2016

Formula Hybrid™ Rules

THAYER SCHOOL OF ENGINEERING AT DARTMOUTH

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RULES CHANGES FOR 2016

The following list is a summary of the significant changes to the 2016 Formula Hybrid rules. It is not a complete list and is not binding. If there are any differences between this summary and the official rules, the Rules will prevail. Therefore, it is the responsibility of the competitors to read the published Rules thoroughly.

Rule Number	Section	Change
A1.2.3	Battery capacity	Added description of capacity calculations
A7.5	Multiple year vehicles	Section revised
A8.7	Vehicle shipping	Rule clarification
ARTICLE A9	Documents and deadlines	Reorganized section
A9.3	Late submissions	Several changes to late penalties
A9.4	Early Submissions	Some early submissions now qualify for bonus points
T1.2.2(k)	Permitted modifications	Clarified replacement of tires and brake pads
T1.2.2(o)	Permitted modifications	Added alteration of motor control parameters
T2.1.2	Definition of open wheel	Simplified and aligned with FSAE definition
T3.4.3	Alternative tubing	Clarified wording
T3.21.1 – 5	Impact attenuator	Section revised
T4.1.1	Cockpit opening	Movement of template permitted
T4.2.1	Cockpit template	Added note re. vertical movement of template
T5.1.2(e)	Harness Requirements	Added recommendation for tilt lock adjuster
T6.5.5	Rear wheel steer	Now permitted per. FSAE rules
T6.5.9	Steering Rack	Added mounting requirements
T6.5.10	Steering rack	Added joint requirements
T7.4	Brake light	Changed to align with FSAE requirements
T8.1.2	Cooling fluids (footnote)	Added “Opticool” as approved electrical system coolant.
T8.2	System Sealing	Section reworded and clarified
T11.1.2	Prohibited fasteners	Added flat head screws
T14.1	Driver’s Equipment	Added “or with the tractive system energized”.
T14.2	Helmets	Added new helmets, deleted obsolete & clarified “open faced”
T14.4	Eye Protection	Removed goggles as allowable eye protection
ARTICLE T16	On-board cameras	Revised and relocated
Figure 5	Percy	Replaced anthropometrical drawing with FSAE version
ARTICLE IC4	I.C. Shutdown	Rewritten
EV1.2.2	Max. GLV Voltage	Added footnote
EV2.2.1	Throttle error checking	Added Note.
EV2.3	Accelerator isolation	Added section
ARTICLE EV3	TSV Electrical	Removed all exemptions for LiFePO4[1]
EV3.3	Accumulator Housings	Added new “Virtual Accumulator Housing” rule
EV3.4.4	SMD Lockout	Removed padlock as a locking means
EV3.4.7	Accumulator V Indicator	Changed requirement to apply to removable containers only
EV3.5.8	Accumulator openings	Simplified section
EV3.6.3	Isolation Relays	Clarified
EV3.7.8	AMS Shutdown	Clarified systems that may remain powered
EV3.7.10	AMS Test Port	Updated connection drawing (**Figure 28**)
EV3.6.10(a)	AMS Test Port	Changed banana jack spacing

[1] Teams that have already invested in LiFePO4 packs that comply with the 2015 rules may request a one-year exemption from this rule change by contacting the Formula Hybrid rules committee.

EV3.9	Pouch Cells	Added note
EV4.3	Grounding	Max resistance changed to 100 ohms
EV4.4.6	TSMP protection	Removed fuses as permissible protection devices
EV4.7.4	HVD lockout	Removed padlock as a locking means
EV4.10	TSEL Indicator	All references to TSAL have been changed to TSEL
EV4.10.2	TSEL Indicator	Required color changed to amber
EV5.1	Shutdown Circuits	Shutdown Button (BRB) sections clarified and reorganized
EV5.2	Master Switches	Section rewritten and reorganized
EV5.6.1	Side mounted buttons	Location clarified
EV5.5.6	Elect. w/ internal power	Was note. Changed to rule.
EV5.9.4	IMD Shutdown	Clarified systems that may remain powered
EV8.2.2	Vehicle Charging	Added chassis to earth grounding requirement
EV8.4	Required equipment	List updated
EV9.1.4	MSDS Sheets	Added MSDS requirement
ARTICLE S1	PEER Review	Section rewritten
S2.3	Inspection condition	Waived for HIP or SEO entries
ARTICLE S3	Project Management	Section contains many clarifications and has been reorganized
S4.10.2	Static Events Only (SEO)	Rule rewritten and clarified
D5.4.2	Hybrid acceleration	Removed restriction on order of runs
Appendix J	Firewall Equivalency test	Required torch changed from Mapp gas to Propane

New Feature: Several Formula Hybrid tech inspectors have identified those rules that multiple teams missed in 2015, causing many to have to sit out the dynamic events.

We have flagged those rules with the "Attention" symbol and we strongly advise teams to pay particular attention to them.

-*The Formula Hybrid Rules Committee*

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Heath Hoffman, Univ. of Michigan
Ted Arbo, Test Equity
Paul Messier, BAE Systems
Rob Wills, Net Solar, llc
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Dennis Brown, General Motors
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Tony Nuzzo, Pika Energy
Mike Irvine, Clearpath Robotics

Not in the photo: Ricky Willems, Innovative Dynamics

2015 Formula Hybrid Electrical Tech Inspectors

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PART A - ADMINISTRATIVE REGULATIONS

ARTICLE A1 FORMULA HYBRID OVERVIEW AND COMPETITION

A1.1 Formula Hybrid Competition Objective

A1.1.1 The Formula Hybrid™ competition challenges teams of university undergraduate and graduate students to conceive, design, fabricate, develop and compete with small, formula-style, hybrid-powered and electric cars.

A1.1.2 The Formula Hybrid competition is intended as an educational program requiring students to work across disciplinary boundaries, such as those of electrical and mechanical engineering.

A1.1.3 To give teams the maximum design flexibility and the freedom to express their creativity and imagination there are very few restrictions on the overall vehicle design apart from the requirement for a mechanical/electrical hybrid or electric-only drivetrain.

A1.1.4 Teams typically spend eight to twelve months designing, building, testing and preparing their vehicles before a competition. The competitions themselves give teams the chance to demonstrate and prove both their creativity and their engineering skills in comparison to teams from other universities around the world.

A1.2 Energy Limits

A1.2.1 Competitiveness and high efficiency designs are encouraged through limits on Accumulator capacities and the amount of energy that a team has available to complete the Endurance event.

A1.2.2 The accumulator capacities and endurance energy allocation will be reviewed by the Formula Hybrid rules committee each year, and posted as early in the season as possible.

Hybrid (and Hybrid In Progress)	
Endurance Energy Allocation	35.5 MJ
Maximum Accumulator Capacity	4,449 Wh
Electric	
Maximum Accumulator Capacity	5,400 Wh

Table 1 – 2016 Energy and Accumulator Limits

A1.2.3 Battery capacities are computed at the 2C (0.5 Hour) rate and then de-rated to allow for useable energy content. See **Appendix A** for information on how to convert from other rates, and for energy calculations for capacitors.

A1.3 Vehicle Design Objectives

For the purpose of this competition, the students are to assume that a manufacturing firm has engaged them to design, fabricate and demonstrate a prototype hybrid-electric competition vehicle for evaluation as a production item. The intended market is the nonprofessional weekend autocross competitor. Therefore, the car must balance exceptional performance with fuel efficiency. Performance will be evaluated in terms of its acceleration, braking, and handling qualities. Fuel efficiency will be evaluated during the 44 km endurance event. The car must be low in cost, easy to maintain, and reliable. It should accommodate drivers whose stature varies from a 5th percentile female to a 95th percentile male. In addition, the car's marketability is enhanced by other factors such as aesthetics, comfort and use of common parts. The manufacturing firm is planning to produce four (4) cars per day for a limited production run. The challenge to the design team is to develop a prototype car that best meets these goals and intents. Each design will be compared and judged with other competing designs to determine the best overall car.

A1.4 Good Engineering Practices

A1.4.1 Vehicles entered into Formula Hybrid competitions are expected to be designed and fabricated in accordance with good engineering practices.

Note, in particular, that the electrical systems in a Formula Hybrid car present health and safety risks unique to a hybrid/electric vehicle, and that carelessness or poor engineering can result in serious injury or death.

A1.4.2 The organizers have produced several advisory publications that are available on the Formula Hybrid website. It is expected that all team members will familiarize themselves with these publications, and will apply the information in them appropriately.

A1.5 Judging Categories

The cars are judged in a series of static and dynamic events including: technical inspections, project management skills , engineering design, solo performance trials, and high performance track endurance. These events are scored to determine how well the car performs.

Static Events		**Hybrid**	**Electric**
	Project Management	100	100
	Engineering Design	200	200
Dynamic Events			
	Acceleration - Electric	75	75
	Acceleration - Unrestricted	75	
	Autocross	150	150
	Endurance	400	400
Total Points		1000	925

Table 2 - Event Points

A1.5.1 A team's final score will equal the sum of their event scores plus or minus penalty and/or bonus points.

Note: If a team's penalty points exceed the sum of their event scores, their final score will be Zero (0). I.e. negative final scores will not be given

ARTICLE A2 FORMULA HYBRID VEHICLE CATEGORIES

A2.1 Hybrid

A2.1.1 A Hybrid vehicle is defined as a vehicle using a propulsion system which comprises both a 4-stroke Internal Combustion Engine (ICE) and electrical storage (accumulator) with electric motor drive.

A2.1.2 A hybrid drive system may deploy the ICE and electric motor(s) in any configuration, including series and/or parallel. Coupling through the road surface is permitted.

A2.1.3 To qualify as a hybrid, vehicles must be capable of:

(a) Completing a 75 meter acceleration run in electric-only mode in less than10 Seconds **or**

(b) As determined to be a hybrid by the design judges.

A2.2 Electric

An Electric vehicle is defined as a vehicle that is charged from an electrical source (or through braking regeneration) and propelled by electric drive only.

A2.3 Hybrid in Progress

A2.3.1 A Hybrid-in-Progress (HIP) is a not-yet-completed hybrid vehicle.

Note: The purpose of the HIP category is to give teams that are on a 2-year development/build cycle an opportunity to enter and compete their vehicle alongside the regular entries. The HIP is regarded, for all scoring purposes, as a hybrid, but will run the dynamic events on electric power only.

A2.3.2 To qualify as an HIP, a vehicle must have been designed, and intended for completion as a hybrid vehicle.

A2.3.3 Teams planning to enter a vehicle in the HIP category will initially register as a Hybrid. To change to the HIP category, the team must submit a request to the organizers <u>in writing</u> before the start of the design event.

Note: The advantages of entering as an HIP are:

(a) Receive a full technical inspection of the vehicle and electrical drive systems.

(b) Participate in all the competition events. (Provided tech inspection is passed).

(c) Receive feedback from the design judges.

Note: Teams can maximize the benefits of an HIP entry by including the full-hybrid designs in their document submissions and design event presentations, as well as including the full multi-year program in their Project Management materials.

(d) When the vehicle is completed and entered as a hybrid, in a subsequent competition, it is considered an all-new vehicle, and not a second-year entry.

A2.4 Electric vs. Hybrid Vehicles

A2.4.1 The Electric and Hybrid categories are separate. Although they compete in the same events, and may be on the endurance course at the same time, they are scored separately and receive separate awards.

A2.4.2 The event scoring formulas will maintain separate baselines (T_{max}, T_{min}) for Hybrid and Electric categories.

Note: Electric vehicles, because they are not carrying the extra weight of engines and generating systems, may demonstrate higher performances in some of the dynamic events. Design scores should not be compared, as the engineering challenge between the two classes is different and scored accordingly.

ARTICLE A3 THE FORMULA HYBRID COMPETITION

A3.1 Open Registration

The Formula Hybrid Competition has an open registration policies and will accept registrations by student teams representing universities in any country.

A3.2 Official Announcements and Competition Information

A3.2.1 Teams are required to read the newsletters published by SAE and Formula Hybrid and to be familiar with all official announcements concerning the competition and rules interpretations released by the Formula Hybrid Rules Committee.

A3.2.2 Formula Hybrid posts announcements to the "News and Important Information" section of the Formula Hybrid forum at **www.formula-hybrid.org/forums**. and on the announcements page of the website **http://www.formula-hybrid.org/students/announcements.**

A3.3 Official Language

The official language of the Formula Hybrid competition is English.

ARTICLE A4 FORMULA HYBRID RULES AND ORGANIZER AUTHORITY

A4.1 Rules Authority

A4.1.1 The Formula Hybrid Rules are the responsibility of the Formula Hybrid Rules Committee and are issued under the authority of the SAE Collegiate Design Series Committee. Official announcements from the Formula Hybrid Rules Committee shall be considered part of, and shall have the same validity as, these rules.

A4.1.2 Ambiguities or questions concerning the meaning or intent of these rules will be resolved by the Formula Hybrid Rules Committee, SAE or by the individual competition organizers as appropriate. (See **ARTICLE A12**)

A4.2 Rules Validity

The Formula Hybrid Rules posted on the Formula Hybrid website and dated for the calendar year of the competition are the rules in effect for the competition. Rule sets dated for other years are invalid.

A4.3 Rules Compliance

A4.3.1 By entering a Formula Hybrid competition the team, members of the team as individuals, faculty advisors and other personnel of the entering university agree to comply with, and be bound by, these rules and all rule interpretations or procedures issued or announced by SAE, the Formula Hybrid Rules Committee or the organizers.

A4.3.2 Any rules or regulations pertaining to the use of the competition site by teams or individuals and which are posted, announced and/or otherwise publically available are incorporated into the these rules by reference. As examples, all event site waiver requirements, speed limits, parking and facility use rules apply to Formula Hybrid participants.

A4.3.3 All team members, faculty advisors and other university representatives are required to cooperate with, and follow all instructions from, competition organizers, officials and judges.

A4.4 Understanding the Rules

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

A4.5 Participating in the Competition

Teams, team members as individuals, faculty advisors and other representatives of a registered university who are present on-site at a competition are considered to be "participating in the competition" from the time they arrive at the event site until they depart the site at the conclusion of the competition or earlier by withdrawing.

A4.6 Violations of Intent

A4.6.1 The violation of intent of a rule will be considered a violation of the rule itself.

A4.6.2 Questions about the intent or meaning of a rule may be addressed to the Formula Hybrid Rules Committee or by the individual competition organizers as appropriate. (See **ARTICLE A12**)

A4.7 Right to Impound

SAE and other competition organizing bodies reserve the right to impound any onsite registered vehicles at any time during a competition for inspection and examination by the organizers, officials and technical inspectors. The organizers may also impound any equipment deemed hazardous by the technical inspectors.

A4.8 Restriction on Vehicle Use

Teams are cautioned that the vehicles designed in compliance with these Formula Hybrid Rules are intended for competition operation only at the official Formula Hybrid competitions.

A4.9 Headings

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

A4.10 General Authority

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

A4.11 SAE Technical Standards Access

A4.11.1 A cooperative program of SAE's Education Board and Technical Standards Board is making some of SAE's Technical Standards available to teams registered for any North American CDS competition at no cost. The Technical Standards referenced in the Collegiate Design Series rules, along with other standards with reference value, will be accessible online to registered teams, team members and faculty advisors. To access the standards (1) your team must be registered for a competition in North America and (2) the individual team member or faculty advisor wanting access must be linked to the team in SAE's system.

A4.11.2 Access Procedure: Once your team has registered there will be a link to the technical standards titled "Design Standards" on the main registration screen where all the required onsite insurance information is added. On the technical standards webpage you will have the ability to search standards either by J-number assigned or topic of interest such as brake light.

A list of accessible SAE Technical Standards can be found in **Appendix I**

ARTICLE A5 INDIVIDUAL PARTICIPATION REQUIREMENTS

A5.1 Eligibility Limits

Eligibility is limited to undergraduate and graduate students to insure that this is an engineering design competition.

A5.2 Student Status

A5.2.1 Team members must be enrolled as degree seeking undergraduate or graduate students in the college or university of the team with which they are participating. Team members who have graduated during the seven (7) month period prior to the competition remain eligible to participate.

A5.2.2 Teams which are formed with members from two or more Universities are treated as a single team. A student at any University making up the team may compete at any event where the team participates. The multiple Universities are in effect treated as one University with two campuses and all eligibility requirements is enforced.

A5.3 Society Membership

A5.3.1 Team members must be members of at least one of the following societies:

(a) SAE

(b) IEEE

(c) SAE Australasia

(d) SAE Brazil

(e) ATA

(f) IMechE

(g) VDI

A5.3.2 Proof of membership, such as membership card, is required at the competition. Students who are members of one of the societies listed above are not required to join any of the other societies in order to participate in the Formula Hybrid competition.

A5.3.3 Students can join

SAE at: http://www.sae.org/students

IEEE at http://www.ieee.org/web/membership/join/join.html

Note: SAE membership is required to complete the on-line vehicle registration process, so at least one team member must be a member of SAE.

A5.4 Age

Team members must be at least eighteen (18) years of age.

A5.5 Driver's License

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

A5.6 Driver Restrictions

Drivers who have driven for a professional racing team in a national or international series at any time may not drive in any competition event. A "professional racing team" is defined as a team that provides racing cars and enables drivers to compete in national or international racing series and employs full time staff in order to achieve this.

A5.7 Liability Waiver

All on-site participants, including students, faculty, volunteers and guests, are required to sign a liability waiver upon registering on-site.

A5.8 Medical Insurance

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

ARTICLE A6 INDIVIDUAL REGISTRATION REQUIREMENTS

A6.1 SAE Student Members

A6.1.1 If your qualifying professional society membership is with the SAE, you should link yourself to your respective school, and complete the following information on the SAE website:

(a) Medical insurance (provider, policy/ID number, telephone number)

(b) Driver's license (state/country, ID number)

(c) Emergency contact data (point of contact (parent/guardian, spouse), relationship, and phone number)

A6.1.2 To do this you will need to go to "Registration" page under the specific event the team is registered and then click on the "Register Your Team / Update Team Information" link. At this point, if you are properly affiliated to the school/college/university, a link will appear with your team name to select. Once you have selected the link, the registration page will appear. Selecting the "Add New Member" button will allow individuals to include themselves with the rest of the team. This can also be completed by team captain and faculty advisor for all team members.

A6.1.3 All students, both domestic and international, must affiliate themselves online or submit the International Student Registration form by March 1, 2016. For additional assistance, please contact CollegiateCompetitions@sae.org.

A6.2 Onsite Registration Requirement

A6.2.1 Onsite registration is required of all team members and faculty advisors

A6.2.2 Registration must be completed and the credentials and/or other identification issued by the organizers properly worn before the car can be unloaded, uncrated or worked upon in any manner.

A6.2.3 The following is required at registration:

(a) Government issued driver's license or passport and

(b) Medical insurance card or documentation

(c) Proof of professional society membership (such as card or member number)

A6.2.4 All international student participants (or unaffiliated faculty advisors) who are not SAE members are required to complete the International Student Registration form for the entire team found under "Competition Resources" on the event specific webpage. Upon completion, email the form to CollegiateCompetitions@sae.org.

A6.2.5 All students, both domestic and international, must affiliate themselves online or submit the International Student Registration form prior to the date shown in the Action Deadlines on the Formula Hybrid website. For additional assistance, please contact CollegiateCompetitions@sae.org.

NOTE: When your team is registering for a competition, only the student or faculty advisor completing the registration needs to be linked to the school. All other students and faculty can affiliate themselves after registration has been completed.

A6.3 Faculty Advisor

A6.3.1 Each team is expected to have a Faculty Advisor appointed by the university. The Faculty Advisor is expected to accompany the team to the competition and will be considered by competition officials to be the official university representative.

A6.3.2 Faculty Advisors are expected to review their team's Structural Equivalency and Impact Attenuator data (See Sections **T3.8** and**T3.21**) prior to submission. Advisors are not required to certify the accuracy of these documents.

A6.3.3 Faculty Advisors may advise their teams on general engineering and engineering project management theory, but may not design any part of the vehicle nor directly participate in the development of any documentation or presentation. Additionally, Faculty Advisors may neither fabricate nor assemble any components nor assist in the preparation, maintenance, testing or operation of the vehicle.

In Brief – Faculty Advisors may not design, build or repair any part of the car.

A6.4 Rules and Safety Officer (RSO)

A6.4.1 Each team must appoint a person to be the “Rules and Safety Officer (RSO)”.

A6.4.2 The RSO must:

(a) Be present at the entire FH event.

(b) Be responsible for understanding the FH rules prior to the competition and ensuring that competing vehicles comply with all FH rules requirements.

(c) System Documentation – Have vehicle designs, plans, schematics and supporting documents available for review by the officials as needed.

(d) Component Documentation – Have manufacturer’s documentation and information available on all components of the electrical system.

(e) Be responsible for team safety while at the event. This includes issues such as:

(i) Use of safety glasses and other safety equipment

(ii) Control of shock hazards such as charging equipment and accessible high voltage sources

(iii) Control of fire hazards such as fuel, sources of ignition (grinding, welding etc.)

(iv) Safe working practices (lock-out/tag-out, clean work area, use of jack stands etc.)

(f) Be the point of contact between the team and FH organizers should rules or safety issues arise.

A6.4.3 If the RSO is also a driver in a dynamic event, a backup RSO must be appointed who will take responsibility for sections **A6.4.2(e)** and **A6.4.2(f)** (above) while the primary RSO is in the vehicle.

A6.4.4 Preferably, the RSO will be the team's faculty advisor or a member of the university's professional staff, but the position may be held by a student member of the team.

A6.4.5 Contact information for the primary and backup RSOs (Name, Cell Phone number, etc.) must be provided to the organizers during registration.

ARTICLE A7 VEHICLE ELIGIBILITY

A7.1 Student Developed Vehicle

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

A7.2 Information Sources

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

A7.3 Professional Assistance

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

A7.4 Student Fabrication

It is the intent of the SAE Collegiate Design Series competitions to provide direct hands-on experience to the students. Therefore, students should perform all fabrication tasks whenever possible.

A7.5 Vehicles Used for Multiple Years

Universities may enter the same vehicle used in previous competitions, provided it complies with all the Formula Hybrid rules in effect at the competition in which it is entered.

Note: A vehicle that may have received a high design score in one year will receive a lower score the following year if it is re-entered without changes. Furthermore, because the Formula Hybrid competition emphasizes high-efficiency drive systems, engineered improvements in the drive train and control systems will be weighted more heavily by the design judges than updates to the chassis, suspension etc.

A7.6 Entries per University

Universities may enter up to two vehicles per competition. Note that there will be a registration wait period imposed for a second vehicle.

ARTICLE A8 REGISTRATION

A8.1.1 Registration for the Formula Hybrid competition must be completed on-line. Online registration must be done by either (a) an SAE member or (b) the official faculty advisor connected with the registering university and recorded as such in the SAE record system.

Note: It typically takes at least 1 working day between the time you complete an online SAE membership application and our system recognizes you as eligible to register your team.

A8.2 Registration Cap

The Formula Hybrid competition is capped at 35 entries. Registrations received after the entry cap is reached will be placed on a waiting list. If no slots become available prior to the competition, the entry fee will be refunded.

A8.3 Registration Dates and Times

A8.3.1 Registration opens on the dates shown below:

Category	Registration opens
Hybrid and Hybrid in Progress	Thursday, October 8, 2015 10:00 AM EDT
Electric-only	Monday, October 12, 2015 10:00 AM EDT
Entry of a second team vehicle	Monday, October 19, 2015 10:00 AM EST

Table 3 – Registration opening dates

A8.3.2 Registration closes on: **Monday, October 26th, 2015 at 11:59 EST.**

> **Important Note:** The 2016 registration period is much shorter than in previous years. Register early!

A8.4 Registration Fees

A8.4.1 The registration fee for 2016 is $2,200.00 (U.S.)

A8.4.2 Registration fees must be paid to the organizer by the deadline specified on the Formula Hybrid website.

A8.4.3 Registration fees are not refundable.

A8.5 Withdrawals

Registered teams that find that they will not be able to attend the Formula Hybrid competition are requested to officially withdraw by notifying the organizers at the following address not later than one (1) week before the event: registrar@formula-hybrid.org

A8.6 United States Visas

A8.6.1 Teams requiring visas to enter to the United States are advised to apply at least sixty (60) days prior to the competition. Although many visa applications go through without an unreasonable delay, occasionally teams have had difficulties and in several instances visas were not issued before the competition.

Don't wait – apply early for your visa.

Note: After your team has registered for the Formula Hybrid competition, the organizers can provide an acknowledgement your registration. We do not issue letters of invitation or participation certificates.

A8.6.2 Neither SAE staff nor any competition organizers are permitted to give advice on visas, customs regulations or vehicle shipping regulations concerning the United States or any other country.

A8.7 Vehicle shipping

A8.7.1 Vehicle shipments must comply with the laws and regulations of nations from which, and to which, the car is being sent.

Note: Teams are strongly advised to consult with their shipping company or freight forwarder to be sure their shipment fully complies with all relevant customs, import /export, aviation and/or ocean shipping requirements.

A8.7.2 Shipments both to and from the competition must be done with the sending team or university listed as both the sending and the receiving party.

Neither the competition organizers nor the competition site can be listed as either the receiving or sending party.

A8.7.3 Vehicle shipping procedures are published on the Formula Hybrid website at: http://www.formula-hybrid.org/students/vehicle-shipping and are incorporated into these Rules by reference.

ARTICLE A9 VEHICLE DOCUMENTS, DEADLINES AND PENALTIES

A9.1 Required Documents

The following documents supporting each vehicle must be submitted by the action deadlines posted on the Formula Hybrid website or otherwise published by the organizers.

Document	Section
Project Management Plan	S3.3
Interim Project Management Report	S3.4
Structural Equivalency Spreadsheet (SES)	T3.8
Impact Attenuator Data (IA)	T3.21
Program Submission	ARTICLE A10(f)
Fuel Request	IC2.1.3
Site Pre-Registration	ARTICLE A10(l)
Design Report	S4.2.1
Sustainability Report	S4.2.2
Design Specification Sheet	S4.2.3
Failure Mode Effects Analysis (FMEA)	EV9.2
Electrical System Form (ESF)	EV9.1

Table 4 - Required Documents

A9.2 Document Submission Policies

Note: Volunteer examiners and judges evaluate all the required submissions and it is essential that they have enough time to complete their work. There are no exceptions to the document submission deadlines and late submissions will incur penalties.

A9.2.1 Document submission penalties or bonus points are factored in to a team's final score. They do not alter the individual event scores.

A9.2.2 Teams must submit the required documents online at http://formula-hybrid.org/uploads

A9.2.3 Document submission deadlines are listed in GMT (Greenwich Mean Time) unless otherwise explicitly stated.

A9.2.4 The time and date that the document is uploaded is recorded in GMT (Greenwich Mean Time) and constitutes the official record for deadline compliance.

A9.2.5 The official time and date of document receipt will be posted on the Formula Hybrid website.

Teams are responsible for ensuring the accuracy of these postings and must notify the organizers within three days of their submission to report a discrepancy. After three days the submission time and date will become final.

A9.3 Late submissions

Documents received after their deadlines will be penalized as follows:

(a) **Structural Equivalency Spreadsheet (SES)** – The penalty for late SES submission is 10 points per day and is capped at negative fifty (-50) points. However, teams are advised that the SES's are evaluated in the order in which they are received and that late submissions will be reviewed last. Late SES approval could delay the completion of your vehicle. We strongly recommend you submit your SES as early as possible.

(b) **Impact Attenuator Report (IA) -** The penalty for late IA submissions is 10 points per day and is capped at negative fifty (-50) points.

(c) **Fuel** – There is no point penalty for late submission of a fuel type order however once the deadline has passed your team will be allocated the basic fuel type (gasoline).

(d) **Design Reports** – The Design Report, Sustainability Report, and Design Spec Sheet collectively constitute the "Design Documents".

Late submission or failure to submit any of the Design Documents will be penalized at ten (10) points per day to a maximum of negative one hundred (-100) points.

IMPORTANT: If your Design Documents are not received within ten (10) days of the submission deadline, they will not be evaluated by the judges, and your team will not be permitted to participate in the Design Event.

(e) **Program Submissions** – There are no penalties for late program submissions. However late submissions will not be included in the race program, which can be an important tool for future team fund raising.

(f) **Project Management Project Plan -** Late submission or failure to submit the Project Plan will be penalized at four (4) points per day and is capped at negative forty (-40) points.

(g) **Project Management Interim Report -** Late submission or failure to submit the interim report will be penalized at one (1) point per day and is capped at negative ten (-10) points.

(h) **FMEA -** The penalty for late submission of the FMEA is 10 points per day and is capped at negative fifty (-50) points.

(i) **ESF -** The penalty for late ESF submissions is 10 points per day and is capped at negative fifty (-50) points.

(j) **Site Pre-Registration -** There is no point penalty for late submission of Site Pre-Registration. However, teams are encouraged to utilize the Site Pre-Registration form, since the onsite registration process can be time consuming.

A9.4 Early submissions

In some cases, documents submitted before their deadline can earn a team bonus points as follows:

(a) **Structural Equivalency Spreadsheet** (SES)

(i) Approved documents that were submitted 30 days or more before the SES deadline will receive 20 bonus points.

(ii) Approved documents that were submitted between 29 and 15 days before the SES deadline will receive 10 bonus points.

Note 1: The qualifying dates for bonus points will be listed on the Formula Hybrid website.

Note 2: The number of bonus points will be based on the submission date of the document, not on the approval date. Documents submitted early that are not approved will not qualify for bonus points.

ARTICLE A10 FORMS AND DOCUMENTS

The following forms and documents are available on the Formula Hybrid website for download:

(a) 2016 Formula Hybrid Rules (This Document)

(b) Structural Equivalency Spreadsheet (SES)

(c) Impact Attenuator (IA) Data Sheet

(d) Electrical Systems Form (ESF) template

(e) Failure Modes Effects Analysis (FMEA) template

(f) Program Information Sheet (Team information for the Event Program)

(g) Mechanical Inspection Sheet (For reference)

(h) Electrical Inspection Sheet (For reference)

(i) Design Specification Sheet

(j) Design Event Judging Form (For reference)

(k) Project Management Judging Form (For reference)

(l) Site pre-registration form (Pre-registering expedites entry into the competition site.)

(m) Paddock Safety Inspection sheet (For reference)

Note: Formula Hybrid strives to provide student engineering teams with timely and useful information to assist in the design and construction of their vehicles. Check the Formula Hybrid website often for new advisory publications.

ARTICLE A11 PROTESTS

A11.1 Protests - General

It is recognized that thousands of hours of work have gone into fielding a vehicle and that teams are entitled to all the points they can earn. We also recognize that there can be differences in the interpretation of rules, the application of penalties and the understanding of procedures. The officials and SAE staff will make every effort to fully review all questions and resolve problems and discrepancies quickly and equitably

A11.2 Preliminary Review – Required

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

A11.3 Cause for Protest

A team may protest any rule interpretation, score or official action (unless specifically excluded from protest) which they feel has caused some actual, non-trivial, harm to their team, or has had substantive effect on their score. Teams may not protest rule interpretations or actions that have not caused them any substantive damage.

A11.4 Protest Format and Forfeit

All protests must be filed in writing and presented to the organizer or SAE staff by the team captain. In order to have a protest considered, a team must post a twenty-five (25) point protest bond which will be forfeited if their protest is rejected.

A11.5 Protest Period

Protests concerning any aspect of the competition must be filed within one-half hour (30 minutes) of the posting of the scores of the event to which the protest relates.

A11.6 Decision

The decision of the competition protest committee regarding any protest is final.

ARTICLE A12 QUESTIONS ABOUT THE FORMULA HYBRID RULES

A12.1 Question Publication

By submitting a question to the Formula Hybrid Rules Committee or the competition's organizing body you and your team agree that both your question and the official answer can be reproduced and distributed by SAE or Formula Hybrid, in both complete and edited versions, in any medium or format anywhere in the world.

A12.2 Question Types

A12.2.1 The Committee will answer questions that are not already answered in the rules or FAQs or that require new or novel rule interpretations. The Committee will not respond to questions that are already answered in the rules. For example, if a rule specifies a minimum dimension for a part the Committee will not answer questions asking if a smaller dimension can be used.

A12.3 Frequently Asked Questions

A12.3.1 Before submitting a question, check the Frequently Asked Questions section of the Formula Hybrid website.

A12.4 Question Submission

Questions must be submitted on the Formula Hybrid Support page:
http://www.formula-hybrid.org/support

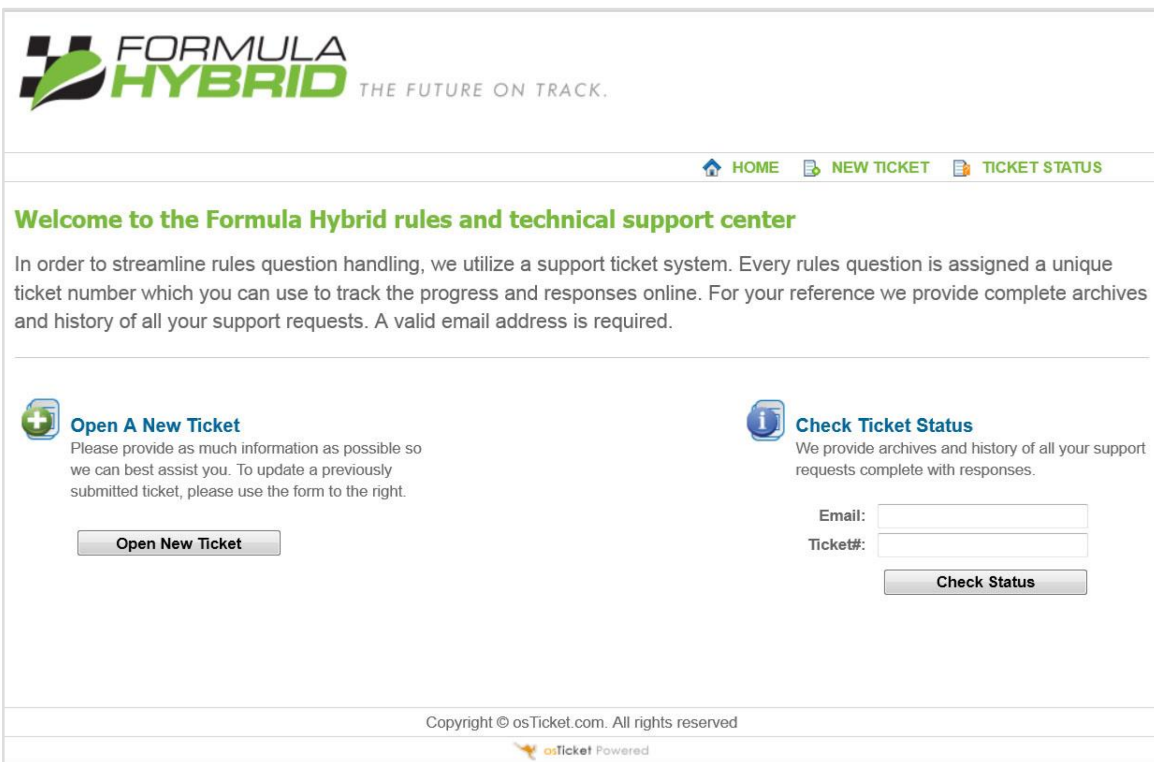

Figure 1 - Formula Hybrid Support Page

A12.5 Question Format

The following information is required:

(a) Submitter's Name

(b) Submitter's Email

(c) Topic (Select from the pull-down menu)

(d) University Name (Registered teams will find their University name in a pull-down list)

You may type your question into the "Message" box, or upload a document.

You will receive a confirmation email with a link to enable you to check on your question's status.

A12.6 Response Time

Please allow a minimum of two (2) weeks for a response. The Rules Committee will respond as quickly as possible, however responses to questions presenting new issues, or of unusual complexity, may take more than two weeks.

Please do not resend questions.

PART T - GENERAL TECHNICAL REQUIREMENTS

ARTICLE T1 VEHICLE REQUIREMENTS & RESTRICTIONS

T1.1 Technical Inspection

T1.1.1 The following requirements and restrictions will be enforced through technical inspection. Noncompliance must be corrected and the car re-inspected before the car is allowed to operate under power.

Note: Teams are advised that cockpit template (**T4.1** and **T4.2**) and Percy (**Figure 5**) compliance will be strictly enforced during mechanical technical inspection. Check the Formula Hybrid website for an instructional video on template and Percy inspection procedures.

T1.2 Modifications and Repairs

T1.2.1 Once the vehicle has been presented for judging in the Design Events, or submitted for Technical Inspection, and until the vehicle is approved to compete in the dynamic events, i.e. all the inspection stickers are awarded, the only modifications permitted to the vehicle are those directed by the Inspector(s) and noted on the Inspection Form.

T1.2.2 Once the vehicle is approved to compete in the dynamic events, the ONLY modifications permitted to the vehicle are:

(a) Adjustment of belts, chains and clutches

(b) Adjustment of brake bias

(c) Adjustment of the driver restraint system, head restraint, seat and pedal assembly

(d) Substitution of the head restraint or seat inserts for different drivers

(e) Adjustment to engine operating parameters, e.g. fuel mixture and ignition timing and any software calibration changes

(f) Adjustment of mirrors

(g) Adjustment of the suspension where no part substitution is required, (except that springs, sway bars and shims may be changed)

(h) Adjustment of tire pressure

(i) Adjustment of wing angle (but not the location)

(j) Replenishment of fluids

(k) Replacement of worn tires or brake pads The replacement tires and/or brake pads must be identical in material, composition and size to those presented and approved at Technical Inspection.

(l) The changing of wheels and tires for “wet” or “damp” conditions as allowed in **D3.1** of the Formula Hybrid Rules.

(m) Recharging of Grounded Low Voltage (GLV) supplies.

(n) Recharging of Accumulators. (See **EV8.2**)

(o) Adjustment of motor controller operating parameters.

T1.2.3 The vehicle must maintain all required specifications, e.g. ride height, suspension travel, braking capacity, sound level and wing location throughout the competition.

T1.2.4 Once the vehicle is approved for competition, any damage to the vehicle that requires repair, e.g. crash damage, electrical or mechanical damage will void the Inspection Approval. Upon the completion of the repair and before re-entering into any dynamic competition, the vehicle MUST be re-submitted to Technical Inspection for re-approval.

ARTICLE T2 GENERAL DESIGN REQUIREMENTS

T2.1 Vehicle Configuration

T2.1.1 The vehicle must be open-wheeled and open-cockpit (a formula style body) with four (4) wheels that are not in a straight line.

T2.1.2 Definition of "Open Wheel" – Open Wheel vehicles must satisfy all of the following criteria:

(a) The top 180 degrees of the wheels/tires must be unobstructed when viewed from vertically above the wheel.

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

(c) No part of the vehicle may enter a keep-out-zone defined by two lines extending vertically from positions 75 mm in front of and 75 mm behind the outer diameter of the front and rear tires in side view elevation of the vehicle with the tires steered straight ahead. This keep-out zone will extend laterally from the outside plane of the wheel/tire to the inboard plane of the wheel/tire. See **Figure 2** below.

Note: The dry tires will be used for all inspections.

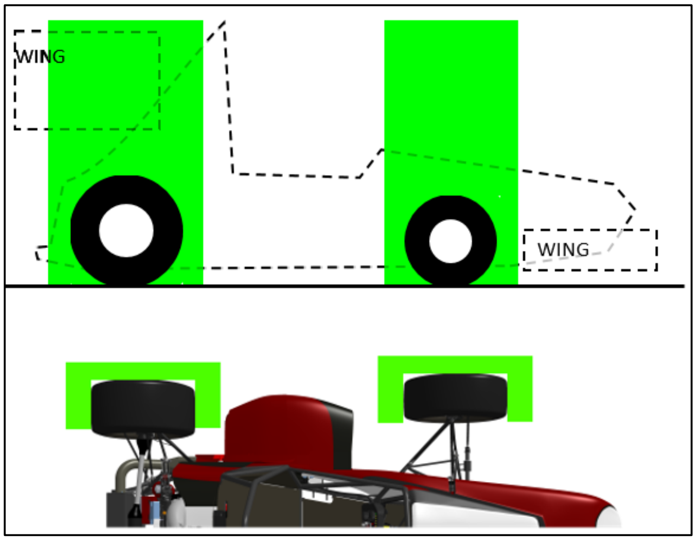

Figure 2 - Open Wheel Definition

T2.2 Bodywork

There must be no openings through the bodywork into the driver compartment from the front of the vehicle back to the roll bar main hoop or firewall other than that required for the cockpit opening. Minimal openings around the front suspension components are allowed.

T2.3 Wheelbase

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

T2.4 Vehicle Track

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

T2.5 Visible Access

All items on the Inspection Form must be clearly visible to the technical inspectors without using instruments such as endoscopes or mirrors. Visible access can be provided by removing body panels or by providing removable access panels.

ARTICLE T3 DRIVER'S CELL

T3.1 General Requirements

T3.1.1 Among other requirements, the vehicle's structure must include two roll hoops that are braced, a front bulkhead with support system and Impact Attenuator, and side impact structures.

Note: Many teams will be retrofitting Formula SAE cars for Formula Hybrid. In most cases these vehicles will be considerably heavier than what the original frame and suspension was designed to carry. It is important to analyze the structure of the car and to strengthen it as required to insure that it will handle the additional stresses.

The technical inspectors will also be paying close attention to the mounting of accumulator systems. These can be very heavy and must be adequately fastened to the main structure of the vehicle.

T3.2 Definitions

The following definitions apply throughout the Rules document:

(a) Main Hoop - A roll bar located alongside or just behind the driver's torso.

(b) Front Hoop - A roll bar located above the driver's legs, in proximity to the steering wheel.

(c) Roll Hoops – Both the Front Hoop and the Main Hoop are classified as "Roll Hoops"

(d) Roll Hoop Bracing Supports – The structure from the lower end of the Roll Hoop Bracing back to the Roll Hoop(s).

(e) Frame Member - A minimum representative single piece of uncut, continuous tubing.

(f) Frame - The "Frame" is the fabricated structural assembly that supports all functional vehicle systems. This assembly may be a single welded structure, multiple welded structures or a combination of composite and welded structures.

(g) Primary Structure – The Primary Structure is comprised of the following Frame components:

- (i) Main Hoop
- (ii) Front Hoop
- (iii) Roll Hoop Braces and Supports
- (iv) Side Impact Structure
- (v) Front Bulkhead
- (vi) Front Bulkhead Support System

(vii) All Frame Members, guides and supports that transfer load from the Driver's Restraint System into items **(i)** through **(vi).**

(h) Major Structure of the Frame – The portion of the Frame that lies within the envelope defined by the Primary Structure. The upper portion of the Main Hoop and the Main Hoop Bracing are not included in defining this envelope.

(i) Front Bulkhead – A planar structure that defines the forward plane of the Major Structure of the Frame and functions to provide protection for the driver's feet.

(j) Impact Attenuator – A deformable, energy absorbing device located forward of the Front Bulkhead.

(k) Side Impact Zone – The area of the side of the car extending from the top of the floor to 350 mm above the ground and from the Front Hoop back to the Main Hoop.

(l) Node-to-node triangulation – An arrangement of frame members projected onto a plane, where a co-planar load applied in any direction, at any node, results in only tensile or compressive forces in the frame members. This is also what is meant by "properly triangulated".

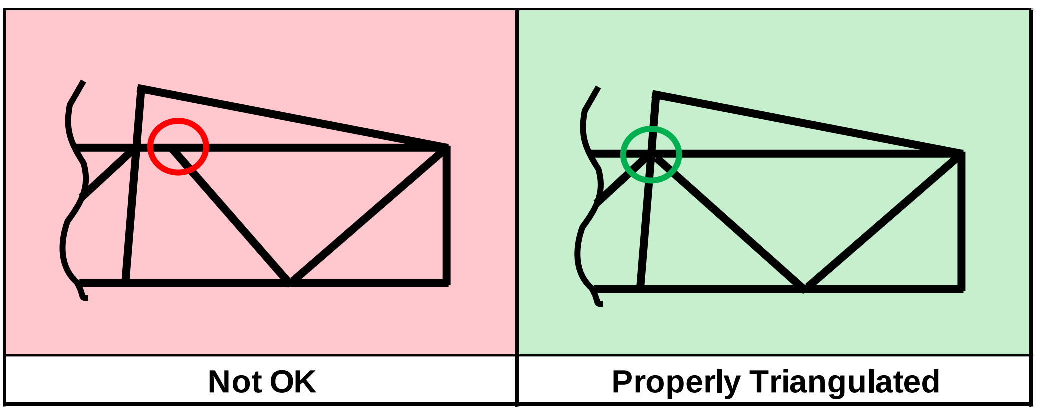

Figure 3 - Triangulation

T3.3 Minimum Material Requirements

T3.3.1 Baseline Steel Material

The Primary Structure of the car must be constructed of:

Either: Round, mild or alloy, steel tubing (minimum 0.1% carbon) of the minimum dimensions specified in **Table 5**.

Or: Approved alternatives per Rules **T3.3**, **T3.4**, **T3.5** and **T3.6**.

ITEM or APPLICATION	OUTSIDE DIMENSION x WALL THICKNESS
Main & Front Hoops, Shoulder Harness Mounting Bar	Round 1.0 inch x 0.095 inch **or** Round 25.0 mm x 2.50 mm metric
Side Impact Structure, Front Bulkhead, Roll Hoop Bracing, Driver's Restraint Harness Attachment (except for Shoulder Harness Mounting Bar - above)	Round 1.0 inch x 0.065 inch **or** Round 25.0 mm x 1.75 mm metric **or** Round 25.4 mm x 1.60 mm metric **or** Square 1.00 inch x 1.00 inch x 0.049 inch **or** Square 25.0 mm x 25.0 mm x 1.25 mm metric **or** Square 26.0 mm x 26.0 mm x 1.2 mm metric
Main Hoop Bracing Supports, Front Bulkhead Supports, Protection of Tractive System Components	Round 1.0 inch x 0.049 inch **or** Round 25.0 mm x 1.5 mm metric **or** Round 26.0 mm x 1.2 mm metric

Table 5 – Baseline Steel

Note 1: The use of alloy steel does not allow the wall thickness to be thinner than that used for mild steel.

Note 2: For a specific application using tubing of the specified outside diameter but with greater wall thickness, **or** of the specified wall thickness and a greater outside diameter, **or** replacing round tubing with square tubing of the same or larger size to those listed above, are NOT rules deviations requiring approval.

Note 3: Except for inspection holes, any holes drilled in any regulated tubing require the submission of an SES.

Note 4: Baseline steel properties used for calculations to be submitted in an SES may not be lower than the following:

Bending and buckling strength calculations:

Young's Modulus (E) = 200 GPa (29,000 ksi)
Yield Strength (S_y) = 305 MPa (44.2 ksi)
Ultimate Strength (S_u) = 365 MPa (52.9 ksi)

Welded monocoque attachment points or welded tube joint calculations:

Yield Strength (S_y) = 180 MPa (26 ksi)
Ultimate Strength (S_u) = 300 MPa (43.5 ksi)

T3.3.2 Where welded tubing reinforcements are required (e.g. inserts for bolt holes or material to support suspension cutouts) the tubing must retain the baseline cold rolled strength while using the welded strength for the additional reinforcement material.

T3.4 Alternative Tubing and Material - General

T3.4.1 Alternative tubing geometry and/or materials may be used except that the Main Roll Hoop and Main Roll Hoop Bracing must be made from steel, i.e. the use of aluminum or titanium tubing or composites for these components is prohibited.

T3.4.2 Titanium or magnesium on which welding has been utilized may not be used for any part of the Primary Structure. This includes the attachment of brackets to the tubing or the attachment of the tubing to other components.

T3.4.3 If a team chooses to use alternative tubing and/or materials they must still submit a "Structural Equivalency Spreadsheet" per Rule **T3.8**. The teams must submit calculations for the material they have chosen, demonstrating equivalence to the minimum requirements found in Section **T3.3.1** for yield and ultimate strengths in bending, buckling and tension, for buckling modulus and for energy dissipation.

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

T3.4.4 To be considered as a structural tube in the SES Submission (**T3.8**) tubing cannot have an outside dimension less than 25 mm or a wall thickness less than that listed in **T3.5** or **T3.6**.

T3.4.5 If a bent tube is used anywhere in the primary structure, other than the front and main roll hoops, an additional tube must be attached to support it. The attachment point must be the position along the tube where it deviates farthest from a straight line connecting both ends. The support tube must have the same diameter and thickness as the bent tube. The support tube must terminate at a node of the chassis.

T3.4.6 Any chassis design that is a hybrid of the baseline and monocoque rules, must meet all relevant rules requirements, e.g. a sandwich panel side impact structure in a tube frame chassis must meet the requirements of rules **T3.27**, **T3.28**, **T3.29**, **T3.30** and **T3.33**.

Note: It is allowable for the properties of tubes and laminates to be combined to prove equivalence. E.g. in a side-impact structure consisting of one tube as per **T3.3** and a laminate panel, the panel only needs to be equivalent to two side-impact tubes.

T3.5 Alternative Steel Tubing

Minimum Wall Thickness Allowed:

MATERIAL & APPLICATION	MINIMUM WALL THICKNESS
Front and Main Roll Hoops Shoulder Harness Mounting Bar	2.0 mm
Roll Hoop Bracing Roll Hoop Bracing Supports Side Impact Structure Front Bulkhead Front Bulkhead Support Driver's Harness Attachment (Except for Shoulder Harness Mounting Bar - above) Protection of accumulators Protection of TSV components	1.2 mm

Table 6 - Steel Tubing Minimum Wall Thicknesses

Note 1: All steel is treated equally - there is no allowance for alloy steel tubing, e.g. SAE 4130, to have a thinner wall thickness than that used with mild steel.

Note 2: To maintain EI with a thinner wall thickness than specified in **T3.3.1**, the outside diameter MUST be increased.

Note 3: To maintain the equivalent yield and ultimate tensile strength the same cross-sectional area of steel as the baseline tubing specified in **T3.3.1** must be maintained.

T3.6 Aluminum Tubing Requirements

T3.6.1 Minimum Wall Thickness of Aluminum Tubing is 3.0 mm

T3.6.2 The equivalent yield strength must be considered in the "as-welded" condition, (Reference: *WELDING ALUMINUM* (latest Edition) by the Aluminum Association, or *THE WELDING HANDBOOK*, Volume 4, 7th Ed., by The American Welding Society), unless the team demonstrates and shows proof that the frame has been properly solution heat treated and artificially aged.

T3.6.3 Should aluminum tubing be solution heat-treated and age hardened to increase its strength after welding; the team must supply sufficient documentation as to how the process was performed. This includes, but is not limited to, the heat-treating facility used, the process applied, and the fixturing used.

T3.7 Composite Materials

T3.7.1 If any composite or other material is used, the team must present documentation of material type, e.g. purchase receipt, shipping document or letter of donation, and of the material properties. Details of the composite lay-up technique as well as the structural material used (cloth type, weight, and resin type, number of layers, core material, and skin material if metal) must also be submitted. The team must submit calculations demonstrating equivalence of their composite structure to one of similar geometry made to the minimum requirements found in Section **T3.3.1**. Equivalency calculations must be submitted for energy dissipation, yield and ultimate strengths in bending, buckling, and tension. Submit the completed "Structural Equivalency Spreadsheet" per Section **T3.8**

T3.7.2 Composite materials are not allowed for the Main Hoop or the Front Hoop.

T3.8 Structural Documentation – SES Submission

All equivalency calculations must prove equivalency relative to steel grade SAE/AISI 1010**.**

T3.8.1 All teams must submit a Structural Equivalency Spreadsheet (SES) even if they are not planning to use alternative materials or tubing sizes to those specified in **T3.3.1** Baseline Steel Materials.

T3.8.2 The use of alternative materials or tubing sizes to those specified in **T3.3.1** "Baseline Steel Material," is allowed, provided they have been judged by a technical review to have equal or superior properties to those specified in **T3.3.1**.

T3.8.3 Approval of alternative material or tubing sizes will be based upon the engineering judgment and experience of the chief technical inspector or his appointee.

T3.8.4 The technical review is initiated by completing the "Structural Equivalency Spreadsheet" (SES) which can be downloaded from the Formula Hybrid website.

T3.8.5 Structural Equivalency Spreadsheet – Submission

SESs must be submitted via the Formula Hybrid Document Upload page. See Section **A9.2**.

Do Not Resubmit SES's unless instructed to do so.

T3.8.6 Vehicles completed under an approved SES must be fabricated in accordance with the materials and processes described in the SES.

T3.8.7 Teams must bring a copy of the approved SES with them to Technical Inspection.

Comment - The resubmission of an SES that was written and submitted for a competition in a previous year is strongly discouraged. Each team is expected to perform their own tests and to submit SESs based on their original work. Understanding the engineering that justifies the equivalency is essential to discussing your work with the officials.

T3.9 Main and Front Roll Hoops – General Requirements

T3.9.1 The driver's head and hands must not contact the ground in any rollover attitude.

T3.9.2 The Frame must include both a Main Hoop and a Front Hoop as shown in **Figure 4**.

T3.9.3 When seated normally and restrained by the Driver's Restraint System, the helmet of a 95th percentile male (anthropometrical data; See **Table 7** and **Figure 5**) and all of the team's drivers must:

(a) Be a minimum of 50.8 mm from the straight line drawn from the top of the main hoop to the top of the front hoop. (**Figure 4a**)

(b) Be a minimum of 50.8 mm from the straight line drawn from the top of the main hoop to the lower end of the main hoop bracing if the bracing extends rearwards. (**Figure 4b**)

(c) Be no further rearwards than the rear surface of the main hoop if the main hoop bracing extends forwards. (**Figure 4c**)

A two dimensional template used to represent the 95th percentile male is made to the following dimensions: • A circle of diameter 200 mm will represent the hips and buttocks. • A circle of diameter 200 mm will represent the shoulder/cervical region. • A circle of diameter 300 mm will represent the head (with helmet). • A straight line measuring 490 mm will connect the centers of the two 200 mm circles. • A straight line measuring 280 mm will connect the centers of the upper 200 mm circle and the 300 mm head circle.

Table 7 - 95th Percentile Male Template Dimensions

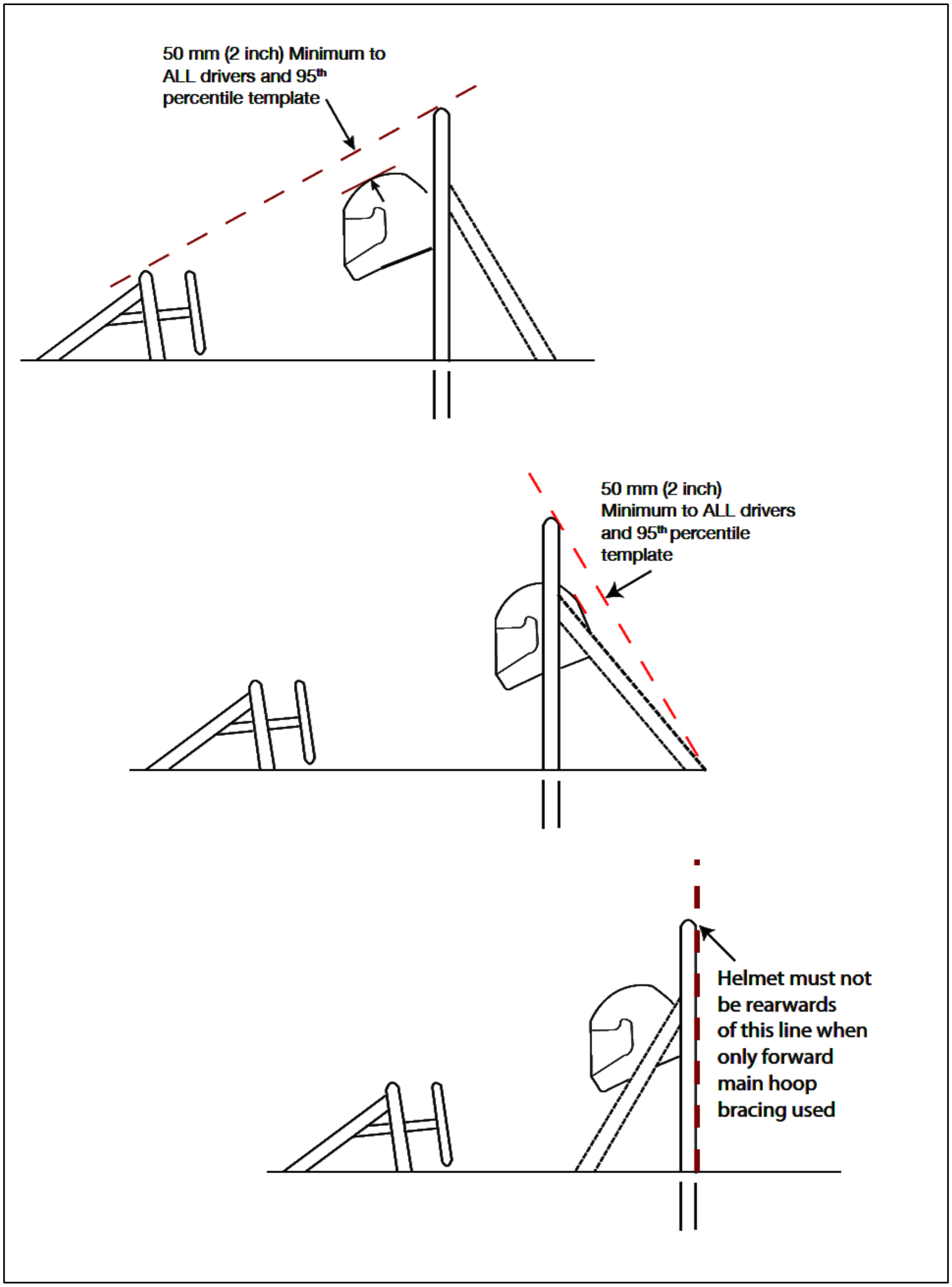

Figure 4- Roll Hoops and Helmet Clearance

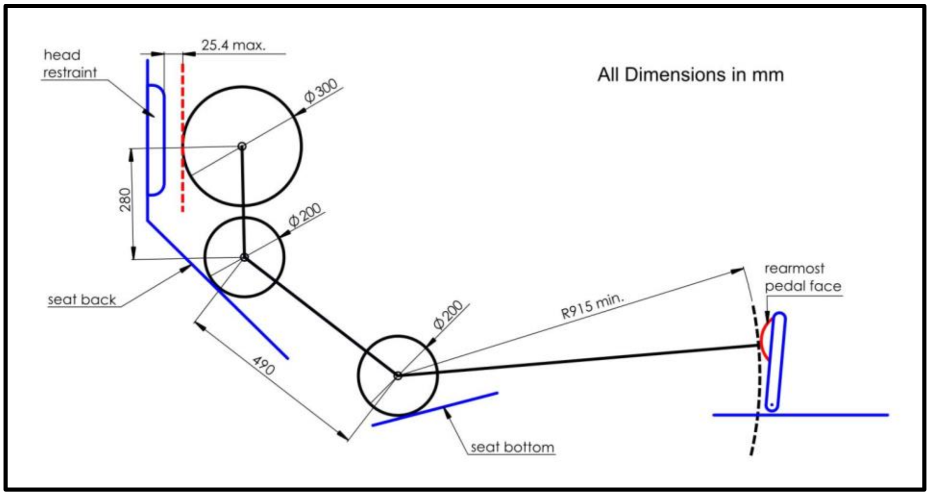

Figure 5 - Percy -- 95th Percentile Male with Helmet

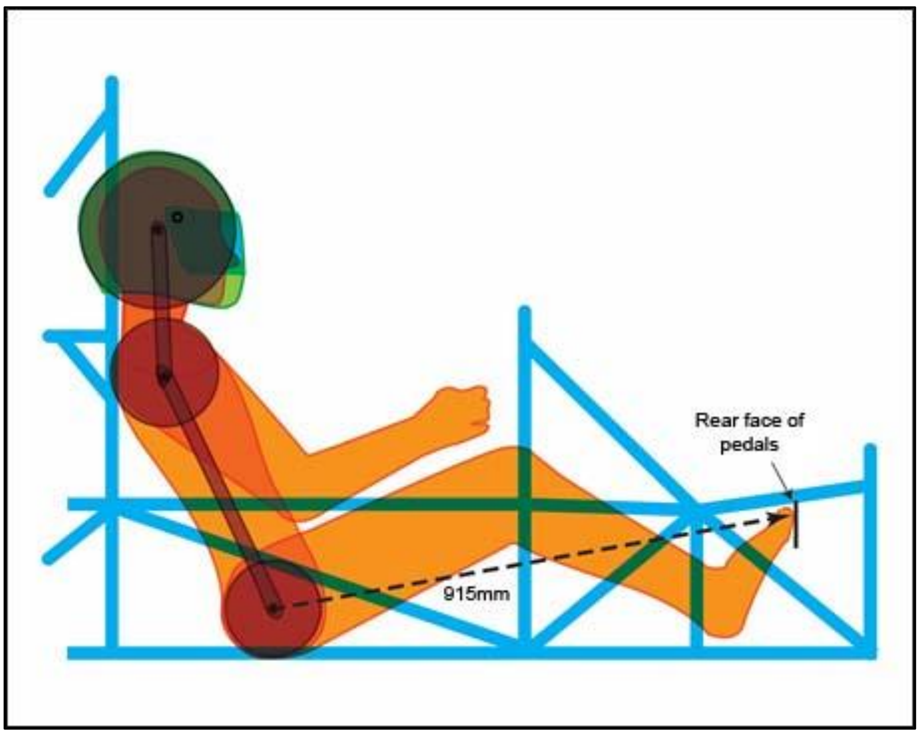

Figure 6 – 95th Percentile Template Positioning

T3.9.4 The 95th percentile male template (Percy) will be positioned as follows: (See **Figure 6**)

(a) The seat will be adjusted to the rearmost position,

(b) The pedals will be placed in the most forward position.

(c) The bottom 200 mm circle will be placed on the seat bottom such that the distance between the center of this circle and the rearmost face of the pedals is no less than 915 mm.

(d) The middle 200 mm circle, representing the shoulders, will be positioned on the seat back.

(e) The upper 300 mm circle will be positioned no more than 25.4 mm away from the head restraint (i.e. where the driver's helmet would normally be located while driving).

IMPORTANT: *If the requirements of* ***T3.9.3*** *are not met with the 95th percentile male template, the car will not receive a Technical Inspection Sticker and will not be allowed to compete in the dynamic events.*

T3.9.5 Drivers who do not meet the helmet clearance requirements of **T3.9.3** will not be allowed to drive in the competition.

T3.9.6 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.

T3.9.7 The Main Hoop and Front Hoop must be securely integrated into the Primary Structure using gussets and/or tube triangulation.

T3.10 Main Hoop

T3.10.1 The Main Hoop must be constructed of a single piece of uncut, continuous, closed section steel tubing per Rule **T3.3.1**

T3.10.2 The use of aluminum alloys, titanium alloys or composite materials for the Main Hoop is prohibited.

T3.10.3 The Main Hoop must extend from the lowest Frame Member on one side of the Frame, up, over and down the lowest Frame Member on the other side of the Frame.

T3.10.4 In the side view of the vehicle, the portion of the Main Roll Hoop that lies above its attachment point to the Major Structure of the Frame must be within ten degrees (10°) of the vertical.

T3.10.5 In the side view of the vehicle, any bends in the Main Roll Hoop above its attachment point to the Major Structure of the Frame must be braced to a node of the Main Hoop Bracing Support structure with tubing meeting the requirements of Roll Hoop Bracing as per Rule **T3.3.1**

T3.10.6 In the front view of the vehicle, the vertical members of the Main Hoop must be at least 380 mm apart (inside dimension) at the location where the Main Hoop is attached to the Major Structure of the Frame.

T3.11 Front Hoop

T3.11.1 The Front Hoop must be constructed of closed section metal tubing per Rule **T3.3.1**.

T3.11.2 The Front Hoop must extend from the lowest Frame Member on one side of the Frame, up, over and down to the lowest Frame Member on the other side of the Frame.

T3.11.3 With proper gusseting and/or triangulation, it is permissible to fabricate the Front Hoop from more than one piece of tubing.

T3.11.4 The top-most surface of the Front Hoop must be no lower than the top of the steering wheel in any angular position.

T3.11.5 The Front Hoop must be no more than 250 mm forward of the steering wheel. This distance shall be measured horizontally, on the vehicle centerline, from the rear surface of the Front Hoop to the forward most surface of the steering wheel rim with the steering in the straight-ahead position.

T3.11.6 In side view, no part of the Front Hoop can be inclined at more than twenty degrees (20°) from the vertical.

T3.12 Main Hoop Bracing

T3.12.1 Main Hoop braces must be constructed of closed section steel tubing per Rule **T3.3.1**.

T3.12.2 The Main Hoop must be supported by two braces extending in the forward or rearward direction on both the left and right sides of the Main Hoop.

T3.12.3 In the side view of the Frame, the Main Hoop and the Main Hoop braces must not lie on the same side of the vertical line through the top of the Main Hoop, i.e. if the Main Hoop leans forward, the braces must be forward of the Main Hoop, and if the Main Hoop leans rearward, the braces must be rearward of the Main Hoop.

T3.12.4 The Main Hoop braces must be attached as near as possible to the top of the Main Hoop but not more than 160 mm below the top-most surface of the Main Hoop. The included angle formed by the Main Hoop and the Main Hoop braces must be at least thirty degrees (30°). See: **Figure 7**

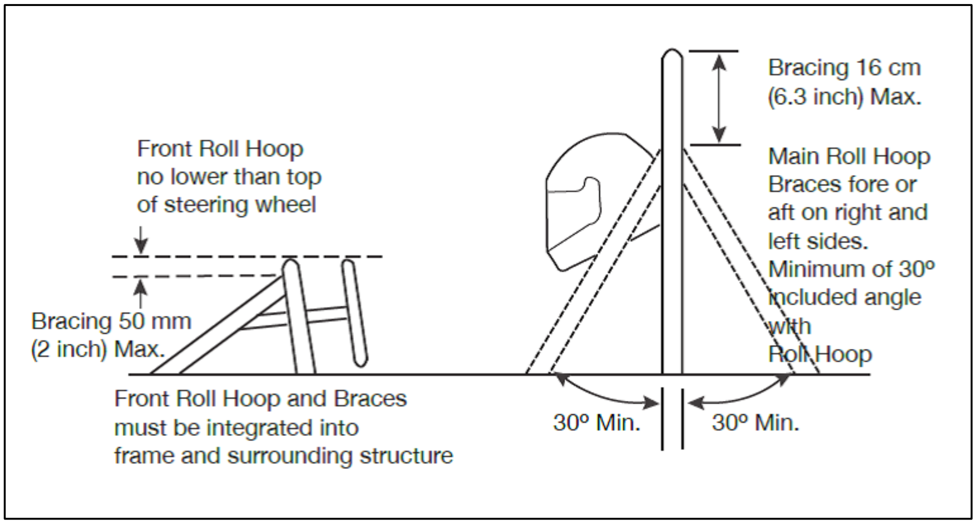

Figure 7 - Main and Front Hoop Bracing

T3.12.5 The Main Hoop braces must be straight, i.e. without any bends.

T3.12.6 The attachment of the Main Hoop braces must be capable of transmitting all loads from the Main Hoop into the Major Structure of the Frame without failing. From the lower end of the braces there must be a properly triangulated structure back to the lowest part of the Main Hoop and the node at which the upper side impact tube meets the Main Hoop. This structure must meet the minimum requirements for Main Hoop Bracing Supports (see Rule **T3.3**) or an SES approved alternative. Bracing loads must not be fed solely into the engine, transmission or differential, or through suspension components.

T3.12.7 If any item which is outside the envelope of the Primary Structure is attached to the Main Hoop braces, then additional bracing must be added to prevent bending loads in the braces in any rollover attitude.

T3.13 Front Hoop Bracing

T3.13.1 Front Hoop braces must be constructed of material per Rule **T3.3.1**.

T3.13.2 The Front Hoop must be supported by two braces extending in the forward direction on both the left and right sides of the Front Hoop.

T3.13.3 The Front Hoop braces must be constructed such that they protect the driver’s legs and should extend to the structure in front of the driver’s feet.

T3.13.4 The Front Hoop braces must be attached as near as possible to the top of the Front Hoop but not more than 50.8 mm below the top-most surface of the Front Hoop. See: **Figure 7**

T3.13.5 If the Front Hoop leans rearwards by more than ten degrees (10°) from the vertical, it must be supported by additional bracing to the rear. This bracing must be constructed of material per Rule **T3.3.1**.

T3.14 Other Bracing Requirements

Where the braces are not welded to steel Frame Members, the braces must be securely attached to the Frame using 8 mm Metric Grade 8.8 (5/16 in SAE Grade 5), or stronger, bolts. Mounting plates welded to the Roll Hoop braces must be at least 2.0 mm thick steel.

T3.15 Other Side Tube Requirements

If there is a Roll Hoop brace or other frame tube alongside the driver, at the height of the neck of any of the team's drivers, a metal tube or piece of sheet metal must be firmly attached to the Frame to prevent the drivers' shoulders from passing under the roll hoop brace or frame tube, and his/her neck contacting this brace or tube.

T3.16 Mechanically Attached Roll Hoop Bracing

T3.16.1 Roll Hoop bracing may be mechanically attached.

T3.16.2 Any non-permanent joint at either end must be either a double-lug joint as shown in **Figure 8** and **Figure 9** or a sleeved butt joint as shown in **Figure 10**.

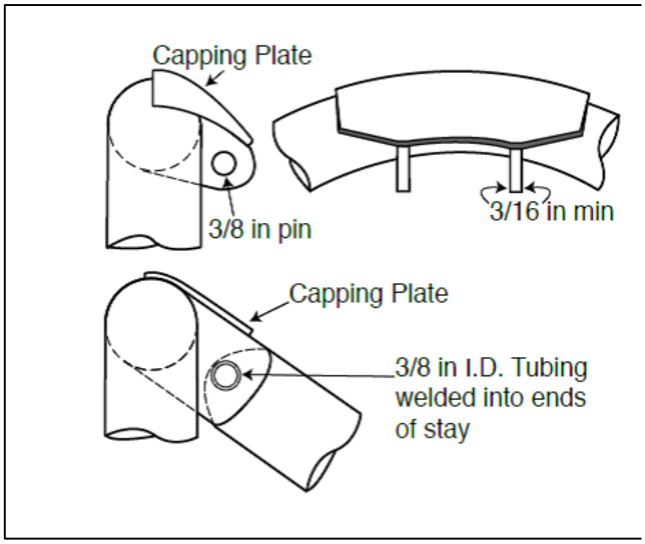

Figure 8 – Double-Lug Joint

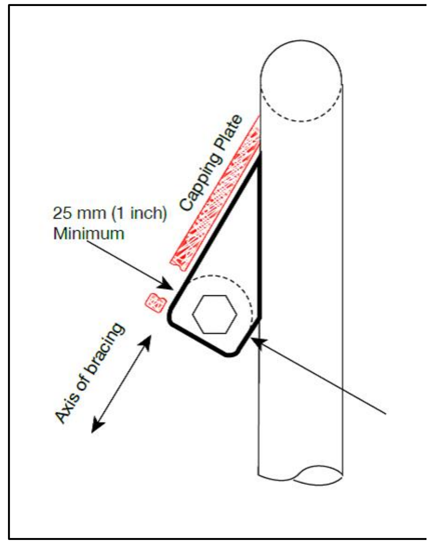

Figure 9 – Double Lug Joint

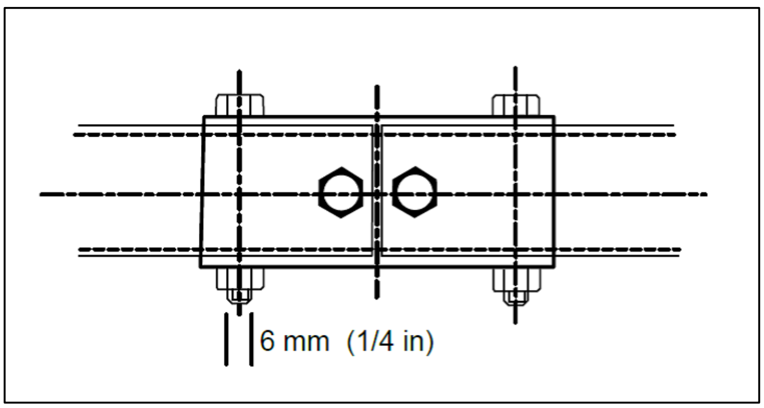

Figure 10 – Sleeved Butt Joint

T3.16.3 The threaded fasteners used to secure non-permanent joints are considered critical fasteners and must comply with **ARTICLE T11**.

T3.16.4 No spherical rod ends are allowed.

T3.16.5 For double-lug joints, each lug must be at least 4.5 mm thick steel, measure 25 mm minimum perpendicular to the axis of the bracing and be as short as practical along the axis of the bracing.

T3.16.6 All double-lug joints, whether fitted at the top or bottom of the tube, must include a capping arrangement. (See **Figure 8** and **Figure 9**)

T3.16.7 In a double-lug joint the pin or bolt must be 10 mm Grade 9.8 or 3/8 inch SAE Grade 8 minimum. The attachment holes in the lugs and in the attached bracing must be a close fit with the pin or bolt.

T3.16.8 For sleeved butt joints (Figure 10), the sleeve must have a minimum length of 76 mm; 38 mm on either side of the joint, and be a close-fit around the base tubes. The wall thickness of the sleeve must be at least that of the base tubes. The bolts must be 6 mm Grade 9.8 or 1/4 inch SAE Grade 8 minimum. The holes in the sleeves and tubes must be a close-fit with the bolts.

T3.17 Frontal Impact Structure

T3.17.1 The driver's feet *and* legs must be completely contained within the Major Structure of the Frame. While the driver's feet are touching the pedals, in side and front views no part of the driver's feet *or legs* can extend above or outside of the Major Structure of the Frame.

T3.17.2 Forward of the Front Bulkhead must be an energy-absorbing Impact Attenuator.

T3.18 Bulkhead

T3.18.1 The Front Bulkhead must be constructed of closed section tubing per Rule **T3.3.1**.

T3.18.2 Except as allowed by**T3.22.2**, The Front Bulkhead must be located forward of all non-crushable objects, e.g. batteries, master cylinders, hydraulic reservoirs.

T3.18.3 The Front Bulkhead must be located such that the soles of the driver's feet, when touching but not applying the pedals, are rearward of the bulkhead plane. (This plane is defined by the forward-most surface of the tubing.) Adjustable pedals must be in the forward most position.

T3.19 Front Bulkhead Support

T3.19.1 The Front Bulkhead must be securely integrated into the Frame.

T3.19.2 The Front Bulkhead must be supported back to the Front Roll Hoop by a minimum of three (3) Frame Members on each side of the vehicle with one at the top (within 50.8 mm of its top-most surface), one (1) at the bottom, and one (1) as a diagonal brace to provide triangulation.

T3.19.3 The triangulation must be node-to-node, with triangles being formed by the Front Bulkhead, the diagonal and one of the other two required Front Bulkhead Support Frame Members.

T3.19.4 All the Frame Members of the Front Bulkhead Support system listed above must be constructed of closed section tubing per Section **T3.3.1**.

T3.20 Impact Attenuator

T3.20.1 The Impact Attenuator must be:

(a) Installed forward of the Front Bulkhead.

(b) At least 200 mm long, with its length oriented along the fore/aft axis of the frame.

(c) At least 100 mm high and 200 mm wide for a minimum distance of 200 mm forward of the Front Bulkhead, such that it cannot penetrate the Front Bulkhead in the event of an impact.

(d) Attached securely and directly to the Front Bulkhead and not by being part of non-structural bodywork.

T3.20.2 The attachment of the Impact Attenuator must be constructed to provide an adequate load path for transverse and vertical loads in the event of off-center and off-axis impacts.

T3.20.3 The attachment of the Impact Attenuator to the anti-intrusion plate requires an approved "Structural Equivalency Spreadsheet" per Article **T3.8** that shows equivalency to a minimum of four (4) 8 mm Grade 8.8 or 5/16 inch SAE Grade 5 bolts.

T3.20.4 On all cars, a 1.5 mm solid steel or 4.0 mm solid aluminum "anti-intrusion plate" must be integrated into the Impact Attenuator. If the IA plate is 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.

T3.20.5 If the anti-intrusion plate is not integral with the frame, i.e. welded, a minimum of four (4) 8 mm Metric Grade 8.8 or 5/16 inch SAE Grade 5 bolts must attach the Impact Attenuator to the Front Bulkhead.

T3.20.6 Alternative designs of the anti-intrusion plate required by **T3.20.4** that do not comply with the minimum specifications given above require an approved "Structural Equivalency Spreadsheet" per **T3.8**. Equivalency must also be proven for perimeter shear strength of the proposed design.

T3.21 Impact Attenuator Test Data Report Requirement

T3.21.1 Impact Attenuator Test Data Report Requirement

All teams, whether they are using their own design of Impact Attenuator (IA) or the "standard" FSAE Impact Attenuator, must submit an Impact Attenuator Data Report using the Impact Attenuator Data (IAD) Template found on the Formula Hybrid download page at:

http://www.formula-hybrid.org/students/tech-support/

T3.21.2 All teams must submit calculations and/or test data to show that their Impact Attenuator, when mounted on the front of their vehicle and run into a solid, non-yielding impact barrier with a velocity of impact of 7.0 meters/second, would give an average deceleration of the vehicle not to exceed 20 g, with a peak deceleration less than or equal to 40 g's.

NOTE 1: Quasi-static testing is allowed.

NOTE 2: The calculations of how the reported absorbed energy, average deceleration and peak deceleration figures have been derived from the test data MUST be included in the report and appended to the report template.

T3.21.3 Calculations must be based on the actual vehicle mass with a 175 lb. driver, full fluids, and rounded up to the nearest 100 lb.

Note: Teams may only use the "Standard" FSAE impact attenuator design and data submission process if their vehicle mass with driver is 300 kgs (661 lbs) or less.

To be eligible to utilize the "Standard" FSAE impact attenuator, teams must either have previously brought a Formula Hybrid vehicle that weighs under 300 kgs (661 lbs) with driver to a Formula Hybrid competition, or submit a detailed mass measurement spreadsheet covering all the vehicle's components as part of the Impact Attenuator Data Report, showing that the new vehicle meets the above requirements.

T3.21.4 Teams using a front wing must prove that the combination of the Impact Attenuator and front wing, when used together, do not exceed the peak deceleration of rule **T3.21.2**. Teams can use the following methods to show the design does not exceed the limits given in **T3.21.2**.

(a) Physical testing of the Impact Attenuator with wing mounts, links, vertical plates, and a structural representation of the airfoil section to determine the peak force. See http://formula-hybrid.org/students/tech-support/ FAQs for an example of the structure to be included in the test. Or

(b) Combine the peak force from physical testing of the Impact Attenuator Assembly with the wing mount failure load calculated from fastener shear and/or link buckling. Or

(c) If they are using the Standard FSAE Impact Attenuator (see **T3.21.3** above), combine the peak load of 95 kN exerted by the Standard FSAE Impact Attenuator with the wing mount failure load calculated from fastener shear and/or buckling.

T3.21.5 When using acceleration data, the average deceleration must be calculated based on the raw data. The peak deceleration can be assessed based on the raw data, and if peaks above the 40g limit are apparent in the data, it can then be filtered with a Channel Filter Class (CFC) 60 (100 Hz) filter per SAE Recommended Practice J211 "Instrumentation for Impact Tests", or a 100 Hz, 3rd order, lowpass Butterworth (-3dB at 100 Hz) filter.

T3.21.6 A schematic of the test method must be supplied along with photos of the attenuator before and after testing.

T3.21.7 The test piece must be presented at technical inspection for comparison to the photographs and the attenuator fitted to the vehicle.

T3.21.8 The report must be submitted electronically in Adobe Acrobat ® format (*.pdf file) to the address and by the date provided in the Action Deadlines provided on the Formula Hybrid website. This material must be a single file (text, drawings, data or whatever you are including).

T3.21.9 The Impact Attenuator Data Report must be named as follows: carnumber_schoolname_competitioncode_IAD.pdf using the assigned car number, the complete school name and competition code e.g.

087_University of SAE_FH_IAD.pdf

T3.21.10 Teams that submit their Impact Attenuator Data Report after the due date will be penalized as listed in section **A9.2**.

T3.21.11 Impact Attenuator Reports will be evaluated by the organizers and the evaluations will be passed to the Design Event Captain for consideration in that event.

T3.21.12 During the test, the attenuator must be attached to the anti-intrusion plate using the intended vehicle attachment method. The anti-intrusion plate must be spaced at least 50 mm from any rigid surface. No part of the anti-intrusion plate may permanently deflect more than 25.1 mm beyond the position of the anti-intrusion plate before the test.

Note: The 25.4 mm spacing represents the front bulkhead support and insures that the plate does not intrude excessively into the cockpit.

T3.21.13 Dynamic testing (sled, pendulum, drop tower, etc.) of the impact attenuator may only be done at a dedicated test facility. The test facility may be part of the University but must be supervised by professional staff or University faculty. Teams are not allowed to construct their own dynamic test apparatus. Quasi-static testing may be performed by teams using their universities facilities/equipment, but teams are advised to exercise due care when performing all tests.

T3.22 Non-Crushable Objects

T3.22.1 Except as allowed by **T3.22.2**, all non-crushable objects (e.g. batteries, master cylinders, hydraulic reservoirs) must be rearward of the bulkhead. No non-crushable objects are allowed in the impact attenuator zone.

T3.22.2 The front wing and wing supports may be forward of the Front Bulkhead, but may NOT be located in or pass through the Impact Attenuator. If the wing supports are in front of the Front Bulkhead, the supports must be included in the test of the Impact Attenuator for **T3.21**.

T3.23 Front Bodywork

T3.23.1 Sharp edges on the forward facing bodywork or other protruding components are prohibited.

T3.23.2 All forward facing edges on the bodywork that could impact people, e.g. the nose, must have forward facing radii of at least 38 mm. This minimum radius must extend to at least forty-five degrees (45°) relative to the forward direction, along the top, sides and bottom of all affected edges.

T3.24 Side Impact Structure for Tube Frame Cars

The Side Impact Structure must meet the requirements listed below.

T3.24.1 The Side Impact Structure for tube frame cars must be comprised of at least three (3) tubular members located on each side of the driver while seated in the normal driving position, as shown in **Figure 11**

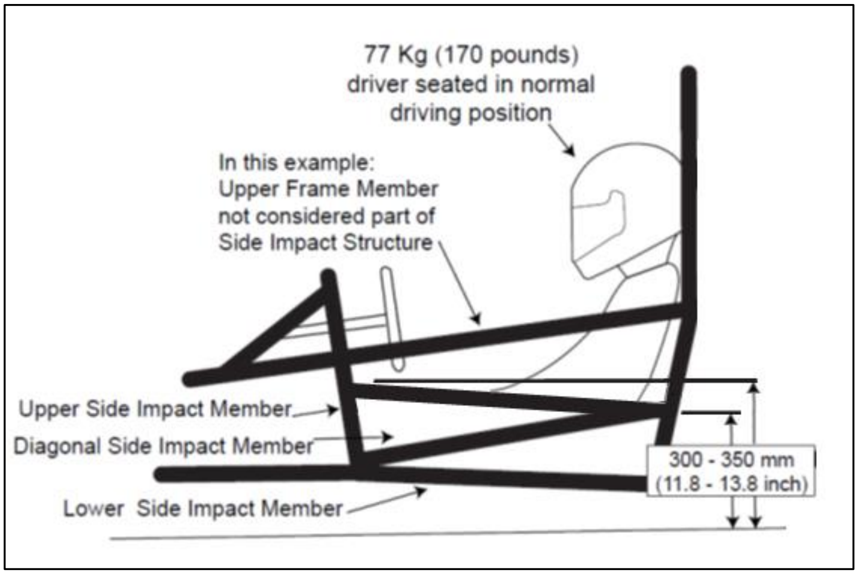

Figure 11 – Side Impact Structure

T3.24.2 The three (3) required tubular members must be constructed of material per Section **T3.3**.

T3.24.3 The locations for the three (3) required tubular members are as follows:

(a) The upper Side Impact Structural member must connect the Main Hoop and the Front Hoop. With a 77 kg driver seated in the normal driving position all of the member must be at a height between 300 mm and 350 mm above the ground. The upper frame rail may be used as this member if it meets the height, diameter and thickness requirements.

(b) The lower Side Impact Structural member must connect the bottom of the Main Hoop and the bottom of the Front Hoop. The lower frame rail/frame member may be this member if it meets the diameter and wall thickness requirements.

(c) The diagonal Side Impact Structural member must connect the upper and lower Side Impact Structural members forward of the Main Hoop and rearward of the Front Hoop.

T3.24.4 With proper gusseting and/or triangulation, it is permissible to fabricate the Side Impact Structural members from more than one piece of tubing.

T3.24.5 Alternative geometry that does not comply with the minimum requirements given above requires an approved "Structural Equivalency Spreadsheet" per Rule **T3.8.**

T3.25 Inspection Holes

T3.25.1 To allow the verification of tubing wall thicknesses, 4.5 mm inspection holes must be drilled in a non-critical location of both the Main Hoop and the Front Hoop.

T3.25.2 In addition, the Technical Inspectors may check the compliance of other tubes that have minimum dimensions specified in **T3.3.1**. This may be done by the use of ultra-sonic testing or by the drilling of additional inspection holes at the inspector's request.

T3.25.3 Inspection holes must be located so that the outside diameter can be measured across the inspection hole with a vernier caliper, i.e. there must be access for the vernier caliper to the inspection hole and to the outside of the tube one hundred eighty degrees (180°) from the inspection hole.

T3.26 Composite Tubular Space Frames

Composite tubular space frames are not allowed for Formula Hybrid.

T3.27 Monocoque General Requirements

T3.27.1 All equivalency calculations must prove equivalency relative to steel grade SAE/AISI 1010**.**

T3.27.2 All sections of the rules apply to monocoque structures except for the following sections which supplement or supersede other rule sections.

T3.27.3 Monocoque construction requires an approved Structural Equivalency Spreadsheet, per Section **T3.8**. The form must demonstrate that the design is equivalent to a welded frame in terms of energy dissipation, yield and ultimate strengths in bending, buckling and tension. Information must include: material type(s), cloth weights, resin type, fiber orientation, number of layers, core material, and lay-up technique. The 3 point bend test and shear test data and pictures must also be included as per **T3.30** Monocoque Laminate Testing. The Structural Equivalency must address each of the items below. Data from the laminate testing results must be used as the basis for any strength or stiffness calculations.

T3.27.4 Composite and metallic monocoques have the same requirements.

T3.27.5 Composite monocoques must meet the materials requirements in Rule **T3.7** Composite Materials.

T3.28 Monocoque Inspections

T3.28.1 Due to the monocoque rules and methods of manufacture it is not always possible to inspect all aspects of a monocoque during technical inspection. For items which cannot be verified by an inspector it is the responsibility of the team to provide documentation, both visual and/or written, that the requirements have been met. Generally the following items should be possible to be confirmed by the technical inspector:

(a) Verification of the Main Hoop outer diameter and wall thickness where it protrudes above the monocoque

(b) Visual verification that the Main Hoop goes to the lowest part of the tub, locally

(c) Verify mechanical attachment of Main Hoop to tub exists and matches the SES, at all points shown on the SES.

(d) Verify the outside diameter and wall thickness of the Front Hoop by providing access as required by Rule **T3.25.3**.

(e) Verify visually or by feel that the Front Hoop is installed.

(f) Verify that the Front Hoop goes to the lowest part of the tub, locally.

(g) Verify mechanical attachment of the Front Hoop (if included) against the SES.

T3.29 Monocoque Buckling Modulus – Equivalent Flat Panel Calculation

When specified in the rules, the *EI* of the monocoque must be calculated as the *EI* of a flat panel with the same composition as the monocoque about the neutral axis of the laminate. The curvature of the panel and geometric cross section of the monocoque must be ignored for these calculations.

Note: Calculations of *EI* that do not reference **T3.29** may take into account the actual geometry of the monocoque.

T3.30 Monocoque Laminate Testing

T3.30.1 Teams must build a representative flat panel section of the monocoque side impact zone ("zone" is defined in **T3.32.2** and **T3.2(k)**) and perform a 3 point bending test on this panel. They must prove by physical test that a section 200 mm x 500 mm has at least the same properties as a baseline steel side impact tube (See **T3.3.1** "Baseline Steel Materials") for bending stiffness and two side impact tubes for yield and ultimate strength.

The data from these tests and pictures of the test samples must be included in the SES, the test results will be used to derive strength and stiffness properties used in the SES formulae for all laminate panels. The test specimen must be presented at technical inspection. If the test specimen does not meet these requirements then the monocoque side impact zone must be strengthened appropriately.

Note: Teams are advised to make an equivalent test with the base line steel tubes such that any compliance in the test rig can be accounted for.

T3.30.2 If laminates with a lay-up different to that of the side-impact structure are used then additional physical tests must be completed for any part of the monocoque that forms part of the primary structure. The material properties derived from these tests must then be used in the SES for the appropriate equivalency calculations.

Note: A laminate with more or less plies, of the same lay-up as the side-impact structure, does not constitute a "different lay-up" and the material properties may be scaled accordingly.

T3.30.3 Perimeter shear tests must be completed by measuring the force required to push or pull a 25 mm diameter flat punch through a flat laminate sample.

The sample, measuring at least 100 mm x 100 mm must have core and skin thicknesses identical to those used in the actual monocoque and be manufactured using the same materials and processes.

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

The force-displacement data and photos of the test setup must be included in the SES.

The first peak in the load-deflection curve must be used to determine the skin shear strength. This may be less than the minimum force required by **T3.32.3/T3.33.3**.

The maximum force recorded must meet the requirements of **T3.32.3/T3.33.3.**

Note: The edge of the punch and hole in the fixture may include an optional fillet up-to a maximum radius of 1 mm.

T3.31 Monocoque Front Bulkhead

See Rule **T3.27** for general requirements that apply to all aspects of the monocoque. In addition when modeled as an "L" shaped section the EI of the front bulkhead about both vertical and lateral axis must be equivalent to that of the tubes specified for the front bulkhead under **T3.18**. The length of the section perpendicular to the bulkhead may be a maximum of 25.4 mm measured from the rearmost face of the bulkhead.

Furthermore any front bulkhead which supports the IA plate must have a perimeter shear strength equivalent to a 1.5 mm thick steel plate.

T3.32 Monocoque Front Bulkhead Support

T3.32.1 In addition to proving that the strength of the monocoque is adequate, the monocoque must have equivalent EI to the sum of the EI of the six (6) baseline steel tubes that it replaces.

T3.32.2 The EI of the vertical side of the front bulkhead support structure must be equivalent to at least the EI of one baseline steel tube that it replaces when calculated as per rule **T3.29** Monocoque Buckling Modulus.

T3.32.3 The perimeter shear strength of the monocoque laminate in the front bulkhead support structure should be at least 4 kN for a section with a diameter of 25 mm. This must be proven by a physical test completed as per **T3.30.3** and the results include in the SES

T3.33 Monocoque Side Impact

T3.33.1 In addition to proving that the strength of the monocoque is adequate, the side of the monocoque must have equivalent EI to the sum of the EI of the three (3) baseline steel tubes that it replaces.

T3.33.2 The side of the monocoque between the upper surface of the floor and 350 mm above the ground (Side Impact Zone) must have an EI of at least 50% of the sum of the EI of the three (3) baseline steel tubes that it replaces when calculated as per Rule **T3.29** Monocoque Buckling Modulus.

T3.33.3 The perimeter shear strength of the monocoque laminate should be at least 7.5 kN for a section with a diameter of 25 mm. This must be proven by physical test completed as per **T3.30.3** and the results included in the SES.

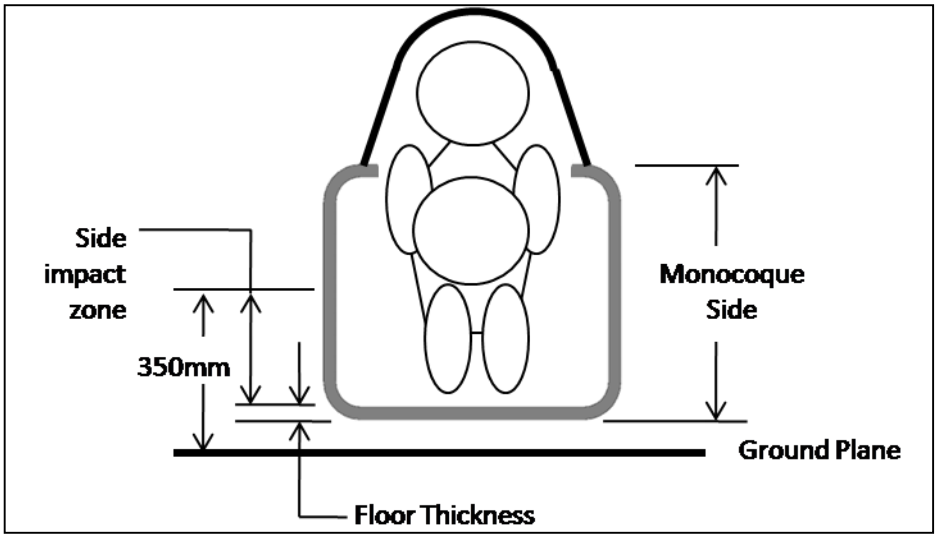

Figure 12 – Side Impact Zone Definition for a Monocoque

T3.34 Monocoque Main Hoop

T3.34.1 The Main Hoop must be constructed of a single piece of uncut, continuous, closed section steel tubing per **T3.3.1** and extend down to the bottom of the monocoque.

T3.34.2 The Main Hoop must be mechanically attached at the top and bottom of the monocoque and at intermediate locations as needed to show equivalency.

T3.34.3 Mounting plates welded to the Roll Hoop shall be at least 2.0 mm thick steel.

T3.34.4 Attachment of the Main Hoop to the monocoque must comply with **T3.39**.

T3.35 Monocoque Front Hoop

T3.35.1 Composite materials are not allowed for the front hoop. See Rule **T3.27** for general requirements that apply to all aspects of the monocoque.

T3.35.2 Attachment of the Front Hoop to the monocoque must comply with Rule **T3.39**.

T3.36 Monocoque Front and Main Hoop Bracing

T3.36.1 See Rule **T3.27** for general requirements that apply to all aspects of the monocoque.

T3.36.2 Attachment of tubular Front or Main Hoop Bracing to the monocoque must comply with Rule **T3.39**.

T3.37 Monocoque Impact Attenuator Attachment

The attachment of the Impact Attenuator to a monocoque structure requires an approved "Structural Equivalency Spreadsheet" per Rule **T3.8** that shows the equivalency to a minimum of four (4) 8 mm Metric Grade 8.8 or 5/16 inch SAE Grade 5 bolts.

T3.38 Monocoque Impact Attenuator Anti-intrusion Plate

See Rule **T3.27** for general requirements that apply to all aspects of the monocoque and Rule **T3.20.6** for alternate anti-intrusion plate designs.

T3.39 Monocoque Attachments

T3.39.1 In any direction, each attachment point between the monocoque and the other primary structure must be able to carry a load of 30 kN.

T3.39.2 The laminate, mounting plates, backing plates and inserts must have sufficient shear area, weld area and strength to carry the specified 30 kN load in any direction. Data obtained from the laminate perimeter shear strength test (**T3.33.3**) should be used to prove adequate shear area is provided

T3.39.3 Each attachment point requires a minimum of two (2) 8 mm Metric Grade 8.8 or 5/16 inch SAE Grade 5 bolts

T3.39.4 Each attachment point requires steel backing plates with a minimum thickness of 2 mm. Alternate materials may be used for backing plates if equivalency is approved.

T3.39.5 The Front Hoop Bracing, Main Hoop Bracing and Main Hoop Bracing Supports only may use one (1) 10 mm Metric Grade 8.8 or 3/8 inch SAE Grade 5 bolt as an alternative to **T3.39.3** if the bolt is on the centerline of tube similar to the figure below.

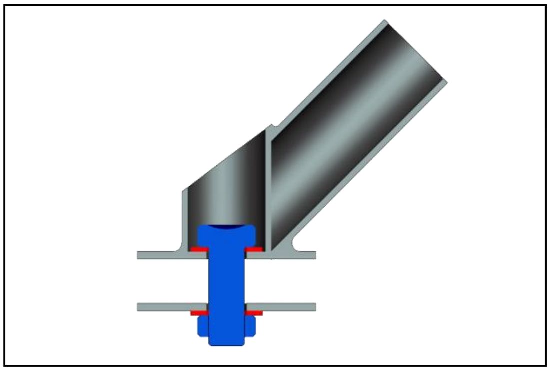

Figure 13 – Alternate Single Bolt Attachment

T3.39.6 No crushing of the core is permitted

T3.39.7 Main Hoop bracing attached to a monocoque (i.e. not welded to a rear space frame) is always considered "mechanically attached" and must comply with Rule **T3.16**.

T3.40 Monocoque Driver's Harness Attachment Points

T3.40.1 The monocoque attachment points for the shoulder and lap belts must support a load of 13 kN before failure.

T3.40.2 The monocoque attachment points for the ant-submarine belts must support a load of 6.5 kN before failure.

T3.40.3 If the lap belts and anti-submarine belts are attached to the same attachment point, then this point must support a load of 19.5 kN before failure.

T3.40.4 The strength of lap belt attachment and shoulder belt attachment must be proven by physical test where the required load is applied to a representative attachment point where the proposed layup and attachment bracket is used.

ARTICLE T4 COCKPIT

T4.1 Cockpit Opening

T4.1.1 In order to ensure that the opening giving access to the cockpit is of adequate size, a template shown in **Figure 14** will be inserted into the cockpit opening. It will be held horizontally and inserted vertically until it has passed below the top bar of the Side Impact Structure (or until it is 350 mm above the ground for monocoque cars).

At the inspectors' discretion, fore and aft translation of the template will be permitted during insertion.

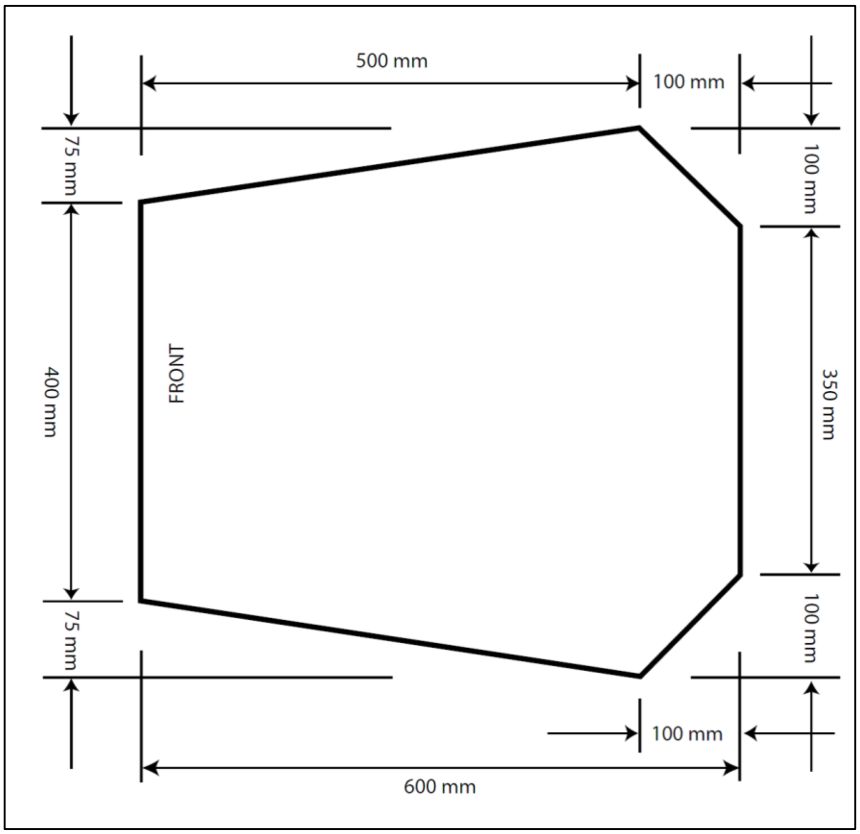

Figure 14 – Cockpit Opening Template

T4.1.2 During this test, the steering wheel, steering column, seat and all padding may be removed. The shifter or shift mechanism may not be removed unless it is integral with the steering wheel and is removed with the steering wheel. The firewall may not be moved or removed.

Note: As a practical matter, for the checks, the steering column will not be removed. The technical inspectors will maneuver the template around the steering column shaft, but not the steering column supports.

T4.2 Cockpit Internal Cross Section:

T4.2.1 A free vertical cross section, which allows the template shown in **Figure 15** to be passed horizontally through the cockpit to a point 100 mm rearwards of the face of the rearmost pedal when in the inoperative position, must be maintained over its entire length. If the pedals are adjustable, they will be put in their most forward position.

Note: At the discretion of the technical inspectors, the internal cross-section template may be moved vertically by small increments during fore and aft travel to clear height deviations in the floor of the vehicle (e.g. those caused by the steering rack, etc.). The template must still fit through the cross-section at the location of vertical deviation.

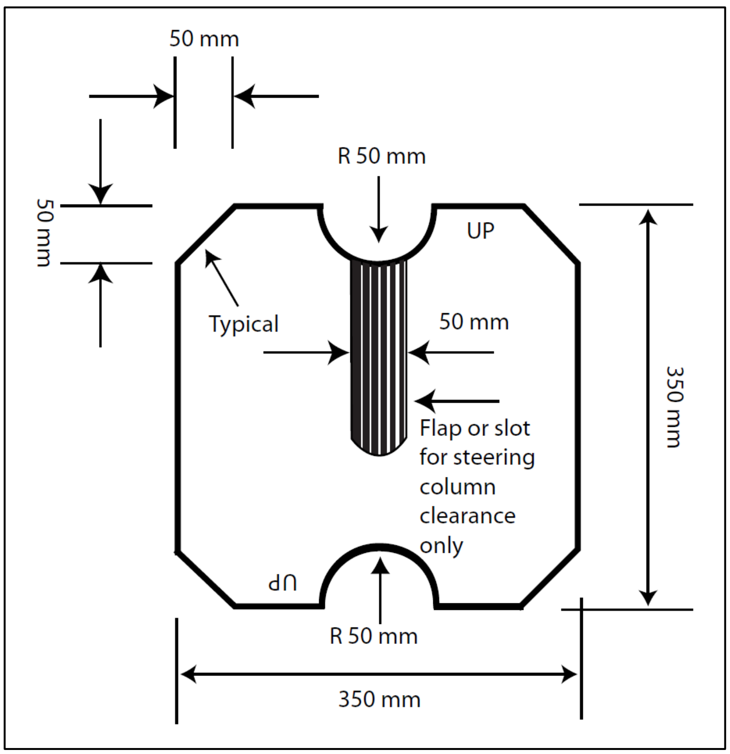

Figure 15 – Cockpit Internal Cross Section Template

T4.2.2 The template, with maximum thickness of 7 mm, will be held vertically and inserted into the cockpit opening rearward of the Front Roll Hoop, as close to the Front Roll Hoop as the car's design will allow.

T4.2.3 The only items that may be removed for this test are the steering wheel, and any padding required by Rule **T5.8** "Driver's Leg Protection" that can be easily removed without the use of tools with the driver in the seat. The seat may not be removed.

T4.2.4 Teams whose cars do not comply with **T4.1** or **T4.2** will not be given a Technical Inspection Sticker and will not be allowed to compete in the dynamic events.

Note: Cables, wires, hoses, tubes, etc. must not impede the passage of the templates required by **T4.1** and **T4.2**.

T4.3 Driver's Seat

T4.3.1 The lowest point of the driver's seat must be no lower than the bottom surface of the lower frame rails or by having a longitudinal tube (or tubes) that meets the requirements for Side Impact tubing, passing underneath the lowest point of the seat.

T4.3.2 When seated in the normal driving position, adequate heat insulation must be provided to ensure that the driver will not contact any metal or other materials which may become heated to a surface temperature above sixty degrees C (60°C). The insulation may be external to the cockpit or incorporated with the driver's seat or firewall. The design must show evidence of addressing all three (3) types of heat transfer, namely conduction, convection and radiation, with the following between the heat source, e.g. an exhaust pipe or coolant hose/tube and the panel that the driver could contact, e.g. the seat or floor:

(a) Conduction Isolation by:

(i) No direct contact between the heat source and the panel, or

(ii) a heat resistant, conduction isolation material with a minimum thickness of 8 mm between the heat source and the panel.

(b) Convection Isolation by a minimum air gap of 25 mm between the heat source and the panel.

(c) Radiation Isolation by:

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

(ii) reflective foil or tape when combined with **T4.3.2(a)(ii)** above.

T4.4 Floor Close-out

All vehicles must have a floor closeout made of one or more panels, which separate the driver from the pavement. If multiple panels are used, gaps between panels are not to exceed 3 mm. The closeout must extend from the foot area to the firewall and prevent track debris from entering the car. The panels must be made of a solid, non-brittle material.

T4.5 Firewall

T4.5.1 Firewall(s) must separate the driver compartment from the following components:

(a) Fuel Tanks.

(b) Accumulators.

(c) All components of the fuel supply.

(d) External engine oil systems including hoses, oil coolers, tanks, etc.

(e) Liquid cooling systems including those for I.C. engine and electrical components.

(f) Lithium-based GLV batteries.

(g) All tractive systems (TS) components

(h) All conductors carrying tractive system voltages (TSV) (Whether contained within conduit or not.)

T4.5.2 The firewall(s) must be a rigid, non-permeable surface made from 1.5 mm or thicker aluminum or proven equivalent. See **Appendix J** – Firewall Equivalency Test.

T4.5.3 The firewall(s) must seal completely against the passage of fluids and hot gasses, including at the sides and the floor of the cockpit, e.g. there can be no holes in a firewall through which seat belts pass.

T4.5.4 Pass-throughs for GLV wiring, cables, etc. are allowable if grommets are used to seal the pass-throughs.

Multiple panels may be used to form the firewall but must be mechanically fastened in place and sealed at the joints.

T4.5.5 For those components listed in **T4.5.1** that are mounted behind the driver, the firewall(s) must extend sufficiently far upwards and/or rearwards such that a straight line from any part of any listed component to any part of the tallest driver that is more than 150 mm below the top of his/her helmet, must pass through the firewall.

T4.5.6 For those components listed in section **T4.5.1** positioned under the driver, the firewall must extend:

(a) Continuously rearwards the full width of the cockpit from the Front Bulkhead, under and up behind the driver to a point where the helmet of the 95th percentile male template (**T3.9.4**) touches the head restraint, and

(b) Alongside the driver, from the top of the Side Impact Structure down to the lower portion of the firewall required by **T4.5.6(a)** and from the rearmost front suspension mounting point to connect (without holes or gaps) behind the driver with the firewall required by **T4.5.6(a).**

See **Figure 16(a)**.

T4.5.7 For those components listed in section **T4.5.1** that are mounted outboard of the Side Impact System (e.g. in side pods), the firewall(s) must extend from 100 mm forward to 100 mm rearward of the of the listed components and

(a) alongside the driver at the full height of the listed component, and

(b) cover the top of the listed components and

(c) run either

(i) under the cockpit between the firewall(s) required by **T4.5.7(a)**, or

(ii) extend 100 mm out under the listed components from the firewall(s) that are required by **T4.5.8(b)**

See **Figure 16(b&c)**.

T4.5.8 For the components listed in section **T4.5.1** that are mounted in ways that do not fall clearly under any of sections **T4.5.5**, **T4.5.6** or **T4.5.7**, the firewall must be configured to provide equivalent protection to the driver, and the firewall configuration must be approved by the Rules Committee.

Note: To ensure adequate time for consideration and possible re-designs, applications should be submitted at least 1 month in advance of the event.

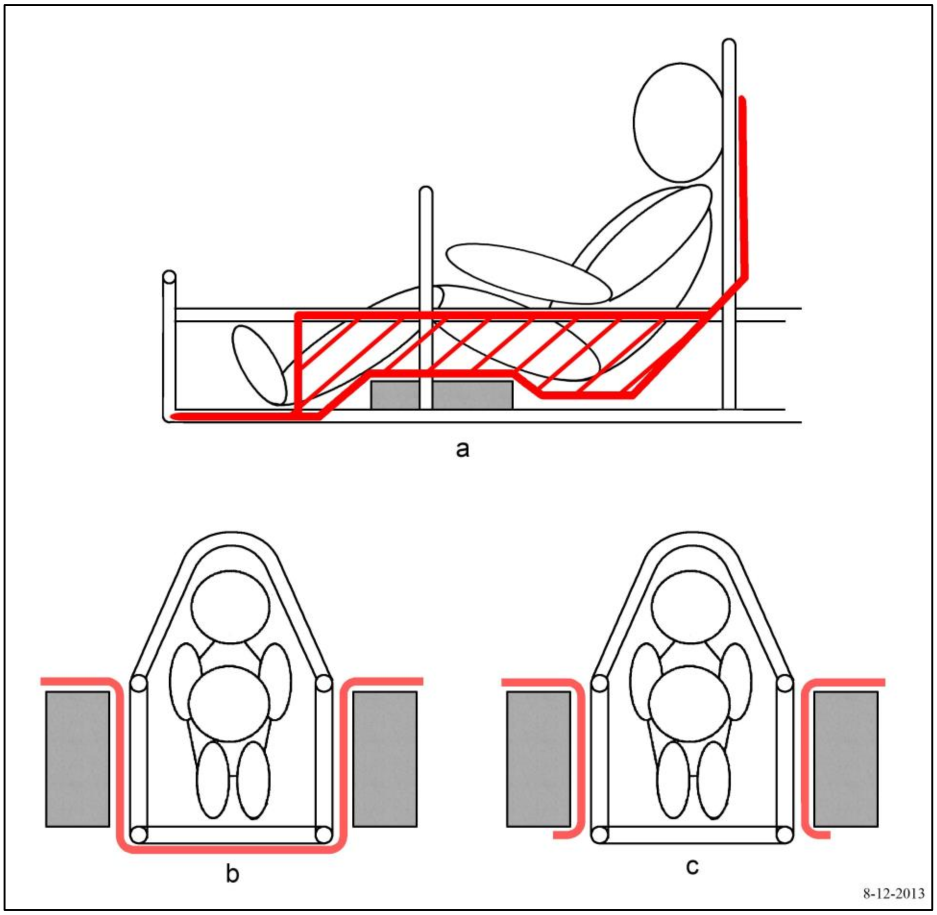

Figure 16 – Examples[2] of firewall configurations

T4.6 Accessibility of Controls

All vehicle controls, including the shifter, must be operated from inside the cockpit without any part of the driver, e.g. hands, arms or elbows, being outside the planes of the Side Impact Structure defined in Rule **T3.24** and **T3.33**.

T4.7 Driver Visibility

T4.7.1 The driver must have adequate visibility to the front and sides of the car. With the driver seated in a normal driving position he/she must have a minimum field of vision of two hundred degrees (200°) (a minimum one hundred degrees (100°) to either side of the driver). The required visibility may be obtained by the driver turning his/her head and/or the use of mirrors.

T4.7.2 If mirrors are required to meet Rule **T4.7.1,** they must remain in place and adjusted to enable the required visibility throughout all dynamic events.

T4.8 Driver Egress

All drivers must be able to exit to the side of the vehicle in no more than 5 seconds. Egress time begins with the driver in the fully seated position, hands in driving position on the connected

[2] The firewalls shown in red in **Figure 16** are examples only and are not meant to imply that a firewall must lie outside the frame rails.

steering wheel and wearing the required driver equipment. Egress time will stop when the driver has both feet on the pavement.

T4.9 Emergency Shut Down Test

T4.9.1 With their vision obscured, all drivers must be able to operate the cockpit Big Red Button (BRB) in no more than one second.

T4.9.2 Time begins with the driver in the fully seated position, hands in driving position on the connected steering wheel, and wearing the required driver equipment.

ARTICLE T5 DRIVERS EQUIPMENT (BELTS AND COCKPIT PADDING)

T5.1 Belts - General

T5.1.1 Definitions (**Note:** Belt dimensions listed are nominal widths.)

(a) **5-point system** – consists of a 3 inch lap belt, 3 inch shoulder straps and a single 2 inch anti-submarine strap. The single anti-submarine strap must have a metal-to-metal connection with the single release common to the lap belt and shoulder harness.

(b) **6-point system** – consists of a 3 inch lap belt, 3 inch shoulder straps and two (2) 2 inch leg or anti-submarine straps.

(c) **7-point system** – system is the same as the 6-point except it has three (3) anti-submarine straps, two (2) from the 6-point system and one (1) from the 5-point system.

Note: 6 and 7-point harnesses to FIA specification 8853/98 and SFI Specification 16.5 with 2 inch lap belts are acceptable.

(d) **Upright driving position -** is defined as one with a seat back angled at thirty degrees (30°) or less from the vertical as measured along the line joining the two 200 mm circles of the template of the 95th percentile male as defined in **Table 7** and positioned per **T3.9.4**.

(e) **Reclined driving position -** is defined as one with a seat back angled at more than thirty degrees (30°) from the vertical as measured along the line joining the two 200 mm circles of the template of the 95th percentile male as defined in **Table 7** and positioned per **T3.9.4**.

(f) **Chest-groin line -** is the straight line that in side view follows the line of the shoulder belts from the chest to the release buckle.

T5.1.2 Harness Requirements

All drivers must use a 5, 6 or 7 point restraint harness meeting the following specifications:

(a) All driver restraint systems must meet SFI Specification 16.1, SFI Specification 16.5, or FIA specification 8853/98.

(b) The belts must bear the appropriate dated labels.

(c) The material of all straps must be in perfect condition.

(d) There must be a single release common to the lap belt and shoulder harness using a metal-to-metal quick release type latch.

(e) To accommodate drivers of differing builds, all lap belts must have a "tilt-lock adjuster" feature.

Note: Lap belts with "pull-up" adjusters are recommended over "pull-down" adjusters, and a tilt lock adjuster in each portion of the lap belt is highly recommended.

(f) Cars with a "reclined driving position" (see **T5.1.1(e)** above) must have either a 6 point or 7-point harness, and have either anti-submarine belts with "tilt-lock adjusters" or have two (2) sets of anti-submarine belts installed.

(g) The shoulder harness must be the over-the-shoulder type. Only separate shoulder straps are permitted (i.e. "Y"-type shoulder straps are not allowed). The "H"-type configuration is allowed.

(h) It is mandatory that the shoulder harness, where it passes over the shoulders, be 3 inch, except as noted below. The shoulder harness straps must be threaded through the three bar adjusters in accordance with manufacturer's instructions.

(i) When the HANS device is used by the driver, FIA certified 2 inch shoulder harnesses are allowed. Should a driver, at any time not utilize the HANS device, then 3 inch shoulder harnesses are required.

T5.1.3 Harness Replacement - 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. (**Note:** FIA belts are normally certified for five (5) years from the date of manufacture.)

T5.1.4 The restraint system must be worn tightly at all times.

T5.2 Belt, Strap and Harness Installation - General

T5.2.1 The lap belt, shoulder harness and anti-submarine strap(s) must be securely mounted to the Primary Structure. Such structure and any guide or support for the belts must meet the minimum requirements of **T3.3.1**.

Note: Rule **T3.4.5** applies to these tubes as well so a non-straight shoulder harness bar would require support per **T3.4.5**

T5.2.2 The tab to which any harness is attached must have:

(a) A minimum cross sectional area of 40 sq. mm of steel to be sheared or failed in tension at any point of the tab, and

(b) A minimum thickness of 1.6 mm.

(c) Where lap belts and anti-submarine belts use the same attachment point, a minimum cross sectional area of 90 sq. mm of steel to be sheared if failed in tension at any point of the tab.

Note: Double shear mounting is preferred.

T5.2.3 Harnesses, belts and straps must not pass through a firewall, i.e. all harness attachment points must be on the driver's side of any firewall.

T5.2.4 The attachment of the Driver's Restraint System to a monocoque structure requires an approved Structural Equivalency Spreadsheet per Rule **T3.8**.

T5.2.5 The restraint system installation is subject to approval of the Chief Technical Inspector.

T5.3 Lap Belt Mounting

T5.3.1 The lap belt must pass around the pelvic area below the Anterior Superior Iliac Spines (the hip bones).

T5.3.2 The lap belts should not be routed over the sides of the seat. The lap belts should come through the seat at the bottom of the sides of the seat to maximize the wrap of the pelvic surface and continue in a straight line to the anchorage point.

T5.3.3 Where the belts or harness pass through a hole in the seat, the seat must be rolled or grommeted to prevent chafing of the belts.

T5.3.4 To fit drivers of differing statures correctly, in side view, the lap belt must be capable of pivoting freely by using either a shouldered bolt or an eye bolt attachment, i.e. mounting lap belts by wrapping them around frame tubes is no longer acceptable.

T5.3.5 With an "upright driving position", in side view the lap belt must be at an angle of between forty-five degrees (45°) and sixty-five degrees (65°) to the horizontal. This means that the centerline of the lap belt at the seat bottom should be between 0 – 76 mm forward of the seat back to seat bottom junction. (See **Figure 17**)

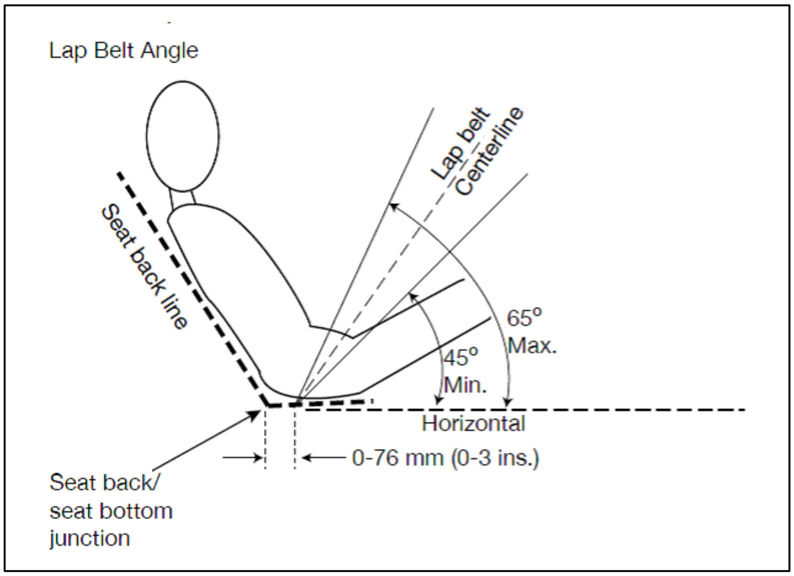

Figure 17 – Lap Belt Angles with Upright Driver

T5.3.6 With a "reclined driving position", in side view the lap belt must be between an angle of sixty degrees (60°) and eighty degrees (80°) to the horizontal.

T5.4 Shoulder Harness

T5.4.1 The shoulder harness must be mounted behind the driver to structure that meets the requirements of **T3.3.1**. However, it cannot be mounted to the Main Roll Hoop Bracing or attendant structure without additional bracing to prevent loads being transferred into the Main Hoop Bracing.

T5.4.2 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 gussets or triangulation tubes to prevent torsional rotation of the harness mounting tube.

T5.4.3 The shoulder harness mounting points must be between 178 mm and 229 mm apart. (See **Figure 18**)

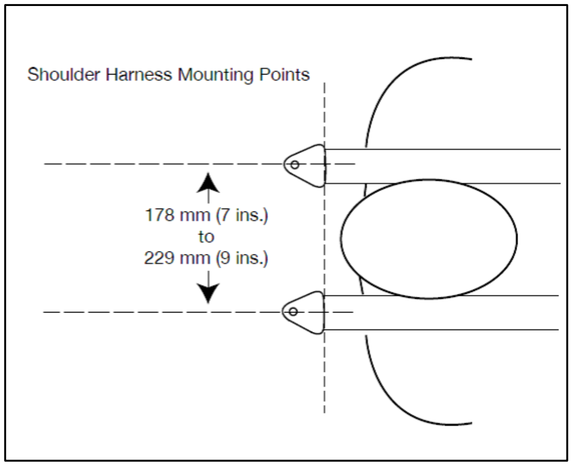

Figure 18 – Shoulder Harness Mounting – Top View

T5.4.4 From the driver's shoulders rearwards to the mounting point or structural guide, the shoulder harness must be between ten degrees (10°) above the horizontal and twenty degrees (20°) below the horizontal. (See **Figure 19**).

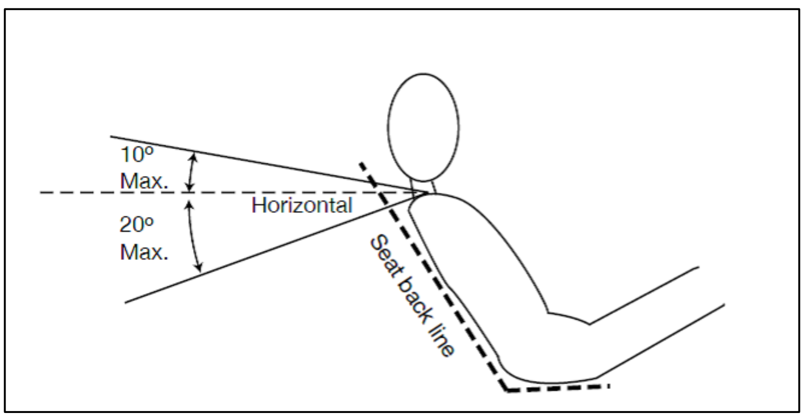

Figure 19 - Shoulder Harness Mounting – Side View

T5.5 Anti-Submarine Belt Mounting

T5.5.1 The anti-submarine belt of a 5 point harness should be mounted in line with, or angled slightly forward (up to twenty degrees (20°)) of, the driver's chest-groin line.

T5.5.2 The anti-submarine belts of a 6 point harness should be mounted either:

(a) With the belts going vertically down from the groin, or angled up to twenty degrees (20°) rearwards. The anchorage points should be approximately 100 mm apart. Or

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

T5.6 Head Restraint

T5.6.1 A head restraint must be provided on the car to limit the rearward motion of the driver's head.

T5.6.2 The restraint must:

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

(b) Be padded with an energy absorbing material such as Ethafoam® or Ensolite® with a minimum thickness of 38 mm.

(c) Have a minimum width of 15 cm.

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

(e) Be located so that for each driver:

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

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

Note 1: Head restraints may be changed to accommodate different drivers (See **T1.2.2(d)**)

Note 2: The above requirements must be met for all drivers.

Note 3: Approximately 100mm longitudinal adjustment is required to accommodate 5th to 95th Percentile drivers. This is not a specific rules requirement, but teams must have sufficient longitudinal adjustment and/or alternative thickness head restraints available, such that the above requirements are met by all their drivers.

T5.6.3 The restraint, its attachment and mounting must be strong enough to withstand a force of 890 Newtons applied in a rearward direction.

T5.7 Roll Bar Padding

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

T5.8 Driver's Leg Protection

T5.8.1 To keep the driver's legs away from moving or sharp components, all moving suspension and steering components, and other sharp edges inside the cockpit between the front roll hoop and a vertical plane 100 mm rearward of the pedals, must be shielded with a shield made of a solid material. Moving components include, but are not limited to springs, shock absorbers, rocker arms, anti-roll/sway bars, steering racks and steering column CV joints.

T5.8.2 Covers over suspension and steering components must be removable to allow inspection of the mounting points.

ARTICLE T6 GENERAL CHASSIS RULES

T6.1 Suspension

T6.1.1 The car must be equipped with a fully operational suspension system with shock absorbers, front and rear, with usable wheel travel of at least 50.8 mm, 25.4 mm jounce and 25.4 mm rebound, with driver seated. The judges reserve the right to disqualify cars which do not represent a serious attempt at an operational suspension system or which demonstrate handling inappropriate for an autocross circuit.

T6.1.2 All suspension mounting points must be visible at Technical Inspection, either by direct view or by removing any covers.

T6.2 Ground Clearance

The ground clearance must be sufficient to prevent any portion of the car (other than tires) from touching the ground during track events, and with the driver aboard there must be a minimum of 25.4 mm of static ground clearance under the complete car at all times.

T6.3 Wheels

T6.3.1 The wheels of the car must be 203.2 mm or more in diameter.

T6.3.2 Any wheel mounting system that uses a single retaining nut must incorporate a device to retain the nut and the wheel in the event that the nut loosens. A second nut ("jam nut") does not meet these requirements.

T6.3.3 Standard wheel lug bolts are considered engineering fasteners and any modification will be subject to extra scrutiny during technical inspection. Teams using modified lug bolts or custom designs will be required to provide proof that good engineering practices have been followed in their design.

T6.3.4 Aluminum wheel nuts may be used, but they must be hard anodized and in pristine condition.

T6.4 Tires

T6.4.1 Vehicles may have two types of tires as follows:

(a) Dry Tires – The tires on the vehicle when it is presented for technical inspection are defined as its "Dry Tires". The dry tires may be any size or type. They may be slicks or treaded.

(b) Rain Tires – Rain tires may be any size or type of treaded or grooved tire provided:

(i) The tread pattern or grooves were molded in by the tire manufacturer, or were cut by the tire manufacturer or his appointed agent. Any grooves that have been cut must have documentary proof that it was done in accordance with these rules.

(ii) There is a minimum tread depth of 2.4 mm.

Note: Hand cutting, grooving or modification of the tires by the teams is specifically prohibited.

T6.4.2 Within each tire set, the tire compound or size, or wheel type or size may not be changed after static judging has begun. Tire warmers are not allowed. No traction enhancers may be applied to the tires after the static judging has begun.

T6.5 Steering

T6.5.1 The steering wheel must be mechanically connected to the wheels, i.e. "steer-by-wire" or electrically actuated steering is prohibited.

T6.5.2 The steering system must have positive steering stops that prevent the steering linkages from locking up (the inversion of a four-bar linkage at one of the pivots). The stops may be placed on the uprights or on the rack and must prevent the tires from contacting suspension, body, or frame members during the track events.

T6.5.3 Allowable steering system free play is limited to seven degrees (7°) total measured at the steering wheel.

T6.5.4 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.

T6.5.5 Rear wheel steering, which can be electrically actuated, is permitted but only if mechanical stops limit the range of angular movement of the rear wheels to a maximum of six degrees (6°). This must be demonstrated with a driver in the car and the team must provide the facility for the steering angle range to be verified at Technical Inspection.

T6.5.6 The steering wheel must have a continuous perimeter that is near circular or near oval, i.e. the outer perimeter profile can have some straight sections, but no concave sections. “H”, “Figure 8”, or cutout wheels are not allowed.

T6.5.7 In any angular position, the top of the steering wheel must be no higher than the top-most surface of the Front Hoop. See **Figure 7**.

T6.5.8 Steering systems using cables for actuation are not prohibited by **T6.5.1** but additional documentation must be submitted. The team must submit a failure modes and effects analysis report with design details of the proposed system as part of the structural equivalency spreadsheet (SES).

The report must outline the analysis that was done to show the steering system will function properly, potential failure modes and the effects of each failure mode and finally failure mitigation strategies used by the team. The organizing committee will review the submission and advise the team if the design is approved. If not approved, a non-cable based steering system must be used instead.

T6.5.9 The steering rack must be mechanically attached to the frame. If fasteners are used they must be compliant with **ARTICLE T11**.

T6.5.10 Joints between all components attaching the steering wheel to the steering rack must be mechanical and be visible at Technical Inspection. Bonded joints without a mechanical backup are not permitted.

T6.6 Jacking Point

T6.6.1 A jacking point, which is capable of supporting the car’s weight and of engaging the organizers’ “quick jacks”, must be provided at the rear of the car.

T6.6.2 The jacking point is required to be:

(a) Visible to a person standing 1 meter behind the car.

(b) Painted orange.

(c) Oriented horizontally and perpendicular to the centerline of the car

(d) Made from round, 25–29 mm O.D. aluminum or steel tube

(e) A minimum of 300 mm long

(f) Exposed around the lower 180 degrees (180°) of its circumference over a minimum length of 280 mm

(g) The height of the tube is required to be such that:

(i) There is a minimum of 75 mm clearance from the bottom of the tube to the ground measured at tech inspection.

(ii) With the bottom of the tube 200 mm above ground, the wheels do not touch the ground when they are in full rebound.

Comment on Disabled Cars – The organizers and the Rules Committee remind teams that cars disabled on course must be removed as quickly as possible. A variety of tools may be used to move disabled cars including quick jacks, dollies of different types, tow ropes and occasionally even boards. We expect cars to be strong enough to be easily moved without damage. Speed is important in clearing the course and although the course crew exercises due care, parts of a vehicle can be damaged during removal. The organizers are not responsible for damage that occurs when moving disabled vehicles. Removal/recovery workers will jack, lift, carry or tow the car at whatever points they find easiest to access. Accordingly, we advise teams to consider the strength and location of all obvious jacking, lifting and towing points during the design process.

T6.7 Rollover Stability

T6.7.1 The track and center of gravity of the car must combine to provide adequate rollover stability.

T6.7.2 Rollover stability will be evaluated on a tilt table using a pass/fail test. The vehicle must not roll when tilted at an angle of sixty degrees (60°) to the horizontal in either direction, corresponding to 1.7 G's. The tilt test will be conducted with the tallest driver in the normal driving position.

ARTICLE T7 BRAKE SYSTEM

T7.1 Brake System - General

T7.1.1 The car must be equipped with a braking system that acts on all four wheels and is operated by a single control.

T7.1.2 It must have two (2) 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 (2) wheels. Each hydraulic circuit must have its own fluid reserve, either by the use of separate reservoirs or by the use of a dammed, OEM-style reservoir.

T7.1.3 A single brake acting on a limited-slip differential is acceptable.

T7.1.4 The brake system must be capable of locking all four (4) wheels during the test specified in section **T7.2**.

T7.1.5 "Brake-by-wire" systems are prohibited.

T7.1.6 Unarmored plastic brake lines are prohibited.

T7.1.7 The braking systems must be protected with scatter shields from failure of the drive train (see **T8.4**) or from minor collisions.

T7.1.8 In side view no portion of the brake system that is mounted on the sprung part of the car can project below the lower surface of the frame or the monocoque, whichever is applicable.

T7.1.9 The brake pedal shall be designed to withstand a force of 2000 N without any failure of the brake system or pedal box. This may be tested by pressing the pedal with the maximum force that can be exerted by any official when seated normally.

T7.1.10 The brake pedal must be fabricated from steel or aluminum or machined from steel, aluminum or titanium.

T7.1.11 The first 50% of the brake pedal travel may be used to control regeneration without necessarily actuating the hydraulic brake system.

The remaining brake pedal travel must directly actuate the hydraulic brake system, but brake energy regeneration may remain active.

Note: Any strategy to regenerate energy while coasting or braking must be covered by the FMEA / ESF.

T7.2 Brake Test

T7.2.1 The brake system will be dynamically tested and must demonstrate the capability of locking all four (4) wheels and stopping the vehicle in a straight line at the end of an acceleration run specified by the brake inspectors.

T7.2.2 After accelerating, the tractive system must be switched off by the driver and the driver has to lock all four wheels of the vehicle by braking. The brake test is passed if all four wheels simultaneously lock while the tractive system is shut down.

Note: It is acceptable if the Tractive System Active Light switches off shortly after the vehicle has come to a complete stop as the reduction of the system voltage may take up to 5 seconds.

T7.3 Brake Over-Travel Switch

T7.3.1 A brake pedal over-travel switch must be installed on the car as part of the shutdown system and wired in series with the shutdown buttons. This switch must be installed so that in the event of brake system failure such that the brake pedal over travels it will result in the shutdown system being activated and controlling the systems as defined in **EV5.8.**

T7.3.2 Repeated actuation of the switch must not restore power to these components, and it must be designed so that the driver cannot reset it.

T7.3.3 The brake over-travel switch must not be used as a mechanical stop for the brake pedal and must be installed in such a way that it and its mounting will remain intact and operational when actuated.

T7.3.4 The switch must be implemented directly. i.e. It may not operate through programmable logic controllers, engine control units, or digital controllers

T7.3.5 The Brake Over-Travel switch must be a mechanical single pole, single throw (commonly known as a two-position) switch (push-pull or flip type) as shown below.

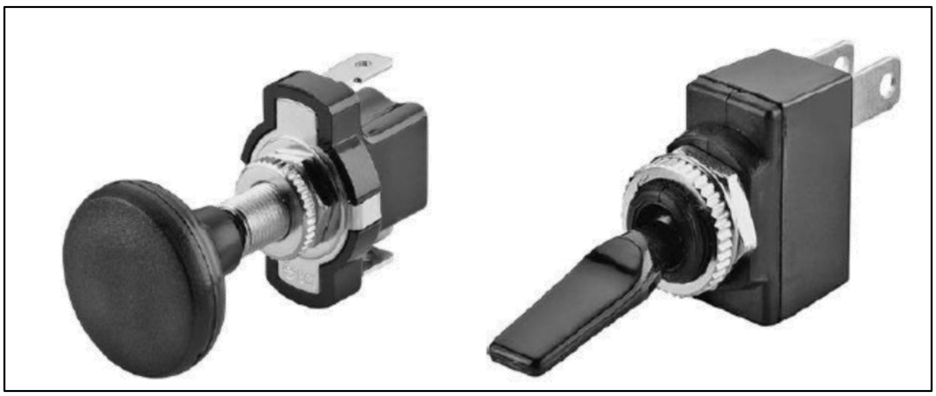

Figure 20 – Over-travel Switches

T7.4 Brake Light

T7.4.1 The car must be equipped with a red brake light.

T7.4.2 The brake light itself must have a black background and a rectangular, triangular or near round shape with a minimum shining surface of at least 15 cm^2.

T7.4.3 The brake light must be clearly visible from the rear in bright sunlight.

T7.4.4 When LED lights are used without an optical diffuser, they may not be more than 20 mm apart. If a single line of LEDs is used, the minimum length is 150 mm.

T7.4.5 The light must be mounted between the wheel centerline and driver's shoulder level vertically and approximately on vehicle centerline laterally.

ARTICLE T8 POWERTRAIN

T8.1 Coolant Fluid Limitations

T8.1.1 Water-cooled engines must use only plain water. Glycol-based antifreeze, "water wetter", water pump lubricants of any kind, or any other additives are strictly prohibited.

T8.1.2 Electric motors, accumulators or electronics must use plain water or approved[3] fluids as the coolant.

T8.2 System Sealing

T8.2.1 Any cooling or lubrication system must be sealed to prevent leakage.

T8.2.2 Any vent on a cooling or lubrication system must employ a catch-can to retain any fluid that is expelled. A separate catch-can is required for each vent.

T8.2.3 Each catch-can on an IC engine cooling or lubrication system must have a minimum volume of ten (10) percent of the fluid being contained, or 0.9 liter whichever is greater.

T8.2.4 Any vent on other systems containing liquid lubricant, e.g. a differential or gearbox, etc., must have a catch-can with a minimum volume of ten (10) percent of the fluid being contained or 0.5 liter, whichever is greater.

T8.2.5 Catch-cans must be capable of containing liquids at temperatures in excess of 100 deg. C without deformation, be shielded by a firewall, be below the driver's shoulder level, and be positively retained, i.e. no tie-wraps or tape as the primary method of retention.

T8.2.6 Any catch-can for an IC engine cooling system must vent through a hose with a minimum internal diameter of 3 mm down to the bottom levels of the Frame.

T8.3 Transmission and Drive

Any transmission may be used.

T8.4 Drive Train Shields and Guards

T8.4.1 Exposed high-speed final drivetrain equipment such as Continuously Variable Transmissions (CVTs), sprockets, gears, pulleys, torque converters, clutches, belt drives and clutch drives, must be fitted with scatter shields in case of failure. The final drivetrain shield must cover the chain or belt from the drive sprocket to the driven sprocket/chain wheel/belt or pulley. The final drivetrain shield must start *and end* parallel to the lowest point of the chain wheel/belt/pulley. (See **Figure 21**) Body panels or other existing covers are not acceptable unless constructed from approved materials per **T8.4.3** or **T8.4.4**.

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

[3] "Opticool" (http://dsiventures.com/electronics-cooling/opticool-a-fluid/) is permitted.

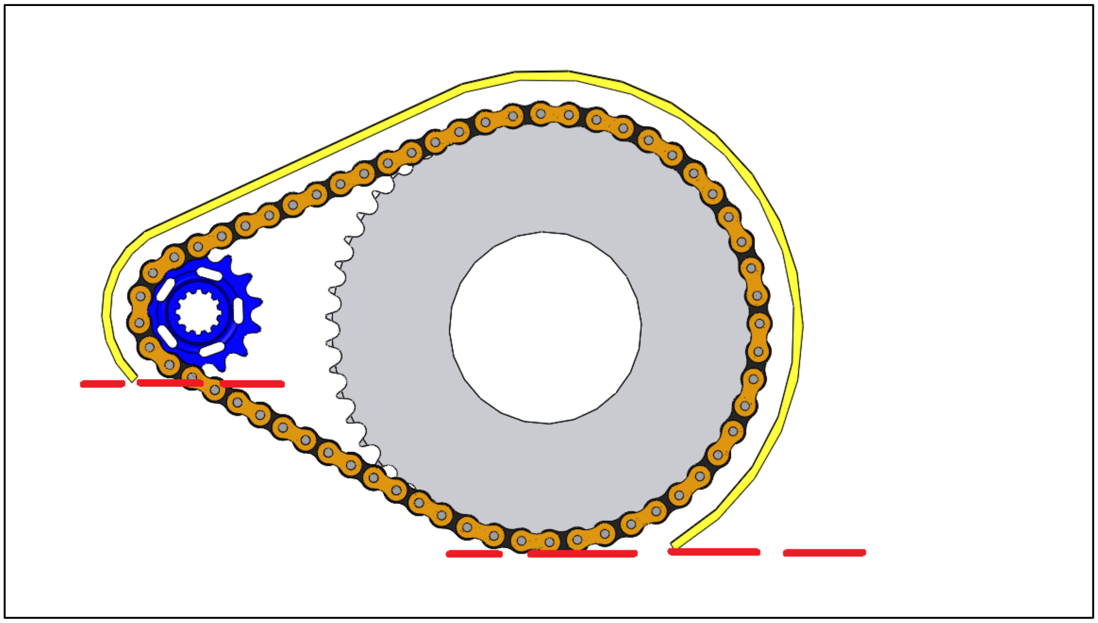

Figure 21 - Final Drive Scatter Shield Example

Comment: Scatter shields are intended to contain drivetrain parts which might separate from the car.

T8.4.2 Perforated material may not be used for the construction of scatter shields.

T8.4.3 Chain Drive - Scatter shields for chains must be made of at least 2.6 mm steel or stainless steel (no alternatives are allowed), and have a minimum width equal to three (3) times the width of the chain. The guard must be centered on the center line of the chain and remain aligned with the chain under all conditions.

T8.4.4 Non-metallic Belt Drive - Scatter shields for belts must be made from at least 3.0 mm Aluminum Alloy 6061-T6, and have a minimum width that is equal to 1.7 times the width of the belt.

T8.4.5 The guard must be centered on the center line of the belt and remain aligned with the belt under all conditions.

T8.4.6 Attachment Fasteners - All fasteners attaching scatter shields and guards must be a minimum 6mm Metric Grade 8.8 or 1/4 inch SAE Grade 5 or stronger.

T8.4.7 Finger Guards – Finger guards are required to cover any drivetrain parts that spin while the car is stationary with the engine running. Finger guards may be made of lighter material, sufficient to resist finger forces. Mesh or perforated material may be used but must prevent the passage of a 12 mm diameter object through the guard.

Comment: Finger guards are intended to prevent finger intrusion into rotating equipment while the vehicle is at rest.

T8.5 Integrity of systems carrying fluids – Tilt Test

T8.5.1 During technical inspection, the car must be capable of being tilted to a forty-five degree (45°) angle without leaking fluid of any type.

T8.5.2 The tilt test will be conducted with the vehicle containing the maximum amount of fluids it will carry during any test or event.

ARTICLE T9 AERODYNAMIC DEVICES

T9.1 Aero Dynamics and Ground Effects - General

All aerodynamic devices must satisfy the following requirements:

T9.2 Location

In plan view, no part of any aerodynamic device, wing, under tray or splitter can be:

(a) Further forward than 460 mm forward of the fronts of the front tires

(b) No further rearward than the rear of the rear tires.

(c) No wider than the outside of the front tires or rear tires measured at the height of the hubs, whichever is wider.

T9.3 Wing Edges - Minimum Radii

All wing leading edges must have a minimum radius 12.7 mm. Wing leading edges must be as blunt or blunter than the required radii for an arc of plus or minus 45 degrees (± 45°) centered on a plane parallel to the ground or similar reference plane for all incidence angles which lie within the range of adjustment of the wing or wing element. If leading edge slats or slots are used, both the fronts of the slats or slots and of the main body of the wings must meet the minimum radius rules.

T9.4 Other Edge Radii Limitations

All wing edges, end plates, Gurney flaps, wicker bills, splitters undertrays and any other wing accessories must have minimum edge radii of at least 3 mm i.e., this means at least a 6 mm thick edge.

T9.5 Ground Effect Devices

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

T9.6 Driver Egress Requirements

T9.6.1 Egress from the vehicle within the time set in Rule **T4.8** "Driver Egress," must not require any movement of the wing or wings or their mountings.

T9.6.2 The wing or wings must be mounted in such positions, and sturdily enough, that any accident is unlikely to deform the wings or their mountings in such a way to block the driver's egress.

ARTICLE T10 COMPRESSED GAS SYSTEMS AND HIGH PRESSURE HYDRAULICS

T10.1 Compressed Gas Cylinders and Lines

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

(a) Working Gas -The working gas must be nonflammable, e.g. air, nitrogen, carbon dioxide.

(b) Cylinder Certification - The gas cylinder/tank must be of proprietary manufacture, designed and built for the pressure being used, certified by an accredited testing laboratory in the country of its origin, and labeled or stamped appropriately.

(c) Pressure Regulation -The pressure regulator must be mounted directly onto the gas cylinder/tank.

(d) Protection – The gas cylinder/tank and lines must be protected from rollover, collision from any direction, or damage resulting from the failure of rotating equipment.

(e) Cylinder Location - The gas cylinder/tank and the pressure regulator must be located either rearward of the Main Roll Hoop and within the envelope defined by the Main Roll Hoop and the Frame (See **T3.2**), or in a structural side-pod. In either case it must be protected by structure that meets the requirements of **T3.24** or **T3.33**. It must not be located in the cockpit.

(f) Cylinder Mounting - The gas cylinder/tank must be securely mounted to the Frame, engine or transmission.

(g) Cylinder Axis - The axis of the gas cylinder/tank must not point at the driver.

(h) Insulation - The gas cylinder/tank must be insulated from any heat sources, e.g. the exhaust system.

(i) Lines and Fittings - The gas lines and fittings must be appropriate for the maximum possible operating pressure of the system.

T10.2 High Pressure Hydraulic Pumps and Lines

The driver and anyone standing outside the car must be shielded from any hydraulic pumps and lines with line pressures of 300 psi (2100 kPa) or higher. The shields must be steel or aluminum with a minimum thickness of 1 mm.

Note: Brake lines are not classified as "hydraulic pump lines" and as such brake lines are excluded from **T10.2**.

ARTICLE T11 FASTENERS

T11.1 Fastener Grade Requirements

T11.1.1 All threaded fasteners utilized in the driver's cell structure, and the steering, braking, driver's harness and suspension systems must meet or exceed, SAE Grade 5, Metric Grade 8.8 and/or AN/MS specifications.

T11.1.2 The use of button head cap, pan head, flat head, round head or countersunk screws or bolts in ANY location in the following systems is prohibited:

(a) Driver's cell structure,

(b) Impact attenuator attachment

(c) Driver's harness attachment

(d) Steering system

(e) Brake system

(f) Suspension system.

Note: Hexagonal recessed drive screws or bolts (sometimes called Socket head cap screws or Allen screws/bolts) are permitted.

T11.2 Securing Fasteners

T11.2.1 All critical bolt, nuts, and other fasteners on the steering, braking, driver's harness, and suspension must be secured from unintentional loosening by the use of positive locking mechanisms.

Positive locking mechanisms are defined as those that:

(a) The Technical Inspectors (and the team members) are able to see that the device/system is in place, i.e. it is visible, **and**

(b) the "positive locking mechanism" does not rely on the clamping force to apply the "locking" or anti-vibration feature. In other words, if it loosens a bit, it still prevents the nut or bolt coming completely loose.

See **Figure 22**

Positive locking mechanisms include:

(c) Correctly installed safety wiring

(d) Cotter pins

(e) Nylon lock nuts

(f) Prevailing torque lock nuts

Note: Lock washers, bolts with nylon patches, and thread locking compounds, e.g. Loctite®, DO NOT meet the positive locking requirement.

Figure 22 - Examples of positive locking nuts

T11.2.2 There must be a minimum of two (2) full threads projecting from any lock nut.

T11.2.3 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 O.D. that is larger than spherical bearing housing I.D.

T11.2.4 Adjustable tie-rod ends must be constrained with a jam nut to prevent loosening.

ARTICLE T12 TRANSPONDERS

T12.1 Transponders

T12.1.1 Transponders will be used as part of the timing system for the Formula Hybrid competition.

T12.1.2 Each team is responsible for having a functional, properly mounted transponder of the specified type on their vehicle. Vehicles without a specified transponder will not be allowed to compete in any event for which a transponder is used for timing and scoring.

T12.1.3 All vehicles must be equipped with at least one MYLAPS Car/Bike Rechargeable Power Transponder or MYLAPS Car/Bike Direct Power Transponder.

Note 1: Except for their name, AMB TranX260 transponders are identical to MYLAPS Car/Bike Transponders and comply with this rule. If you own a functional AMB TranX260 it does not need to be replaced.

Note 2: It is the responsibility of the team to ensure that electrical interference from their vehicle does not stop the transponder from functioning correctly

T12.2 Transponder Mounting – All Events

The transponder mounting requirements are:

(a) **Orientation** – The transponder must be mounted vertically and orientated so the number can be read “right-side up”.

(b) **Location** – The transponder must be mounted on the driver’s right side of the car forward of the front roll hoop. The transponder must be no more than 60 cm above the track.

(c) **Obstructions** – There must be an open, unobstructed line between the antenna on the bottom of the transponder and the ground. Metal and carbon fiber may interrupt the transponder signal. The signal will normally transmit through fiberglass and plastic. If the signal will be obstructed by metal or carbon fiber, a 10.2 cm diameter opening can be cut, the transponder mounted flush with the opening, and the opening covered with a material transparent to the signal.

(d) **Protection** – Mount the transponder where it will be protected from obstacles.

ARTICLE T13 VEHICLE IDENTIFICATION

T13.1 Car Number

T13.1.1 Each car will be assigned a number at the time of its entry into a competition.

T13.1.2 Car numbers must appear on the vehicle as follows:

(a) **Locations**: In three (3) locations: the front and both sides;

(b) **Height**: At least 15.24 cm high;

(c) **Font**: Block numbers (i.e. sans-serif characters). Italic, outline, serif, shadow, or cursive numbers are prohibited.

(d) **Stroke Width and Spacing between Numbers**: At least 2.0 cm.

(e) **Color**: Either white numbers on a black background or black numbers on a white background. No other color combinations will be approved.

(f) **Background shape**: The number background must be one of the following: round, oval, square or rectangular. There must be at least 2.5 cm between the edge of the numbers and the edge of the background.

(g) **Clear**: The numbers must not be obscured by parts of the car, e.g. wheels, side pods, exhaust system, etc.

T13.1.3 Car numbers for teams registered for Formula Hybrid can be found on the “Registered Teams” section of the SAE Collegiate Design Series website.

Comment: Car numbers must be quickly read by course marshals when your car is moving at speed. Make your numbers easy to see and easy to read.

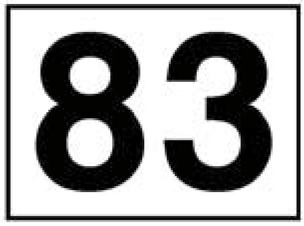

Figure 23 - Example Car Number

T13.2 School Name

T13.2.1 Each car must clearly display the school name (or initials – if unique and generally recognized) in roman characters at least 5 cm high on both sides of the vehicle. The characters must be placed on a high contrast background in an easily visible location.

T13.2.2 The school name may also appear in non-roman characters, but the roman character version must be uppermost on the sides.

T13.3 SAE & IEEE Logos

T13.3.1 SAE and IEEE logos must be prominently displayed on the front and/or both sides of the vehicle. Each logo must be at least 7 cm x 20 cm. The organizers can provide the following decals either by mail or at the competition:

(a) SAE, 7.6 cm x 20.3 cm in either White or Black.

(b) IEEE, 11.4 cm x 30.5 cm (Blue and Gold only).

Actual-size JPEGs may be downloaded from the Formula Hybrid website.

T13.4 Technical Inspection Sticker Space

Technical inspection stickers will be placed on the upper nose of the vehicle. Cars must have a clear and unobstructed area at least 25.4 cm wide x 20.3cm high on the upper front surface of the nose along the vehicle centerline.

ARTICLE T14 EQUIPMENT REQUIREMENTS

T14.1 Driver’s Equipment

The equipment specified below must be worn by the driver anytime he or she is in the cockpit with the engine running or with the tractive system energized.

T14.2 Helmet

T14.2.1 A well-fitting, closed face helmet that meets one of the following certifications and is labeled as such:

(a) Snell K2005, K2010, K2015, M2005, M2010, M2015, SA2005, SA2010, SA2015

(b) SFI 31.2A, SFI 31.1/2005

(c) FIA 8860-2004, FIA 8860-2010

(d) British Standards Institution BS 6658-85 Type A/FR rating (Types A and B are not accepted)

T14.2.2 Open faced helmets and off-road/motocross helmets (helmets without integrated face shields) are not approved.

T14.2.3 All helmets to be used in the competition must be presented during Technical Inspection where approved helmets will be stickered. The organizer reserves the right to impound all non-approved helmets until the end of the competition.

T14.3 Balaclava

A balaclava which covers the driver's head, hair and neck, made from acceptable fire resistant material as defined in **T14.12**, or a full helmet skirt of acceptable fire resistant material. The balaclava requirement applies to drivers of either gender, with any hair length.

T14.4 Eye Protection

An impact resistant face shield, made from approved impact resistant materials. The face shields supplied with approved helmets (See **T14.2** above) meet this requirement.

T14.5 Suit

A fire resistant suit that covers the body from the neck down to the ankles and the wrists. One (1) piece suits are required. The suit must be in good condition, i.e. it must have no tears or open seams, or oil stains that could compromise its fire resistant capability. The suit must be certified to one of the following standards and be labeled as such:

-FIA Standard 8856-1986	NORME 1986/ 1986 STANDARD MODEL 10000, NO.03.046 ACCUS.96
-SFI 3-2A/1 but only when used with fire resistant, e.g. Nomex, underwear that covers the body from wrist to ankles. -SFI 3-2A/5 (or higher)	sfi MANUFACTURER CERTIFIED 3-2A/1
- FIA Standard 8856-2000	Standard 8856-2000 RS.000.00 Manufacturer name Year of manufacture: 0000 Actual size 100x40mm

Table 8 – SFI / FIA Standards Logos

T14.6 Underclothing

It is strongly recommended that all drivers wear fire resistant underwear (long pants and long sleeve top) under their approved driving suit. This fire resistant underwear must be made from acceptable fire resistant material and cover the driver's body completely from the neck down to the ankles and wrists.

Note: If drivers do not wear fire resistant long underwear, it is strongly recommended that they wear cotton underwear under the approved driving suit. Tee-shirts, or other undergarments made from Nylon or any other synthetic materials may melt when exposed to high heat.

T14.7 Socks

Socks made from an accepted fire resistant material, e.g. Nomex, which cover the bare skin between the driver's suit and the boots or shoes. Socks made from wool or cotton are acceptable. Socks of nylon or polyester are not acceptable.

T14.8 Shoes

Shoes of durable fire resistant material and which are in good condition (no holes worn in the soles or uppers).

T14.9 Gloves

Fire resistant gloves made from made from acceptable fire resistant material as defined in **T14.12**. Gloves of all leather construction or fire resistant gloves constructed using leather palms with no insulating fire resisting material underneath are not acceptable.

T14.10 Arm Restraints

Arm restraints certified and labeled to SF1 standard 3.3, or a commercially manufactured equivalent, must be worn such that the driver can release them and exit the vehicle unassisted regardless of the vehicle's position.

T14.11 Driver's Equipment Condition

All driving apparel covered by **ARTICLE T14** must be in good condition. Specifically, driving apparel must not have any tears, rips, open seams, areas of significant wear or abrasion or stains which might compromise fire resistant performance.

T14.12 Fire Resistant Material

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

T14.13 Synthetic Material – Prohibited

T-shirts, socks or other undergarments (not to be confused with FR underwear) made from nylon or any other synthetic material which will melt when exposed to high heat are prohibited.

ARTICLE T15 OTHER REQUIRED EQUIPMENT

T15.1 Fire Extinguishers

T15.1.1 Each team must have at least two (2) 2.3 kg (5 lb.) dry chemical (Min. 3-A:40-B:C) Fire extinguishers

T15.1.2 Extinguishers of larger capacity (higher numerical ratings) are acceptable.

T15.1.3 All extinguishers must be equipped with a manufacturer installed pressure/charge gauge.

T15.2 Special Requirements

Teams must identify any fire hazards specific to their vehicle's components and if fire extinguisher/fire extinguisher material other than those required in section **T15.1** are needed to suppress such fires, then at least two (2) additional extinguishers/material (at least 5 lb or equivalent) of the required type must be procured and accompany the car at all times.

As recommendations vary, teams are advised to consult the rules committee before purchasing expensive extinguishers that may not be necessary.

T15.3 Chemical Spill Absorbent

Teams must have chemical spill absorbent at hand, appropriate to their specific risks. This material must be presented at technical inspection.

T15.4 Insulated Gloves

Insulated gloves are required, rated for at least the voltage in the TSV system, with protective over-gloves.

T15.4.1 Electrical gloves require testing by a qualified company and must have a test date printed on them that is within 14 months of the competition.

T15.5 Safety Glasses

Safety glasses must be worn as specified in section **D10.7**

T15.6 MSDS Sheets

Materials Safety Data Sheets (MSDS) for the accumulator devices are required and must be included in the ESF..

T15.7 Additional

Any special safety equipment called for in the MSDS, for example correct gloves recommended for handling any electrolyte material in the accumulator.

ARTICLE T16 ON-BOARD CAMERAS

T16.1 Mounts

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

T16.1.1 All camera installations must be approved at Technical Inspection.

T16.1.2 Helmet mounted cameras are prohibited.

T16.1.3 The body of a camera or recording unit that weighs more than 0.25 kg must be secured at a minimum of 2 points on different sides of the camera body. Plastic or elastic attachments are not permitted. If a tether is used to restrain the camera, the tether length must be limited so that the camera cannot contact the driver.

PART IC - INTERNAL COMBUSTION ENGINE

ARTICLE IC1 INTERNAL COMBUSTION ENGINE

IC1.1 Engine Limitation

Engines must be Internal Combustion, four-stroke piston engines, with a maximum displacement of 250cc for spark ignition engines and 310cc for diesel engines and be either:

(a) Modified or custom fabricated. (See section **IC1.2)**

Or

(b) Stock – defined as:

(i) Any single cylinder engine,

or

(ii) Any twin cylinder engine from a motorcycle approved for licensed use on public roads,

or

(iii) Any commercially available “industrial” IC engine meeting the above displacement limits.

Note: If you are not sure whether or not your engine qualifies as “stock”, contact the organizers.

IC1.2 Permitted modifications to a stock engine are:

(a) Modification or removal of the clutch, primary drive and/or transmission.

(b) Changes to fuel mixture, ignition or cam timings.

(c) Replacement of camshaft. (Any lobe profile may be used.)

(d) Replacement or modification of any exhaust system component.

(e) Replacement or modification of any intake system component; i.e., components upstream of (but NOT including) the cylinder head. The addition of forced induction will move the engine into the modified category.

(f) Modifications to the engine casings. (This does not include the cylinders or cylinder head.

(g) Replacement or modification of crankshafts for the purpose of simplifying mechanical connections. (Stroke must remain stock.)

IC1.3 Engine Inspection

The organizers reserve the right to tear down any number of engines to confirm conformance to the rules. The initial measurement will be made externally with a measurement accuracy of one (1) percent. When installed to and coaxially with spark plug hole, the measurement tool has dimensions of 381 mm long and 30 mm diameter. Teams may choose to design in access space for this tool above each spark plug hole to reduce time should their vehicle be inspected.

IC1.4 Starter

Each car must be equipped with an on-board starter or equivalent, and be able to move without any outside assistance at any time during the competition. Specifically, push starts are not permitted.

A manual starting system operable by the driver while belted in is permissible.

IC1.5 Air Intake System

IC1.5.1 Air Intake System Location

All parts of the engine air and fuel control systems (including the throttle or carburetor, and the complete air intake system, including the air cleaner and any air boxes) must lie within the surface defined by the top of the roll bar and the outside edge of the four tires. (See **Figure 24**)

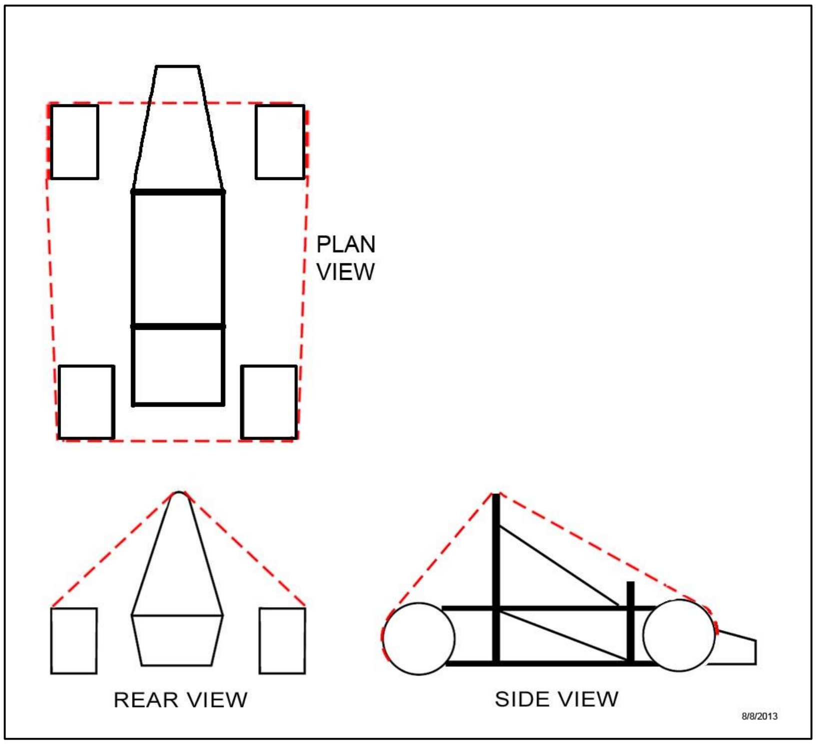

Figure 24- Surface Envelope

IC1.5.2 Any portion of the air intake system that is less than 350 mm above the ground must be shielded from side or rear impact collisions by structure built to Rule **T3.24** or **T3.33** as applicable.

IC1.5.3 Intake Manifold

If an intake manifold is used, it must be securely attached to the engine crankcase, cylinder, or cylinder head with brackets and mechanical fasteners. This precludes the use of hose clamps, plastic ties, or safety wires.

Original equipment rubber parts that bolt or clamp to the cylinder head and to the throttle body or carburetor are acceptable.

Note: These rubber parts are referred to by various names by the engine manufacturers; e.g., “insulators” by Honda, “joints” by Yamaha, and “holders” by Kawasaki.

Other than such original equipment parts the use of rubber hose is not considered a structural attachment. Intake systems with significant mass or cantilever from the cylinder head must be supported to prevent stress to the intake system.

Supports to the engine must be rigid.

Supports to the frame or chassis must incorporate some isolation to allow for engine movement and chassis flex.

IC1.5.4 Air boxes and filters

Large air boxes must be securely mounted to the frame or engine and connections between the air box and throttle must be flexible. Small air cleaners designed for mounting to the carburetor or throttle body may be cantilevered from the throttle body.

IC1.6 Accelerator and Accelerator Actuation

IC1.6.1 Carburetor/Throttle Body

All spark ignition engines must be equipped with a carburetor or throttle body. The carburetor or throttle body may be of any size or design.

IC1.6.2 Accelerator Actuation - General

All systems that transmit the driver's control of the speed of the vehicle, commonly called "Accelerator systems", must be designed and constructed as "fail safe" systems, so that the failure of any one component, be it mechanical, electrical or electronic, will not result in an uncontrolled acceleration of the vehicle. This applies to both IC engines and to electric motors that power the vehicle.

The Accelerator control may be actuated mechanically, electrically or electronically, i.e. electrical Accelerator control (ETC) or "drive-by-wire" is acceptable.

Any Accelerator pedal must have a positive pedal stop incorporated on the Accelerator pedal to prevent over stressing the Accelerator cable or any part of the actuation system.

IC1.6.3 Mechanical Accelerator Actuation

If mechanical Accelerator actuation is used, the Accelerator cable or rod must have smooth operation, and must not have the possibility of binding or sticking.

The Accelerator actuation system must use at least two (2) return springs located at the throttle body, so that the failure of any component of the Accelerator system will not prevent the Accelerator returning to the closed position.

Note: Springs in Throttle Position Sensors (TPS) are NOT acceptable as return springs.

Accelerator cables must be at least 50 mm from any exhaust system component and out of the exhaust stream.

Any Accelerator pedal cable must be protected from being bent or kinked by the driver's foot when it is operated by the driver or when the driver enters or exits the vehicle.

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

The use of a push-pull type Accelerator cable with an Accelerator pedal that is capable of forcing the Accelerator closed (e.g. toe strap) is recommended.

Electrical actuation of a mechanical throttle is permissible, provided releasing the Accelerator pedal will override the electrical system and cause the throttle to close.

IC1.6.4 Electrical Accelerator Actuation

When electrical or electronic throttle actuation is used, the throttle actuation system must be of a fail-safe design to assure that any single failure in the mechanical or electrical components of the Accelerator actuation system will result in the engine returning to idle (IC engine) or having zero torque output (electric motor). See also: **EV2.2.**

Teams are strongly encouraged to use commercially available electrical Accelerator actuation systems.

The methodology used to ensure fail-safe operation must be included as a required appendix to the Design Report. See **S4.2.1** A printed copy must be handed to inspectors at the beginning of Electrical Tech Inspection.

IC1.7 Intake System Restrictor

IC1.7.1 Non-stock engines (See **IC1.1)** must be fitted with an air inlet restrictor as listed below. All the air entering the engine must pass through the restrictor which must be located downstream of any engine throttling device.

IC1.7.2 The restrictor must be circular with a maximum diameter of:

(a) Gasoline fueled cars – 12.9 mm

(b) E-85 fueled cars – 12.3 mm

(c) Biodiesel fueled cars – no inlet restrictor required

IC1.7.3 The restrictor must be located to facilitate measurement during the inspection process.

IC1.7.4 The circular restricting cross section may NOT be movable or flexible in any way, e.g. the restrictor may not be part of the movable portion of a barrel throttle body.

IC1.7.5 Any device that has the ability to throttle the engine downstream of the restrictor is prohibited.

IC1.7.6 If more than one engine is used, the intake air for all engines must pass through the one restrictor.

Note: Section **IC1.7** applies only to those engines that are not on the approved stock engine list, or that have been modified beyond the limits specified in **IC1.2.**

IC1.8 Turbochargers & Superchargers

Turbochargers or superchargers are permitted. The compressor must be located downstream of the inlet restrictor. The addition of a Turbo or Supercharger will move the engine into the Modified category.

IC1.9 Fuel Lines

IC1.9.1 Plastic fuel lines between the fuel tank and the engine (supply and return) are prohibited.

IC1.9.2 If rubber fuel line or hose is used, the components over which the hose is clamped must have annular bulb or barbed fittings to retain the hose. Also, clamps specifically designed for fuel lines must be used. These clamps have three (3) important features;

(a) A full 360 degree (360°) wrap,

(b) a nut and bolt system for tightening, and

(c) rolled edges to prevent the clamp cutting into the hose.

Worm-gear type hose clamps are not approved for use on any fuel line.

IC1.9.3 Fuel lines must be securely attached to the vehicle and/or engine.

IC1.9.4 All fuel lines must be shielded from possible rotating equipment failure or collision damage.

IC1.10 Fuel Injection System Requirements

IC1.10.1 Fuel Lines – Flexible fuel lines must be either

(a) metal braided hose with either crimped-on or reusable, threaded fittings, or

(b) reinforced rubber hose with some form of abrasion resistant protection with fuel line clamps per **IC1.9.2**.

Note: Hose clamps over metal braided hose will not be accepted.

IC1.10.2 Fuel Rail – If used, a fuel rail must be securely attached to the engine cylinder block, cylinder head, or intake manifold with brackets and mechanical fasteners. This precludes the use of hose clamps, plastic ties, or safety wire.

IC1.11 Crankcase / Engine lubrication venting

IC1.11.1 Any crankcase or engine lubrication vent lines routed to the intake system must be connected upstream of the intake system restrictor, if fitted.

IC1.11.2 Crankcase breathers that pass through the oil catch tank(s) to exhaust systems, or vacuum devices that connect directly to the exhaust system, are prohibited.

ARTICLE IC2 FUEL AND FUEL SYSTEM

IC2.1 Fuel

IC2.1.1 All fuel at the Formula Hybrid Competition will be provided by the organizer.

IC2.1.2 During all performance events the cars must be operated with the fuels provided by the organizer.

IC2.1.3 The fuels provided at the Formula Hybrid Competition are:

(a) Gasoline (Sunoco Optima)

(b) Ethanol (Sunoco E-85R)

(c) Diesel (B100)

Note: More information including the fuel energy equivalencies, and a link for the Sunoco fuel specifications are given in **Appendix A**

IC2.1.4 Teams must submit their fuel request to the organizers before the fuel request deadline. Only those fuels listed in **IC2.1.3** will be available.

IC2.2 Fuel Additives - Prohibited

IC2.2.1 Nothing may be added to the provided fuels. This prohibition includes nitrous oxide or any other oxidizing agent.

IC2.2.2 No agents other than fuel and air may be induced into the combustion chamber. Non-adherence to this rule will be reason for disqualification.

IC2.2.3 Officials have the right to inspect the oil.

IC2.3 Fuel Temperature Changes - Prohibited

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

IC2.4 Fuel Tanks

IC2.4.1 The fuel tank is defined as that part of the fuel containment device that is in contact with the fuel. It may be made of a rigid material or a flexible material.

IC2.4.2 Fuel tanks made of a rigid material cannot be used to carry structural loads, e.g. from roll hoops, suspension, engine or gearbox mounts, and must be securely attached to the vehicle structure with mountings that allow some flexibility such that chassis flex cannot unintentionally load the fuel tank.

IC2.4.3 Any fuel tank that is made from a flexible material, for example a bladder fuel cell or a bag tank, must be enclosed within a rigid fuel tank container which is securely attached to the vehicle structure. Fuel tank containers (containing a bladder fuel cell or bag tank) may be load carrying.

IC2.4.4 Any size fuel tank may be used.

IC2.4.5 The fuel system must have a drain fitting for emptying the fuel tank. The drain must be at the lowest point of the tank and be easily accessible. It must not protrude below the lowest plane of the vehicle frame, and must have provision for safety wiring.

IC2.5 Fuel System Location Requirements

IC2.5.1 All parts of the fuel storage and supply system must lie within the surface defined by the top of the roll bar and the outside edge of the four tires. (See **Figure 24**).

IC2.5.2 All fuel tanks must be shielded from side or rear impact collisions. Any fuel tank which is located outside the Side Impact Structure required by **T3.24** or **T3.33** must be shielded by structure built to **T3.24** or **T3.33**.

IC2.5.3 A firewall must separate the fuel tank from the driver, per **T4.5.**

IC2.6 Fuel Tank Filler Neck

IC2.6.1 All fuel tanks must have a filler neck[4]:

(a) With a minimum inside diameter of 38 mm

(b) That is vertical (with a horizontal filler cap) or angled at no more than forty-five degrees (45º) from the vertical.

IC2.6.2 All filler caps and necks must have provision for a seal to be attached such that the filler cap may not be removed without the removal of the seal. This should consist of two 3 mm holes, one on the neck and one on the cap. When the fuel cap is secured, these holes should be located within 6 mm of each other.

IC2.6.3 Any sight tube may not run below the top surface of the fuel tank.

[4] Some flush fillers may be approved by contacting the Formula Hybrid rules committee. (Be sure to receive approval before committing to the use of a particular tank and filler.)

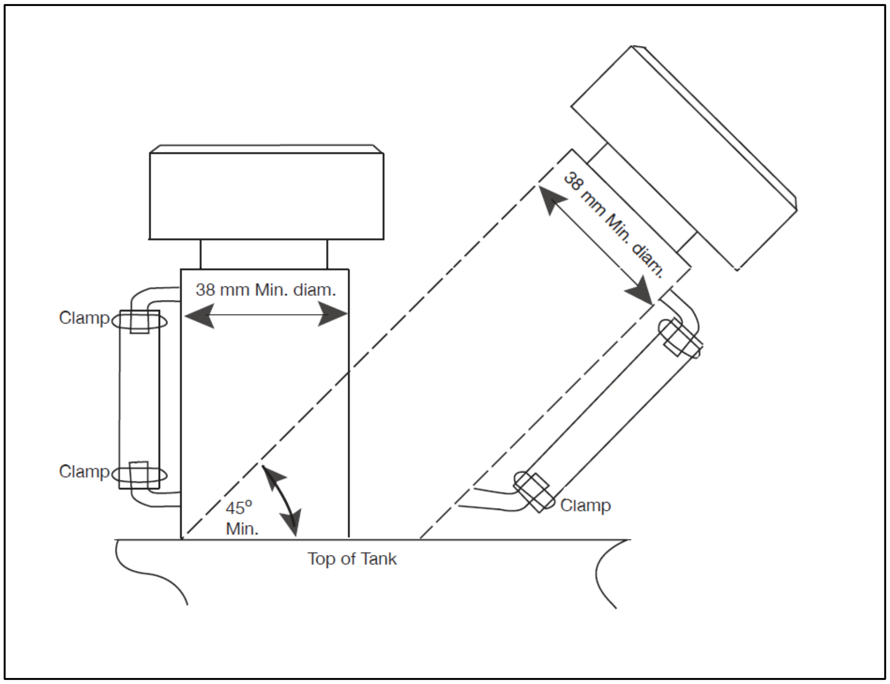

Figure 25 - Filler Neck

IC2.7 Tank Filling Requirement

IC2.7.1 The tank must be capable of being filled to capacity without manipulating the tank or vehicle in any way (shaking vehicle, etc.).

IC2.7.2 The fuel system must be designed such that the spillage during refueling cannot contact the driver position, exhaust system, hot engine parts, or the ignition system.

IC2.7.3 Belly pans must be vented to prevent accumulation of fuel.

IC2.8 Venting Systems

IC2.8.1 The fuel tank and carburetor venting systems must be designed such that fuel cannot spill during hard cornering or acceleration. This is a concern since motorcycle carburetors normally are not designed for lateral accelerations.

IC2.8.2 All fuel vent lines must be equipped with a check valve to prevent fuel leakage when the tank is inverted. All fuel vent lines must exit outside the bodywork.

ARTICLE IC3 EXHAUST SYSTEM AND NOISE CONTROL

IC3.1 Exhaust System General

IC3.1.1 Exhaust Outlet

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

IC3.1.2 The exhaust outlet(s) must not extend more than 45 cm behind the centerline of the rear wheels, and shall be no more than 60 cm above the ground.

IC3.1.3 Any exhaust components (headers, mufflers, etc.) that protrude from the side of the body in front of the main roll hoop must be shielded to prevent contact by persons approaching the car or a driver exiting the car.

IC3.1.4 The application of fibrous material, e.g. “header wrap”, to the outside of an exhaust manifold or exhaust system is prohibited.

IC3.2 Noise Measuring Procedure

IC3.2.1 The sound level will be measured during a static test. Measurements will be made with a free-field microphone placed free from obstructions at the exhaust outlet level, 0.5 m from the end of the exhaust outlet, at an angle of forty-five degrees (45°) with the outlet in the horizontal plane. The test will be run with the gearbox in neutral at the engine speed defined below. Where more than one exhaust outlet is present, the test will be repeated for each exhaust and the highest reading will be used.

Vehicles that do not have manual throttle control must provide some means for running the engine at the test RPM.

IC3.2.2 The car must be compliant at all engine speeds up to the test speed defined below.

IC3.2.3 If the exhaust has any form of movable tuning or throttling device or system, it must be compliant with the device or system in all positions. The position of the device must be visible to the officials for the noise test and must be manually operable by the officials during the noise test.

IC3.2.4 Test Speeds

The test speed for a given engine will be the engine speed that corresponds to an average piston speed of 914.4 m/min for automotive or motorcycle engines, and 731.5 m/min for Diesels and “Industrial” engines. The calculated speed will be rounded to the nearest 500 rpm. The test speeds for typical engines will be published by the organizers.

IC3.2.5 An “industrial engine” is defined as an engine which, according to the manufacturers’ specifications and without the required restrictor, is not capable of producing more than 5 hp per 100cc. To have an engine classified as “an industrial engine”, approval must be obtained from organizers prior to the Competition.

IC3.2.6 Vehicles not equipped with engine tachometers must provide some external means for measuring RPM, such as a hand-held meter or lap top computer.

Note: Teams that do not provide the means to measure engine speed will not pass the noise test, will not receive the sticker and hence will not be eligible to compete in any dynamic event .Engines with mechanical, closed loop speed control will be tested at their maximum (governed) speed.

IC3.2.7 Engines with mechanical, closed loop speed control will be tested at their maximum (governed) speed.

IC3.3 Maximum Sound Level

The maximum permitted sound level is 110 dB A, fast weighting.

IC3.4 Noise Level Re-testing

At the option of the officials, noise can be measured at any time during the competition. If a car fails the noise test, it will be withheld from the competition until it has been modified and re-passes the noise test.

ARTICLE IC4 SHUTDOWN SYSTEMS

IC4.1.1 The I.C. Engine and fuel pumps must be capable of being shut down by any of the following systems: (See: **ARTICLE EV5** and **Table 16**).

(a) GLV Master Switch

(b) Side or cockpit-mounted shutdown buttons

(c) Brake Over-Travel Switch

(d) AMS

(e) IMD

PART EV - ELECTRICAL POWERTRAINS AND SYSTEMS

ARTICLE EV1 ELECTRIC SYSTEM DEFINITIONS

EV1.1 Basic Definitions

EV1.1.1 The **Accumulator** is defined as all the batteries or capacitors that store the electrical energy to be used by the tractive system.

EV1.1.2 **Accumulator Segments** are sub-divisions of the accumulator and must respect either a maximum voltage or energy limit. (See **EV3.4.3**). Splitting the accumulator into segments is intended to reduce the risks associated with working on the accumulator.

EV1.1.3 The **Tractive System** of the car is defined as every part that is electrically connected to the motor(s) and accumulators.

EV1.1.4 The **Grounded Low Voltage (GLV)** system of the car is defined as every electrical part that is not part of the tractive system.

EV1.2 Grounded Low Voltage and Tractive System Voltage

EV1.2.1 The maximum permitted operating voltage for Formula Hybrid is 300 V. (See **Table 9.)** The maximum operating voltage is defined as the maximum measured accumulator voltage during normal charging conditions.

Note 1: The Tractive System Voltage limit may be exceeded within the motor/controller system as a result of transient inductive effects, but may not be intentionally increased through the use of DC/DC converters, transformers, etc.

Note 2: Commercially available motor controllers containing boost converters that have internal voltages greater than 300 VDC may be used provided the unit is approved in advance by the electrical rules committee.

EV1.2.2 The GLV system may not have a voltage greater than 30 VDC or 25 VAC[5]. (See **Table 9**).

Formula Hybrid Maximum Voltages	
Maximum operating voltage	300 V
Maximum GLV	30 VDC or 25 VAC

Table 9 – Maximum Voltages

EV1.2.3 The GLV system must be grounded to the chassis. See **EV3.8.5**

EV1.2.4 The tractive and GLV system must be galvanically isolated from one another.

Note: The border between tractive and GLV systems is the galvanic isolation between both systems. Therefore, some components, such as the motor controller, may be part of both systems.

EV1.2.5 The tractive system must be electrically isolated from the chassis and any other conductive parts of the car.

[5] GLV system voltages up to 60 VDC may be allowed with prior review and approval of the rules committee.

EV1.2.6 The tractive system motor(s) must be connected to the accumulator through a motor controller. Bypassing the control system and connecting the tractive system accumulator directly to the motor(s) is prohibited.

EV1.2.7 The GLV system must be powered up before it is possible to activate the tractive system. (See **EV4.7**). Furthermore, a failure causing the GLV system to shut down must immediately deactivate the tractive system as well.

EV1.3 Electrical Insulating Materials

EV1.3.1 All Electrical insulating materials used must:

(a) be UL recognized (i.e., have an Underwriters Laboratories (http://www.ul.com) or equivalent rating and certification).

(b) be rated for the maximum expected operating temperatures at the location of use or

(c) have a minimum temperature rating of 90 ºC. (Whichever is greater)

EV1.3.2 Electrical insulating barriers used to meet the requirements of **EV4.1.4** for separation of tractive system and GLV wiring must be rated for 150 ºC.

EV1.3.3 Vinyl electrical insulating tape and rubber-like paints and coatings are not acceptable electrical insulating materials.

ARTICLE EV2 ELECTRIC POWERTRAIN

EV2.1 Accelerator Pedal

EV2.1.1 The accelerator pedal must be a right-foot-operated foot pedal.

EV2.1.2 The foot pedal must return to its original, rearward position when released. The foot pedal must have positive stops at both ends of its travel, preventing its sensors from being damaged or overstressed.

EV2.2 Accelerator Signal Limits Check

EV2.2.1 All analog acceleration control signals (between accelerator pedal and motor controller) must have error checking which can detect open circuit, short to ground and short to sensor power and will shut down the torque production in less than one (1) second if a fault is detected.

Note: If these capabilities are built into the motor controller, then no additional error-checking circuitry is required.

EV2.2.2 The accelerator signal limit shutoff may be tested during electrical tech inspection by replicating any of the fault conditions listed in **EV2.2.1**

EV2.3 Accelerator Signal Isolation

EV2.3.1 The accelerator signal and similar electric motor controller input circuits must be galvanically isolated from the Tractive System.

EV2.3.2 These circuits must be positively bonded to GLV ground.

Note: This is typically accomplished by connecting the negative or common accelerator input conductor to GLV ground.

ARTICLE EV3 TRACTIVE SYSTEM - ENERGY STORAGE

EV3.1 Allowed Tractive System Accumulators

EV3.1.1 The following accumulators are acceptable; batteries (e.g. lithium-ion batteries, NiMH batteries, lead acid batteries and many other rechargeable battery chemistries) and capacitors, such as super caps or ultracaps.

The following accumulators are not permitted; molten salt batteries, thermal batteries, fuel cell, atomic and flywheel mechanical batteries.

EV3.1.2 Manufacturer's data sheets showing the rated specification of the accumulator cell(s) which are used must be provided in the ESF along with their number and configurations.

EV3.2 Tractive System Accumulator Container – General Requirements

EV3.2.1 All batteries or capacitors which store the tractive system energy must be enclosed in (an) accumulator container(s)

EV3.2.2 If spare accumulators are to be used then they all must be of the same size, weight and type as those that are replaced. Spare accumulator packs must be presented at Electrical Tech Inspection.

EV3.2.3 If the accumulator container(s) is not easily accessible during Electrical Tech Inspection, detailed pictures of the internals taken during assembly must be provided. If the pictures do not adequately depict the accumulator, it may be necessary to disassemble the accumulator to pass Electrical Tech Inspection.

EV3.3 Virtual Accumulator Housing.

Teams may interconnect multiple (non-removable) accumulator housings such that the grouping will be considered one container provided the following conditions are met:

EV3.3.1 The interconnect conduit(s) (See **Figure 26** below) must be flexible METALLIC liquid-tight steel electrical conduit (NEC type LFMC) securely fastened at each end with fittings rated for metallic LFMC).

EV3.3.2 The conduit must be red, or painted red[6].

EV3.3.3 The maximum unsupported length of the interconnect conduit is 150 mm. i.e. it must be physically supported at least every 150 mm to ensure that it cannot droop or be snagged by something on the track.

EV3.3.4 Separate conduits must be provided between housings for:

(a) Individual tractive System conductors (Only one high-current TSV conductor may pass through any one conduit.)

(b) GLV-level wiring.

(c) AMS wiring such as cell voltage sense wires that are at TS potential.

EV3.3.5 The accumulator housings may not be removable (as referenced in **EV3.4.7** and **EV8.3.1**)

EV3.3.6 All rules relating to accumulator housings (including, but not limited to firewalls, location etc.) also apply to the interconnect conduit.

EV3.3.7 If the interconnect conduit is the lowest point in the virtual housing it must have a 3-5 mm drain hole in its lowest point to allow accumulated fluids to drain.

[6] LFMC conduit is available with a red jacket - see for example: http://www.afcweb.com/liquid-tuff-conduit/ul-liquidtight-flexible-steel-conduit-type-lfmc/

EV3.3.8 Segmentation requirements must be met considering the housings individually, and as an interconnected system

EV3.3.9 Each housing must comply individually with TS fusing requirements (**EV3.4.2**)

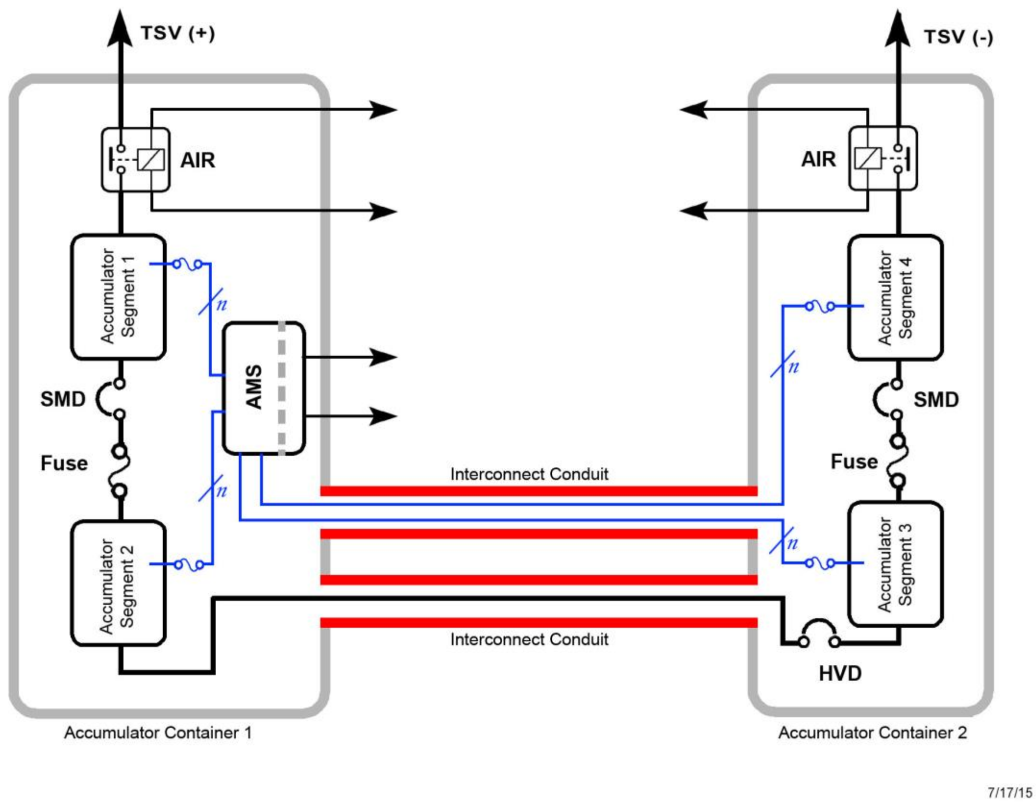

Figure 26 - Virtual Accumulator Housing Example

EV3.4 Tractive System Accumulator Container - Electrical Configuration

EV3.4.1 If the container is made of electrically conductive material, the poles of the accumulator stack(s) and/or cells must be electrically insulated from the inside wall of the accumulator container by insulating material rated for the maximum voltage of the tractive system.

All conductive surfaces on the outside of the container must have a low-resistance connection to the GLV system ground. All conductive penetrations (mounting hardware, etc.) must be located outside of the insulation and configured such that there is no possibility that they could penetrate the insulating barrier.

EV3.4.2 Every accumulator container must contain at least one fuse See **EV3.6**.

EV3.4.3 All batteries or capacitors that make up the accumulator must be divided into accumulator segments. A Segment Maintenance Disconnect (SMD) must be installed between each segment, to allow electrical separation such that the separated segments contain a maximum voltage of less than 120 VDC (fully charged) and a maximum energy of 6 MJ[7].

[7] Commercial packs with larger segment energy may be permitted upon approval by the rules committee.

Note: If the high-voltage disconnect (HVD, section **EV4.7**) is located between segments, it satisfies the requirement for an SMD between these segments. (See **Figure 27**)

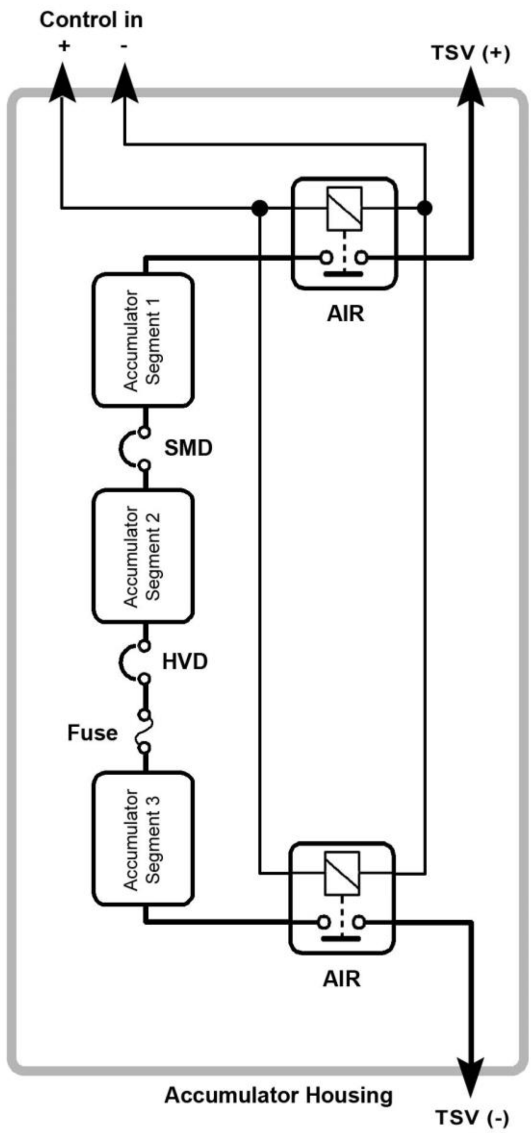

Figure 27 - Example Accumulator Segmenting

The SMD must be used whenever the accumulator containers are opened for maintenance and whenever accumulator segments are removed from the container.

EV3.4.4 The SMD may be implemented with a switch or a removable maintenance plug. There must be a positive means of securing the SMD in the disconnected state; for example, a lockable switch can be secured with a zip-tie or simply a clip.

Note: A removable plug meets this requirement if the plug is secured or fully removed such that it cannot accidentally reconnect.

EV3.4.5 SMD methods requiring tools to isolate the segments are not permitted. If the SMD is operated with the accumulator container open, any removable part used with the SMD (e.g., a clip or zip-tie used to secure the SMD off, or a plug that is removed) must be non-conductive on surfaces that are not used to make electrical connections.

EV3.4.6 Contacting / interconnecting the single cells by soldering in the high current path is prohibited.

Note: Soldering wires to cells for the voltage monitoring input of the AMS is allowed since these wires are not part of the high current path.

EV3.4.7 Any removable accumulator container must have a prominent indicator, such as an LED, that is visible through a closed container that will illuminate whenever a voltage greater than 30 VDC is present at the vehicle side of the AIRs.

EV3.4.8 The accumulator voltage indicator must be directly controlled by voltage present at the container connectors using analog electronics. No software control is permitted.

EV3.4.9 The minimum spacing or creepage distance[8] for conductive materials at different voltages in the Accumulator shall be according to **Table 10**. This requirement applies to all conductors including cell-to-cell connections.

Maximum Vehicle TS Voltage	**Spacing**	
	Over Surface	**Through Air**
0-150 VDC	6.4 mm (1/4")	3.2 mm (1/8")
150-300 VDC	9.5 mm (3/8")	6.4 mm (1/4")

Table 10 - Accumulator spacing

EV3.4.10 The accumulator container may not contain circuitry or components other than the accumulator itself and necessary supporting circuitry such as the AIRs, AMS, and pre-charge circuitry.

For example, the accumulator container may not contain the motor controller, IMD, TSVP or any GLV circuits other than those required for necessary accumulator functions.

Note 1: The purpose of this requirement is to allow work on other parts of the tractive system without opening the accumulator container and exposing (always-live) high voltage.

Note 2: It is possible to meet this requirement by dividing a large box into an accumulator section and a non-accumulator section, with an insulating barrier between them. In this case, it must be possible to open the non-accumulator section while keeping the accumulator section closed, meeting the requirements of the "finger probe" test. See: **EV4.5.1** . When the tractive system is not energized, there must be no tractive system voltage present in the non-accumulator section. The AIRs must therefore be located in the accumulator section.

EV3.5 Tractive System Accumulator Container - Mechanical Configuration

EV3.5.1 All accumulator containers must be rugged and rigidly mounted to the chassis to prevent the containers from loosening during the dynamic events or possible accidents.

[8] Creepage distance is the shortest distance measured along the surface of the insulating material between two conductors.

EV3.5.2 The mounting system for the accumulator container must be designed to withstand forces from a 40g deceleration in the horizontal plane and 20 g deceleration in the vertical plane. The calculations/tests proving this must be part of the SES.

(a) For tube frame cars, each accumulator container must be attached to the Frame by a minimum of four (4) 8 mm Metric Grade 8.8 or 5/16 inch Grade 5 bolts.

(b) For monocoques:

(i) Each accumulator container must be attached to the Frame at a minimum of four (4) points, each capable of carrying a load in any direction of 400 Newtons x the mass of the accumulator in kgs, i.e. if the accumulator has a mass of 50 kgs, each attachment point must be able to carry a load of 20kN in any direction.

(ii) The laminate, mounting plates, backing plates and inserts must have sufficient shear area, weld area and strength to carry the specified load in any direction. Data obtained from the laminate perimeter shear strength test (**T3.30**) should be used to prove adequate shear area is provided

(iii) Each attachment point requires a minimum of one (1) 8 mm Metric Grade 8.8 or 5/16 inch SAE Grade 5 bolt.

(iv) Each attachment point requires steel backing plates with a minimum thickness of 2 mm. Alternate materials may be used for backing plates if equivalency is approved.

(v) The calculations/tests must be included in the SES.

EV3.5.3 All accumulator containers must lie within the surface envelope as defined by **IC1.5.1**

EV3.5.4 The accumulator container(s) must be built of mechanically robust material; See **EV3.5.1**.

EV3.5.5 The container material must be fire resistant according to UL94-V0, FAR25 or equivalent.

EV3.5.6 The cells and/or segments must be appropriately secured against loosening inside the container. All accumulator segments must be attached to the accumulator container(s) with mechanical fasteners. The fasteners must comply with **ARTICLE T11**.

EV3.5.7 The accumulator segments contained within the accumulator must be separated by an electrically insulating barrier such that the limits of **EV3.4.3** are met. For all lithium based cell chemistries, these barriers must also be fire resistant (according to UL94-V0, FAR25 or equivalent).

EV3.5.8 Holes in the container are only allowed for the wiring-harness, ventilation, cooling or fasteners. These holes must be sealed according to **EV4.5**. Openings for ventilation should be of a reasonable size, e.g. completely open side pods containing accumulators are not allowed.

EV3.5.9 A sticker with an area of at least 750mm² and a red or black lightning bolt on yellow background or red lightning bolt on white background must be applied on every accumulator container. The sticker must also contain the text "High Voltage" or something similar if the accumulator voltage is greater than 30 VDC.

EV3.5.10 Any accumulator that may vent an explosive gas must have a ventilation system or pressure relief valve to prevent the vented gas from reaching an explosive concentration.

EV3.5.11 Every accumulator container which is completely sealed must have a pressure relief valve to prevent high-pressure in the container.

EV3.6 Accumulator Isolation Relay(s) (AIR)

EV3.6.1 At least two isolation relays must be installed in every accumulator container.

EV3.6.2 The accumulator isolation relays must open both poles of the accumulator.

EV3.6.3 If these relays are open, no TSV may be present outside of the accumulator container. (Including to the AMS and/or IMD)

EV3.6.4 The isolation relays must be of a "normally open" type.

EV3.6.5 The fuse protecting the accumulator circuit must have a rating lower than the voltage and current ratings of the isolation relays.

Note: The AIR contacts must be protected by Pre-Charge and Discharge circuitry, See **EV4.9**

EV3.6.6 Accumulator isolation relays containing mercury are not permitted.

EV3.7 Accumulator Management System (AMS)

EV3.7.1 Each accumulator must be monitored by an accumulator management system whenever the tractive system is active or the accumulator is connected to a charger.

EV3.7.2 The AMS must continuously measure cell voltages in order to keep those voltages inside the allowed minimum and maximums stated in the cell data sheet. If single cells are directly connected in parallel, only one voltage measurement is needed. (See **Table 11**)

Chemistry	Maximum number of cells per voltage measurement
PbAcid	6
NiMh	6
Lithium based	1

Table 11 - AMS Voltage Monitoring

EV3.7.3 The AMS must continuously measure the temperatures of critical points of the accumulator to keep the cells below the allowed maximum cell temperature bound stated in the cell data sheet.

EV3.7.4 All voltage sense wires to the AMS must be either protected by fuses as defined in **ARTICLE EV6** or must be protected by resistors so that they cannot exceed their current carrying capacity in the event of a short circuit. Any fuse or resistor must be located as close as possible to the energy source. If any of these fuses are blown or if the connection to measure the cell voltage is interrupted in any other way then this must be detected by the AMS and must be reported as a critical voltage problem. If the AMS monitoring board is directly connected to the cell, it is acceptable to have a fuse integrated into the monitoring board.

EV3.7.5 Any GLV connection to the AMS must be galvanically isolated from the TSV. This isolation must be documented in the ESF.

Note: Per **EV3.6.3**, AMS connections that are not isolated, such as cell sense wires, cannot exit the accumulator container, unless they are isolated by additional relays when the AIRs are off. This requirement should be considered in the selection of an AMS system for a vehicle that uses more than one accumulator container.

EV3.7.6 All connections from external devices such as laptops to a tractive system component must include galvanic isolation, and include a connection to frame ground. These connections must be documented in the ESF.

EV3.7.7 The AMS must monitor the temperature of the minimum number of cells in the accumulator as specified in **Table 12** below. The monitored cells must be equally distributed over the accumulator container(s).

Chemistry	Cells monitored
PbAcid	5%
NiMh	10%
Li-Ion	30%

Table 12 – AMS Temperature Monitoring

NOTE: It is acceptable to monitor multiple cells with one sensor if this sensor has direct contact to all monitored cells.

NOTE: It is strongly recommended to monitor the temperature of all cells.

EV3.7.8 The AMS must shut down all the electrical systems, open the AIRs and shut down the I.C. drive system if critical voltage or temperature values are detected. (Some GLV systems may remain energized - See **Table 16**) The tractive system must remain disabled until manually reset by a person other than the driver. It must not be possible for the driver to re-activate the tractive system from within the car in case of an AMS fault.

EV3.7.9 Team-Designed Accumulator Management Systems

Teams may design and build their own Accumulator Management Systems. However, microprocessor-based accumulator management systems are subject to the following restrictions:

(a) The processor must be dedicated to the AMS function only. However it may communicate with other systems through shared peripherals or other physical links.

(b) The AMS circuit board must include a watchdog timer. It is strongly recommended that teams include the ability to test the watchdog function in their designs.

EV3.7.10 AMS Test Port.

A break-out test connector must be provided inside the accumulator enclosure for AMS voltage testing. This port allows testing of the AMS by substituting a test box voltage for a measured cell voltage. See **Figure 28.**

The connector must be located where it can be readily accessed during technical testing.

Note: This may require opening the accumulator container. It does not need to be accessible during dynamic events.

The test connector must be either:

(a) Four (4) 4 mm shrouded banana jacks arranged in a 0.75 inch square pattern, meeting the requirements of **EV4.4** or

(b) A four conductor Molex Minifit junior 1 x 4 pin housing, PN 39-01-4040 (**Figure 29 A**) with PN 39-00-0039 female receptacles which Mates with Molex Minifit Jr housing, PN 39-01-4046 (**Figure 29 B**) with PN 39-00-0041 male pins[9].

[9] A set of Molex Minifit Jr. connectors will be provided to teams on request. Contact the organizers at info@formula-hybrid.org

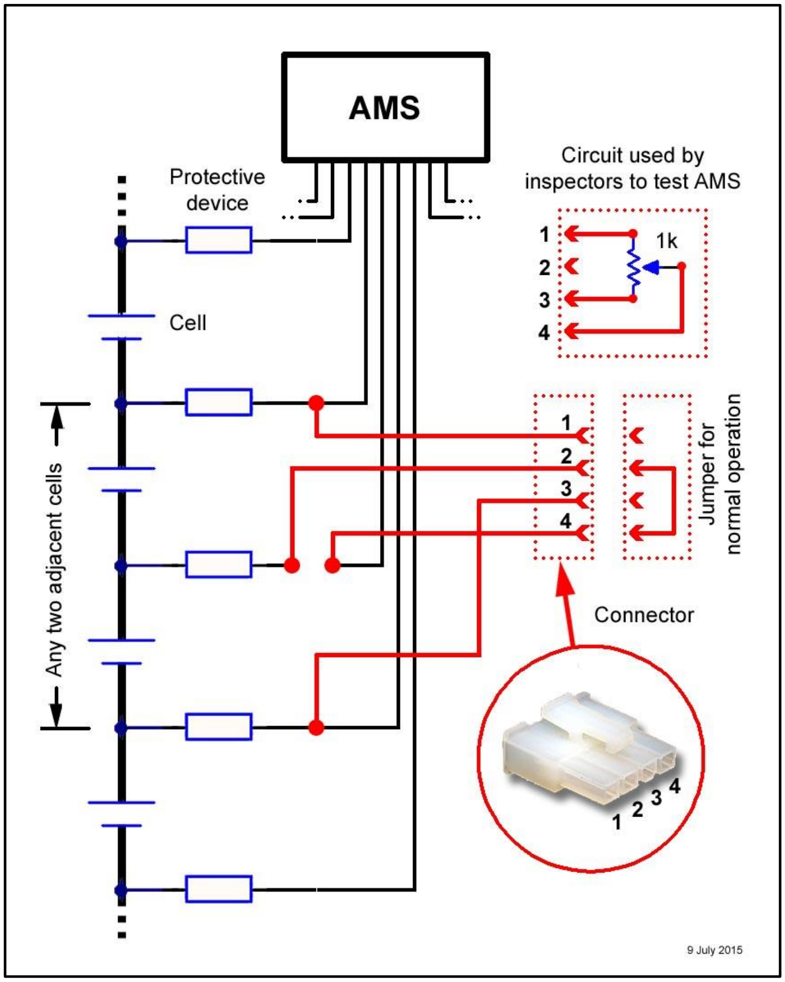

Figure 28 - AMS Test Connector Wiring

Notes:

1. The test connector makes three adjacent cell connections and an AMS input available for testing.
2. During testing, inspectors will connect a test circuit, energize the tractive system, and vary the cell voltage sense using the potentiometer in the test circuit. Cell voltage will be measured and compared to ESF values for AMS trip points.
3. For normal operation, a jumper that connects pins 2 & 4 is used.
4. It is recommended that teams construct their own test circuit to confirm proper wiring and operation prior to the competition. (Use extreme caution, since TSV will be present at the potentiometer connections.)

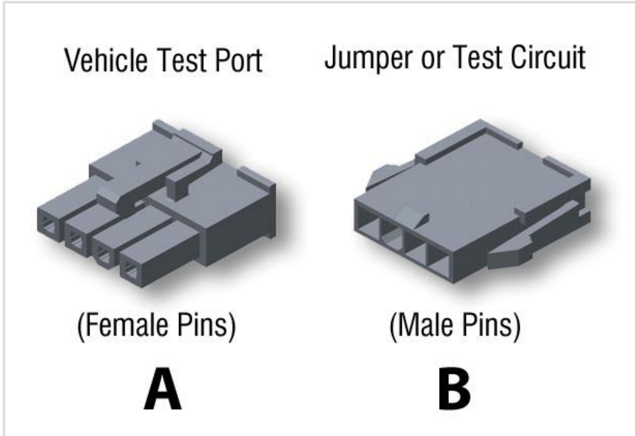

Figure 29 - Molex Minifit Connectors

EV3.8 Grounded Low Voltage System

EV3.8.1 All GLV batteries must be attached securely to the frame.

EV3.8.2 Any wet-cell battery located in the driver compartment must be enclosed in a nonconductive marine-type container or equivalent and include a layer of 1.5 mm of aluminum or equivalent between the container and driver.

EV3.8.3 The hot (ungrounded) terminal must be insulated.

EV3.8.4 Battery packs based on Lithium Chemistry (other than commercially assembled packs) must have over-voltage, under-voltage, short circuit and over-temperature cell protection. Details on how the required protection is achieved must be included as part of the ESF submission.

EV3.8.5 One terminal of the GLV battery or other GLV power source must be connected to the chassis by a ground wire. The ground wire must be sized adequately for the GLV system fusing. The ground wire must be robustly secured and protected from mechanical damage. Note that minimizing the length of the ground wire is also recommended.

Note: The ungrounded conductor of the GLV system must be fused as close as possible to the battery terminal in accordance with **EV6.1.5**

EV3.9 Pouch type Lithium Ion cells

Batteries constructed using pouch type lithium ion cells are subject to the following design constraints:

Note: Teams are responsible for documenting compliance with all of the following requirements. This documentation must be submitted as part of the ESF.

Designing an accumulator system utilizing pouch cells is a substantial engineering undertaking which may be avoided by using prismatic or cylindrical cells.

EV3.9.1 Stack arrangement

Cells in a stack (a group of pouch cells) must be arranged face-to-face not edge-to-edge.

EV3.9.2 Expansion Limiter

A mechanical restraining system (the expansion limiter) must limit volumetric expansion. The expansion limiter must:

(a) Be capable of applying ≥10 psi without yielding at temperatures up to 150 °C.

(b) allow the stack to expand by at least 8% and not more than 12% in volume before reaching 10 psi.

(c) use materials that are fire retardant and immune to creep.

(d) not impinge on the cell separator internal to the cell.

Conductive materials must be electrically insulated from cells.

Expansion limiter calculations (simulation results or appropriate mechanical analysis) must be included in the ESF.

NOTE: Formula Hybrid will consider variances to **EV3.9.2** if the request includes:

1. Manufacturer's data sheets containing recommendations and/or requirements for assembling a stack of the intended devices, **or**

   a letter from the cell manufacturer with the same information.

2. Drawings and a mechanical analysis of the team's proposed cell mounting structures.

EV3.9.3 Filler

Soft elastic material (filler) is required between cells.

The filler must:

(a) be evenly distributed through the stack, between every cell.

(b) apply pressure evenly to each cell surface.

(c) be non-conductive and fire resistant with a rating of UL94-V0 or compliant with FAR25.

EV3.9.4 Pouch Cell tabs

Pouch cell tabs must be:

(a) Mechanically restrained so they cannot move in relation to the cell due to vibration or physical handling.

(b) connected above the level of the tab insulator. No metallic parts of battery assembly may bridge the insulation gap provided by the tab insulator.

(c) insulated such that it is not possible to short circuit adjacent cells by accident.

EV3.9.5 Repeating Frame

Each cell in a stack must be held in position using a repeating frame or equivalent method. A repeating frame must not:

(a) change the natural shape of the cell.

(b) impinge on the cell separator internal to the cell.

(c) allow the edges of the cell to move in relation to the cell due to vibration or physical handling.

No cell may be in contact with or be likely to contact sharp corners or metal/plastic burrs.

A repeating frame or similar component, if conductive, must be resistively grounded such that an insulation failure will trip the IMD. The grounding resistance should be less than 250 ohms per volt (based on nominal system voltage) and be rated for the power it would dissipate at full system voltage.

EV3.9.6 General Construction

(a) Pouch cells must be handled with care before, during, and after assembly. They must be protected from being dented or deformed, or contaminated with debris such as shavings or filings. Evidence of pouch cell damage or debris will require removal of the damaged or contaminated cells.

(b) Each stack must be firmly anchored in the accumulator enclosure. See **EV3.5**. Construction must be robust and mechanically sound. Accumulator electrical spacing requirements must be observed, including paths through tension rods etc.

ARTICLE EV4 TRACTIVE SYSTEM – GENERAL REQUIREMENTS

Minimum Conductor/Conductor Spacing			
Location		**GLV/TS**	**TS/TS**
Inside Accumulator	PCB	**Table 15**	**Table 10**
	Non-PCB	**Table 14**	**Table 10**
Outside Accumulator	PCB	**Table 15**	Not specified
	Non-PCB	**Table 14**	Not specified

Table 13 - Applicability of different spacing rules

EV4.1 Separation of Tractive System and Grounded Low Voltage System

EV4.1.1 The layout of electrical devices designed by the team must be documented accurately in the ESF.

EV4.1.2 There must be no electrical connection between the frame of the vehicle (or any other conductive surface that might be inadvertently touched by a crew member or spectator), and any part of any tractive system circuits.

EV4.1.3 Tractive system and GLV circuits must be physically segregated. I.e. they may not run through the same conduit or connector, except for interlock circuit connections.

EV4.1.4 Where both tractive system circuits and GLV circuits are present within an enclosure, they must be:

(a) separated by electrical insulating barriers meeting the requirements of **EV4.1.6** or

(b) separated by the spacings shown in **Table 14** through air, or over a surface (similar to those defined in UL1741)

Voltage	**Spacing**
V < 100 VDC	1 cm
100 VDC < V < 200 VDC	2 cm
V > 200 VDC	3 cm

Table 14 - Enclosure Conductor Spacing

EV4.1.5 Insulating barriers used to meet the requirements of **EV4.1.4** Must be:

(a) UL recognized as electrical insulating materials for a temperature of 150 ºC or higher.

(b) Must be adequately robust for the application and in no case thinner than 0.25 mm.

(c) Must be in addition to wire insulation.

(d) Must extend far enough at the edges to block any path between uninsulated GLV and tractive-system conductors shorter than the distances specified in **Table 14**.

EV4.1.6 Spacing must be clearly defined. Components and cables capable of movement must be positively restrained to maintain spacing.

EV4.1.7 If tractive system circuits and GLV circuits are on the same circuit board they must be on separate, clearly defined areas of the board. Furthermore, the tractive system and GLV areas must be clearly marked on the PCB.

EV4.1.8 Required spacing between GLV and TS circuits are as shown in **Table 15**. If a cut or hole in the board is used to allow the "through air" spacing, the cut must not be plated with metal, and the distance around the cut must satisfy the "over surface" spacing requirement.

Maximum Vehicle TS Voltage	**Spacing**	
	Over Surface	**Through Air (Cut in board)**
0-50 VDC	1.6 mm	1.6 mm
50-150 VDC	6.4 mm	3.2 mm
150-300 VDC	9.5 mm	6.4 mm

Table 15 - PCB Conductor Spacing

EV4.1.9 Teams must be prepared to demonstrate spacings on team-built equipment. Information on this must be included in the ESF (**EV9.1**). Spare boards and photographs must be available for inspection. Teams should also be prepared to remove boards for direct inspection if asked to do so during the technical inspection.

EV4.1.10 Plated prototyping boards having plated holes and/or generic conductor patterns may not be used for applications where both GLV and TS circuits are present on the same board. Bare perforated board may be used, if the spacing and marking requirements (**EV4.1.7** and **EV4.1.9**) are met, and if the board is easily removable for inspection.

EV4.2 Positioning of tractive system parts

(See also: Section **T4.5.1**)

EV4.2.1 All parts belonging to the tractive system including conduit, cables and wiring must be contained within the Surface Envelope of the vehicle (See **Figure 24**) such that they are protected against being damaged in case of a crash or roll-over situation or being caught (snagged) by road hazards.

EV4.2.2 If tractive system parts are mounted in a position where damage will occur from a side or rear impact, for example motors at the rear of the car, they must be protected by a structure meeting the requirements of **T3.3**

EV4.2.3 Outboard wheel motors are allowed where the motor is outside of the frame but only if an interlock is added such that the Shutdown Circuit, **EV5.1**, is opened if the wheel assembly is damaged or separates from the car.

EV4.2.4 In side or front view no part of the tractive-system can project below the lower surface of the frame or the monocoque, whichever is applicable.

EV4.2.5 There must be a layer of an electrically insulating material between any tractive terminal or connection and the firewall or frame if they are within 50 mm of one another.

NOTE: If the enclosure of the tractive system component is electrically insulating it can be used to meet this requirement.

EV4.3 Grounding

EV4.3.1 All accessible metal parts of the vehicle, except conductors and components of the GLV system, must have a resistance below 300 mΩ (measured with a 4-point technique at a current of 100 mA) to GLV system ground.

NOTE: Accessible parts include that those that are exposed in the normal driving configuration or when the vehicle is partially disassembled for maintenance or charging.

EV4.3.2 All accessible parts of the vehicle containing conductive material (e.g. coated metal parts, carbon fiber parts, etc.) which might contact a damaged wire or electrical part, no matter if tractive system or GLV, must have a resistance below 100 ohms to GLV system ground. (Measured using a 4-point technique.)

EV4.3.3 Electrical conductivity of any part may be tested by checking any point which is likely to be conductive, for example the driver's harness attachment bolts. Where no convenient conductive point is available then an area of coating may be removed.

NOTE: Carbon fiber parts may need special measures such as using copper mesh or similar modifications to keep the ground resistance below 100 ohms.

NOTE: Conductors used for grounding shall be stranded and 16 AWG minimum.

EV4.4 Tractive System Measuring Points (TSMP)

EV4.4.1 Two tractive system voltage measuring points must be installed in an easily accessible well marked location. Access must not require the removal of body panels.

EV4.4.2 The TSMPs must be protected by a non-conductive housing that can be opened without tools.

EV4.4.3 The TSMP must be protected from being touched with the bare hand / fingers, even when the housing is opened.

EV4.4.4 4 mm safety banana jacks that accept shrouded (sheathed) banana plugs with non-retractable shrouds must be used for the TSMPs.

See **Figure 30** for examples of the correct jacks and of jacks that are not permitted because they do not accept the required plugs (also shown).

EV4.4.5 The TSMPs must be connected to the positive and negative motor controller/inverter supply lines.

EV4.4.6 Each TSMP must be secured with an appropriately rated current limiting resistor. (Fuses are not permitted)

EV4.4.7 The TSMPs will be used to check during Electrical Tech Inspection that the tractive system is shut down properly in the given time; see **EV5.1.3**. They are also needed to ensure the isolation of the tractive system of the vehicle for possible rescue operations after an accident or when work on the vehicle is to be done.

EV4.4.8 Next to the TSMP a GLV system ground measuring point must be installed. This measuring point must be connected to the GLV system ground.

EV4.4.9 A 4 mm safety banana jack that accepts shrouded (sheathed) banana plugs with non-retractable shrouds must be used for the GLV ground measuring point. See **Figure 30** for examples of the correct jacks and of jacks that are not permitted because they do not accept the required plugs (also shown).

Figure 30 - Shrouded 4mm Banana Jack

EV4.5 TSV Insulation, wiring and conduit

EV4.5.1 All parts especially live wires, contacts, etc. of the tractive system need to be isolated by non-conductive material or covers to be protected from being touched. In order to achieve this, it must not be possible to touch any tractive system connections with a 10 cm long, 0.6 cm diameter insulated test probe when the tractive system enclosures are in place. (The “finger probe” test.)

EV4.5.2 Non-conductive covers must prevent inadvertent human contact with any tractive system circuit. This must include crew members working on or inside the vehicle. Covers must be secure and adequately rigid. Body panels that must be removed to access other components, etc. are not a substitute for enclosing tractive system connections.

EV4.5.3 Tractive systems and containers must be protected from moisture in the form of rain or puddles.

EV4.5.4 All controls, indicators and data acquisition connections or similar must be galvanically isolated from the tractive system.

EV4.5.5 All electrical insulating material must be appropriate for the application in which it is used. See: **EV1.3**

EV4.5.6 All wires and terminals and other conductors used in the tractive system must be sized appropriately for the continuous rating of the fuse which protects them. Wires must be marked with wire gauge, temperature rating and insulation voltage rating. Alternatively a manufacturers part number printed on the wire is sufficient if this can be referenced to a manufacturers data sheet.

The minimum acceptable temperature rating for TSV cables is 90°C.

Note: Many high current fuses can allow significant overcurrent conditions which may be adequate to cover the peak power requirements and allow sizing of fusing and wiring according to continuous or RMS needs.

EV4.5.7 All tractive system wiring must be done to professional standards with appropriately sized conductors and terminals and with adequate strain relief and protection from loosening due to vibration etc. Conductors and terminals cannot be modified from their original size/shape and must be appropriate for the connection being made.

EV4.5.8 All tractive system wiring that runs outside of electrical enclosures must be either:

(a) Shielded, dual-insulated cable (in accordance with ISO 6722 / ISO 14572 or approved equivalent) with a minimum cross section of 25 mm^2 (0.039 in^2) **or**

(b) Enclosed in separate orange non-conductive conduit.

EV4.5.9 Tractive system wiring run without conduit per Formula Hybrid rule **EV4.5.8** must be 25 mm^2 or larger and must be shielded.

EV4.5.10 If conduit is used, it must be non-metallic and UL Listed as "Conduit".

Note 1: "Sleeving" does not qualify as conduit.

Note 2: "UL Recognized" is not the same as "UL Listed" and will not be automatically accepted by the technical inspectors.

Note 3: UL Listed Conduit of other colors may be painted orange or wrapped with orange tape provided it is done in a professional manner. I.e. it will not chip or fall off.

EV4.5.11 Teams must receive rules committee approval before using any non-UL Listed conduit.

EV4.5.12 Cable or conduit exiting or entering a tractive system enclosure must use a liquid-tight fitting proving strain relief to the cable or conduit such that it will withstand a force of 200N without straining the cable[10].

The fitting must be one of the following:

(a) A conduit fitting rated for use with the conduit used **or**

(b) A cable gland rated for use with the cable used **or**

(c) A connector rated for use with the cable used. The connector must provide termination of the shield to ground (per **EV4.5.16**) and latch in place securely enough to meet the strain-relief requirements listed above. Both portions of the connector must meet or exceed IEC standards IP53 (mated) and IP20 (unmated).

EV4.5.13 Tractive system wiring outside of the frame must be in conduit, with the exception of connections to wheel motors.

Note: Shielded, dual insulated cables without conduit are only permitted inside the frame.

EV4.5.14 Wiring to outboard wheel motors may be in conduit or shielded dual insulated cable, meeting the specifications of **EV4.5.8**. In either case, at least one wire of the interlock system must accompany each conduit or cable.

EV4.5.15 All tractive system connections must be designed so that they use intentional current paths through conductors such as copper or aluminum and should not rely on steel bolts to be the primary conductor. The connections must not include compressible material such as plastic in the stack-up.

EV4.5.16 If shielded, dual-insulated cable is used, (per **EV4.5.8(a)**) the shield must be terminated and connected to chassis ground at both ends of the cable.

EV4.5.17 Tractive system wiring must be mechanically shielded against damage by rotating and / or moving parts.

[10] This will be tested during the electrical tech inspection by pulling on the conduit using a spring scale.

EV4.6 Tractive System Enclosures

EV4.6.1 Every housing or enclosure containing parts of the tractive system except motor housings must be labeled with sticker(s) (minimum 4 x 4 cm) with a red or black lightning bolt on yellow background or red lightning bolt on white background. The sticker must also contain the text “High Voltage” or something similar if the voltage is more than 30 VDC or 25 VAC.

EV4.6.2 If the housing material is electrically conductive, it must have a minimum-resistance connection to GLV system ground; see **EV4.3**.

EV4.6.3 If external, un-insulated heat sinks are used, they must be properly grounded to the GLV system ground; see **EV4.3**.

EV4.7 High Voltage Disconnect (HVD)

EV4.7.1 It must be possible to positively break the current path of the tractive system accumulator quickly by turning off a disconnect switch or removing an accessible element, fuse or connector.

EV4.7.2 It must be possible to disconnect the HVD within 10 seconds in ready-to-race condition.

Note: Ready-to-race means that the car is fully assembled, including having all body panels in position, with a driver seated in the vehicle and without the car jacked up.

The team must demonstrate this during Electrical Tech Inspection. Being able to quickly disconnect the accumulator(s) from the rest of the tractive system by its connector(s) will satisfy this rule.

EV4.7.3 The disconnect must be clearly marked with "HVD".

EV4.7.4 There must be a positive means of securing the HVD in the disconnected state; for example, a lockable switch can be secured with a zip-tie or simply a clip.

Note: A removable plug will meet this requirement if the plug is secured or fully removed such that it cannot accidentally reconnect.

EV4.7.5 Teams must establish a formal lockout/tagout procedure that is documented in the ESF, and that all team members know and follow.

EV4.7.6 The recommended electrical location for the HVD is near the middle of the accumulator string. In this case, it can serve as one of the SMDs (**EV3.4.3** and **Figure 27**)

EV4.7.7 The HVD must be operable without the use of tools.

EV4.8 Activating the Tractive System

EV4.8.1 The driver must be able to re-activate or reset the tractive system from within the cockpit without the assistance of any other person except for situations in which the AMS or IMD have shut down the tractive system; see **EV5.1.5**.

Note: Resetting or re-activating the tractive system by operating controls which cannot be reached by the driver is considered to be working on the car.

EV4.8.2 At least one action in addition to enabling the shutdown circuits is required to set the car to ready-to-drive mode. (The car is ready to drive as soon as the motor(s) will respond to the input of the torque control sensor / acceleration pedal.)

For example, the additional action could be pressing a dedicated “start” button. However this must be configured such that it cannot inadvertently be left in the “on” position after system shutdown.

Note: This action may also be used to trigger the required “Ready to drive” sound. (**See EV4.11**)

EV4.9 Pre-Charge and Discharge Circuits

EV4.9.1 The AIR contacts must be protected by a circuit that is able to pre-charge the intermediate circuit to at least 90% of the rated accumulator voltage before closing the second AIR. This circuit must be disabled by a de-activated shutdown circuit; see **EV5.1**. Therefore, the pre-charge circuit must not be able to pre-charge the system if the shutdown circuit is open.

EV4.9.2 It is allowed to pre-charge the intermediate circuit for a conservatively calculated time before closing the second AIR. A feedback via monitoring the intermediate circuit voltage is not required.

EV4.9.3 If a discharge circuit is needed to meet the requirements of **EV5.1.3**, it must be designed to handle the maximum discharge current for at least 15 seconds. The calculation proving this must be part of the ESF.

EV4.9.4 The discharge circuit must be fail-safe. I.e. wired in a way that it is always active whenever the shutdown circuit is open or de-energized.

EV4.9.5 The pre-charge circuit must operate regardless of the sequence of operations used to energize the vehicle, including, for example, restarting after being automatically shut down by a safety circuit.

EV4.9.6 All components and insulating materials used in and near the pre-charge circuits must be rated for the maximum expected operating temperature. (See also **EV1.3.1(b)).**

Note: For always-on discharge circuits and other circuits that dissipate significant power for extended time periods, measurements of the maximum operating temperature of the power dissipating components (e.g., resistors) must be included in the ESF. If the resistor operating temperature exceeds the rating of nearby insulating or structural materials, their temperatures must also be measured.

EV4.10 Tractive System Energized Light (TSEL)

EV4.10.1 The car must be equipped with a TSEL mounted under the highest point of the main roll hoop which must be lit and clearly visible any time the AIR coils are energized.

EV4.10.2 The TSEL must be amber.

EV4.10.3 The TSEL must flash continuously with a frequency between 2 Hz and 5 Hz.

EV4.10.4 It must not be possible for the driver's helmet to contact the TSEL.

EV4.10.5 The TSEL must be clearly visible from every horizontal direction, (except for the small angles which are covered by the main roll hoop) even in very bright sunlight.

EV4.10.6 The TSEL must be visible from a person standing up to 3 m away from the TSEL itself. The person's minimum eye height is 1.6 m.

NOTE: If any official e.g. track marshal, scrutineer, etc. considers the TSEL to not be easily visible during track operations the team may not be allowed to compete in any dynamic event before the problem is solved.

EV4.10.7 It is prohibited to mount other lights in proximity to the TSEL.

EV4.11 Ready-To-Drive-Sound

EV4.11.1 The car must make a characteristic sound, for a minimum of 1 second and a maximum of 3 seconds, when it is ready to drive. (**See EV4.8.2**)

(The car is ready to drive as soon as the motor(s) will respond to the input of the torque control sensor / accelerator pedal.)

EV4.11.2 The emitting device must produce a tone of approximately 2500 to 3500 Hz with a minimum loudness of 68 dB(A) at 2 ft. One device that meets this requirement is the Mallory Sonalert SC648AJR[11].

The emitting device must be located and oriented so as to be easily audible from in front of the vehicle in noisy environments.

EV4.12 Tractive System Voltage Present (TSVP) indicators

There must be two TSVP lamps. One mounted on each side of the roll bar in the vicinity of the side-mounted shutdown buttons (**EV5.6**) that can easily be seen from the sides of the vehicle.

EV4.12.1 They must be Red, complying with DOT FMVSS 108 for trailer clearance lamps[12]. See **Figure 31**

EV4.12.2 They must be lit and clearly visible any time the voltage outside the accumulator containers exceeds 32 V or 1/3 the maximum bus voltage, whichever is higher.

EV4.12.3 The TSVP system must be powered entirely by the tractive system and must be directly controlled by voltage being present at the output of the accumulator (no software control is permitted). TS wiring and/or voltages must not be present at the lamps themselves.

Note: This requirement may be met by locating an isolated dc-dc converter inside a TS enclosure, and connecting the output of the dc-dc converter to the lamps. Although the wiring from the dc-dc converter to the TSVP lamps must not be connected to the main GLV system, it must be ground-referenced by connecting one side of it to the frame or GLV ground in order to comply with **EV1.1.4** and **EV1.2.3.**

Figure 31 - TSVP Lamp

ARTICLE EV5 SHUTDOWN CIRCUIT AND SYSTEMS

EV5.1 Shutdown Circuit

EV5.1.1 The shutdown circuit must directly carry the current driving the accumulator isolation relays (AIRs).

EV5.1.2 The shutdown circuit (See: **Figure 35**) must consist of at least:

(a) GLVMS See: **EV5.3**

(b) TSMS See: **EV5.4.1**

[11] http://www.mallory-sonalert.com/specifications/SC648AJR.PDF
[12] http://www.superbrightleds.com - Part Number M9-x4 or equivalent

(c) 2 Side mounted shutdown buttons See: **EV5.6**

(d) Cockpit-mounted shutdown button See: **EV5.7**

(e) Brake over-travel switch. See: **EV5.8**

(f) Insulation monitoring device (IMD) See: **EV5.9**

(g) Accumulator management system (AMS) See: **EV3.7**

(h) Plus all required interlocks.

EV5.1.3 If the shutdown circuit is opened/interrupted the tractive system must be shut down by opening all accumulator isolation relay(s). The voltage in the tractive system must drop to under 30 VDC or 25 VAC RMS in less than five seconds after opening the shutdown circuit.

EV5.1.4 An example schematic of the required shutdown circuit, excluding possibly needed interlock circuitry, is shown in **Figure 35**.

EV5.1.5 It must not be possible for the driver to re-activate the tractive system from within the car in case of an AMS or IMD fault. Remote reset, for example via WLAN or use of the three shutdown buttons or TSMS to reset the AMS or IMD is not permitted.

Note: Applying an IMD test resistor between tractive system positive and GLV system ground must deactivate the system. Disconnecting the test resistor must not re-activate the system. The tractive system must remain inactive until it is manually reset.

EV5.1.6 If the tractive system is de-activated while driving, the motor(s) must spin free, e.g. no braking torque may be derived from the motor(s).

EV5.1.7 The recommended sequence of operation of the shutdown circuit and related systems is shown in the form of a state diagram in **Figure 32**.

Teams are required to either:

(a) Demonstrate that their vehicle operates according to this state diagram, or,

(b) Obtain approval for an alternative state diagram by submitting an electrical rules query on or before the ESF submission deadline, and demonstrate that the vehicle operates according to the approved alternative state diagram.

EV5.1.8 If the shutdown circuit operates differently from the standard or approved alternative state diagram during inspection, the car will be considered to have failed inspection, regardless of whether the way it operates meets other rules requirements.

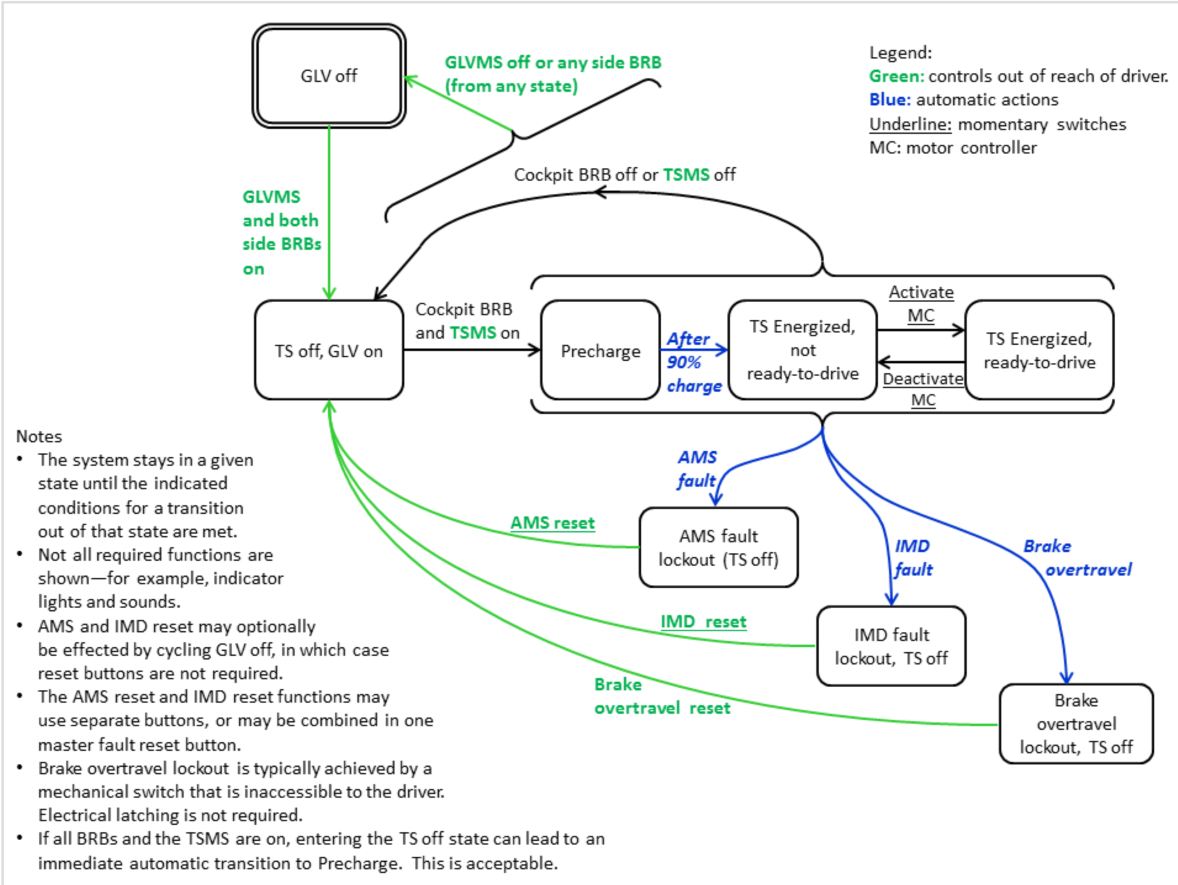

Figure 32 - Example Shutdown State Diagram

EV5.2 Master Switches

EV5.2.1 Each vehicle must have two Master Switches:

(a) Grounded Low Voltage Master Switch (**GLVMS**)

(b) Tractive System Master Switch (**TSMS**).

EV5.2.2 Both master switches must be located on the right side of the vehicle, in proximity to the Main Hoop, at the driver's shoulder height and be easily actuated from outside the car.

EV5.2.3 Both master switches must be of the rotary type, with a red, removable key, similar to the one shown in **Figure 33**.

EV5.2.4 Both master switches must be direct acting. I.e. they may not operate through a relay.

EV5.2.5 The master switches are not allowed to be easily removable, e.g. mounted onto removable body work.

EV5.2.6 The function of both switches must be clearly marked with "**GLV**" and "**TSV**".

EV5.2.7 The "ON" position of both switches must be parallel to the fore-aft axis of the vehicle

Figure 33 - Typical Master Switch

EV5.3 Grounded Low Voltage Master Switch (GLVMS)

EV5.3.1 The GLVMS must disable power to ALL electrical circuits, including the alternator, lights, fuel pump(s), ignition and electrical controls. See **Table 16.**

EV5.3.2 All GLV current must flow through the GLVMS.

EV5.4 Tractive System Master Switch (TSMS)

EV5.4.1 The TSMS must open the Tractive System shutdown circuit.

EV5.4.2 The TSMS must be identified with a sticker with a red lightning bolt in a blue triangle. (See **Figure 34.**)

EV5.4.3 The TSMS must be the last switch in the loop carrying the holding current to the AIRs. (See **Figure 35.**)

Figure 34 - International Kill Switch Symbol

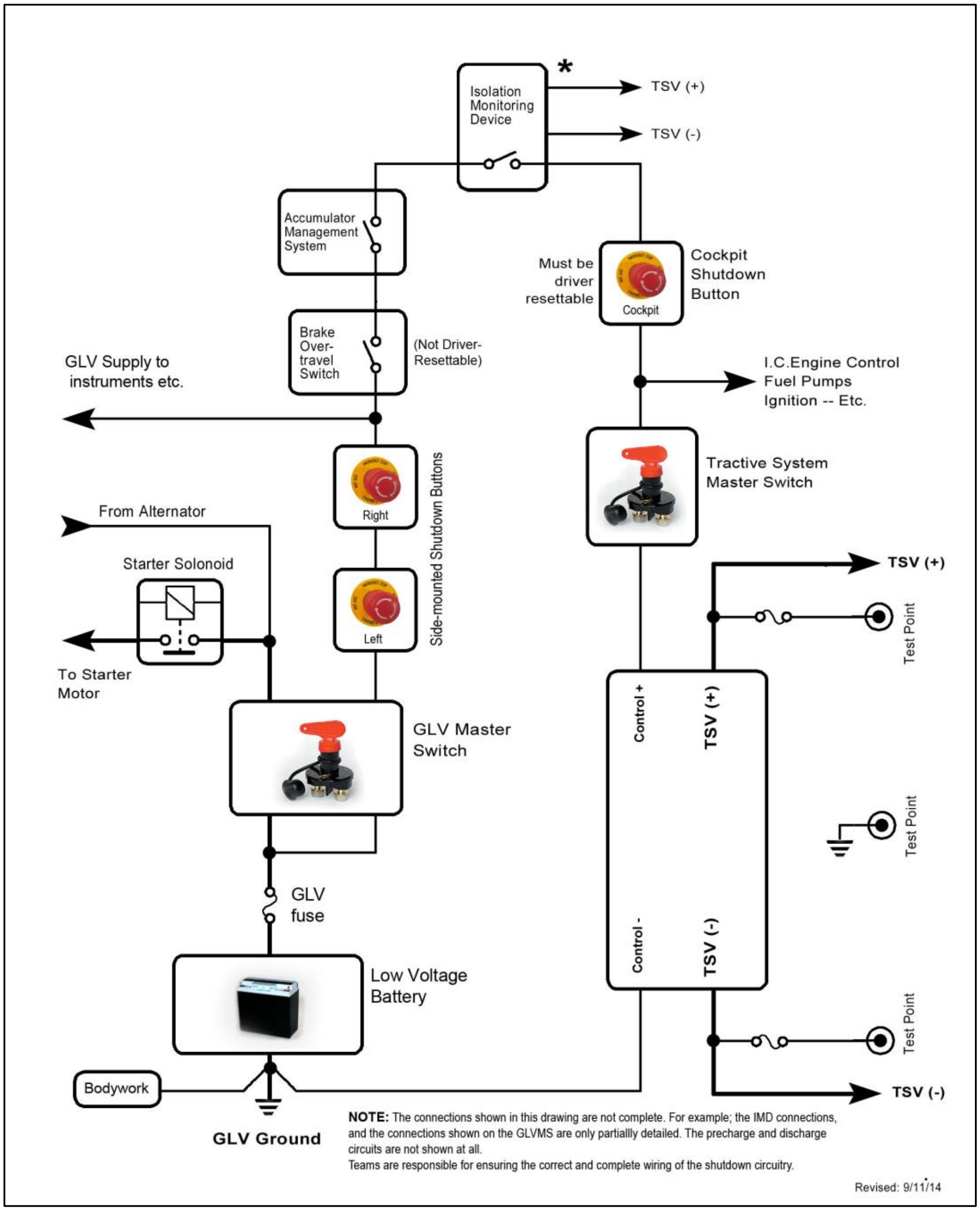

Figure 35 – Example Master Switch and Shutdown Circuit Configuration

EV5.5 Shutdown Buttons

EV5.5.1 A system of three shut-down buttons (“Big Red Buttons” or BRBs) must be installed on the vehicle.

EV5.5.2 The shut-down buttons must all be normally-closed, push-pull or push-rotate where pushing the button opens the circuit.

EV5.5.3 Pressing any of the shut-down buttons must isolate the accumulator from the rest of the vehicle by opening the shutdown circuit. This must also kill the engine and fuel pumps; see **EV5.1**.

EV5.5.4 The shut-down buttons may not act through logic such as a micro-controller or relays.

EV5.5.5 The shutdown buttons may not be easily removable, e.g. they may not be mounted onto removable body work.

EV5.5.6 Electronic systems that contain internal energy storage to allow an orderly shutdown of operations upon the loss of GLV, must be prevented from feeding power back into the GLV.

EV5.6 Side Mounted Shutdown Buttons

EV5.6.1 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. They must be installed facing outward and be easily visible from the sides of the car. The minimum allowed diameter of the side-mounted shutdown buttons is 40 mm.

EV5.6.2 The side-mounted shutdown buttons must shut down all electrical systems. (See: **Table 16**)

EV5.7 Cockpit Shutdown Button

EV5.7.1 One shutdown button is mounted in the cockpit and must be easily accessible by the driver with the steering wheel in any position.

EV5.7.2 The cockpit mounted button must shut down all electrical systems except for those listed in **EV5.7.3** (below).

EV5.7.3 Control, Telemetry, and Instrumentation systems may remained energized if the cockpit BRB is depressed. (See: **Table 16**)

EV5.7.4 The cockpit shutdown button must be driver resettable. I.e. if the driver disables the system by pressing the cockpit-mounted shutdown button, the driver must then be able to restore system operation by pulling the button back out.

Note: There must still be one additional action by the driver after pulling the button back out to reactivate the motor controller. (See: **EV4.8.2**)

EV5.7.5 The cockpit shutdown button must be at least 24 mm in diameter.

EV5.8 Brake Over-Travel Switch

EV5.8.1 The brake over-travel switch, as defined in **T7.3**, must shut down:

(a) The tractive system by opening the shutdown circuit (See: **EV5.1**) **and**

(b) the engine and fuel pumps, as illustrated in **Table 16**.

EV5.8.2 The Brake over-travel switch may not be driver resettable. See: **T7.3.2**.

EV5.9 Insulation Monitoring Device (IMD)

EV5.9.1 Every car must have an insulation monitoring device (IMD) installed in the tractive system.

EV5.9.2 The IMD must be a Bender A-ISOMETER ® iso-F1 IR155-3203 or IR155-3204 or equivalent IMD approved for automotive use. Equivalency may be approved by the rules committee based on the following criteria: robustness to vibration, operating temperature range, availability of a direct output, a self-test facility and must not be powered by the system which is monitored.

EV5.9.3 The response value of the IMD needs to be set to no less than 500 ohm/volt, related to the maximum tractive system operation voltage.

EV5.9.4 In case of an insulation failure or an IMD failure, the IMD must shut down all the electrical systems, open the AIRs and shut down the I.C. drive system. (Some GLV systems may remain energized – See: **Table 16**). This must be done without the use of any logic (e.g., a micro-controller).

EV5.9.5 The tractive system must remain disabled until manually reset by a person other than the driver. It must not be possible for the driver to re-activate the tractive system from within the car in case of an IMD-related fault. (See **Appendix H** – Example Relay Latch Circuits.)

Note: The electrical inspectors may test the IMD by applying a test resistor between tractive system positive (or negative) and GLV system ground. This must deactivate the system. Disconnecting the test resistor must not re-activate the system.

EV5.9.6 The status of the IMD must be shown to the driver by a red indicator light in the cockpit that is easily visible even in bright sunlight. This indicator must light up if the IMD detects an insulation failure or if the IMD detects a failure in its own operation e.g. when it loses reference ground.

EV5.9.7 The IMD indicator light must be clearly marked with the lettering “IMD” or “GFD” (Ground Fault Detector).

EV5.9.8 The IMD ground connection must be wired according to the manufacturer's instructions so that the reference ground detector is functional.

		Controlled Systems			
		Engine Starter (High Current)	GLV Supply to: Instrumentation Data acquisition Computers Telemetry Etc.	I.C. Engine Ignition Fuel pumps Starter solenoid Etc.	AIRs (TS Voltage)
Shutdown Sources	TSMS				OFF
	Cockpit BRB			OFF	OFF
	AMS			OFF	OFF
	IMD			OFF	OFF
	Brake Over-travel			OFF	OFF
	Side-mounted BRBs		OFF	OFF	OFF
	GLVMS	OFF	OFF	OFF	OFF

Table 16 - Shutdown Priority Table

ARTICLE EV6 FUSING

EV6.1 Fusing

EV6.1.1 All electrical systems (including tractive system, grounded low voltage system and charging system) must be appropriately fused.

Note: For further guidance of fusing, see the Fusing Tutorial on the Formula Hybrid Web site.

EV6.1.2 The continuous current rating of a fuse must not be greater than the continuous current rating of any electrical component that it protects. This includes wires, busbars, battery cells or other conductors. See **Appendix E** for ampacity rating of copper wires.

EV6.1.3 All fuses and fuse holders must be rated for the highest voltage in the systems they protect. Fuses used for DC must be rated for DC, and must carry a DC rating equal to or greater than the system voltage of the system in which they are used.

EV6.1.4 All fuses must have an interrupt current rating which is higher than the theoretical short circuit current of the system that it protects.

EV6.1.5 The fuse protecting a circuit or must be physically located at the end of the wiring closest to an uncontrolled energy source (e.g., a battery).

Note: For this rule, a battery is considered an energy source even for wiring intended to charge the battery, because current could flow in the opposite direction in a fault scenario.

EV6.1.6 Circuits with branches using smaller wire than the main circuit require fuses located at the branching point, if the branch wire is too small to be protected by the main fuse for the circuit.

EV6.1.7 If more than one battery cell or capacitor is used to form a set of single cells in parallel such that groups of parallel cells are then combined in series, then either each cell must be appropriately fused or the cell manufacturer must certify that it is acceptable to use this number of single cells in parallel. Any certification must be included in the ESF.

EV6.1.8 If multiple parallel strings of batteries or capacitors are used then each string must be individually fused. If individual fuses are used this must provide a total fusing equal to the number of fuses multiplied by the fuses rating. Any conductors, for example wires, bus bars, cells etc. conducting the entire pack current must be appropriately sized to this total fusing or an additional fuse must be used to protect the conductors.

EV6.1.9 Battery packs with low or non-voltage rated fusible links for cell connections may be used provided that:

(a) A fuse rated at a current three times lower than the sum of the parallel fusible links and complying with **EV6.1** is connected in series.

(b) The accumulator monitoring system can detect an open fusible link, and will shut down the electrical system by opening the AIRs if a fault is detected.

(c) Fusible link current rating is specified in manufacturer's data or suitable test data is provided.

EV6.1.10 Cells with internal over-current protection may be used without external fusing or fusible-links if suitably rated.

Note: Most cell internal over-current protection devices are low or non-voltage rated and conditions of **EV6.1.9** will apply.

EV6.1.11 The ESF must include all details of fuse and fusible link and internal over current protection including documentation from manufacturer for the particular series and parallel configuration, and string voltage.

ARTICLE EV7 ELECTRICAL SYSTEM TESTS

Note: The following three tests must be done in order, and each test passed before the next can be performed. i.e. (IMDT) then (IMT) then the rain test.

EV7.1 Insulation Monitoring Device Test (IMDT)

EV7.1.1 The insulation monitoring device will be tested during Electrical Tech Inspection. This is done by connecting a resistor between the TSMP (see **EV4.4**) and several electrically conductive vehicle parts while the tractive system is active, as shown in the example below.

EV7.1.2 The test is passed if the IMD shuts down the tractive system within 30 seconds at a fault resistance of 250 ohm/volt (50% below the response value).

EV7.1.3 The IMDT may be repeated at any time during the event. After the car passes the test for the first time, critical parts of the tractive system will be sealed. The vehicle is not allowed to take part in any dynamic event if any of the seals are broken until the IMDT is successfully passed again.

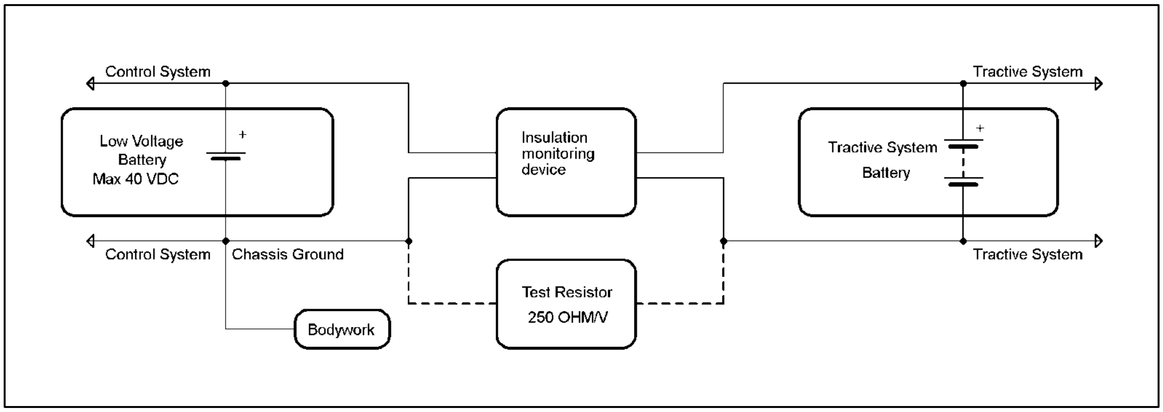

Figure 36 – Insulation Monitoring Device Test

EV7.2 Insulation Measurement Test (IMT)

EV7.2.1 The insulation resistance between the tractive system and control system ground will be measured during Electrical Tech Inspection. The available measurement voltages are 250 V and 500 V. All cars with a maximum nominal operation voltage below 300 V will be measured with the next available voltage level. For example, a 175 V system will be measured with 250 V; a 300 V system will be measured with 500 V etc.

EV7.2.2 To pass the IMT the measured insulation resistance must be at least 500 ohm/volt related to the maximum nominal tractive system operation voltage.

EV7.3 Rain test

EV7.3.1 Upon passing the rain test a vehicle will receive a "Rain Certified" sticker and may be operated in damp or wet conditions. See: **ARTICLE D3**

If the vehicle does not pass the rain test, or if the team chooses to forego the rain test, then the vehicle is not rain certified and will not be allowed to operate in damp or wet conditions.

EV7.3.2 During the rain test the tractive system must be active and none of the driven wheels may touch the ground. It is not allowed to have a driver seated in the car during the rain test.

EV7.3.3 Water will then be sprayed at the car from any possible direction for 120 seconds. The water spray will be rain like. Therefore there will be no direct high-pressure water jet shot at the car.

EV7.3.4 The test is passed if the insulation monitoring device does not react while water is sprayed at the car and 120 seconds after the water spray has stopped. Therefore the total time of the rain test is 240 seconds, 120 seconds with water-spray and 120 seconds without.

EV7.3.5 Teams must make sure that water cannot aggregate anywhere in the chassis.

ARTICLE EV8 HIGH VOLTAGE PROCEDURES & TOOLS

EV8.1 Working on Tractive System Accumulator Containers

EV8.1.1 If the organizers have provided a "Designated Charging Area", then opening of or working on accumulator containers is only allowed in that charging area, see **EV8.2**, and during Electrical Tech Inspection.

EV8.1.2 Whenever the accumulator containers are opened the accumulator segments must be separated by using the maintenance plugs; see **EV3.4.3**.

EV8.1.3 Whenever the accumulator or tractive system is being worked on, only appropriate insulated tools may be used.

EV8.1.4 Whenever the accumulator or tractive system is open or being worked on, a "Danger High Voltage" sign (or other warning device provided by the organizers) must be displayed.

Note: Be sure to remove the warning sign or indicator once the hazards are no longer present.

EV8.2 Charging

EV8.2.1 If the organizers have provided a "Designated Charging Area", then charging tractive system accumulators is only allowed inside this area.

EV8.2.2 The chassis or frame of the vehicle must be securely connected to earth ground using a (minimum) 16 AWG green wire during charging.

Note: Earth ground can be a water pipe or metal electrical conduit permanently installed at the competition site.

EV8.2.3 If the organizers have provided "High Voltage" signs and/or beacons these must be displayed prominently while charging.

EV8.2.4 The accumulators may be charged inside the vehicle or outside, if fitted with a removable accumulator container.

EV8.2.5 In addition to the requirement in **EV8.2.9**, the accumulator containers or the car itself, depending on whether the accumulators are charged externally or internally, must have a label with the following data during charging:

(a) Team name

(b) RSO Name with cell phone number(s).

EV8.2.6 Only chargers presented and sealed at Electrical Tech Inspection are allowed. All connections of the charger(s) must be isolated and covered. No open connections are allowed.

EV8.2.7 No work is allowed on any of the car's systems during charging if the accumulators are charging inside of or connected to the car.

EV8.2.8 No grinding, drilling, or any other activity that could produce either sparks or conductive debris. is allowed in the charging area.

EV8.2.9 At least one team member who has knowledge of the charging process must stay with the accumulator(s) / car during charging.

EV8.2.10 Moving accumulator cells and/or stack(s) around at the event site is only allowed inside a completely closed accumulator container.

EV8.2.11 High Voltage wiring in an off board charger does not require conduit; however it must be a UL listed flexible cable that complies with NEC Article 400; jacketed.

EV8.2.12 All chargers must be UL (Underwriters Laboratories) listed. Any waivers of this requirement require approval in advance, based on documentation of the safe design and construction of the system, including galvanic isolation between the input and output of the charger. Waivers for chargers must be submitted at least 30 days prior to the start of the competition.

EV8.2.13 The vehicle charging connection must be appropriately fused for the rating of its connector and cabling in accordance with **EV6.1.1**.

EV8.2.14 The charging port shall only be energized when the tractive system is energized and the TSEL is flashing.

There shall be no voltage present on the charging port when the tractive system is de-energized.

The external charging system shall be disconnected if there is an AMS or IMD fault, or if one of the shutdown buttons (See **EV5.5**) is pressed.

EV8.3 Accumulator Container Hand Cart

EV8.3.1 In case removable accumulator containers are used in order to accommodate charging, a hand cart to transport the accumulators must be presented at Electrical Tech Inspection.

EV8.3.2 The hand cart must have a brake such that it can only be released using a dead man's switch, i.e. the brake is always on except when someone releases it by pushing a handle for example.

EV8.3.3 The brake must be capable to stop the fully loaded accumulator container hand cart.

EV8.3.4 The hand cart must be able to carry the load of the accumulator container(s).

EV8.3.5 The hand cart(s) must be used whenever the accumulator container(s) are transported on the event site.

EV8.4 Required Equipment

Each team must have the following equipment accessible at all times during the event. The equipment must be in good condition, and must be presented during technical inspection. (See also **Appendix F**)

(a) Multimeter rated for CAT III use with UL approval. (Must accept shrouded banana leads.)

(b) Multimeter leads with shrouded banana leads at one end and probes at the other end. The probes must have finger guards and no more than 3 mm of exposed metal. (Heat shrink tubing may be used to cover additional exposed metal on probes.)

(c) At least one pair of leads with shrouded banana plugs at both ends.

(d) Insulated tools. (I.e. screwdrivers, wrenches etc. compatible with all fasteners used inside the accumulator housing or on other TSV connections.)

(e) Face shield which meets ANSI Z87.1-2003

(f) HV insulating gloves (tested within the last14 Months) plus protective outer gloves.

(g) HV insulating blankets of sufficient size and quantity to cover the vehicle’s accumulator(s).

(h) Safety glasses with side shields (ANSI Z87.1-2003 compliant) for all team members.

Note: All electrical safety items must be rated for at least the maximum tractive system voltage.

ARTICLE EV9 ELECTRICAL SYSTEM FORM AND FMEA

EV9.1 Electrical System Form (ESF)

EV9.1.1 All teams must submit clearly structured documentation, prior to the posted deadline, of their entire electrical system (including control and tractive system) called the Electrical System Form (ESF).

EV9.1.2 The ESF must illustrate the interconnection of all electric components including the voltage level, the topology, the wiring in the car and the construction and build of the accumulator(s).

EV9.1.3 Teams must present data pages with rated specifications for all tractive system parts used and show that none of these ratings are exceeded (including wiring components). This includes stress caused by the environment e.g. high temperatures, vibration, etc.

EV9.1.4 MSDS Sheets must be included for the accumulator cells.

EV9.1.5 A template containing the required structure for the ESF will be made available online.

EV9.1.6 The ESF must be submitted as an Adobe PDF file.

EV9.2 Failure Modes and Effects Analysis (FMEA)

EV9.2.1 Teams must submit a complete failure modes and effects analysis (FMEA) of the tractive system prior to the event.

EV9.2.2 A template including required failures to be described will be made available online.

Note: Do not change the format of the template. Pictures, schematics and data sheets to be referenced in the FMEA must be included in the ESF.

ARTICLE EV10 ACRONYMS

AC	Alternating Current
AIR	Accumulator Isolation Relay
AMS	Accumulator Management System
ANSI	American National Standards Institute
BRB	Big Red Buttons (Emergency shutdown switches)
DC	Direct Current
ESF	Electrical System Form
EV	Electrical Vehicle
FMEA	Failure Modes and Effects Analysis
GLV	Grounded Low Voltage
GLVMS	Grounded Low Voltage Master Switch
HVD	High Voltage Disconnect
IMD	Insulation Monitoring Device
IMDT	Insulation Monitoring Device Test
IMT	Insulation Measurement Test
LV	Low Voltage
NiMH	Nickel Metal Hydride
PCB	Printed Circuit Board
RMS	Root Mean Squared
TSEL	Tractive System Energized Lamp (Formerly TSAL)
TSAL	Tractive System Active Light (Superseded)
TSMP	Tractive System Measuring Point
TSMS	Tractive System Master Switch
TSV	Tractive System Voltage (Formerly “HV”)
TSVP	Tractive Voltage Present
UL	Underwriters Laboratory

PART S - STATIC EVENTS

PEER Inspection	*0 points*
Technical Inspection	*0 points*
Presentation	100 points
Design	200 points
Total	300 points

Table 17 – Static Event Maximum Scores

ARTICLE S1 PRE-EVENT ELECTRICAL REVIEW (PEER)

S1.1.1 The first inspection of a vehicles electrical systems will take place at the team's home institution approximately three (3) weeks before the competition.

The review will be performed by volunteer Electrical Engineers from the IEEE or by other qualified professionals.

Note: The electrical reviewers are professionals who have volunteered their time to assist your team meet the Formula Hybrid electrical rules requirements. For the review to be effective, <u>the vehicle ESF and schematics must be complete and as accurate as possible</u>. Asking these engineers to review your vehicle with incomplete system documentation could be seen as disrespectful.

S1.1.2 Vehicles should be presented in a condition that will allow an inspection of its electrical systems.

At a minimum this would be:

- Major electrical components mounted in their final locations within the vehicle.
- GLV control wiring in place and functional
- TSV wiring in place with conduit and strain relief where required.
- TSV protective covers mounted in their final positions.
- Accumulator enclosures finished and mounted to the vehicle structure with conduit, strain relief etc. in place.

Note: Accumulator devices do not need to be installed for the PEER inspection. However the AIRs should be located in their final positions and should be functional, with all TSV wiring outboard of the AIRs in place. AMS sense wiring should be complete up to where they would connect to the accumulator cells.

S1.1.3 Teams will be contacted by the organizers approximately one month before the competition to schedule the technical reviews.

ARTICLE S2 TECHNICAL INSPECTION

S2.1 Objective

S2.1.1 The objective of technical inspection is to determine if the vehicle meets the FH rules requirements and restrictions and if, considered as a whole, it satisfies the intent of the Rules.

S2.1.2 For purposes of interpretation and inspection the violation of the intent of a rule is considered a violation of the rule itself.

S2.1.3 Technical inspection is a non-scored activity.

S2.2 Inspection & Testing Requirement

S2.2.1 Each vehicle must pass all parts of technical inspection and testing, and bear the inspection stickers, before it is permitted to participate in any dynamic event or to run on the practice track. The exact procedures and instruments employed for inspection and testing are entirely at the discretion of the Chief Technical Inspector.

S2.2.2 Technical inspection will examine all items included on the Inspection Form found on the Formula Hybrid website, all the items on the Required Equipment list (**Appendix F**) plus any other items the inspectors may wish to examine to ensure conformance with the Rules.

S2.2.3 All items on the Inspection Form must be clearly visible to the technical inspectors.

S2.2.4 Visible access can be provided by removing body panels or by providing removable access panels.

S2.2.5 Once a vehicle has passed inspection, except as specifically allowed under **T1.2** Modification and Repairs, it must remain in the "As-approved" condition throughout the competition and must not be modified.

S2.2.6 Decisions of the inspectors and the Chief Scrutineer concerning vehicle compliance are final and are not permitted to be appealed.

S2.2.7 Technical inspection is conducted only to determine if the vehicle complies with the requirements and restrictions of the Formula Hybrid rules.

S2.2.8 Technical approval is valid only for the duration of the specific Formula Hybrid competition during which the inspection is conducted.

S2.3 Inspection Condition

Vehicles must be presented for technical inspection in finished condition, i.e. fully assembled, complete and ready-to-run. Technical inspectors will not inspect any vehicle presented for inspection in an unfinished state.

This requirement will be waived if the vehicle is registered as an HIP (**A2.3)** or SEO (**S4.10.2)**.

Note: Cars may be presented for technical inspection even if final tuning and set-up has not been finished.

S2.4 Inspection Process

Vehicle inspection will consist of five separate parts as follows:

(a) **Part 1: Preliminary Electrical Inspection**

Vehicles must pass a preliminary electrical safety inspection before they will be permitted to proceed to Mechanical Scrutineering. A sticker will be affixed to the vehicle upon passing the Preliminary Electrical Inspection.

(b) **Part 2: Scrutineering - Mechanical**

Each vehicle will be inspected to determine if it complies with the mechanical and structural requirements of the rules. This inspection will include examination of the driver's equipment (**ARTICLE T5**) a test of the emergency shutdown response time (Rule **T4.9**) and a test of the driver egress time (Rule **T4.8**).

The vehicle will be weighed, and the weight placed on a sticker affixed to the vehicle for reference during the Design event.

(c) **Part 3: Scrutineering – Electrical**

Each vehicle will be inspected for compliance with the electrical portions of the rules.

Note: This is an extensive and detailed inspection. Teams that arrive well-prepared can reduce the time spent in electrical inspection considerably.

The electrical inspection will include all the tests listed in **ARTICLE EV7**;

Note: In addition to the electrical rules contained in this document, the electrical inspectors will use SAE Standard J1673 "High Voltage Automotive Wiring Assembly Design" as the definitive reference for sound wiring practices.

Note: Parts 1, 2 and 3 must be passed before a vehicle may apply for Part 4 or Part 5 inspection.

(d) **Part 4: Tilt Table Tests**

Each vehicle will be tested to insure it satisfies both the 45 degree (45°) fuel and fluid tilt requirement (Rule **T8.5.1**) and the 60 degree (60°) stability requirement (Rule **T6.7**).

(e) **Part 5: Noise, Master Switch, and Brake Tests.**

Noise will be tested by the specified method (Rule **IC3.2**). If the vehicle passes the noise test then its master switches (**ARTICLE IC4** and **ARTICLE EV5**) will be tested.

Once the vehicle has passed the noise, master switch tests and then its brakes will be tested by the specified method (see Rule **T7.2**).

S2.5 Correction and Re-inspection

S2.5.1 If any part of a vehicle does not comply with the Rules, or is otherwise deemed to be a concern, then the team must correct the problem and have the car re-inspected.

S2.5.2 The judges and inspectors have the right to re-inspect any vehicle at any time during the competition and require correction of non-compliance.

S2.6 Inspection Stickers

Inspection stickers issued following the completion of any part of Technical Inspection will be placed on the upper nose of the vehicle as specified in **T13.4** "Technical Inspection Sticker Space". Inspection stickers are issued contingent on the vehicle remaining in the required condition throughout the competition. Inspection stickers may be removed from vehicles that are not in compliance with the Rules or are required to be re-inspected.

ARTICLE S3 PROJECT MANAGEMENT

S3.1 Project Management Objective

The objective of the Formula Hybrid Project Management component is to evaluate the team's ability to structure and execute a project management plan that helps the team define and meet its goals.

Note: For guidance and specific examples see:

(a) **Appendix K** *Application of the Project Management Method to Formula Hybrid*.

(b) Formula Hybrid Tech Support Page at: http://www.formula-hybrid.org/students/tech-support/

S3.2 Project Management Segments

The Formula Hybrid Project Management component consists of three parts: submission of a written project plan and a written interim report followed by an oral final presentation to be delivered before a review board at the competition.

Segment	Points
Project Plan	40
Interim Progress Report	10
Presentation	50
Total	100

Table 18 - Project Management Scoring

S3.3 Submission 1 -- Project Plan

S3.3.1 Each Formula Hybrid team is required to submit a formal project plan that reflects their goals and objectives for the upcoming competition, the management structure and tasks that will be completed to accomplish these objectives, and the time schedule over which these tasks will be performed. The topics covered in the project plan should include:

(a) Scope: What will be accomplished, “SMART” goals and objectives, major deliverables and milestones

(b) Structure: Organization of the project team, Succession Plan, Work Breakdown Structure, project schedule

(c) Expected Results: “measures of success”, quantifiable attributes used to determine the extent to which the goals and objectives have been achieved

(d) Change Management Process: system designed by the team for administering project change and managing uncertainty.

S3.3.2 This Project Plan must consist of at least (1) page and not exceed three (3) pages of text. Appendixes may be attached to the back of the Project Plan.

Note 1: Appendixes do not count as “pages”.

Note 2: Submittal of the Project Plan is due soon after registration closes. See the Formula Hybrid rules and deadlines page at: http://www.formula-hybrid.org/students/rules-and-deadlines for the exact due date.

S3.4 Submission 2 -- Interim Progress Report

S3.4.1 Following completion and acceptance of the formal project plan by team members, the project team begins the execution phase. During this phase, members of the project team and other stakeholders must be updated periodically on progress being made and on issues identified that put the project schedule at risk. The project manager communicates this information by periodically issuing interim progress reports.

S3.4.2 These reports are not lengthy but are intended to clearly and concisely communicate to others the status of the project. The progress report is also a way to document changes to the project scope and plan that have been approved using the change management process. The topics covered in the progress report should include:

(a) **Scope:** Deliverables and milestones achieved, and if not achieved explain why; revised project plan if changes were made

(b) **Structure:** estimate of schedule status, ahead, behind, on plan; verify major accomplishments (data, descriptions, photographs).

(c) **Expected Results:** Comparison of actual versus expected results at the project midpoint; if necessary, actions being taken to get project back on schedule; identify major barriers encountered, approaches to overcome challenges

(d) **Change Management Process**: Significant change requests made and approved; effectiveness of the change management process, revision made to the process

S3.4.3 The Interim Progress Report must not exceed one (1) page. Appendixes may be included with the Progress Report.

Note 1: Appendixes do not count as "pages".

Note 2: See the Formula Hybrid rules and deadlines page at: http://www.formula-hybrid.org/students/rules-and-deadlines for the due date of the Interim Progress Report.

S3.5 Submission Formats

S3.5.1 The Project Plan and Interim Progress Reports must be submitted electronically in separate Adobe Acrobat™ Format files (*.pdf file). These documents must each be a single file (text, drawings, and optional content).

S3.5.2 These Report files must be named as follows: *carnumber_schoolname_Project Plan.pdf* and *carnumber_schoolname_Progress Report.pdf* using the SAE assigned car number and the complete school name, e.g.:

999_University of SAE_Project Plan.pdf

999_University of SAE_Progress Report.pdf

S3.6 Submission Deadlines

The Project Plan and Interim Progress Report must be submitted by the date and time shown in the Action Deadlines. (See **A9.2**). Submission instructions are in section **A9.2**.

You will receive confirmation of receipt via email and submissions will be posted on the event website once report is reviewed for accuracy. Teams should have a printed copy of this reply available at the competition as proof of submission in the event of discrepancy.

S3.6.1 Penalty for Late Submission or Non-Submission

See section **A9.3** for late submission penalties.

S3.7 Presentation

S3.7.1 Objective: Teams must convince a review board that the team's project has been carefully planned, effectively and dynamically executed.

S3.7.2 The Project Management presentation will be made on the static events day. Presentation times will be scheduled by the organizers and either posted in advance on the competition website or released during on-site registration (or both).

Note: The presentation schedule set by Formula Hybrid organizers is final and non-negotiable.

S3.7.3 Teams that fail to make their presentation during their assigned time period will receive zero (0) points for that section of the event.

Note: Teams are encouraged to arrive fifteen (15) minutes prior to their scheduled presentation time to deal with unexpected technical difficulties.

The scoring of the event is based on the average of the presentation judging forms.

S3.8 Presentation Format

The presentation judges should be regarded as a project management or executive review board.

S3.8.1 Evaluation Criteria - Project Management presentations will be evaluated team's accomplishments in project planning, execution, change management, and succession planning. Presentation organization and quality of visual aids as well as the presenters' delivery, timing and the team's response to questions will also be factors in the evaluation.

For specific criteria see **Appendix C**: Project Management Presentation Judging Form.

S3.8.2 One or more team members will give the presentation to the judges. It is strongly suggested, although not required, that the project manager accompany the presentation team. All team members who will give any part of the presentation, or who will respond to the judges' questions, must be in the podium area when the presentation starts and must be introduced to the judges. Team members who are part of this "presentation group" may answer the judge's questions even if they did not speak during the presentation itself.

S3.8.3 Presentations are limited to a maximum of ten (10) minutes. Teams may use hand-outs, posters, etc. to convey information relevant to their project management case that cannot be contained within a 10-minute presentation.

S3.8.4 The judges will stop any presentation exceeding ten minutes. The presentation itself will not be interrupted by questions. Immediately following the presentation there will be a question and answer session of up to five (5) minutes. Only judges may ask questions. Only team members who are part of the "presentation group" may answer the judges' questions.

S3.8.5 Feedback on presentations will take place immediately following the question and answer session. Judges and any team member present may ask questions. The maximum feedback time for each team is ten (10) minutes.

S3.8.6 Formula Hybrid may record a team's presentation for publication or educational purposes. Students have the right to opt out of being recorded - however they must notify the chief presentation judge in writing prior to the beginning of their presentation.

S3.9 Data Projection Equipment

Projection equipment is provided by the organizers. However teams are advised to bring their own computer equipment in the event the organizer's equipment malfunctions or is not compatible with their presentation software.

S3.10 Scoring Formula

The Project Management score (P_{your}) is equal to the Project Plan score (max. 40 points), plus the Interim Progress Report score (max. 10 points), plus the presentation score (max. 50 points). It is then normalized as follows:

$$FINAL\ PROJECT\ MANAGEMENT\ SCORE = 100 \cdot \frac{P_{your}}{P_{max}}$$

Where:
P_{max} is the highest point score awarded to any team in your vehicle category
P_{your} is the point score awarded to your team.

Notes:

1. It is intended that the scores will range from near zero (0) to one hundred (100) to provide good separation.
2. The Project Management Presentation Captain may at his/her discretion, normalize the scores of different presentation judging teams.

3. Penalties associated with late submittals (see **A9.3** “Late Submission Penalties”) are applied after the scores are normalized up to a maximum of the teams normalized Project Management Score.

ARTICLE S4 DESIGN EVENT

S4.1 Design Event Objective

The concept of the design event is to evaluate the engineering effort that went into the design of the car (or the substantial modifications to a prior year car), and how the engineering meets the intent of the market. The car that illustrates the best use of engineering to meet the design goals and the best understanding of the design by the team members will win the design event.

Comment: Teams are reminded that FH is an engineering design competition and that in the Design event, teams are evaluated on their design. Components and systems that are incorporated into the design as finished items are not evaluated as a student designed unit, but are only assessed on the team’s selection and application of that unit. For example, teams that design and fabricate their own shocks are evaluated on the shock design itself as well as the shock’s application within the suspension system. Teams using commercially available shocks are evaluated only on selection and application within the suspension system.

S4.2 Submission Requirements

S4.2.1 **Design Report -** Judging will start with a Design Review before the event.

The principal document submitted for the Design Review is a Design Report. This report must not exceed eight (8) pages, consisting of not more than four (4) pages of text, three (3) pages of drawings (see **S4.4**, “Vehicle Drawings”) and one (1) optional page containing content to be defined by the team (photos, graphs, etc…).

This document should contain a brief description of the vehicle with the majority of the report specifically addressing only the engineering, design features, and vehicle concepts new for this year's event. Include a list of different analysis and testing techniques (FEA, dynamometer testing, etc.).

Evidence of this analysis and back-up data should be brought to the competition and be available, on request, for review by the judges. These documents will be used by the judges to sort teams into the appropriate design groups based on the quality of their review.

Comment: Consider your Design Report to be the “resume of your car”.

S4.2.2 **Sustainability Report –** The Sustainability Report is a separate document to be submitted at the same time as the Design Report. This report will contribute to the team’s overall design score and may be used as partial criteria for an efficiency award given out by one of the sponsors. The report should be no longer than one page, including text, diagrams and formulas, and be submitted as a separate .pdf file.

S4.2.3 **Design Spec Sheet -** In addition to the above documents, a completed FH Design Spec Sheet must also be submitted. The FH Design Spec Sheet template can be found on the FH website. (See **ARTICLE A10**). Do not alter or re-format the template prior to submission.

The design judges realize that final design refinements and vehicle development may cause the submitted figures to diverge slightly from those of the completed vehicle. For specifications that are subject to tuning, an anticipated range of values may be appropriate.

The Design Report, Sustainability Report and the Design Spec Sheet, while related documents, should stand alone and be considered three (3) separate submissions. Three separate file submissions are required.

S4.3 Sustainability Requirement

S4.3.1 Sustainability is an oft used, but ill-defined objective of minimizing a product's impact on the environment. One of the ways to quantify sustainability is to calculate or measure the CO_2 generated by a vehicle. Two techniques for automobiles are common, LCA (Life Cycle Analysis) and WTW (Well To Wheels) analysis. Although LCA is more comprehensive, a WTW analysis is easier to perform and nearly as useful, accounting for approximately 80% of an automobile's lifetime CO_2 emissions.

S4.3.2 CO_2 reduction is one justification for transitioning to alternative powertrains or fuels. To properly compare and contrast various design and fuel options, FH is requiring a one page sustainability report analysis as part of the design report. This analysis consists of three parts:

(a) Calculation of the CO_2 generated in the production and delivery of each MJ of fuel used by the vehicle (well to tank).

(b) Calculation of the CO_2 generated by the vehicle per km of the endurance race (tank to wheels)

(c) A discussion of how sustainability and efficiency objectives affected the engineering and design decision process. For example, how did the team's performance and efficiency targets influence the type of energy storage, its capacity and liquid fuel choice?

S4.3.3 For part **S4.3.2(a)** teams are encouraged to use public databases to calculate CO_2 generated during the production and delivery of all fuels used by the vehicle. Do not include factors for land use change and reference all sources.

S4.3.4 For part **S4.3.2(b)** calculate vehicle fuel consumption and CO_2 emissions generated during the endurance event as defined for the current year. (See **ARTICLE D7**). Reference all sources and use only publically available vehicle simulation models. This can be done by modeling or extrapolation of vehicle test data.

S4.3.5 At a minimum, provide the following data for parts **S4.3.2(a)** & **S4.3.2(b)**

	Electricity	Fuel
CO_2 generated in fuel production	CO_2/MJ	CO_2/MJ
Delivery efficiency – from plant to battery or tank	%	%
Fuel consumption	MJ/km	MJ/km
Total CO_2 generated	kg/km	kg/km

Table 19 – Minimum Sustainability Data Requirements

S4.3.6 The Sustainability Report is worth thirty (30) points - 15 points for parts **S4.3.2(a)** and **S4.3.2(b)** and 15 points for part **S4.3.2(c)** - toward the team's overall design score.

S4.4 Vehicle Drawings

S4.4.1 The Design report must include all of the following drawings:

(a) One set of 3 view drawings showing the vehicle from the front, top, and side.

(b) A schematic of the high voltage wiring showing the wiring between the major components. (See section **EV9.1**)

(c) A wiring diagram superimposed on a top view of the vehicle showing the locations of all major high voltage components and the routing of high voltage wiring. The components shown must (at a minimum) include all those listed in the major sections of the ESF (See section **EV9.1**)

S4.5 Submission Formats

S4.5.1 The Design and Sustainability Reports must be submitted electronically in separate Adobe Acrobat™ Format files (*.pdf file). These documents must each be a single file (text, drawings, and optional content). These Report files must be named as follows: carnumber_schoolname_Design.pdf and carnumber_schoolname_Sustain.pdf using the SAE assigned car number and the complete school name, e.g.:

999_University of SAE_Design.pdf

999_University of SAE_Sustain.pdf

S4.5.2 Design Spec Sheets must be submitted electronically in Microsoft Excel™ Format. The format of the Spec Sheet MUST NOT be altered. Similar to the Design Report, the Design Spec Sheet file must be named as follows: carnumber_schoolname_Specs.xls (or .xlsx) using the Formula Hybrid assigned car number and the complete school name, e.g.

999_University of SAE_Specs.xls (or)

999_University of SAE_Specs.xlsx

WARNING – Failure to exactly follow the above submission requirements may result in exclusion from the Design Event. If your files are not submitted in the required format or are not properly named then they cannot be included in the documents provided to the design judges and your team will be excluded from the event.

S4.6 Excess Size Design Reports

If a team submits a Design Report that exceeds four (4) pages of text, three (3) pages of drawing and one (1) optional page, then only the first four pages of text, three pages of drawings and first optional page will be read and evaluated by the judges.

Note: If included, cover sheets and tables of contents will count as text pages.

S4.7 Submission Deadlines

The Design Report and the Design Spec Sheets must be submitted by the date and time shown in the Action Deadlines. (See **A9.2**). You will receive confirmation of receipt via email and/or the event website once report is reviewed for accuracy. Teams should have a printed copy of this reply available at the competition as proof of submission in the event of discrepancy.

S4.8 Penalty for Late Submission or Non-Submission

See section **A9.3** for late submission penalties.

S4.9 Penalty for Unsatisfactory Submissions

S4.9.1 At the discretion of the judges, teams that submit a Design Report or a Design Spec Sheet which is deemed to be unsatisfactory, will not compete in the design event, but may receive between five (5) and twenty (20) points for their efforts.

S4.9.2 Failure to fully document the changes made for the current year's event to a vehicle used in prior FH events, or reuse of any part of a prior year design report are just two examples of Unsatisfactory Submissions

S4.10 Vehicle Condition

S4.10.1 With the exception of Static Event Only (See **S4.10.2**) or Hybrid In Progress (See **A2.3**) cars must be presented for design judging in finished condition, i.e. fully assembled, complete and ready-to-run. The judges will not evaluate any car that is presented at the design event in what they consider to be an unfinished state.

Unfinished cars that are refused judging will receive zero (0) points for design. Point penalties may be assessed for cars with obvious preparation issues, e.g. notably loose or missing fasteners.

Note: Cars can be presented for design judging without having passed technical inspection, or if final tuning and setup is still in progress.

S4.10.2 A team may declare themselves as Static Events Only (SEO) and participate in the design[13] and other static events even if the vehicle is in an unfinished state.

(a) An SEO vehicle may not participate in any of the dynamic events.

(b) An SEO vehicle may continue the technical inspection process, but will be given a lower priority than the non-SEO teams.

An SEO declaration must be submitted in writing to the organizers before the start of the design event.

S4.11 Judging Criteria

The design judges will evaluate the engineering effort based upon the team's Design Report, Spec Sheet, responses to questions and an inspection of the car. The design judges will inspect the car to determine if the design concepts are adequate and appropriate for the application (relative to the objectives set forth in the rules). It is the responsibility of the judges to deduct points on the design judging form, as given in Appendix F, if the team cannot adequately explain the engineering and construction of the car.

S4.12 Judging Sequence

The actual format of the design event may change from year to year as determined by the organizing body. Formula Hybrid Design Judging will normally involve two parts:

(a) Initial judging of all vehicles

(b) Final judging ranking the top 2 to 4 vehicles.

[13] Provided the team has met the document submission requirements of **A9.3(d)**

S4.13 Scoring Formula

The scoring of the event is based on either the average of the scores from the Design Judging Forms (see **Appendix D**) or the consensus of the judging team.

$$DESIGN\ SCORE = 200\ \frac{P_{your}}{P_{max}}$$

Where: P_{max} is the highest point score awarded to any team in your vehicle category

P_{your} is the point score awarded to your team

Notes:

1. It is intended that the scores will range from near zero (0) to two hundred (200) to provide good separation.
2. The Design Event Captain may at his/her discretion normalize the scores of different judging teams.
3. Penalties applied during the Design Event (see **Appendix D** "Design Judging Form - Miscellaneous") are applied before the scores are normalized.
4. Penalties associated with late submittals (see **A9.3** "Late Submission Penalties") are applied after the scores are normalized up to a maximum of the teams normalized Design Score.

S4.14 Support Materials

Teams may bring with them to the Design Event any photographs, drawings, plans, charts, example components or other materials that they believe are needed to support the presentation of the vehicle and the discussion of the their development process.

PART D - DYNAMIC EVENTS

ARTICLE D1 DYNAMIC EVENTS GENERAL

D1.1 Maximum Scores

Event	Hybrid	Electric
Acceleration	150 Points	75 Points
Autocross	150 Points	150 Points
Endurance	400 Points	400 Points
Total	700 Points	625 Points

Table 20 – Dynamic Event Maximum Scores

D1.2 Driving Behavior

During the Formula Hybrid Competition, any driving behavior that, in the opinion of the Event Captain, the Director of Operations or the Clerk of the Course, could result in potential injury to an official, worker, spectator or other driver, will result in a penalty.

Depending on the potential consequences of the behavior, the penalty will range from an admonishment, to disqualification of that driver from all events, to disqualification of the team from that event, to exclusion of the team from the Competition.

D1.3 Safety Procedures

D1.3.1 Drivers must properly use all required safety equipment at all times while staged for an event, while running the event and while stopped on track during an event. Required safety equipment includes all drivers gear and all restraint harnesses.

D1.3.2 In the event it is necessary to stop on track during an event the driver must attempt to position the vehicle in a safe position off of the racing line.

D1.3.3 Drivers must not exit a vehicle stopped on track during an event until directed to do so by an event official. An exception to this is if there is a fire or a risk of fire due to fuel leakage and/or electrical problems.

D1.4 Vehicle Integrity and Disqualification

D1.4.1 During the Dynamic Events, the mechanical and electrical integrity of the vehicle must be maintained. Any vehicle condition that could compromise vehicle integrity, e.g. damaged suspension, brakes or steering components, electrical failure[14], or any condition that could compromise the track surface, e.g. fluid leaks or dragging bodywork, will be a valid reason for exclusion by the officials.

D1.4.2 Dynamic events may not be run with a disabled electrical system. The electrical systems must be functional as indicated by an illuminated TSEL to enter or continue in any dynamic event.

D1.4.3 If vehicle integrity is compromised during the Endurance Event, scoring for that segment will be terminated as of the last completed lap.

[14] Extinguishing of the TSEL will be interpreted as indicative of an electrical failure.

ARTICLE D2 WEATHER CONDITIONS

The organizer reserves the right to alter the conduct and scoring of the competition based on weather conditions.

ARTICLE D3 RUNNING IN RAIN

A vehicle may not be operated in damp (**D3.1(b)**) or wet (**D3.1(c)**) conditions unless Rain Certified. (See section **EV7.3**)

D3.1 Operating Conditions

The following operating conditions will be recognized at Formula Hybrid:

(a) Dry – Overall the track surface is dry.

(b) Damp – Significant sections of the track surface are damp.

(c) Wet – The entire track surface is wet and there may be puddles of water.

(d) Weather Delay/Cancellation – Any situation in which all, or part, of an event is delayed, rescheduled or canceled in response to weather conditions.

D3.2 Decision on Operating Conditions

The operating condition in effect at any time during the competition will be decided by the competition officials.

D3.3 Notification

If the competition officials declare the track(s) to be "Damp" or "Wet",

(a) This decision will be announced over the public address system, and

(b) A sign with either "Damp" or "Wet" will be prominently displayed at both the starting line(s) and the start-finish line of the event(s), and the entry gate to the "hot" area.

D3.4 Tire Requirements

The operating conditions will determine the type of tires a car may run as follows:

(a) Dry – Cars must run their Dry Tires, except as covered in **D3.8.**

(b) Damp – Cars may run either their Dry Tires or Rain Tires, at each team’s option.

(c) Wet – Cars must run their Rain Tires.

D3.5 Event Rules

All event rules remain in effect.

D3.6 Penalties

All penalties remain in effect.

D3.7 Scoring

No adjustments will be made to teams' times for running in "Damp" or "Wet" conditions. The minimum performance levels to score points may be adjusted if deemed appropriate by the officials.

D3.8 Tire Changing

D3.8.1 During the Acceleration or Autocross Events:

Within the provisions of **D3.4** above, teams may change from Dry Tires to Rain Tires or vice versa at any time during those events at their own discretion.

D3.8.2 During the Endurance Event: Teams may change from Dry to Rain Tires or vice versa at any time while their car is in the staging area inside the "hot" area.

All tire changes after a car has received the "green flag" to start the Endurance Event must take place in the Driver Change Area.

(a) If the track was "Dry" and is declared "Damp":

(i) Teams may start on either Dry or Rain Tires at their option.

(ii) Teams that are on the track when it is declared "Damp", may elect, at their option, to pit in the Driver Change Area and change to Rain Tires under the terms spelled out below in "Tire Changes in the Driver Change Area".

(b) If the track is declared "Wet":

(i) A Red Flag will be shown at the Start/Finish Line and all cars will enter the Driver Change Area.

(ii) Those cars that are already fitted with "Rain" tires will be allowed restart without delay subject to the discretion of the Event Captain/Clerk of the Course.

(iii) Those cars without "Rain" tires will be required to fit them under the terms spelled out below in "Tire Changes in the Driver Change Area". They will then be allowed to re-start at the discretion of the Event Captain/Clerk of the Course.

(c) If the track is declared "Dry" after being "Damp" or "Wet":

The teams will NOT be required to change back to “Dry” tires.

(d) Tire Changes at Team's Option:

(i) Within the provisions of **D3.4** above and **D3.8** below, a team will be permitted to change tires at their option.

(ii) If a team elects to change from “Dry” to “Rain” tires, the time to make the change will NOT be included in the team’s total time.

(iii) If a team elects to change from “Rain” tires back to “Dry” tires, the time taken to make the change WILL be included in the team’s total time for the event, i.e. it will not be subtracted from the total elapsed time. However, a change from “Rain” tires back to “Dry” tires will not be permitted during the driver change.

(iv) To make such a change, the following procedure must be followed:

1. Team makes the decision,
2. Team has tires and equipment ready near Driver Change Area,
3. The team informs the Event Captain/Clerk of the Course they wish their car to be brought in for a tire change,
4. Officials inform the driver by means of a sign or flag at the checker flag station,
5. Driver exits the track and enters the Driver Change Area in the normal manner.

(e) Tire Changes in the Driver Change Area:

(i) Per Rule **D7.13.3** no more than three people for each team may be present in the Driver Change Area during any tire change, e.g. a driver and two crew or two drivers and one crew member.

(ii) No other work may be performed on the cars during a tire change.

(iii) Teams changing from "Dry" to "Rain" tires will be allowed a maximum of ten (10) minutes to make the change.

(iv) If a team elects to change from "Dry" to "Rain" tires during their scheduled driver change, they may do so, and the total allowed time in the Driver Change Area will be increased without penalty by ten (10) minutes.

(v) The time spent in the driver change area of less than 10 minutes without driver change will not be counted in the team's total time for the event. Any time in excess of these times will be counted in the team's total time for the event.

ARTICLE D4 DRIVER LIMITATIONS

D4.1 Two Event Limit

D4.1.1 An individual team member may not drive in more than two (2) events.

Note: A minimum of two (2) drivers is required to participate in all of the dynamic events. A minimum of four (4) drivers is required to participate in all possible runs in all of the dynamic events.

D4.1.2 It is the team's option to participate in any event. The team may forfeit any runs in any performance event.

D4.1.3 In order to drive in the endurance event, a driver must have attended the mandatory drivers meeting and walked the endurance track with an official.

D4.1.4 The time and location of the meeting and walk-around will be announced at the event.

ARTICLE D5 ACCELERATION EVENT

D5.1 Acceleration Objective

The acceleration event evaluates the car's acceleration in a straight line on flat pavement.

D5.2 Acceleration Procedure

The cars will accelerate from a standing start over a distance of 75 m (82 yards) on a flat surface. The foremost part of the car will be staged at 0.30 m behind the starting line. A green flag will be used to indicate the approval to begin, however, time starts only after the vehicle crosses the start line. There will be no particular order of the cars in the event. A driver has the option to take a second run immediately after the first.

D5.3 Acceleration Event – Electric only and HIP

D5.3.1 Electric and HIP vehicles may make up to three acceleration runs. The fastest run will be the recorded acceleration time. It is permissible for one driver to make all the acceleration runs.

D5.4 Acceleration Event – Hybrid

D5.4.1 Hybrids will have two modes of acceleration runs; electric-only and unrestricted. Electric-only must be run with the engine shut off. Unrestricted may be run in any configuration the team chooses.

D5.4.2 Electric-only and unrestricted runs may be done in any sequence, but the driver must inform the starting flagger of the mode prior to positioning on the starting line.

D5.4.3 Hybrids have the option of making up to two additional runs in each mode (electric-only and unrestricted) for a total of up to 6 runs. The fastest run in each category will be the recorded acceleration time. It is permissible for one driver to make all the acceleration runs.

D5.5 Tire Traction – Limitations

Special agents that increase traction may not be added to the tires or track surface and "burnouts" are not allowed.

D5.6 Acceleration Scoring

The acceleration score is based upon the corrected elapsed time. Elapsed time will be measured from the time the car crosses the starting line until it crosses the finish line.

D5.7 Acceleration Penalties

D5.7.1 Cones Down Or Out (DOO)

A two (2) second penalty will be added for each DOO (including entry and exit gate cones) that occurred on that particular run to give the corrected elapsed time.

D5.7.2 Off Course

An Off Course (OC) will result in a DNF for that run.

D5.8 Did Not Attempt

The organizer will determine the allowable windows for each event and retains the right to adjust for weather or technical delays. Cars that have not run by the end of the event will be scored as a Did Not Finish (DNF).

D5.9 Acceleration Scoring Formula

D5.9.1 There are three sets of runs in the acceleration event; two Hybrid and one Electric with each scored separately.

The equation below is used to determine the scores for the acceleration event. The first term ~~on the right~~ represents "performance" points and the ~~second~~ last term represents "participation" points, or the minimum score for having successfully completed the event.

$$ACCELERATION\ SCORE = 60 \times \frac{\left(\frac{0:00:10.0}{T_{your}}\right) - 1}{\left(\frac{0:00:10.0}{T_{min}}\right) - 1} + 15$$

Where:

T_{your} is the lowest corrected elapsed time (including penalties) recorded by your team.
T_{min} is the lowest corrected elapsed time (including penalties) recorded by the fastest team in your vehicle category.

Notes:

a) All three acceleration events are scored separately resulting in a different T_{min} for each.

b) Negative "performance" points will not be given. However, 15 points will be given for a car that completes a run, even if T_{your} exceeds 10 seconds.

c) DNF = zero (0) points

ARTICLE D6 AUTOCROSS EVENT

D6.1 Autocross Objective

The objective of the autocross event is to evaluate the car's maneuverability and handling qualities on a tight course without the hindrance of competing cars. The autocross course will combine the performance features of acceleration, braking, and cornering into one event.

D6.2 Autocross Procedure

D6.2.1 There will be four (4) Autocross-style heats, with each heat having a different driver. Three (3) timed laps will be run (weather and time permitting) by each driver and the best lap time will stand as the time for that heat.

D6.2.2 The car will be staged such that the front wheels are 6 m (19.7 feet) behind the starting line. The timer starts only after the car crosses the start line.

D6.2.3 There will be no particular order of the cars to run each heat but a driver has the option to take a second run immediately after the first.

D6.2.4 The organizer will determine the allowable windows for each event and retain~~s~~ the right to adjust for weather or technical delays. Cars that have not run by the end of the event will be scored as a Did Not Finish (DNF).

D6.3 Autocross Course Specifications & Speeds

D6.3.1 The following specifications will suggest the maximum speeds that will be encountered on the course. Average speeds should be 40 km/hr (25 mph) to 48 km/hr (30 mph).

(a) **Straights**: No longer than 60 m (200 feet) with hairpins at both ends (or) no longer than 45 m (150 feet) with wide turns on the ends.

(b) **Constant Turns:** 23 m (75 feet) to 45 m (148 feet) diameter.

(c) **Hairpin Turns:** Minimum of 9 m (29.5 feet) outside diameter (of the turn).

(d) **Slaloms:** Cones in a straight line with 7.62 m (25 feet) to 12.19 m (40 feet) spacing.

(e) **Miscellaneous:** Chicanes, multiple turns, decreasing radius turns, etc. The minimum track width will be 3.5 m (11.5 feet).

D6.3.2 The length of each run will be approximately 0.805 km (1/2 mile) and the driver will complete a specified number of runs.

D6.4 Autocross Penalties

The cars are judged on elapsed time plus penalties. The following penalties will be added to the elapsed time:

D6.4.1 Cone Down or Out (DOO)

Two (2) seconds per cone, including any after the finish line.

D6.4.2 Off Course

Driver must re-enter the track at or prior to the missed gate or a twenty (20) second penalty will be assessed. Penalties will not be assessed for accident avoidance or other reasons deemed sufficient by the track officials.

If a paved road edged by grass or dirt is being used as the track, e.g. a go kart track, four (4) wheels off the paved surface will count as an "off course". Two (2) wheels off will not incur an immediate penalty; however, consistent driving of this type may be penalized at the discretion of the event officials.

D6.4.3 Missed Slalom

Missing one or more gates of a given slalom will be counted as one "off-course" per occurrence. Each occurrence will incur a twenty (20) second penalty.

D6.4.4 Stalled & Disabled Vehicles

If a car stalls and cannot restart without external assistance, the car will be deemed disabled. Cars deemed disabled will be cleared from the track by the track workers. At the direction of the track officials team members may be instructed to retrieve the vehicle. Vehicle recovery may only be done under the control of the track officials.

D6.5 Corrected Elapsed Time

The elapsed time plus any penalties from that specific run will be used as the corrected elapsed time. Cars that are unable to complete the course with an average speed of 80% of the fastest car will not be awarded “performance” points. This means that any autocross time in excess of 125% of the fastest time will receive no “performance” points.

D6.6 Best Run Scored

The time required to complete each run will be recorded and the team’s best corrected elapsed time will be used to determine the score.

D6.7 Autocross Scoring Formula

The equation below is used to determine the score for the autocross event. The first term represents “performance” points, and last term represents “participation” points or the minimum score for having successfully completed the event.

$$AUTOCROSS\ SCORE = 120 \times \frac{\left(\frac{T_{max}}{T_{your}}\right) - 1}{\left(\frac{T_{max}}{T_{min}}\right) - 1} + 30$$

Where:

T_{min} is the lowest corrected elapsed time (including penalties) recorded by the fastest team in your vehicle category over their four heats.

T_{max} is 125% of T_{min}.

T_{your} is the lowest corrected elapsed time (including penalties) recorded by your team over the four heats.

Notes:

(a) A DNF in all four heats will score zero (0) points.

(b) Negative “performance” points will not be given. However, 30 points will be given for a car that completes a run, even if T_{your} exceeds T_{max}.

ARTICLE D7 ENDURANCE EVENT

D7.1 Right to Change Procedure

The following are general guidelines for conducting the endurance event. The organizers reserve the right to establish procedures specific to the conduct of the event at the site. All such procedures will be made known to the teams through newsletters, or the Formula Hybrid website, or on the official bulletin board at the event.

D7.2 Endurance Objective

The endurance event is designed to evaluate the vehicle's overall performance, reliability and efficiency. Unlike fuel economy tests that result in vehicles going as slow as possible in order to use the least amount of fuel, Formula Hybrid rewards the team that can cover a designated distance on a fixed amount of energy in the least amount of time.

D7.3 Endurance General Procedure

D7.3.1 In general, the team completing the most laps in the shortest time will earn the maximum points available for this event. Formula Hybrid uses an endurance scoring formula that rewards both speed and distance traveled. (See **D7.18**)

D7.3.2 The endurance distance is approximately 44km (27.34 miles) comprised of four (4) 11 km (6.84 mile) segments.

D7.3.3 Driver changes will be made between each segment.

D7.3.4 Wheel to wheel racing is prohibited.

D7.3.5 Passing another vehicle may only be done in an established passing zone or under the control of a course marshal.

D7.4 Endurance Course Specifications & Speeds

Course speeds can be estimated by the following course specifications. Average speed should be 48 km/hr (29.8 mph) to 57 km/hr (35.4 mph) with top speeds of approximately 105 km/hr (65.2 mph). Endurance courses will be configured, where possible, in a manner which maximizes the advantage of regenerative braking.

(a) **Straights**: No longer than 77.0 m (252.6 feet) with hairpins at both ends (or) no longer than 61.0 m (200.1 feet) with wide turns on the ends. There will be passing zones at several locations.

(b) **Constant Turns**: 30.0 m (98.4 feet) to 54.0 m (177.2 feet) diameter.

(c) **Hairpin Turns**: Minimum of 9.0 m (29.5 feet) outside diameter (of the turn).

(d) **Slaloms:** Cones in a straight line with 9.0 m (29.5 feet) to 15.0 m (49.2 feet) spacing.

(e) **Minimum Track width:** The minimum track width will be 4.5 m (14.76 feet).

(f) **Miscellaneous**: The organizers may include chicanes, multiple turns, decreasing radius turns, elevation changes, etc.

D7.5 Energy

D7.5.1 All vehicles competing in the endurance event must complete the event using only the energy stored on board the vehicle at the start of the event plus any energy reclaimed through regenerative braking during the event.

D7.5.2 Prior to the beginning of the endurance event, all competitors may charge their electric accumulators from any power source they wish.

D7.5.3 Once a vehicle has begun the endurance event, recharging accumulators from an outside source is not permitted.

D7.6 Hybrid Vehicles

D7.6.1 All Hybrid vehicles will begin the endurance event with the same amount of energy on board.

D7.6.2 The amount of energy allotted to each team is determined by the Formula Hybrid Rules Committee and is listed in **Table 1** – 2016 Energy and Accumulator Limits

D7.6.3 The fuel allocation for each team is based on the tables in **Appendix A**, adjusted downward by an amount equal to the stated energy capacity of the vehicle's accumulator(s).

D7.6.4 There will be no extra points given for fuel remaining at the end of the endurance event.

D7.7 Fueling - Hybrid Vehicles

D7.7.1 Prior to the beginning of the endurance event, the vehicle fuel tank and any downstream fuel accumulators, e.g., carburetor float bowls, will be drained. The allocated amount of fuel will then be added to the tank by the organizers and the filler will be sealed.

D7.7.2 Once fueled, the vehicle must proceed directly to the endurance staging area.

D7.8 Charging - Electric Vehicles

Each Electric vehicle will begin the endurance event with whatever energy can be stored in its accumulator(s), given the accumulator capacity limitations in **Table 1.**

D7.9 Endurance Run Order

Endurance run order will be determined by the team's corrected elapsed time in the autocross. Teams with the best autocross corrected elapsed time will run first. If a team did not score in the autocross event, the run order will then continue based on acceleration event times, followed by any vehicles that may not have completed either previous dynamic event. Endurance run order will be published at least one hour before the endurance event is run.

D7.10 Entering the Track

At the start of the event and after driver changes, vehicles will be directed to enter the track by the starter based on traffic conditions.

D7.11 Endurance Vehicle Restarting

D7.11.1 The vehicle must be capable of restarting without external assistance at all times once the vehicle has begun the event.

D7.11.2 If a vehicle stops out on the track, it will be allowed one (1) lap by the vehicle that is following it (approximately one (1) minute) to restart.

D7.11.3 At the end of Driver Change, the vehicle will be allowed two (2) minutes to reenergize the electrical system and restart the vehicle drive system (See: **D7.13.8**).

D7.11.4 If restarts are not accomplished within the above times, the vehicle will be deemed disabled and scored as a DNF for the event.

D7.12 Breakdowns & Stalls

D7.12.1 If a vehicle breaks down it will be removed from the course and will not be allowed to re-enter the course.

D7.12.2 If a vehicle spins, stalls, ingests a cone, etc., it will be allowed to restart and re-enter the course where it went off, but no work may be performed on the vehicle

D7.12.3 If a vehicle stops on track and cannot be restarted without external assistance, the track workers will push the vehicle clear of the track. At the discretion of event officials, two (2) team members may retrieve the vehicle under direction of the track workers.

D7.13 Endurance Driver Change Procedure

D7.13.1 There must be a minimum of two (2) drivers for the endurance event, with a maximum of four (4) drivers. One driver may not drive in two consecutive segments.

D7.13.2 Each driver will drive an 11 km (6.83 miles) segment, and then be signaled into the driver change area.

D7.13.3 Only three (3) team members, including the driver or drivers, will be allowed in the driver change area. Only the tools necessary to adjust the vehicle to accommodate the different drivers and/or change tires will be carried into this area (no tool chests etc.). Extra people entering the driver change area will result in a twenty (20) point penalty to the final endurance score for each extra person entering the area.

Note: Teams are permitted to "tag-team" in and out of the driver change area as long as there are no more than three (3) team members present at any one time.

D7.13.4 The vehicle must come to a complete stop, the IC engine turned off and the TSV shut down. These systems must remain shut down until the new driver is in place. (See **D7.13.8**)

D7.13.5 The driver will exit the vehicle and any necessary adjustments will be made to the vehicle to fit the new driver (seat cushions, head restraint, pedal position, etc.). The new driver will then be secured in the vehicle.

D7.13.6 Three (3) minutes are allowed for the team to change drivers. The time starts when the vehicle comes to a halt in the driver change area and stops when the correct adjustment of the driver restraints and safety equipment has been verified by the driver change area official. Any time taken over the allowed time will incur a penalty. (See **D7.17.2(k)**)

D7.13.7 Other than changes required to accommodate each driver or covered by **D3.8** "Tire Changing", the team is not permitted to perform any work on the vehicle during driver change. .

D7.13.8 Once the new driver is in place and an official has verified the correct adjustment of the driver restraints and safety equipment, a maximum of two (2) minutes are allowed to re-energize the electrical system, restart the vehicle drive system and begin moving out of the driver change area.

D7.13.9 The process given in **D7.13.2** through **D7.13.8** will be repeated for each 11 km (6.83 mile) segment. The vehicle will continue until it completes the total 44 km (27.34 miles) distance or until the endurance event track closing time, at which point the vehicle will be signaled off the course.

D7.13.10 The driver change area will be placed such that the timing system will see the driver change as an extra-long lap. Unless a driver change takes longer than three (3) minutes, this extra-long lap will not count into a team's final time. If a driver change takes longer than three minutes, the extra time will be added to the team's final time.

D7.14 Endurance Lap Timing

D7.14.1 Each lap of the endurance event will be individually timed either by electronic means, or by hand.

D7.14.2 Each team is required to time their vehicle during the endurance event as a backup in case of a timing equipment malfunction. An area will be provided where a maximum of two team members can perform this function. All laps, including the extra-long laps must be recorded legibly and turned in to the organizers at the end of the endurance event. Standardized lap timing forms will be provided by the organizers.

D7.15 Exiting the Course

D7.15.1 Timing will stop when the vehicle crosses the start/finish line.

D7.15.2 Teams may elect to shut down and coast after crossing the start/finish line, but must fully enter the driver change area before coming to a stop. There will be no “cool down” laps.

D7.15.3 The speed limit when entering the shut-down area is 15 MPH. Excessive speed will be penalized.

D7.16 Endurance Minimum Speed Requirement

D7.16.1 A car's allotted number of laps must be completed in a maximum of 120 minutes elapsed time from the start of that car's first lap.

Cars that are unable to comply will be flagged off the course and their actual completed laps tallied.

D7.16.2 If a vehicle’s lap time becomes greater than *Max Average Lap Time* (See: **D7.18**) it may be declared “out of energy”, and flagged off the course. The vehicle will be deemed disabled and scored as a DNF for the event.

Note: Teams should familiarize themselves with the Formula Hybrid endurance scoring formulas. Attempting to complete additional laps at too low a speed can cost a team points.

D7.17 Endurance Penalties

D7.17.1 Penalties will not be assessed for accident avoidance or other reason deemed sufficient by the track official.

D7.17.2 The penalties in effect during the endurance event are listed below.

(a) **Cone down or out (DOO)**

Two (2) seconds per cone. This includes cones before the start line and after the finish line.

(b) **Off Course (OC)**

For an OC, the driver must re-enter the track at or prior to the missed gate or a twenty (20) second penalty will be assessed.

If a paved surface edged by grass or dirt is being used as the track, e.g. a go kart track, four (4) wheels off the paved surface will count as an "off course". Two (2) wheels off will not incur an immediate penalty. However, consistent driving of this type may be penalized at the discretion of the event officials.

(c) **Missed Slalom**

Missing one or more gates of a given slalom will incur a twenty (20) second penalty.

(d) **Failure to obey a flag**

Penalty: 1 minute

(e) **Over Driving (After a closed black flag)**

Penalty: 1 Minute

(f) **Vehicle to Vehicle Contact**

Penalty: DISQUALIFIED

(g) **Running Out of Order**

Penalty: 2 Minutes

(h) **Mechanical Black Flag**

See **D7.23.3(b).** No time penalty. The time taken for mechanical inspection under a "mechanical black flag" is considered officials' time and is not included in the team's total time. However, if the inspection reveals a mechanical integrity problem the vehicle may be deemed disabled and scored as a DNF for the event.

(i) **Reckless or Aggressive Driving**

Any reckless or aggressive driving behavior (such as forcing another vehicle off the track, refusal to allow passing, or close driving that would cause the likelihood of vehicle contact) will result in a black flag for that driver.

When a driver receives a black flag signal, he/she must proceed to the penalty box to listen to a reprimand for his/her driving behavior.

The amount of time spent in the penalty box will vary from one (1) to four (4) minutes depending upon the severity of the offense.

If it is impossible to impose a penalty by a stop under a black flag, e.g. not enough laps left, the event officials may add an appropriate time penalty to the team's elapsed time.

(j) **Inexperienced Driver**

The Chief Marshall/Director of Operations may disqualify a driver if the driver is too slow, too aggressive, or driving in a manner that, in the sole opinion of the event officials, demonstrates an inability to properly control their vehicle. This will result in a DNF for the event.

(k) **Driver Change**

Driver changes taking longer than three (3) minutes will be penalized.

D7.18 Endurance Scoring Formula

D7.18.1 The scoring for the endurance event will be based upon the total laps completed, the on-track elapsed time for all drivers (less the uncharged extra-long laps for the driver changes, change to wet tires, etc.), plus any penalty time and penalty points assessed against all drivers and team members.

Vehicles scored as a DNF for the event will get credit for all laps completed prior to the DNF

The equation below is used to determine the score for the endurance event. The first term represents "performance" points, and the last term represents "participation" points, or the minimum score for having successfully completed all or part of the event.

$$ENDURANCE\ SCORE\ =\ 320\left(\frac{LapSum(n)_{your}}{LapSum(n)_{max}}\right)\frac{\left(\frac{Max\ Average\ Lap\ Time}{T_{your}}\right)-1}{\left(\frac{Max\ Average\ Lap\ Time}{T_{min}}\right)-1}+80$$

Where:

Max Average Lap Time = 120 / the number of laps required to complete 44 km.

T_{min} = the lowest corrected average lap time (including penalties) recorded by the fastest team in your vehicle category over their completed laps.

T_{your} = the corrected average lap time (including penalties) recorded by your team over your completed laps.

$LapSum(n)_{max}$ = The value of *LapSum* corresponding to number of complete laps credited to the team in your vehicle category that covered the greatest distance.

$LapSum(n)_{your}$ = The value of *LapSum* corresponding to the number of complete laps credited to your team

Notes:

(a) If your team completes all of the required laps, then $LapSum(n)_{your}$ will equal the maximum possible value of *LapSum(n)*. (990 for a 44 lap event).

(b) If your team does not complete the required number of laps, then $LapSum(n)_{your}$ will be based on the number of laps completed. See **Appendix B** for *LapSum(n)* calculation methodology.

(c) Negative "performance points" will not be given. However, 80 points will be given for a car that completes at least one (1) lap, even if T_{your} exceeds the *Max Average Lap Time*.

D7.18.2 Teams exceeding 120 minutes elapsed time will have their results truncated at the last lap completed within the 120 minute limit.

D7.19 Post Event Engine and Energy Check

The organizer reserves the right to impound any vehicle immediately after the event to check accumulator capacity, engine displacement (method to be determined by the organizer) and restrictor size (if fitted).

D7.20 Endurance Event – Driving

D7.20.1 During the endurance event when multiple vehicles are running on the course it is paramount that the drivers strictly follow all of the rules and driving requirements. Aggressive driving, failing to obey signals, not yielding for passing, etc. will result in a black flag and a discussion in the penalty box with course officials. The amount of time spent in the penalty box is at the discretion of the officials and is included in the run time. Penalty box time serves as a reprimand as well as informing the driver of what he/she did wrong. Drivers should be aware that contact between open wheel racers is especially dangerous because tires touching can throw one vehicle into the air.

D7.20.2 Endurance is a timed event in which drivers compete only against the clock not against other vehicles. Aggressive driving is unnecessary.

D7.21 Endurance Event – Passing

D7.21.1 Passing during the endurance event may only be done in the designated passing zones and under the control of the track officials. Passing zones have two parallel lanes – a slow lane for the vehicles that are being passed and a fast lane for the vehicles that are making a pass. On approaching a passing zone a slower leading vehicle will be blue flagged and must shift into the slow lane and decelerate. The following faster vehicle will continue in the fast lane and make the pass. The vehicle that had been passed may reenter traffic only under the control of the passing zone exit marshal.

The passing lanes, e.g. the slow lanes, may be either to the left or the right of the fast lane depending on the design of the specific course.

D7.21.2 These passing rules do not apply to vehicles that are passing disabled vehicles on the course or vehicles that have spun out and are not moving. When passing a disabled or off-track vehicle it is critical to slow down, drive cautiously and be aware of all the vehicles and track workers in the area.

D7.21.3 Under normal driving conditions when not being passed all vehicles use the fast lane.

D7.22 Endurance Event – Driver's Course Walk

The endurance course will be available for walk by drivers prior to the event. All endurance drivers should walk the course before the event starts.

D7.23 Flags

D7.23.1 The flag signals convey the commands described below, and must be obeyed immediately and without question.

D7.23.2 There are two kinds of flags for the competition: Command Flags and Informational Flags. Command Flags are just that, flags that send a message to the competitor that the competitor must obey without question. Informational Flags, on the other hand, require no action from the driver, but should be used as added information to help him or her maximize performance. What follows is a brief description of the flags used at the competitions in North America and what each flag means.

Note: Not all of these flags are used at all competitions and some alternate designs are occasionally displayed. Any variations from this list will be explained at the drivers meetings.

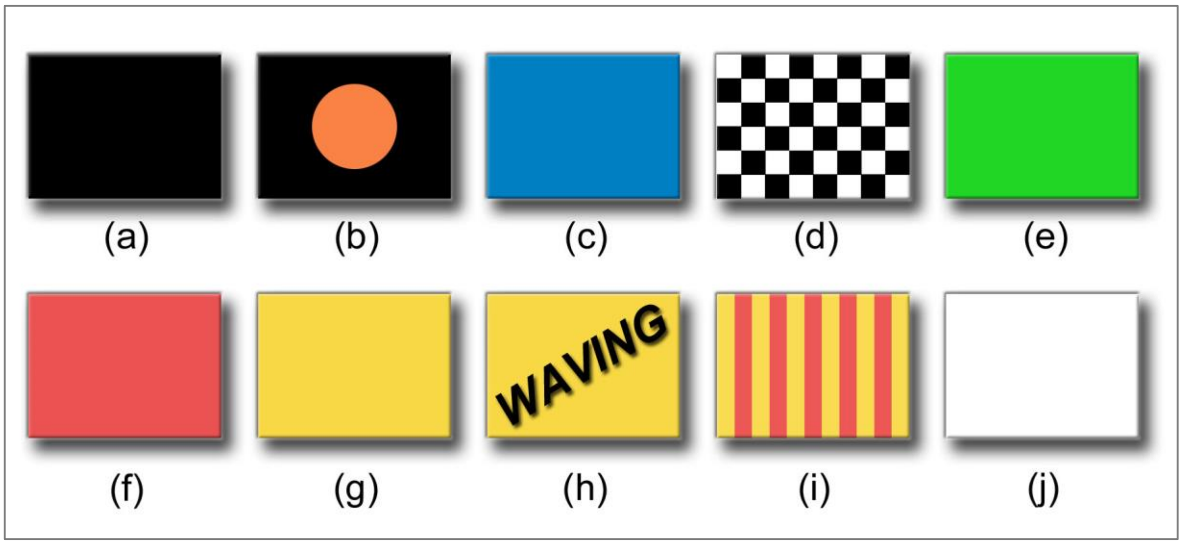

Table 21 - Flags

D7.23.3 Command Flags

(a) **BLACK FLAG -** Pull into the penalty box for discussion with the Director of Operations or other official concerning an incident. A time penalty may be assessed for such incident.

(b) **MECHANICAL BLACK FLAG** (Black Flag with Orange Dot) ("Meatball") **-** Pull into the penalty box for a mechanical inspection of your vehicle, something has been observed that needs closer inspection.

(c) **BLUE FLAG -** Pull into the designated passing zone to be passed by a faster competitor or competitors. Obey the course marshal's hand or flag signals at the end of the passing zone to merge into competition.

(d) **CHECKER FLAG -** Your segment has been completed. Exit the course at the first opportunity after crossing the finish line.

(e) **GREEN FLAG -** Your segment has started, enter the course under direction of the starter. **NOTE**: If you are unable to enter the course when directed, await another green flag as the opening in traffic may have closed.

(f) **RED FLAG -** Come to an immediate safe controlled stop on the course. Pull to the side of the course as much as possible to keep the course open. Follow course marshal's directions.

(g) **YELLOW FLAG** (Stationary) **-** Danger, SLOW DOWN, be prepared to take evasive action, something has happened beyond the flag station. NO PASSING unless directed by the course marshals.

(h) **YELLOW FLAG** (Waved) **-** Great Danger, SLOW DOWN, evasive action is most likely required, BE PREPARED TO STOP, something has happened beyond the flag station, NO PASSING unless directed by the course marshals.

D7.23.4 Informational Flags

(i) **RED AND YELLOW STRIPED FLAG -** Something is on the racing surface that should not be there. Be prepared for evasive maneuvers to avoid the situation. (Course marshals may be able to point out what and where it is located, but do not expect it.)

(j) **WHITE FLAG -** There is a slow moving vehicle on the course that is much slower than you are. Be prepared to approach it at a cautious rate.

ARTICLE D8 RULES OF CONDUCT

D8.1 Competition Objective – A Reminder

The Formula Hybrid event is a design engineering competition that requires performance demonstration of vehicles and is NOT a race. Engineering ethics will apply. It is recognized that hundreds of hours of labor have gone into fielding an entry into Formula Hybrid. It is also recognized that this event is an "engineering educational experience" but that it often times becomes confused with a high stakes race. In the heat of competition, emotions peak and disputes arise. Our officials are trained volunteers and maximum human effort will be made to settle problems in an equitable, professional manner.

D8.2 Unsportsmanlike Conduct

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

D8.3 Official Instructions

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

Note: This penalty can be individually applied to all members of a team.

D8.4 Arguments with Officials

Argument with, or disobedience to, any official may result in the team being eliminated from the competition. All members of the team may be immediately escorted from the grounds.

D8.5 Alcohol and Illegal Material

Alcohol, illegal drugs, weapons or other illegal material are prohibited on the event site during the competition. This rule will be in effect during the entire competition. Any violation of this rule by a team member will cause the expulsion of the entire team. This applies to both team members and faculty advisors. Any use of drugs, or the use of alcohol by an underage individual, will be reported to the local authorities for prosecution.

D8.6 Parties

Disruptive parties either on or off-site should be prevented by the Faculty Advisor.

D8.7 Trash Clean-up

D8.7.1 Cleanup of trash and debris is the responsibility of the teams. The team's work area should be kept uncluttered. At the end of the day, each team must clean all debris from their area and help with maintaining a clean paddock.

D8.7.2 Teams are required to remove all of their material and trash when leaving the site at the end of the competition. Teams that abandon furniture, or that leave a paddock that requires special cleaning, will be billed for removal and/or cleanup costs.

D8.7.3 All liquid hazardous waste (engine oil, fuel, brake fluid, etc.) must be put in well-marked, capped containers and left at the hazardous waste collection building. The track must be notified as soon as the material is deposited by calling the phone number posted on the building. See the map in the registration packet for the building location.

ARTICLE D9 GENERAL RULES

D9.1 Dynamometer Usage

D9.1.1 If a dynamometer is available, it may be used by any competing team. Vehicles to be dynamometer tested must have passed all parts of technical inspection.

D9.1.2 Fuel, ignition and drivetrain tuning will be permitted while testing on the dynamometer.

D9.2 Problem Resolution

Any problems that arise during the competition will be resolved through the Operations Center and the decision will be final.

D9.3 Forfeit for Non-Appearance

It is the responsibility of teams to be in the right place at the right time. If a team is not present and ready to compete at the scheduled time they forfeit their attempt at that event. There are no make-ups for missed appearances.

D9.4 Safety Class – Attendance Required

A safety class is required for all team members. The format and requirements will be posted on the Formula Hybrid website.

D9.5 Drivers Meetings – Attendance Required

All drivers for an event are required to attend the pre-event drivers meeting(s). The driver for an event will be disqualified if he/she does not attend the driver meeting for the event.

D9.6 Personal Vehicles

D9.6.1 Personal cars, motorcycles and trailers must be parked in designated areas only. Only FH competition vehicles will be allowed in the track areas.

All vehicles and trailers must be parked behind the white "Fire Lane" lines.

D9.6.2 Some self-powered transport such as Bicycles and Skate boards are permitted, subject to restrictions posted in the event guide

D9.7 Self-propelled Pit Carts, Tool Boxes, etc. - Prohibited

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

ARTICLE D10 PIT/PADDOCK/GARAGE RULES

D10.1 Vehicle Movement

D10.1.1 Vehicles may not move under their own power anywhere outside of an officially designated dynamic area.

D10.1.2 When being moved outside the dynamic area:

(a) The vehicle TSV must be deactivated.

(b) The vehicle must be pushed at a normal walking pace by means of a "Push Bar" (**D10.2)**.

(c) The vehicle's steering and braking must be functional.

(d) A team member must be sitting in the cockpit and must be able to operate the steering and braking in a normal manner.

(e) A team member must be walking beside the car.

(f) The team has the option to move the car either with

(i) all four (4) wheels on the ground or

(ii) with the rear wheels supported on a dolly or push bar mounted wheels, provided that the external wheels supporting the rear of the car are non-pivoting such that the vehicle will travel only where the front wheels are steered.

D10.1.3 Cars with wings are required to have two team members walking on either side of the vehicle whenever the vehicle is being pushed.

D10.1.4 During performance events when the excitement is high, it is particularly important that the car be moved at a slow pace in the pits. The walking rule will be enforced and a point penalty of twenty five (25) points will be assessed for each violation.

D10.2 Push Bar

Each car must have a removable device that attaches to the rear of the car that allows two (2) people, standing erect behind the vehicle, to push the car around the event site. This device must also be capable of decelerating, i.e. slowing and stopping the forward motion of the vehicle and pulling it rearwards. It must be presented with the car at Technical Inspection.

D10.3 Smoking – Prohibited

Smoking is prohibited in all competition areas.

D10.4 Fueling and Refueling

Officials must conduct all fueling and refueling. The vehicle must be de-energized when refueling, and no other activities (including any mechanical or electrical work) are allowed while refueling.

D10.5 Energized Vehicles in the Paddock or Garage Area

Any time a vehicle is energized and capable of electric motion the drive wheels must be supported clear of the ground or removed, complying with the requirements of Section **D10.6**

D10.6 Engine Running in the Paddock

Engines may be run in the paddock provided the car has passed technical inspection and the following conditions are satisfied:

(a) The car is on an adequate stand, and

(b) The drive wheels are at least 10.2 cm off the ground, or the drive wheels have been removed.

D10.7 Safety Glasses

Safety glasses must be worn at all times while working on a vehicle, and by anyone within 10 ft. (3 meters) of a vehicle that is being worked on.

ARTICLE D11 DRIVING RULES

D11.1 Driving Under Power

D11.1.1 Cars may only be driven under power

(a) When running in an event,

(b) When on the practice track

(c) During the brake test

(d) During any powered vehicle movement specified and authorized by the organizers.

D11.1.2 For all other movements cars must be pushed at a normal walking pace using a push bar.

D11.1.3 Driving a vehicle outside of scheduled events or scheduled practice will result in a two hundred (200) point penalty for the first violation and expulsion of the team for a second violation.

D11.2 Driving Off-Site - Prohibited

Driving off-site is absolutely prohibited. Teams found to have driven their vehicle at an off-site location during the period of the competition will be excluded from the competition.

D11.3 Practice Track

D11.3.1 A practice track for testing and tuning cars may be available at the discretion of the organizers. The practice area will be controlled and may only be used during the scheduled practice times.

D11.3.2 Practice or testing at any location other than the practice track is absolutely forbidden.

D11.3.3 Cars using the practice track must have passed all parts of the technical inspection.

D11.4 Situational Awareness

Drivers must maintain a high state of situational awareness at all times and be ready to respond to the track conditions and incidents. Flag signals and hand signals from course marshals and officials must be immediately obeyed.

ARTICLE D12 DEFINITIONS

DOO - A cone is “Down or Out”—if the cone has been knocked over or the entire base of the cone lies outside the box marked around the cone in its undisturbed position.

DNF- Did Not Finish

Gate - The path between two cones through which the car must pass. Two cones, one on each side of the course define a gate: Two sequential cones in a slalom define a gate.

Entry Gate -The path marked by cones which establishes the required path the vehicle must take to enter the course.

Exit Gate - The path marked by cones which establishes the required path the vehicle must take to exit the course.

Staging Area - An area prior to the entry to an event for the purpose of gathering those cars that are about to start.

OC - A car is Off Course if it does not pass through a gate in the required direction.

Appendix A
Accumulator Rating & Fuel Equivalency

Each accumulator device will be assigned a fuel equivalency based on the following:

Note: C, V_{nom}, V_{peak} and Ah are device nameplate values at the 2C (0.5 hour) rate. To convert from manufacturer's data at other hour-rates, Peukert's equation should be used (see below).

Batteries:	$Energy(Wh) = (V_{nom})(Ah)(0.8)$
Capacitors:	$Energy(Wh) = \left(\frac{C(V_{peak}^{2} - V_{\min}^{2})}{2}\right)/3600$ where V_{min} is assumed to be 10% of V_{peak}.

Table 22 – Accumulator Device Energy Calculations

Liquid Fuels	Wh / Liter[15]
Gasoline (Sunoco[16] Optima)	2,343
Biodiesel (B100)	2,500±[17]
Ethanol (Sunoco E-85R)	1,718

Table 23 – Fuel Energy Equivalencies

For example, using 89 Maxwell MC 2600 ultracaps (2600 F, 2.7 V), the fuel equivalency would be 2.606 Wh per device, or 231.9 Wh for a bank of 89, resulting in a 99cc reduction of gasoline or 135cc reduction of E-85.

Peukert's Equation

The Peukert equation models how the capacity of a battery changes with its rate of discharge:

$$C_{0.5} / C_n = (I_{0.5} / I_n)^P$$

Where:

$C_{0.5}$ is the capacity at the 0.5 hour rate
C_n is the capacity at the "*n*" hour rate
$I_{0.5}$ is the current at the 0.5 hour rate
I_n is the current at the "*n*" hour rate, and
P is the "Peukert Number" which can be scaled from discharge curves for the battery when plotted on logarithmic axes.

[15] Formula Hybrid assumes a mechanical efficiency of 27%
[16] Full specifications for Sunoco racing fuels may be found at: http://www.racegas.com/fuel/compare
[17] Because BioDiesel can vary seasonally and between suppliers, the diesel fuel provided at the competition will have been tested for energy content and the allocations adjusted accordingly.

Appendix B

Determination of *LapSum(n)* Values

The parameter *LapSum(n)* is used in the calculation of the scores for the endurance event. It is a function of the number of laps (*n*) completed by a team during the endurance event. It is calculated by summing the lap numbers from 1 to (*n*), the number of laps completed. This gives increasing weight to each additional lap completed during the endurance event.

For example:
If your team is credited with completing five (5) laps of the endurance event, the value of $LapSum(n)_{your}$ used in compute your endurance score would be the following:

$$LapSum(5)_{your} = 1 + 2 + 3 + 4 + 5 = 15$$

Number of Laps Completed (*n*)	*LapSum(n)*	Number of Laps Completed (*n*)	*LapSum(n)*
0	0	23	276
1	1	24	300
2	3	25	325
3	6	26	351
4	10	27	378
5	15	28	406
6	21	29	435
7	28	30	465
8	36	31	496
9	45	32	528
10	55	33	561
11	66	34	595
12	78	35	630
13	91	36	666
14	105	37	703
15	120	38	741
16	136	39	780
17	153	40	820
18	171	41	861
19	190	42	903
20	210	43	946
21	231	44	990
22	253		

Table 24 - Example of LapSum(n) calculation for a 44-lap Endurance event

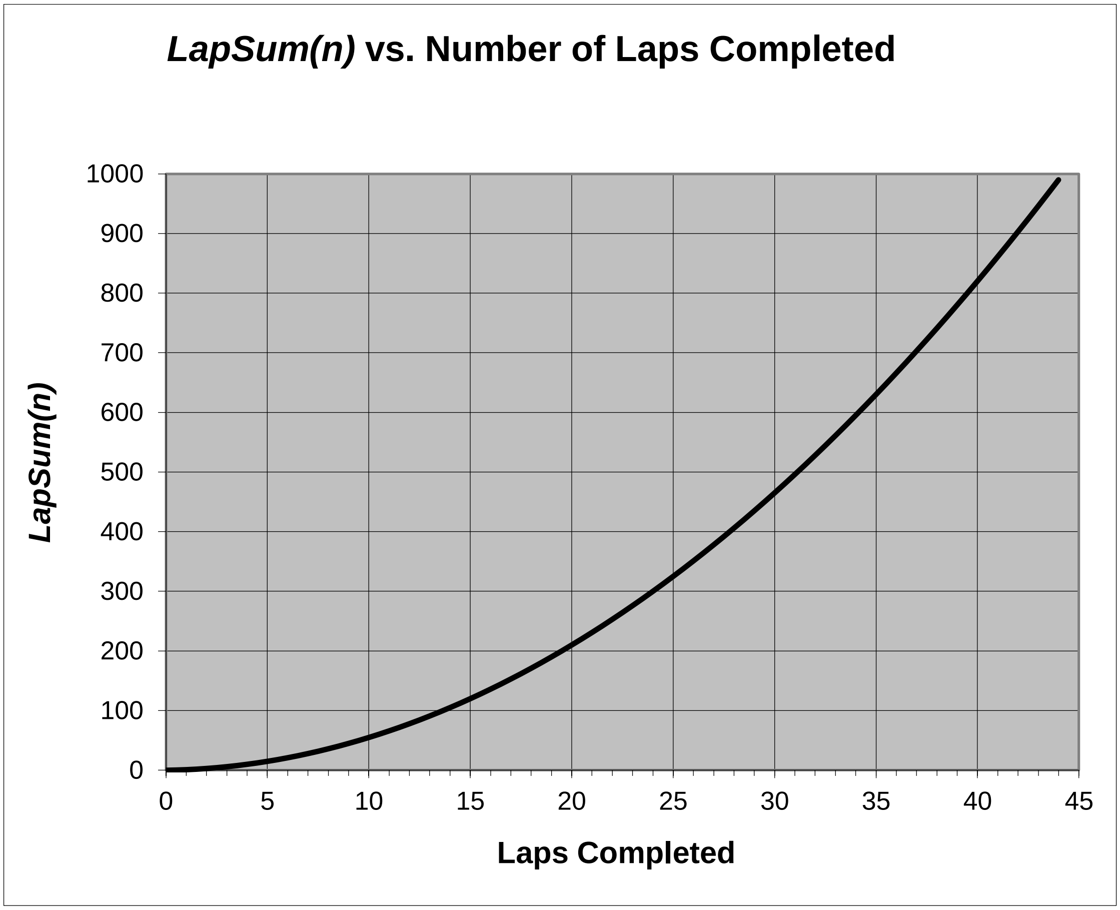

Figure 37 - Plot of *LapSum(n)* calculation for a 44-lap Endurance event

Appendix C
Presentation Judging Form

Note: This form is subject to change. Check the Formula Hybrid website for the most recent version.

CAR NUMBER: ___________ SCHOOL: ____

Judge Team: ____________ Judge #: ___________

Score the following categories on the basis of the maximum possible score for each category. The following table is a suggested guide.

Percentage	0	25	50	75	100
1. PROJECT PLAN (0-40): This report was to be submitted to FH by December 22nd, 2014.	0	10	20	30	40
2. INTERIM PROGRESS REPORT (0-10): This report was to be submitted to FH by February 18th, 2015.	0	3	5	8	10
3. **PRESENTATION** (0-50): **Scope:** What will be accomplished, goals and objectives **Structure:** Organization of project team, Work Breakdown Structure (WBS) **Expected Results:** Measure of success, which goals/objectives were achieved **Effective Change Management:** System designed to handle project change **Lessons Learned:** What would team do differently and why?	0	13	25	38	50
VISUAL AIDS, TIMING & DELIVERY: Were visual aids used? Did the presenter speak in a clear voice? Did the presenter show enthusiasm and promote confidence in the technical aspects? Did he/she maintain eye contact?					
QUESTIONS: Did the answers illustrate that the team fully understood the questions? Promote complete confidence in their response to the questions?					

PRESENTATION POINTS (100 points maximum) Total: ___________

Presentation content scoring:

	Not Present 0%	Novice 25%	Developing 50%	Proficient 75%	Advanced 100%
Scope What will be accomplished, goals and objectives	Absent	Incomplete and lacks definition	Some aspects are explained and defined	Most aspects are clearly explained and defined	Every aspect is clearly explained and defined
Structure Organization of team and WBS	Absent	Limited explanation	Nearing complete explanation with a roughly organized WBS	Mostly complete explanation with sufficiently organized WBS	Complete explanation and well organized with clearly defined WBS
Expected Results Measures of success, quantifiable attributes to determine which goals and objectives have been achieved	Absent	Described with a basic understanding	Mostly accurate	Accurate	Meets and exceeds expectations
Effective Change Management Process System designed for administering project change	Insignificantly effective	Moderately effective	Nearing effective	Very effective	Extremely effective process
Lessons Learned	Could not articulate issues encountered in process	Weak attempt to describe issues and/or solutions	Issues defined, explained actions taken to correct problems	Clearly, identified issues, articulated corrective action taken and benefits	Clear, thoughtful and professional evaluation of obstacles, how handled, to what effect and further improvements considered for next year
					Total /50

COMMENTS: *(Continue on other side if necessary.)*

Appendix D
Design Judging Form[18]

SCHOOL ________________________________ CAR NUMBER __________

DESIGN PROCESS – The most common question to the students from the design judges is "Why?" For each subsystem of the car the team should be able to clearly and quickly state:

a) The design objectives.
b) What the design must do to achieve the objectives (functions).
c) The performance requirements (design specifications) that quantify how well the design must perform the required functions.
d) How well the final design meets the requirements based on both engineering analyses and testing. (No points are directly associated with this item, but the judges will expect the students to demonstrate their understanding of the design process as they address each of the items below.)

The judges will consider the following factors when assigning scores to each of the scored items.

a) SAFETY
b) Reliability – the winner is usually found among the finishers.
c) Manufacturing and assembly - Were manufacturing and ease of assembly considered during design?
d) Serviceability – Are items that require frequent inspection, service, or adjustment easily accessible?
e) Innovation – Does the car include innovative features?

NOTE TO JUDGES: Judges with limited expertise in any area may insert an 'X' in that sections score. The chief Design Judge will scale the remaining scores so that the omitted score will not penalize the team.

[18] This form is for informational use only – the actual form used may differ. Check the Formula Hybrid website prior to the competition for the latest Design judging form.

CHASSIS & SUSPENSION

__________ CHASSIS (0-20)
What are the requirements for the chassis design? Are load paths direct and short? Are components sized properly for the loads? Were weight distribution and C.G. height optimized?

__________ COCKPIT & HUMAN FACTORS (0-10)
Is the vehicle designed to accommodate & function with a wide variety of body sizes? Are controls and instruments easy to use? Are electrical systems well isolated? Does the design consider occupant safety beyond the requirements?

__________ SUSPENSION (0-25)
What were the requirements for suspension design? How were kinematics, lateral load transfer, adjustability, etc. addressed? How was vehicle handling developed?

__________ BRAKES (0-10)
How was the brake system designed?

__________ STEERING (0-10)
How was the steering system designed?

POWERTRAIN

__________ POWERTRAIN SYSTEM ARCHITECTURE (0-25)
Was the balance between I.C. engine and electric drive well thought out. What were the resulting requirements? How does the system architecture relate to scoring points in the FH competition?

__________ POWERTRAIN ELECTRICAL (0-25)
Are the accumulator, power electronics, and electrical machine well matched? What were the requirements for the accumulator/power electronics/electrical machine? Why was this accumulator/power electronics/electrical machine chosen? How well does the accumulator/power electronics/electrical machine meet the requirements?

__________ POWERTRAIN / MECHANICAL (0-20)
What were the requirements for the IC engine? Was the engine modified (optimized) for the hybrid application?

__________ ELECTRONICS & CONTROLS (0-20) What are the requirements on the electronics and controls system and what determined these requirements? Did the students design the electronic systems? Is there closed loop control of the engine? Data acquisition?

GENERAL

__________ SUSTAINABILITY (0 to 30)
Did the team demonstrate an understanding and ability to calculate upstream and vehicle CO2 emissions? How were sustainability and efficiency objectives incorporated into the design process? Did the team demonstrate an understanding of how sustainability can impact wide-ranging design decisions? (See Section **S4.3**)

__________ AESTHETICS & CRAFTSMANSHIP (0-5)
Fit and finish, use of appropriate materials, professional quality fabrication (e.g., wiring routed, loomed, and labeled; quality of fabrication, welding, machine work), detail work completed. Does the vehicle look attractive?
Does it have a high performance appearance?

__________ MISCELLANEOUS (0 to -50)
If the team does not exhibit a good understanding of the car a penalty may be applied.

__________ TOTAL DESIGN POINTS (200 points maximum)

DESIGN COMMENTS:

Appendix E
Wire Current Capacity (DC)

Wire AN gauge Copper	Wire Area (Thousands of circular Mils)	Max. Fuse Continuous Rating
24		5
22		7
20		10
18		14
16		20
14		28
12		40
10		55
8		80
6		105
4		140
3		165
2		190
1		220
0		260
2/0		300
3/0		350
4/0		405
	250	455
	300	505

Table 25 – Wire Current Capacity

Appendix F
Required Equipment

☐ Fire Extinguishers

Minimum Requirements

Each team must have at least two (2) 2.3 kg (5 lb.) dry chemical (Min. 3-A:40-B:C) Fire extinguishers

Extinguishers of larger capacity (higher numerical ratings) are acceptable.
All extinguishers must be equipped with a manufacturer installed pressure/charge gauge.

Special Requirements

Teams must identify any fire hazards specific to their vehicle's components and if fire extinguisher/fire extinguisher material other than those required in section **T15.1** are needed to suppress such fires, then at least two (2) additional extinguishers/material (at least 5 lb. or equivalent) of the required type must be procured and accompany the car at all times. As recommendations vary, teams are advised to consult the rules committee before purchasing expensive extinguishers that may not be necessary.

☐ Chemical Spill Absorbent

Teams must have chemical spill absorbent at hand, appropriate to their specific risks. This material must be presented at technical inspection.

☐ Insulated Gloves

Insulated gloves, rated for at least the voltage in the TSV system, with protective over-gloves. Electrical gloves require testing by a qualified company. The testing is valid for 14 months after the date of the test. All gloves must have the test date printed on them.

☐ Safety Glasses

Safety glasses must be worn as specified in section **D10.7**

☐ MSDS Sheets

Materials Safety Data Sheets (MSDS) for the accumulator.

☐ Additional

Any special safety equipment called for in the MSDS, for example correct gloves recommended for handling any electrolyte material in the accumulator.

Appendix G

Example TSV Electrical Diagram

Deleted

Appendix H
Example Relay Latch Circuits

The diagrams below are examples of relay-based latch circuits that can be used to latch the momentary output of the Bender IMD (either high-true or low-true) such that it will comply with Formula Hybrid rule **EV5.1**

Note: It is important to confirm by checking the data sheets, that the output pin of the IMD can power the relay directly. If not, an amplification device will be required.

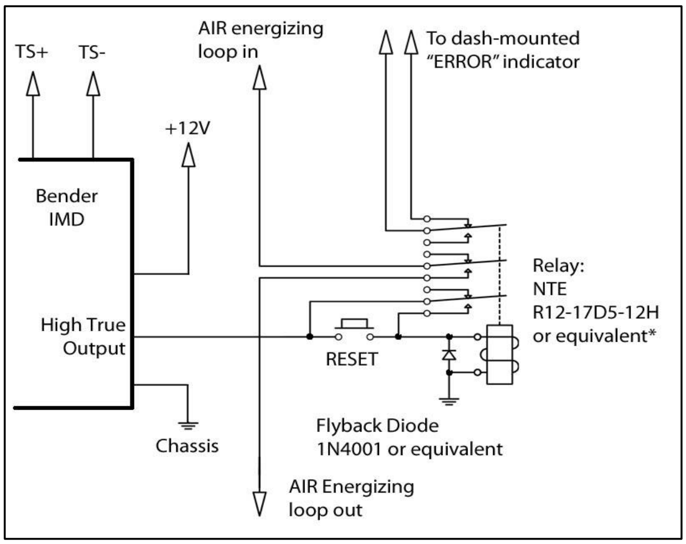

Figure 38- Latching Circuit for High-True output

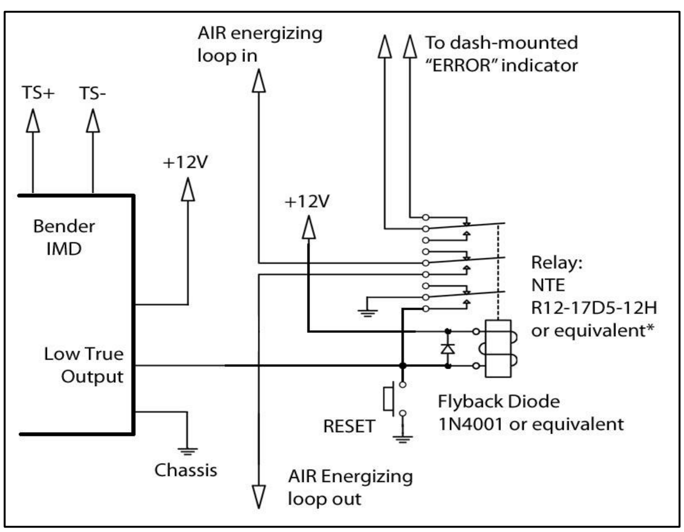

Figure 39 - Latching Circuit for Low-True output

Appendix I
SAE Technical Standards included in the CDS Rules

The SAE Technical Standards Board (TSB) has made the following SAE Technical Standards available on line, **at no cost**, for use by Collegiate Design teams. Standards are important in all areas of engineering and we urge you to review these documents and to become familiar will their contents and use

.

The technical documents listed below include both (1) standards that are identified in the rules and (2) standards that the TSB and the various rules committees believe are valuable references or which may be mentioned in future rule sets.

All Collegiate Design Series teams registered for competitions in North America have access to all the standards listed below - including standards not specific to your competition.

Baja SAE
J586 - Stop Lamps for Use on Motor Vehicles Less Than 2032 mm in Overall Width
J759 - Lighting Identification Code
J994 - Alarm - Backup – Electric Laboratory Tests
J1741 - Discriminating Back-Up Alarm Standard

Clean Snowmobile Challenge
J192 - Maximum Exterior Sound Level for Snowmobiles
J1161 - Sound Measurement – Off-Road Self-Propelled Work Machines Operator-Work Cycle

Formula Hybrid
J1318 - Gaseous Discharge Warning Lamp for Authorized Emergency, Maintenance and Service Vehicles
J1673 - High Voltage Automotive Wiring Assembly Design

Formula SAE
SAE 4130 steel is referenced but no specific standard is identified
SAE Grade 5 bolts are required but no specific standard is identified

Supermileage
J586 - Stop Lamps for Use on Motor Vehicles Less Than 2032 mm in Overall Width

SAE Technical Standards for Supplemental Use

Standards Relevant to Baja SAE

J98 – Personal Protection for General Purpose Industrial Machines – Standard
J183 – Engine Oil Performance and Engine Service Classification - Standard
J306 – Automotive Gear Lubricant Viscosity Classification - Standard
J429 – Mechanical and Material Requirements for Externally Threaded Fasteners – Standard
J512 – Automotive Tube Fittings - Standard
J517 – Hydraulic Hose - Standard
J1166 – Sound Measurement – Off-Road Self-Propelled Work Machines Operator-Work Cycle
J1194 – Rollover Protective Structures (ROPS) for Wheeled Agricultural Tractors
J1362 – Graphical Symbols for Operator Controls and Displays on Off-Road Self-Propelled Work Machines - Standard

J1614 – Wiring Distribution Systems for Construction, Agricultural and Off-Road Work Machines
J1703 - Motor Vehicle Brake Fluid - Standard
J2030 – Heavy Duty Electrical Connector Performance Standard
J2402 – Road Vehicles – Symbols for Controls, Indicators and Tell-Tales – Standard

Standards Relevant to Clean Snowmobile Challenge

J44 – Service Brake System Performance Requirements – Snowmobiles - Recommended Practice
J45 – Brake System Test Procedure – Snowmobiles – Recommended Practice
J68 – Tests for Snowmobile Switching Devices and Components **-** Recommended Practice
J89 – Dynamic Cushioning Performance Criteria for Snowmobile Seats **-** Recommended Practice
J92 – Snowmobile Throttle Control Systems – Recommended Practice
J192 – Maximum Exterior Sound Level for Snowmobiles **-** Recommended Practice
J288 – Snowmobile Fuel Tanks **-** Recommended Practice
J1161 – Operational Sound Level Measurement Procedure for Snowmobiles **-** Recommended Practice
J1222 – Speed Control Assurance for Snowmobiles **-** Recommended Practice
J1279 – Snowmobile Drive Mechanisms **-** Recommended Practice
J1282 – Snowmobile Brake Control Systems **-** Recommended Practice
J2567 – Measurement of Exhaust Sound Levels of Stationary Snowmobiles **-** Recommended Practice

Standards Relevant to Formula SAE

J183 – Engine Oil Performance and Engine Service Classification **-** Standard
J306 – Automotive Gear Lubricant Viscosity Classification **-** Standard
J429 – Mechanical and Material Requirements for Externally Threaded Fasteners – Standard
J452 - General Information – Chemical Compositions, Mechanical and Physical Properties of SAE Aluminum Casting Alloys – Information Report
J512 – Automotive Tube Fittings **-** Standard
J517 – Hydraulic Hose **-** Standard
J637 – Automotive V-Belt Drives – Recommended Practice
J829 – Fuel Tank Filler Cap and Cap Retainer
J1153 - Hydraulic Cylinders for Motor Vehicle Brakes – Test Procedure
J1154 – Hydraulic Master Cylinders for Motor Vehicle Brakes **-** Performance Requirements **-** Standard
J1703 - Motor Vehicle Brake Fluid **-** Standard
J2045 – Performance Requirements for Fuel System Tubing Assemblies **-** Standard
J2053 – Brake Master Cylinder Plastic Reservoir Assembly for Road Vehicles – Standard

Standards Relevant to Formula Hybrid

J1772 – SAE Electric Vehicle and Plug in Hybrid Conductive Charge Coupler

Standards Relevant to all CDS Competitions

J1739 – Potential Failure Mode and Effects Analysis in Design (Design FMEA) Potential Failure Mode and Effects Analysis in Manufacturing and Assembly Processes (Process FMEA) and Potential Failure Mode and Effects Analysis for Machinery (Machinery FMEA)

Appendix J
Firewall Equivalency Test

To demonstrate equivalence to the aluminum sheet specified in rule **T4.5.2**, teams should submit a video, showing a torch test of their proposed firewall material.

Camera angle, etc. should be similar to the video[19] found here:

http://www.formula-hybrid.org/torch-test/

A propane plumber's torch should be held at a distance from the test piece such that the hottest part of the flame (the tip of the inner cone) is just touching the test piece.

The video must show two sequential tests and be contiguous and unedited (except for trimming the irrelevant leading and trailing portions).

The first part of the video should show the torch applied to a piece of Aluminum of the thickness called for in **T4.5.2**, and held long enough to burn through the aluminum. The torch should then be moved directly to a similarly sized test piece of the proposed material without changing any settings, and held for at least as long as the burn-through time for the Aluminum.

There must be no penetration of the test piece.

[19] Note that early versions of this procedure called for a Mapp gas torch (yellow tank) which can be seen being used in the video. The correct torch is propane. (Blue tank)

Appendix K

Application of the Project Management Method to Formula Hybrid

Introduction

Engineering design and development projects are complex. The Formula Hybrid vehicle program is such a project. To complete these types of projects successfully, a structured, disciplined process for moving forward must be used. The project team must proceed in an orderly way during project execution rather than react to each situation that arises. Resources are limited and a set completion date must be met; resources and time cannot be wasted if project success is to be achieved. And success is normally defined as meeting the specifications and goals of the project, on-time, within the allocated budget. Application of the Project Management method is expected to improve the construction and compliance of the cars developed along with promoting effective teamwork throughout the competition.

Benefit of Project Management

Project management is a method for bringing discipline to a design and development effort throughout the four phases of the project life cycle. Figure 1 gives an overview of the project life cycle and the major supporting activities for each phase. Once a proposed project is approved to begin, the project manager initiates the planning process in which the project is more clearly defined and a path for successful completion is created. During the execution phase the project manager monitors the completion of project tasks. When challenges or barriers are encountered the project manager intervenes and develops a revised plan that will once again lead the team members toward achieving project goals despite these problems.

During the final phase, when the project is completed, the focus is upon continuous improvement. A debriefing session is conducted by the project manager with the team to identify the strengths of the plan and weaknesses that need correction for future projects. To prevent the loss of lessons learned from project debriefing sessions and other project experiences, a succession plan for transferring knowledge is developed. This plan minimizes the risk that a project team must relearn valuable lessons from the past. It also helps the team to begin much higher up the learning curve when planning and executing new projects.

A reoccurring weakness of many projects is the inability to maintain accurate documentation and keep all team members aligned with the most current "plan of record" during project execution. All project plans are created with some level of uncertainty; unanticipated events will occur and new knowledge gained during execution which will require a change in project scope or plan. To accommodate these situations, a disciplined change management process is used to ensure that all project team members are working to the same requirements and schedule despite changes that are being made. By using this process, at project completion all documentation will accurately reflect what was actually constructed. Thus, a key component of the project execution phase is a change management process designed to be compatible with the team's method of operation.

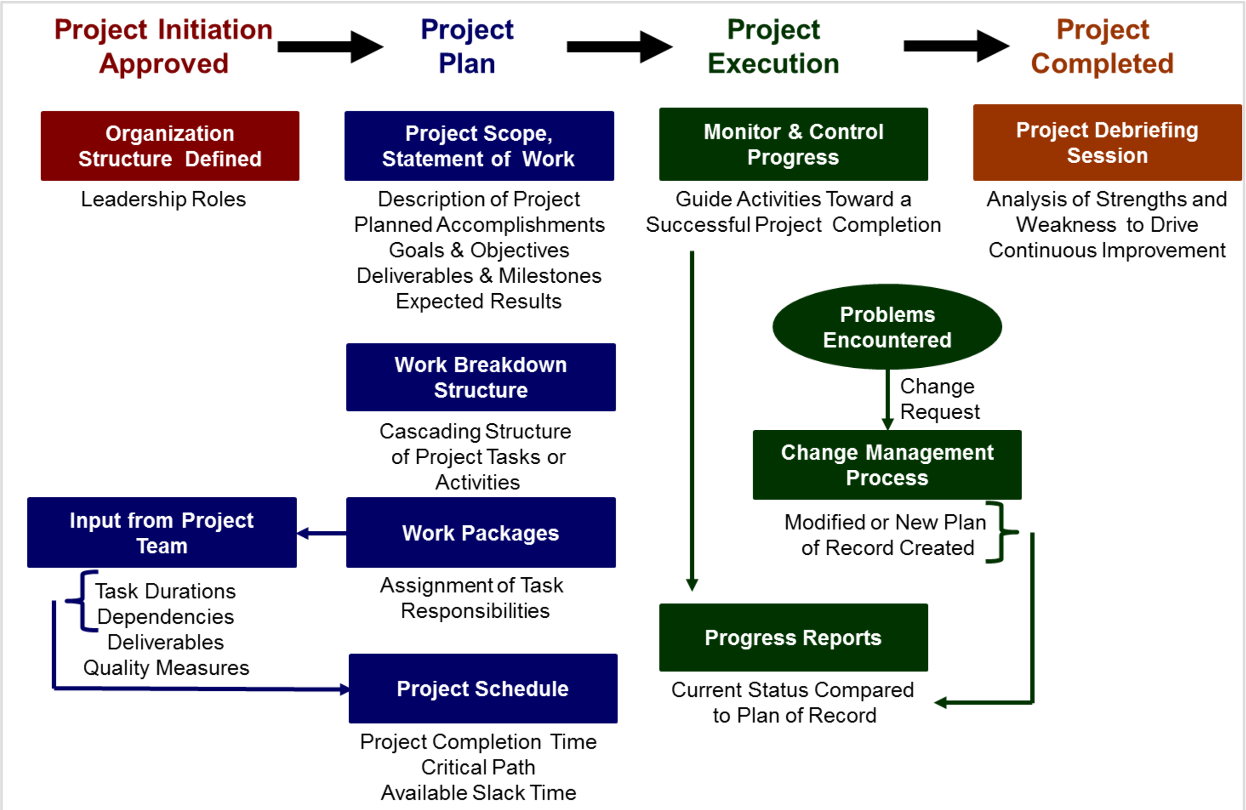

Figure 1 – Project Life Cycle

Project management requires the team to "think" and "strategize" before beginning a design and development effort. Time is allocated before the project execution begins to plan a course of action. This is counter to the natural tendency, when facing tight deadlines for challenging projects, to "stop wasting time" and "do something". Without a project plan, the team members "react" to situations that frequently lead to lost time, wasted resources, and overlooking specifications that must be met for compliance.

Project Management

Project management is not a bureaucratic process, but a structure that is intended to help the project team succeed. It is designed to assist the project team not hinder it. If project management becomes an obstacle, then the process is not designed correctly and must be re-engineered by the project team.

An effective project management process requires some documentation, but not a large quantity of documentation. As a disciplined process, strict adherence to due dates, deliverables, milestones, and change management is a necessity. If it appears that any of these items may be in jeopardy, the project manager must be notified immediately. If deadlines are missed or specifications cannot be met, the project manager must create a recovery plan that gets the project back on track using a change management process. The constraints of time, resources, and budget will influence the decisions made during the execution phase. Unfortunately, at times these constraints may affect the ability of the team to meet all of the project goals and objectives. When this occurs, the team must make a decision on what will be retained and what goals will be abandoned. But, this is the result of discussion and a conscious decision rather than the result of "whatever happens" at the end of the project.

1. PROJECT PLANNING

The plan is the road map to successful project completion. Project execution should not be started without a well-defined, achievable plan. Projects started with an incomplete plan, but the intention of completing it at a later date when the project team acquires a greater understanding, usually fail. They needlessly consume resources and waste time on tasks that do not help achieve the project goals. The project manager's first priority is leading the project team members in developing an acceptable project plan.

To create a project plan, information is needed regarding four different areas: (1) scope of the project, (2) tasks or activities that must be completed, (3) roles and responsibilities of the project team members, (4) project schedule. Once a project has been approved, three standard types of project documents are generated that summarize the information needed for creating the plan; Statement of Work, Work Breakdown Structure, and Work Packages. With inputs received from members of the project team, the project manager develops the entire project plan.

Project Scope: Statement of Work

Statement of Work (SOW) is a short description of the project. It is also referred to as the project scope and must be completed before significant planning of activities or tasks can occur. A meaningful SOW can be written in less than 2 pages. Information contained includes:

A. Reason for the Project: In a business setting this is usually associated with (1) increasing revenue, (2) reducing cost, (3) strategic objectives. In Formula Hybrid "strategic objectives" of the team or individual members would most likely be the reason for competing.

B. Project Objectives: The goals and objectives are usually answers to the question: as a team what are we trying to achieve in this year's competition, beyond winning? These can be secondary goals such as increasing performance of the car, testing new components or technologies, improving overall team performances. The stated objectives should be a standard against which decisions made throughout the project are measured. When selecting from among alternatives; the team must ask: how does this choice move us closer to achieving our objectives? In general, effective team objectives are defined by following the guidelines for creating "SMART" goals

C. Sponsor of the Project: the company, organizational, or individual sponsors have objectives for own involvement ; the objectives of the sponsors must also be considered in defining project scope

D. Project Manager: Accountable for success of the project; even though members of the team have responsibilities contributing to the successful completion of the project, the Project Manager is accountable for bringing the project to a successful completion. Therefore, the Project Manager collaborates with the Project Team Leader to arrive at a consensus on how to proceed with project planning and execution but if consensus is not reached in a timely manner the Project Manager makes the decision.

E. Key Project Deliverables, Milestones: These items define the pathway to successful completion. Milestones represent completion of several tasks that together mark the completion of a significant part of the project. Typical Formal Hybrid milestones include: Team Understands Formula Hybrid Rules, Fundraising Goals Achieved, Vehicle Architecture Defined, Key Electrical System Components Selected, Electrical System Integration Completed, Vehicle Testing Initiated.

F. Expected Results: These items are "measures of success" helpful guides in determining to what extent the project goals and objectives were achieved. They are used at project completion to assess if it was a success, partial success or failure.

Typically when an engineering project has been finished, the project manager conducts a debriefing session with project team members to identify what worked well during project execution and areas of weakness where improvement is needed. A root-cause analysis is performed to identify improvement opportunities for future projects. The "expected results" criteria are used to focus the deliberations during the debriefing session.

The project scope, SOW, describes at a high level the work that is to be done and the goals and objectives of the project. This work, and only this work, should be performed unless the scope is officially modified using the team's change management process. During project execution, the project scope is the "stake in the ground" serving as a guide to all team members operating in the fast paced, sometimes chaotic environment typical during project execution. When a decision must be made immediately by a team member, and there is insufficient time to consult with team leaders, the decision should be made considering how it supports the goals and objectives defined in the SOW.

"SMART" Goals

Projects are initiated to achieve predetermined goals. Well-defined goals are recognized as "SMART" goals if they have the following characteristics:

- Specific: sufficient detail is provided to clearly identify the targeted development areas
- Measurable: quantify the expected improvement so that progress can be measured, "measures of success"
- Assignable: the person or group responsible for achieving the goal is known
- Realistic: establish goals that can actually be achieved given the resources and time available
- Time-Related: specify deadlines for achieving each goal

Following these guidelines will result in tangible objectives being established that are effective in aligning the efforts of individual team member with the common purpose of the team. Being achievable the goals can be motivational rather than a burden to the team members. SMART goal characteristics are referenced throughout Formula Hybrid Project Management.

Formula Hybrid Program: SOW Considerations

Formula Hybrid Program Objectives: Design and build a formula hybrid race car with superior on-track performance

Design Constraints: Meet the specified design guidelines and safety standards

Project Constraints: Time schedule, budget, technical expertise, resources

One obvious objective of the Formula Hybrid project is to win the competition, the overarching goal. But there can be additional secondary goals that should be included in the SOW so they are not forgotten when establishing priorities or making decisions during project execution. These could be perfecting the design of last year's car, strengthening sub-systems that failed or performed poorly, testing the endurance of a new component or sub-system, introducing a completely new design, introducing a new technology to determine if it enhances performance and is durable.

Seldom is a breakthrough product developed with all aspects being an entirely new design. Technology based products usually evolve with the progressive introduction of new technologies or features into existing designs that ultimately lead to an entirely new product with superior performance and capabilities not available in the past.

2. PROJECT STRUCTURE

Organization

A project is conducted within an organizational structure to enable the efficient use of resources. Traditionally, a large organization is partitioned into an arrangement of independent components, which decentralizes responsibilities and promotes distributed decision making. When the partitions are created around functions, this is called a functional organization. Projects are supported in this type of organization by assigning specialists to work groups focused on completing an assigned task. When they are done, they are reassigned to another project.

A project team is an alternative to the functional work group. A team is an interdisciplinary group of individuals who are responsible not only for their own assignment but for the success of the entire team. Team members frequently assist others in an effort to complete tasks and advance the project forward, even if a task is outside their area of expertise. Reassignment of team members is not done until the entire project is completed.

To fully understand a project plan it is necessary to know the organization structure in which it is being conducted. If either a work group or project team structure is used, there will be a leadership hierarchy created to manage the project. Each formula hybrid team will have a management structure suitable for its operation. A schematic of the organization structure should be included in the project plan along with a brief description of how project management will be performed. Because it is a demanding position, it is recommended that the Project Manager be someone other than the team captains.

Succession Plans

Formula Hybrid Project Management requires a set of deliverables specific to a team's plan for designing and producing a high performance hybrid race car. In addition, two process related deliverables are required describing how the team will operate. The change management process is used to administer necessary deviations from the plan of record; it is a method for dealing with uncertainty and risk. The succession plan is the process for passing along the knowledge and experience the team has gained in the past onto future members who can capitalize upon these "organizational learnings" in the planning and execution of new projects.

The succession plan describes an approach to recruit, retain, and develop individuals with skills needed to sustain the functional operation of the Formula Hybrid Team. It also describes how continuity in leadership will be maintained. These are particularly challenging tasks because experienced individuals repeatedly depart after graduation and the demands of classwork routinely limit the active participation of team members. Succession planning also involves the retention of important technical information for use in future designs or development efforts.

Within the organization structure section, each team should provide a brief overview of its succession plan to describe how the knowledge and experience gained will be passed along to future Formula Hybrid team members, giving them the opportunity to benefit from past "organizational learnings".

Work Breakdown Structure (WBS)

To make a large project more manageable and increase the probability that all necessary work will be completed in an orderly manner, a process of "segmentation" is performed dividing the project into smaller manageable pieces. The WBS is a schematic representation of the pieces of the project, called activities or tasks. Using a cascading representation, the WBS shows how the pieces fit together to form the structure of the total project. It is a tool for planning the detailed execution of the project; it structures the way work will be performed.

WBS Example:

Your company makes back-plates for vehicle braking systems. Your customer, a major auto manufacturer, has informed you that a high failure rate of brake systems has been experienced because of corrosion within the brake wheel unit and severe abrasion of moving parts within the wheel unit.

A Failure Mode Analysis indicates the cause as:

(1) Inadequate drainage of trapped water within the unit

(2) Dull metal cutting tooling that is leaving rough edges on the back-plate stampings

Your customer wants this problem fixed immediately!

A five-level WBS for this project is shown in Figure 2. Levels 1-2 involve administrative functions supporting the project. Authorization to initiate the project is received at Level 1 "Program". The project budget, or resource allocation, is approved at Level 2 "Project". Identification of the large scale efforts or functional areas that are needed to complete the project are identified in Level 3 "Tasks". A sub-division of these broad activities or responsibilities are shown in Levels 4 and 5, "Sub-Tasks" and "Work Packages".

The budget and allocated resources approved at the "Project" level are distributed among the Level 5 "Wok Packages" tasks by the project manager during creation of the project plan. The project team members may estimate that more resources are needed than what have been allocated. If this occurs, the project manager adjusts the schedule or project scope until a balance between budget, resources, project scope, and time schedule is achieved.

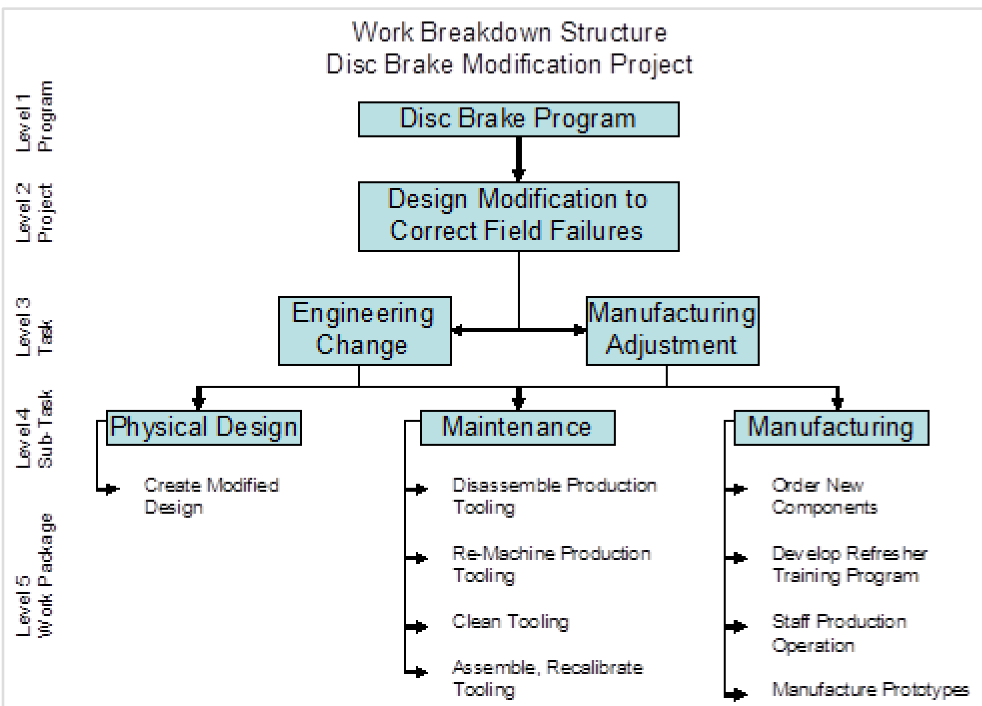

Figure 2 – Work Breakdown Structure

WBS Guidance for the Formula Hybrid Competition

Using the example in Figure 1 as reference, the Level 1 "Program" entry could be the Formula Hybrid Competition. The Level 2 "Project" entry could be a series of sub-projects or focus areas which combined will cover all the work necessary for the competition. These areas could be aligned with the structure defined in the organization schematic.

The Level 3 "Tasks" entries could be more specific of the major activities that must be conducted in the sub-projects. For example, these could include the following:

- Mechanical Design
- Electrical Design
- Design Optimization
- Vehicle Integration
- Verification Testing
- Quality & Safety Compliance
- Performance Optimization

Work Packages (WP)

The Project Manager is responsible for segmenting the project into manageable pieces. The relationship between these pieces is presented schematically in the WBS. Levels 1-2 are administrative designations, levels 3-5 identify tasks that must be completed. Information needed to create the project plan is obtained from the most detailed level of the WBS, Level 5 "Work Packages".

The Project Manager creates Work Packages using four guidelines. A well-defined WP is:

A. Manageable: Specific responsibilities and deliverables are assigned
B. Independent: Minimum interfaces and dependencies exist with other groups; even though dependencies are unavoidable
C. Unifiable: Total project can be assembled from the pieces
D. Measurable: Progress and quality in each of the pieces can be determined

The Project Manager assigns WPs to individuals or groups capable of completing the work. A WP is less than 1 page and each person responsible for a WP is required to provide the following information to the Project Manager. This information is used to create the project schedule, describes resources required, defines deliverables from the effort, and identifies interdependencies between tasks.

- WP Objectives
- Budget required
- Assigned Responsibilities
- Resources Needed
- Required Inputs from Predecessor Activities
- Time required to Complete WP
- Deliverables to Following Activities
- Performance Measures

With completion of the SOW, WBS, and all WP information received, the Project Manager can proceed to developing the project schedule.

Project Scheduling:

The WBS schematically shows the basic project tasks that must be completed and the groups or individuals responsible for completing those tasks, but it does not provide information on the timeframe in which each must be performed. Also, because some of these tasks can be performed in parallel, and some must occur sequentially, the overall project duration cannot be calculated by simply adding up individual task times.

Construction of a Gantt cart will enable the project completion time to be determined graphically along with the necessary start and finish times for each task. In addition, the Gantt chart serves as a useful tool for tracking progress during project execution.

The Gantt chart graphically shows the interdependencies between tasks or activities for a project. From the Gantt chart several important project parameters can be determined:

A. Expected time for project completion
B. Critical activities; if they are delayed the project completion date is pushed-out
C. Activities with slack; they can be delayed, within limits, without affecting the project completion date
D. Start and finish dates for each activity; performing each activity within these specified time intervals will lead to the overall project being completed on time

In addition, the Gantt chart can be used to plan resource utilization. Using the WPs as a reference, it can show when specific resources must be available and can be used as a tool for coordinating resource deployment across the entire project schedule. A staffing profile can be constructed using the WPs and Gantt chart.

Table 1
Disc Brake Modification Project Activity Parameters

Activity Name	Description	Immediate Predecessor	Activity Duration (Weeks)
A	Create Modified Design	None	3
B	Disassemble Production Tooling	None	1
C	Order New Components	A	2
D	Re-Machine Production Tooling	B	3
E	Clean Tooling	B	2
F	Develop Training Program	B	2
G	Assemble, Recalibrate Tooling	D, E	3
H	Manufacture Prototypes	C, G	1
I	Staff Production Operation	F	4

Table 1 lists information needed for creating a schedule for the Disc Brake Modification Project. This information was extracted from the WPs prepared by the project team members. Duration of each activity is needed to determine the total completion time of the project. Information on immediate predecessors defines the interrelationships between activities. Some activities cannot begin before results, or deliverables, are obtained from an earlier task. Predecessor information affects which activities can be conducted in parallel and which must be done sequentially.

The Gantt chart for the Disc Brake Modification Project example is shown in Figure 3. It was constructed using the information from Table 1 and applying the critical path scheduling method.

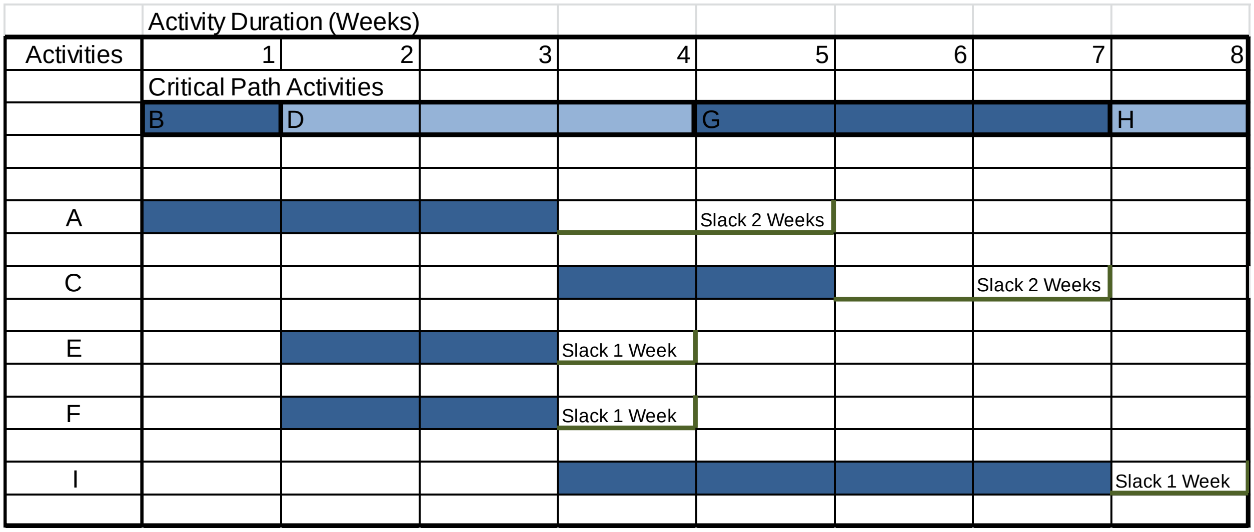

Figure 3 - Disc Brake Modification Project

The schedule shows that the duration of this project is 8 weeks. There are 4 critical path activities; if time beyond the planned interval is needed to complete any one of these tasks, completion of the entire project will be delayed beyond 8 weeks. There are also 5 activities with slack ranging from 1 to 2 weeks. If additional time is used to complete any of these activities, but it is less than the slack value, then there will be no impact to overall project completion. Slack time provides a time buffer in the project schedule and can be used selectively to balance the demand for resources during project execution and to compensate for slips in schedule.

Construction of a Gantt Chart

The Gantt chart can be constructed graphically using an excel spreadsheet. A summary chart similar to the one shown in Figure 2 is generated through a series of four steps.

> **Step 1**: construct a project schedule when all actives are started at the earliest time possible, a forward pass.
>
> **Step2**: construct a schedule when all activities are completed as late as possible, a backward pass.
>
> **Step 3**: compile a table of activity times from the forward and backward pass schedules; Earliest Start, Earliest Finish, Latest Start, Latest Finish
>
> **Step 4**: calculate Slack Time from the activity times in the table; tasks with zero Slack Time are critical path activities, combine these activities together to define the critical path of the project. But be aware that it is not unusual for a project to have more than one critical path.

Following are the results from the 4-step process used to construct the Gantt Chart in Figure 3 for the Disc Brake Modification Project.

Step 1 Forward Pass

Figure 4 - Earliest Start Gantt Chart

Using the activity duration times and precedence relationships given in Table 1, place each activity on the chart as early as possible while also maintaining the correct precedence between activities. The logic used to create the early start Gantt chart is given in Table 2.

Activity	Duration	Precedence Relationship	Earliest Starting Time
A	3 weeks	no predecessor	at project start
B	1 week	no predecessor	at project start
C	2 weeks	must follow A	A ends at week 3, start at week 3
D	3 weeks	must follow B	B ends at week 1, start at week 1
E	2 weeks	must follow B	B ends at week 1, start at week 1
F	2 weeks	must follow B	B ends at week 1, start at week 1
G	3 weeks	must follow D and E	D ends at week 4, E ends at week 3 start at week 4
H	1 week	must follow C and G	C ends at week 5, G ends at week 7 start at week 7
I	4 weeks	must follow F	F ends at week 3, start at week 3

Table 2 – Logic for Constructing the Earliest Start Gantt Chart

The forward pass process is used to determine the Earliest Start, Earliest Finish times for each activity. In Figure 4, the combined activities give a project completion time of 8 weeks.

Step 2 Backward Pass

The forward pass process is used to determine the total duration of the project. This completion time is used as the starting point when performing the backward pass process. All actives directly linked to the end of the project, not another activity, are assigned the project completion time as their Latest Finish time.

The Latest Start Gantt Chart is given in Figure 5. It was constructed using the backward pass process. The Latest Start and Latest Finish activity times are determined using the backward pass process. Care must be taken when using the backward pass process because it is easy to be confused.

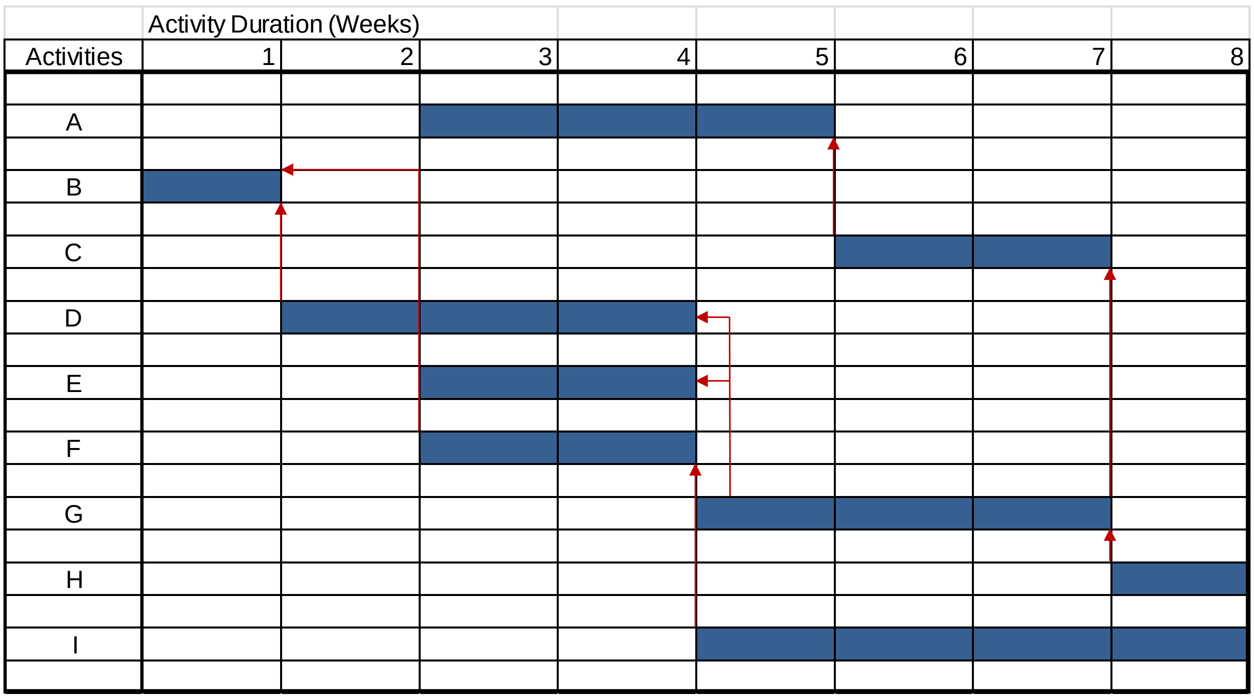

Figure 5 – Earliest Start Gantt Chart

The logic used to create the Latest Start Gantt chart is given in Table 3. Starting with the activities directly linked to the end of the project, define their Latest Finish times as the completion time of the project. Subtract the duration of each activity to calculate the corresponding Latest Start times for these activities. Then continue "progressing backwards" by assigning Latest Finish times to activities to the immediate predecessors of activities already processed.

Activity	Duration	Precedence Relationship	Latest Finishing Time
I	4 weeks	linked to project end	assign I finish time end of 8, I starts at beginning of week 5
H	1 week	linked to project end	assign H finish time end of 8 week, H starts at beginning of week 8
G	3 weeks	followed by H	H starts at beginning of week 8
			G finishes at end of week 7, G starts at beginning of week 5
F	2 weeks	followed by I	I starts at beginning of week 5,
			F finishes at end of week 4, F starts at beginning of week 3
E	2 weeks	followed by G	G starts at beginning of week 5
			E finishes at end of week 4, E starts at beginning of week 3
D	3 weeks	followed by G	G starts at beginning of week 5
			D finishes at end of week 4, D starts at beginning of week 2
C	2 weeks	followed by H	H starts at beginning of week 8
			C finishes at end of week 7, C starts at beginning of week 6
B	1 week	followed by F, E, D,	F starts at beginning of week 3, E starts at beginning of week 3,
			D starts at beginning of week 2**
			thus B must finish at end of week 1
A	3 weeks	followed by C	C starts at beginning of week 6
			A finishes at end of week 5, A starts at beginning of week3

Table 3 – Logic for Constructing the Latest Start Gantt Chart

Step 3 Compile Activity Times

The activity times from the Early Start, Latest Start Gantt Charts are summarized in Table 4.

Activity	Earliest Start (Weeks)	Earliest Finish (Weeks)	Latest Start (Weeks)	Latest Finish (Weeks)	Slack Time (Weeks)
A	0	3	2	5	2
B	0	1	0	1	0**
C	3	5	5	7	2
D	1	4	1	4	0**
E	1	3	2	4	1
F	1	3	2	4	1
G	4	7	4	7	0**
H	7	8	7	8	**
I	3	7	4	8	1
				** Critical Path Activities	

Table 4 - Activity Times for the Disc Brake Modification Project

Step 4 Calculate Slack Time, identify Critical Path Activities

Slack Time can be calculated two ways; both methods give the same result:

A. Slack Time = (Latest Finish Time) – (Earliest Finish Time)

B. Slack Time = (Latest Start Time) – (Earliest Start Time)

Slack Times for the Disc Brake Modification Project are given in Table 4. Activities without Slack are Critical Path Activities. For this project they are:

- Activity B Disassemble Production Tolling
- Activity D Re-Machine Production Tooling
- Activity G Assemble, Recalibrate Tooling
- Activity H Manufacture Prototypes

During project execution these critical path activities must be carefully monitored and controlled to prevent a delay in project completion. But the other activities must also be monitored. If the available slack time is fully consumed, these activities can become critical path activities.

The results from this 4 step process have been consolidated into a single Gantt chart for the Disc Brake Modification Project shown in Figure 2.

3. PROJECT EXECUTION

With the project plan completed and all members of the project team informed of their roles and responsibilities using the WPs, execution of the project plan can begin. The role of the project manager shifts at this point from planning to monitoring and control. The primary focus is on directing the project toward a successful completion; with success defined as meeting the project goals and objectives on-time and within the budget and resource constraints.

The Gantt chart constructed during the project planning phase is a good tool for monitoring progress. At any point during project execution, called the cut-off time, the project manager can call for a report on progress. Using this cut-off time as a reference, the project team members report on the activities completed, not started, or those in progress. For activities in progress an estimate of percent complete is needed. The project manager compares this information to the plan of record and determines if the project is on schedule, behind schedule, or ahead of schedule.

Recovery Planning

When activities are behind schedule two basic actions should be considered. If additional people with the correct skills and expertise can be brought into the project, or existing team members can be temporarily reassigned, increasing the staff working on specific activities will reduce the time interval needed to complete these activities. By applying additional people to downstream activities, the adverse impact from schedule over-runs by earlier activities can be reduced or eliminated.

If additional resources cannot be applied, then splitting activities should be a considered. If deliverables from a predecessor activity are late, splitting downstream activities can allow work to begin on-schedule for tasks that are not dependent upon these deliverables. This practice will cause some activities that were originally planned to be performed sequentially to now be performed in parallel with other activities upon which they are dependent.

Splitting activities introduces a risk into the project because once the deliverables are received it may be necessary to redo some of the work performed in response to the actual inputs. But, when additional resources are not available, splitting may be the only way to offset the adverse impact of delays in predecessor activities, without modifying project scope.

Project Monitoring and Control Example

An example of how to use the Gantt chart to monitor and control a project follows. The project manager for the Disc Brake Modification Project has called for a read-out of progress at a cut-off time of 4 weeks. Figure 5 shows a summary of the reports received from project team members. The red circles represent the actual status of each activity; the blue bars represent the planned status of these activities.

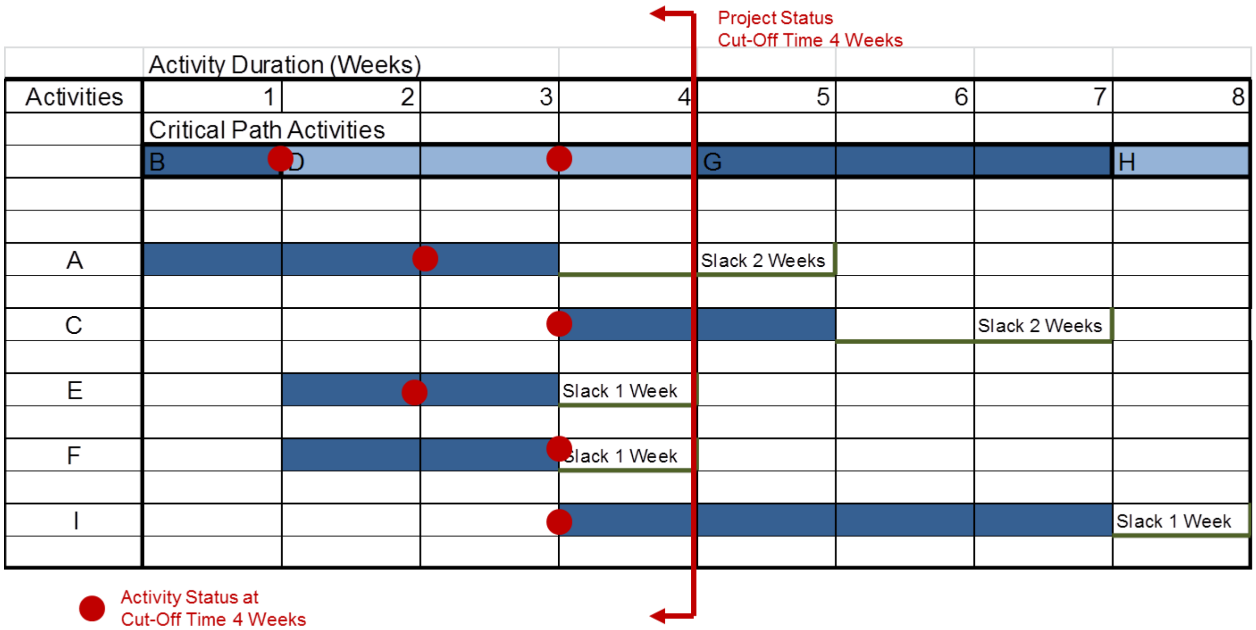

Figure 6 - Disc Brake Modification Project – 4 Week Status Report

A comparison of the planned and actual status of each activity is given in Table 6. From this summary of project status against plan, it is reasonable to conclude that the project is behind schedule at the 4 week cut-off point and recovery actions are necessary. Given this situation, the project manager takes “control” of the project and identifies recovery actions necessary to get the project back on schedule. Because the cut-off time is midway in the project schedule, there is sufficient time to get the project back on track before the planned completion. As the project proceeds closer to scheduled completion recovery becomes more difficult or impossible.

Table 5 lists the recovery actions needed to bring the project back on schedule. They include adding resources, activity splitting, and using available slack time.

Overall the activities related to tooling improvement are causing the most serious delays. However, even though it is not a critical path activity, Activity A, creating the modified design, will affect several downstream activities related to material availability and prototype manufacture. The project manager must carefully monitor this design activity so that excessive delays will not create a new critical path in the project.

Once decisions are made on the actions to be taken to get the project back on schedule, the project manager will create a new Gantt chart reflecting new activities created by splitting and reduced durations resulting from application of additional resources. This then becomes the “plan of record” against which future progress will be measured.

Activity	Planned Status	Actual Status	Status Against Plan	Recovery Actions
A	Complete	2/3 Complete	Behind Schedule	One week needed to complete Activity A, carefully manage completion within the 1 week of available slack remaining
B	Complete	Complete	On Schedule	No action required
C	1/2 Complete	Not Started	Behind Schedule	One week behind schedule, manage completion within the 2 weeks of available slack
D	Complete	2/3 Complete	Behind Schedule	One week behind schedule, as a critical path activity this extends completion time of entire project by one week; add resources to Activities G or H to reduce their durations to compensate for the excessive time consumed by Activity D ; as an alternative, split Activity G and begin work not dependent upon Activity D immediately, or begin work with assumptions of what the inputs or deliverables from Activity D will be
E	Complete	1/2 Complete	Behind Schedule	One week needed to complete Activity E, but there is no slack left; add resources to quickly complete Activity E; this activity is a predecessor to Activity G, add resources to Activity G to reduce its duration to compensate for the excessive time consumed by Activity E
F	Complete	Complete	On Schedule	No action required
G	Not Started	Not Started	On Schedule	No action required
H	Not Started	Not Started	On Schedule	No action required
I	1/4 Complete	Not Started	Behind Schedule	One week needed to complete Activity I, carefully manage completion within the 1 week of available slack

Table 5 - Disc Brake Modification Project – 4 Week Status Report Recovery Actions

Change Management

Encountering unanticipated problems during project execution is a common occurrence in project management. When problems arise, this is an opportunity for the project manager and members of the project team to develop creative solutions or new approaches to move the project forward. This is done with a determination to achieve the goals and objectives defined for the project despite barriers. However, frequently student engineers make changes in an undisciplined way, reacting to a problem rather than in a more thought-out manner that selects the best solution from a number of alternatives and document changes to make all team members aware of the revised project plan.

It has already been seen that a project may need to be changed to compensate for delays or set-backs during execution. However, at times it may not be possible, or even desirable, to preserve the original plan; a modified or new project plan may be the best alternative. Typically this results in new activities, a new time schedule, or a re-working of project scope in which the specifications or goals and objectives of the project are modified. When circumstances or new knowledge acquired dictate a significant modification to the project plan, to maintain discipline during project execution, these changes must be approved using a “change management process” before including them in the “plan of record”.

Change management is a simple process that ensures that all project team members affected are notified that unanticipated circumstances or new information obtained during project execution required that the project scope or plan be modified. They are informed of the approved changes and everyone’s work is aligned with the revised “plan of record”.

The change management process also serves as a way to control "scope creep", the tendency for a project to extend beyond its initial boundaries as project team members succumb to pressure, either self-imposed or from external sources, and attempt to deliver more than originally planned. Only work approved through the change management process is authorized; resources are not to be applied to any other efforts.

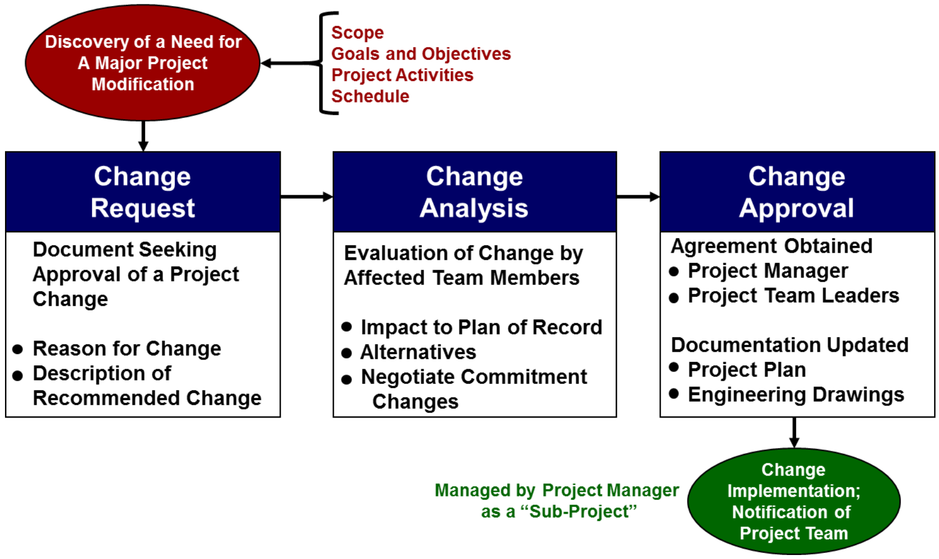

Figure 7 - The Project "Change Management Process"

A basic change management system is shown schematically in Figure 7. When the need for a major change is discovered by any team member, a change request is submitted to the project manager. This request briefly describes the change and the reason it is necessary. Also it states if the change must be made immediately or if it less urgent and can be bundled with other changes for implementation at a set time in the future.

In response to the change request, the project manager calls a meeting with all affected members of the project team to determine the impact of the change on the current plan, identify other alternatives for addressing the problem identified, and assess the possibility of re-directing resources and changing current schedule commitment to accommodate the change.

After obtaining agreement with the project team leaders on the best approach to follow, the project manager approves the change for implementation. A revised project plan is created and instructions are given for updating engineering drawings so that they will accurately reflect what is being constructed under this version of the project plan. All members of the project team are notified by the project manager of the new "plan of record" and all efforts are now directed toward completing this new plan.

The change management process adopted should not be cumbersome or time consuming. But, it should help maintain discipline during project execution. When project teams are driving hard to complete the project, it is easy for a chaotic environment to develop. Under such conditions team members may be uncertain about the plan being followed and documentation gradually "drifts from reality", not accurately reflecting the end product actually produced. The time spent using a well-designed change management process will be a fraction of the time wasted in a poorly managed, undisciplined environment in which team members react to situations rather than proceed in an orderly way to achieve the project goals.