Formula SAE Design Judging Score Sheet – EV

School Name: ___________________________________ Car #: _____

Paddock #: _____ Contact Name/Cell #: ___________________________

Summary of Design Judge Scoring Areas

Overall Vehicle	**/25**
Vehicle Dynamics	**/25**
Aerodynamics	**/15**
Powertrain	**/30**
Chassis	**/30**
Driver Interface	**/15**
Low Voltage/Data Acquisition	**/10**
Total	**/150**

About your score…
This Design Judging Score Sheet totals 150pts. Your official Design Event score will differ from the score on this page. **Do not panic!** This scoresheet is a tool.

The score listed on this sheet reflects your assigned judges' assessments relative to other teams in your queue. Despite attempts to ensure consistency, judge scores always vary somewhat from queue to queue. Hence, the chief judges compare notes across queues, working to normalize scores and minimize bias via multi-tier rankings of teams. The official Design Event score is the result of this process.

Design Judging Score Sheets with written judges' comments shall be distributed to the teams but are not shared with other teams. Teams should expect to receive written comments along with verbal feedback from their First Round Design Judges.

About this scoresheet...
This scoresheet divides the vehicle into numerous subsystems. For each subsystem, the topics listed on the following pages will be of interest to the Design Judges. NOTE: The topics listed are not all-inclusive and should **not** be treated as a checklist by students or judges.

As always, **Design, Build, Validation/Refinement and Understanding** are essential aspects of the Design Event. For any topic, students should be ready to discuss their decision-making process, goals, the underlying theory, modeling choices, options considered, constraints, assumptions, component/material selection, manufacturing, testing, validation/correlation and any successes/failures encountered.

Remember, judges are evaluating your **knowledge and understanding**, along with your vehicle.

More on the Design Process…
Design Judges are interested in your implementation/execution of the full design process as applied to every aspect of your car. The process begins with underlying theory and proceeds through several steps, culminating in your understanding. Reflective of this, Design Judges evaluate the teams and assess points per the following breakdown:

- **Design (~25%):** Were different design options considered? What criteria was used to make design decisions? How much is a new design, an evolution or a carryover? How well do students understand the underlying science/engineering? What pre-build analyses were performed? Is this an integrated design, or a series of independent sub-systems?

- **Build (~25%):** Does the car reflect the design work? Does it reflect the design documents? If not, why not? What special manufacturing considerations were encountered? Were the build methods and processes appropriate and well-executed?

- **Refinement/Validation (~25%):** How thorough and objective was the team's testing? Was a test plan developed and executed? Were discrepancies between predicted and tested results documented and acted upon to improve final build? How has the team developed their car through testing?

- **Understanding (~25%):** Do the students at competition understand their car? Are they intimate with the design and the engineering fundamentals it attempts to exploit? What has the team learned from testing their car? How would the team improve their car for a future competition?

More on Sub-System Categories…
This scoresheet divides the vehicle into seven scoring categories. These overlap, as do the expertise of individual Design Judges and the focus areas of individual students. During First Round Judging, Design Judges and students alike work together to ensure all areas of the vehicle are discussed. Approximately six Design Judges will be evaluating your team in First Round Judging.

The Overall Vehicle category necessarily spans the other six sub-systems. Teams should be prepared to discuss top level design and management topics. The remaining six sub-systems also have some overlap, as no sub-system exists in a vacuum. Design Judges will be looking for interactions between various subsystems while focusing on each specific category.

Final thoughts…
Be sure to read the Design Event section of the official Rules and the supplemental Design Event Description found on the Series Resources page of fsaeonline.com.

Keep in mind that Design Judges are not picking the fastest car, nor do they presume that certain design elements are the best way to win the competition. Instead, Design Judges want to know your top-level goals. They will then evaluate your subsequent decisions, engineering and implementation in that context. The knowledge/understanding demonstrated by students is paramount to high Design Event scores.

The next few pages provide a survey of topics within each subsystem. Again, these lists are not all-inclusive and should not be treated as a checklist.

Overall Vehicle

Vehicle Fundamentals
• Driver, engine and other big parts well packaged • Suspension points and linkages connect contact patches through stiff structure • Straight line load paths that lead to low mass and disciplined mass management • Aero (if equipped) is designed and well-integrated into vehicle • Integration and functional combination
Goals
• Competition/design strategy: Demonstrate depth of understanding of the racecar engineering domain, competition rules and competition point structure • Vehicle architecture selection: Are these questions answered for multiple vehicle concepts? • Synthesis of subsystems: Does the vehicle design work as a whole? • Team constraints: Impacts on approach, impact minimization and work arounds • Correlate competition points to vehicle performance • Correlate vehicle performance to vehicle characteristics • Were multiple competition strategies and vehicle concepts considered? • Overall vehicle goals: Consistent with competition point allocation, vehicle performance, vehicle characteristics, and stated team objectives and constraints?
Concept Definition & Tradeoff Studies
• System specifications (performance & characteristics) for selected concept • Demonstration that concept can achieve vehicle goals • Vehicle Definition: Mass, center of gravity (CG) location, aero • Tire selection & performance • Powertrain sizing: Targets, Fit to Vehicle Goals • Aerodynamics: Center of pressure (CP) static and dynamic • Front/rear lateral load transfer definition, brake balance, unsprung mass • Use of Integrated sims to resolve these trades
Project Management & Execution
• Schedule & Schedule Rigor • Team Organization: Structure and Effectiveness • Systems Engineering • Resource Management: Budget, Facilities, Team Size • Knowledge Management: Training and documentation • Top vehicle level design criteria (safety factors, etc.)
Vehicle Execution
• Consistent application of engineering fundamentals: load-paths, material use, etc. • Build quality: Welds, bodywork, machining, composites, paint • Refinement and overall tidiness • Aesthetics
Tools, Simulation & Validation
• Clarity, depth, and utility of analytical, computational, and experimental processes that assure accuracy of correlations to competition points, vehicle performance and vehicle characteristics • Demonstration that Overall Vehicle Concept evaluations are accurate, pre- and post-build

Vehicle Dynamics

Overall
• Vehicle dynamics concepts: F=ma, masses, inertias, balance, tire friction coefficient
• Synthesis of CG location, tire selection, lateral load transfer distribution and aero balance
• Wheelbase, track width, chassis stiffness
• Effect of brakes, drivetrain, torque-vectoring, etc. on vehicle response
• Performance/handling/balance metrics
• Use/analysis of collected data (stopwatch, accelerometers, wheel speeds, etc.)
• Full-vehicle calculations/modeling & correlation
Tires
• Selection: Size, manufacturer, compound
• Static settings: Toe, inclination, pressure
• Dynamic operating conditions: Loads, slip angles, inclination angles, pressures, temperatures
• In-plane forces & moments including stiffnesses & peaks
• Vertical rates & damping
• Tire dynamic responses: Load sensitivity, relaxation length, temperatures
• Wheel selection: Width, offset, material
• Tire data, calculations/modeling & correlation
Suspension & Steering (Non-structural)
• Vehicle modes: Heave, pitch, roll & warp
• Tire control: Load, inclination, toe
• Kinematics (camber gain, etc.)
• Anti-geometry
• Compliances
• Springs and Dampers: Rates, frequencies & damping ratios (sprung and unsprung masses)
• Motion ratios
• Steering: Forces, kinematics (Ackermann, ride-steer, etc.), dynamic toe
• Adjustability: Functionality, ease of use, tuning process, relationships to vehicle performance
• Suspension data, calculations/modeling & correlation

Aerodynamics

Aero Design & Architecture
• Downforce, Drag and Center of Pressure (CP) targets • Selection and sizing of aerodynamic components • Downforce vs. drag vs. mass tradeoff • Aerodynamic coefficients (C_D, C_L, etc.), reference area (A), and $F = \frac{1}{2}\rho v^2 CA$ • Design elements: Front/rear/side wings, undertray, vortex generators, Gurney flaps, multi-element wings, etc. • Component interaction: e.g. front wing effect on rear wing, connection of rear wing and undertray, driver's head and roll hoop • Angle of attack, chord length, camber, thickness; standard/tabulated airfoils, e.g., NACA • Aero Maps: Downforce, drag, side force, moments; effects of ride heights, yaw angle, yaw rate, roll angle, steering • Center of Pressure location, migration, and platform sensitivity; effect on vehicle balance, understeer/oversteer, relationship with CG • Flow separation/stall, energized flow, slot gaps, boundary layers • Ground effect, aeroelasticity, flutter, and active aero
Cooling
• Heat transfer vs. velocity, mass airflow, heat transfer coefficients • Size and placement of radiators, fans, ducting, duct area ratios, velocity vs. pressure • Impact on aerodynamics, drag, and downforce; cooling vs. aero tradeoff
Computational Fluid Dynamics (CFD)
• Modeling / simulation tools used • Solution Methods: Direct/DNS, Reynolds Averaged, etc. • Turbulence models • Accuracy/convergence • Design case selection: Ride height, yaw, roll, pitch, steering, etc.
Testing and Instrumentation
• Wind Tunnel Testing: Reynolds scaling, rolling road, rotating wheels, blockage fraction, force and moment measurements, boundary layer control • Track testing, agreement/disagreement with predictions, driver feedback, and lessons learned • Sensors: Pitot tubes, pressure taps, suspension linear potentiometers, load cells, air density, weather stations, ground speed (GPS, wheel speed), slope measurement (accelerometers) • Practical tools: Yarn tufts, flow-vis oil ← Correlate with CFD and wind tunnel data
Mechanical Design
• Manufacturing techniques, surface finish, materials, fasteners • Structural loads, chassis attachment, compliance, and stiffness • Packaging, clearance, and accessibility • Tolerances: Do the parts match the CAD? Surface tolerance and position tolerance? • Repeatable manufacturing and adjustments

Powertrain – EV

System Architecture
• Power and torque goals: Motor and accumulator sizing, are selections appropriate for FSAE • Driven wheel strategy (RWD/AWD/FWD, independent vs. coupled), inboard vs. hub motors • Regenerative braking, charging and torque vectoring strategies • Student engineered vs. purchased accumulator, motors, power electronics
Accumulator Design
• Cell selection: Cylindrical, prismatic or pouch type and performance criteria: energy density, chemistry, C-rate, DCIR (Direct Current Internal Resistance), size • Cell arrangement, pack voltage, current and power requirements • Accumulator Integration: Is enclosure a stressed member? Mechanical & electrical durability • Cooling Strategy: Passive/active, air/liquid, performance to requirements • Safety: Thermal Runaway Propagation and arcing • Battery Management System
Analysis & Development
• Synthesizing the desired outcome and making design decisions with data • Lap times, power/torque curves, thermal management • Drivetrain gearing, differential selection • CAE: FEA, CFD, electrical, thermal • Design trade-off studies
Test, Tune & Validation
• Component testing, hardware in the loop • Data acquisition vs. calculations • Dynamometer testing • Software Calibration • Failure analysis and recovery plans
Systems
• Cell fundamentals, wire bonding, mechanical mounting, charging strategy, cooling • Motor fundamentals: Type, torque curve, RPM limits, cooling, etc. • Power Electronics & bussing: Invertor & motor controls, DC/DC convertors, fuses, disconnects • Cooling System: Sizing, integration, package, parasitic loss • Lubrication / Tribology: Specifications, Use cases • Materials, coatings, or other modifications for performance? • Structure: Accumulator and motor mounting and loads from engine and from vehicle, especially if a stressed accumulator • Drivetrain: Differential details, CV selection, half shaft angles, chain selection and tensioning • Electronic powertrain controls: ECU choice, calibration approach, sensors, data acquisition • Safety and technical inspection implications
Integrated Vehicle Validation
• Track Testing • Agreement/Disagreement to prediction • Driver feedback and drivability • Lessons Learned

Chassis

Global Targets
• Global loads targets and rationale: X g's in bump, lateral, fore/aft • Structural margin targets, failure modes, and methodology for assessment • Vehicle level mass and stiffness targets and how budgeted to subsystems
Frame & Structure
• Input loads and structural margins • Stiffness targets and validation, model correlation (e.g. chassis twist testing) • Primary structure: Material selection, load-paths, manufacturing, mass/stiffness targets • Attachment Points: Methods, adjustability, strength/stiffness • Bodywork: Material selection, manufacturing, cosmetics • Impact Attenuator: Material selection, mounting strategy • Paint and surface treatments
Suspension & Steering (Structural)
• Suspension links: Materials, sizing, strength/stiffness balance, load-paths • Joints and Flexible members: Materials, sizing, load-paths • Tuning: Adjustment methods, precision of adjustment, ease of access • Hub/Upright: Material selection, manufacturing, strength/stiffness, adjustability • Wheel bearings: Configuration, materials, loads, stiffnesses, sealing • Springs: Configuration, materials, mounting, strength/stiffness, adjustability • Dampers: Configuration, type, sizing, mounting, strength/stiffness, adjustability • Steering Rack: Materials, mounting, friction/lash targets, control arms • Steering Column: Joint configuration/phasing, stiffness, friction, lash
Fasteners
• Bolted joint analysis methods • Bolted and bonded joints material selections • Installation process / targets

Driver Interface

Ingress & Cockpit
• Ease of step-in • Driver adjustment and accommodations up to 5% Female & 95% Male • Adequate room (elbows/knees) • Adequate shielding (e.g. steering rack) • Lack of snag points (sharp objects, exposed fasteners, wiring, etc.)
Seat & Pressure Points
• Seat and Headrest support and comfort • Materials and Manufacturing process • Adjustability: Methods and range of adjustment • Driver visibility: Track, dash, controls • Seat / Cockpit pressure points • Belts: Configuration, mounting, placement, adjustability
Controls & Instrumentation
• Pedals: Travel/effort, adjustability, manufacture & foot support • Steering: Effort/feedback, wheel angle, grip/comfort & material/manufacture • Clutch: Accessibility, effort & feedback • Overall slop, stiffness and compliance • Switches: Visibility, labeling & ease of use • Instrumentation: Visibility, readability, logic & simplicity • Active Controls (launch control, etc., if any): Ease of use, tunability
Brakes
• System level requirements, front/rear balance, adjustability, stiffness, driver feel • Master cylinders: Configuration, placement, sizing, reservoir volume • Brake lines: Type, routing, size • Rotors: Materials, sizing, isolation, treatments, thermal capacity • Calipers: Materials, sizing, configuration, placement, mounting strength/stiffness • Brake Pads: Materials, thermal considerations, friction levels, rotor compatibility • Heat management: Materials, sizing, geometry, airflow, validation • Active systems: ABS, stability control, regeneration, etc., including pump specification, tuning parameters/selection, integration with powertrain, safety systems
Egress
• Ease of driver egress and extraction • Intuitiveness • Robustness of cockpit structures • Robustness of surrounding structures (sidepods, aero, etc.)

Low Voltage/Data Acquisition

Battery
• Battery Chemistry • Sizing and Overall configuration • Vehicle Mounting
Wiring Harness
• Layout methodology and documentation • Wire Selection: Materials, configuration/shielding, gages, color coding • Connector selection and Termination • LAN / Ethernet / High speed data • Harness overwrap: shielding, routing, thermal and abrasion protection
Power Management
• Power Control Strategies • Grounding Strategy • Fusing and Circuit Breakers • Charging Circuit: Capacity, Controls, Battery Protection • Master Switches: Configuration and access
Data Acquisition (DAQ)
• Acquisition type and strategy • Channel selection, logging rates, and filtering • Sensor selection and configuration • Telemetry and Communication Protocols • Data analysis: Tools and feedback into simulations • Use of data for model correlation

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Design Judge Comments **Judge Name:** ___________________________

School Name: _____________________________________ **Car #:** ______

Enter score (circle areas judged):	**Overall Vehicle ___ / 25**	
Vehicle Dynamics ___ / 25	**Aerodynamics ___ / 15**	**Powertrain ___ / 30**
Chassis ___ / 30	**Driver Interface ___ / 15**	**Low Voltage/DAQ ___ / 10**

Comments: ____

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