to a complete stop as the reduction of the system voltage is not immediate.**

## **IN.13 INSPECTION APPROVAL**

### **IN.13.1 Inspection Approval**

#### **IN.13.1.1 When all parts of Technical Inspection are complete as shown on the Technical Inspection sheet, the vehicle receives Inspection Approval**

#### **IN.13.1.2 The completed Inspection Sticker denotes the Inspection Approval**

#### **IN.13.1.3 The Inspection Approval is contingent on the vehicle remaining in the required condition throughout the competition.**

### **IN.13.2 Inspection Sticker**

#### **IN.13.2.1 Inspection Sticker(s) are issued following the completion of any part of Technical Inspection**

#### **IN.13.2.2 Inspection Sticker(s) must be placed on the upper nose of the vehicle**

### **IN.13.3 Inspection Validity**

#### **IN.13.3.1 Inspection stickers may be removed from vehicles that are not in compliance with the Rules or are required to be reinspected.**

#### **IN.13.3.2 Inspection Approval is valid only for the duration of the specific Formula SAE competition during which the inspection is conducted.**

## **IN.14 MODIFICATIONS AND REPAIRS**

### **IN.14.1 Prior to Inspection Approval**

Once the vehicle has been presented for judging in the Cost or Design Events, or submitted for Technical Inspection, and until the vehicle has the full Inspection Approval, the only modifications permitted to the vehicle are those directed by the Inspector(s) and noted on the Inspection Form.

### **IN.14.2 After Inspection Approval**

IN.14.2.1 The vehicle must maintain all required specifications (including but not limited to ride height, suspension travel, braking capacity (pad material/composition), sound level and wing location) throughout the competition.

IN.14.2.2 Once the vehicle is approved to compete in the Dynamic events, the ONLY modifications permitted to the vehicle are the following:

- Adjustment of belts, chains and clutches
- Adjustment of 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, including fuel mixture and ignition timing, and any software calibration changes
- Adjustment of mirrors
- Adjustment of the suspension.
- Changing springs, sway bars and shims in the suspension
- Adjustment of tire pressure
- Adjustment of wing angle, but not the location
- Replenishment of fluids
- Replacement of worn tires or brake pads. Replacement tires and brake pads must be identical in material/composition/size to those presented and approved at Technical Inspection.
- Changing of wheels and tires for weather conditions (**D.5.3, D.5.4**)
- Recharging Low Voltage batteries
- Recharging High Voltage accumulators

### **IN.14.3 Repairs After Inspection Approval**

IN.14.3.1 Any damage to the vehicle that requires repair will void the Inspection Approval.

IN.14.3.2 The repaired vehicle must be Reinspected at the discretion of the Chief Technical Inspector to receive Inspection Approval.

## **IN.15 REINSPECTION**

### **IN.15.1 Requirement**

IN.15.1.1 The vehicle may be Reinspected at any time for any reason

IN.15.1.2 Reinspection must be completed to restore Inspection Approval, if voided

### **IN.15.2 Conduct**

IN.15.2.1 The Inspection process may be repeated in entirety or in part

IN.15.2.2 Specific areas or items to be inspected are at the discretion of the Chief Technical Inspector

### **IN.15.3 Result**

IN.15.3.1 With Voided Inspection Approval

Successful completion of Reinspection will restore Inspection Approval, see **IN.13.1**

#### IN.15.3.2 During Dynamic Events

- a. Issues found during Reinspection will void Inspection Approval
- b. Penalties may be applied to the Dynamic Events the vehicle has competed in  
Applied penalties may include additional time added to event(s), loss of one or more fastest runs, up to DQ, subject to official discretion.

## S - STATIC EVENTS

### S.1 GENERAL STATIC

Presentation	75 points
Cost	100 points
Design	150 points
<b>Total</b>	<b>325 points</b>

### S.2 PRESENTATION EVENT

#### S.2.1 Presentation Event Objective

The Presentation Event evaluates the team's ability to develop and deliver a comprehensive business, logistical, production, or technical case that will convince outside interests to invest in the team's concept.

#### S.2.2 Presentation Concept

S.2.2.1 The concept for the Presentation event will be provided on the Event website.

S.2.2.2 The concept for the Presentation event may change for each competition

S.2.2.3 The team presentation must meet the concept

S.2.2.4 The team presentation must relate specifically to the vehicle as entered in the competition

S.2.2.5 Teams should assume that the judges represent different areas, including engineering, production, marketing and finance, and may not all be engineers.

S.2.2.6 The presentation may be given in different settings, such as a conference room, a group meeting, or in conjunction with other static events. Specific details will be included in the presentation concept.

#### S.2.3 Presentation Schedule

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

#### S.2.4 Presentation Submissions

S.2.4.1 The Presentation Concept may require information to be submitted prior to the event. Specific details will be included in the presentation concept.

S.2.4.2 Submissions may be graded as part of the Presentation event score.

S.2.4.3 Pre event submissions will be subject to penalties imposed as described in section **DR - Document Requirements**.

#### S.2.5 Presentation Format

S.2.5.1 One or more team members will give the presentation to the judges.

S.2.5.2 All team members who will give any part of the presentation, or who will respond to judges' questions must be:

- In the presentation area when the presentation starts
- Introduced and identified to the judges.

S.2.5.3 Presentations will be time limited. The judges will stop any presentation exceeding the time limit.

- S.2.5.4 The presentation itself will not be interrupted by questions. Immediately following the presentation there may be a question and answer session.
- S.2.5.5 Only judges may ask questions. Only team members who meet **S.2.5.2** may answer questions.

### **S.2.6 Presentation Equipment**

- S.2.6.1 Teams planning to use data projectors, visual display devices (tablets, computers, etc.), or other communication means as part of their presentation must bring, or arrange for, their own equipment.

### **S.2.7 Evaluation Criteria**

- S.2.7.1 Presentations will be evaluated on content, organization, visual aids, delivery and the team's response to the judges' questions.
- S.2.7.2 The actual quality of the prototype itself will not be considered as part of the presentation judging
- S.2.7.3 Presentation Judging Score Sheet – available at the FSAE Online website.

### **S.2.8 Presentation Event Scoring**

- S.2.8.1 The Presentation Event score is based on the average of the scores of each judge.
- S.2.8.2 Scoring Term Definitions
- Pmax - the highest score awarded to any team
  - Pyour - the score awarded to your team
- S.2.8.3 Presentation Score is given by  
$$\text{PRESENTATION SCORE} = 75 \times \text{Pyour}/\text{Pmax}$$
- S.2.8.4 Presentation Event scoring may include normalizing the scores of different judging teams.

## **S.3 COST AND MANUFACTURING EVENT**

***The Cost and Manufacturing Event section revision is not complete***

***There will be additional changes to this section***

### **S.3.1 Cost Event Objective**

Cost and Manufacturing are an integral part of any engineering project. Making tradeoff decisions between content and cost based on the performance of each part and assembly and accounting for each part and process to stay within a budget is part of project management.

*Additional information about the Cost and Manufacturing Event including Cost Tables and other information may be obtained from the FSAE Online website*

### **S.3.2 Cost Requirements**

- S.3.2.1 Cost Report  
The preparation and submission of a report (the "Cost Report")
- S.3.2.2 Event Day Discussion  
A discussion at the Competition with the Cost Judges around the team's vehicle.
- S.3.2.3 Cost Scenario  
Teams will respond to a challenge related to cost or manufacturing of the vehicle.

### S.3.3 Cost Report

S.3.3.1 The Cost Report must :

- a. Be generated and submitted using the FSAE Online website
- b. List and cost every part on the vehicle using the standardized Cost Tables.
- c. Base the cost on the actual manufacturing technique used on the prototype. Cast parts on the prototype must be cost as cast, and fabricated parts as fabricated, etc.
- d. Include tooling cost (welding jigs, molds, patterns and dies) for processes requiring it.
- e. Exclude R & D and capital expenditures (plant, machinery, hand tools and power tools).

### S.3.4 Bill of Materials (BOM)

S.3.4.1 The BOM is a list for every vehicle part, showing the relationships between the items.

- a. Systems - The overall vehicle is broken down into eight systems
- b. Systems are made up of Assemblies
- c. Assemblies are made up of Parts
- d. Parts consist of materials, processes and fasteners
- e. Tooling is associated with each process that requires production tooling

S.3.4.2 All assemblies, parts and fasteners in the BOM must use a standard numbering convention, see the Appendix S-2 on the FSAE Online Website

S.3.4.3 The comment section for each material, process or fastener may refer to the specific part by actual local designation.

*For example, a 6.35mm bolt is cost but the comments would say "1/4 inch A-arm bolt".*

### S.3.5 Cost Report – eBOM - Electronic Submission Required

S.3.5.1 Submit the eBOM in a single file as described in section **DR - Document Requirements**

S.3.5.2 This file must include the eBOM and the cost summary page, each on a separate tab of the spreadsheet.

### S.3.6 Cost Report Supporting Materials – Electronic Submission Required

S.3.6.1 Submit the Supporting Materials in a single file as described in section **DR - Document Requirements**

S.3.6.2 The Supporting Documentation must include:

- Cover sheet with (a) university name, (b) competition name(s), and (c) vehicle number(s)
- A letter of introduction addressed to the Judges explaining the submission and its total cost
- Table of Contents
- Cost Summary page listing each section's cost, and the total vehicle cost with a graphic representation of each of those sections as they reflect their part of the whole vehicle.
- Eight commodity report sections with the parts placed in the sections as specified in Appendix S-3 on the FSAE Online Website.
- Each section should begin with a copy of the eBOM for that commodity section followed by complete BOM for that section as generated by the cost module.
- Graphics, drawings and prints for each section for key assemblies.

### **S.3.7 Cost Reports when Entering Multiple Competitions**

- S.3.7.1 Teams may submit one Cost Report covering all similar Formula SAE competitions entered.
- S.3.7.2 The report cover sheet must identify both competition names and car numbers

### **S.3.8 Late Submission of Cost Report and Supporting Materials**

- S.3.8.1 Penalties for Late Submission will be imposed as described in section **DR - Document Requirements**.

### **S.3.9 Cost Report Specific Items**

#### S.3.9.1 Engine

- a. Engine cost includes transmission (whether integral or not by design), components used to transmit power between engine and transmission and all components necessary to run including spark plugs, coils, wires, oil filter, etc.
- b. The following are not part of the engine cost and must be included separately:
  - Air induction and fuel system components
  - Any driveline component downstream of the transmission output gear/shaft
  - Custom parts such as dry sump pans, PCV changes, etc. (fully internal engine changes are free)
  - If covers or other parts are removed disassembly labor must be included in labor cost.

#### S.3.9.2 Finishes

Any finishes (paint, polish, etc.) that are only used to beautify are not costed. Preservative finishes intended to protect the appearance or function of a part for an extended period of time must be costed.

#### S.3.9.3 Fire Extinguisher and Suppression System

An onboard fire suppression system is not costed.

#### S.3.9.4 Tires and Wheels

Only one set of tires and wheels is included in the Cost Report. The tires and wheels that are declared as dry tires per **T.1.8.1** must be the tires in the Cost Report, and must be the tires on the vehicle during the Cost Event judging.

#### S.3.9.5 Transponders, Video and Radio Systems

Transponders, video and radio systems, are not costed.

#### S.3.9.6 Data Acquisition Systems

- a. Data acquisition systems must be costed. This includes display screens, control modules, wiring and all sensors.
- b. Data logger control modules that are “standalone” data acquisition systems ( a device that passively logs data) are to be included at \$0. Standalone systems must be removable without compromising any vehicle functionality.
- c. Systems offering additional functionality have to have this functionality (such as a driver display) included, whether it is used or not.

### **S.3.10 Cost Addenda**

- S.3.10.1 A supplement to the Cost Report that reflects any changes or corrections made after the submission of the Cost Report may be submitted.



- S.3.10.2 The addendum must be submitted at Registration when the Team registers onsite at the Event.
- S.3.10.3 The addendum must follow the format as described in section **DR - Document Requirements**
- S.3.10.4 Addenda apply only to the competition at which they are submitted.
- S.3.10.5 A separate addendum is permitted for every competition a vehicle attends.
- S.3.10.6 Any items added to the Cost Report through addenda will be cost at 1.25 times the table cost.
- S.3.10.7 Any items removed through addenda will be credited 0.75 times the table cost.

### **S.3.11 Cost Tables**

- S.3.11.1 All costs in the Cost Report come from the standardized Cost Tables.
- S.3.11.2 All Cost Tables are presented using metric units. The tables do not differentiate between parts designed in metric and US systems of measure.
- S.3.11.3 The tables represent cost based on specific parameters. Most items have a cost expressed as a function of one parameter. In cases where more than one parameter is necessary, additional categories are listed
- S.3.11.4 The following Cost Tables are used
  - a. Materials
  - b. Processes
  - c. Process Multipliers
  - d. Fasteners
  - e. Tooling
- S.3.11.5 Process Multipliers are used to modify the standard costs of different operations to account for material and geometric differences in the part. For every process included in the Cost Report the list of process multipliers must be checked to determine if any apply, and if they do their effect on the cost must be included.
- S.3.11.6 When adding items from tables to the BOM the comments section should be reviewed thoroughly to understand what is included in the table entry. For example, is the spring included in the damper cost? Do the spark plugs come with the engine or are they a separate line item?
- S.3.11.7 If a team wishes to use any parts, processes or materials not included in the tables an Add Item Request must be submitted. See **S.3.14**

### **S.3.12 Cost Models & Costing Methodology**

The cost models are the underlying methodology and equations that relate the final cost of a part or process to the different operations and goods used in that part. The detailed explanation of the Cost Models and Costing Methodology is available on the FSAE Online Website and should be referenced for understanding the use of the Cost Tables.

### **S.3.13 Make Versus Buy**

- S.3.13.1 Every part may be classified as Made or Bought. This designation does not necessarily refer to whether a team actually purchased or fabricated a part but is a reflection of how the part must be cost from the Cost Tables.
  - a. Made (or manufactured) parts must be cost as if the company manufacturing the vehicle was going to make the part internally. That is by purchasing raw materials and processing them into a finished product.

Parts that must be Made can be distinguished because they do not appear explicitly in the Cost Tables or appear with a “Cost as Made” option.

- b. Bought parts must be cost as if the company manufacturing the vehicle was going to outsource the fabrication of that part. These parts would be received by the vehicle manufacturer in a relatively finished state (see the particular table entry comments field for specific information).

*The Made versus Bought designation enables certain parts to be simplified to a relatively few number of entries. For example, most steering racks are bought but then significantly modified. Steering racks are designated Make parts so even teams that purchase them and make no modifications must cost them as if they had made them starting with raw materials. Certain types of parts are supplier specific and other types are generic as per the table entry*

- S.3.13.2 If a team genuinely Makes a part listed on the table as a Bought part, they may alternatively cost it as a Made part only if a place holder entry is listed in the tables enabling them to do so.

*For example, in the category of dampers a “student built” entry is included. This line item must be included in the BOM (it has zero cost). The team must cost the damper they actually designed and built.*

- S.3.13.3 Any part which is normally purchased that is optionally shown as a Made part must have supporting documentation submitted to prove team manufacture. This might include engineering drawings, pictures of machining, etc.

- S.3.13.4 Teams found costing Bought parts as Made parts will be penalized appropriately.

#### **S.3.14 Add Item Request**

- S.3.14.1 An Add Item Request must be submitted to add items to the Cost Tables for individual team requirements.

- S.3.14.2 The form must be completely filled out and contains the necessary instructions. Some supporting documentation will be required such as receipts or website links.

- S.3.14.3 After review, the item may be added to the Cost Table with an appropriate cost. It will then be available to all teams.

#### **S.3.15 Public Cost Reports**

- S.3.15.1 The competition organizers may publish all or part of the submitted cost reports.

- S.3.15.2 Cost reports for a given competition season will not be published before the end of the calendar year. Support materials, such as technical drawings, will not be released.

#### **S.3.16 Cost Report Judging and Penalties Process**

- S.3.16.1 The following procedure will be used in determining penalties:

- a. Penalty A will be calculated using procedure **Penalty Method A - Fixed Point Deductions**
- b. Penalty B will be calculated using procedure **Penalty Method B – Adjusted Cost Deductions**
- c. The greater of the two penalties will be applied against the cost score
- d. Penalty A expressed in points will be deducted from the Cost Event score
- e. Penalty B expressed in dollars will be added to the Adjusted Cost of the vehicle

- S.3.16.2 Any error that results in a team over reporting a cost in their Cost Report will not be further penalized.

S.3.16.3 Any instance where a team's score benefits by an intentional or unintentional error on the part of the students will be corrected on a case by case basis.

S.3.16.4 Penalty Method A - Fixed Point Deductions

- a. From the Bill of Material, the cost judges will determine if all parts and processes have been included in the analysis.
- b. In the case of any omission or error the judges will deduct a penalty proportional to the BOM level of the error:
  - Missing/inaccurate material, process, fastener 1 point
  - Missing/inaccurate part 3 point
  - Missing/inaccurate assembly 5 point
- c. Each of the penalties listed above supersedes the previous penalty. If a 5 point deduction is given for a missing assembly, the missing parts are ignored.
- d. Differences other than those listed above will be deducted at the discretion of the cost judges.

S.3.16.5 Penalty Method B – Adjusted Cost Deductions

The table cost for the missing or incomplete items will be calculated from the standard Cost Tables. The penalty will be a value equal to twice the difference between the team cost and the correct cost for all items in error.

Penalty = 2 x (Table Cost – Team Reported Cost)

*The table costs of all items in error are included in the calculation. A missing assembly would include the price of all parts, materials, processes and fasteners making up the assembly.*

### S.3.17 Discussion

S.3.17.1 The team must present their vehicle at the designated time to the Cost Judges.

S.3.17.2 The Cost Judges will:

- a. Review whether the specification of the vehicle in the Cost Report accurately reflects the vehicle brought to the Competition
- b. Review the manufacturing feasibility of the vehicle
- c. Assess supporting documentation based on its quality, accuracy and thoroughness.
- d. Apply penalties for missing or incorrect information in the Cost Report compared to the vehicle presented at inspection.

### S.3.18 Cost Audit

S.3.18.1 Teams may be selected for additional review of the vehicle to verify all processes and materials on their vehicle are in the cost report.

S.3.18.2 Audits will be held on the same event day but by a separate team of auditors after initial cost judging.

S.3.18.3 Adjustments from the Cost Audit will be included in the final scores

### S.3.19 Cost Scenario

The specific scenario will be provided prior to the competition and will include additional detail of how it will be conducted.

### S.3.20 Cost Event Scoring

#### S.3.20.1 Scoring Term Definitions

- Adjusted Cost – reported cost (including Cost Addendum) plus adjustments and penalties in dollars
- P<sub>your</sub> - the adjusted cost of your vehicle
- P<sub>min</sub> - the adjusted cost of the lowest cost vehicle
- P<sub>max</sub> - the adjusted cost of the highest cost vehicle

#### S.3.20.2 Price Score is given by

$$\text{Price Score} = 40 \times \frac{(P_{\text{max}} / P_{\text{your}}) - 1}{(P_{\text{max}} / P_{\text{min}}) - 1}$$

#### S.3.20.3 Cost Event Score is the Sum of:

- Price Score 40 points maximum
- Discussion Score 40 points maximum
- Scenario Score 20 points maximum
- Penalty Points deducted from score, no maximum limit
- Total Score 100 points maximum

## S.4 DESIGN EVENT

### S.4.1 Design Event Objective

- S.4.1.1 The Design Event evaluates the engineering effort that went into the vehicle and how the engineering meets the intent of the market both in terms of vehicle performance and overall value.
- S.4.1.2 The team and vehicle that illustrate the best use of engineering to meet the design goals, a cost effective high performance vehicle, and the best understanding of the design by the team members will win the design event.
- S.4.1.3 Components and systems that are incorporated into the design as finished items are not evaluated as a student designed unit, but are assessed on the team's selection and application of that unit.

### S.4.2 Design Documents – Required Submission

- S.4.2.1 The Design Report and the Spec Sheet must be submitted prior to the event.
- S.4.2.2 The Design Documents will be used for:
- Design Judge reviews prior to the Design Event
  - Sorting teams into appropriate design groups based on the quality of their review.
- S.4.2.3 Penalties for Late Submission of all or any one of the Design Documents will be imposed as described in section **DR - Document Requirements**
- S.4.2.4 Teams that submit a Design Report or a Spec Sheet which does not represent a serious effort to comply with the requirements may be excluded from the Design Event or be awarded a lower score.

### **S.4.3 Design Report Content and Format**

S.4.3.1 The Design Report should contain:

- a. A brief description of the vehicle with your team's design objectives
- b. Discussion of any important design features and vehicle concepts.
- c. Analysis and testing techniques that were utilized

S.4.3.2 The Design Report must not exceed eight pages total. If included, cover pages, table of contents, etc count as pages

S.4.3.3 The Design Report must include vehicle drawings:

- a. Three view drawings showing the vehicle, from the front, top, and side
- b. Each drawing must appear on a separate page (three of the allowed eight)
- c. May be manually or computer generated

S.4.3.4 Submit the Design Report as described in section **DR - Document Requirements**

### **S.4.4 Spec Sheet Content and Format**

S.4.4.1 Use the format provided and submit the Design Spec Sheet as described in section **DR - Document Requirements**

*The Design Judges realize that final design refinements and vehicle development may cause the submitted values to differ from those of the completed vehicle. For specifications that are subject to tuning, an anticipated range of values may be appropriate.*

### **S.4.5 Vehicle Condition**

S.4.5.1 Passing Technical Inspection is not required prior to Design judging.

S.4.5.2 Vehicles must be presented for Design judging in finished condition, fully assembled, complete and ready to run.

S.4.5.3 The judges will not evaluate any vehicle that is presented at the Design event in what they consider to be an unfinished state.

S.4.5.4 Point penalties may be assessed for vehicles with obvious preparation issues

### **S.4.6 Support Material**

S.4.6.1 Teams may bring to Design Judging any photographs, drawings, plans, charts, example components or other materials that they believe are needed to support the presentation of the vehicle and the discussion of their development process.

S.4.6.2 The available space in the Design Event judging area may be limited.

### **S.4.7 Judging Sequence**

S.4.7.1 Design judging may be conducted in one or more phases.

*Typical Design judging includes a first round review of all teams, then additional review of selected teams.*

### **S.4.8 Judging Criteria**

S.4.8.1 The Design Judges will:

- a. Evaluate the engineering effort based upon the team's Design Report, Spec Sheet, discussion with the team, and an inspection of the vehicle

- b. Inspect the vehicle to determine if the design concepts are adequate and appropriate for the application (relative to the objectives stated in the rules).
- c. Deduct points if the team cannot adequately explain the engineering and construction of the vehicle

S.4.8.2 The Design Judges may assign a portion of the Design Event points to the Design Report and/or Spec Sheet

S.4.8.3 Design Judging Score Sheets are available at the FSAE Online website.

#### **S.4.9 Design Event Scoring**

S.4.9.1 Scoring may range from 0 to 150 points, at the discretion of the Chief Design Judge

S.4.9.2 Penalty points may be applied to the Design score

S.4.9.3 Vehicles that are excluded from Design judging or refused judging will receive zero points for design.

## D - DYNAMIC EVENTS

### D.1 GENERAL DYNAMIC

#### D.1.1 Dynamic Events and Maximum Scores

Acceleration	100 points
Skid Pad	75 points
Autocross	125 points
Efficiency	100 points
Endurance	275 points
<b>Total</b>	<b>675 points</b>

#### D.1.2 Definitions

D.1.2.1 **Dynamic Area** – Any designated portion(s) of the competition site where the vehicles may move under their own power. This includes competition, inspection and practice areas.

D.1.2.2 **Staging Area** – Any area(s) within the Dynamic Area prior to the entry to an event for the purpose of gathering those vehicles that are about to start.

### D.2 PIT AND PADDOCK

#### D.2.1 Vehicle Movement

D.2.1.1 Outside of the Dynamic Area(s), vehicles must be pushed at a normal walking pace using the Push Bar (**VE.2.2**), with a driver in the cockpit and with another team member walking beside

D.2.1.2 The team may move the vehicle either with (a) all four wheels on the ground or with (b) the rear wheels supported on dollies, by push bar mounted wheels.

The external wheels supporting the rear of the vehicle must be non pivoting so the vehicle travels only where the front wheels are steered. The driver must always be able to steer and brake the vehicle normally.

D.2.1.3 When the Push Bar is attached, the engine must remain off, unless authorized by the officials.

D.2.1.4 Vehicles must be Shutdown when being moved around the paddock.

D.2.1.5 Vehicles with wings must have two team members, one walking on each side of the vehicle whenever the vehicle is being pushed.

D.2.1.6 A 25 point penalty may be assessed for each violation.

#### D.2.2 Fueling and Refueling

Officials must conduct all fueling and refueling in the designated location on the event site.

#### D.2.3 Engine Running Requirements

Engines may be run in the paddock if:

- The vehicle has passed Technical Inspection up to and including the Tilt Test
- The vehicle is supported on a stand
- The drive wheels are at least 10 cm off the ground, or the drive wheels have been removed

## **D.3 DRIVING**

### **D.3.1 Drivers Meetings – Attendance Required**

All drivers for an event must attend the drivers meeting(s). The driver for an event will be disqualified if he/she does not attend the driver meeting for the event.

### **D.3.2 Dynamic Area Limitations**

*Check the Event Website or event handbook for specific information*

D.3.2.1 The organizer may specify restrictions for the Dynamic Area. These could include limiting the number of team members and what may be brought into the area.

D.3.2.2 The organizer may specify additional restrictions for the Staging Area. These could include limiting the number of team members and what may be brought into the area.

D.3.2.3 The organizer may establish requirements for persons in the Dynamic Area, such as closed toe shoes or long pants.

### **D.3.3 Driving Under Power**

D.3.3.1 Vehicles may move under their own power only within the designated Dynamic Area(s), unless otherwise directed by the officials.

D.3.3.2 For all other movements, vehicles must be pushed at a normal walking pace using the Push Bar.

D.3.3.3 Driving a vehicle outside of scheduled events or scheduled practice will result in a 200 point penalty for the first violation and disqualification for a second violation.

### **D.3.4 Driving Offsite - Prohibited**

Teams found to have driven their vehicle at an offsite location during the period of the competition will be excluded from the competition.

### **D.3.5 Driver Equipment**

D.3.5.1 The Driver Equipment and Harness must be worn by the driver anytime in the cockpit with:  
a. (IC) Engine running or (EV) Tractive System active  
b. Anytime between starting a Dynamic run and finishing or abandoning that Dynamic run.

D.3.5.2 Removal of any Driver Equipment during a Dynamic event will result in Disqualification.

### **D.3.6 Starting**

D.3.6.1 Push starts are prohibited

D.3.6.2 Auxiliary batteries must not be used once a vehicle has moved to the starting line of any event.

### **D.3.7 Practice Area**

D.3.7.1 A practice area for testing and tuning may be available

D.3.7.2 The practice area will be controlled and may only be used during the scheduled times

D.3.7.3 Vehicles using the practice area must have a complete Inspection Sticker

### **D.3.8 Instructions from Officials**

Obey flags and hand signals from course marshals and officials immediately



### D.3.9 Vehicle Integrity

Officials may revoke the Inspection Approval for any vehicle condition that could compromise vehicle integrity, compromise the track surface, or pose a potential hazard.

This could result in DNF or DQ of any Dynamic event.

## D.4 FLAGS

*Any specific variations will be addressed at the drivers meeting.*

### D.4.1 Command Flags

D.4.1.1 Any Command Flag must be obeyed immediately and without question.

D.4.1.2 **Black Flag** - Pull into the Driver Change Area for discussion with the track officials. A time penalty may be assessed.

D.4.1.3 **Black Flag with Orange Dot** - Pull into the Driver Change Area for a mechanical inspection, something has been observed that needs closer inspection.

D.4.1.4 **Blue Flag** - Pull into the designated passing zone to be passed by a faster competitor. Obey the corner workers signals at the end of the passing zone to merge into competition.

D.4.1.5 **Checkered Flag** - Run has been completed. Exit the course at the designated point.

D.4.1.6 **Green Flag** – Approval to begin your run, enter the course under direction of the starter. If you stall the vehicle, please restart and await another Green Flag

D.4.1.7 **Red Flag** - Come to an immediate safe controlled stop on the course. Pull to the side of the course as much as possible to keep the course open. Follow corner worker directions.

D.4.1.8 **Yellow Flag (Stationary)** - Danger, SLOW DOWN, be prepared to take evasive action, something has happened beyond the flag station. NO PASSING unless directed by the corner workers.

D.4.1.9 **Yellow Flag (Waved)** - Great Danger, SLOW DOWN, evasive action is most likely required, BE PREPARED TO STOP, something has happened beyond the flag station, NO PASSING unless directed by the corner workers.

### D.4.2 Informational Flags

D.4.2.1 An Information Flag communicates to the driver, but requires no specific action.

D.4.2.2 **Red and Yellow Striped Flag** - Something is on the racing surface that should not be there. Be prepared for evasive maneuvers to avoid the situation.

D.4.2.3 **White Flag** - There is a slow moving vehicle on the course. Be prepared to approach it at a cautious rate.

## D.5 WEATHER CONDITIONS

### D.5.1 Operating Adjustments

D.5.1.1 The organizer may alter the conduct and scoring of the competition based on weather conditions.

D.5.1.2 No adjustments will be made to times for running in differing Operating Conditions.

D.5.1.3 The minimum performance levels to score points may be adjusted by the officials.

### D.5.2 Operating Conditions

D.5.2.1 The following operating conditions will be recognized:

- **Dry**
- **Damp**
- **Wet**

D.5.2.2 The current operating condition will be decided by the Officials and may change at any time.

D.5.2.3 The current operating condition will be prominently displayed at the Dynamic Area, and may be communicated by other means.

### D.5.3 Tire Requirements

D.5.3.1 Teams must run the tires allowed for each Operating Condition:

Operating Condition	Tires Allowed
Dry	Dry ( <b>T.1.8.1</b> )
Damp	Dry or Wet
Wet	Wet ( <b>T.1.8.2</b> )

D.5.3.2 When the operating condition is Damp, teams may change between Dry Tires and Wet Tires:

- a. Any time during the Acceleration, Skidpad, and Autocross Events
- b. Any time before starting their Endurance Event

### D.5.4 Tire Changes during Endurance

D.5.4.1 All tire changes after a vehicle has received the Green flag to start the Endurance Event must take place in the Driver Change Area.

D.5.4.2 If the Operating Condition changes to Wet during Endurance, the track will be Red Flagged or vehicles will be Black Flagged and brought into the driver change area

D.5.4.3 The allowed tire changes and associated conditions are given in the following tables.

Existing Operating Condition	Currently Running on:	Operating Condition Changed to:		
		Dry	Damp	Wet
Dry	Dry Tires	ok	A	B
Damp	Dry Tires	ok	A	B
Damp	Wet Tires	C	C	ok
Wet	Wet Tires	C	C	ok

	Requirement	Allowed at Driver Change?
A	may change from Dry to Wet	Yes
B	MUST change from Dry to Wet	Yes
C	may change from Wet to Dry	NO

D.5.4.4 Time allowed to change tires:

- a. Change to Wet Tires - Any time in excess of 10 minutes without driver change, or 13 minutes with driver change, will be added to the team's total time for Endurance
- b. Change to Dry Tires - The time used to change to Dry tires will be added to the team's total time for Endurance

- D.5.4.5 If the vehicle has a tire puncture,
- The wheel and tire may be replaced with an identical wheel and tire
  - When the puncture is caused by track debris and not a result of component failure or the vehicle itself, the tire change time will not count towards the team's total time.

## D.6 DRIVER LIMITATIONS

### D.6.1 Three Event Limit

- D.6.1.1 An individual team member may not drive in more than three events.
- D.6.1.2 The Efficiency Event is considered a separate event although it is conducted simultaneously with the Endurance Event.

*A minimum of four drivers are required to participate in all of the dynamic events.*

## D.7 DEFINITIONS

- D.7.1.1 **DOO** - Cone is Down or Out when either:
- Cone has been knocked over (Down)
  - The entire base of the cone lies outside the box marked around the cone in its undisturbed position (Out)
- D.7.1.2 **DNF** - Did Not Finish – The team attempted a run, but did not complete it, or was not allowed to complete it
- D.7.1.3 **DQ** - Disqualified - run(s) no longer valid
- D.7.1.4 **Gate** - The path between two cones through which the vehicle must pass. Two cones, one on each side of the course define a gate. Two sequential cones in a slalom define a gate.
- D.7.1.5 **Entry Gate** -The path marked by cones which establishes the required path the vehicle must take to enter the course.
- D.7.1.6 **Exit Gate** - The path marked by cones which establishes the required path the vehicle must take to exit the course.
- D.7.1.7 **OC** – Off Course
- The vehicle did not pass through a gate in the required direction.
  - The vehicle has all four wheels outside the course boundary as indicated by cones, edge marking or the edge of the paved surface.

*Where more than one boundary indicator is used on the same course, the narrowest track will be used when determining off course penalties.*

## D.8 ACCELERATION EVENT

The Acceleration event evaluates the vehicle acceleration in a straight line on flat pavement.

### D.8.1 Acceleration Layout

- D.8.1.1 Course length will be 75 m from starting line to finish line
- D.8.1.2 Course width will be at least 4.9 m wide as measured between the inner edges of the bases of the course edge cones
- D.8.1.3 Cones are placed along the course edges at intervals, approximately 6 m
- D.8.1.4 Cone locations are not marked on the pavement

## D.8.2 Acceleration Procedure

D.8.2.1 Each team may attempt up to four runs, using two drivers, limited to two runs for each driver

D.8.2.2 Runs with the first driver have priority

D.8.2.3 Each Acceleration run is performed as follows:

- a. The foremost part of the vehicle will be staged at 0.30 m behind the starting line
- b. A Green Flag or light signal will give the approval to begin the run
- c. Timing starts when the vehicle crosses the starting line
- d. Timing ends when the vehicle crosses the finish line

D.8.2.4 Each driver may return to the front of the staging line immediately after their first run to make a second run

## D.8.3 Acceleration Penalties

D.8.3.1 Cones (DOO)

Two second penalty for each DOO (including entry and exit gate cones) on that run

D.8.3.2 Off Course (OC)

DNF for that run

## D.8.4 Acceleration Scoring

D.8.4.1 Scoring Term Definitions:

- Corrected Time = Acceleration Run Time + ( DOO \* 2 )
- T<sub>your</sub> - the best Corrected Time for the team
- T<sub>min</sub> - the lowest Corrected Time recorded for any team
- T<sub>max</sub> - 150% of T<sub>min</sub>

D.8.4.2 When T<sub>your</sub> < T<sub>max</sub>. the team score is determined as:

$$\text{Acceleration Score} = 95.5 \times \frac{(T_{\text{max}} / T_{\text{your}}) - 1}{(T_{\text{max}} / T_{\text{min}}) - 1} + 4.5$$

D.8.4.3 When T<sub>your</sub> > T<sub>max</sub> , Acceleration Score = 4.5

## D.9 SKIDPAD EVENT

The Skidpad event measures the vehicle cornering ability on a flat surface while making a constant radius turn.

### D.9.1 Skidpad Layout

D.9.1.1 Course Design

- Two pairs of concentric circles in a figure of eight pattern
- Centers of the circles      18.25 m apart
- Inner circles                    15.25 m in diameter
- Outer circles                    21.25 m in diameter
- Driving path                    the 3.0 m wide path between the inner and outer circles

### D.9.1.2 Cone Placement

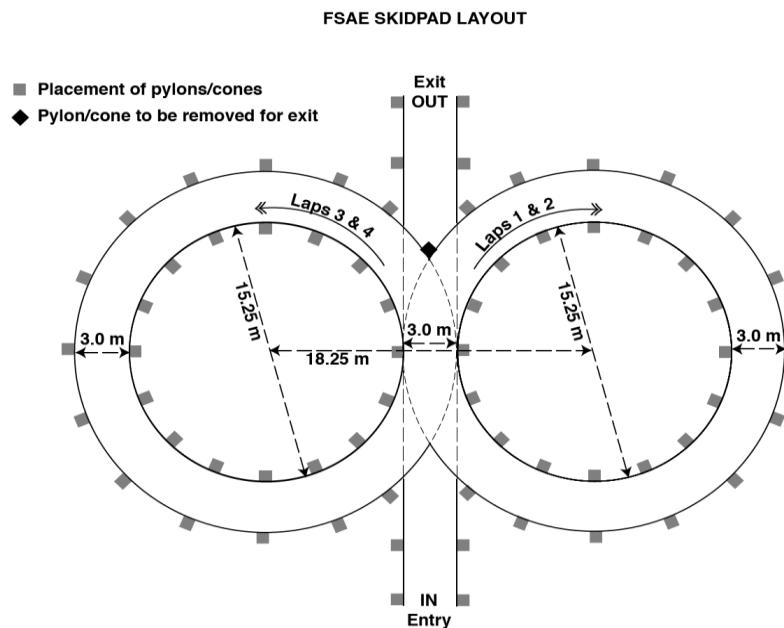
- Sixteen (16) pylons will be placed around the inside of each inner circle and thirteen (13) pylons will be positioned around the outside of each outer circle in the pattern shown in the Skidpad layout diagram.
- Each circle will be marked with a chalk line, inside the inner circle and outside the outer circle

*The Skidpad layout diagram shows the circles for cone placement, not for course marking. Chalk lines are marked on the opposite side of the cones, outside the driving path*

- Additional pylons will establish the entry and exit gates.
- A cone may be placed in the middle of the exit gate until the finish lap.

### D.9.1.3 Course Operation

- Vehicles will enter and exit through gates on a 3.0 m wide path that is tangential to the circles where they meet.
- The line between the centers of the circles defines the start/stop line.
- A lap is defined as traveling around either of the circles from the start/stop line and returning to the start/stop line.



## D.9.2 Skidpad Procedure

D.9.2.1 Each team may attempt up to four runs, using two drivers, limited to two runs for each driver.

D.9.2.2 Runs with the first driver have priority

D.9.2.3 Each Skidpad run is performed as follows:

- A Green Flag or light signal will give the approval to begin the run
- The vehicle will enter perpendicular to the figure eight and will take one full lap on the right circle
- The next lap will be on the left circle and will be timed

- d. Immediately following the second lap, the vehicle will enter the left circle for the third lap
- e. The fourth lap will be on the left circle and will be timed
- f. Immediately upon finishing the fourth lap, the vehicle will exit the track. The exit is at the intersection moving in the same direction as entered

D.9.2.4 Each driver may return to the front of the staging line immediately after their first run to make a second run

### D.9.3 Skidpad Penalties

#### D.9.3.1 Cones (DOO)

A 0.125 second penalty for each DOO (including entry and exit gate cones) on that run

#### D.9.3.2 Off Course (OC)

DNF for that run. Vehicles that stall or spin out may continue as long as they have not gone off course.

#### D.9.3.3 Incorrect Laps

Vehicles that run an incorrect number of laps or run the laps in the wrong sequence will be DNF for that run.

### D.9.4 Skidpad Scoring

#### D.9.4.1 Scoring Term Definitions

- Corrected Time = ( Right Lap Time + Left Lap Time ) / 2 + ( DOO \* 0.125 )
- T<sub>your</sub> - the best Corrected Time for the team
- T<sub>min</sub> - is the lowest Corrected Time recorded for any team
- T<sub>max</sub> - 125% of T<sub>min</sub>

D.9.4.2 When T<sub>your</sub> < T<sub>max</sub>. the team score is determined as:

$$\text{Skidpad Score} = 71.5 \times \frac{(T_{\text{max}} / T_{\text{your}})^2 - 1}{(T_{\text{max}} / T_{\text{min}})^2 - 1} + 3.5$$

D.9.4.3 When T<sub>your</sub> > T<sub>max</sub> , Skidpad Score = 3.5

## D.10 AUTOCROSS EVENT

The Autocross event evaluates the vehicle maneuverability and handling qualities on a tight course

### D.10.1 Autocross Layout

D.10.1.1 The Autocross course will be designed with the following specifications. Average speeds should be 40 km/hr to 48 km/hr

- a. Straights: No longer than 60 m with hairpins at both ends
- b. Straights: No longer than 45 m with wide turns on the ends
- c. Constant Turns: 23 m to 45 m diameter
- d. Hairpin Turns: 9 m minimum outside diameter (of the turn)
- e. Slaloms: Cones in a straight line with 7.62 m to 12.19 m spacing
- f. Miscellaneous: Chicanes, multiple turns, decreasing radius turns, etc.

- g. Minimum track width: 3.5 m
- h. Length of each run should be approximately 0.80 km

D.10.1.2 The Autocross course specifications may deviate from the above to accommodate event site requirements.

#### **D.10.2 Autocross Procedure**

D.10.2.1 Each team may attempt up to four runs, using two drivers, limited to two runs for each driver

D.10.2.2 Runs with the first driver have priority

D.10.2.3 Each Autocross run is performed as follows:

- a. The vehicle will be staged at a specific distance behind the starting line
- b. A Green Flag or light signal will give the approval to begin the run
- c. Timing starts when the vehicle crosses the starting line
- d. Timing ends when the vehicle crosses the finish line

D.10.2.4 Each driver may return to the front of the staging line immediately after their first run to make a second run

#### **D.10.3 Autocross Penalties**

D.10.3.1 Cones (DOO)

Two second penalty for each DOO (including cones after the finish line) on that run

D.10.3.2 Off Course (OC)

- a. When an OC occurs, the driver must reenter the track at or prior to the point of exit or receive a 20 second penalty
- b. Penalties will not be assessed for accident avoidance or other reasons deemed sufficient by the track officials.

D.10.3.3 Missed Slalom

Missing one or more gates of a given slalom will be counted as one Off Course

#### **D.10.4 Stalled & Disabled Vehicles**

D.10.4.1 If a vehicle stalls and cannot restart without external assistance, or is damaged and not able to complete the run, it will be deemed disabled and scored DNF for that run

D.10.4.2 Disabled vehicles will be cleared from the track by the track workers. At the direction of the track officials team members may be instructed to retrieve the vehicle. Vehicle recovery may only be done under the control of the track officials.

#### **D.10.5 Autocross Scoring**

D.10.5.1 Scoring Term Definitions:

- Corrected Time = Autocross Run Time + ( DOO \* 2 ) + ( OC \* 20 )
- T<sub>your</sub> - the best Corrected Time for the team
- T<sub>min</sub> - the lowest Corrected Time recorded for any team
- T<sub>max</sub> - 145% of T<sub>min</sub>

D.10.5.2 When T<sub>your</sub> < T<sub>max</sub>. the team score is determined as:

$$\text{Autocross Score} = 118.5 \times \frac{(\text{T}_{\text{max}} / \text{T}_{\text{your}}) - 1}{(\text{T}_{\text{max}} / \text{T}_{\text{min}}) - 1} + 6.5$$

D.10.5.3 When  $T_{your} > T_{max}$  , Autocross Score = 6.5

## **D.11 ENDURANCE EVENT**

The Endurance event evaluates the overall performance of the vehicle and tests the durability and reliability.

### **D.11.1 Endurance General Information**

- D.11.1.1 The organizer may establish one or more requirements to allow teams to compete in the Endurance event.
- D.11.1.2 Each team may attempt the Endurance event once.
- D.11.1.3 The Endurance event consists of two Endurance runs, each using a different driver, with a Driver Change between.
- D.11.1.4 Teams may not work on their vehicles once their Endurance event has started
- D.11.1.5 Multiple vehicles may be on the track at the same time
- D.11.1.6 Wheel to Wheel racing is prohibited.
- D.11.1.7 Vehicles must not be driven in reverse

### **D.11.2 Endurance Layout**

- D.11.2.1 The Endurance event will consist of multiple laps over a closed course to a total distance of approximately 22 km.
- D.11.2.2 The Endurance course will be designed with the following specifications. Average speed should be 48 km/hr to 57 km/hr with top speeds of approximately 105 km/hr.
  - a. Straights: No longer than 77 m with hairpins at both ends
  - b. Straights: No longer than 61 m with wide turns on the ends
  - c. Constant Turns: 30 m to 54 m diameter
  - d. Hairpin Turns: 9 m minimum outside diameter (of the turn)
  - e. Slaloms: Cones in a straight line with 9 m to 15 m spacing
  - f. Miscellaneous: Chicanes, multiple turns, decreasing radius turns, etc.
  - g. Minimum track width: 4.5 m
  - h. Designated passing zones at several locations
- D.11.2.3 The Endurance course specifications may deviate from the above to accommodate event site requirements.

### **D.11.3 Endurance Run Order**

- D.11.3.1 The Endurance Run Order is established so that vehicles of similar speed potential are on track together to reduce the need for passing.
- D.11.3.2 The Endurance Run Order should be based on the Autocross event finish order and include the teams eligible for Endurance which did not compete in the Autocross event.
- D.11.3.3 The Endurance Run Order sequence may be altered by the organizer to accommodate specific circumstances or event considerations.
- D.11.3.4 Teams must keep track of the Endurance Run Order and have their vehicle fueled, in line and prepared to start when their turn to run arrives.



#### **D.11.4 Endurance Vehicle Starting / Restarting**

- D.11.4.1 Teams that are not ready to run or are unable to start their Endurance event within the allowed time when their turn in the Run Order arrives:
- Will receive a time penalty (**D.11.12.5**)
  - May then run at the discretion of the officials
- D.11.4.2 Following Driver Change, the vehicle will be allowed up to 120 seconds (two minutes) to (IC) restart the engine or to (EV) enable the Tractive System.
- The time will start when the driver first tries to restart the engine or to enable the Tractive System.
  - The time to attempt start / restart is not counted towards the Endurance time
- D.11.4.3 If a vehicle stalls on the track, it will be allowed one lap by the vehicle that is following it (approximately 60 seconds) to restart. This time counts toward the Endurance time.
- D.11.4.4 If starts / restarts are not accomplished within the above times, the vehicle may be DNF.

#### **D.11.5 Endurance Event Procedure**

- D.11.5.1 Vehicles will be staged per the Endurance Run Order
- D.11.5.2 The first driver will perform an Endurance run
- D.11.5.3 The Driver Change must then be performed
- D.11.5.4 The second driver will perform an Endurance run
- D.11.5.5 The Endurance Event is complete when both:
- the team has completed the specified number of laps
  - the second driver crosses the finish line

#### **D.11.6 Endurance Run Procedure**

- D.11.6.1 A Green Flag or light signal will give the approval to begin the run
- D.11.6.2 The driver will drive approximately half of the Endurance distance
- D.11.6.3 A Checkered Flag will be displayed
- D.11.6.4 The vehicle must exit the track into the Driver Change area

#### **D.11.7 Driver Change Limitations**

- D.11.7.1 The team may bring only the following into the Driver Change Area:
- Three team members, including the driver or drivers
  - (EV Only) The three team members must consist of an ESO and two drivers.
  - Only the tools necessary adjust the vehicle to accommodate the second driver and/or change tires may be carried into this area by hand (no carts, tool chests etc.).
  - Each extra person entering the Driver Change area: 20 point penalty
- D.11.7.2 The only work permitted during Driver Change is:
- Operation of master switches
  - Adjustments to accommodate the driver
  - Tire changes per **D.5.4**

### **D.11.8 Driver Change Procedure**

D.11.8.1 The Driver Change will be performed in this sequence :

- a. Vehicle will stop in Driver Change Area
- b. First Driver turns off the engine / tractive system. Driver Change time starts.
- c. First Driver exits the vehicle
- d. Any necessary adjustments may be made to the vehicle to fit the Second Driver (harness, seat, pedals, head restraint) as allowed by **IN.14.2.2**
- e. Second Driver is secured in the vehicle.
- f. Second Driver is ready to start the engine / enable the tractive system. Driver Change time stops.
- g. Second Driver receives permission to continue
- h. The vehicle engine is started or Tractive System enabled. See **D.11.4**
- i. The vehicle stages to go back onto course, at the direction of the event officials

D.11.8.2 Three minutes are allowed for the team to complete the Driver Change

- a. Any additional time for inspection of the vehicle and the Driver Equipment is not included in the Driver Change time
- b. Time in excess of the allowed will be added to the team Endurance time

D.11.8.3 The Driver Change area will be placed such that the timing system will see the Driver Change as a long lap which will be deleted from the total time.

### **D.11.9 Breakdowns & Stalls**

D.11.9.1 If a vehicle breaks down it will be removed from the course and will not be allowed to reenter the course.

D.11.9.2 If a vehicle stalls, or ingests a cone, etc., it will be allowed to continue subject to **D.11.4** and reenter the course where it went off, but no work may be performed on the vehicle.

D.11.9.3 If a vehicle stalls and cannot be restarted without external assistance, the track workers will push it clear of the track.

### **D.11.10 Endurance Event – Black Flags**

D.11.10.1 A Black Flag will be shown at the designated location

D.11.10.2 The vehicle must pull into the Driver Change Area at the first opportunity

D.11.10.3 Driving Black Flag

- a. May be shown for any reason such as aggressive driving, failing to obey signals, not yielding for passing, etc.
- b. Course officials will discuss the situation with the driver
- c. The amount of time spent in the Driver Change Area is at the discretion of the officials.
- d. The time spent in Black Flag or a time penalty may be included in the Endurance Run time.
- e. If not possible to impose a penalty by a stop under a Black Flag, (not enough laps left), or during post event review, officials may add a time penalty

#### D.11.10.4 Mechanical Black Flag

- a. May be shown for any reason to question the vehicle condition
- b. Time spent off track is not included in the Endurance Run time.

D.11.10.5 Based on the inspection or discussion during a Black Flag period, the vehicle may not be allowed to continue the Endurance Run and will be scored DNF

#### **D.11.11 Endurance Event – Passing**

D.11.11.1 Passing during Endurance may only be done in the designated passing zones, under the control of the track officials.

D.11.11.2 Passing zones have two parallel lanes – a slow lane for the vehicles that are being passed and a fast lane for vehicles that are making a pass.

D.11.11.3 When a pass is to be made:

- a. A slower leading vehicle will receive a Blue Flag
- b. The slower vehicle must move into the slow lane and decelerate.
- c. The following faster vehicle will continue in the fast lane and make the pass.
- d. The vehicle that had been passed may reenter traffic only under the control of the passing zone exit flag.

D.11.11.4 Passing rules do not apply to vehicles that are passing disabled vehicles on the course or vehicles that have spun out and are not moving. When passing a disabled or off track vehicle, slow down, drive cautiously and be aware of all the vehicles and track workers in the area.

#### **D.11.12 Endurance Penalties**

D.11.12.1 Cones (DOO)

Two second penalty for each DOO (including cones after the finish line) on that run

D.11.12.2 Off Course (OC)

- a. When an OC occurs, the driver must reenter the track at or prior to the point of exit or receive a 20 second penalty
- b. Penalties will not be assessed for accident avoidance or other reasons deemed sufficient by the track officials.

D.11.12.3 Missed Slalom

Missing one or more gates of a given slalom will be counted as one Off Course

D.11.12.4 Penalties for Moving or Post Event Violations

- a. Black Flag penalties per **D.11.10**, if applicable
- b. Post Event Inspection penalties per **D.13.2**, if applicable

D.11.12.5 Endurance Starting (**D.11.4.1**)

Two minutes (120 seconds) penalty

D.11.12.6 Vehicle Operation

The Chief Marshall/Director of Operations may end the Endurance event (DNF) a vehicle if, for any reason including driver inexperience or mechanical problems, it is too slow or being driven in a manner that demonstrates an inability to properly control.

### D.11.13 Endurance Scoring

#### D.11.13.1 Scoring Term Definitions:

- Endurance Run Time - Total Time for both Drivers, minus the Driver Change lap, minus any Mechanical Black Flag Time, plus any Penalty time
- Corrected Time = Endurance Run Time + ( DOO \* 2 ) + ( OC \* 20 )
- T<sub>your</sub> - the Corrected Time for the team
- T<sub>min</sub> - the lowest Corrected Time recorded for any team
- T<sub>max</sub> - 145% of T<sub>min</sub>

#### D.11.13.2 The vehicle must complete the Endurance Event to receive a score based on their Corrected Time

- a. When T<sub>your</sub> < T<sub>max</sub>. the team score is determined as:

$$\text{Endurance Score} = 250 \times \frac{(T_{\text{max}} / T_{\text{your}}) - 1}{(T_{\text{max}} / T_{\text{min}}) - 1} + 25$$

- b. When T<sub>your</sub> > T<sub>max</sub> , Endurance Score = 25

#### D.11.13.3 When the vehicle does not complete Endurance (DNF), one point is awarded per lap:

$$\text{Endurance Score} = \text{Number of Completed Laps}$$

## D.12 EFFICIENCY EVENT

The Efficiency event evaluates the fuel/energy used to complete the Endurance event

### D.12.1 Efficiency General Information

D.12.1.1 The Efficiency is based on a metric of the amount of fuel consumed or energy used and the lap time on the endurance course, averaged over the length of the event.

D.12.1.2 The Efficiency score is based only on the distance the vehicle runs on the course during the Endurance event, and the total fuel/energy used. No adjustment to distance or fuel/energy will be made.

### D.12.2 Efficiency Procedure

#### D.12.2.1 For IC vehicles:

- a. The fuel tank must be filled to the fuel level line (**IC.5.5.4**)
- b. During fueling, once filled to the scribe line, no shaking or tilting of the tank, fuel system, or the entire vehicle is allowed.

D.12.2.2 (EV only) The vehicle may be fully charged

D.12.2.3 The vehicle will then compete in the Endurance event, refer to **D.11.5**

D.12.2.4 Vehicles must power down after leaving the course and be pushed to the fueling station or data download area

#### D.12.2.5 For IC vehicles:

- a. The fuel tank must be filled to the fuel level line (**IC.5.5.4**) to measure fuel used.
- b. Fuel pumps may be turned on and fuel valves may be opened to insure complete refuelling.

- c. If the fuel level changes after refuelling:
  - Additional fuel will be added to return the fuel tank level to the fuel level line.
  - Twice this amount will be added to the previously measured fuel consumption

D.12.2.6 (EV only) Energy meter data will be downloaded to determine energy used and check for power violations. Penalties will be applied per **EV.1.4**

### D.12.3 Efficiency Eligibility

#### D.12.3.1 Maximum Time

Vehicles whose average Endurance laptime exceeds 1.45 times the average Endurance laptime of the fastest team that completes the Endurance event will receive zero points

#### D.12.3.2 Maximum Fuel/Energy Used

Vehicles whose corrected average fuel consumption per lap exceeds 26 liter/100 km or energy equivalent of 60.06 kgCO<sub>2</sub>/100 km will receive zero points

#### D.12.3.3 Partial Completion of Endurance

- a. Vehicles which cross the start line following Driver Change are eligible for Efficiency points
- b. Other vehicles will receive a score of zero points

D.12.3.4 If damage or a potential environmental hazard (such as fuel tank leakage) exists, the fuel tank will not be refilled and the team will receive zero points for Efficiency

#### D.12.3.5 Efficiency Scoring (EV only)

The organizer may decide to not measure efficiency for Electric Vehicles that are run in their own class. If Efficiency will not be measured:

- a. The decision will be communicated prior to the start of the event
- b. Each vehicle that is eligible for Efficiency points per **D.12.3** will be awarded 100 points for Efficiency

### D.12.4 Efficiency Scoring

#### D.12.4.1 Conversion Factors

Each fuel or energy used is converted using the factors:

- a. Gasoline / Petrol            2.31 kg of CO<sub>2</sub> per litre
- b. E85                                1.65 kg of CO<sub>2</sub> per litre
- c. Electric                         0.65 kg of CO<sub>2</sub> per kWh

D.12.4.2 (EV only) Full credit will be given for energy recovered through regenerative braking

#### D.12.4.3 Scoring Term Definitions:

- CO<sub>2</sub> min - the smallest mass of CO<sub>2</sub> used by any competitor who is eligible for Efficiency
- CO<sub>2</sub> your - the mass of CO<sub>2</sub> used by the team being scored
- Tmin - the lowest Endurance time of the fastest team which is eligible for Efficiency
- Tyour - same as Endurance (**D.11.13.1**)
- Lapyours - the number of laps driven by the team being scored
- Laptotal Tmin and Latptotal CO<sub>2</sub>min - be the number of laps completed by the teams which set Tmin and CO<sub>2</sub>min, respectively

D.12.4.4 The Efficiency Factor is determined by:

$$\text{Efficiency Factor} = \frac{T_{\min} / \text{LapTotal } T_{\min}}{T_{\text{your}} / \text{Lap yours}} \times \frac{\text{CO}_2 \text{ min} / \text{LapTotal } \text{CO}_2 \text{ min}}{\text{CO}_2 \text{ your} / \text{Lap yours}}$$

D.12.4.5 EfficiencyFactor min will be calculated using the above formula with:

- CO<sub>2</sub> your equivalent to 60.06 kg CO<sub>2</sub>/100km
- T<sub>your</sub> 1.45 times T<sub>min</sub>

D.12.4.6 When the team is eligible for Efficiency. the team score is determined as:

$$\text{Efficiency Score} = 100 \times \frac{(\text{Efficiency Factor min} / \text{Efficiency Factor your}) - 1}{(\text{Efficiency Factor min} / \text{Efficiency Factor max}) - 1}$$

## D.13 POST ENDURANCE

### D.13.1 Technical Inspection Required

D.13.1.1 After Endurance and refuelling are completed, all vehicles must report to Technical Inspection.

D.13.1.2 Vehicles may then be subject to [IN.15 Reinspection](#)

### D.13.2 Post Endurance Penalty Guidelines

D.13.2.1 Penalties may be applied to the Endurance and/or Efficiency events based on Post Endurance Technical Inspection.

D.13.2.2 Any imposed penalty will be at the discretion of the officials.

D.13.2.3 One or more minor violations (rules compliance, but no advantage to team): 15-30 sec

D.13.2.4 Violation which is a potential or actual performance advantage to team: 120-360 sec

D.13.2.5 Violation with potential to affect safety or environment: 240 sec up to DNF or DQ

D.13.2.6 Team may be DNF or DQ for:

- a. Multiple violations involving safety, environment, or performance advantage
- b. A single substantial violation