

# Progressive Insurance Automotive X PRIZE Supplemental Regulations for Knockout and Finals Stages Amendment and Addendum v2.2 to Competition Guidelines Version 1.3

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# **1 Progressive Insurance Automotive X PRIZE**

The goal of the Progressive Insurance Automotive X PRIZE is to inspire a new generation of viable, super-efficient vehicles that help break our addiction to oil and stem the effects of climate change.

A ten million dollar cash purse will be awarded to the Teams that win a long-distance stage competition for clean, production-capable vehicles that exceed 100 miles-per-gallon energy equivalent (MPGe). Both new vehicles and modifications of existing vehicles may enter.

The Progressive Insurance Automotive X PRIZE will encourage production-capable vehicles and vehicle modifications (not concept cars and experimental products) through tough entrance requirements, judging criteria, performance tests, and a stage competition that together evaluate manufacturability, marketability, safety, durability and performance. The Progressive Insurance Automotive X PRIZE will devote considerable traditional and online media resources to public outreach, education, and involvement.

## **2 Competition Principles**

### **2.1 Safety is Paramount**

Safety is the paramount consideration in all aspects of the Progressive Insurance Automotive X PRIZE. The technical specifications presented here are designed to ensure the safety of the members of Teams, other participants, workers, and organizers, and spectators as well as to level the playing field between all competitors. Here we document the Technical Specifications established to guide the Teams in delivering competition-ready vehicles that have been designed and constructed with safety in mind, and that have inherent safety features.

### **2.2 Establishing a Level Playing Ground**

Another key reason for these vehicle Technical Specifications is to set a level playing field for the Competition. The vehicle Technical Specifications set the methods, procedures, and expectations such that every participant will meet the same requirements and be treated in the same objective, rigorous way.

### **2.3 Equality and Fairness**

Each participant has a right to know that all participants are being treated equally and fairly. Given the nature of this Competition, each participant needs to know that their performance will be measured accurately and without bias. It is the intention of the Competition organizers and sponsors to be fair and honest with all Teams. These vehicle Technical Specifications are a primary method of institutionalizing that intent.

### **2.4 Good Faith**

Progressive Insurance Automotive X PRIZE organizers and sponsors are entering into this Competition in good faith. We expect and require the Teams and all participants to join us in working to make the Progressive Insurance Automotive X PRIZE a positive and constructive experience for all involved, including Teams, sponsors, and spectators. Individuals and Teams that cannot keep this good faith and positive attitude will be excluded from the Competition. As

in all human endeavors, mistakes, and misunderstandings can happen. To address these potential situations, an appeals process for decisions of Competition organizers is provided (see Section 7.5 of this addendum). All Progressive Insurance Automotive X PRIZE participants are expected to cooperate with the organizers to provide the most favorable experience possible for all involved.

## **2.5 Evolving Specifications**

The Progressive Insurance Automotive X PRIZE expects to publish revisions of these Technical Specifications, to provide more information and to include additional specifications whose need becomes apparent as the Competition evolves. There may also be unanticipated issues that arise and require modifications to this document. Thus, the Progressive Insurance Automotive X PRIZE reserves the right to revise these Competition Guidelines as appropriate.

## **2.6 Guiding Principles**

Additional details on the guiding principles for the development of these Guidelines can be found in version 1.3 of the Competition Guidelines.

# **3 Purpose of This Document**

These Supplemental Regulations are an amendment and addendum to the Competition Guidelines and are meant to augment the Competition Guidelines by combining the Technical Specifications with information intended to clarify and quantify the rules of the Competition so that they can be easily understood and fairly applied during the events. Items in this document supersede statements regarding the same topic in previous documentation. Items not addressed in this Addendum should be considered to still be governed by Competition Guidelines v1.3 and/or the Vehicle Technical Specifications. As agreed to in Section 5.1 (a) of the Master Team Agreement, Teams must comply with this amendment to the Competition Guidelines.

# **4 Administrative Regulations**

## **4.1 Contact Information**

Teams should use the Progressive Insurance Automotive X PRIZE Team Development and Relations staff as the primary point of contact.

- Julie Zona ([julie.zona@xprize.org](mailto:julie.zona@xprize.org))
- Bethann Buddenbaum ([bethann.buddenbaum@xprize.org](mailto:bethann.buddenbaum@xprize.org))

### **4.1.1 Administrative Questions Process**

All administrative questions should be addressed to the Team Development and Relations staff.

### **4.1.2 Technical Questions Process**

All technical questions should be addressed to the Team Development and Relations staff.

## **4.2 Team Contact Info**

Teams are responsible for providing updated contact information, reporting changes of address, email, etc. to the Team Development and Relations staff.

### 4.3 Withdrawals

Teams should contact the Team Development and Relations staff with their intention to withdraw from the Competition.

### 4.4 Competition Schedule

28 February, 2009:	Deadline for Initial Applications
15 June, 2009:	Deadline for Data Submissions
19 October, 2009:	Media event including: Announcement of Qualified Teams (the Teams that passed Design Judging) Announcement of the <i>DASH+</i> National High School Contest Display of representative vehicles Location: New York City
2-4 November, 2009:	Technical Summit for Teams in conjunction with the SEMA convention (with some vehicles on public display) Location: Las Vegas, NV
15 December, 2009	First Technical Deliverable Due (including fuel selection and ESS documentation)
15 January, 2010	Waiver Request Deadline
30 January, 2010	Second Technical Deliverable Due
30 March, 2010	Third Technical Deliverable Due
25 April, 2010	Shakedown Stage Wave #1 Team Arrival and Registration Location: Michigan International Speedway (MIS)
26–30 April, 2010 &	Shakedown Stage Wave #1 Location: Michigan International Speedway (MIS)
2 May, 2010	Shakedown Stage Wave #2 Team Arrival and Registration Location: Michigan International Speedway (MIS)
3–7 May, 2010	Shakedown Stage Wave #2 Location: Michigan International Speedway (MIS)
14 June, 2010	Vehicle Modification Documentation
16-18 June, 2010	Shakedown Stage (Wave #3 – Make-up Session) Location : Michigan International Speedway (MIS)
20–30 June, 2010	Knockout Qualifying Stage Location: Michigan International Speedway (MIS)
12 July, 2010	Vehicle Modification Documentation
19–30 July, 2010	Finals Stage and Coast Down Testing Location: Michigan International Speedway (MIS)
2—21 August, 2010	Validation Testing (Dynamometer Tests) Location: Chicago (DOE Argonne National Laboratory)
September, 2010:	Awards Ceremony Announcing Winners Location: TBD

## **4.5 Mandatory Insurance**

Each Progressive Insurance Automotive X PRIZE Team must possess proof of insurance, as described in Section 4.1 of the Master Team Agreement before it is allowed to participate in any testing, or compete in any Progressive Insurance Automotive X PRIZE event. This proof of insurance must be shown to the organizers at the first vehicle safety and technical inspection and remain with the vehicles at all times.

## **4.6 Promotional and Non-Scored Events**

The organizers reserve the right to establish promotional or non-scored events to enhance the visibility, credibility, and/or impact of the Progressive Insurance Automotive X PRIZE. Teams may be required to participate in these events at the discretion of the Competition organizers with reasonable advance notice.

# **5 Technical Reporting and Requirements**

## **5.1 Vehicle Modifications Documentation**

Between the Shakedown, Knockout, and Finals Stages Teams must submit a report listing any modifications applied to their vehicles since the previous stage. Teams should also bring this list to the Technical Inspection at each stage. For the Shakedown Stage, Teams should bring a list of differences between their Third Technical Deliverable and actual vehicle. Teams should review Section 8.3 to determine what changes are allowed between Competition Stages.

## **5.2 Hazardous Materials Documentation**

Teams must have a list of any hazardous materials and their associated Material Safety Data Sheet (MSDS). Unless the item is generic (e.g., gasoline), the MSDS must be from the manufacturer of the material. Teams must present three copies of all MSDS forms at registration of each stage. One copy must remain with the vehicle at all times. The other two copies will be held by competition officials at the registration area and in the fueling area.

## **5.3 Team Visits**

The Progressive Insurance Automotive X PRIZE reserves the right to visit Team headquarters or facilities at any time to review the vehicle status.

# **6 Definitions**

Certain terms used in this document are described below.

## **6.1 Engine**

An engine is any component that converts liquid or gaseous fuel into mechanical energy.

## **6.2 Electric Drive, Electric Drivetrain, Electric Propulsion.**

These terms refer to the electric motor system (i.e., the electric motor and controller).

## **6.3 Electrical Energy Storage System (EESS)**

The EES consists of electrochemical batteries, ultracapacitors, flywheels, compressed fluids, compressed gas, or other on-board systems (separate from any consumable fuel system) that provides an energy or power source for the vehicle's propulsion system.

#### **6.4 Alternator**

The alternator is a component usually connected to an engine that converts mechanical power into electrical power.

#### **6.5 Generator Set**

This term refers to the system of components that produces electrical power from consumable fuel (i.e., an engine and alternator, fuel cell, or similar system).

#### **6.6 Conductors**

Conductors are current-carrying parts (e.g., large traction drive cables, high- or low-voltage wiring, and bus bars).

#### **6.7 Conductor Sizes**

Conductor sizes are expressed in American Wire Gage (AWG) or, for conductors over 4/0 AWG, in circular mil area (cmil). The circular mil area of a conductor is the diameter of the conductor (in mils) squared.

#### **6.8 Bus Bars**

A conductor of solid material, such as copper, usually used to connect EESS devices.

#### **6.9 Low Voltage**

Any potential 50 V or less between any two conductors in a circuit is considered low voltage.

#### **6.10 High Voltage**

Any potential over 50 V, between any two conductors in a circuit during any operating condition is considered high voltage. Vehicles with an electrical system less than 50 V, but with a nominal power exceeding 2.5 kW are required abide by any high voltage referenced requirement.

#### **6.11 Rated Voltage**

Rated voltage is the typical operating voltage of a device, such as a motor.

#### **6.12 Breakdown Voltage**

This term refers to the voltage at which the dielectric strength of a wire's insulation is exceeded and the insulation ceases to be a high-impedance path to the flow of current.

#### **6.13 High-Voltage Surface**

Any part of a terminal, wire, bolt, nut, fuse, bus bar, resistor, etc., to which insulation has not been directly applied. The "surface" need not be flat; the term refers to the exposed metal surface of the part that is energized with either positive or negative high voltage with reference to the opposite polarity of the circuit.

#### **6.14 Continuous Current Rating**

This term refers to the maximum current a device can carry for an extended period of time without exceeding temperature limits, such as a motor, can carry for three or more hours.

### **6.15 Peak or Full-Load Current Rating**

The maximum current a device, such as a motor, can carry at any time while operating normally is the peak or full-load current rating. The peak or full-load current is usually defined by the current and the amount of time the device can carry the current.

### **6.16 Ampacity**

Ampacity is defined as a value (in amperes) that expresses the maximum safe current-handling value for a particular wire and insulation combination. This value is dependent on the conductor type and its cross-sectional area, the insulator type and thickness, the desired maximum operating temperature, and the ambient temperature.

### **6.17 Uncontrolled Generation (UCG)**

The UCG is the increase in voltage on an electrical system when either the battery has been removed or cause by high back electromagnetic field (EMF) of a permanent magnet motor. Without the voltage bus being loaded and controlled by the battery, the instantaneous voltage can significantly increase causing permanent damage to components.

## **7 General Competition Regulations**

### **7.1 Safety**

Rules on competition safety are final and must be adhered to; person(s) not in compliance may be removed from the Competition and the Competition venues. Vehicles found out of compliance with safety requirements may be disqualified from the Competition.

### **7.2 Good Sportsmanship**

Team personnel are expected to behave in a professional manner. The following actions will not be tolerated:

- Any actions that attempt to gain an unfair advantage through misrepresentation or substitution of hardware, tampering with electronic programming, or by any other means, is subject to elimination.
- Consumption, use, or storage of intoxicating liquors or controlled substances will not be allowed in the garage or track area.
- Physical contact, abuse, or threat to do harm by any competitor to any event official, or to any fellow competitor, or their vehicle or property, will be cause for penalty or possible elimination.

Participants at events are at all times required to follow the instructions of event officials, follow safety procedures, to be on-time for competition events, inspections, and meetings, and to observe track/garage opening and closing times. Team leaders are responsible for the behavior of their entire crew, as well as any guests of any members of the Team.

### **7.3 Right to Impose Penalties**

Participant compliance with all Progressive Insurance Automotive X PRIZE rules, regulations, and decisions is required. The Progressive Insurance Automotive X PRIZE has the right to take penalty action against any participant for failure to comply with any decision, rule or regulation

of the Progressive Insurance Automotive X PRIZE, including but not limited to, failure to comply with the dispute resolution processes in this document. The Progressive Insurance Automotive X PRIZE may in its sole and absolute discretion take the penalty action it deems appropriate, up to and including elimination of vehicle and Team from the Competition in response to any such failure to comply.

#### **7.4 Prizes**

The total purse of the Progressive Insurance Automotive X PRIZE is ten million U.S. Dollars. Half of the purse will be awarded to the winning vehicle in the Mainstream Class vehicle. The remaining five million dollars will be divided evenly between two winners in the Alternative Class – the winning vehicle with a side-by-side seating configuration, and the winning vehicle with a tandem seating configuration.

#### **7.5 Protest and Appeals Process**

##### **7.5.1 Purpose**

The purpose of the Protest and Appeals process is to provide Teams an opportunity to have actions of other Teams reviewed and to have administrative and competition decisions of the organizers reconsidered. It is provided to ensure that equality and fairness is a cornerstone of the Progressive Insurance Automotive X PRIZE. The scope of this process is limited to procedural and competition-related actions and decisions. This process does not extend to decisions related to safety of the competitors, organizers, or spectators.

##### **7.5.2 Procedure**

This on-track appeals process will allow for any Team that wishes to appeal a decision regarding their elimination occurring during an on-track event to have an opportunity to have the decision reviewed on an expedited basis so as to enable the Competition to proceed in an orderly and timely manner. Pursuant to Section 11.3(b) of the Master Team Agreement, each Team acknowledges and accepts this process as the exclusive process to govern appeals from elimination decisions made during on-track events. Accordingly, all appeals determined by this process are final; Teams will have no further recourse for resolving a dispute or protest. It is designed to enable the same basic appeals process that would otherwise apply under the Master Team Agreement to be carried out in a more condensed time frame.

- All appeals must be filed within 5 hours of the occurrence of the elimination
- Appeals must be submitted to Team Relations via the official form (see Team Relations representatives)
- Technical Operations and Team Relations leads will review the form together and decide to proceed in one of two ways:
  1. Deny - decision must be based on the Competition Guidelines and Regulations and be a clear violation of established requirements or based on a claim that is completely unsubstantiated. Denials by Technical Operations and Team Relations for the foregoing reasons are final and may not be appealed further.

2. Decision by Technical Operations Team and Potential Referral to Appeals Panel - appeals that are not denied by Technical Operations and Team Relations leads for the foregoing reasons will be referred to, and considered by, the Technical Operations Team through the use of data and evidence submitted by the Team; a decision by the Technical Operations Team will be supported by a unanimous response from the technical experts in the area cited by the protesting Team and the Team Relations lead; if a unanimous decision of the technical experts in the cited field and Team Relations lead cannot be established, the appeal will be forwarded to the Appeals Panel for a final decision as described below. Unanimous decisions by the Technical Operations Team are final and may not be appealed further.
- Appropriately completed forms will be copied; a copy will be given to the Team filing the protest for inclusion in their vehicle binder; the original will be filed by Team Relations.
  - Competition organizers will make every attempt to provide a final decision within 24 hours of the filing of the appeal, it being understood that some elements of this expedited appeals process (e.g., the timely input of technical experts) are outside the control of the Competition organizers. Further, in the case of appeals referred to the Appeals Panel, the Appeals Panel reserves the right to deliberate for up to 72 hours or more in its sole discretion in the event that it deems additional discussion or presentation of materials to be necessary or desirable.

### 7.5.3 Appeals Panel Composition

If an Appeal is submitted for Appeals Panel Review:

- Appeals Panel will consider all unresolved appeals forwarded to it following review by the Technical Operations Team as described above in connection with any on-track event, in lieu of an “Appeals Panel” noted in the Master Team Agreement appeals process that would otherwise apply.
- Appeals Panel will convene nightly (Monday thru Friday) at 5:15 pm in Garage 1. Spectators will not be allowed in garage.
- The panel will consist of three expert inspectors/judges who are not employees of the X PRIZE Foundation. The panel will be staffed by the experts/inspectors/judges contracted specifically for the on-ground events.
- All panel discussions will include Team Relations and Technical Operations representation, as determined by the Appeals Panel, at a minimum.
- Protesting Teams and Teams being protested will be allowed to bring 3 representatives, and documentation to present their case to the Panel.

- Decisions rendered by not less than a majority of the members of the Appeals Panel will be final. No further appeals will be permitted.

#### 7.5.4 Frivolous Protests and Appeals

The protest and appeals process shall not be abused. Teams that file a protest may be required to put up a to-be-announced number of minutes of competition time as a bond to discourage frivolous use of this process. If this bond is required, and if the protest or appeal is deemed frivolous by the Progressive Insurance Automotive X PRIZE Technical Operations Team, Team Relations Team, and/or Appeals Panel, the bond is forfeit; if the protest or appeal is deemed to have standing by the Progressive Insurance Automotive X PRIZE Technical Operations Team, Team Relations Team, and/or Appeals Panel, the bond will be returned no matter if the Progressive Insurance Automotive X PRIZE Technical Operations Team, Team Relations Team, and/or Appeals Panel rules in favor or against the protester.

### **7.6 Teams and Their Members**

Teams and members should review Section 7.1-7.3 for requirements of all participants in the Progressive Insurance Automotive X PRIZE.

#### 7.6.1 Registration

At the beginning of each competition stage, all Team members must register in person at designated time and location, present requested documents, sign required forms and agreements, and receive a personal identification “Credential”, before being allowed access to the track or garage. Any Teams wanting to register members under eighteen years old to any Competition Stage should contact the Team Development and Relations staff listed in Section 4.1 at least one week prior to the start of the Stage.

#### 7.6.2 Team Uniforms

Regulations regarding uniforms are listed in the Progressive Insurance Automotive X PRIZE Style Guide.

#### 7.6.3 Controlled Substances

Alcohol, drugs, and other controlled substances are not allowed at the Competition location(s) or on any other Competition-related property. Furthermore, the use of alcohol, drugs, or other controlled substances during the Competition stages will be grounds for the immediate removal of the individual or Team from the Competition venues and elimination of the Team from the Progressive Insurance Automotive X PRIZE.

#### 7.6.4 Weapons

Weapons of any type are not allowed at any Competition event or on any Competition property. This includes firearms.

#### 7.6.5 Open Fires

Open fires of any sort, including charcoal and gas grills, are not allowed on Competition property.

### 7.6.6 Smoking

Smoking is prohibited in all Competition, pit, refueling, and recharging areas.

### 7.6.7 Parking and Non-competition Vehicles

Only competing vehicles and authorized organizer vehicles will be allowed in the Competition event areas. Only Competition vehicles will be allowed in the pit area. Team support vehicles and trailers will be parked in designated parking lots.

### 7.6.8 Meetings

Attendance of announced Team or Driver Meetings at the Competition will be mandatory. A maximum of two members per Team may attend such meetings. Teams with additional registered drivers will be allowed access for those drivers in Drivers Meetings, or at other meetings when drivers are specifically required.

## **7.7 Garage and Pit Regulations**

### 7.7.1 Personnel Allowed in Garage and Pit Areas

Non-registered visitors are not allowed in the garage and pit areas. Furthermore, no one under the age of eighteen, who is not a registered member of a participating Team, is allowed in any garage or pit area without accompanying parent or guardian.

### 7.7.2 Personal Protective Equipment (PPE)

Everyone in the garage and pit area must wear shirts with short or long sleeves, and closed toed shoes and eye protection at all times. The protective clothing requirements are minimum requirements; Teams are free to upgrade protective clothing.

Furthermore, Team members must wear PPE appropriate for the work they are doing. This includes, but is not limited to electrically insulated, chemically resistant, and thermally insulated gloves; hearing protection; steel-toed shoes; and fire resistant clothing. Officials have the right to stop work being conducted by a Team for any of their Team members and anyone (member or non-member) in their garage area for not wearing appropriate PPE, until proper PPE is applied.

### 7.7.3 Fire Extinguisher

Teams must provide at least one 20 pound fire extinguisher rated to any potential fire that a Team may encounter while with their vehicle. In addition, a 20 pound fire extinguisher rated for metal fires is required for Teams with High Voltage Energy Storage Systems.

### 7.7.4 Moving Vehicles in the Garage and Pit Area

In the garage and pit areas, all vehicles must be pushed. For the safety of all participants, organizers, etc., driving in the garage area will not be permitted. Support vehicles will only be permitted, and to be driven, in the garage area during prescribed competition vehicle unloading or loading times.

### 7.7.5 Garage and Pit Space Assignments

Garage space and pits will be pre-assigned on a random basis. Garages cannot be guaranteed to have equipment other than 15A 110V electric power.

### 7.7.6 Hoists

Hoists will not be provided. Teams that plan to work under their vehicles must provide their own jack, stands, and ramps with sufficient capability to support their vehicle. Competition officials have the right to inspect Teams' equipment for capacity and condition before their use is authorized on any competition property. Teams may only use jacks to elevate their vehicle. Once elevated, the vehicle must be placed on jack stands or ramps.

### 7.7.7 Welding and Other Fabrication Equipment

Vehicles should be shipped to the Competition with all welding, machining, and fabrication completed. Welding and other fabrication equipment will not be provided. Welding for minor repairs during the Competition will be allowed only during normal garage hours, and only after a Team receives permission from competition organizers. All such work shall take place in a special designated area removed from the garage, fuel storage, and charging areas. One Team member must be dedicated to staff a fire extinguisher during all such work. Violations of this provision will result in penalties up to and including elimination from the Competition.

## **7.8 Driving Regulations**

### 7.8.1 Drivers License

All drivers of any vehicle must have a valid driver's license.

### 7.8.2 Drivers School

All competition vehicle drivers must have, at a minimum, taken a "High Performance" driving class to participate in any Dynamic Testing or Competition Events. Drivers must bring their certification to each Stage to be able to drive in any event.

There are numerous driving schools that offer High Performance driving training and because the Skip Barber Racing School is available in several locations, the officials have chosen its "One Day High Performance" class as the baseline course for drivers. Drivers may take classes from similar organizations, as long as the curriculum is equivalent. Below are minimum requirements necessary to qualify as an acceptable course:

- Understand vehicle dynamics & behavior
- Experience slides & recoveries
- Learn at the limit
- Experience lane-toss exercises & accident avoidance
- Lead-follow on the race track

A racing license from a recognized racing series (IMSA, SCCA, FIA, etc.) that was current in 2009 or 2010 will also be accepted.

### 7.8.3 Helmets

Safety helmets are required to be worn during all competition events and must be supplied by Teams for their drivers. Helmets will be inspected during the technical inspection and must meet Snell M2000, M2005, M2010, K2005, Snell SA2000, or SA-2005 standards, or SFI or FIA

equivalent. The helmets may have an open-face or full-face design, however, “Shorty” or half helmets are not permitted.

#### 7.8.4 Protective Clothing

All drivers must wear full length pants, long-sleeved shirts, and closed toed shoes and socks. No open toe, or open-heel shoes, or sandals area allowed. Clothing made of synthetic materials, except fire retardant clothing such as Nomex, is not allowed. The protective clothing requirements are minimum requirements; drivers are free to upgrade protective clothing.

#### 7.8.5 Driving Conduct

Safety during the Competition shall be considered the responsibility of the competitors. All vehicles, including support vehicles must be driven in a safe manner at all times while at the Competition. Rules on competition safety are final and must be adhered to; person(s) not in compliance will be removed from the Competition and the Competition venues. Thus, aggressive or dangerous driving, and/or failure to follow track or official directions, may result in penalties, elimination from the Competition, and removal from the Competition property. Teams may be disqualified for unsafe driving by any of its Team members.

#### 7.8.6 Seat Belts

Seat belt use is mandatory for all occupants whenever competing, or when support vehicles are in motion.

#### 7.8.7 Driving on Public Roads

Before or after the Competition scoring events, competing vehicles may be requested to drive on closed public roads for authorized demonstration or promotional purposes. No operation on public roads will be included as part of the Competition scoring events. When a competition vehicle travels on public roads, the driver must obey all traffic laws and drive in accordance with normal rules of the road.

#### 7.8.8 Driving on Competition Track and Event Courses

Teams are not permitted to drive Competition vehicles, or support vehicles, on the Competition track or the other event courses except during designated times.

#### 7.8.9 Drafting

Drafting or slipstreaming is not allowed. Each vehicle should stay at least three seconds behind any vehicle it is following, as determined by the time interval between the leading vehicle passing a stationary landmark and the trailing vehicle passing the same landmark.

#### 7.8.10 Passing

No passing is allowed except at designated Passing Locations which will be announced at Driver Meetings. Turn signals must be used for any lane change or passing maneuver. The driver being passed may not prevent anyone from passing them. It is the responsibility of the driver who is passing to do so in a safe manner. Any driver who is judged to be “blocking” another vehicle, may be stopped for consultation, and be subject to a time penalty.

### 7.8.11 Reporting Accidents

All accidents must be reported immediately to a Progressive Insurance Automotive X PRIZE competition official immediately. Individuals to be contacted in an emergency will be identified at registration or at Team Meetings for each competition stage. In the event of an accident involving personal injury and/or property damage, the organizers will contact the appropriate safety or medical officials. Phone numbers of competition officials will be distributed at registration for each competition stage.

### 7.8.12 Passengers

The organizers reserve the right to require that a passenger identified by the X PRIZE Foundation rides in competing vehicles during any non-scored Progressive Insurance Automotive X PRIZE events. Passenger seats must be usable for occupancy as needed.

## **8 Overall Vehicle Requirements**

### **8.1 Vehicle Classes**

The Progressive Insurance Automotive X PRIZE will consist of three vehicle classes:

- Mainstream
- Alternative – Tandem
- Alternative – Side-by-side

Teams may not switch classes once their Design Submissions are accepted. The requirements and regulations for the Mainstream and Alternative Classes are discussed in the appropriate sections below.

### **8.2 Vehicle Safety**

Safety is the paramount consideration in all aspects of the Progressive Insurance Automotive X PRIZE. At any time during the Competition, organizers may require Teams to correct any safety concerns, even those outside of these regulations. Officials may disqualify or prevent any unsafe vehicles from participating in any event. Disqualification from an event may lead to elimination from the Competition.

### **8.3 Vehicle Modifications**

This section discusses what vehicle modifications are allowed between Competition Events and Stages.

#### 8.3.1 Modifications between Competition Events

In general, any modification that gives an unfair advantage as defined in Section 7.2 or modifies vehicle performance to achieve an advantage for a specific event (e.g., Acceleration and Fuel Economy Event) is prohibited.

The only exception is in the event of a component failure. In such an event, Teams must request permission to replace components using the official process provided to them at Registration. Teams must have an official signature before they begin any modifications to their vehicle. Teams that gain an advantage in replacing a failed component may be assessed a penalty. At a

minimum, Teams are not allowed to modify the following components between Competition Events within a stage:

- Vehicle body and chassis
- Engine and motor equipment and control strategy
- Fuel and any modification to competition fuel
- Emissions equipment and control strategy
- Powertrain equipment and control strategy, including electrical propulsion components
- High voltage equipment and control strategy including inverters, electric traction motors, electric generators, ESS chargers, high voltage dc/dc converters
- ESS and control strategy
- Charger and charging strategy
- Tires and wheels
- Suspension
- Any other control strategy or software that has any impact to performance
- Any other modification that has any impact to weight or performance

### 8.3.2 Modifications between Competition Stages

Vehicle modifications between Stages (e.g., Knockout and Finals) are restricted in order to ensure the components have been sufficiently inspected by officials and tested by the Teams. Vehicle modifications are also restricted in order to ensure the same vehicle specifications are used in all stages. If there are any questions regarding whether a component can be modified, Teams should contact the Team Development and Relations staff prior to starting any work and receive written approval for their modifications.

An exception may be made in the event of a component failure. In this event, Teams must request permission to replace components using the official process provided to them. Teams must have an official signature before they begin any modifications to their vehicle. Teams that gain an advantage in replacing a failed component may be assessed a penalty or disqualified.

Teams must submit a list of modifications to their vehicle at each stage as discussed in Section 5.1.

The following modifications are restricted between Stages:

#### Between Shakedown and Knockout Stages

- Fuel type
- ESS type, manufacturer, and model
- Powertrain
- Vehicle chassis
- Location of major components in vehicle

#### Between Knockout and Finals Stages

Any modifications or replacement of all mechanical or electrical components, except general automotive maintenance, such as fluids, tires, etc. If a Team is unsure if a

modification is allowed, they should request written authorization from Competition organizers in advance. Modifications to vehicle software and control strategy are allowed.

#### Between Finals and Coast Down/Validation Stages

No changes are allowed after the Finals Stage. Vehicles will be impounded by Competition organizers and kept in the possession of the X PRIZE Foundation until the end of the Validation Stage.

#### 8.3.3 Competition Seals

Officials may apply a seal to ensure a component is not modified or tampered with during the Competition. Teams are not allowed to remove the seal without submitting a request in writing to the officials and receiving an approval signature. Broken seals without proper advanced written approval from the Competition organizers may result in penalties up to and including elimination.

#### **8.4 Production Capable**

In general, vehicle designs entered by Teams must be “production capable” and be designed to reach the U.S. market. This means that they must be designed to be fully-compliant with the Federal Motor Vehicle Safety Standards (FMVSS) and other applicable National Highway and Traffic Safety Administration (NHTSA) requirements but are not necessarily required to have all the associated equipment on board for the Competition. Resulting design and equipment requirements for vehicles are discussed below.

#### **8.5 Vehicle Logos and Decals**

Detailed regulations on vehicle logos and decals are listed in the Progressive Insurance Automotive X PRIZE Style Guide. Teams should review the document to ensure they meet the requirements for the Competition. Teams should also review Section 9.5.3 for the restrictions of logos on the windshield and windows. The general requirements for logos and decals on vehicles include:

- The assigned vehicle number must be the correct size and place in the correct location
- Progressive Insurance Automotive X PRIZE Competition Decal(s) must be placed in the correct location with the correct size and white space
- Progressive Insurance Automotive X PRIZE Sponsor Decal(s) must be placed in the correct location with the correct white space
- Team sponsor logos must meet size requirements

Vehicles may be required to have a decal on the front and rear bumpers identifying the type of fuel and battery they are using.

#### **8.6 Vehicle Registration**

The Progressive Insurance Automotive X PRIZE has received a waiver from NHTSA under which Competition vehicles will be permitted to operate on closed public roads during Competition events and demonstrations, even though they will not be in full compliance with the FMVSS. Note that, although the public roads will be closed to other vehicles, Progressive Insurance Automotive X PRIZE vehicles must obey all speed limits and other traffic regulations.

## **9 Mechanical Components Requirements**

### **9.1 Vehicle Dimensions and General Specifications**

#### **9.1.1 Passenger Capacity**

Vehicles in the Mainstream Class must seat four or more occupants in a traditional arrangement of two side-by-side front and rear seats. The front seats must be able to fit 95<sup>th</sup> percentile adult males and the rear seats must fit 75<sup>th</sup> percentile adult males. Production version of vehicle must meet the Code of Federal Regulations 49CFR571.209.

Vehicles in the Alternative Class must seat two 95<sup>th</sup> percentile adult males. Production version of vehicle must meet the Code of Federal Regulations 49CFR571.209.

#### **9.1.2 Ground Clearance**

Vehicles must demonstrate sufficient ground clearance to clear typical road-rated driveways and transporter ramps. Vehicles must have a minimum of 4 inches of ground clearance, which will be evaluated by having a vehicle cross a speed bump. No parts of the vehicle, except the tires can touch the speed bump while traveling across it in the same direction as a vehicle would typically cross a speed bump on a road. Furthermore, the vehicle must travel over the speed bump in a perpendicular direction without touching it. The test will be performed at 5 mph.

#### **9.1.3 Cargo Capacity**

Vehicles in the Mainstream Class must have ten cubic feet of useful cargo space (when the vehicle has four occupants). Cargo space must be in one contiguous location.

#### **9.1.4 Static Stability Factor (SSF)**

The Static Stability Factor (SSF) for four-wheel vehicles must be greater than 1.3. Adequate stability will be demonstrated in calculations submitted in the Design Reports.

### **9.2 Chassis and Crash Safety**

The competition vehicle's occupant compartment must be designed for crashworthiness (including appropriate energy absorbing features) to provide adequate protection in frontal, side and rollover crashes, as well as, to prevent occupant ejection.

Teams must ensure that heavy, critical, and hazardous (high voltage, flammable, high speed, etc.) components are well protected and securely fastened to a structural member on the Competition vehicle in the event of a crash. No critical or hazardous components should be located in a crush zone, especially ahead of the front axle or behind the rear axle. Sharp edges or protruding parts (bolts) should not be pointed at fuel tanks, battery boxes, fuel lines, or high-voltage lines anywhere in the vehicle. All enclosures and the method of securing all components to the vehicle must also meet these requirements.

Competition officials will be closely examining the structural integrity and crash safety of the Competition vehicle during Technical Inspection. For some vehicles, further analysis of structural safety will be required through the vehicle safety Voucher Program. Vehicles which do not meet the minimum safety requirements will have ballast added to reflect the missing

structure. The officials reserve the right to disqualify a vehicle if it does not provide adequate crash safety to the vehicle, its components, and the passengers. Disqualification from any event may result in elimination of the vehicle from the Competition.

### 9.2.1 Modifications to Existing Production Vehicles

Entries in either Class may be created by modifying existing popular production vehicles. However, the modified vehicles must satisfy all of the safety requirements for their class, in addition to all of the requirements listed in these regulations. In addition, modified vehicles entered in the Mainstream Class must continue to satisfy all safety standards that applied to the year of the original vehicle.

Teams should be aware that any modification or additions to an existing vehicle chassis or other structural components must not compromise vehicle safety and occupant protection. Modifying structural components, including the addition of heavy components, such as an ESS may significantly affect the vehicle's crash safety characteristics.

### 9.2.2 Other Components

All components and their mounting components must meet the crash safety requirements listed in this section. Teams should be aware that heavy components, such as the ESS, will require significant analysis and strong mounting to meet these requirements. No critical components may be located outside the frame rail (or equivalent unibody component) or in the crush zones, behind the rear or ahead of the front axle.

## **9.3 Interior and Passenger Safety**

### 9.3.1 Occupant Seating

Vehicle must be designed so that the production vehicle would likely be able to meet FMVSS 201, 202a, 203, 207, 208, 209, and 210. On the Competition vehicle, occupant seats, head rests, seat belts, and seat belt mountings must be automotive or racing quality level equipment, attached per manufacturers' instructions. Front and rear seats must have adequate padding to prevent injuries to rear occupants, if applicable. No components are allowed to be placed or stored on passenger seats during the Competition, unless authorized by Competition officials. Removal of seats during the Competition is not allowed, unless authorized by Competition officials.

### 9.3.2 Seatbelts

At a minimum, three-point automotive quality seat belts must be provided for all out-board (e.g. next to an exterior door or window) passenger locations. In-board locations must have a minimum of a lap belt. All seat belt anchors must be in locations that have the strength to absorb the loads of restraining passengers for all foreseeable impacts, per manufacturers' instructions.

At the discretion of the officials, competition vehicles may be approved with 4- or 5-point restraint systems for the driver, and one passenger that are manufactured in accordance with SFI 16.1.

### 9.3.3 Airbags

For vehicles with airbags (including modified production vehicles that retain airbags), the airbags must be fully disarmed in the vehicle in order to pass the pre-competition Technical Inspection. This is required so that when work is being performed on airbag-equipped vehicles, accidental deployment can be prevented. Also, disarming the airbags eliminates the possibility, if vehicle mass has been altered, of the airbag deployment action/timing being adversely impacted. If airbags are not present in any vehicle, compensating ballast will be added to represent their weight.

### 9.3.4 Steering Column

Vehicle must be designed so that the production vehicle would likely be able to meet FMVSS 203 and 204. On the Competition vehicle, a means to reduce steering wheel and column movement during a frontal impact is required for all vehicles. This may be accomplished with a collapsible column or by U-joints and off-set intermediate shafts from the steering box to the steering wheel.

### 9.3.5 Egress

The passenger and driver of a vehicle must be able to completely exit a closed vehicle within 5 seconds without any assistance, when initially in typical seated position with seatbelts attached.

### 9.3.6 Bulkheads

If any major, moving, or hazardous components intrude into the passenger compartment, they must be separated and isolated from the passenger compartment by a bulkhead of the same thickness and material as the production bulkhead for modified production vehicle or by the same thickness and material as the floor pan for custom vehicles. All bulkheads or component covers must be sealed and securely fastened, providing suitable protection for the occupants from mechanical failure, fluids, and fumes.

## **9.4 Other Mechanical Requirements**

### 9.4.1 Fluid Leaks

The vehicle must not have any active fluid leaks while sitting at rest or while operating. Body panels, trays, or any flat surface below the engine, transmission, or differential must have provisions to prevent the collection of engine oil, fuel, or any other flammable fluids (even if the engine is assumed to be, at present, oil-tight and the fuel system is leak-free). Panels must have leakage holes; flat surfaces must be inclined and channel away fluid. All high temperature components must be isolated from contact by any flammable liquid.

### 9.4.2 Shielding

Teams must cover all moving and high temperature components from accidental contact while the hood or trunk is open. Furthermore, shielding must cover all components which can injure anyone nearby the vehicle, in the event of component failure.

### 9.4.3 Critical Fasteners

All critical mechanical fasteners for, but not limited to, the following: suspension, steering, brakes, throttle and brake controls, must have lock nuts, be pinned, or be safety wired. Otherwise, they must always be tightened to manufacturer recommended torque levels, and double checked.

### 9.4.4 Dynamometer Testing

All vehicles, including all-electric vehicles should review Section 15.5 to ensure they are able to participate in the dynamometer testing.

## **9.5 Body**

### 9.5.1 Passenger Cabin

The vehicle must be capable of fully enclosing driver and all passengers, to protect them in inclement weather conditions, including rain. Vehicles designed as convertibles may compete in track events with the top down and secured, or totally removed, as long as compensation ballast weight is then added to vehicle. If vehicle is designed with removable doors, when removed, they must be securely stored in the vehicle, or if not carried in the vehicle, compensation ballast weight must be added. The option to remove doors must be addressed in a Waiver Request, due by the date noted in Section 4.4.

### 9.5.2 Latching of Doors/Hood

Vehicle must be designed so that the production vehicle would likely be able to meet FMVSS 113, 206, and 401. On competition vehicle, doors, hood, trunk lid, and any other closure panels must be securely latched while vehicle is running, with a positive latch and release system, to avoid unintentional opening, due to air flow at speed, or bumpy road conditions, etc., while vehicle is in motion. Driver and passenger doors must be able to be easily opened from outside of vehicle by safety officials, without use of any tools.

### 9.5.3 Windows and Windshields

Vehicle must be designed so that the production vehicle would likely be able to meet FMVSS 205, 212, and 219. On the Competition vehicle, windshield must be automotive laminated safety glass on production car based vehicles. New vehicles may use a laminated safety glass, or a 3/16-in.-minimum-thickness polycarbonate, windshield. If the latter is used, a weight penalty will be imposed to off-set the lighter weight material. Any windows besides the windshield may be tempered safety glass or 1/8-in.-minimum-thickness shatter-resistant, polycarbonate.

Vehicle must be designed so that the production vehicle would likely be able to meet FMVSS 104. Competition vehicle must have an effective wiper system that clears the windshield in heavy rain. This system must be enabled by a driver input or motion. Once activated it must remain operational on its own, until being deactivated by the driver.

### 9.5.4 Weatherproofing

Teams are responsible for ensuring that the vehicle can safely be driven in inclement weather, including rain. All sensitive and electrical equipment must be housed in sealed enclosures or in locations where water (or other environmental effects) cannot damage the component or cause a

hazardous situation (such as ground faults). For example, proper routing of air flow to an EES enclosure must prevent entrapment of water.

## **9.6 Transmission**

### **9.6.1 Neutral Gear**

Drivetrain should have a selectable neutral gear to be used during coast down testing, or for towing of vehicle. Vehicles with direct-coupled electric drives will need a system to disconnect the motor from the wheels (a “neutral” position) in order to eliminate the electrical resistance generated inside the motor and its inertial effect. All Teams should review Section 15.4 to ensure their vehicle and transmission meets the requirements for the Coast Down Testing.

### **9.6.2 Shift Lock**

All vehicles must preclude activation of the powertrain unless: a) for automatic or single-speed transmission-equipped vehicles, the transmission is in “neutral” or in “park”; or b) for manual transmission-equipped vehicles, the transmission is in “neutral” or the clutch is fully disengaged (clutch open). This requirement ensures that the driver does not accidentally move the vehicle forward while trying to start, while in gear. The functionality of the neutral safety switch will be checked during pre-competition inspection. If none is present, Teams will not be able to compete until it is properly implemented.

Teams shall also take care in ensuring that hybrid operations, such as engine start-stop functions, do not cause unintended vehicle movement. Teams with hybrid vehicles shall design the engine start/stop function(s) with similar safety functions and procedures as current production hybrid vehicles.

## **9.7 Controls**

Teams are strongly encouraged to use conventional driver controls and nomenclature. Vehicles using an electrical propulsion system are also required to have the switches listed in Section 10.13.

### **9.7.1 Drivability Requirements**

All vehicles must be able to be driven by an independent driver with average driving skills given only ten (10) minutes of instruction/training. This requirement is particularly necessary for the emission testing (Section 14.4) which will be performed by professional drivers from the emissions laboratories.

### **9.7.2 Remote Controls**

Remote-control of the vehicle or any and all components on the vehicle, including the charger is strictly forbidden. Telemetry systems may be used for data acquisition and monitoring by Teams but no transmissions of any kind can be sent to competing vehicles that affect any aspect of vehicle operation.

### **9.7.3 Vehicle On/Off Switch**

Teams are required to install a switch which completely deactivates or disables the following components:

- All propulsion systems, including engines and motors
- All generators and alternators
- Fuel pump or regulators
- High voltage system
- Low voltage system
- Any accessories

Whenever possible, the switch should be a key installed in the steering column or dashboard, similar to conventional vehicles. Other switches are allowed, but must be labeled “Vehicle Power” in highly contrasting, one inch high letters. The on and off positions must be labeled with similar style lettering.

#### 9.7.4 Inertia Switch

All competing vehicles must utilize an inertia switch to operate the EDS in the vehicle in the event of a serious accident. This switch must be tied into the EDS of the vehicle, and in the event of a crash, must provide the same functionality as the EDS (i.e. disconnect high-voltage / power, stop fuel flow / engine running). For vehicles with electric propulsion or high voltage systems, the Inertia Switch must operate the EDS (Section 10.13.1) in the event of a vehicle crash exceeding 8 G's of deceleration rate. Teams shall mount the switch to a sturdy part of the vehicle structure protected from initial impact (e.g. not in a front or rear crush zone).

#### 9.7.5 Throttle

All vehicles must have only one single control for vehicle propulsion, including those which use multiple propulsion sources. The throttle on all vehicles must be free-moving and, when released, must return to the zero-torque setting for all components, including motors and engines. There must be at least two independent spring mechanisms to return the throttle to the zero-torque setting in case one spring system fails. A loss of signal or power must result in the throttle closing and returning to the zero-torque position. If cruise control is used, it must automatically be deactivated when the brake pedal is depressed.

#### 9.7.6 Steering

All vehicles must have only one control for steering control. The direction of operation of the steering mechanism must correspond to the intended change of direction of the vehicle (i.e., turning the steering control right, turns the vehicle right). Furthermore, there shall be a continuous relation between the steering control deflection and steering angle.

Steering mechanisms must have positive stops at the end of travel such that the wheels responsible for steering do not contact the vehicle body, chassis, or components throughout their range of motion. If power-assisted steering mechanisms are used, they must not rely on the engine for power unless the vehicle operation strategy requires the engine to be running full-time. The steering function must be unaffected by the selection of any possible operational mode.

### 9.7.7 Electronic Stability Control

Vehicle must be designed so that the production vehicle would likely be able to meet FMVSS 126. On the Competition vehicle, ESC is not required, but vehicle must have satisfactory stability, as demonstrated in the required lane change and acceleration tests.

### 9.7.8 Display

All competition vehicles must provide the driver with feedback mechanisms to display essential information for the operation of the vehicle. As a minimum the display must provide the following:

- Vehicle speed
- Fuel gauge
- Electrical energy consumption (Section 10.17.1)
- State of charge of all on board energy storage systems
- Alarms in the event of hazardous conditions, such as a ground fault, or components exceeding critical parameters such as the powertrain or ESS

### 9.7.9 Horn

All vehicles must be equipped with a production electric automotive horn capable of steady, uninterrupted sound at a level of 82-102 dB at a distance of 50 feet.

## **9.8 Visibility**

### 9.8.1 Occupant Visibility

Tinting, shading, or any process that alters the transmission of visible light through the glass to a greater extent than permitted by law for new vehicles is prohibited. Dynamic tinting is acceptable as long as the aforementioned requirement is met and the tinting complies with FMVSS 205. Removable window shades are not allowed. Decals, graphics, or lettering may not be placed anywhere on the windshield or any other window except by event officials.

### 9.8.2 Mirrors and Cameras

Vehicle must be designed so that the production vehicle would likely be able to meet FMVSS 111. On the Competition vehicle, requirements are: adjustable, central rear-view, and right- and left-hand side-view mirrors that can be adjusted for use by all drivers. Rear-view and side-view cameras are allowed as long as they meet the same requirements as the same mirror.

The mirrors must meet the following criteria:

- The driver can see headlamps that are 2 ft above the ground and 50 ft behind the rear bumper of the vehicle.
- With the driver's mirrors in a fixed position, a small vehicle passing on a parallel path 12 ft away (measured between the vehicle centerlines) on either side of the Competition vehicle should never completely disappear from the driver's direct or peripheral view. The driver's head rotation is limited to that necessary to look directly at the side-view mirrors.

- A pedestrian must not be hidden from view by either A-pillar when the pedestrian is walking along a path that is either 24 ft left or right from the centerline of the vehicle, starting even with the front bumper, and extending 24 ft ahead. The driver is allowed lateral head movement of 2 in left or right.
- The driver's outside mirror must be a plane mirror. The inside rear-view mirror must be a plane mirror. The passenger's outside mirror may be a convex mirror if there is an inside rear-view mirror in the vehicle. If not, the passenger's outside mirror must be a plane mirror.
- If a convex mirror is used, the average radius of curvature may not be less than 35 in and not more than 65 in. In addition, the mirror must be permanently marked at the lower edge of the mirror's reflective surface, in letters not less than 3/16 in and not more than 1/4 in high, with the words "Objects in Mirror are Closer Than They Appear."

## **9.9 Lighting**

Vehicle must be designed so that the production vehicle would likely be able to meet FMVSS 108. On the Competition vehicle, external lighting may be modified, provided the lamps are designed for automotive use, and are mounted as securely as the original units. All lamps must retain their original function. Visibility must not be obstructed by any vehicle modifications or additional hardware.

### **9.9.1 Headlights**

Competition vehicles must be equipped with fully functional headlights which are clearly visible during daylight. The driver must be able to easily turn on the headlights while driving.

### **9.9.2 Turn Signals**

Competition vehicles must be equipped with fully functional left and right turn signals which are clearly visible during daylight. The driver must be able to easily turn on the turn signals while driving.

### **9.9.3 Reverse Lights**

Competition vehicles must be equipped with fully functional reverse lights which are clearly visible during daylight. The reverse light must automatically engage when the transmission or motor is in reverse.

### **9.9.4 Brake Lights**

Competition vehicles must be equipped with fully functional brake lights which are clearly visible during daylight. The running lights must automatically engage when the vehicle's brakes are engaged.

## **9.10 Brakes**

For Alternative Class vehicles with fewer than 4 wheels, vehicle must be designed so that the production vehicle would likely be able to meet FMVSS 122. For Mainstream Class, and

Alternative Class vehicles with 4 wheels, the vehicle must be designed so that the production vehicle would likely be able to meet FMVSS 135.

All competition vehicles must meet required braking performance test listed in Section 13.4.

#### 9.10.1 Primary Braking System

All Mainstream Class vehicles must incorporate a dual circuit, hydraulic braking system intended for automotive use operated by a common pedal and act directly on the wheels. Power-assisted braking systems must not rely on the engine for vacuum or power if the vehicle can ever be operated in an electric-only mode. Regenerative braking systems are allowed, but cannot be employed as the primary braking system.

#### 9.10.2 Anti-lock Braking System (ABS)

Vehicles must be designed so that the production vehicle would be equipped with ABS. On the Competition vehicle, ABS is not required but strongly suggested for the dynamic vehicle qualifying events. Vehicles that do not have ABS functionality, or exhibit limited ABS functionality, may be deemed unsafe by Competition organizers and may be disqualified from participating in one or more Competition events. Failure to complete a Competition event may result in elimination from the Competition.

#### 9.10.3 Parking/Emergency Brake

All vehicles must have a manual parking brake capable of holding the vehicle's weight at rest on a 20% grade and that can be used while driving in the event the primary brake system fails. This will be evaluated during Technical Inspection with the vehicle in neutral (when possible). If the vehicle does not have a neutral position, the tests will be run in the normal drive position.

#### 9.10.4 Brake Fluids

Competition vehicles must use automotive brake fluid that meets FMVSS 116. Teams should bring the original container of brake fluid they use to the Competition to prove to Competition organizers that the fluid meets FMVSS 116.

#### 9.10.5 Brake Hoses

Vehicle must be designed so that the production vehicle would be able to meet FMVSS 106. On the Competition vehicle, automotive quality brake hoses, lines, and fittings must be used.

### **9.11 Tires**

#### 9.11.1 Mainstream Class and Other Four Wheeled Vehicles

All vehicles in the Mainstream Class, and Alternative Class vehicles with four wheels, must use DOT approved tires. Teams shall choose the appropriate tire and wheel size that meets the speed and load ratings for vehicle control.

All vehicles in the mainstream class and other vehicles with four wheels must use DOT approved tires with a minimum traction rating of B and a tread wear rating 100 under the Uniform Tire Quality Grading Standard (UTQGS), 49 CFR 575.104.

### 9.11.2 Alternative Class Vehicles with Three or Fewer Wheels

Alternative Class vehicles that are technically motorcycles may use motorcycle tires regulated by FMVSS 119. If passenger car tires are used, they must comply with the specifications listed in Section 9.11.1.

### 9.11.3 Tread Depth and Modifications

All automotive tires must have a minimum tread depth of 5mm across the entire width of the tire measured at the wear bars. Motorcycle tires must have a minimum depth of 5mm in, from 1 inch to either side of the centerline. Teams must use tires that have enough tread to meet this requirement throughout the Competition under planned use. Markings on the tire sidewalls may not be altered or removed. Tires may not be re-grooved, shaved, or altered in any way that reduces the minimum load rating, or changes to tire contact patch area. This regulation has been changed from previous documents after research on the tire depth of commercially available tires. Organizers have the right to require Teams to replace tires if the tread depth is unsafe.

### 9.11.4 Spare Tire and Wheel

Teams are required to bring at least one functioning spare tire and wheel to competition. This tire does not need to be carried in the vehicle and does not count towards the vehicle's mass. This wheel does not need to aesthetically match the four on the vehicle; however, it does need to meet all of the technical requirements.

### 9.11.5 Tire Pressure

Tire pressures will be limited to the maximum pressure as stated on the sidewalls or according to the manufacturer's recommendation as stated in a letter from the manufacturer. Letters indicating a recommended tire pressure greater than stated on the sidewalls must be submitted to the organizers no later than Competition registration. Teams may not change their vehicle's tire pressure after the vehicle passes the technical inspection. The tire pressure selected by the Team at inspection will be noted on the vehicle. The organizers reserve the right to alter tire pressures to within acceptable limits at any time during the Competition for safety reasons or if a Team is achieving an unfair advantage as defined in Section 7.2.

### 9.11.6 Wheels

Wheels must have been tested and approved by DOT, JWV, TÜV, or other certification means. If wheels are not labeled, and there is a question about certification, Team must present documentation of compliance through independent certified testing which shows the wheels achieve the equivalent level of strength and durability compliance.

### 9.11.7 Wheel and Tire Replacement

Wheels and tires may not be changed after safety and technical inspection unless a change is necessary due to safety concerns, failure, or excessive wear. The replacement(s) must be identical to the wheel or tire being replaced, and any replacement tire and/or wheel must be inspected by competition organizers prior to installation. The competition officials reserve the right to require replacement at any time and may assess a penalty if a Team is achieving an unfair advantage from the replacement of the tire.

#### 9.11.8 Softeners and Warmers

Teams may not use tires that have been subjected to chemical compounds that soften the tire or change its composition. Tire warmers may not be used.

#### **9.12 Cooling System**

Vehicle must have adequate cooling for complete powertrain and electronics during track events, but also adequate cooling for the demands of dynamometer testing. This environment can put extra demands on a vehicle's cooling system capability, even with the powerful fan provided by the emissions testing lab.

#### **9.13 Audio System**

Vehicles in the Mainstream Class must have a functioning audio system that is audible while the vehicle is being driven. Headphones are not allowed.

#### **9.14 Heating, Ventilation, and Air Conditioning System (HVAC)**

Vehicles are not required to have traditional air conditioning systems provided vehicles are able to maintain an interior temperature below 95° F, when the vehicle is running. Vehicles must be able to achieve this target temperature within ten minutes of "start-up". If this temperature cannot be maintained at or below this level, Teams will be required to modify their vehicle to meet this goal. Competition officials may monitor the passenger compartment temperature and reserve the right to disqualify a vehicle with inadequate cooling. Disqualification may lead to elimination from the Competition if the cause for disqualification cannot be corrected to the satisfaction of Competition officials.

##### 9.14.1 Defrosting

Vehicles must have provisions to continuously de-fog the windshield, side, and rear windows, as required, to allow visibility for safe driving.

#### **9.15 Fire Extinguisher**

All vehicles must have a class ABC fire extinguisher onboard, with a minimum 2.5 lb charge. It must be readily accessible to a belted-in driver, and securely mounted.

#### **9.16 Ballast**

Each competing vehicle may be required to carry ballasts to represent:

- The weight of components that would be present on the production vehicle but are not installed in the Competition vehicle
- Weight difference due to lack in the Competition vehicle of structure required for FMVSS impact safety compliance
- Compensation for drivers weighing less than 200 lbs; If the driver (with helmet) weighs less than 200 pounds, the difference in weight will be added to the vehicle (there will be no weight "reduction" to vehicle for drivers weighing more than 200 lbs)

Officials have the right to require additional ballast if a Team has an unfair advantage as defined in Section 7.3, does not meet any regulations, or for penalty purposes.

#### 9.16.1 Ballast Container

Vehicles must have a ballast container, or “ballast box” that is constructed of 1/8” thick metal or material of similar strength (e.g. Kevlar), and securely attached to the structure or frame members with a minimum of two ½ inch diameter, steel bolts. The ballast box must have a securely attaching lid that can be locked using a conventional padlock. The ballast container may not be placed within the front and rear crush zones. One passenger seat may be removed and the seat mounting bolts used for secure attachment of the ballast container. The weight of the removed seat will be added to the combined ballast that must be carried.

The combined weight of an individual ballast box, plus the ballast, cannot exceed 100 lbs., but additional ballast boxes are necessary if the vehicle’s total required ballast weight exceeds 100 lbs. The weight of the ballast box(es) will be included in a vehicle’s total ballast weight. Therefore, ballast containers should be easily removable at technical inspection for weighing. No credit will be given for containers which exceed a vehicle’s ballast weight.

#### 9.16.2 Ballast Material

Team must provide all ballast material. The ballast must be made of a non-hazardous solid metal, except lead which is prohibited for environmental reasons. The ballast must not move when placed in the ballast container. Furthermore, small objects, such as ball bearings, must be contained in sturdy canvas or vinyl bags of a five pound minimum.

Ballast container containing estimated ballast should be presented at Technical Inspection at Shakedown. However, the exact total required amount of ballast for each individual vehicle may not be established until the break between Shakedown and Knockout Stages.

Any Team that removes or tampers with vehicle ballast during the Competition will be subject to elimination.

### **9.17 Trailers**

Competition vehicles may use trailers, but must have them attached and fully loaded throughout all Dynamic Testing and Competition Events. The trailer and its components must meet the same technical requirements as the vehicle. All fuel lines between the vehicle and trailer must automatically seal if the lines are broken when the trailer is separated from the vehicle. All high voltage cables between the vehicle and trailer must be completely isolated on both ends if the cables are broken when the trailer is separated from the vehicle. Furthermore, trailers must have active running, turn, and brake lights as discussed in Section 9.9. The trailer must have a trailer brake rated to the weight of the trailer that automatically activates the brakes if the trailer is separated from the vehicle. The trailer hitch on the vehicle must be rated to meet the weight of the trailer.

### 9.17.1 Trailer Hitch

Competition vehicles with engines that produce emissions must have a Class 1 trailer hitch installed capable of supporting 150 lb tongue weight, in order to allow for pulling an emissions testing trailer.

## 9.18 **Emissions System**

Progressive Insurance Automotive X PRIZE vehicles must be designed to meet criteria emissions standards no worse than US EPA Tier II, Bin 5 over 120,000 miles. The Competition vehicle must meet the on-road and dynamometer emissions requirements.

### 9.18.1 Location

All emissions from a vehicles engine(s) must exhaust through a single outlet at the rear of the vehicle. The outlet of the exhaust pipe must contain a Marmon flange to enable connection to emissions testing equipment. Tailpipes must have at least two inches of accessible, straight exhaust pipe where the exhaust exits the vehicle. It is the Teams' responsibility to ensure that the emissions equipment can be attached to the exhaust. Failure to do so will result in the vehicle being disqualified from the Emissions Event.

All emissions equipment and piping must meet the heat shielding requirements listed in Section 9.4.2. No emissions equipment and piping may pass through the passenger compartment or any ESS compartment. All emissions components and piping need to be a minimum of 2.36 in from any fuel line, wiring conduit, or electrical wiring.

### 9.18.2 Portable Emissions Equipment

All competing vehicles which produce emissions must be able to tow the portable emissions testing equipment in a trailer (see Section 9.17.1).

### 9.18.3 Smoke

Vehicles may not emit any visible smoke during the Competition events. Competition officials may remove a vehicle from an event if smoke is evident and reserve the right to disqualify a vehicle if the source of the smoke cannot be addressed. Disqualification may lead to elimination from the Competition if the cause for disqualification cannot be corrected to the satisfaction of Competition officials.

### 9.18.4 Leaks

No leaks are allowed in any emissions equipment on the vehicle. If leaks exist, vehicles will not be emission tested. Officials will test for leaks by attaching a 2 psi regulated hose to the exhaust exit with a leak-checking fixture similar to the one shown in Figure 1 below. Teams are strongly encouraged to test for leaks in advance of the Competition.

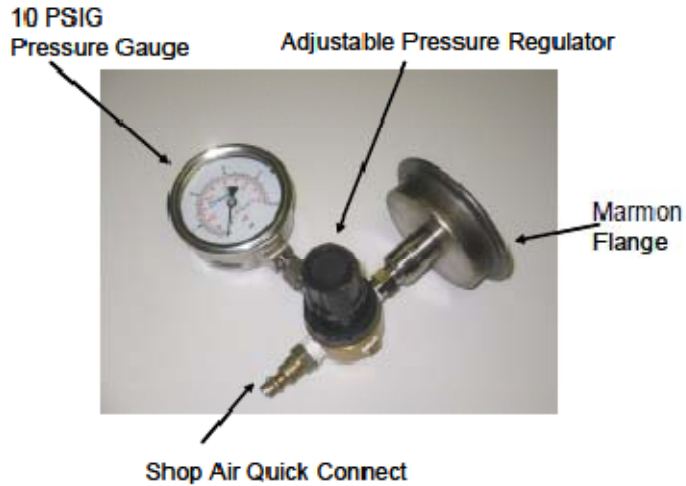


Figure 1

#### 9.18.5 Engine On Mode

All vehicles with a fuel system that produces exhaust emissions must incorporate a switch that forces the engine on in order to facilitate emissions testing (a manual on-engine switch)

### 9.19 Fuel Systems

The following table shows the fuels allowed during the Competition and their specifications.

Gasoline	87 Octane <10% ethanol Gasoline Meets ASTM D-4814
E85	85% ethanol/15% gasoline $\pm$ 1% Gasoline 87 Octane Gasoline Meets ASTM D-4814 Ethanol Meets ASTM D4806 - 09
Biodiesel (BD20)	20% biodiesel/80% ULSD $\pm$ 1% <10 ppm sulfur Biodiesel meets ASTM D6751-09a ULSD meets ASTM 975 Grade No. 2-D S15

Teams must select the fuel(s) they plan to use during the Competition by the date noted in Section 4.44 and may not switch fuels after this date.

Vehicles may only use the fuel provided by the Competition officials and Teams are not allowed to bring their own fuel on Competition property including to the emissions test laboratory. All fuel consumed during each Competition event must be registered, recorded, and measured. Teams found using un-measured or unofficial energy sources will be disqualified.

The fuels will be similar to those found at a public fueling station and most final fuel specifications will be provided before the Competition. However, the actual energy content of

the fuel will be measured at a laboratory one week before the Competition. Charging and electrical specifications are listed in Section 10.16.

Vehicles which use gasoline will be emissions tested using Indolene certification test fuel. E85 certification fuel for emissions testing will be a blend of ASTM grade ethanol and Indolene, as prescribed by our testing partners. B20 certification fuel for emissions testing will be a combination of ASTM grade biodiesel and certification diesel.

#### 9.19.1 Additives

Teams may not add anything to their fuel, including any additives. Furthermore, no fuel additives are allowed on competition property, including at the emissions test lab. Test samples of vehicle fuel will be taken from each of the provided barrels of competition fuel. In addition, at anytime without notice a Progressive Insurance Automotive X PRIZE Technical Operations representative may ask any Team for a fuel sample. Refusal to allow the Technical Operations rep access to a competition vehicle fuel system is grounds for elimination from the Competition.

#### 9.19.2 Fuel System Crash Safety

All fuel components must meet the crash safety requirements listed in Section 9.2 and any other applicable crash safety regulation. In addition, fuel system routing information will be required as part of the technical deliverables each Team is required to submit to the event officials. If the information in the submission is not adequate to provide the Progressive Insurance Automotive X PRIZE Technical Operations team with a competition level of confidence, the Technical Operations team will ask for additional information. Failure to submit the appropriate information will be regarded as an incomplete technical deliverable. Incomplete technical deliverables may lead to elimination from the Competition. Acceptance of a fuel system design is not an approval of a fuels systems capability to meet safety compliance standards, only that a fuel system meets with minimal expectations required.

#### 9.19.3 Multiple Fuels

A vehicle can use more than one fuel as long as accurate measurement of total energy consumption can be performed accurately and consistently. Furthermore, the selection of the fuel that is used during any part of the Competition must be done automatically by the vehicle's electronic control unit. No Team may manually or automatically change fuels during the Competition to gain an advantage for a particular event. Technical officials have the right to test a vehicle in worst case scenario. Teams planning to use multiple fuels must provide special notification to the Competition officials by the date noted in Section 4.4 and receive a special waiver to ensure they meet the measurement requirements.

#### 9.19.4 Location of Components

No fuel system component can be located outside the frame rail (or equivalent unibody component) or the crush zone (behind the rear or in front of the front axle). Fuel system components cannot be routed into or through the passenger compartment. Refueling receptacles must be isolated from the passenger compartment.

#### 9.19.5 Original Fuel Tanks

Teams may retain their original fuel tank in addition to the removable fuel tank listed below. The original fuel tank must be fully drained, sealed and completely isolated from the engine. Teams must provide a way of draining their tank and proving that it is completely empty.

#### 9.19.6 Removable Fuel Tanks

The competition organizers will supply a racing fuel cell with mounting brackets and quick-disconnect fuel line fittings which shall be used to hold all fuel used during the Competition. The tank must be mounted with the fuel filler up and meet the crash safety requirements listed in Section 9.2. Customized tanks for specific applications may be used as long as these tanks are constructed by the approved Progressive Insurance Automotive X PRIZE tank supplier.

Upon receipt of fuel tanks and quick-disconnect fittings, all Teams must send the original packing slips to the Progressive Insurance Automotive X PRIZE headquarters at the following address:

Progressive Insurance Automotive X PRIZE  
Attn: David Locke  
5510 Lincoln Blvd  
Suite 100  
Playa Vista, CA 90094

Failure to send in the packing slips will result in suspension from the Competition until such time that the paperwork is submitted. Teams could potentially face elimination from the Competition if they are unable to complete the Shakedown Stage due to missing paperwork.

The Competition fuel tanks must be able to be easily and safely removed within 15 minutes to allow precise mass measurement to determine fuel consumption. Teams will be responsible for removing their own fuel tank during the Competition and any spilt fuel will count against a vehicle's fuel economy measurement.

All fuel tanks must be leak free before and after refueling. Fuel tanks must arrive at each Competition Stage empty and clean.

#### 9.19.7 Fuel Lines

Vehicles must use braided stainless steel hoses or tubing for all fuel lines. The fuel lines shall be kept to the shortest length possible; consistent with safe fuel line routing, appropriate considerations for stress in the fuel line during a collision and easy access to the fuel fittings for removal, and re-connection of the Competition fuel tank.

Teams are required to use uniform diameter fuel lines of the minimum practical length throughout their fuel system. No fuel storage is allowed in the fuel lines. Since the volume of fuel consumed during competition stages may be very small, any extra fuel storage concealed on any competing vehicle is prohibited, and if found will be grounds for elimination and ejection.

## **9.20 Gaseous Fuel Systems**

Vehicles that generate or store gaseous fuels must not leak any fuel. Gaseous fuel systems including fuel lines must meet the requirements in Section 9.19 and other applicable regulations. Vehicles must also have a leak detection system which, in the event of a leak, shuts down the vehicle in the same manner as the Vehicles On/Off Switch (Section 9.7.3).

## **10 Electrical Component Requirements**

All Teams, even those with vehicles that do not use electric propulsion, should review this section.

### **10.1 General Electrical Practice**

The entire electrical system for all competing vehicles must follow accepted electrical practices. Where applicable, Teams should use references such as the National Electrical Code (NEC), SAE International (SAE) standards, Underwriters' Laboratory (UL), and the Institute of Electrical and Electronic Engineers (IEEE) standards in their design and fabrication efforts. Through the specifications in this section and with careful design and work practices, it is the intention of the Progressive Insurance Automotive X PRIZE organizers to prevent electrical shock, over-current, chemical spills, fire, and other hazards. Teams are strongly encouraged to research works on human exposure to electrical currents such as the studies conducted by Charles Dalziel (IEEE Publication, Reevaluation of Lethal Electrical Currents, 1970). Teams are also encouraged to review National Fire Protection Association publication 70E, Part II, Chapter 2, "Personal and Other Protective Equipment," and Chapter 3, "Specific Safety-Related Work Practices".

### **10.2 Documentation of Electrical Components and Wiring Schematic**

Documentation of all electrical components and schematics must be kept in the vehicle at all times. The documentation should detail the specific components used in the electrical system (including the wiring) complete with manufacturer data sheets. Figure 1 provides a general example of the required high-voltage wiring diagram that includes the locations of the Emergency Disconnect Switch, inertia disconnect switch, Manual Isolation Switch, traction battery fuses, and the attachments of all high-voltage leads.

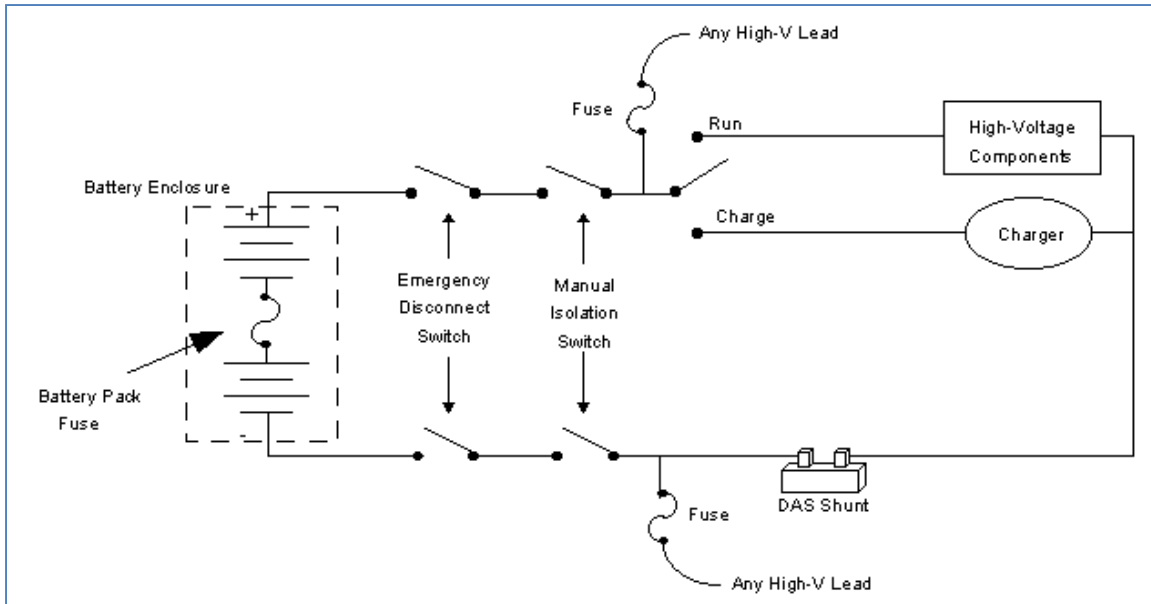


Figure 1: Example Wiring Schematic

### 10.3 Maximum Voltage

The peak open-circuit voltage of any part of an electrical system may not exceed 600 V including states of uncontrolled generation (UCG) and back-EMF from permanent magnet motors. The peak voltage limit is 650V during charging, but the voltage must return to below 600 V within 24 hours after the charging period.

The HV bus shall be below 50 V within 2 minutes after turning off the on/off switch (Section 9.7.3) or EDS (Section 10.13.1) for the safety of emergency first responders and mechanics working on the vehicle. Although not required for the Competition, it is noted that after the activation of the inertia switch (Section 9.7.4), the HV bus should be below 60 V within 5 seconds of the vehicle coming to a stop. Please refer to SAE J1766 for further information.

### 10.4 Component Ratings

All components of any electrical system must be rated at the appropriate voltage, current, and temperature for the system's environment and maximum operating conditions.

### 10.5 Environmental Conditions

All electrical components must be protected from harsh environmental conditions, including water, dust, corrosive materials, and heat through cover, shields, and enclosures. Electrical components should not be placed directly below components that contain fluids or below liquid-fill areas without barriers that must, under any conditions, prevent fluids from reaching the electrical components.

Shielding underneath the vehicle protecting critical components must be robust enough to remain in position after coming in contact with obstructions typical to those seen by on-road vehicles (i.e., road debris, rocks, accidental contact with a curb, etc.).

## 10.6 Conductors

All conductor and insulation must meet the appropriate voltage, temperature, and environmental ratings for its application as discussed in Section 10.4 and 10.5. All insulation must also be in good physical condition without any breaks. Electrical tape is not a satisfactory insulation.

### 10.6.1 Protection of Conductors

All conductors must be strain-relieved and securely fastened throughout the vehicle to minimize movement. Conductors that may be damaged by moving parts, bending, chaffing on corners or surfaces, pinching, crushing, high temperatures, or corrosive liquids must be protected by nonmetallic protective conduit or similar protection. Wires must be secured to prevent them from getting caught in rotating parts, falling on hot surfaces, or snagging on-road features. When a wire must pass through a frame, panel, or bulkhead, it must be protected by a feed-through or grommet securely fastened to the opening.

All high-voltage conductors routed under the vehicle or through the passenger compartment must be protected by conduit. Conductors within the engine or motor compartment(s) that are near high-temperature components (e.g. exhaust systems or heat exchangers) or are exposed to road debris and rain water must also be enclosed in conduit. High voltage systems may not be run outside or down the middle of the vehicle's frame rails (or equivalent body-frame integral structural component).

### 10.6.2 Connections

All high voltage connections between wires and terminals must be made by a secure means that will not loosen during operation of the vehicle (e.g., lock nuts, welds, etc.).

### 10.6.3 Spacing and Insulation Barriers

Table 1 specifies the minimum spacing to prevent accidental contact or arcing between any un-insulated energized (positive or negative) part and conductive material, or between any two parts of opposite polarity. An insulating barrier or liner, possibly made of rubber, may be used in place of required spacing, but not as the sole barrier. The barrier must be at least 0.71-mm thick. For further information, refer to IEC 60664-1 Section 3.

Table 1: Minimum Spacing to Prevent Accidental Contact

Potential, Volts RMS (peak)	Minimum Spacing (mm)		
	Between any two un-insulated live parts of opposite polarity		Between any un-insulated live part and any conductive material
	Through Air	Over Surface	Shortest Distance
0 to 50 (0 to 70.7)	1.6	1.6	1.6
> 50 to 150 (70.7 to 212.1)	3.2	6.4	6.4
>150 to 300 (212.1 to 424.2)	6.4	9.5	12.7
>300 to 400	9.5	12.7	12.7

#### 10.6.4 Bus Bars

Bus bars may be used as conductors provided they have a direct insulation barrier over their entire surface to prevent accidental contact. Note: Each bus bar must have its own insulation; shielding that covers multiple bus bars is not adequate. Bus bars must use a secure connection, such as a rivet or bolt with a spring washer or a split-ring lock washer and a flat washer. The size of the bus bar must be rated for the current, voltage, and other conditions it is expected to handle (Section 10.4). At a minimum, a copper bus bar must be sized for the current ratings shown in Table 2.

Table 2: Copper Bus Bar Current Ratings

Current Rating (A)	Cross-Section (mm <sup>2</sup> )
225	70.3
400	242.0
600	322.6
800	483.9

#### 10.6.5 Conductors in Parallel

Conductors may be used in parallel provided each conductor can meet the ampacity requirements of that electrical path without the aid of the other parallel paths. All parallel conducting paths must be individually and fully fuse-protected.

#### 10.6.6 High-Voltage Conductor Labeling

All high-voltage wiring (positive and negative) must be minimally marked with orange electrical tape, but preferably marked continuously with orange insulation or orange conduits. Large conductors may have tape spiraled along their lengths; small pieces of orange tape may be periodically wrapped around smaller leads to easily identify them as high voltage. Several cable manufacturers make cable with orange insulation that satisfies the “orange tape” requirement. For further information, refer to ISO 23273-3 Section 6.2 and SAE J2578 Section 4.4.1.

### **10.7 Fuses**

All electrical components must be fused to protect from over-current. Fuses should be rated to 125% of the maximum continuous load current with a voltage rating that is greater than the maximum voltage. The type of fuse used for an ac or dc circuit should be considered.

### **10.8 Electrical System Packaging**

#### 10.8.1 Incidental Contact

Teams must design their vehicle to prevent accidental contact with any portion of a high-voltage electrical system at any time, except when the vehicle is being serviced and the system is de-energized. This includes potential contact by non-Team Members while the hood, truck, and doors are open. All high-voltage conductors, connectors, and terminals must be insulated and all

electrical components must be shielded or contained in an appropriate box. All high-voltage electrical systems must satisfy the following conditions:

- Finger-proof: All portions of an electrical system must be protected against accidental contact with the human body. For further information, refer to IEC 60529 (Finger safe IP2X protection), specifically the section specifying that a 12 mm diameter jointed “test finger” cannot make contact to any HV electrical terminal or conductor.
- Drop-proof: All portions of an electrical system must be protected against loose or dropped items, such as a wrench or bolt.

### 10.8.2 Arcing Components

Any system that may generate arcs must be fully shielded or enclosed in a sealed, flame-resistant enclosure to prevent the possibility of fused material contacting flammable substances.

### 10.8.3 Conductive Enclosures

When using conductive boxes and covers in high-voltage systems, the cover or lid must be designed so that it can never come in contact with the enclosed components or energized surfaces when opened or closed or if bumped or pushed, or leaned against. All HV components enclosed by conductive casing must have equipotential (conductive) bonding between other conductive enclosed casing and vehicle chassis. The maximum allowable resistance of the bonding is 0.1 Ohms. For further information, refer to ECE R100 Section 5.1.2.3.3.

Furthermore, the conductive enclosure shall be lined with a tough insulating material that has a breakdown voltage rated at 150% of the maximum battery pack voltage. Insulating sprays are not acceptable. All insulating barriers and coatings shall be sufficiently strong to prevent any high-voltage component (connectors, attachment devices, relays, etc.) from cutting through in the event of hard contact.

## 10.9 Labeling

All equipment or conductors operating at high voltage (>50 V), which are visible when the truck or hood is open, must be clearly marked with clearly visible labeling that states “Warning High Voltage” in letters at least 1 in high and in a high-contrast color. Enclosures containing exposed high voltage components must be similarly labeled. For further information the following references can be used: ECE R100 Section 5.1.2.1.8, ISO 23273-3 Section 6.1, or SAE J2578 4.4.6.

## 10.10 Electric Motors

All propulsion system electric motor(s) must have their own short-circuit or over-current protection devices or proof of a proper control strategy for protection. It is also strongly recommended that each motor have a device that de-energizes it to prevent overheating or proof of a proper control strategy for prevention. AC motors using three single-phase conductors must have over-current protection on all three conductors or proof of a proper control strategy for protection.

### 10.10.1 Erroneous Propulsion Signal Failure

Vehicles must be designed to prevent high-power components, such as the electric motor, from carrying out an erroneous order that may cause a hazardous situation. If a power component receives an erroneous signal from a control device that has failed (such as an accelerator potentiometer with a short circuit), the control hardware for the propulsion system (electric and fuel) or generator system (for series HEVs) must have a fail-safe system that prevents unintended operation of the drive system. “Throttle-by-wire” accelerator pedals must use dual potentiometers as a failsafe device with separate grounds. Additionally, erroneous propulsion shall be prevented in the event of loss of low voltage power to the electric motor controller.<sup>1</sup>

### 10.11 Permanently Energized Systems

Any high-voltage electrical component that is always energized (even when the manual isolation switch is off) must be shielded or isolated from all other electrical components. These other components include, but are not limited to: fuses, switches, contactors, relays, and solenoids. Separate enclosure(s) for permanently energized component(s) must meet the requirements of Section 10.8 and have clearly visible labeling that states “High Voltage Always Energized” in letters at least 1 in high and in a high-contrast color.

### 10.12 Ground Faults

All high-voltage systems must be electrically isolated from the vehicle chassis or any other exposed component. Components requiring isolation include not only the main high-voltage leads, but also high-voltage, low-current leads such as those for voltage monitoring, the battery box, and motor/power electronics. To prevent electrical shock, it is strongly recommended that Teams frequently check for ground faults as they install their electrical system. The minimum allowed electrical isolation is  $500 \Omega/V$ , where V is equal to the nominal voltage of the traction battery. Refer to FMVSS 305 for more details. The electrical isolation requirement requires that all high voltage components are connected to the HV bus. Note that since the high voltage components are in parallel, the equivalent resistance decreases with each high voltage component added. Generally, each component by itself requires at least some  $M\Omega$  of isolation to meet the requirement.

All vehicles with an EESS must be equipped with an active ground-fault detection system that alerts the operator of the vehicle to any ground faults on the vehicle. The system must monitor the isolation between the battery pack and chassis ground. The high-voltage sense leads of the ground-fault detection system must be fused at the source (pico fuses are acceptable). The output of the monitor should light a clearly labeled indicator light on the dashboard that is visible to the driver when seated normally behind the steering wheel. It is recommended that Teams use the Bender A-Isometer for this function. Other ground-fault detection systems are acceptable if they can reliably detect when electrical isolation is lower than  $500 \Omega/V$ . Use of any other ground fault detection system will require Progressive Insurance Automotive X PRIZE authorization in advance of the pre-competition inspection. This component must be called out on your high-voltage circuit diagram.

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<sup>1</sup> The regulating requirement for erroneous propulsion is stated in ECE R100 Section 5.2.2.3, that “Unintentional acceleration, deceleration, and reversal of the drive train shall be prevented. In particular, a failure (e.g. in the power train) shall not cause more than 0.1 m movement of a standing un-braked vehicle.”

During the pre-competition technical inspection, each vehicle's high-voltage ground-fault detection system will be tested. A resistor between one of the high-voltage legs and chassis ground will simulate a ground current large enough to trigger the ground-fault/isolation monitor. The dashboard ground-fault detection indicator light must illuminate. The threshold on the ground-fault monitor should be set to trip the warning light at approximately 500  $\Omega/V$ .

### **10.13 Mandatory Electrical System Switches**

All Teams should review the controls requirements listed in Section 9.7

#### **10.13.1 Emergency Disconnect Switch**

All vehicles with high voltage or electric propulsion systems must include an emergency disconnect switch (EDS) that is triggered from a minimum of two locations. This button is for the safety of the operator of the vehicle and anyone aiding the operator in case of an emergency. The EDS is intended as an "Emergency Stop" button and must completely disable all moving parts and disconnect all high voltage components. The EDS must also close the fuel system at its source (fuel tank).

If a contactor or relay is used as the EDS, it must be normally open and, thus must require external power to put it into the closed position. A fail-safe switch that interrupts the power supply to a relay is allowable for the EDS. It is recommended the switch be replaced in the event the switch is opened multiple times under load (check with the manufacturer for recommendations); there have been instances in which the contactors will weld closed after multiple cycles and open slower than expected. The EDS must be able to be triggered from at least two locations, one in and one outside the vehicle:

- From the dashboard area located within reach of both a belted-in driver and a person standing outside the vehicle (with window open)
- Right rear fender of vehicle (not on bumper where it can be damaged by incidental contact)

The EDS must be clearly labeled, "Emergency Disconnect." Letters must be at least 1 in high and be in a high-contrast color. The EDS must be a push button design at least 1 in diameter and colored in bright red.

The EDS circuit must be located in its own enclosure; it cannot be combined with other electrical connections or components. The EDS must satisfy the requirements listed in Section 10.8

The EDS should be placed directly adjacent to the EESS to reduce the amount of wiring that is always energized and before the MIS. The switch must also fully disconnect the positive and negative terminals of the ESS.

The EDS must be able to disconnect the system under a full-load current without failure. "Full load" is defined as the EESS or battery pack fuse rating. The EDS must possess arc suppression to fully disconnect current under full load. The EDS function can be tested by the judges in both

unloaded and loaded conditions. Uncontrolled generation (UCG) voltages shall be properly addressed in a fully loaded condition.

#### 10.13.2 Manual Isolation Switch

All vehicles with high voltage or electric propulsion systems must include a manual isolation switch (MIS) which completely disables the entire vehicle while work is being performed on it. The MIS must disable all moving components and de-energize all high voltage systems. Teams are required to use the MIS at all times while working on a vehicle. The MIS differs from the EDS in that the MIS is intended to be used routinely when working on the Competition vehicle; the EDS is to quickly disconnect all sources of high voltage in an emergency or when using the MIS is not convenient (e.g. public vehicle display).

The MIS must be disconnected by physically pulling and separating (not by electric actuation) the contacts or terminals that lead to the high-voltage system. The MIS must be able to be physically locked in the open position and be re-energized only with a key or other locking device held by the person working on the vehicle. The switch may be located in any convenient location in the vehicle, so that lock-out/tag-out procedures will be used every time the vehicle is being serviced. It should be in a location such that a person unfamiliar with the vehicle will not confuse it with the EDS.

The MIS must de-energize the entire high-voltage electrical system in a completely fail-safe manner while work is performed on the vehicle. The MIS is not required to interrupt the current at full load; however, current rating of the switch should exceed the current rating of the main fuse. The MIS for high voltage systems must meet all of the requirements in Section 10. The MIS must be located downstream from the EDS. If the vehicle has multiple traction battery packs with parallel strings, all parallel strings must be electrically separated and isolated when the MIS is in the open position.

#### 10.13.3 Regenerative Braking Disable Switch

All vehicles with regenerative braking must have a way to disable the system to enable testing of friction brakes during qualifying and coast down testing prior to dynamometer tests. Regenerative braking will be disabled for braking tests during pre-competition vehicle qualifying. The disabling method must be employed such that it does not prevent the vehicle from performing these tests. Contact the Progressive Insurance Automotive X PRIZE organizers if there are any problems meeting this requirement.

### **10.14 On-Board Solar Cells**

Vehicles that are allowed to carry photovoltaic (PV) cells are limited to a potential of 50 V with respect to all nodes of the PV circuitry (series strings of 50-V modules are not allowed). The PV array and associated wiring must meet all of the requirements in Section 10. PV cells should be protected from damage (e.g., hail, physical contact) and must be completely covered to prevent electrical contact.

### **10.15 Low-Voltage Electrical Systems**

This section pertains to any system less than 50 volts, typically the 12-V electrical accessory system or other ancillary equipment used in competing vehicles. These systems, which include

batteries that provide power to auxiliary components (lights, fuel pump, data acquisition systems, etc.), must meet the following requirements:

- Complete isolation from the EESS and any electrical propulsion components
- Complete isolation from any other system above 50 volts

The low-voltage system may be recharged from a high voltage source, provided they remain isolated (e.g., through a DC/DC converter). The auxiliary battery may be grounded to the chassis, provided it does not ground the traction EESS to the chassis. If a DC/DC converter is used, it should have an isolation voltage rating at least twice the maximum peak voltage of the high-voltage circuit.

Teams using auxiliary batteries with chemistries other than lead-acid must meet the requirements in Section 11. For low-voltage electrical systems, Teams should use electrical systems, parts, connectors, wires, lights, etc., designed for automotive applications wherever practical.

## **10.16 Charging**

All chargers shall be inspected at technical inspections prior to competition events. Competition organizers reserve the right to disapprove the use of any charger if they believe it poses a safety risk.

### **10.16.1 Charging Times and Location**

All charging for the Progressive Insurance Automotive X PRIZE events shall be done in a specific charging area only during designated times. Vehicles must remain uncovered during charging and no work can be done on any competing vehicle while it is charging. No charging may occur in the pit area, except a vehicle's 12V auxiliary battery if it is a conventional lead acid automotive battery.

### **10.16.2 Electrical Energy Consumption Measurement**

Any and all electrical energy the vehicle receives during the charging period must be measured. Teams are not allowed the opportunity to charge from the grid or other external sources. Official electrical energy consumption will be measured using official Progressive Insurance Automotive X PRIZE meters provided by the organizers.

### **10.16.3 General Charger Specifications**

All chargers must meet the requirements listed in Section 10. All chargers must be commercially available with proper UL certification or be able to pass the inspections using the inspection form, to be provided prior to the first event. The organizers will not allow "home-made" chargers or power supplies without prior approval. Teams should be aware that most charging will occur outside and overnight under all weather conditions and Teams will not have access to the charging area during this time. Therefore, all chargers must be designed to operate automatically without any human intervention and must be weatherproof. Chargers and any couplings on the charge cable must be kept at least 24 in to 48 in above the ground.

#### 10.16.4Charging Control Strategy

The charger must be equipped or work in conjunction with the vehicle's battery management system. The charger must automatically stop charging when the batteries are fully charged and must utilize closed-loop (feedback) control. In addition, the charger must cease operation when the battery exceeds its critical voltage, current, and temperature and any other critical parameters. Remote control of a charger is not allowed.

In order to ensure that a vehicle begins the fuel economy event with an ESS at 100% and recharges to the same level, a vehicle must be able to fully recharge its ESS from its minimum charge within the designated charging period of ten hours (or less).

Teams must use the same charging strategy throughout the Competition and may not alter any part of the charger, including software unless there is a safety issue or failure.

#### 10.16.5AC Power for Chargers

Progressive Insurance Automotive X PRIZE organizers will provide two options for AC Power to Teams' chargers:

- Single Phase, 240V AC up to 40A Maximum Continuous Current through a NEMA 14-50 Connector
- Single Phase, 120V AC up to 15A Maximum Continuous Current through a NEMA 5-15 Connector

All chargers must be equipped with the appropriate plug. Teams should be aware that the current limit and plug may have changed from previous documents. The SAE J1172 charging protocol is no longer required.

#### 10.16.6Charger On/Off Switch

All chargers must have an on/off switch which will terminate charging and electrically disconnect the charger from the ESS. The switch must be designed to be used by anyone and accessible from the outside of the vehicle. The switch must be clearly labeled "Charger Switch" in highly contrasting, one inch high letters. The On/Off positions should also be labeled in the same manner. This switch may be used by Progressive Insurance Automotive X PRIZE officials to terminate charging at the end of the official charging period without the presence of any Team members. It is the Teams' responsibility to ensure that terminating charging using this switch will not damage the ESS and will cease charging in a safe manner.

#### 10.16.7Ground Fault Interruption

The charger must be properly connected to earth ground and the vehicle chassis, and have a ground-fault interrupter circuit (GFI). The ground wiring shall be sufficiently sized that it does not sever as a result of a large ground fault, thus eliminating its protection. The organizers strongly recommend a unity power factor-rated charger. The charger (on-board and off-board) shall be fused on both supply circuits to the charger and the vehicle and shall be routed separately from the motor drive.

#### 10.16.8 Charging Isolation

The entire electrical propulsion system shall be completely isolated from the battery pack on all vehicles while charging from the grid (with the exception of the battery box ventilation system). A separate charging switch may be used for this function, provided the switch meets the requirements listed in Section 10. The MIS may be used, provided it isolates the battery pack and charger from the rest of the system, and the charger is de-energized when the MIS is in the open position. Physically disconnecting/connecting the electric propulsion system before/after the charging period is also allowed, again, provided the MIS isolates the batteries and charger.

#### 10.16.9 Charge Cables

The charge cable wire shall comply with the requirements listed in Section 10 and not exceed 25 feet in length. If the cable is pulled apart from any of its connections, no high-voltage surfaces shall be exposed. Charge cable connectors must be polarized. The coupling of the connector and inlet shall be provided with a positive means to prevent unintentional disconnection. The supply connector shall be provided with a grounding pole; the pole should be the first component to make contact and the last to break contact with the mating inlet.

#### 10.16.10 Noisy Chargers

Chargers that exhibit a disruptive amount of total harmonic distortion (THD) will be unplugged at the event. Teams should have their chargers checked for THD (seek help from local utility power quality group, if needed); THD should be below 10%.

#### 10.16.11 Off-Board Charging from Renewable Sources

Off-board charging from renewable sources is allowed and will not be included in calculating a vehicles' fuel economy. However, all renewable charging may only be done during designated charging times in the charging area. Furthermore, throughout the Competition, all equipment used for off-board renewable charging must be carried inside the vehicle at all times.

### **10.17 Data Acquisition and Telemetry**

Teams should review Section 9.7 for any additional regulations.

#### 10.17.1 Measuring Electricity Use On-Board Competing Vehicles

Every competing vehicle that uses electricity for propulsion must have a way to measure electricity use or generation. Each competing vehicle is required to use an amp-hour meter or the equivalent.

#### 10.17.2 Data Acquisition System

To facilitate scoring and rules enforcement as well as provide information for interested viewers worldwide, all competing Teams must properly install and calibrate the Progressive Insurance Automotive X PRIZE provided data acquisition system (DAS). The DAS will have a GPS and telemetry built into it and will broadcast as well as record a variety of vehicle level inputs. This device, the signals sent to it and from it, and the data stored in it must remain unaltered and un-tampered with during all competition events and related activities. No vehicle can compete in any Competition stages or testing without the DAS in proper and full functioning order. All required vehicle information regarding the DAS must be provided to the organizers in order for

them to provide the proper DAS for each vehicle. Not complying with proper installation of the DAS may be cause for elimination.

All competing vehicles will receive a Controller Area Network (CAN)-based DAS. Vehicles using CAN will be able to plug into the DAS using a CAN bus input conforming to CAN 2.0B standards with 29-bit identifiers and operating at a bus speed of 250Kbaud. For those vehicles that do not use CAN, up to two 12 analog channels of 0-5 V will be provided with the DAS. Any other voltages require either level shifting or an A/D-CAN converter to allow connection to the DAS. Refer to the DAS manual for further information. It is each Team's responsibility to wire the requisite signals to the DAS. The DAS custom system developed for vehicle use, captures data at 100HZ and stores it at 1 Hz intervals, and includes a GPS sensor and cellular modem that requires the installation of an exterior antenna (Hirschmann Car Communication magnet mount GPS; 39 mm x 39 mm 14 mm; 65 g; <25 mA current consumption at 5 V). The DAS and its connections will be tested during pre-competition inspection and shall be in working order for vehicles to participate in any competition stage.

The DAS records all data collected and automatically uploads it to the Competition organizers at the end of each stage. The DAS will also be able to download its stored data on a removable data memory stick for the Teams' use.

The signals that must be collected from every vehicle's DAS were previously provided to Teams and include, but are not limited to:

- Vehicle speed
- Vehicle position (from GPS data)
- Throttle position
- Brake position
- Fuel flow or mass airflow (if necessary, from a fuel-flow or mass airflow sensor or sensors)
- EESS voltage (if applicable)
- EESS current (if applicable)

Additional signals may be collected to help the organizers review the performance of the vehicle in order to enforce the rules or to consider a protest or appeal. Additionally, the collected data will be used for the educational website.

## **11 On-Vehicle Energy Storage System (ESS)**

### **11.1 ESS Documentation**

Teams must submit the following documentation regarding their ESS by the dates shown in Section 4.44:

- Material Safety Data Sheets for any hazardous or flammable materials or components, including battery packs, ultracapacitors, cooling fluid, hydraulic fluid, etc.
- Manufacturing specification and safety sheets for ESS

- Design and crash safety analysis of ESS system and any enclosures
- Teams must show fuse curve information: A fuse curve is defined as a current versus time plot showing when the fuse will blow; this information is available from the fuse manufacturer
- Documentation on operation and capabilities of BMS

## **11.2 ESS Structural Requirements**

No ESS can be mounted in the front or rear crush zones of the vehicle and all ESS systems and their enclosures must satisfy the crash safety requirements listed in Section 9.2. If enclosed, the ESS must also be secured to a structural component on the vehicle, such as the frame, in a manner to prevent any movement within the enclosure. If the ESS is high voltage, no hardware or hold-down parts in the ESS enclosure can have exposed conductive surfaces. Nylon straps can be used to secure the EESS if they meet the requirements in Section 9.2 and are coated with a material to prevent them from absorbing electrolyte which could cause degradation or ground faults.

## **11.3 External ESS**

All ESS must be carried inside the vehicle at all times during the Competition. Trailers containing ESS are allowed, but Teams must comply with Section 9.17.

## **11.4 Spare ESS**

All spare ESS (even individual battery cells) must be inspected and approved during the pre-competition inspection. Competition organizers must approve all ESS changes. The ESS may be changed only in the event of a failure or malfunction, such as physical damage or an internal short circuit. Teams will be required to store any and all spare ESS' in a designated area. Officials reserve the right to assess a penalty if a vehicle receives an unfair advantage in changing their ESS.

## **11.5 Compressed Fluid or Gas ESS**

Teams that use a compressed fluid or gas ESS must meet all of the requirements listed in Section 9. Teams that plan on using this type of EES must provide the organizers with a complete system schematic listing all components exposed to pressure and along with their part numbers and specifications and where they will be mounted in the vehicle. The due dates for information on the gas or liquid ESS is shown in Section 4.4. The organizers reserve the right to disallow any compressed fluid or gas ESS that they do not believe meets the spirit or intent of Competition safety standards.

## **11.6 Kinetic Energy ESS**

Teams that intend to use a kinetic energy ESS must provide competition organizers with data that convinces the organizers that a full speed failure of their EES will be absorbed within the system's containment vessel before the vehicle will be allowed to participate in the Competition. In addition, the kinetic ESS system must satisfy the crash safety requirements listed in Section 9.2. A complete technical description of the kinetic ESS must be supplied to competition organizers. The due dates for information on the gas or liquid ESS is shown in Section 4.4. The

organizers reserve the right to disallow any kinetic ESS that they do not believe meets the spirit or intent of competition safety standards.

## **11.7 Electrical Energy Storage System (EESS)**

The organizers reserve the right to disallow any EESS that they do not believe meets the spirit or intent of competition safety standards or poses an unwarranted danger to Progressive Insurance Automotive X PRIZE participants or the public.

### 11.7.1 EESS Capacity

No restrictions are placed on the size or number of cells or capacitors, although the EESS may not violate any other regulations, including weight and voltage limits.

### 11.7.2 EESS Enclosure

EESS (e.g. batteries used to provide motive power) must be located in an enclosure in order to meet the following goals:

- Contain any liquids and fumes emanating from the batteries,
- Secure individual batteries to the vehicle chassis,
- Protect the battery pack from damage
- Prevent accidental contact

Each EESS shall be fully contained in a separate enclosure which meets all other regulations including Sections 9.2 and 10.8. The enclosure shall be made of a fire-resistant material. In addition, the enclosure shall electrically insulate the batteries.

### 11.7.3 EESS Terminals

All EESS terminals and electrically exposed parts within the battery enclosure must be individually covered and must satisfy the requirements for incidental contact listed in Section 10.8. The terminals should be insulated when the battery enclosure is open and service is being performed on the vehicle. For example, each battery post should be covered with an individual plastic cover to prevent incidental contact. If the EESS has many individual cells, covers shall be fabricated to securely cover rows or segments of the battery string.

### 11.7.4 EESS Ventilation

All EESS enclosures must be equipped with forced-air ventilation to the outside of the vehicle to remove any gases and vapors. The venting system shall draw air from the bottom to the top of the enclosure in order to exchange all of the air in the battery box. Each fan shall induce a negative pressure in the enclosure to force the air out (i.e., draw, not push, gases out the battery box).

Each EESS ventilation fan shall be rated for at least 10 cubic feet per minute (cfm). The fan motor must have an explosion-proof rating such that it cannot produce sparks. The fan must operate any time the battery system is energized and during recharging of the batteries. The ventilation system for the battery box may draw air from the passenger compartment; however, the battery box must remain sealed from the passenger compartment when the battery box fans

are not powered. A check valve on the duct must be installed to prevent air flow back into the passenger compartment.

#### 11.7.5 EESS Fuses

Each EESS system must have over-current protection in the form of a non-renewable current-limiting fuse connected in series roughly halfway through the battery string. No components are allowed to be between the EESS and its fuse. However, additional EESS fuses wired in series in the circuit are allowed. Voltage, current, and temperature sensors for DAS or battery management systems are allowed, but must also be fused as close to the sensor as possible.

Fuses must meet the requirements listed in Section 10.4. In addition, the fuse must have a current rating lower than the maximum expected current capacity of all high-current conductors and no higher than 150% of the full-load current the system can draw. The battery fuses must satisfy the requirements governing energized parts in the traction battery enclosure(s). Technical inspectors and organizers reserve the right to limit the battery pack fuse rating based on the battery type and size used during the Competition.

#### 11.7.6 Multiple EESS Systems

EESS may be contained in any number of enclosures as long as each conforms to the requirements outlined in this section. Each individual enclosure must be fused independently and have their own ventilation system. Separate EESS systems must be electrically separated when the Manual Isolation Switch is removed.

#### 11.7.7 Advanced EESS Batteries

All EESS, other than lead-acid, must have an active battery management system (BMS). At minimum, the BMS shall monitor the temperature and voltage of the battery cells, and the current of each individual EESS string. Any time the EESS is energized (including charging) the BMS is required to signal if the EESS exceeds manufacturer specified voltage and temperature safety limits or if any other problems exist. The BMS must notify the driver through a visual alarm on the vehicle's dash board which can be clearly seen in all operating conditions while the vehicle is being driven. The BMS must also automatically adjust the parameters or shut down the system on the EESS or its charger to prevent any thermal or other safety incidents. At a minimum, an adequate number of thermocouples shall be present inside the battery enclosure to detect impending thermal incident before it reaches a critical temperature. The BMS will be rigorously tested during inspection, including simulating a thermal incident to determine the actions the BMS will take. Teams charging advanced EESS should also review Section 10.16.

#### 11.7.8 Ultracapacitors

Ultracapacitors are large high-current solid state electrical energy storage devices. For the purposes of the Competition, they must meet the requirements of all EESS. The capacitors used may not develop pressures capable of causing injury to persons in the event of a malfunction. Capacitors containing flammable materials must not result in a risk of fire or electric shock under normal and abnormal conditions, including internal shorting. Capacitors must be constructed to reduce the risk of expelling hazardous materials under all foreseeable situations. All high-voltage (over 50 V) capacitor(s) shall be equipped with an automatic means of discharging stored energy

when disconnected from a supply source. Normal off/on operation of the vehicle does not require capacitors to be discharged.

#### 11.7.9 Other Energy Storage Systems

Other ESS' are allowed, however, Teams planning to use any other ESS listed here shall inform the officials by the dates noted in Section 4.4. Any other ESS must meet the same requirements and Teams are strongly encouraged to work closely with officials to ensure the ESS is well understood and safe. Competition organizers have the right to reject any ESS if they feel that it endangers the safety of participants and/or spectators.

## **12 Technical Inspection**

All vehicles must pass Technical Inspection before they are allowed to participate in any Dynamic Testing or Competition Events. Technical Inspection will only be available at certain times and for a limited number of days during each Competition Event, and all vehicles must pass before the close of Technical Inspection. Teams will be notified, in advance, of the duration and timing of Technical Inspection.

The scope of Technical Inspection will include any and all regulations in this document. Furthermore, inspectors reserve the right to not pass a vehicle for any safety concerns. Officials reserve the right to inspect a vehicle at any time, especially after any major vehicle modification, repair, and safety incident or accident. Officials may also require a technical inspection after any extended break between stages where the vehicle is not under Progressive Insurance Automotive X PRIZE supervision.

## **13 Vehicle Dynamic Safety Requirements and Testing**

This section discusses the dynamic requirements and test methods for all vehicles. Performance requirements, such as, emissions, range, and fuel economy are listed in Section 14. Dynamic tests will be conducted with advice from Consumers Union (CU) and certain tests will be performed in accordance with procedures developed by CU. All competing vehicles must pass the dynamic safety tests in order to participate in any competition stage.

In general, vehicles will be allowed to attempt each Dynamic Safety Test twice and must finish their attempts before the end of the test period. Vehicles which have not attempted the test are given priority over Teams who are re-testing. Any vehicle which misses its designated start time will be placed at the end of the test schedule. Competition officials may change these requirements for each test depending on the circumstances.

### **13.1 Highway Capable**

Vehicles must be able to accelerate from 40 to 65 mph in 9 seconds or less. This test will be conducted by Consumers Union, using a speed pad to confirm a 40 mph starting speed and a radar gun and stopwatch to confirm acceleration to 65 mph in less than 9 seconds.

### **13.2 Linear Acceleration**

Vehicles in the Mainstream Class must show they are able to accelerate from 0 to 60 mph in less than 15 seconds. Vehicles in the Alternative Class must accelerate from a standstill to 60 mph in less than 18 seconds. This test will be conducted by Consumers Union, as completed during the Shakedown Stage, using a radar gun and stopwatch to determine time to 60 mph.

### **13.3 Lateral Acceleration**

All vehicles must show they are capable of a lateral acceleration of 0.70 g within a circle with a radius of 150 ft. This test will be conducted in an open, paved area on the grounds at Michigan International Speedway, with assistance from Consumers Union. Vehicles will drive on the outside of a circle scribed on the pavement, accelerating up to at least 39.6 mph. This number is derived from the following equation:

$$a=v^2/R$$

$$a = 0.7 \times 32.2 \text{ ft/sec}^2$$

$$R = 150\text{ft}$$

$$v = \sqrt{0.7 \times 32.2 \times 150} = 58.1464 \text{ ft/sec} = 39.645 \text{ mph}$$

### **13.4 Braking**

Vehicles must be able to come to a complete stop from 60 mph within 170 feet or less. The vehicle may not deviate from a lane 12 feet wide at any time while performing the brake test. This test will be conducted by Consumers Union, as completed during the Shakedown Stage, using a speed pad and cones 170 ft away to determine stopping distance.

### **13.5 Vehicle Stability**

#### 13.5.1 Static Stability

The vehicle must stay upright without any human assistance when it comes to a complete stop.

#### 13.5.2 General Dynamic Stability

The vehicle must not fall over if traction is lost. Staying upright when in motion must not depend on the balancing skills of the driver.

#### 13.5.3 High Speed Dynamic Stability

Vehicles must pass the Consumers Union “Avoidance Maneuver” or “Double Lane Change Test” without hitting any cones at 45 mph. This test will be conducted by Consumers Union, as completed during the Shakedown Stage. Vehicles will cross a speed pad at 45 mph, traverse on lane width to the left and back within the prescribed distance of 120 ft.

### **13.6 Gradeability**

All vehicles must be able to be driven safely on a public highway. Therefore, vehicles in the Mainstream Class must be able to maintain 55 mph constant speed on a dynamometer simulated 4% grade for 30 minutes. Vehicles in the Alternative Class must meet the same requirements for 15 minutes. This test will be conducted on the dynamometer, during the Validation Stage.

## 14 Competition Events

Unless noted, each competition event will be run once and vehicles not present during the start, or vehicles which do not finish the event within the schedule time of the event, for whatever reason, will not be scored. Retesting will not be allowed.

### 14.1 Fairness

Competition officials reserve the right to adjust the results of a vehicle's event if it has achieved an unfair advantage as defined in Section 7.2.

### 14.2 Speed Limits

Minimum and maximum speed limits will be established for all on-road events to prevent driving styles not reflective of typical drivers. Vehicles falling below the minimum speed or exceeding the maximum speed will receive penalties which will affect their overall score.

### 14.3 On-Road Range

Vehicles in the Mainstream Class must have a continuous on-road driving range of 200 miles. Vehicles in the Alternative Class must have a continuous driving range of 100 miles. Vehicles not achieving these requirements during the Finals will not be eligible for the Grand Prize.

All vehicles must begin the Range Event with a completely full competition fuel tank and ESS. The range measurement must be completed without refueling, recharging, or any external energy sources, except those specifically allowed in these regulations. Failure to follow these requirements may result in elimination.

The driving cycle of the Range Event will be representative of normal driving, as determined by the officials. The exact specifications of the route will not be released in advance, to avoid competitors designing their vehicles for the events and not for normal everyday driving.

### 14.4 On Road Fuel Economy

Vehicles must achieve a fuel economy of 100 miles per gallon gasoline equivalent (MPGe) when their on-road fuel economy as measured during the Fuel Economy Event during the Finals Stage and the fuel economy measured on the dynamometer during the Validation Stage are averaged together. Vehicles not achieving this requirement will not be eligible for the Grand Prize. The fuel economy of the vehicle will be measured on the track with a combination of city and highway cycles, as determined by the 2001 NHTS data. The fuel economy of a vehicle will be calculated using following equation:

$$MPG_e^{City\ and\ Highway} = \frac{Total\ Miles\ Driven\ during\ City\ and\ Highway\ Cycle}{Total\ Energy\ Consumed/LHV\ gasoline}$$

No adjustments will be made for additional miles driven, penalties, or "lost" energy (e.g., fuel spills). The energy content of each of the fuels will be determined by measuring the lower heating value of the Competition fuels (see Section 9.18.5). The energy content of electricity is

3412 BTU/kWh and the electrical energy consumed by a vehicle will be measured at the plug and include the charger efficiency.

All vehicles must begin the Fuel Economy Event with a completely full competition fuel tank and ESS and must refill the fuel tank and ESS to the same level at the end of the event. The Fuel Economy Event must be completed without refueling, recharging, or any external energy sources except those specifically allowed in these regulations. Failure to follow these requirements may result in elimination.

#### **14.5 On-Road Greenhouse Gas Emissions**

For the purposes of the Competition, CO<sub>2</sub> is the only greenhouse gas emissions which will be measured. Vehicles must achieve an on-road life cycle or wells-to-wheels (WTW) greenhouse gas (GHG) emissions level of 200 equivalent grams of CO<sub>2</sub> per mile or less. Vehicles not achieving these requirements during the Finals Stage will not be eligible for the Grand Prize.

The GHG emissions will be based upon the sum of all fuels consumed during the On-Road Fuel Economy Events. The tailpipe or tank-to-wheels (TTW) emissions of each fuel will be calculated using the carbon content of the Competition fuels. The TTW GHG emissions of electricity are zero.

The organizers will use the GREET model, created by the Department of Energy and Argonne National Laboratory, to determine the upstream emissions or wells-to-tank (WTT) using average default values that reflect fuel production today and in the near future. Competition officials will release the upstream emissions per gallon of each of the fuels and electricity before the start of the Knockout Stage.

The WTW GHG emissions of a vehicle will be calculated using following equation:

*Total GHG emissions per mile*

$$\sum = \frac{\text{Fuel consumed} \times (\text{TTW CO}_2 \text{ per amount of fuel} + \text{WTT CO}_2 \text{ per amount of fuel})}{\text{Total miles driven}}$$

The equation above is summed for each fuel, including electricity.

No adjustments will be made for additional miles driven, penalties, or “lost” energy (e.g., fuel spills). CO<sub>2</sub> will be calculated from the On-Road Fuel Economy Events and the Validation Stage.

#### **14.6 On-Road Criteria Emissions**

Competition vehicles must achieve at least US EPA Tier II, Bin 10 emissions during on road emissions testing for total organic gases (TOG)/ total hydrocarbons (THC), carbon monoxide (CO), and nitrous oxides (NO<sub>x</sub>). Particulate matter and other criteria pollutants will not be measured during the On-Road Criteria Emissions Event. Vehicles unable to achieve these emissions levels at the Knockout Stage will not be eligible for the Grand Prize.

The portable emissions testing devices will measure the total hydrocarbons, carbon monoxide, and oxides of nitrogen and will be towed behind the vehicle (Section 9.17.1). The on-road testing will begin with a hot start and the route will simulate urban and highway driving. A vehicle's engine must remain on during the entire event.

## 15 Competition Stages

The dates for each of the stages are listed in Section 4.4. Additional information including a detailed schedule will be sent to Teams before the start of each Stage.

### 15.1 Shakedown Stage

The goal of the Shakedown Stage is to allow the officials an opportunity to inspect and evaluate the vehicles to ensure they meet the safety and other vehicle regulations as well as to verify that competing entries are operational. This stage is also designed to give the Teams the opportunity to subject their vehicles to a subset of performance testing events in advance of the scored stages. Vehicles must be registered by 6:00 PM (or 8:00 PM for June 16-18 special session) one day before the start of a vehicle's assigned Shakedown Stage period listed in Section 4.4. Vehicles must pass Technical Inspection and Dynamic Safety Testing by 5:00 PM at the end of the designated inspection period to continue on to the Knockout Qualifying Stage.

The Shakedown Stage will take place over a period of two weeks, with a special session for those teams unable to attend the previously scheduled events due to travel restrictions overseas and teams that have been identified as requiring re-inspection of their vehicles and participation in the Durability event before moving on to Knockout. Vehicles will be divided into two waves, with each provided one week to complete testing. International Teams will be afforded positions in the later wave to offset the additional time lost for Team travel and vehicle transport. All other Teams will be assigned randomly to week one or two and may not switch weeks.

The following events will be held during the Shakedown Stage:

- Technical Inspection and data acquisition installation  
Vehicles must pass Technical Inspection to participate in Dynamic Safety Testing.
- The following Dynamic Safety Testing events listed below.  
Vehicles must pass Dynamic Safety Testing to participate in any Competition or other Events, or be granted a conditional pass from Competition officials.
  - Linear Acceleration (Section 13.2)
  - Braking (Section 13.4)
  - Vehicle Stability (Section 13.5)
- Durability Testing  
Vehicles must drive approximately 40 miles at an average speed of 40 mph on a road course. The top speed on the course is 65 mph. All vehicles must complete the Durability event before they are allowed to move on to the Knockout Stage of the Competition.

- **On-Road Fuel Economy Event (Section 14.4)**  
For the Shakedown Stage, this event is for informational purposes only and will not count toward a vehicle's fuel economy or CO<sub>2</sub> results in subsequent Stages. The event will take place on the track oval and no recharging or refueling will be allowed until the end of the event. Vehicles will drive 50 miles with the following speed/time profile:
  - 20 miles at average 20 mph with five stops per lap
  - 30 miles at an average speed of 50 mph with one stop every five laps
- **On-Road Criteria Emissions (Section 14.6)**  
For the Shakedown Stage, this event is for informational purposes only and will not count toward a vehicle's emissions results in subsequent Stages. Vehicles will tow the portable emissions equipment to measure their criteria emissions. Vehicles will drive on the road-course for 7 miles at an average speed of 20 mph with a total of 17 stops. Vehicles start fully warmed up, and PHEVs must be in charge sustaining mode.

## **15.2 Knockout Stage**

The Knockout Stage is the first on-track stage in which performance determines whether a vehicle continues on in the Competition to the Finals Stage to compete for the Grand Prize. Vehicles must be registered by 6:00 PM on Sunday, June 20, 2010. Vehicles must complete all inspection and all specified test events prior to the end of the Stage. Furthermore, Technical Inspection will be closed at 11:00 AM on Wednesday, June 23, 2010, with no additional opportunity for re-inspection after that point. Teams that fail inspection will be eliminated from the Competition. Teams should review Section 8.3 to determine what modifications are allowed after this stage.

The events of the Knockout Stage, listed below, have been divided into 2 categories – Elimination Events and Consumer Acceptance Events. Elimination Events are exactly that; failure to pass any one or all of these events will result in the permanent elimination of the vehicle from the Competition and forfeiture of the vehicle's eligibility to win the Grand Prize. Consumer Acceptance Tests, on the other hand, will not result in elimination from the Competition unless a hazard that prevents safe operation of the vehicle is encountered. Remember, Competition officials reserve the right to disqualify and/or eliminate a vehicle for safety reasons at any time.

Elimination Events include Technical Inspection, the three major elements of the Competition – Efficiency, Range and Emissions. Elimination Events also include three critical dynamic safety tests: 0-60 mph acceleration, 60-0 mph braking, and the emergency double lane change maneuver, also known as the avoidance maneuver.

Failure to meet the requirements of these Elimination Events as stipulated will result in immediate and permanent elimination from the Competition.

The Consumer Acceptance Events listed below are recognized as necessary capabilities in a production vehicle. The Competition organizers recognize that the latter stages of vehicle development are often used to fine tune these performance attributes. However, because of their importance to the public in their overall purchase consideration, it is necessary to highlight these

tests in the Competition and to publicly report the results of these tests. These events do not warrant elimination at this stage of development and failure to meet the requirements as stipulated will not result in elimination from the Competition. Participation in these events, however, is mandatory.

### **Elimination Events:**

- Technical Inspection and data acquisition verification  
Vehicles must pass Technical Inspection to participate in on-track testing.
  - Each vehicle will be assigned an appointed time in the Inspection garage
  - Vehicles with internal combustion engines only will be given a three-hour time slot for their initial appointment
  - Vehicles with high voltage will be given a four-hour time slot for their initial appointment
  - Vehicles failing inspection on the first pass will be allowed to go back to their garage and correct any deficiencies before returning for re-inspection. The time limit for re-inspection is one hour. All vehicles must pass inspection on either their first attempt or in one re-inspection.
    - Vehicles inspected on Monday, June 21, 2010 must complete their re-inspection no later than 8:00 PM on Tuesday, June 22, 2010.
    - Vehicles inspected on Tuesday, June 21, 2010 must complete their re-inspection no later than 11:00 AM on Wednesday, June 23, 2010
  
- On-Road Range Event (Section 14.3)  
With no refueling or recharging allowed during the entirety of the event (start to finish), vehicles must meet the following additional requirements to continue on to the Finals Stage:
  - Maintain an average lap speed of 55 mph
  - Vehicles will stop every 10 miles
  - Alternative Class must complete 68 miles
  - Mainstream Class must complete 134 miles
  - Teams are reminded this is not a “speed wins” event. Vehicles must run at the prescribed speed for this to be a valid test. Failure to follow the prescribed speed may invalidate the test and result in the elimination of the vehicle from the Competition.
  
- On-Road Fuel Economy Event (Sections 14.4 and 14.5)  
All vehicles must achieve at least 67 MPGe and less than or equal to 300g/mile CO<sub>2</sub> to continue on to the Finals Stage. The event will take place on the track oval and will consist of the following driving cycles:
  - City Driving Cycle
    - Vehicles will drive 16 miles with three stops per mile (six stops per lap) at a minimum average speed of 22 mph
    - Vehicles will be allowed to charge for 3 hours: No refueling allowed.
  - Urban Driving Cycle

- Vehicles will drive 30 miles with two stops per mile (four stops per lap) at a minimum average speed of 29 mph
    - Overnight recharging; No refueling allowed
  - Highway Driving Cycle
    - Vehicles will drive 90 miles with one stop every ten miles (every five laps) at a minimum average speed of 45 mph
    - Refueling and charging
  - Teams are reminded this is not a “speed wins” event. Vehicles must run at the prescribed speed for this to be a valid test. Failure to follow the prescribed speeds may invalidate the test and result in the elimination of the vehicle from the Competition.
- On-Road Criteria Emissions (Section 14.6)
 

Vehicles that consume liquid fuel must achieve EPA Tier II Bin 10 criteria emissions standards to continue on to the Finals Stage. Vehicles that consume liquid fuel will either tow portable emissions equipment or place the portable emissions equipment inside their vehicle, if required, to allow Competition organizers to measure their criteria exhaust emissions. Vehicles will drive on the road-course for 8 miles (4 laps) with 6 stops per lap (a total of 24 stops) on a course that emulates testing procedures.

Teams are allowed three practice laps with emissions measurement instrumentation installed before immediately beginning their official test cycle. Vehicles start fully warmed up and all vehicles using electric drive must be in charge sustaining mode. Before starting the test, vehicles will be driven until they are at normal operating temperature.

Charge depleting hybrids (e.g., plug-in hybrids) must be at normal operating temperatures and be in charge sustaining mode. Competition organizers will give teams a reasonable amount of time to charge-deplete before the start of the test. Affected teams should end EESS charging the night before the test at or near their charge sustaining level. To allow all teams the chance to test, the Competition organizers will set a time limit to complete the event. Consequently, driving time to reach charge sustaining state will be limited; affected teams should plan accordingly. Traction drive system operation will be monitored for compliance with this regulation. Upon post-test analysis, if data from the test vehicles indicates charge-depleting behavior, the test results may be disallowed and the vehicle eliminated from the Competition. For the purposes of this screening, the ending state of charge needs to be within 5% of where it was at the start of this test.

Teams are reminded this is not a “speed wins” event. Vehicles must run at the prescribed speed for this to be a valid test. Failure to follow the prescribed speeds, thus resulting in an invalid test, may result in the elimination of the vehicle from the Competition.

- Dynamic Safety Testing
  - 0-60 mph Linear Acceleration (Section 13.2)
  - 60-0 mph Braking (Section 13.4)

- High Speed Dynamic Stability (Section 13.5.3)

### **Consumer Acceptance Events:**

- Dynamic Safety Testing
  - 40-65 mph Linear Acceleration (Section 13.1)
  - 0.7 g Lateral Acceleration (Section 13.3)

### **15.3 Finals Stage**

The Finals Stage is the last on-track stage in which performance determines whether a vehicle continues to the Validation Stage to compete for the Grand Prize. Vehicles must be registered by 6:00 PM on Sunday, July 18, 2010. Vehicles must complete all of the inspection and test events prior to the end of the Stage. Furthermore, Technical Inspection will be closed at 11:00 AM on Wednesday, July 21, 2010. Teams should review Section 8.3 to determine what modifications are allowed after this stage.

The following events will be held during the Finals Stage; teams must successfully complete these events and meet the performance thresholds to continue to in the Competition:

- Technical Inspection and data acquisition verification  
Vehicles must pass Technical Inspection to participate in on-track testing.
- The following Dynamic Safety Testing events listed below:
  - 0-60 mph Linear Acceleration (Section 13.2)
  - 60-0 mph Braking (Section 13.4)
  - High Speed Dynamic Stability (Section 13.5.3)
- Range Test – vehicles must meet the minimums as described in the Competition Guidelines in order to continue in the Progressive Insurance Automotive X PRIZE
  - Alternative and Mainstream Classes – 100 miles continuous lapping (50 laps) with 1 stop every 10 mi (5 laps). Average speed of 55 mph; no re-fueling or re-charging.
  - Mainstream Class – an additional 100 miles continuous lapping (50 laps) for a total of 200 miles with 1 stop every 10 mi (5 laps). Average speed of 55 mph; no re-fueling or re-charging.
- On-Road Fuel Economy Event – vehicles must achieve at least 100 MPGe in this test in order to continue in the Progressive Insurance Automotive X PRIZE. All sources of energy will be combined to determine MPGe over this 136 mile test.
  - City Efficiency Testing
    - 16 miles in length with 3 stops per mile at an average speed of 22 mph
    - Recharging (three hour maximum) but no refueling
  - Urban Efficiency Testing

- 30 miles in length with 2 stops per mile at an average speed of 29 mph
    - Overnight recharging but no refueling
  - Highway Efficiency Testing
    - 90 miles in length with 1 stop every 10 mi (5 laps) with an average speed of 45 mph
    - Refuel only at the completion of this test and recharge overnight
- Combined Performance and Efficiency Test -- In order to be eligible for this event, vehicles must have successfully completed the Range Test and demonstrated a minimum of 100 MPGe on the Efficiency test. All sources of energy will be combined to determine MPGe over the duration of this test. This is a timed event. To score well, a comprehensive knowledge of your vehicle, strategy, and driving skills will be required.
  - Elapsed times will be recorded and used to determine Grand Prize winners if a vehicle qualifies to continue to the Validation Stage (and meets all other performance and emissions requirements)
  - Distance for Alternative class: 100 miles with one stop every 10 miles (5 laps)
  - Distance for Mainstream class: 200 miles with one stop every 10 miles (5 laps)
  - Refuel and recharge only at the completion of the test
  - Maximum speed of 70 mph and a minimum speed of 45 mph
    - A 6 minute and 40 second penalty for Alternative Class vehicles and 13 minute 20 second penalty for Mainstream Class vehicles (5% of maximum time) will be applied for every instance of a vehicle exceeding 70 mph or going slower than 45 mph. If such instance of exceeding 70 mph or going slower than 45 mph lasts longer than 10 seconds, the penalty will be repeated for each consecutive 5 second period of violation. (For example, a period of exceeding 70 mph for 20 consecutive seconds would receive 3 times the penalty time – one for exceeding initially (and up to 10 seconds) and two for the additional increments of 5 seconds more than 10.
  - Minimum fuel economy equal to at least 100 MPGe
    - A 1 minute and 20 second penalty for Alternative Class and a 2 minute and 40 second penalty for Mainstream Class will be applied for every MPGe below 100 (1% of maximum time). ASTM rounding rules will apply to the calculation of MPGe and awarding of penalties.

#### **15.4 Coast Down Testing**

The vehicles that pass all of the requirements in the Finals Stage will continue on to the Coast Down Testing Event. In preparation for dynamometer testing, a vehicle's aerodynamic drag and rolling resistance must be measured in order to accurately set the road load for the dynamometer testing in the Validation Stage. Vehicles will be impounded by Competition organizers, will remain in the possession of the X PRIZE Foundation after the end of the Finals Stage until the

end of the Validation Stage, and no vehicle modifications will be allowed during this period. No computers may be attached to the vehicles for the remainder of the Competition events; data collection must be accomplished only through the Progressive Insurance Automotive X PRIZE Data Acquisition System (DAS).

The competition fuel tanks, if applicable, will be drained and filled with emissions certification fuel. The vehicles will be instrumented and a professional test driver will accelerate the vehicle to 80 mph or the vehicle's top speed on a level, straight road and then place the vehicle in neutral gear. Data will be taken as the vehicle coasts to a stop. The process will be repeated going the other direction and the results averaged.

If the vehicle does not have a neutral position, the tests will be run in the normal drive position. The coast down results of vehicle that do not have a neutral gear may be adjusted on the dynamometer to compensate for added inertia or other unique vehicle characteristics in order to have the most accurate test results.

Since coast down testing can only take place a few hours a day when temperatures are moderate and the wind is below a certain speed, this stage could take up to a week to conduct. Teams must be in attendance when their vehicles are being tested but will be allowed to leave upon completion of testing of their vehicles. Coast Down testing is not open to the public. Vehicles that are unable to complete the Coast Down Testing Event may not continue in the Competition and will not be eligible for the Grand Prize.

## **15.5 Validation Stage**

### **15.5.1 Emissions Requirements**

Vehicles are required to achieve the following requirements while tested on a chassis dynamometer.

#### **Mainstream Class**

- Gradeability—Dynamometer simulated 4% grade for 30 minutes
- Range—200 miles range extrapolated from vehicle energy consumption over a combined urban and highway cycles
- Criteria Emissions (where applicable)—US EPA Tier II, Bin 8 over a cold start Federal Test Procedure
- Greenhouse Gas Emissions—200 g CO<sub>2</sub>/mi lifecycle emissions over 200 miles of combined urban and highway cycles
- Fuel Economy—100 MPGe over a combination of federal urban and highway certification cycles

#### **Alternative Class**

- Gradeability—Dynamometer simulated 4% grade for 15 minutes
- Range—100 miles range extrapolated from vehicle energy consumption over a combined urban and highway cycles
- Criteria Emissions (where applicable)—US EPA Tier II, Bin 8 over a cold start Federal Test Procedure

- Greenhouse Gas Emissions—200 g CO<sub>2</sub>/mi lifecycle emissions over 100 miles of combined urban and highway cycles
- Fuel Economy—100 MPGe over 100 miles over a combination of federal urban and highway certification cycles

Vehicles must meet the US EPA Tier II, Bin 8 standard for all criteria pollutants, including Non-methane organic gases (NMOG) or non-methane hydrocarbons (NMHC), CO, NO<sub>x</sub>, and particulate matter (PM). The WTW GHG emissions will be calculated using the same procedure as discussed in Section 14.5.

### 15.5.2 General Dynamometer Requirements

During the Validation Stage, each competing vehicle will be tested under controlled conditions on a state-of-the-art chassis dynamometer. The emissions laboratories use 48 inch dynamometer rolls and sophisticated and sensitive emissions and energy consumption measurement systems.

Teams are required to be in attendance when their competing vehicle is being tested but can depart as soon as testing of their vehicles is complete. No more than two team members will be permitted in the dynamometer control room during testing and mounting or dismounting of the vehicles. No team members will be allowed in the test cell area during testing. Other team members are allowed on site but must remain outside of the test area.

Each team will be afforded two chances at dynamometer testing for each vehicle to allow teams the opportunity to address a mechanical or electrical problem with the vehicle should one occur during testing. Failure to meet the required standard is not reason for re-test, and all re-testing must be completed within the testing schedule. Safety rules of the dynamometer test facility state that no team member will be allowed to perform any repair work on site. To perform any repair work, vehicle must be taken off-site and will be accompanied by a Competition official at all times. If the vehicle cannot complete all the test cycles with two tries it will be excluded from this stage and ineligible to win the Grand Prize.

Team members will not be allowed to drive their vehicles on the dynamometer; professional test drivers will be used for this testing. Vehicles must meet the drivability requirements listed in Section 9.7.1. Any unusual vehicle operating instructions must be clearly written down in a form that the dynamometer test drivers can understand and implement during the tests. It is highly encouraged that all aspects of vehicle powertrain control and operation be automatic so that special driver intervention will not be required.

Note that chassis dynamometer testing is very stressful on vehicles due to limited air flow through heat exchangers. Many advanced technology vehicles do not have adequate cooling of primary and secondary subsystems to successfully complete this testing. Teams should make sure to provide sufficient cooling for all drivetrain components and all electronics before coast down and dynamometer testing.

The vehicles will remain impounded during the Validation Stage to discourage any changes to the vehicles. Prior to the Coast Down Testing the Competition fuel tank will be drained and

filled with emissions certification fuel. Vehicles must use the official emissions certification fuel for all testing on the dynamometer.

In some cases, where applicable, the Engine-on Mode Switch may need to be used for the emissions testing portion of the dynamometer test. Furthermore, for vehicles equipped with traction control or ABS, a “dynamometer mode” switch will be required that disables these electronic control features as they would adversely affect the result. The organizers reserve the right to test the emissions of a vehicle in its worst case scenario.

The details of the test procedure for each type of vehicle are discussed in a subsequent document. However, in general, each vehicle will be placed on the rolls for the Gradeability Test and emissions testing on the Urban Dynamometer Driving Schedule (UDDS or city cycle) and the Highway Fuel Economy Test Schedule (HWFET or highway cycle). Vehicles will be put through a conditioning cycle and then undergo a 12 hour soak. Vehicles with any on board sources of emissions will get a second 12 hour soak period with no refueling or recharging and will then return to the dynamometer for cold start emissions testing utilizing an FTP 75 drive cycle.

### **15.6 Grand Prize Eligibility**

Vehicles must successfully pass Technical Inspection and Dynamic Safety Testing, and meet the on-road and dynamometer performance requirements during the Finals and Validation Stages. Those that do are eligible for the Progressive Insurance Automotive X PRIZE Grand Prize. To be eligible for the Grand Prize, Teams must meet the following energy efficiency criterion:

$$\frac{(\text{MPGe On_Road}) + (\text{MPGe Dynamometer})}{2} \geq 100$$

In the event there are multiple vehicles that are able to achieve this criteria, the Mainstream, Alternative (side-by-side) and Alternative (tandem) vehicles with the lowest elapsed time from the Combined Performance and Efficiency Test in the Finals Stage will be the winners of the Grand Prize for their classes. No overall winner amongst the Classes will be determined.