

Product Development Basics and Technical Deliverables

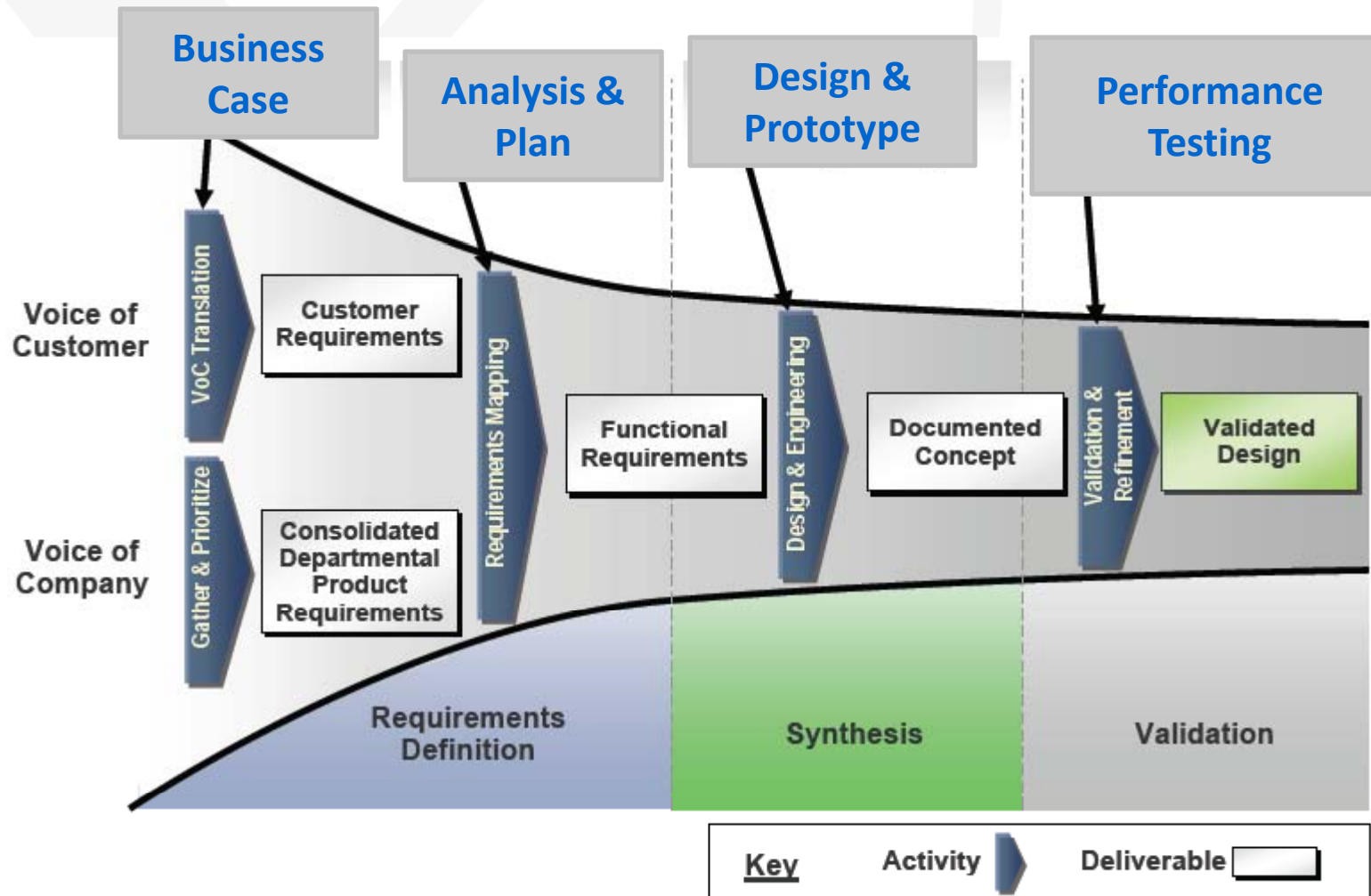
P.T. Jones, Sr. Advisor, Competition Operations

Development Overview

All OEMs use a Vehicle Development Process

- A brief look at the stages of the Vehicle Development Process
- Where the deliverables fit into the process
- What are the deliverables
- Why does the competition require these deliverables
- The Federal Motor Vehicle Safety Standards (FMVSS)
- Considerations for your development

Prototype is only a part of Development

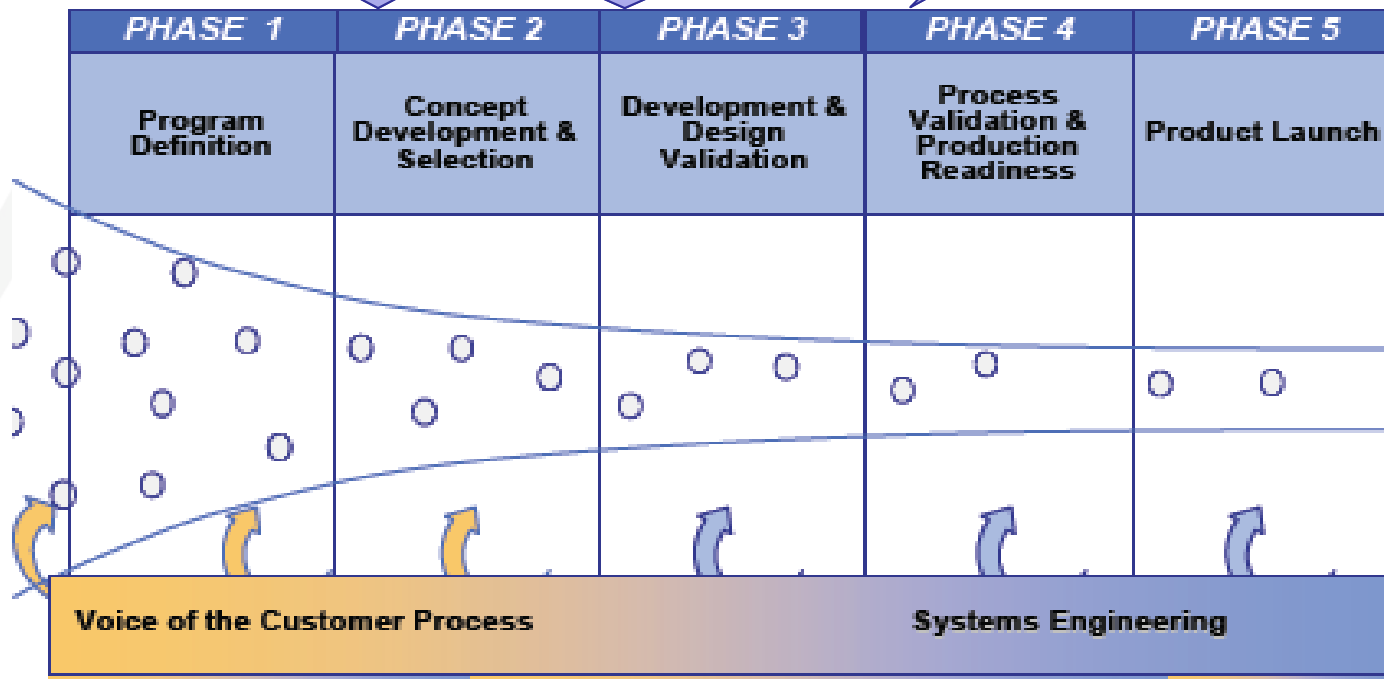


Competition Deliverables are Steps in Vehicle Development

Structure & safety req.
drive design

Component and bench test before prototype

Prototype test –
“Drivers Wanted”



Deliverables/Milestones

- Vehicle design & definition
 - Defining your vehicle and selecting components
 - Analysis of design to meet FMVSS ensures fair evaluation of designs/technology
- Safety & HV Systems development/build
 - Understanding and adherence to goals
 - Progress and use of competition-provided support
- Basic vehicle performance status
 - Do we ship it?

Competition Requirements (Safety Standards)

Establishes vehicle design requirements and considerations:

- Vehicle structure to ensure crashworthiness
- Energy storage system and high voltage system requirements
- Fuel system integrity and temporary removable tank integration
- Passenger considerations for safety – including closures
- Standard on-road operating requirements (lights, mirrors, HVAC)
- Braking and basic vehicle handling safety maneuvers
- Basic performance levels
- Features and expectations

FMVSS? There should be an app for that!

FMVSS 101 - Controls and displays. FMVSS 102 - Transmission shift lever sequence, starter interlock, and transmission braking effect. FMVSS 103 - Windshield defrosting and defogging systems. 30 minutes to clear area in chamber FMVSS 104 - Windshield wiping and washing systems. FMVSS 105 - Hydraulic and electric brake systems. FMVSS 106 - Brake hoses. FMVSS 108 - Lamps, reflective devices, and associated equipment. FMVSS 109 - New pneumatic tires. FMVSS 110 - Tire selection and rims for motor vehicles with a GVWR of 4,536 kilograms (10,000 pounds) or less. FMVSS 111 - Rearview mirrors. FMVSS 113 - Hood latch system. FMVSS 114 - Theft protection. FMVSS 116 - Motor vehicle brake fluids. FMVSS 117 - Retreaded pneumatic tires. FMVSS 118 - Power-operated window, partition, and roof panel systems. FMVSS 119 - New pneumatic tires for vehicles other than passenger cars. FMVSS 120 - Tire selection and rims for motor vehicles with a GVWR of more than 4,536 kilograms (10,000 pounds). FMVSS 121 - Air brake systems. FMVSS 122 - Motorcycle brake systems. FMVSS 123 - Motorcycle controls and displays. FMVSS 124 - Accelerator control systems. FMVSS 125 - Warning devices. FMVSS 129 - New non-pneumatic tires for passenger cars. FMVSS 131 - School bus pedestrian safety devices. FMVSS 135 - Light vehicle brake systems. FMVSS 138 - Tire pressure monitoring systems. FMVSS 139 - New pneumatic radial tires for light vehicles. FMVSS 202 - Head restraints - Applicable at the manufacturers option until September 1, 2008. FMVSS 202a - Head restraints - Mandatory applicability begins on September 1, 2008. FMVSS 203 - Impact protection for the driver from the steering control system. FMVSS 204 - Steering control rearward displacement. FMVSS 205(a) - Glazing equipment manufactured before September 1, 2006 and glazing materials used in vehicles manufactured before November 1, 2006. FMVSS 206 - Door locks and door retention components. FMVSS 207 - Seating systems. FMVSS 208a - Optional test procedures for vehicles manufactured between January 27, 2004 and August 31, 2004. FMVSS 213 - Child restraint systems. FMVSS 302 - Flammability of interior materials. FMVSS 303 - Fuel system integrity of compressed natural gas vehicles. FMVSS 304 - Compressed natural gas fuel container integrity. FMVSS 305 - Electric-powered vehicles: electrolyte spillage and electrical shock protection. FMVSS 401 - Internal trunk release. FMVSS 403 - Platform lift systems for motor vehicles. FMVSS 404 - Platform lift installations in motor vehicles. FMVSS 219 - Windshield zone intrusion. FMVSS 223 - Rear impact guards. FMVSS 224 - Rear impact protection.

FMVSS “Derived” Requirements

Minimum safety standards and competition awareness

“A list of those FMVSS and other safety-related aspects of the vehicle design that will not be implemented in the race vehicle, and an estimate of the amount of **additional weight** that would likely result from full implementation and compliance“

Objectives:

- All development, events and displays are conducted without incident
- Understanding of safety and North American regulations
- Being good competitors and ambassadors of the competition
- Safety expectations of the North American customer are a priority

FMVSS Breakdown

All vehicles were not designed for this competition

- Allowances made for vehicles that met, or were designed to meet, the fuel efficiency and emissions requirements

Nine FMVSS aid in a balanced competition:

- FMVSS 201 – Occupant Protection on Interior Impact
- FMVSS 205 – Glazing Materials
- FMVSS 208 – Occupant Crash Protection
- FMVSS 209 – Seat Belt Assemblies
- FMVSS 210 – Seat Belt Anchorage
- FMVSS 212 – Windshield Mounting
- FMVSS 214 – Side Impact Protection
- FMVSS 216 – Roof Crush Resistance
- FMVSS 301 – Fuel System Integrity

Basic “On-highway inspection” from a local authority does not qualify

Development Summary

Required milestones for advancement in competition:

- A brief part of Vehicle Development Process
- Aid in establishing understanding and adherence to goals
- All competitors are “X PRIZE Partners”
- Ongoing development of the Deliverables is an attempt to keep them relevant
- The Technical Team is not a design resource
- The number of vehicles qualified today will likely be greater than the number of vehicles approved to run at competition

First Technical Deliverable

Don Taylor, Sr. Advisor, Competition Rules

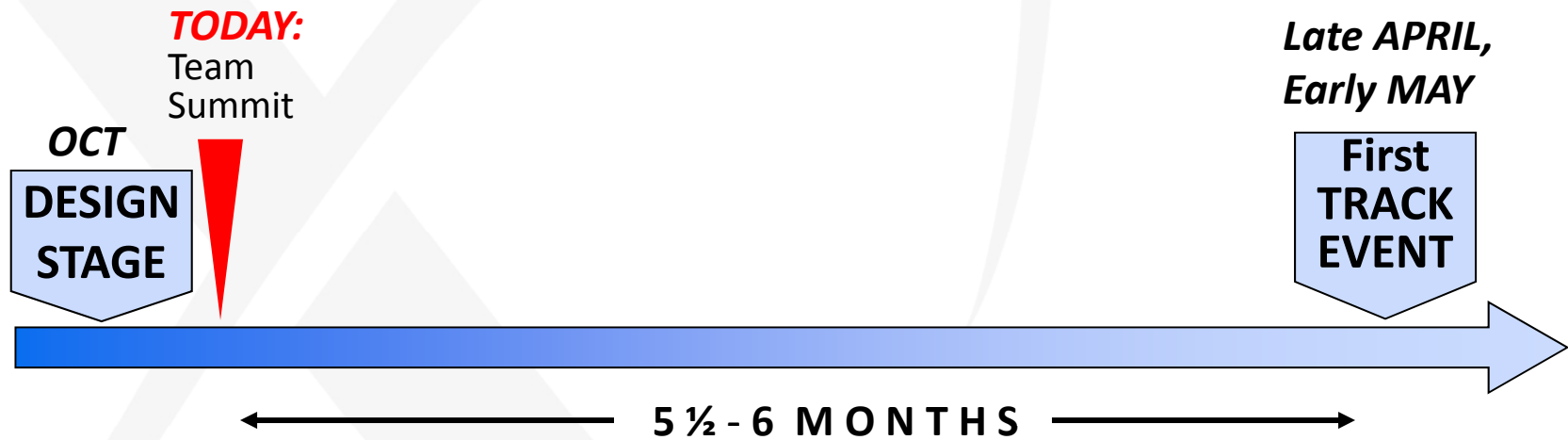
Technical Deliverables

Pre-Competition Technical Progress Reports
from Teams

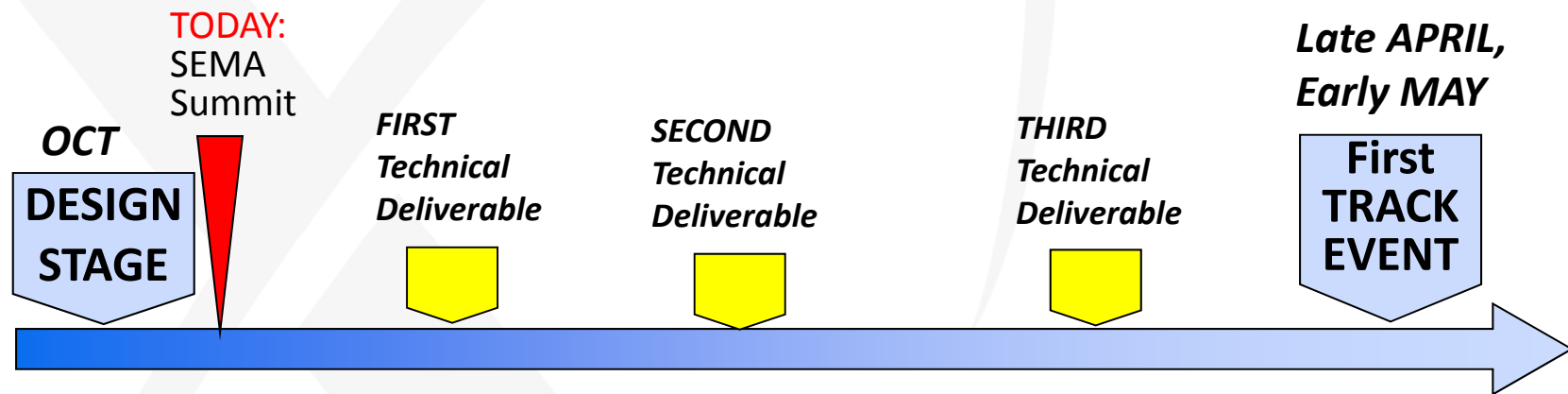
Objectives:

- Safety
- Competition readiness
- Compliance with competition goals

Technical Deliverables



Technical Deliverables



Pre-Race Technical Progress Reports from Teams

- **First Technical Deliverable:** Due December 15, 2009
- **Second Technical Deliverable:** Due January 30, 2010
- **Third Technical Deliverable:** Due March 30, 2010

Technical Deliverables

- Items to be addressed in the reports will include the following:
 - High Voltage Energy Storage Systems / other ESS
 - Fuel System
 - Powertrain and Emissions
 - Body and Chassis
 - Current Performance, Measurements & Specs
- Qualified Teams that do not comply with Technical Deliverable progress report deadlines, or do not address items as directed by the organizers, may face disqualification from the Progressive Insurance Automotive X PRIZE

First Deliverable

- First Technical Deliverable details sent out on October 23
- Included a template to fill-out
- Instructions:
 - *A separate template must be completed for each qualified vehicle*
 - *If a section does not apply to your vehicle, do not leave it blank, instead insert “DNA”*
 - *The submission of all requested photos, charts, drawings, graphs, tables, manufacturer’s sheets, etc.:*
 - *Must all be in PDF format*
 - *Must all be included in one PDF format file*
 - *Each picture, etc. must be clearly identified or titled, with Team, Subject and Tech Deliverable Section identifier (i.e. TD1-1-19a)*

1. Energy Storage and High Voltage System Specification

What documentation is being asked for?

- Status of ESS
- ESS Manufacturer
- Cell Specifications
- Pack Specifications
- ESS Enclosure
- Battery Management System (BMS)
- Charger
- High Voltage Schematics
- Etc.

1. Energy Storage & High Voltage System Specification

What documentation is being asked for?

- ESS specification sheet
- ESS manufacturer provided MSDS
- CAD level technical drawing(s) of ESS showing cell placement within pack, sensor placement, wire routing etc.
- Photo(s) of ESS showing cell placement pack, sensor placement, wire routing etc.
- Technical drawing(s) of ESS showing battery placement and wire routing within vehicle
- Photo(s) of ESS showing battery placement and wire routing within vehicle
- Electrical schematic(s) of ESS showing fuses, contactors, switches, sensors, shunts, etc
- Technical drawing(s) of battery enclosure showing battery placement within vehicle, mounting points, etc.
- Calculations or finite element analysis showing the ESS enclosure can withstand crash safety requirements listed in the Technical Specifications
- Teams must provide a BMS specification sheet either from the manufacturer or their own
- Attach charger specification sheet from the manufacturer to this report
- Attach solar array specification sheet from the manufacturer to this report

2. Fueling System Specifications

Progressive Insurance Automotive X Prize

Section TD1-2

Fueling System Specifications (1)

TD1-2-1 Fuel Type—Mark all fuels the vehicle will use during the competition

Gasoline__ Diesel__ Biodiesel _____% Biodiesel
E85__ CNG__ Other_____

NOTE: Teams must finalize their fuel choice by the Second Technical Deliverable. No changes will be allowed after this date. Teams may use multiple fuels during the competition. However, the vehicle must pass all tests using all fuels, especially the emissions test. Teams not using PIAXP provided fuels are asked to contact that Fueling Director directly to coordinate fueling supplies.

TD1-2-2 Liquid Fuel Tank

Primary Tank

_____ Volume (gal) _____
_____ Dimensions (in) _____
_____ Manufacturer _____
_____ Model # _____

A vehicle's primary tank must be installed throughout the competition, but drained of all fuel and completely disconnected from the fuel system.

PIAXP Competition Tank
Horizontal (approx 13" x 13" x 8.5") Vertical (approx 8.5" x 8.5" x 15") Custom

2. Fueling System Specifications

What documentation is being asked for?

- Primary tank manufacturer specification sheet
- Vehicle schematics or drawings (front, top/bottom, side) showing the fuel system – drawings should show the placement of tank, fueling lines and all other fuel components (filters, pumps, etc.)
- Photograph(s) of competition fuel tank clearly showing mounting brackets, fittings and hoses
- Photograph or video of fuel system
- Fuel MSDS (not required for gasoline, diesel, biodiesel, E85, CNG or hydrogen)
- Pressure and temperature sensor specification sheets (gaseous fuels only)

3. Powertrain Specifications

Powertrain Specifications (v2)

TD1-3-1 Powertrain Type—Mark one appropriate powertrain that best describes the vehicle to be used during the competition

ICE_____ HEV Series_____ HEV Parallel_____ HEV Series/Parallel_____

BEV_____ PHEV Series_____ PHEV Parallel_____

PHEV Series/Parallel_____

Other_____

TD1-3-2 Drive Type_____ 2 Wheel_____ 4 Wheel_____

Other_____

3. Powertrain Specifications

What documentation is being asked for?

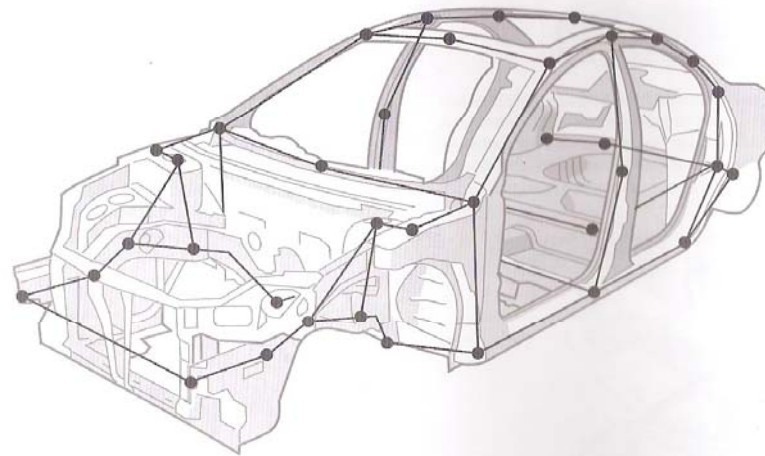
- Original engine specification sheet
- Original transmission specification sheet
- Original motor specification sheet
- Photos of powertrain, including engine, motor and transmission mounted in vehicle
- A technical drawing(s) of the powertrain showing all major components and power flow during different operation conditions
- • Emissions testing or other emissions validation

4. Body and Chassis System Specifications

MODIFIED PRODUCTION VEHICLES

Detailed description of modifications to structure:

Include details regarding how the modifications are expected to maintain or improve structural integrity of the original equipment, especially with regard to changes in weight, placement of major components, and reduction in crush zones. Also include details regarding material selection, structural member sizing, attachment scheme, and load path confirmation.

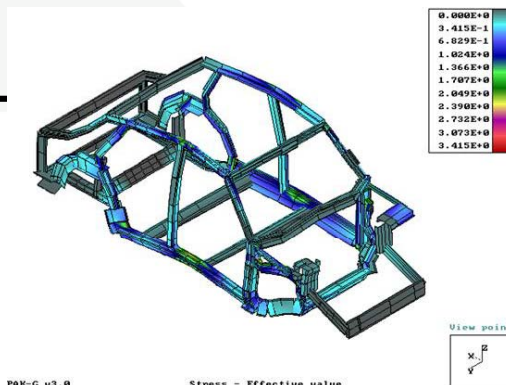


4. Body and Chassis System Specifications

NEW CONSTRUCTION VEHICLES

Detailed description of structure:

Required documentation includes calculations, simulation, Finite Element Analysis, etc. used to make decisions regarding material selection, structural member sizing, attachment scheme, and load path confirmation. Must include pictorial representation of entire structure with notations for sizing, thickness, material, attachment, etc. Pictorial can be CAD screen plot, scanned drawings, photos, etc.



PRK-G v3.0

Stress - Effective value

4. Body and Chassis System Specifications

ALL VEHICLES

Detailed description of plan to meet FMVSS Crashworthiness Requirements:

Reference <http://www.nhtsa.dot.gov/cars/rules/standards/> for details regarding specific requirements. Per the PIAXP Guidelines, compliance with the following is required: FMVSS 201, 205, 208, 209, 210, 212, 214, 216, 301. Include calculations, simulation, Finite Element Analysis, etc. as means to demonstrate how engineering decisions were made in the design of “crush zones” and protection of vehicle occupants per US Federal standards. Of specific concern is verification that fuel systems and occupants will not be in the intrusion zones for front, rear or side impact. Please include a description of any non-structural components that may reside within crash intrusion zones and explain their interaction during a crash event – i.e. contributing to crush resistance or deflect out of the way, etc.

4. Body and Chassis System Specifications

Section Representations (include pictorial showing dimensions, thickness and material for the following cross sections):

Front/motor compartment rail

Rocker/door sill

A-pillar/windshield side member

Roof side rail/door header

Front hinge pillar

B-pillar/lock pillar

Rear compartment rail

Rear roof header/roll hoop

Front of dash cross-car members

Seat back/rear bulkhead (structure behind seats)

Front bumper beam

Rear bumper beam

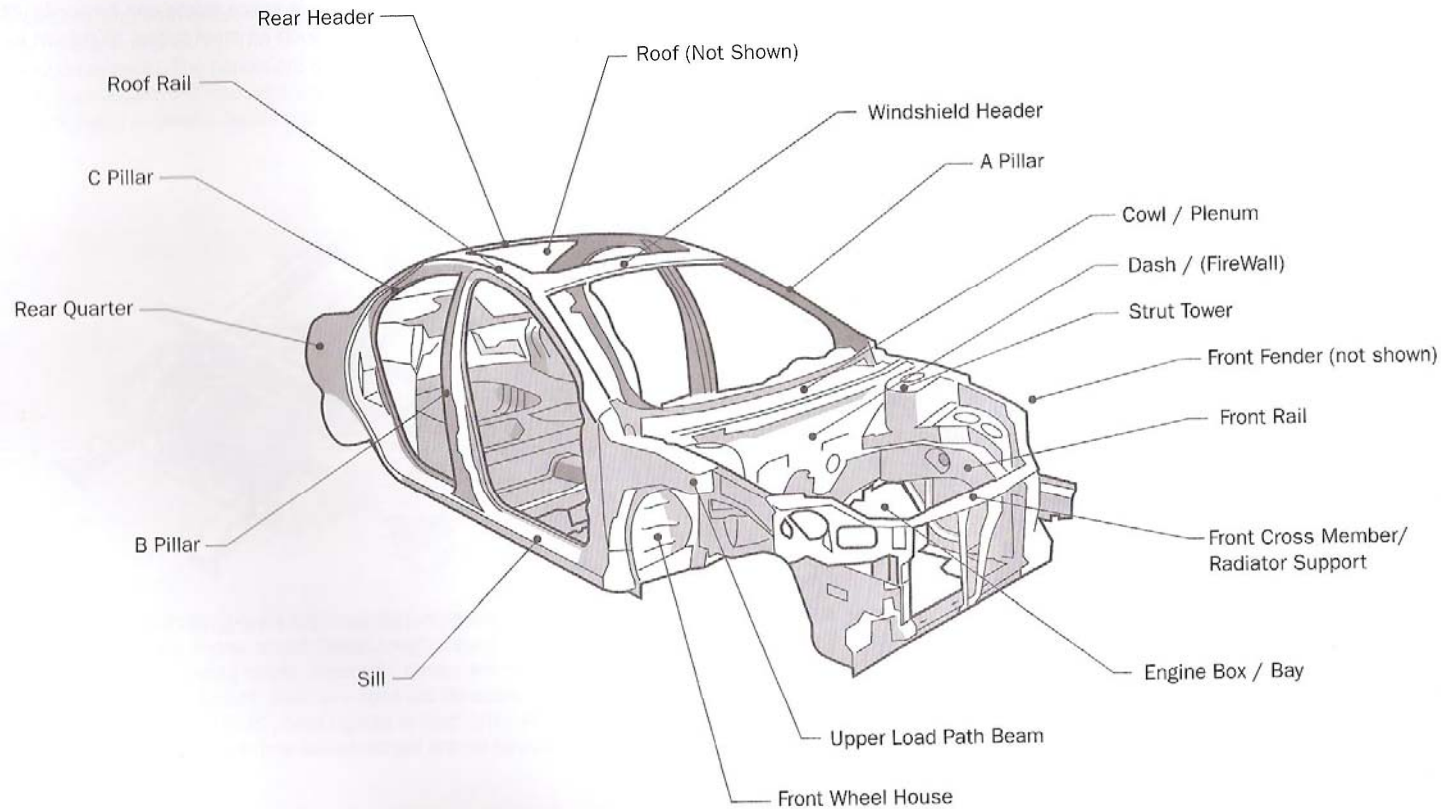
Under-floor longitudinal support

Under-floor cross-car support/seat bars

Door beam(s) and interface to structure

4. Body and Chassis System Specifications

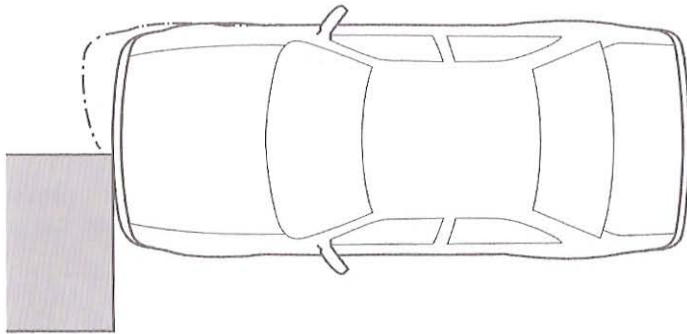
Typical assembly – stamped sheet metal



4. Body and Chassis System Specifications

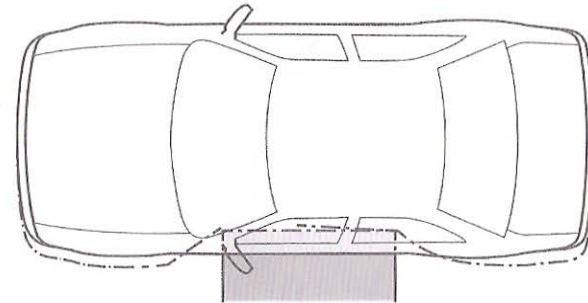
FMVSS Crash Test

Primary interest is frontal and side impact, plus roof crush protection



HIGH SPEED (40mph) OFFSET IMPACT TEST

The most demanding test, affecting the front end and interior design. It ensures the driver and passengers can walk away from a high-speed impact. This test most resembles a typical head-on collision which typically is slightly offset.



SIDE (30mph) IMPACT TEST

This test simulates one vehicle driving into the side of another. It affects the design of the doors, their apertures and the underbody structure.

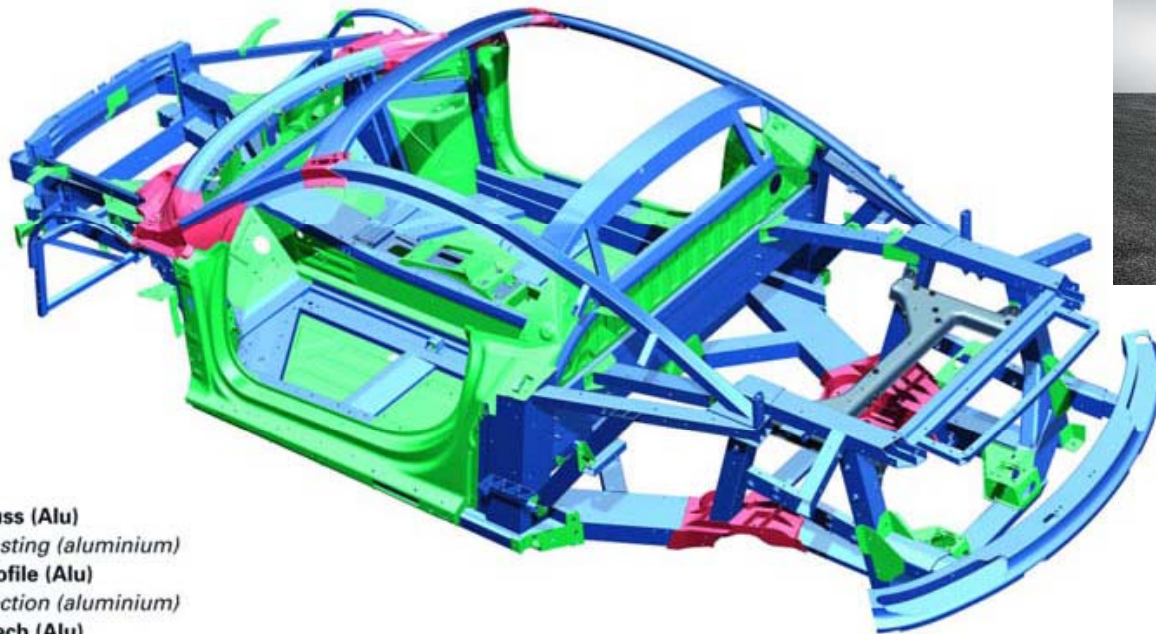
4. Body and Chassis System Specifications

Smart Car FMVSS Compliance



4. Body and Chassis System Specifications

Alternative – extrusions and nodes



- Guss (Alu)**
Casting (aluminium)
- Profile (Alu)**
Section (aluminium)
- Blech (Alu)**
Sheet (aluminium)
- Magnesium**
Magnesium

4. Body and Chassis System Specifications

Alternatives – composite and tube frames



4. Body and Chassis System Specifications

FMVSS Specs of Interest

- FMVSS 201 – Occupant Protection on Interior Impact
- FMVSS 205 – Glazing Materials
- FMVSS 208 – Occupant Crash Protection
- FMVSS 209 – Seat Belt Assemblies
- FMVSS 210 – Seat Belt Anchorage
- FMVSS 212 – Windshield Mounting
- FMVSS 214 – Side Impact Protection
- FMVSS 216 – Roof Crush Resistance
- FMVSS 301 – Fuel System Integrity

4. Body and Chassis System Specifications

ALL VEHICLES

What documentation is being asked for?

- CAD level technical drawing(s) of Chassis Structure showing packaging of structural and non-structural components
- Photos of chassis in current state if construction
- Calculations, simulation results or Finite Element Analysis report regarding structural integrity and crashworthiness

Safety and FMVSS Compliance

Vehicles must be designed so that a production vehicle would likely be able to meet U.S. safety standards

- In some cases, race vehicles may not be equipped to meet all FMVSS standards
 - Analysis must be provided for how vehicle could be made to meet requirements
 - Race vehicles must carry additional weight to compensate for missing equipment
- Safety requirements for the Alternative Class are inspired by those of the Mainstream Class

Second Technical Deliverable

Jody J. Nelson, Sr. Advisor, Energy Storage Technologies

Milestones for the Teams

“In the interest of competition safety, and to facilitate having a maximum number of competitive vehicles, we will require certain pre-Race technical progress reports. Failure to provide the reports may be cause for disqualification.”

Objectives: Second Deliverable (Due January 30, 2010)

- Select Teams requiring pre-event, in-person inspection:
 - Determine if Team can progress to next stage
- HV safety (if applicable)
- Evidence that all major components have been received
- Evidence that each system is operating
- Update the status of previously provided vehicle information

Preview 2nd Deliverable: Pre-event Inspection Criteria

Second Technical Deliverable criteria to determine the necessity of a pre-event inspection and whether a Team is allowed to progress to the next stage:

- **Proper progress and implementation of HV safety items:**
 - ESS containment, hold-downs and attachments
 - Results from ESS thermal management test
 - Evidence of HV isolation from vehicle chassis
 - Evidence of isolation fault detection, EDS, MIS and inertia switch
- **Proper progress of vehicle construction and component integration:**
 - All critical HV electrical components received (photos required)
 - All critical ESS components received (photos required)
 - All critical fuel system components received (photos required)
 - All critical powertrain components received (photos required)
 - All critical emissions components received (photos required)
 - All critical body materials received (photos required)
- **Evidence that the chassis is fully complete** (photos required)
- **Evidence of vehicle operating under its own power** (video required)

Preview 2nd Deliverable: Other Deliverables

Other requirements for the Second Technical Deliverable:

- Fuel type is frozen at the end of the Second Technical Deliverable
- Evidence that powertrain control system exhibits impact on emissions
- Provide the mass of the vehicle and a description on how the mass was determined (estimate based on components or systems is acceptable)
- Evidence vehicle ground clearance meeting or exceeding the 4 inch requirement (photo required)
- The vehicle can be at stand still
- A dynamic test will be required in the Third Technical Deliverable
- Update the status of previously provided vehicle information

Evidence of Not Meeting 2nd Deliverable Criteria

Would pass photos of all critical components, but would fail proving an operating vehicle



Third Technical Deliverable

P.T. Jones, Sr. Advisor, Competition Operations

Milestones for the Teams

“In the interest of competition safety, and to facilitate having a maximum number of competitive vehicles, we will require certain pre-Race technical progress reports. Failure to provide the reports may be cause for disqualification.”

Objectives: Third Deliverable

- Safety systems operation and testing
- Competition readiness – including verification of “on-road” testing
- Emissions compliance
- Awareness of customer expectations
- Update the status of previously provided vehicle information

Vehicle Safety Systems Operation and Testing

The Third Deliverable includes:

- Video reporting of the High Voltage (HV) Safety systems in operation (if applicable)
- Video and data reporting of basic brake and handling testing
- Video reporting of fuel system and HV routing and components
- Video reporting of vehicle “Walk Around” emphasizing required features that are safety related

Competition Readiness

- Establishes a Team's vehicle has been operating as designed and is capable of safe competition driving
- These basic performance tests are precursors to the Shakedown event, a sample of tests that Teams should be performing on their own
- On-road mileage accumulation is a requirement for progression/acceptance into the Shakedown event; documentation of registration or license, notarized mileage
- Video documentation of performance testing

Typical Performance Data

Performance

Accels:

0-60 mph time: _____ sec

45-60 mph time: _____ sec

Braking:

60-0 mph in less than 170 ft
time: _____ sec

25-0 mph max brake effort
time/distance: _____ sec/ft

Ride & Handling:

25 mph "S-Turn" maneuver - time: _____ sec

4 inch Ground clearance obstacle

Video Files

File name: _____

File name: _____

File name: _____

File name: _____

File name: _____

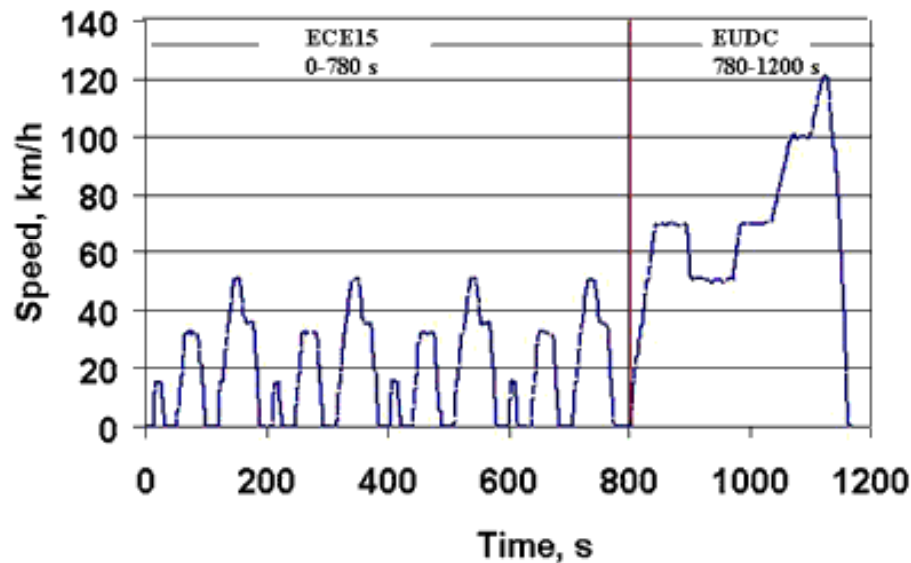
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Practice Safety in All Test and Operational Modes



Basic Emissions Testing

- Emissions testing per competition guidelines
- Establish hybrid or conventional ICE operation
- Driving modes and vehicle PCM tune/calibration
- Coast-down approximations
- Certified testing laboratory results



Awareness of Customer Expectations

- Ergonomic considerations; sizes and egress
- Features, operating without manual control
- Safety considerations for door closures, windows and hoods
- Driving and feature controls and displays
- Intuitive operations of the vehicle
- Passive systems are passive

Vehicle Requirements



Update Status of Previously Supplied Information

- Technical Deliverables are not optional
- Any Tech Team request for additional information must be completed by requested date and should be updated at next deliverable
- Competition organizers reserve the right to inspect any vehicle prior to agreement to ship
- Ongoing development of future Technical Deliverables exist to ensure that expectations are appropriate
- “Qualified Teams” > “Competition Teams”

Summary

Competition-ready means:

- Operating as designed / intended / “Production”
- Safety and competition required equipment
- Validated on road and emissions data
- All vehicle submissions are part of the partnership

“IN IT to WIN IT” begins when we “SHIP IT”