T GENERAL TECHNICAL REQUIREMENTS

T 1 DEFINITIONS

T 1.1 Chassis Definitions

T 1.1.1 Chassis – the fabricated structural assembly that supports all functional vehicle systems. This assembly may be a single welded structure, multiple welded structures or a combination of composite and welded structures.

T 1.1.2 Bodywork – the outermost surface of the chassis or any fairing parts and covers.

T 1.1.3 Cockpit – the volume which accommodates the driver which is defined by the top of the vehicle, the floor closeout, the inner side of the bodywork, the front bulkhead and the firewall.

T 1.1.4 Chassis member – a minimum representative single piece of uncut, continuous tubing or equivalent structure.

T 1.1.5 Front bulkhead – a planar structure that defines the forward plane of the chassis and provides protection for the driver's feet (in front view, together with the Anti Intrusion Plate (AIP), covers the driver's feet).

T 1.1.6 Front bulkhead support – a structure that defines the side of the chassis from the front bulkhead back to the top of the upper side impact structure and the bottom of the front hoop.

T 1.1.7 Front hoop – a roll bar located above the driver's legs, in proximity to the steering wheel.

T 1.1.8 Impact Attenuator (IA) – a deformable, energy absorbing device located forward of the front bulkhead.

T 1.1.9 Main hoop – a roll bar located alongside or just behind the driver's torso.

T 1.1.10 Monocoque – a chassis made of composite material.

T 1.1.11 Node-to-node triangulation – an arrangement of chassis members projected onto a plane, where a co-planar load applied in any direction, at any node, results in only tensile or compressive forces in the chassis members as shown in figure 1.

T 1.1.12 Primary structure – the primary structure is comprised of the following components:

- Main hoop
- Front hoop
- Roll hoop braces and supports
- Impact structures as mentioned under T 3.14
- Anti Intrusion Plate

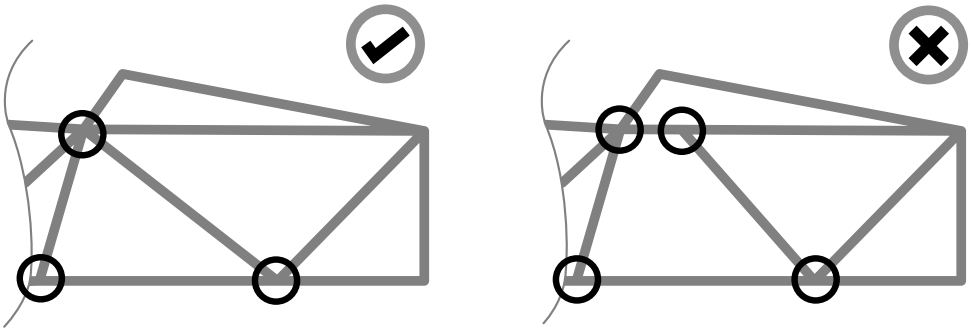

Figure 1: Node-to-node triangulation of chassis members (left correct and right incorrect).

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

T 1.1.13 Roll hoops – both the front hoop and the main hoop are classified as "roll hoops"

T 1.1.14 Roll hoop bracing – the structure from a roll hoop to the roll hoop bracing support.

T 1.1.15 Roll hoop bracing supports – the structure from the lower end of the roll hoop bracing back to the roll hoop(s).

T 1.1.16 Rollover protection envelope – the union of

- the primary structure and any additional structures fixed to the primary structure which meet the minimum specification defined in T 3.2 or equivalent
- the plane from the top of the main hoop to the top of the front hoop
- the plane from the top of the main hoop to the rearmost structure according to T 3.2 or equivalent

Example depicted in figure 2.

T 1.1.17 Side impact structure – the area of the side of the chassis between the front hoop and the main hoop and from the chassis floor to the height as required in T 3.14 above the lowest inside chassis point between front hoop and main hoop.

T 1.1.18 Surface envelope – the surface envelope is the surface of the union of the rollover protection envelope, see T 1.1.16, and the volume defined by

- the top of the main hoop and the outside edges of the four tires
- a plane from the top of the main hoop to the top of the front bulkhead
- a plane from the top of the main hoop to the the rearmost structure according to T 3.2 or equivalent
- a projection in side view of the lower boundaries of the rollover protection envelope

Example depicted in figure 3.

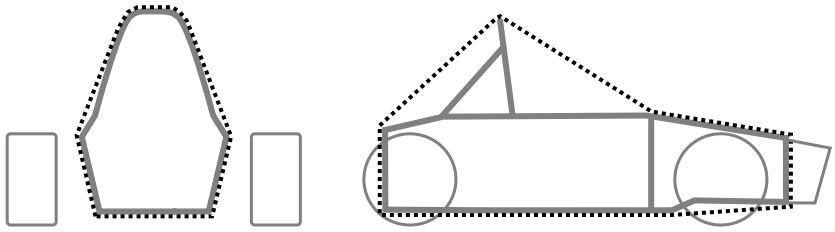

Figure 2: Rollover protection envelope T 1.1.16, thick lines are primary structure members according to T 3.2

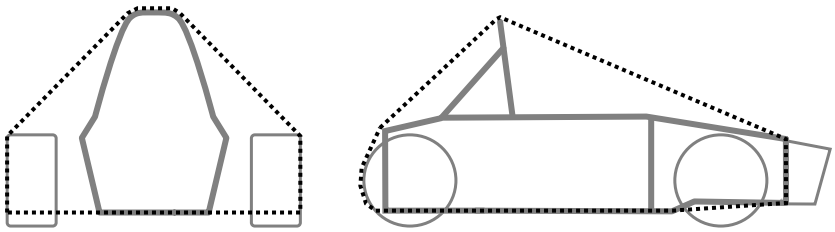

Figure 3: Surface Envelope T 1.1.18

T 1.2 Material Definitions

T 1.2.1 Fire Retardant – a material meeting one of the following standards:

- UL94 V-0 for the minimum used material thickness
- FAR 25.853(a)(1)(i)
- For foams only: UL94 HF-1 and UL94 VTM-0

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

T 1.2.2 Coolant – a substance used for heat transfer by convection.

T 1.3 Electrical Definitions

T 1.3.1 Direct Connection – two devices or circuits are directly connected if the connection is not routed through any common PCB and does not include any devices or functionality other than overcurrent protection or connectors.

T 1.4 Driving Mode Definitions

T 1.4.1 Manual Mode – a vehicle is in manual mode when driven by a human driver. In this case the ASMS must be off (AS deactivated).

T 1.4.2 Autonomous Mode – a vehicle is in autonomous mode when the AS is activated. When a vehicle is in autonomous mode, there must be no person inside the vehicle.

T 2 GENERAL DESIGN REQUIREMENTS

T 2.1 Vehicle Configuration

T 2.1.1 The vehicle must be designed and fabricated in accordance with good engineering practices.

T 2.1.2 The vehicle must be open-wheeled, single seat and open cockpit (a formula style body) with four wheels that are not in a straight line.

T 2.1.3 Open wheel vehicles must satisfy the following, see also figure 4:

- The wheel/tire assembly must be unobstructed when viewed from the side.
- No part of the vehicle may enter a keep-out-zone defined by two lines extending vertically from positions 75 mm in front of and 75 mm behind the outer diameter of the front and rear tires in the side view of the vehicle, with steering straight ahead. This keep-out zone extends laterally from the outside plane of the wheel/tire to the inboard plane of the wheel/tire assembly.

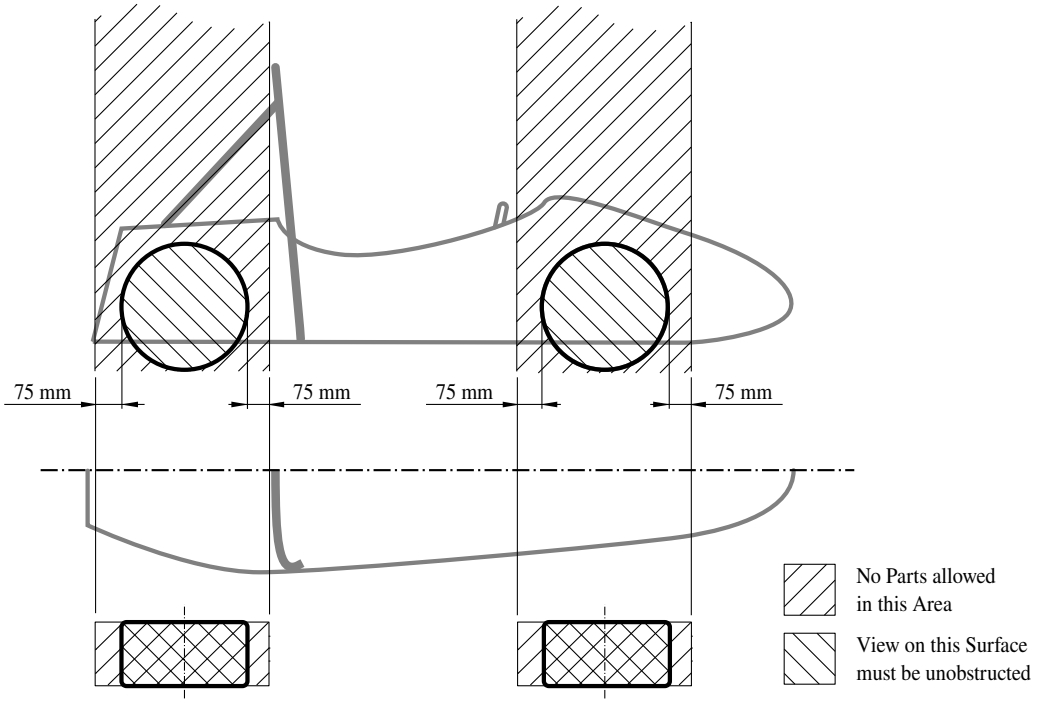

Figure 4: Keep-out-zones for the definition of an open-wheeled vehicle.

T 2.2 Ground Clearance

T 2.2.1 The minimum static ground clearance of any portion of the vehicle, other than the tires, including a driver, must be 30 mm. If an active suspension system is installed, the static ground clearance is measured in the lowest adjustable position.

T 2.2.2 Sliding skirts or other aerodynamic devices that by design, fabrication or as a consequence of moving, contact the track surface are prohibited.

T 2.3 Bodywork

T 2.3.1 There must be no openings through the bodywork into the cockpit other than that required for the cockpit opening. Minimal openings around the front suspension and steering system components are allowed.

T 2.3.2 In any side view in front of the cockpit opening and outside the area defined in T 8.2 all parts of the bodywork must have no external concave radii of curvatures. Any gaps between bodywork and other parts must be reduced to a minimum.

T 2.3.3 Enclosed chassis structures and structures between the chassis and the ground must have two venting holes of at least 25 mm diameter in the lowest part of the structure to prevent accumulation of liquids. Additional holes are required when multiple local lowest parts exist in the structure.

T 2.3.4 The bodywork in front of the front wheels with the tangent of surface above 45° relative to the forward direction must have a radius of at least 38 mm along the top, sides and bottom of all affected edges.

T 2.4 Minimum Edge Radii of Bodywork and Aerodynamic Devices

T 2.4.1 For all edges that could come into contact with any standing pedestrian without reaching to the vehicle, the minimum radius of the bodywork and aerodynamic devices is 3 mm for all forward facing edges and 1 mm for all other edges.

T 2.5 Suspension

T 2.5.1 The vehicle must be equipped with fully operational front and rear suspension systems including shock absorbers and a usable wheel travel of at least 50 mm and a minimum jounce of 25 mm with driver seated.

T 2.5.2 All suspension mounting points must be visible at technical inspection, either by direct view or by removing any covers.

T 2.6 Wheels

T 2.6.1 Any wheel mounting system that uses a single retaining nut must incorporate a device to prevent loosening of the nut and the wheel. A second nut (“jam nut”) does not meet these requirements.

T 2.6.2 Wheel lug bolts, drive pegs and studs must be made of steel or titanium. The team must be able to show good engineering practice and providing adequate strength by calculations. Wheel lug bolts, drive pegs and studs must not be hollow.

T 2.6.3 Aluminium wheel nuts may be used, but they must be hard anodized and in pristine condition.

T 2.6.4 The distance between any non-rotating part and the inner rim base must be at least 5 mm in static condition.

T 2.7 Tires

T 2.7.1 Vehicles must have two types of tires as follows:

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

T 2.7.2 Tires on the same axle must have the same manufacturer, size and compound.

T 2.7.3 Tire warmers are not allowed.

T 2.7.4 Special agents that increase traction must not be added to the tires or track surface.

T 2.8 Steering

T 2.8.1 Steering systems using cables or belts for actuation are prohibited. This does not apply for autonomous steering actuators.

T 2.8.2 The steering wheel must directly mechanically actuate the front wheels.

T 2.8.3 The steering system must have positive steering stops that prevent the steering linkages from locking up. The stops must be placed on the rack and must prevent the tires and rims from contacting any other parts. Steering actuation must be possible during standstill.

T 2.8.4 Allowable steering system free play is limited to a total of 7° measured at the steering wheel.

T 2.8.5 The steering wheel must be attached to the column with a quick disconnect. The driver must be able to operate the quick disconnect while in the normal driving position with gloves on.

T 2.8.6 The steering wheel must be no more than 250 mm rearward of the front hoop. This distance is measured horizontally, on the vehicle centerline, from the rear surface of the front hoop to the forward most surface of the steering wheel with the steering in any position.

T 2.8.7 The steering wheel must have a continuous perimeter that is near circular or near oval. The outer perimeter profile may have some straight sections, but no concave sections.

T 2.8.8 In any angular position, the top of the steering wheel must be no higher than the top-most surface of the front hoop.

T 2.8.9 The steering rack must be mechanically attached to the primary structure and all stationary parts must be within the rollover protection envelope, see T 1.1.16.

T 2.8.10 Joints between all components attaching the steering wheel to the steering rack must be mechanical and visible at technical inspection. Bonded joints are allowed in accordance with T 3.2.8.

T 2.8.11 Rear wheel steering, which can be electrically actuated, is allowed if mechanical stops limit the range of angular movement of the rear wheels to a maximum of 6°. This must be

demonstrated with a driver in the vehicle and the team must provide the equipment for the steering angle range to be verified at technical inspection.

T 2.9 Wheelbase, Track and Rollover Stability

T 2.9.1 The vehicle must have a wheelbase of at least 1525 mm.

T 2.9.2 The smaller track of the vehicle (front or rear) must be no less than 75 % of the larger track.

T 2.9.3 The track and center of gravity of the vehicle must combine to provide adequate rollover stability. This is tested by the tilt test IN 7.

T 3 General Chassis Design

T 3.1 General Requirements

T 3.1.1 Among other requirements, the vehicle's structure must include:

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

T 3.2 Minimum Material Requirements

T 3.2.1 Table 4 shows the minimum requirements for the members of the primary structure if made from steel tubing.

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

Table 4: Minimum Material Requirements

T 3.2.2 Steel tubing has to be made from unalloyed carbon steel with a maximum content of 0.3 % carbon, 1.7 % manganese and 0.6 % of any other element. All other steel grades are considered alternative materials and require additional testing and documentation, see T 3.3.

T 3.2.3 Except for inspection holes, any holes drilled in any part which is a member of the primary structure must be considered in the SES.

T 3.2.4 The steel properties used for the calculations in the SES must be the following, or what is written in the material property documentation, whichever is lower:

Non-welded strength for continuous material calculations:

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

Welded strength for discontinuous material such as joint calculations:

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

T 3.2.5 Any tubing with a wall thickness less than 1.2 mm or a minimum area moment of inertia less than 6695 mm^4 is considered non-structural and will be ignored when assessing compliance to any rule regarding the vehicle structure.

T 3.2.6 If a member of the primary structure (except for the roll hoops) is a bent tube or made from multiple tubes an additional tube must support it. This support tube must:

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

T 3.2.7 Any welded seams shape must not be mechanically altered in any way.

T 3.2.8 Where bonded joints are applicable and governed by the rules, a 50 % reduction must be applied to all nominal and tested adhesive values. Bonded joints in the primary structure must be documented in the SES.

T 3.3 Alternative Materials

T 3.3.1 Alternative materials may be used for all parts of the primary structure and the TSAC with the following exceptions:

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

T 3.3.2 If any other materials than steel tubing are used in the primary structure or the TSAC, physical testing is required to show equivalency to the minimum material properties for steel in T 3.2.

T 3.3.3 If alloyed steel as defined by T 3.2.2 is used, the team has to include tests and documentation in the SES to show structural equivalency. This may include, but is not limited to:

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

T 3.4 Composite Structures

T 3.4.1 If composite structures are used in the primary structure and/or the TSAC, the Flexural Rigidity (EI) of that structure must be calculated with the tools and formulas in the SES and/or Accumulator Structural Equivalency Spreadsheet (ASES). The EI must be calculated as the EI of a flat panel about its neutral axis. This panel must have the same composition as the structure used in the primary structure or the TSAC. The actual geometry and curvature of the panel may only be taken into account, if the flat panel EI equivalency is greater than 60 %, for the main hoop bracing support, the front hoop bracing, the front bulkhead support structure, the shoulder harness bar, the TS and TSAC protective structure.

T 3.4.2 If composite materials are used in the primary structure or the TSAC the SES must include:

- Material type(s)
- Cloth weights
- Resin type
- Fiber orientation
- Number of layers
- Core material
- Lay-up technique
- 3-point-bend test and shear test data

T 3.4.3 For any laminate in the primary structure and/or the TSAC, the maximum weight content of parallel fibers, relative to the weight of all fibers in the laminate, is 50 %. All fibers laid within any orientation +/-10° count as parallel in this case.

T 3.4.4 If an asymmetrical lay-up is used in the primary structure, the thinner skin must have a thickness of at least 40 % of the thicker skin or 1 mm whichever is less.

T 3.4.5 Wherever backing plates are required, they must be fully supported by the structure they are attached to.

T 3.4.6 Backing plates must have a continuous perimeter that is near circular or near oval. The outer perimeter profile may have some straight sections, but no concave sections. Backing plates must not have any cut-outs within their outside perimeter except for the holes for bolts.

T 3.5 Laminate Testing

T 3.5.1 If composite materials are used for any part of the primary structure or the TSAC the team must:

- Build a representative test panel which must measure exactly 275 mm × 500 mm that has the same design, laminate and fabrication method as used for the respective part of the primary structure represented as a flat panel. The sides of the test panel must not be laminated (core material must be visible).
- Perform a 3-point bending test on this panel

The data from these tests and pictures of the test samples and test setup must be included in the SES. In the pictures, the following must be identifiable: distance between the two supports, dimensions of the load applicator and test sample marking as per T 3.5.5. The test results must be used to derive strength and stiffness properties used in the SES formula for all laminate panels.

Representative test panels for parts of the TSAC may use smaller dimensions, provided that the panel core thickness is 5 mm or smaller. This representative test panel must then measure 150 mm × 275 mm. In this case, the distance between the two test panel supports must be at least 200 mm and the load applicator must have a radius of at least 5 mm. T 3.5.6 and T 3.5.7 do not apply.

T 3.5.2 If a panel represents side impact structure it must be proven that it has at least the same properties as two steel tubes meeting the requirements for side impact structure tubes for buckling modulus, yield strength and absorbed energy.

T 3.5.3 Composite structures with different core thicknesses but otherwise identical construction may use material properties derived from a single test panel. The panel with the thicker core must be tested and the structure using derived material properties must not use a core thickness of less than 66 % of the tested panel.

T 3.5.4 When a laminate is not quasi-isotropic, i.e. has equal strength and stiffness in the 0°, 90° and ±45° direction, the results from the 3 point bending test will be assigned to the 0° lay-up direction. To show equivalence in the SES, the 0° lay-up direction must be used and oriented accordingly in the chassis.

T 3.5.5 The test samples must be presented at technical inspection. All samples must be marked with the following non-removable (e.g.: permanent marker or engraving, but no sticker) information: laminated structure acronym and date of testing.

T 3.5.6 The distance between the two test panel supports must be at least 400 mm.

T 3.5.7 The load applicator used to test any panel or tube must be metallic and have a radius of 50 mm.

T 3.5.8 The load applicator must overhang the test piece to prevent edge loading.

T 3.5.9 There must be no material between the load applicator and the test piece.

T 3.5.10 Perimeter shear tests must be completed which measure the force required to push or pull a 25 mm diameter flat punch through a flat laminate sample. The sample must be at least 100 mm × 100 mm. Core and skin thicknesses must be identical to those used in the actual primary structure and be manufactured using the same materials and processes. If an asymmetrical lay-up is used, the thinner skin must face the punch

T 3.5.11 The test fixture must support the entire sample, except for a 32 mm hole aligned co-axially with the punch. The sample must not be clamped to the fixture.

T 3.6 Structural Documentation

T 3.6.1 All teams must submit a Structural Equivalency Spreadsheet (SES), Structural Equivalency 3D Model (SE3D) and [EV ONLY] ASES.

T 3.6.2 The SES and [EV ONLY] ASES can be downloaded from the competition website.

T 3.6.3 The SE3D must contain a three dimensional CAD model of the chassis including all members of the primary structure and their mechanical attachment details.

- [MONOCOQUE ONLY] The SE3D must include the inner, outer skin and core thicknesses.
- [MONOCOQUE ONLY] If the actual EI of a structure is used in the SES, this must be highlighted and included as a measurable instance.
- [EV ONLY] The TSACs and their attachment must be included.
- [CV ONLY] The air intake system, the fuel tank and filler neck must be included.

T 3.6.4 Vehicles must be fabricated in accordance with the materials and processes described in the SES.

T 3.6.5 Teams must bring a copy of the approved SES to technical inspection.

T 3.7 Roll Hoops

T 3.7.1 Both roll hoops must be securely integrated to the primary structure using node-to-node triangulation or equivalent joining methods.

T 3.7.2 The minimum radius of any bend, measured at the tube centerline, must be at least three times the tube outside diameter. Bends must be smooth and continuous with no evidence of crimping or wall failure. The minimum area moment of inertia, see T 3.2, must be maintained in all areas, including the bends of the manufactured tubes.

T 3.7.3 In a plane perpendicular to the longitudinal axis of the vehicle and through the lower endpoints of the roll hoop, no part of the primary structure may lie below 30 mm of the endpoints of the roll hoop.

T 3.7.4 Roll hoops attached to a composite primary structure must be mechanically attached at the top and bottom of both sides of that structure and at intermediate locations if needed to show equivalency. The lower roll hoop tubing attachment points must be within 50 mm of the endpoints of the roll hoop.

T 3.7.5 Mounting plates welded to the roll hoops must be at least 2 mm thick steel or 3 mm thick aluminium, dependent of the roll hoop material.

T 3.7.6 Both roll hoops must have one 4.5 mm inspection hole in a non-critical straight location and its surface at this point must be unobstructed for at least 180°.

T 3.8 Main Hoop

T 3.8.1 The main hoop must be constructed of a single piece of uncut, continuous, closed section steel tubing.

T 3.8.2 In side view the portion of the main hoop which is above its upper attachment point to the side impact structure must be inclined less than 10° from vertical.

T 3.8.3 In side view any bends in the main hoop above its upper attachment point to the primary structure must be braced to a node of the main hoop bracing support structure with tubing meeting the requirements of main hoop bracing.

T 3.8.4 In side view any portion lower than the upper attachment point to the side impact structure must be inclined either forward or not more than 10° rearward.

T 3.9 Front Hoop

T 3.9.1 The front hoop must be constructed of a continuous and closed section.

T 3.9.2 If the front hoop is made from more than one piece it must be supported by node-to-node triangulation or an equivalent construction.

T 3.9.3 In side view, no part of the front hoop can be inclined more than 20° from vertical.

T 3.9.4 If the front hoop is a welded construction made from multiple aluminium profiles, the equivalent yield strength must be considered in the as-welded condition unless the team demonstrates and shows proof that it has been properly solution heat treated and artificially aged. The team must supply sufficient documentation proving the appropriate heat treatment process was performed.

T 3.9.5 The front hoop requires six attachment points, two on each side connecting to the front bulkhead support structures and two connecting to the front hoop bracing, and must therefore show equivalency to 180 kN, as follows from T 3.15.1 and T 3.11.4.

T 3.9.6 Fully laminating the front hoop to the monocoque is acceptable. Fully laminating means that the hoop has to be encapsulated with laminate around its whole circumference, see figure 5. Equivalence to T 3.7.4 must be shown in the SES. The laminate encapsulating the front hoop must overlap by at least 25 mm on each side. It must have the same lay-up as the laminate that it is connecting to.

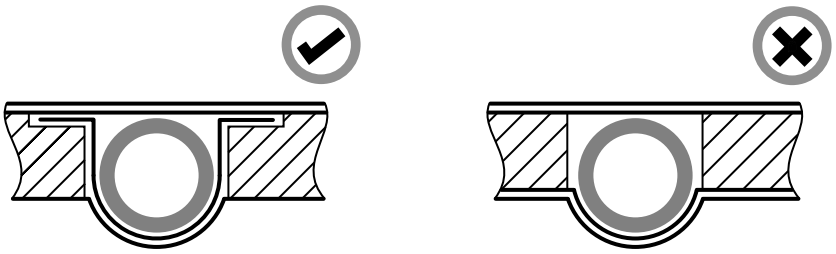

Figure 5: Front hoop laminating requirements

T 3.10 Main Hoop Bracing

T 3.10.1 The main hoop must be supported to the front or the rear by bracing tubes on each side of the main hoop.

T 3.10.2 In side view the main hoop and the main hoop braces must not lie on the same side of a vertical line coincident with the top of the main hoop.

T 3.10.3 The main hoop braces must be attached to the main hoop no lower than 160 mm below the top-most surface of the main hoop. The included angle formed by the main hoop and the main hoop braces must be at least 30°.

T 3.10.4 The main hoop braces must be straight.

T 3.10.5 The lower ends of the main hoop braces must be supported back to the upper attachment point of the main hoop to the side impact structure and to the lower attachment point of the main hoop to the side impact structure by a node-to-node triangulated structure or equivalent composite structure.

T 3.10.6 If any item which extends outside of the primary structure is attached to the main hoop braces, additional bracing is required to prevent bending loads in a rollover situation.

T 3.11 Front Hoop Bracing

T 3.11.1 The front hoop bracing attaches on each side of the front hoop as well as the structure forward of the driver's feet. A minimum of two tubes without any bends must be straight on a line in side view of the frame and must have a minimum distance of 100 mm between each other at the front hoop.

T 3.11.2 The front hoop bracing structure must be attached no lower than 50 mm below the top-most surface of the front hoop, see figure 6.

T 3.11.3 If the front hoop is inclined more than 10° to the rear, additional braces extending rearwards are required.

T 3.11.4 Composite front hoop bracing structures and their attachments cannot be counted towards the front bulkhead support structures and vice-versa for the structural equivalency documentation.

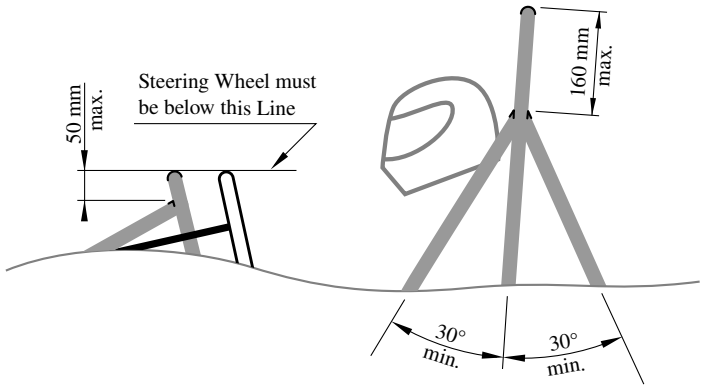

Figure 6: Front hoop bracing, main hoop bracing and steering wheel requirements

T 3.12 Front Bulkhead

T 3.12.1 Any alternative material used for the front bulkhead must have a perimeter shear strength equivalent to a 1.5 mm thick steel plate.

T 3.12.2 If the front bulkhead is part of a composite structure and is modeled as an "L" shape, the EI of the front bulkhead about the vertical and lateral axes must be equivalent to a steel tube meeting the requirements for the front bulkhead. The length of the section perpendicular to the bulkhead may be a maximum of 25 mm measured from the rearmost face of the bulkhead.

T 3.13 Front Bulkhead Support

T 3.13.1 The front bulkhead must be supported back to the front hoop by a minimum of three tubes on each side; an upper member, a lower member and diagonal bracing to provide triangulation.

- The upper support member must be attached to the front bulkhead a maximum of 50 mm below the top-most surface of the front bulkhead, and attached to the front hoop a maximum of 50 mm below the upper side impact member. If the attachment point of the upper member is greater than 100 mm above the upper side impact member, node-to-node triangulated bracing is required to transfer load to the main hoop.
- The lower support member must be attached to the base of the front bulkhead and the base of the front hoop.
- The diagonal bracing must triangulate the upper and lower support members node-to-node.

T 3.13.2 If the front bulkhead support is part of a composite structure, it must have equivalent EI to the sum of the EI of the six baseline steel tubes that it replaces and it must not be counted towards the composite front hoop bracing structures for the structural equivalency documentation, i.e. T 3.11.4.

T 3.13.3 The EI of the vertical side of the front bulkhead support structure must be equivalent to at least the EI of one baseline steel tube that it replaces.

T 3.13.4 The perimeter shear strength of the monocoque laminate in the front bulkhead support structure must be at least 4 kN.

T 3.14 Impact Structures

T 3.14.1 The side impact structure must consist of at least three steel tubes, see T 3.2, on each side of the cockpit, see figure 7.

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

T 3.14.2 Other impact structures, see CV 1.3.2, EV 4.4.2 and EV 5.5.2, must be fully triangulated structures and consist of at least three steel tubes, see T 3.2, on each side and rearward of the component that needs to be protected.

- If the component projects outwards from the roll hoops to the side, the front of the component must also be protected.
- The upper member must not be higher than 320 mm above the lowest inside chassis point between the front and main hoop.

T 3.14.3 If the impact structure is part of a composite structure, the following is required:

- The region of the structure up to a height of 320 mm above the lowest inside chassis point between the front and main hoop must have an EI equal to the three baseline steel tubes that it replaces. An example for side impact structure is given in figure 8.
- The vertical impact structure must have an EI equivalent to two baseline steel tubes and half the horizontal floor must have an EI equivalent to one baseline steel tube.
- The vertical impact structure must have an absorbed energy equivalent to two baseline steel tubes, exceeding 65 J.
- The perimeter shear strength must be at least 7.5 kN.

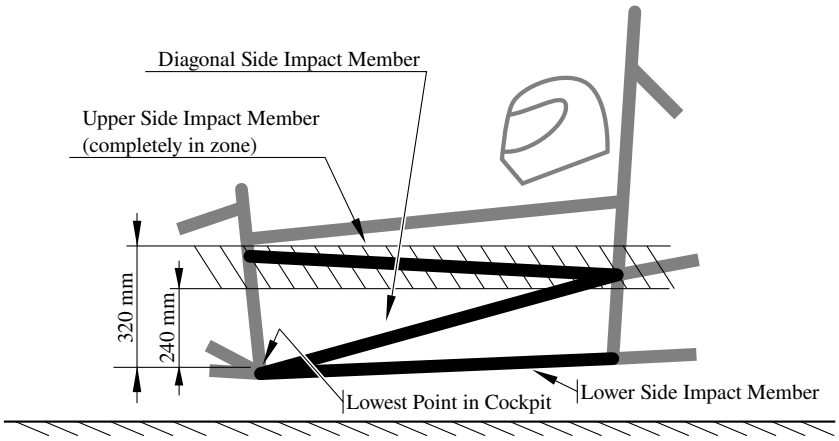

Figure 7: Side impact structure

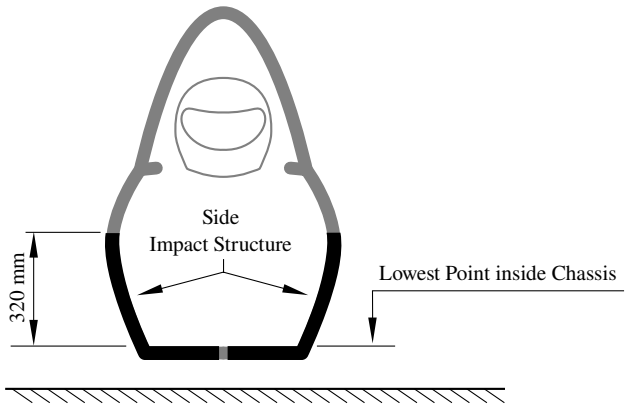

Figure 8: Side impact structure monocoque

T 3.15 Bolted Primary Structure Attachments

T 3.15.1 If two parts of the primary structure are bolted together, each attachment point between the two parts must be able to carry a load of 30 kN in any direction.

T 3.15.2 Data obtained from the laminate perimeter shear strength test must be used to prove that adequate shear area is provided.

T 3.15.3 Each attachment point requires a minimum of two 8 mm metric grade 8.8 bolts and steel backing plates with a minimum thickness of 2 mm.

T 3.15.4 For the attachment of front hoop bracing, main hoop bracing and main hoop bracing support to the primary structure the use of one 10 mm metric grade 8.8 bolt is sufficient, if the bolt is on the centerline of the tube, see figure 9.

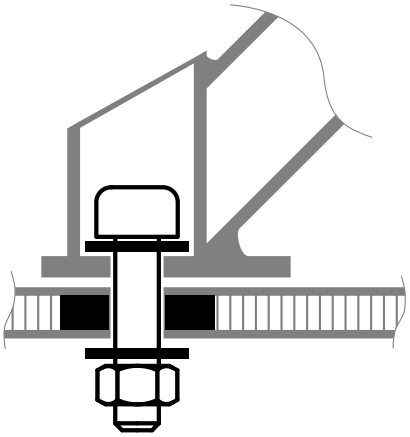

Figure 9: Bolted roll hoop bracing support

T 3.15.5 When using bolted joints within the primary structure, no crushing of the laminate core material is allowed.

T 3.15.6 For the AIP to front bulkhead attachment, and if two panels or plates of the primary structure are bolted together, for each 200 mm of reference perimeter a minimum of one 8 mm metric grade 8.8 bolt(s) must be used, rounded up to the next integer. Smaller, but more, bolts may be used, if equivalency is shown. The bolts must be evenly distributed over the circumference using good engineering practices. The reference perimeter is the outside perimeter of the attached part at the connection. The bolts are considered critical fasteners, must comply with T 10 and require steel backing plates with a minimum thickness of 2 mm.

T 3.15.7 For the bolted connections of T 3.15.6 an exception in favor of blind inserts may be given, if physical testing is documented in the SES, where the bolted connection can carry a load of 15 kN in any direction.

T 3.16 Impact Attenuator

T 3.16.1 Each vehicle must be equipped with an IA assembly consisting of an IA and AIP.

T 3.16.2 The IA must:

- Be installed forward of the front bulkhead.
- Be at least 100 mm high and 200 mm wide for a minimum distance of 200 mm forward of the front bulkhead.
- Not be positioned more than 350 mm above the ground, for any portion of the required $100 \times 200 \times 200\,mm^3$ volume.
- Not be able to penetrate the front bulkhead in the event of an impact.
- Be attached securely and directly to the AIP.
- Not be part of the non-structural bodywork.
- Be designed with a closed front section.
- Not be wider or higher than the AIP.

T 3.16.3 The baseline design for the AIP is a 1.5 mm solid steel or 4.0 mm solid aluminium plate.

- If the IA and AIP (IA assembly) are bolted to the front bulkhead, it must be the same size as the outside dimensions of the front bulkhead.
- If it is welded to the front bulkhead, it must extend at least to the centerline of the front bulkhead tubing in all directions.
- The AIP must not extend past the outside edges of the front bulkhead.

T 3.16.4 Alternative AIP designs are permissible if equivalency to T 3.16.3 is proven by physical testing as in T 3.18.2.

T 3.16.5 The IA may be attached to the AIP by a minimum of four 8 mm metric grade 8.8 bolts that are considered critical fasteners and must comply with T 10. Attachment(s) using adhesive must be able to carry a load of 60 kN in any direction.

T 3.16.6 The attachment of the IA assembly must be designed to provide an adequate load path for transverse and vertical loads in the event of off-center and off-axis impacts. Segmented foam attenuators must have the segments bonded together to prevent sliding or parallelogramming.

T 3.16.7 A team may use one of the "standard" FSAE IAs, in order to avoid testing, provided that:

- if the front bulkhead width is larger than 400 mm and/or its height is larger than 350 mm a diagonal or X-bracing that is a front bulkhead support tube or an approved equivalent per T 3.2, must be included in the front bulkhead. Or equivalent for monocoque bulkheads.
- must use a 1.5 mm solid steel AIP that is welded along its full perimeter to a steel bulkhead or use a 4 mm solid aluminium AIP that is bolted to any bulkhead with a minimum of eight 8 mm metric grade 8.8 bolts
- if the "standard" honeycomb IA is used, the IA must be of pre-crushed type
- adhesive used to mount the "standard" IA to the AIP must have a shear strength of at least 24 MPa

T 3.16.8 If the standard IA is used, but does not comply with the requirements of T 3.16.7 physical testing must be carried out to prove that the AIP does not permanently deflect more than 25 mm.

T 3.17 Impact Attenuator Data Requirement

T 3.17.1 All teams must submit an IA data report using the Impact Attenuator Data (IAD) template provided at the competition website.

T 3.18 Impact Attenuator Test Requirements

T 3.18.1 The IA assembly, when mounted on the front of a vehicle with a total mass of 300 kg and impacting a solid, non-yielding impact barrier with a velocity of impact of 7 $^{m}/_{s}$, must meet the following requirements:

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

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

T 3.18.2 During the IA test:

- The IA must be attached to the AIP using the intended vehicle attachment method.
- The IA assembly must be attached to a test fixture that has geometry representative of the intended primary structure and equal or higher stiffness and strength. When alternative materials are used for the AIP, the test fixture must be a copy of the intended primary structure (i.e. materials, lay-up, joining methods).
- There must be at least 50 mm clearance rearwards of the AIP to the test fixture.
- No part of the AIP may permanently deflect more than 25 mm beyond the position of the AIP before the test.

T 3.18.3 Teams using IAs (typically structural noses) directly attached to the front bulkhead, which shortcut the load path through the bulk of the AIP, must conduct an additional test. This test must prove that the AIP can withstand a load of 120 kN (300 kg multiplied by 40 g), where the load applicator matches the minimum IA dimensions.

T 3.18.4 Vehicles with aerodynamic devices and/or sensors in front of the front bulkhead must not exceed the peak deceleration of T 3.18.1 for the combination of their IA assembly and the non-crushable object(s). One of the following three methods must be used to prove the design does not exceed 120 kN:

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

T 3.18.5 Dynamic testing (sled, pendulum, drop tower, etc) of the IA may only be conducted at a dedicated test facility. This facility may be part of the university, but must be supervised by professional staff. Teams are not allowed to design their own dynamic test apparatus.

T 3.18.6 When using acceleration data from the dynamic test, the average deceleration must be calculated based on the raw unfiltered data. If peaks above the 40 g limit are present in the data, a 100 Hz, 3rd order, low pass Butterworth (−3 dB at 100 Hz) filter may be applied.

T 3.19 Non-Crushable Objects

T 3.19.1 All non-crushable objects (e.g. pedals, master cylinders, hydraulic reservoirs) must be rearward of the rear most plane of the front bulkhead and at least 25 mm behind the AIP at any time, except for sensors, aerodynamic devices and their mountings.

T 4 COCKPIT

T 4.1 Cockpit Opening

T 4.1.1 The size of the cockpit opening needs to be sufficient for the template shown on the left of figure 10 to pass vertically from the cockpit opening to below the upper side impact member when held horizontally. The template may be moved fore and aft.

T 4.1.2 If the side impact structure is not made of tubes, the template must pass until it is 320 mm above the lowest inside chassis point between the front and main hoop.

T 4.1.3 The steering wheel, seat and all padding may be removed for the template to fit. Any other parts may only be removed if they are integrated with the steering wheel.

T 4.2 Cockpit Internal Cross Section

T 4.2.1 The cockpit must provide a free internal cross section sufficient for the template shown on the right in figure 10 to pass from the cockpit opening to a point 100 mm rearwards of the face of the rearmost pedal in an inoperative position. The template may be moved up and down. Adjustable pedals must be in their most forward position.

T 4.2.2 The steering wheel and any padding that can be removed without the use of tools while the driver is seated may be removed for the template to fit.

T 4.2.3 The driver's feet and legs must be completely contained within the primary structure when the driver is seated normally and the driver's feet are touching the pedals. In side and front views, any part of the driver's feet or legs must not extend above or outside of this structure.

T 4.3 Percy (95th percentile male)

T 4.3.1 When seated normally and restrained by the driver's restraint system, the helmet of a 95th percentile male and all of the team's drivers must, see figure 11:

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

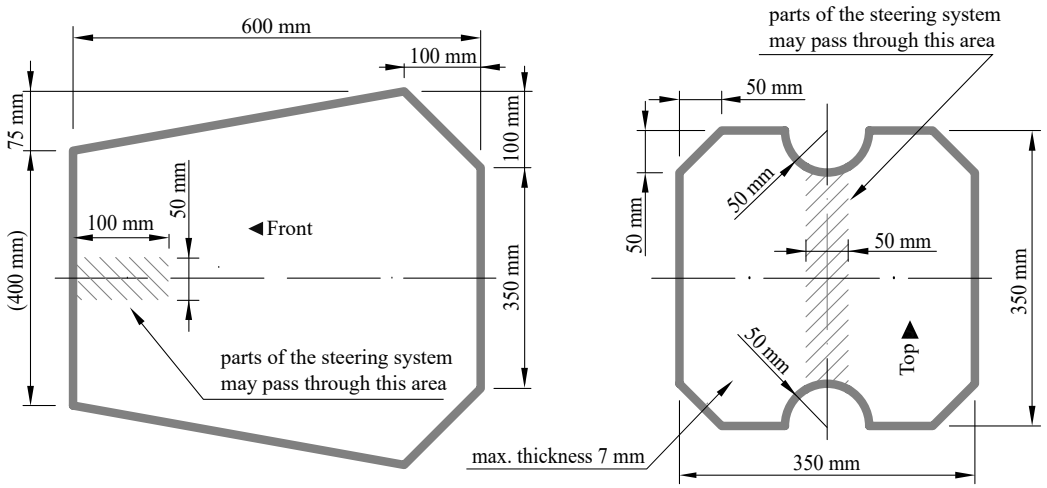

Figure 10: Cockpit opening template (left) and cockpit internal cross section template (right)

- Be a minimum of 50 mm away from the straight line drawn from the top of the main hoop to the lower end of the main hoop bracing if the bracing extends rearwards.
- Be no further rearwards than the rear surface of the main hoop if the main hoop bracing extends forwards.

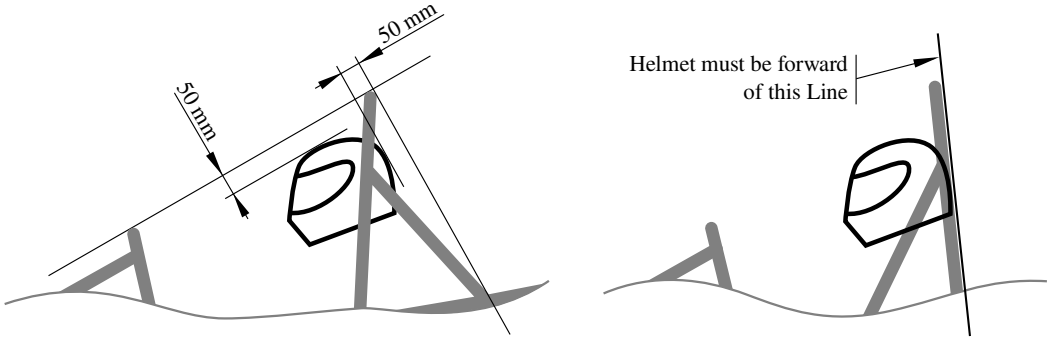

Figure 11: Minimum helmet clearance

T 4.3.2 The 95th percentile male is represented by a two dimensional figure consisting of two circles of 200 mm diameter (one representing the hips and buttocks and one representing the shoulder region) and one circle of 300 mm (representing the head with helmet).

T 4.3.3 The two 200 mm circles are connected by a straight line measuring 490 mm. The 300 mm circle is connected by a straight line measuring 280 mm with the upper 200 mm circle.

T 4.3.4 The figure has to be positioned in the vehicle as follows, see figure 12:

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

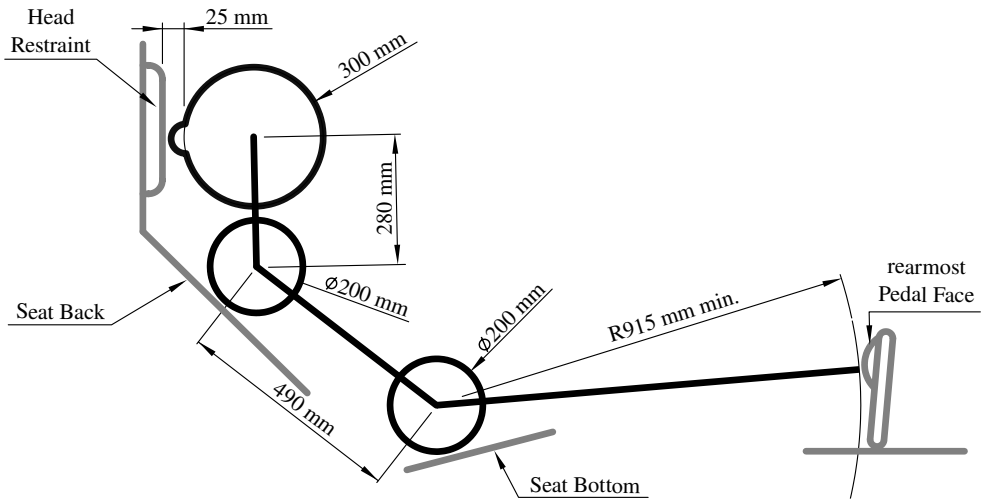

Figure 12: Percy placement

T 4.4 Side Tubes

T 4.4.1 If there is any chassis member alongside the driver at the height of the neck of any of the drivers in the team, a metal tube or piece of sheet metal must be attached to the chassis to prevent the driver's shoulders from passing under that chassis member.

T 4.5 Driver's Harness Attachment

T 4.5.1 Any harness attachment to a monocoque must be using one 10 mm metric grade 8.8 bolt or two 8 mm metric grade 8.8 bolts (or bolts of an equivalent standard) and steel backing plates with a minimum thickness of 2 mm.

T 4.5.2 Any harness that is fastened to the primary structure using brackets must use two 8 mm metric grade 8.8 or stronger fasteners.

T 4.5.3 It must be proven that the attachments for shoulder and lap belts can support a load of 13 kN and the attachment points of the anti-submarine belts can support a load of 6.5 kN.

T 4.5.4 If the lap belts and anti-submarine belts are attached less than 100 mm apart, these must support a total load of 19.5 kN.

T 4.5.5 If the belts are attached to a laminated structure or the mounting brackets and tabs are not made from steel at least 1.6 mm thick, physical testing is required. The following requirements must be met:

- Load is applied to a test sample representing the tubular or laminated structure and must use the same brackets and tabs
- Edges of the test fixture supporting the sample must be a minimum of 125 mm from the load application point.
- The width of the shoulder harness test sample must not be any wider than the shoulder harness panel height used to show equivalency for the shoulder harness mounting bar.

- Designs with attachments near a free edge must not support the free edge during the test.
- Harness loads must be tested with the worst case for the range of the angles specified for the driver's harness.

T 4.6 Driver's Seat

T 4.6.1 The lowest point of the driver's seat must in side view not extend below the upper face of the lowest side impact structure member or have a longitudinal tube (or tubes) that meets the material requirements for the side impact structure, see T 3.2, passing underneath the lowest point of the seat.

T 4.6.2 Adequate heat insulation must be provided to ensure that the driver is not able to contact any parts of the vehicle with a surface temperature above 60 °C. The insulation may be external to the cockpit or incorporated with the driver's seat or firewall. The design must address all three types of heat transfer with the following minimum requirements between the heat source and the part that the driver could contact:

(a) Conduction insulation by:

(i) No direct contact, or

(ii) a heat resistant, conduction insulation material with a minimum thickness of 8 mm.

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

(c) Radiation insulation by:

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

(ii) reflective foil or tape when combined with T 4.6.2.a.ii.

T 4.7 Floor Closeout

T 4.7.1 All vehicles must have a floor closeout made of one or more panels, which separate the driver from the ground.

T 4.7.2 The closeout must extend from the front bulkhead to the firewall.

T 4.7.3 The panels must be made of a solid, non-brittle material.

T 4.7.4 If multiple panels are used, gaps between panels must not exceed 3 mm.

T 4.8 Firewall

T 4.8.1 A firewall must separate the cockpit from all components of the fuel supply system, hydraulic fluid (except brake system and dampers), flammable liquids, the LV battery and any TS component, see EV 1.1.1.

T 4.8.2 The firewall must cover any straight line between the parts mentioned in T 4.8.1 and any part of the tallest driver below a plane 100 mm above the bottom of the helmet.

T 4.8.3 The firewall must be a non-permeable surface made from a rigid, fire resistant material, see T 1.2.1, which must be rigidly mounted to the vehicle's structure.

T 4.8.4 Any firewall must seal completely against the passage of fluids, especially at the sides and the floor of the cockpit.

T 4.8.5 Pass-throughs for wiring, cables, etc. are allowed if grommets, cable glands or connectors are used to seal the pass-through.

T 4.8.6 Multiple panels may be used to form the firewall but must overlap at least 5 mm and be sealed at the joints. Any sealing material must not be vital to the structural integrity of the firewall.

T 4.8.7 [EV ONLY] The TS firewall between driver and TS components must be composed of two layers:

- One solid layer, facing the TS side, must be made of aluminium with a thickness of at least 0.5 mm. This part of the TS firewall must be grounded according to EV 3.1.
- The second layer, facing the driver, must be made of an electrically insulating and fire retardant material, see T 1.2.1. The second layer must not be made of CFRP.
- The thickness of the second layer must be sufficient to prevent penetrating this layer with a 4 mm wide screwdriver and 250 N of force.

A sample of the TS firewall must be presented at technical inspection.

T 4.8.8 [EV ONLY] Conductive parts, except for the chassis and firewall mounting points, must not protrude through the TS firewall or must be properly insulated on the driver's side. The driver must not be able to touch uninsulated firewall mounting points while operating the vehicle.

T 4.8.9 [EV ONLY] TS parts outside of the rollover protection envelope, see T 1.1.16 and EV 4.4.3, do not need a firewall.

T 4.9 Accessibility of Controls

T 4.9.1 All vehicle controls must be operated from inside the cockpit without any part of the driver, e.g. hands, arms or elbows, being outside the vertical planes tangent to the outermost surface of the side impact structure.

T 4.10 Driver Visibility

T 4.10.1 The driver must have adequate visibility to the front and sides of the vehicle. Seated in a normal driving position, the driver must have a minimum field of vision of 100° to either side. The required visibility may be obtained by the driver turning their head and/or the use of mirrors.

T 4.10.2 If mirrors are required to meet T 4.10.1, they must remain in place and be adjusted to enable the required visibility throughout all dynamic events.

T 4.11 Driver Egress

T 4.11.1 All drivers must be able to exit to the side of the vehicle in less than 5 s with the driver in the fully seated position, hands in the driving position on the connected steering wheel (in all possible steering positions) and wearing the required driver equipment as in T 13.3. The egress time will stop when the driver has both feet on the ground.

T 5 DRIVER RESTRAINT SYSTEM

T 5.1 Definitions

T 5.1.1 6-point system – consists of a two-piece lap belt (minimum width 50 mm), two shoulder straps (minimum width 75 mm) and two leg or anti-submarine straps (minimum width 50 mm).

T 5.1.2 7-point system – same as the 6-point system except it has three anti-submarine straps.

T 5.1.3 upright driving position – position with a seat back angled at 30° or less from the vertical as measured along the line joining the two 200 mm circles of the 95th percentile male template as defined in T 4.3 and positioned per T 4.3.4.

T 5.1.4 reclined driving position – position with a seat back angled at more than 30° from the vertical as measured along the line joining the two 200 mm circles of the 95th percentile male template as defined in T 4.3 and positioned per T 4.3.4

T 5.2 Belts - General

T 5.2.1 All drivers must use a 6-point or 7-point restraint harness meeting the following specifications:

- All driver restraint systems must meet SFI Specification 16.1, SFI Specification 16.5, SFI Specification 16.6 or FIA specification 8853/2016.
- The belts must bear the appropriate dated labels.
- The material of all straps must be in perfect condition.
- There must be a single metal-to-metal latch type quick release for all straps.
- All lap belts must incorporate a tilt lock adjuster (“quick adjuster”). A tilt lock adjuster in each portion of the lap belt is highly recommended. Lap belts with “pull-up” adjusters are recommended over “pull-down” adjusters.
- Vehicles with a “reclined driving position” must have either anti-submarine belts with tilt lock adjusters (“quick adjusters”) or have two sets of anti-submarine belts installed.
- The shoulder harness must be the “over-the-shoulder type”. Only separate shoulder straps are allowed (i.e. “Y”-type shoulder straps are not allowed). The “H”-type configuration is allowed.
- The shoulder harness straps must be threaded through the three bar adjusters in accordance with the manufacturer’s instructions.
- When a HANS device is used by the driver, FIA certified 50 mm wide shoulder harnesses are allowed.

T 5.2.2 SFI spec harnesses must be replaced following December 31st of the 2nd year after the date of manufacture as indicated by the label. FIA spec harnesses must be replaced following December 31st of the year marked on the label.

T 5.2.3 The restraint system must be worn tightly at all times.

T 5.3 Belt, Strap and Harness Installation - General

T 5.3.1 The lap belt, shoulder harness and anti-submarine strap(s) must be securely mounted to the primary structure. This structure and any guide or support for the belts must meet the minimum requirements of T 3.2.

T 5.3.2 Harnesses, belts and straps must not pass through a firewall, i.e. all harness attachment points must be on the driver's side of any firewall.

T 5.3.3 The attachment of the driver's restraint system requires an approved SES per T 3.6 The lap belts and anti submarine belts must not be routed over the sides of the seat. Where the belts or harness pass through a hole in the seat, the seat must be rolled or grommeted to prevent chafing of the belts.

T 5.4 Lap Belt Mounting

T 5.4.1 The lap belt must pass around the pelvic area below the anterior superior iliac spines (the hip bones).

T 5.4.2 The lap belts must come through the seat at the bottom of the sides of the seat to maximize the wrap of the pelvic surface and continue in a straight line to the anchorage point.

T 5.4.3 In side view, the lap belt must be capable of pivoting freely by using either a shouldered bolt or an eye bolt attachment.

T 5.4.4 With an "upright driving position", in side view the lap belt must be at an angle of between 45° and 65° to the horizontal.

T 5.4.5 With a "reclined driving position", in side view the lap belt must be between an angle of 60° and 80° to the horizontal.

T 5.4.6 The centerline of the lap belt at the seat bottom must be between 0 mm to 76 mm forward of the seat back to seat bottom junction as in figure 13.

T 5.5 Shoulder Harness

T 5.5.1 The shoulder harness must be mounted behind the driver to a structure that meets the requirements of the primary structure. However, it cannot be mounted to the main hoop bracing or attendant structure without additional bracing to prevent loads being transferred into the main hoop bracing.

T 5.5.2 If the harness is mounted to a tube that is not straight, the joints between this tube and the structure to which it is mounted must be reinforced in side view by triangulation tubes to prevent torsional rotation of the harness mounting tube. Supporting calculations are required. Analysis method: Use 7 kN load per attachment and the range of angles in T 5.5.5, calculate

that the bent shoulder harness bar triangulation stresses are less than as welded yield strength T 3.2.4 for combined bending and shear and does not fail in column buckling. If the team chooses not to perform the strength analysis T 3.2.6 will apply.

T 5.5.3 The strength of any shoulder harness bar and bracing tubes must be proven in the relevant tab of the team's SES submission.

T 5.5.4 The shoulder harness mounting points must be between 180 mm and 230 mm apart, measured center to center.

T 5.5.5 From the driver's shoulders rearwards to the mounting point or structural guide, the shoulder harness must be between 10° above the horizontal and 20° below the horizontal as in figure 13.

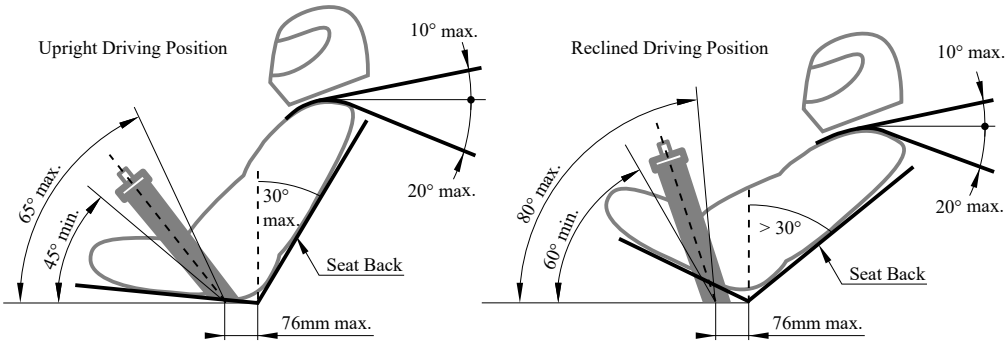

Figure 13: Lap belt and shoulder harness mounting

T 5.6 Anti-Submarine Belt Mounting

T 5.6.1 The anti-submarine belts of a 6 point harness must be mounted in one of the following setups:

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

T 5.7 Head Restraint

T 5.7.1 A head restraint must be provided on the vehicle to limit the rearward motion of the driver's head.

T 5.7.2 The head restraint must:

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

- Be located so that for each driver:
  - The restraint is no more than 25 mm away from the back of the driver's helmet, with the driver in their normal driving position.
  - The contact point of the back of the driver's helmet on the head restraint is no less than 50 mm from any edge of the head restraint.

T 5.7.3 The head restraint and its mounting must withstand a force of 890 N applied in the rearward direction at any point on its surface.

T 5.8 Roll Bar Padding

T 5.8.1 Any portion of the roll bar, roll bar bracing or chassis which might be contacted by the driver's helmet must be covered with a minimum thickness of 12 mm of padding which meets SFI spec 45.1 or FIA 8857-2001.

T 5.9 Driver's Leg Protection

T 5.9.1 All moving suspension and steering components and other sharp edges inside the cockpit between the front hoop and a vertical plane 100 mm rearward of the pedals, must be shielded with solid material.

T 5.9.2 Covers over suspension and steering components must be removable to allow inspection of the mounting points.

T 6 BRAKE SYSTEM

T 6.1 Brake System - General

T 6.1.1 The vehicle must be equipped with a hydraulic brake system that acts on all four wheels and is operated by a single control.

T 6.1.2 The brake system must have two independent hydraulic circuits such that in the case of a leak or failure at any point in the system, effective braking power is maintained on at least two wheels. Each hydraulic circuit must have its own fluid reserve, either by the use of separate reservoirs or by the use of a dammed reservoir.

T 6.1.3 The brake system must be sealed to prevent leakage.

T 6.1.4 A single brake acting on a limited-slip differential is acceptable.

T 6.1.5 "Brake-by-wire" systems are prohibited in manual mode.

T 6.1.6 Unarmored plastic brake lines are prohibited.

T 6.1.7 The brake system must be protected from failure of the drivetrain, see T 7.3.2, from touching any movable part and from minor collisions.

T 6.1.8 Any part of the brake system must be within the surface envelope, see T 1.1.18.

T 6.1.9 The brake pedal and its mounting must be designed to withstand a force of 2 kN without any failure of the brake system or pedal box. This may be tested by pressing the pedal with the maximum force that can be exerted by any official when seated normally.

T 6.1.10 The brake pedal, including pedal face, must be fabricated from steel or aluminium or machined from steel, aluminium or titanium.

T 6.1.11 The first 90 % of the brake pedal travel may be used to regenerate brake energy without actuating the hydraulic brake system. The remaining brake pedal travel must directly actuate the hydraulic brake system, but brake energy regeneration may remain active.

T 6.2 Brake Over-Travel Switch (BOTS)

T 6.2.1 A BOTS must be installed on the vehicle as part of the Shutdown Circuit (SDC), as in EV 6 or CV 4.1. This switch must be installed so that in the event of a failure in at least one of the brake circuits the brake pedal over-travel will result in the SDC being opened. This must function for all possible brake pedal and brake balance settings without damaging any part of the vehicle.

T 6.2.2 Repeated actuation of the switch must not close the SDC, and it must be designed so that the driver cannot reset it.

T 6.2.3 The BOTS must be a push-pull, push-rotate or flip type mechanical switch. It may consist of a series connection of switches.

T 6.3 Brake Light

T 6.3.1 The vehicle must be equipped with one brake light that is illuminated if and only if

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

T 6.3.2 The brake light must

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

T 6.3.3 In side view the brake light must be oriented vertically and mounted between the wheel centerline and driver's shoulder level. Viewed from the back it must be positioned approximately at the vehicle's centerline.

T 7 POWERTRAIN

T 7.1 Transmission and Drive

T 7.1.1 Movement of the vehicle without a person in the vehicle and with the master switch(es) in the off position must be possible.

T 7.2 Coolant Fluid and System Sealing

T 7.2.1 [CV ONLY] Water-cooled internal combustion engines must only use plain water as the coolant.

T 7.2.2 Other cooling systems may only use plain water, air or oil as the coolant, see T 1.2.2.

T 7.2.3 Cooling systems using plain water (except outboard wheel motors and their cooling hoses) must have a heat resistant (Permanently rated for at least 100 °C), rigid and rigidly mounted cover which covers any part of the tallest driver below a plane 100 mm above the bottom of the helmet.

T 7.2.4 Any cooling or lubrication system must be sealed to prevent leakage.

T 7.2.5 Separate catch cans must be employed to retain fluids other than plain water from any vents of the cooling system or combustion engine lubrication system. Each catch-can must have a minimum volume of 10 % of the fluid being contained or 900 mL whichever is greater.

T 7.2.6 Any vent for systems containing plain water must have a catch-can with a minimum volume of 10 % of the fluid being contained or 100 mL, whichever is greater.

T 7.2.7 All parts of the engine, motor(s) cooling and lubrication system, including their mountings, must be rated for at least 120 °C or the temperatures the respective fluid may reach, whichever is higher.

T 7.2.8 Catch cans must be rigidly mounted to the chassis and located rearwards of the firewall below the driver's shoulder level.

T 7.2.9 Any catch can must vent through a hose with a minimum internal diameter of 3 mm down to the bottom level of the chassis and must exit outside the bodywork.

T 7.3 Drive Train Shields and Guards

T 7.3.1 The lowest point of any lubrication system can only be lower than the line between the lowest point of the main hoop and the lowest chassis member behind the lubrication system if it is protected from hitting the ground by a structure mounted directly to the chassis.

T 7.3.2 Exposed rotating final drivetrain parts, such as gears, clutches, chains and belts must be fitted with scatter shields. Scatter shields and their mountings must:

- Be constructed of non-perforated 2 mm steel or 3 mm aluminium alloy 6061-T6.
- Be attached with 6 mm metric grade 8.8 or stronger and must comply with T 10.1.

T 7.3.3 In addition to T 7.3.2, scatter shields must:

- Cover chains and belts from the drive sprocket to the driven sprocket/chain wheel/belt or pulley.
- Start and end parallel to the lowest point of the driven sprocket/chain wheel/belt or pulley.
- Be at least three times the width of the chain or belt and be centered at the centerline of the chain or belt

T 7.3.4 The tractive electric motor(s) must have a housing or separate scatter shield from non-perforated 2 mm aluminium alloy 6061-T6 or equivalent. The scatter shield may be split into two equal sections, each 1 mm thick.

T 7.3.5 Finger guards are required to cover any parts that spin while the vehicle is stationary. Finger guards may be made of lighter material, sufficient to resist finger forces. Mesh or perforated material may be used but must prevent the passage of a 12 mm diameter object through the guard.

T 8 AERODYNAMIC DEVICES

T 8.1 Definition Aerodynamic Device

T 8.1.1 A specifically designed structure mounted on the vehicle to guide the airflow around the vehicle, increasing the downforce acting on the vehicle and/or lowering its drag. The mounting of this structure is not regarded as an aerodynamic device, unless it is intentionally designed to be one.

T 8.2 Restrictions for Aerodynamic Devices

T 8.2.1 Height restrictions:

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

T 8.2.2 Width restrictions:

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

T 8.2.3 Length restrictions:

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

T 8.2.4 All restrictions must be fulfilled with the wheels pointing straight and with any suspension setup with or without a driver seated in the vehicle.

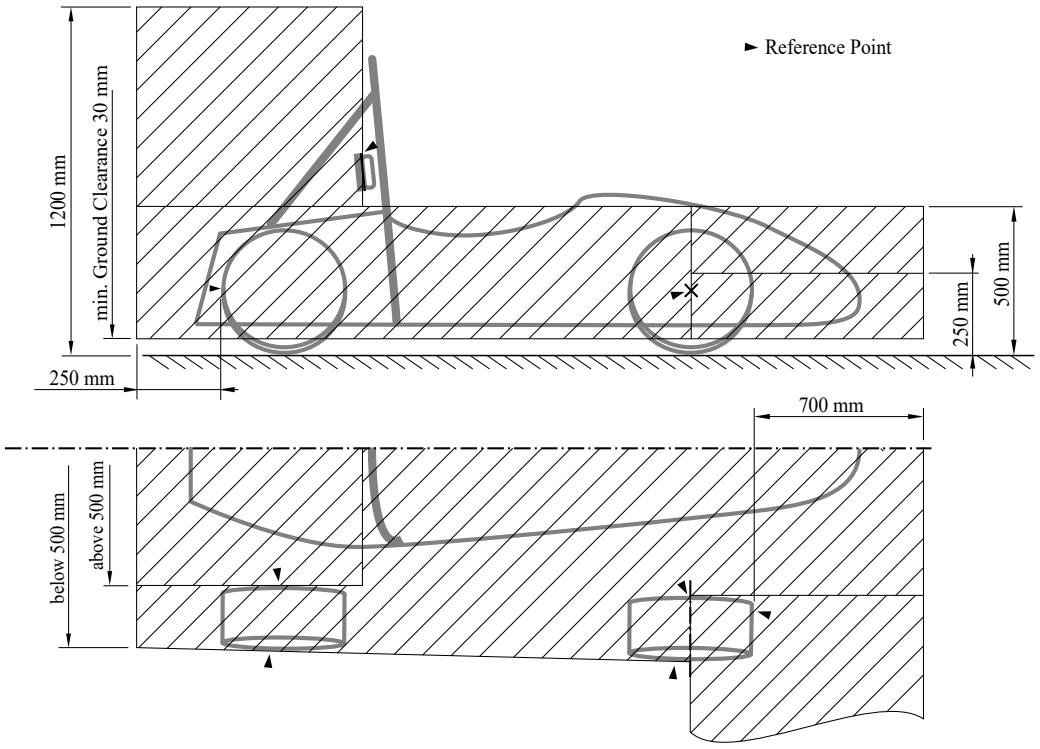

Figure 14: Maximum dimensions and positioning of aerodynamic devices. The positioning space is further restricted, see T 2.1.

T 8.3 Aerodynamic Devices Stability and Strength

T 8.3.1 Any aerodynamic device must be able to withstand a force of 200 N distributed over a minimum surface of 225 cm^2 and not deflect more than 10 mm in the load carrying direction.

T 8.3.2 Any aerodynamic device must be able to withstand a force of 50 N applied in any direction at any point and not deflect more than 25 mm.

T 9 Critical Components

T 9.1 Compressed Gas Systems

T 9.1.1 Compressed Gas System (CGS) – any system that uses a compressed gas as an actuating medium, except for gas springs.

T 9.1.2 The working gas of any CGS must be non-flammable.

T 9.1.3 The pressure inside any CGS must not exceed 10 bar. Gas cylinders/tanks may exceed the 10 bar limit, if a pressure regulator which limits the output pressure to a maximum of 10 bar is mounted directly onto them.

T 9.1.4 All parts of any CGS must be designed for the maximum possible operating pressure.

T 9.1.5 Gas cylinders/tanks and their pressure regulators must be of proprietary manufacture, certified and labeled as such.

T 9.1.6 The pressure in the function critical part of any CGS required to ensure the functionality of the Autonomous System Brake (ASB), see T 15, must be limited by means of an overpressure protection, if compressed gas cylinders/tanks exceed the pressure threshold as defined in T 9.1.3.

T 9.1.7 All parts of any CGS and their mountings must be located within the rollover protection envelope, see T 1.1.16 and must be protected from collision or damage.

T 9.1.8 Gas cylinders/tanks must be mounted according to T 9.3.1 and their axis must not point at the driver.

T 9.1.9 Gas cylinders/tanks and their pressure regulators must be shielded from the driver. The shields must be steel or aluminium with a minimum thickness of 1 mm.

T 9.1.10 Gas cylinders/tanks must be insulated from any heat sources.

T 9.2 High Pressure Hydraulic Pumps and Lines

T 9.2.1 The driver and anyone standing outside the vehicle must be shielded from any hydraulic pumps and lines with line pressures of 2100 kPa or higher. The shields must be steel or aluminium with a minimum thickness of 1 mm. Brake lines are not considered as high pressure hydraulic lines.

T 9.3 Critical Component Mounting

T 9.3.1 Critical components themselves and their mountings must be able 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)

T 10 FASTENERS

T 10.1 Critical Fasteners

T 10.1.1 Critical fasteners are defined as bolts, nuts, and other fasteners utilized in the primary structure, the steering, braking, driver's harness, suspension systems and those specifically designated as critical fasteners in the respective rule.

T 10.1.2 All threaded critical fasteners must be at least 4 mm metric grade 8.8 (OEM parts 3 mm metric grade 8.8), equivalent size or of that specified in the referencing rule, whichever is larger.

T 10.1.3 All threaded critical fasteners must be of the type hexagon bolts (ISO 4017, ISO 4014 or an equivalent standard.) or socket head cap screws (ISO 4762, DIN 7984, ISO 7379 or an equivalent standard.) including their fine-pitch thread versions.

T 10.1.4 Any bolted joint in the primary structure and mounting of the TSAC to the chassis using either tabs or brackets, must have an edge distance ratio "e/D" of 1.5 or greater. "D" equals

the hole diameter and "e" equals the distance from the hole centerline to the nearest free edge of the tab or bracket. Any tabs attaching suspension members to the primary structure are not required to meet this rule.

T 10.1.5 For steering and suspension systems, alternative fasteners are allowed if equivalency to T 10.1.2 and T 10.1.3 can be shown.

T 10.2 Securing Fasteners

T 10.2.1 All critical fasteners must be secured from unintentional loosening by the use of positive locking mechanisms.

T 10.2.2 The following methods are accepted as positive locking mechanisms:

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

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

T 10.2.3 Snap or retaining rings according to DIN 471, DIN 472, or equivalent standard are allowed in OEM applications or for securing bearings or springs or brake disc floaters given that they do not bear any loads under normal driving conditions. The groove must be in pristine condition and manufactured according to the standard of the snap or retaining ring.

T 10.2.4 A minimum of two full threads must project from any lock nut.

T 10.2.5 All spherical rod ends and spherical bearings on the steering or suspension must be in double shear or captured by having a screw/bolt head or washer with an outer diameter that is larger than the spherical bearing housing inner diameter.

T 10.2.6 Adjustable tie-rod ends must be constrained with a jam nut to prevent loosening.

T 11 Electrical Components

T 11.1 Low Voltage System

T 11.1.1 The Low Voltage System (LVS) is defined as

- [CV ONLY] all electrical circuits of the vehicle.
- [EV ONLY] every electrical part that is not part of the TS, see EV 1.1.1

T 11.1.2 The maximum allowed voltage that may occur between any two electrical connections in the LVS is 60 V DC or 50 V AC RMS.

T 11.1.3 All LVS parts must be adequately insulated.

T 11.1.4 [CV ONLY] The following systems are excluded from the LVS voltage limit, see T 11.1.2:

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

T 11.1.5 [CV ONLY] The maximum allowed voltage for motor controller/inverters internal low power control signals is 75 V DC

T 11.1.6 [EV ONLY] The LVS must not use orange wiring or conduit.

T 11.1.7 [EV ONLY] The LVS must be grounded to the chassis.

T 11.2 Master Switches

T 11.2.1 Master switches, see T 11.3, EV 6.2, and T 14.5, must be a mechanical switch of the rotary type, with a red, removable handle. The handle must have a width of at least 50 mm and must only be removable in electrically open position. They must be direct acting, i.e. they must not act through a relay or logic.

T 11.2.2 Master switches must be located on the right side of the vehicle, in proximity to the main hoop, at the 95th percentile male driver's shoulder height, as defined in T 4.3, and be easily actuated from outside the vehicle.

The center of any master switch must not be mounted lower than the vertical distance of the template's, see T 4.3, middle circle center to the ground surface multiplied by 0.8.

T 11.2.3 The "ON" position of the switch must be in the horizontal position and must be marked accordingly. The "OFF" position of the master switch must also be clearly marked.

T 11.2.4 Master switches must be rigidly mounted to the vehicle and must not be removed during maintenance.

T 11.2.5 Master switches must be mounted next to each other.

T 11.3 Low Voltage Master Switch

T 11.3.1 An LVMS according to T 11.2 must completely disable

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

T 11.3.2 The LVMS must be mounted in the middle of a completely red circular area of $\geq$50 mm diameter placed on a high contrast background.

T 11.3.3 The LVMS must be marked with "LV" and a symbol showing a red spark in a white edged blue triangle.

T 11.4 Shutdown Buttons

T 11.4.1 A system of three shutdown buttons must be installed on the vehicle.

T 11.4.2 Each shutdown button must be a push-pull or push-rotate mechanical emergency switch where pushing the button opens the SDC, see EV 6.1 and CV 4.1.

T 11.4.3 One button must be located on each side of the vehicle behind the driver's compartment at approximately the level of the driver's head. The minimum allowed diameter of the shutdown buttons on both sides of the vehicle is 40 mm.The buttons must be easy reachable from outside the vehicle.

T 11.4.4 One shutdown button serves as a cockpit-mounted shutdown button and must:

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

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

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

T 11.4.7 Shutdown buttons must be red.

T 11.5 Inertia Switch

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

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

T 11.5.3 The device must not include any semiconductor components.

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

T 11.6 Brake System Plausibility Device

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

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

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

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

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

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

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

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

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

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

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

T 11.7 Low Voltage Batteries

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

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

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

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

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

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

T 11.7.7 Battery packs based on lithium chemistry other than lithium iron phosphate ($LiFePO_4$) and all hybrid system energy storages regardless of chemistry type:

- Must have a fire retardant casing, see T 1.2.1.
- Must include overcurrent protection that trips at or below the maximum specified discharge current of the cells.
- Must include overtemperature protection of at least 30 % of the cells, meeting EV 5.8.4, that trips when any cell leaves the allowed temperature range according to the manufacturer's datasheet, but not more than 60 °C, for more than 1 s and disconnects the battery.
- Must include voltage protection of all cells that trips when any cell leaves the allowed voltage range according to the manufacturer's datasheet for more than 500 ms and disconnects the battery.

- It must be possible to display all cell voltages and measured temperatures, e.g. by connecting a laptop.
- Must meet EV 5.8.11
- Signals needed to fulfill these requirements are SCS, see T 11.9.

T 11.8 Accelerator Pedal Position Sensor

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

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

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

T 11.8.4 The foot pedal must return to the 0 % position when not actuated. The foot pedal must have a positive stop preventing the mounted sensors from being damaged or overstressed. Two springs must be used to return the foot pedal to the 0 % position and each spring must work when the other is disconnected. Springs in the APPS are not accepted as return springs.

T 11.8.5 At least two separate sensors must be used as APPSs. The sensors may share the housing.

T 11.8.6 If analog sensors are used, they must have different, non-intersecting transfer functions. A short circuit between the signal lines must always result in an implausibility according to T 11.8.9.

T 11.8.7 The APPS signals are SCSs, see T 11.9.

T 11.8.8 If an implausibility occurs between the values of the APPSs and persists for more than 100 ms

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

T 11.8.9 Implausibility is defined as a deviation of more than ten percentage points pedal travel between any of the used APPSs or any failure according to T 11.9.

T 11.8.10 If three sensors are used, then in the case of an APPS implausibility, any two sensors that are plausible may be used to define the torque target and the 3rd APPS may be ignored.

T 11.8.11 It must be possible to separately disconnect each APPS signal wire to check all functionalities.

T 11.8.12 A fully released accelerator pedal in manual mode must result in:

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

T 11.9 System Critical Signal

T 11.9.1 SCS are defined as all electrical signals which

- Influence actions on the SDC, see CV 4.1 and EV 6.1.
- Influence the wheel torque.
- [EV ONLY] Influence indicators according to EV 5.8.9, EV 4.10 or EV 6.3.8.

T 11.9.2 Any of the following SCS single failures must result in a safe state of all connected systems:

(a) Failures of signals transmitted by cable:

- Open circuit
- Short circuit to ground

(b) Failures of analog sensor signals transmitted by cable:

- Short circuit to supply voltage

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

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

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

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

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

T 11.9.3 If a signal failure is correctable, e.g. due to redundancy or worst case values, the safe state must be entered as soon as an additional non correctable failure occurs.

T 11.9.4 The maximum allowed delay of messages according to T 11.9.2.d must be chosen depending on the impact of delayed messages to the connected system, but must not exceed 500 ms.

T 11.9.5 Safe state is defined depending on the signals as follows:

- signals only influencing indicators – Indicating a failure of its own function or of the connected system
- LV battery signals – At least one pole is electrically disconnected from the rest of the vehicle
- ASSI, see T 14.9 – indicating “AS Off”
- [EV ONLY] For all others signals – opened SDC and opened AIRs
- [CV ONLY] For all others signals – opened SDC and stopped engine

T 11.9.6 Indicators according to T 11.9.1 with safe state “illuminated” (e.g. absence of failures is not actively indicated) must be illuminated for 1 s to 3 s for visible check after power cycling the LVMS.

T 11.10 System status light

T 11.10.1 Any system status light(s), see T 6.3 and T 14.9, must meet the following requirements:

- Black background.

- Rectangular, triangular or near round shape.
- Minimum illuminated surface of 15 cm^2 with even luminous intensity.
- Clearly visible in very bright sunlight.
- If LED lights are used without a diffuser, they must not be more than 20 mm apart.
- If a single line of LED lights is used, the minimum length is 150 mm.

T 11.11 Fans and Turbines

T 11.11.1 The maximum total power of any active devices designed to move air is 500 W, this does not apply to CV 1.8.

T 11.12 Sensors, Cameras & Electrical Components Mounting

T 11.12.1 All sensors, cameras and components must be securely mounted.

T 11.12.2 Sensors, cameras and components must not come into contact with the driver's helmet under any circumstances.

T 11.12.3 All sensors, cameras and components must be positioned within the surface envelope, see T 1.1.18, or within the box defined in T 8.2.

T 11.12.4 Passive antennas which do not incorporate active electronic parts, e.g. amplifiers with the longest side <100 mm may additionally to T 11.12.3 protrude from the surface envelope, see T 1.1.18, but not their mounting.

T 11.13 Legal & Work Safety

T 11.13.1 All sensors must fulfill the local legislative specifications (i.e. eye-protection classification for laser sensors, power limitation for radar sensors, etc.) in the country of competition.

T 12 VEHICLE IDENTIFICATION

T 12.1 Vehicle Number

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

T 12.1.2 Vehicle numbers must appear on the vehicle at the front and both sides as follows:

- Height: At least 150 mm high;
- Font: Roman Sans-Serif characters. Italic, outline, serif, or shadow numbers are prohibited.
- Stroke width and spacing between numbers: At least 20 mm.
- Color: Either white numbers on a black background or black numbers on a white background.

- Background shape: The number background must be one of the following: round, oval, square or rectangular. There must be at least 25 mm between the edge of the numbers and the edge of the background.
- Clear: The numbers must not be obscured by parts of the vehicle.
- Alignment: In front view the number at the front and in side view the numbers on the sides must be horizontally aligned.

T 12.2 Hybrid Vehicle Identification

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

T 12.3 University Name

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

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

T 12.3.2 The university name must be displayed and written in Roman Sans-Serif characters of at least 50 mm high on both sides of the vehicle.

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

T 12.4 Timing Equipment

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

T 13 VEHICLE AND DRIVER EQUIPMENT

T 13.1 Push Bar

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

T 13.1.2 The push bar must have a red color.

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

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

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

T 13.1.6 [EV ONLY] Two pairs of high-voltage insulating gloves and a multimeter with two 4 mm banana plug test leads rated for 600 V CAT III or better must be attached to the push bar. The High Voltage (HV) gloves must be protected by a case or similar means from mechanical damage, humidity and sunlight. It must be possible to open the case without using tools.

T 13.2 Jacks

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

T 13.2.2 Lifting the vehicle and positioning of the device(s) must be done by the team in a safe way.

T 13.2.3 In lifted position:

- The vehicle must be adequately supported and stable.
- It must be safe for a driver to enter and exit the vehicle, without additional devices.
- The device(s) must not extend out of the vehicles projected surface area.

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

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

T 13.3 Driver Equipment

T 13.3.1 The equipment specified below must be worn by the driver anytime while in the cockpit with the engine running or with the TS active for electric vehicles and anytime between starting a dynamic event and either finishing or abandoning a dynamic event. Removal of any driver equipment during the event will result in disqualified (DQ).

T 13.3.2 A well-fitting, closed face helmet that meets one of the following certifications and is labeled as such:

- Snell SA2020, EA2016, SA2025 or newer
- SFI 31.1/2015, 31.1/2020 or newer
- FIA 8860-2010, FIA 8860-2018, FIA 8859-2015, 8859-2024 or newer

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

T 13.3.3 If Frontal Head Restraint systems (FHR, HANS) are used, they must be certified to one of the following standards and be labeled as such:

- FIA 8858-2010

- FIA 8860-2004
- SFI 38.1

T 13.3.4 A balaclava which covers the driver's head, hair and neck, made from acceptable fire resistant material as defined in T 13.3.13, or a full helmet skirt of acceptable fire resistant material.

T 13.3.5 A fire resistant one piece suit, made from a minimum of two layers that covers the body from the neck down to the ankles and the wrists. The suit must be certified to one of the following standards and be labeled as such:

- SFI 3.2A/5 (or higher)
- SFI 3.4/5 (or higher)
- FIA Standard 8856-2000
- FIA Standard 8856-2018

T 13.3.6 Fire resistant underwear (long pants and long sleeve t-shirt). This fire resistant underwear must be made from acceptable fire resistant material as listed in T 13.3.13 and must cover the driver's body completely from neck down to ankles and wrists.

T 13.3.7 Fire resistant socks made from acceptable fire resistant material as defined in T 13.3.13, that cover the bare skin between the driver's suit and the boots or shoes.

T 13.3.8 Fire resistant shoes made from acceptable fire resistant material as defined in T 13.3.13. The shoes must be certified to the standard and labeled as such:

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

T 13.3.9 Fire resistant gloves made from acceptable fire resistant material as defined in T 13.3.13. Gloves of all leather construction or fire resistant gloves constructed using leather palms with no insulating fire resisting material underneath are not allowed.

T 13.3.10 Fire resistant clothing must not be older than 10 years, recognizable since no FIA hologram label present.

T 13.3.11 Arm restraints are required and must be worn such that the driver can release them and exit the vehicle unassisted regardless of the vehicle's position. Arm restraints must be commercially manufactured according to SFI Standard 3.3 or equivalent.

T 13.3.12 All driver equipment covered in T 13.3: must be in good condition. Specifically, it must not have any tears, rips, open seams, areas of significant wear or abrasion or stains which might compromise fire resistant performance. Teams must be able to show that the clothing still meets the requirements of T 13.3 if driver's clothing is embroidered. This requires, but is not limited to, that only the outer shell is perforated. The officials reserve the right to impound all non-approved driver equipment until the end of the competition.

T 13.3.13 For the purpose of this section some, but not all, of the approved fire resistant materials are: Nomex, Aramid, Belcotex and Indura.

T 13.3.14 T-shirts, socks or other undergarments made from nylon or any other synthetic material which will melt when exposed to high heat are prohibited.

T 13.4 Fire Extinguishers

T 13.4.1 Each team must have at least two foam type fire extinguishers with valid inspection tag.

T 13.4.2 Fire extinguishers must have a rating of at least:

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

T 13.4.3 Except for the initial inspection, one extinguisher must readily be available in the team's paddock area.

T 14 AUTONOMOUS SYSTEM

T 14.1 Definitions

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

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

- Ready-to-drive (R2D) – engine is running and a gear is engaged.
- TS active – engine is running but gearbox is in neutral, also assumed for TS not active.
- TS activation button – the engine start button is the equivalent.
- Accumulator Isolation Relay (AIR) - the fuel pump relay, see figure 19, is the equivalent.

T 14.2 Data Logger

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

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

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

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

T 14.3 Remote Emergency System

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

T 14.3.2 The RES must be purchased by the team.

T 14.3.3 The RES has two functions:

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

T 14.3.4 The RES vehicle module must be directly, see T 1.3.1, integrated in the vehicle's SDC with one of its relays hard-wired in series to the shutdown buttons.

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

- Be directly supplied, see T 1.3.1, by the ASMS, see T 14.5.
- Have a safety certified forcibly guided or a mirrored normally open contact which is directly connected, see T 1.3.1, in series to the ASMS.

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

T 14.4 Shutdown Circuit

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

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

T 14.5 Autonomous System Master Switch

T 14.5.1 Each vehicle must be equipped with an ASMS, according to T 11.2.

T 14.5.2 The ASMS must be mounted in the middle of a completely blue circular area of $\geq$50 mm diameter placed on a high contrast background.

T 14.5.3 The ASMS must be marked with "AS".

T 14.5.4 The power supply of the steering and braking actuators must be switched by

- LVMS
- ASMS
- The normally open contact of the relay according to T 14.3.5

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

T 14.5.5 When the ASMS is in "Off" position, the following must be fulfilled:

- No steering, braking and propulsion actuation can be performed by request of the autonomous system.
- The sensors and the processing units can stay operational.
- The vehicle must be able to be pushed as specified in A 6.6.
- It must be possible to operate the vehicle manually as a normal CV or EV.

T 14.5.6 It is strictly forbidden to switch the ASMS to the “On” position if a person is inside the vehicle.

T 14.5.7 After switching the ASMS to the “On” position, the vehicle must not start moving, until R2D mode is entered, see Figure 15.

T 14.5.8 The ASMS must be fitted with a “lockout/tagout” capability to prevent accidental activation of the AS. The ASR must ensure that the ASMS is locked in the off position whenever the vehicle is outside the dynamic area or driven in manual mode.

T 14.6 Steering Actuation

T 14.6.1 Steering system actuation, i.e. movement, must only happen if the vehicle is in R2D mode.

T 14.6.2 The steering system may remain active during an emergency brake maneuver while the vehicle is in movement.

T 14.6.3 Manual steering must be possible without manual release steps, e.g. operating manual valves and/or (dis-) connecting mechanical elements, while the ASMS is switched “Off”.

T 14.7 Actuator Decoupling

T 14.7.1 It is not allowed to remove any parts of the ASfor dynamic events.

T 14.7.2 The actuators may be disconnected for manual driving if:

- no parts including bolts, clips, etc. are removed for disconnection i.e. they must never loose the physical contact to the disconnection mechanism.
- the disconnection mechanism cannot block manual operation in any position.
- the disconnection mechanism is securely locked in both positions.

T 14.8 Autonomous System Status Definitions

T 14.8.1 The Emergency Brake System (EBS) is considered to be “activated”, if the power supply path defined in T 15.2.2 is cut after passing the initial checkup sequence, see T 15.3.1. Brakes may only be released by operating the deactivation point(s) defined in T 15.1.7.

T 14.8.2 The EBS is no longer considered to be activated, if all brakes have been released using the deactivation point(s) defined in T 15.1.7.

T 14.8.3 The status of the AS must be determined according to the flowchart in Figure 15.

T 14.8.4 R2D mode may only be entered by the “Go” signal from the RES, after the system has remained in “AS Ready” for at least 5 s.

T 14.8.5 Performing manual steps, other than activating the TS, at the vehicle while the ASMS is switched “On” is prohibited.

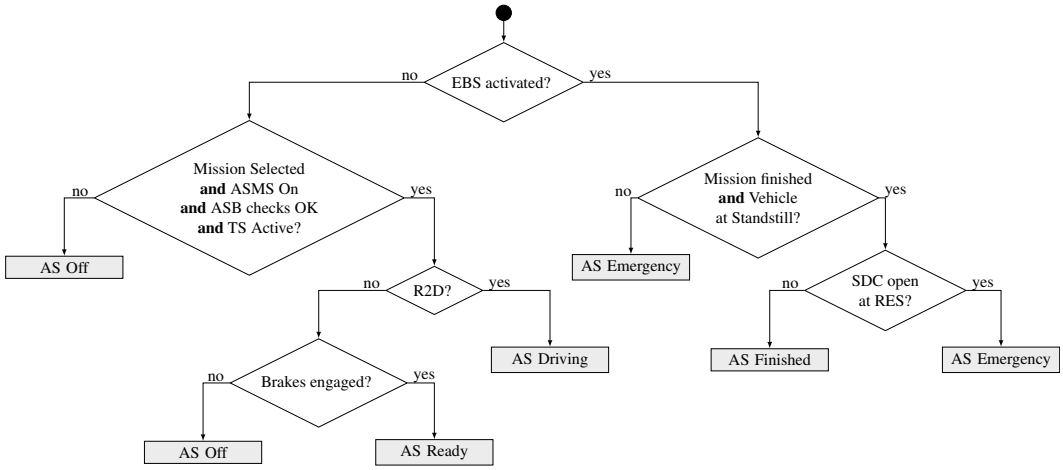

Figure 15: AS Status Flowchart

T 14.9 Autonomous System Status Indicators

T 14.9.1 The vehicle must include three ASSIs that must indicate the status of the AS, as defined in T 14.8, correlating to illumination as shown:

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

The ASSIs must not perform any other functions.

T 14.9.2 One ASSI must be located on each side of the vehicle behind the driver's compartment, in a region 160 mm below the top of the main hoop and 600 mm above the ground. The third ASSI must be located at the rear of the vehicle, on the vehicle centerline, in a region 160 mm below the top of the main hoop and 100 mm above the brake light.

T 14.9.3 At least one ASSI must be visible from any angle of the vehicle from a point 1.60 m vertically from ground level, within 3 m horizontal radius from the top of the main hoop.

T 14.9.4 Each ASSI must meet requirements according to T 11.10.

T 14.9.5 The status "AS Emergency" has to be indicated by an intermittent sound with the following parameters:

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

T 14.10 Autonomous Missions

T 14.10.1 The AS must at least implement the following missions:

- Acceleration

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

T 14.10.2 The inspection mission is defined by slowly spinning the drivetrain and actuating the steering system with a sine wave while the vehicle is jacked up and all wheels are removed. After 25 s to 30 s the AS must transition to "AS Finished".

T 14.10.3 It must be possible to select any mission without the use of an external device.

T 14.10.4 The selected mission must be indicated by the Autonomous Mission Indicator (AMI).

T 14.10.5 The AMI must be easily readable and can either be part of the dashboard or located next to the ASMS. If an e-ink display is used, it must be visible that the shown mission is up-to-date. AMI is considered SCS!

T 14.11 Autonomous System Form

T 14.11.1 Before the competition, all teams must submit a clearly structured documentation of their entire AS, including ASB, called ASF.

T 15 AUTONOMOUS SYSTEM BRAKE

T 15.1 Technical Requirements

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

T 15.1.2 All parts of the ASB and their mountings must be located within the rollover protection envelope, see T 1.1.16, with the following exceptions:

- brake system according to T 6
- deactivation point(s) according to T 15.1.8

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

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

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

T 15.1.6 The ASB may be part of the hydraulic brake system. For all components inside the vehicles brake circuit T 6 is applied. On all remaining pneumatic and hydraulic components T 9 applies.

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

T 15.1.8 All deactivation points of the ASB must:

- work without the aid of electrical power
- be in proximity to each other
- be mounted in the surface envelope, see T 1.1.18
- either be mounted in proximity to the ASMS or on the top side of the vehicle between front bulkhead and front hoop close to the vehicles center line
- be protected against unintended actuation, e.g. by being hit by a cone, while driving
- be operable by maximum two simple push/pull and/or turning actions, the order and direction of these actions must be shown next to the deactivation points.
- be marked with “Brake release”
- have a red handle

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

T 15.2 Emergency Brake System

T 15.2.1 The EBS must only use passive systems with mechanical energy storage. Electrical power-loss at EBS must lead to a direct emergency brake maneuver with the performance specified in T 15.4.

T 15.2.2 The EBS must be directly supplied, see T 1.3.1, by LVMS, ASMS, RES and a relay which is supplied by the SDC, parallel to the AIRs, but must not be delayed.

T 15.3 Functional Safety

T 15.3.1 An initial check has to be performed to ensure that ASB is able to build up brake pressure as expected, before AS transitions to “AS Ready”.

T 15.3.2 After the initial check the ASB and its SCS must be continuously monitored for failures.

T 15.3.3 The vehicle must automatically transition to the safe state, if:

- the functionality according to T 15.2.1 cannot be ensured.
- an (additional) single point of failure would lead to total loss of brake capability.

T 15.3.4 The safe state is the vehicle at a standstill, brakes engaged to prevent the vehicle from rolling, and an open SDC.

T 15.3.5 To get to the safe state, the vehicle must perform an autonomous brake maneuver described in section T 15.4 and IN 11.2.

T 15.4 Emergency Brake System Performance

T 15.4.1 The system reaction time, the time between opening of the SDC and the start of the deceleration, must not exceed 200 ms.

T 15.4.2 The average deceleration must be greater than $10\,{}^{m}/_{s^2}$ under dry track conditions.

T 15.4.3 In case of a single failure the ASB should be designed to achieve at least half of the performance specified in T 15.4.2.

T 15.4.4 Whilst decelerating, the vehicle must remain in a stable driving condition.