inspector may request for additional documentation should the material presented be deemed questionable.

T10.3.2 Queries over self-made fasteners can be made directly to the Rules Committee prior to the competition.

T11 ELECTRICAL COMPONENTS

T11.1 Low Voltage System (LVS)

T11.1.1 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 EV1.1.1)

T11.1.2 The maximum permitted voltage that may occur between any two electrical connections in the LVS is 60 V DC or 25 V AC RMS.

T11.1.3 [CV ONLY] The following systems are excluded from the LVS voltage limit (see T11.1.2):

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

T11.1.4 [EV ONLY] The LVS must not use orange wiring or conduit.

T11.1.5 [EV ONLY] The LVS must be grounded to the chassis.

T11.2 Master Switches

T11.2.1 Master switches (see T11.3 and EV6.2) 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. The handle must have the car number mentioned on it. They must be direct acting, i.e. they must not act through a relay or logic.

T11.2.2 Master switches must be located on the right side of the vehicle, in proximity to the main hoop, at the 95th percentile male driver's shoulder height, as defined in T4.3, and be easily actuated from outside the vehicle.

The center of any master switch must not be mounted lower than the vertical distance of the template's (see T4.3) middle circle center to the ground surface multiplied by 0.8.

T11.2.3 The "ON" position of the switch must be in the horizontal position and must be marked accordingly. The "OFF" position of the master switch must also be clearly marked.

T11.2.4 Master switches must be rigidly mounted to the vehicle and must not be removed during maintenance.

T11.2.5 [EV ~~OR DV~~ ONLY] Master switches must be mounted next to each other.

T11.3 Low Voltage Master Switch (LVMS)

T11.3.1 An LVMS according to T11.2 must completely disable

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

T11.3.2 The LVMS must be mounted in the middle of a completely red circular area of ≥50 mm diameter placed on a high contrast background.

T11.3.3 The LVMS must be marked with "LV" and a symbol showing a red spark in a white edged blue triangle.

T11.4 Shutdown Buttons

T11.4.1 A system of three shutdown buttons must be installed on the vehicle.

T11.4.2 Each shutdown button must be a push-pull or push-rotate mechanical emergency switch where pushing the button opens the shutdown circuit (see EV6.1 and CV4.1).

T11.4.3 One button must be located on each side of the vehicle behind the driver's compartment at approximately the level of the driver's head. The minimum allowed diameter of the shutdown buttons on both sides of the vehicle is 40 mm. The buttons must be easy reachable from outside the vehicle.

T11.4.4 One shutdown button serves as a cockpit-mounted shutdown button and must

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

T11.4.5 The international electrical symbol consisting of a red spark on a white-edged blue triangle must be affixed in close proximity to each shutdown button.

T11.4.6 Shutdown buttons must be rigidly mounted to the vehicle and must not be removed during maintenance.

T11.5 Inertia Switch

T11.5.1 An inertia switch must be part of the shutdown circuit (see EV6.1 and CV4.1) such that an impact will result in the shutdown circuit being opened. The inertia switch must latch until manually reset.

T11.5.2 The device must trigger due to an omni-directional peak acceleration of ≤8 g for a half sine test pulse of ≥50 ms length and ≤13 g for a half sine test pulse of ≥20 ms length. The "Sensata Resettable Crash Sensor" should meet those requirements.

T11.5.3 The device must not include any semiconductor components.

T11.5.4 The device must be rigidly attached to the vehicle. It must be possible to demount the device so that its functionality may be tested by shaking it.

T11.6 Brake System Plausibility Device (BSPD)

T11.6.1 A standalone non-programmable circuit, the BSPD, must open the shutdown circuit (see EV6.1 and CV4.1) when hard braking occurs, whilst

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

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

T11.6.2 The action of opening the shutdown circuit must occur if the implausibility is persistent for more than 500 ms.

T11.6.3 The BSPD must be directly supplied (see T1.3.1) from the LVMS (see T11.3).

T11.6.4 Standalone is defined as there is no additional functionality implemented on all required Printed Circuit Boards (PCBs). The interfaces must be reduced to the minimum necessary signals, i.e. power supply, required sensors and the shutdown circuit. Supply and sensor signals must not be routed through any other devices before entering the BSPD.

T11.6.5 To detect hard braking, a brake system pressure sensor must be used. The threshold must be chosen such that there are no locked wheels and the brake pressure is ≤ 30 bar.

T11.6.6 [EV ONLY] To measure power delivery, a DC circuit current sensor only must be used. The threshold must be chosen to an equivalent of ≤5 kW for maximum TS voltage.

T11.6.7 It must be possible to separately disconnect each sensor signal wire for technical inspection.

T11.6.8 All necessary signals are System Critical Signal (SCS) (see T11.9).

T11.6.9 [EV ONLY] The team must prove the function of the BSPD during technical inspection by sending an appropriate signal that represents the current, in order to achieve ≤ 5 kW whilst pressing the brake pedal. This test must prove the functionality of the complete BSPD except for any commercially available current sensors.

T11.6.10 [EV ONLY] The BSPD including all required sensors must not be installed inside the accumulator container.

T11.7 LV Batteries

T11.7.1 LV batteries are all batteries connected to the LVS.

T11.7.2 LV batteries must be securely attached to the chassis and located within the rollover protection envelope (see T1.1.15).

T11.7.3 Any wet-cell battery located in the driver compartment must be enclosed in a non-conductive, water proof (according to IPX7 or higher, IEC 60529) and acid resistant container.

T11.7.4 LV batteries must have a rigid and sturdy casing.

T11.7.5 Ungrounded terminals must be insulated.

T11.7.6 LV batteries must be protected from short circuits, not more than 100 mm from ungrounded terminals.

T11.7.7 Battery packs based on lithium chemistry other than lithium iron phosphate ($LiFePO_4$):

- Must include overcurrent protection that trips at or below the maximum specified discharge current of the cells.
- Must have a fire retardant casing (see T1.2.1).
- Must include over temperature protection of at least 30% of the cells, meeting EV5.8.3, that trips when any cell leaves the allowed temperature range according to the manufacture'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 manufacture'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.
- Signals needed to fulfill these requirements are SCS (see T11.9).

T11.8 Accelerator Pedal Position Sensor (APPS)

T11.8.1 T11.8 only apply for electric vehicles (see chapter EV), or internal combustion vehicles using Electronic Throttle Control (ETC) (see CV1.6).

T11.8.2 The APPS must be actuated by a foot pedal.

T11.8.3 Pedal travel is defined as percentage of travel from fully released position to a fully applied position where 0% is fully released and 100% is fully applied.

T11.8.4 The foot pedal must return to the 0% position when not actuated. The foot pedal must have a positive stop preventing the mounted sensors from being damaged or overstressed. Two springs must be used to return the foot pedal to the 0% position and each spring must work when the other is disconnected. Springs in the APPS are not accepted as return springs.

T11.8.5 At least two separate sensors must be used as APPSs. Separate is defined as not sharing supply or signal lines.

T11.8.6 If analog sensors are used, they must have different, non-intersecting transfer functions. A short circuit between the signal lines must always result in an implausibility according to T11.8.9.

T11.8.7 The APPS signals are SCSs (see T11.9).

T11.8.8 If an implausibility occurs between the values of the APPSs and persists for more than 100 ms

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

T11.8.9 Implausibility is defined as a deviation of more than ten percentage points pedal travel between any of the used APPSs or any failure according to T11.9.

T11.8.10 If three sensors are used, then in the case of an APPS implausibility, any two sensors that are plausible may be used to define the torque target and the 3rd APPS may be ignored.

T11.8.11 It must be possible to separately disconnect each APPS signal wire to check all functionalities.

T11.8.12 A fully released accelerator pedal 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 500ms.

T11.9 System Critical Signals (SCSs)

T11.9.1 SCS are defined as all electrical signals which

- Influence actions on the shutdown circuit (see CV4.1 and EV6.1).
- Influence the wheel torque.
- [EV ONLY] Influence indicators according to EV5.8.8, EV4.10 or EV6.3.7.

T11.9.2 Any of the following SCS single failures must result in a safe state of all connected systems:

(a) Failures of signals transmitted by cable:
- Open circuit
- Short circuit to ground

(b) Failures of analog sensor signals transmitted by cable:
- Short circuit to supply voltage

(c) Failures of sensor signals used in programmable devices:
- Implausibility due to out of range signals, e.g. mechanically impossible angle of an angle sensor.

(d) Failures of digitally transmitted signals by cable or wireless:
- Data corruption (e.g. checked by a checksum)
- Loss and delay of messages (e.g. checked by transmission time outs)

Signals might be a member of multiple signal classes, e.g. analog signals transmitted by cable might be a member of T11.9.2.a, T11.9.2.b and T11.9.2.c.

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

T11.9.3 The maximum allowed delay of messages according to T11.9.2.d must be chosen depending on the impact of delayed messages to the connected system, but must not exceed 500ms.

T11.9.4 Safe state is defined depending on the signals as follows:

- signals only influencing indicators – Indicating a failure of its own function or of the connected system
- low voltage battery signals – At least one pole is electrically disconnected from the rest of the vehicle
- [EV ONLY] For all others signals – opened shutdown circuit and opened AIRs
- [CV ONLY] For all others signals – opened shutdown circuit and stopped engine

T11.9.5 Indicators according to T11.9.1 with safe state "illuminated" (e.g. absence of failures is not actively indicated) must be illuminated for 1s to 3s for visible check after power cycling the LVMS.

T11.10 Sensors & Electrical Components Mounting

T11.10.1 All sensors and components must be securely mounted. For all mounts, T2.2.3 applies.

T11.10.2 Sensors and components may not come into contact with the driver's helmet under any circumstances.

T11.10.3 All sensors and components must be positioned within the surface envelope, see T1.1.16. Actors for aerodynamic devices must be within the box defined in T8.2.

T11.10.4 Passive antennas that are exclusively acting as such with the longest side <100 mm may protrude from the envelope.

T11.10.5 Antennas may also be mounted on the aerodynamic devices, if they do not protrude from the bounding box of the device.

T11.10.6 Additionally, sensors may be mounted with a maximum distance of 500 mm above the ground and less than 700 mm forward of the front of the front tires (see Figure 16). They must not exceed the width of the front axle (measured at the height of the hubs).

T11.10.7 The body of any video/photographic camera must be secured at a minimum of two points on different sides of the camera body. If a tether is used to restrain the camera, the tether length must be limited so that the camera cannot contact the driver. Such camera installations must be approved at technical inspection.

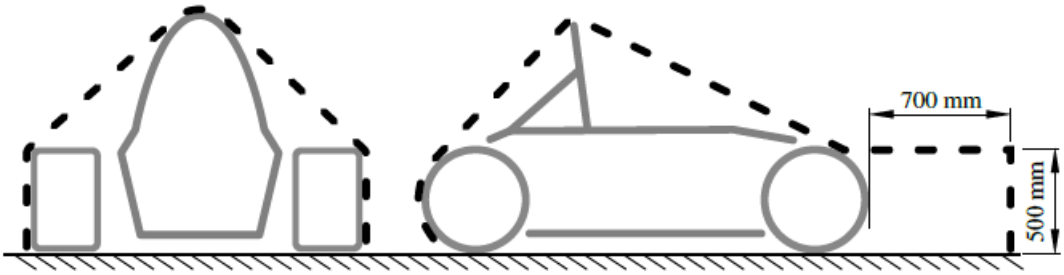

Figure 16: Envelope to mount sensor systems.