FSAE/FS--EV Design Score Sheet

Team Name_____ Car #_____

Category	Areas Covered	Score
Suspension ○ Design ○ Build ○ Refinement/Validation ○ Understanding	Tires, wheels, hubs, uprights, control arms, steering linkage, springs, dampers, anti-roll bars, geometry, kinematics, vehicle dynamics. Selection and use of materials.	____/25
Frame/Body/Aero ○ Design ○ Build ○ Refinement/Validation ○ Understanding	Primary structure/tub/tubing, body, and aerodynamic/ ductwork systems. Rigidity and stress-relief methods. Load analyses. Fasteners. Selection and use of materials.	____/25
Tractive/Drive/ Recovery System ○ Design ○ Build ○ Refinement/Validation ○ Understanding	Accumulator(s), Power conversion, Motor/Controller selection/design, Wiring considerations, Transmission. Torque vectoring. Gearing. Regenerative braking. Selection/use of materials.	____/25
Cockpit/Controls/ Brakes/Safety ○ Design ○ Build ○ Refinement/Validation ○ Understanding	Driver interfaces, seat, belts, steering wheel, steering column, control panel/dash, cockpit sizing & protection, driver comfort/ease of control, pedals, braking system. Is this car as safe as it can be? Selection and use of materials.	____/25
Systems Management/ Integration ○ Packaging ○ Electronics/power mgmt ○ Team Organization ○ Analysis methods/tools	Design integration, plumbing/wiring, power management, schematics. Are sensitive items protected? Proper use of data? Do systems compliment another? Are progressive project management/ organization methods evident? Special communication tools utilized? What testing/development tools have been used or created?	____/20
Manufacturability/ Serviceability	Ease of repair? Sub-systems accessibility, parts interchangeability, manufacturing complexity? Have fasteners been standardized? Are special tools required to diagnose/service vehicle?	____/15
Aesthetics/Style	Attractive overall appearance? Is car clean, reflective of professional work? Does car instill pride in team, or apologies?	____/ 5
Creativity	Will this car cause a rules change? Have the judges learned something new? On rare occasions, creative or innovative design may merit special points.	____/10

Car Weight:_____ OVERALL DESIGN SCORE: ___/150

FSG Design Event Scoring (Some Insight into the Process)

The design and developmental process of a FSAE/FS EV car is a complex process. So is judging! Although many metrics and details are reviewed during judging, it is easy to overlook various features which are critical to a given team's efforts. It is important for team members to be pro-active in communicating these special details which separate their design from their competition. Do not force the judges to hunt for such areas!

Judges and teams should be familiar with the scoring categories. A more detailed break-down of each category can be found on the following pages. The judging criteria which follows are not simply check-lists to be blindly followed, but instead lists *some* of the key attributes every team should be able to demonstrate. Consider why the team may include or omit items in their design. The scope of judging is certainly not limited to these items exclusively.

Space for comments has been provided, so judges' observations may be shared with students.
Judges: Please provide as many detailed comments, for the benefit of students!

REMEMBER: Judges are not just scoring your vehicle. They are scoring ***your knowledge and understanding*** of vehicle development and performance. Reflective of this, for each physical design category (**Suspension**, **Frame/Body/Aero**, **Tractive System**, and **Cockpit/Controls/Brakes/Safety**) judges evaluate the team's development process. Generally, each category is judged with the following emphasis:

> ***Design (~25%)***: Assessment of design process used by team. Is this a new design, evolution, or complete carryover? Were different design options considered? Were appropriate pre-build analyses performed?
> ***Build (~25%)***: Does the physical specimen presented reflect the early design work? Is it reflected in design report? If not, why not? What special manufacturing considerations were encountered?
> ***Refinement/Validation (~25%)*:** How thorough and honest has the team been about testing? Was a test plan developed and executed? Were discrepancies between predicted and tested results documented and acted upon to improve final build?
> ***Understanding (~25%)***: Is the team that presents the car at competition truly intimate with the design? Can they quickly give detailed answers about any sub-system? Or do they have to "go ask someone else"?

About your score…

The Engineering Design Event Score Sheet totals 150pts. At the end of competition, you will most certainly find that your assigned final points do not match the score listed here. **Do not panic!**

The score listed on this sheet is reflective of your assigned judges' assessment, relative to other teams in your queue. Typically, judges score slightly differently from queue to queue. Hence, judges compare notes about cars from different queues, with the assistance of specialty and floating judges, to ensure minimal bias. This is accomplished after the initial score sheet has been submitted.

After scores have been submitted, multi-tier rankings of teams is created. Score sheets and written judge's comments are not shared with other teams. Thus, consider your "score" (on this sheet) as a first cut review, subject to discussion among judges prior to Engineering Design Finals selection. Do not attempt to compare your (score sheet) score to that of another team!

Engineering Design Scoring Assessment Areas & Judging Comments

The Engineering Design score sheet is designed for both judges and students. The following topical area breakdown offers some suggested items which should be addressed. It is not a check-off list, as each vehicle may have unique properties which should be covered. If you have further design questions (as a judge) or offerings (as a team) not included here, be sure to ask during your evaluation.

SUSPENSION (0-25pts) Score:_____

Will the tires stay in satisfactory contact with the road under all conditions?

This category focuses primarily on the unsprung masses of the vehicle, particularly those related to road holding and directional control. In addition, steering geometry downstream of steering column/shaft is assessed. Where appropriate, understanding of failure modes and critical limp-home requirements should be addressed as well. This is known as *robustness*. Teams should demonstrate analysis methods, appropriate execution, and validation within their design. Sample areas include, but are not limited to:

- Does the team understand vehicle dynamics fundamentals?
- What methods were used for selecting tires and sizes?
- How was the handling, response and tractive capability of the tires considered in the design of the suspension?
- What analysis methods were used in the development of wheel base, weight distribution, c.g. height, front and rear track widths, roll axis location (static and dynamic), camber gain curves, link lengths, Ackerman, anti-squat/dive, king pin inclination scrub radius, bump steer, and other geometry/kinematics?
- Have peak loads been determined and designed for?
- Have appropriate materials and heat treatments/coatings been selected for their function?
- Have attachments been properly analyzed and implemented? (e.g., no rods-ends in bending, double shear joints, etc)
- How were dampers selected and how are they valved?
- How were wheel rates and roll resistance values developed/determined?
- Has every effort been used to reduce unsprung mass?
- Have adjustments been provided for different competition environments?
- Has system friction, hysteresis and bearing lubrication been addressed?
- Do suspension/steering links and hardware have excessive compliance?
- Have predicted handling characteristics been validated? If so, How?
- Other_____
- Other_____
- Other_____

Comments:_____
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FRAME / BODY / AERO (0-25pts) Score:_____

Is the chassis sufficiently stiff, strong and light? Is the body durable and functional?

This category focuses on the mechanical design of the sprung masses of the vehicle, particularly those related to the frame/tub, and body. Where appropriate, understanding of failure modes and critical limp-home requirements should be addressed as well. Teams should demonstrate analysis methods, appropriate execution, and validation within their design. Sample areas include, but are not limited to:

- Does the mechanical design exhibit simplicity and elegance?
- Does the car reflect professional build quality?
- Are components properly designed and sized for the anticipated loads?
- Have appropriate materials been selected and used?
- Is the weight of the car reasonable? Excessive? Unreliably light?
- Are the chassis load paths well though out? Are loads located at frame nodes?
- Does the chassis have sufficient torsional rigidity?
- Have attachments (welds, fasteners, bonded joints, etc.) been properly analyzed and implemented? (e.g., proper adhesive selection, weld stress relief, etc.)
- Where is the weakest link, from a durability point of view?
- Have adequate drag-reduction strategies been employed? Validated?
- Does the team understand fundamental principals of aerodynamics?
- Has radiator/oil cooler ducting been adequately designed and executed?
- Has airflow to brakes been considered?
- Has the need for wings or under-tray been established / justified?
- Does the team know the C_D, C_L, and frontal area of their car?
- Other_____
- Other_____
- Other_____

Comments:_____

Tractive Drive/Recovery System (0-25pts) Score:_____

Is the tractive system lightweight, efficient & robust? Does it have manageable power delivery?

This category focuses on design of the drive management systems, motor(s), accumulators and driveline. Where appropriate, understanding of failure modes and critical limp-home requirements should be addressed. Teams should demonstrate competent and reasonable analysis methods, appropriate physical execution, and validation within their design. Sample areas include, but are not limited to:

- o Are the benefits of electric motors fully utilized (e.g. over powering/boosting, regenerative braking, vehicle control)?
- o Is the system well packaged/integrated into the remainder of the vehicle?
- o Has a good balance of Make vs. Buy decisions been employed?
- o Were motor(s) appropriately selected and developed? Does the team have a good insight in the limitations of their motor(s) and the trade-offs on weight and energy efficiency?
- o Which power/torque ratio is chosen? Are the reasons for this understood?
- o Are cooling systems properly sized for the motor, battery, electronics, accumulator, etc…?
- o Is the accumulator configuration properly designed to meet the team's stated goals? (e.g. capacity, power, temperature dependence)
- o Is an energy management strategy clearly defined and implemented?
- o Temperature management: which are the weakest components and under which conditions? (consider short term and long term failure modes).
- o Is there data communication/feedback between different parts of the tractive system?
- o Has data logging of tractive system been well executed? Was gathered data properly utilized?
- o Are safety hazards well understood? (e.g. battery over/under charging, arcing, energy storage, battery leakage due to impact and/or vibration, personal safety concerns, etc…)
- o Regenerative braking: How does it influence overall weight, motor temperatures, controller and battery reliability? Have the strategies been well defined and developed?
- o Has the team demonstrated adequate working knowledge of tractive system simulation tools? If so, what tools were used and how were they validated?
- o Torque vectoring: which strategy is used Is the strategy and implementation effective to sufficiently benefit vehicle dynamics?
- o Have the transmission and final drive been adequately engineered? Gearing Strategy?
- o Are the CV / U-joints appropriately sized and properly aligned?
- o Has the team demonstrated understanding of tribology, viscosity characteristics, viscous drag, additive packages, coatings, etc.?
- o Have special materials or surface prep been used to reduced drag, weight, increased strength, or heat management? (Ti, Inconel, ceramic bearings, coatings, heat-treat, peening, etc.)
- o Other_____
- o Other_____
- o Other_____

Comments:_____

COCKPIT / CONTROLS / BRAKES / SAFETY (0-25pts) Score:_____

Can a driver comfortably and safely drive this car at speed?

This category focuses on the vehicle from the point of view of the driver. Cockpit ergonomics and safety systems, including steering, brake and shifter controls are covered. A potent vehicle will not perform well if the driver cannot get the most from it. The driver must be able to use all controls with comfort and within his/her physical limits of strength, girth, & reach. The vehicle should also be capable of adequately protecting the driver, in case of an accident or component failure. Where appropriate, understanding of failure modes and critical limp-home requirements should be addressed as well. Teams should demonstrate analysis methods, appropriate execution, and validation within their design. Sample areas include, but are not limited to:

- Have Driver Controls (Throttle, Clutch, Shifter, Brake, Steering) been designed, sized, executed, and tested for reliable consistent operation?
- Regenerative braking (EV/Hybrid): how did it influence the design of the mechanical brake system? Have provisions been made to improve pedal feel/feedback?
- Are Active Controls (Traction Control, Launch Control, No-Lift-Shift, Auto shift, ABS) intuitive to use, well marked?
- Do the team drivers understand how to use on-vehicle control systems?
- Have adequate limp/backup modes been employed, in case of system failures?
- Does the team appreciate the importance of consistent / reliable brakes?
- Were proper kinetic energy calculations employed during brake system design?
- Have pedal-force gain requirements been addressed?
- Were properly sized brake components selected / developed?
- Were proper brake materials utilized (rotors, pads, and pedal assembly)?
- Have instant brake bias requirements been analyzed and properly implemented?
- Is the driver adequately supported under the effect of lateral, longitudinal, vertical, and combined g-forces?
- Is visibility, arm/leg room, head restraint well thought out and implemented?
- Are controls properly placed for efficient operation? (i.e., will it pass the blindfold test?)
- Are controls easily adjustable for different driver needs?
- Does cockpit size permit 5^{th}-95^{th} percentile drivers?
- Are the essential instruments easily readable?
- Is the interior free of potentially injury-causing projections, etc.?
- Does the design advance safety beyond the minimum requirements?
- Other_____
- Other_____
- Other_____

Comments:_____

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SYSTEMS MANAGEMENT & INTEGRATION (0-20pts) Score:_____

Is the team progressive, well-balanced and capable of repeating their effort?

This category considers the packaging, instrumentation, team development methods, and team management / organization. It is crucially important for team performance, though not always directly applicable to the performance of the car in a given session.

- Are accessory devices (ECU, Data, Comm. Equip., Control system components) placed in protected areas?
- Do test equipment / data systems complement the vehicle development (or just to show off?)
- Is data utilized during the competition to improve performance?
- Has wiring been safely routed, color coded, and marked for function?
- Can the team produce wiring, plumbing, and sub-system schematics for the vehicle?
- Has plumbing (fuel/oil/water/brakes/etc) been sized and routed safely and with serviceability / inspection in mind?
- Has the team proven its fluency with simulation and advanced analysis techniques?
- Has Project Management been a priority for the team?
- Have the organizational skills of the team been well demonstrated?
- Has the team really read the rulebook?
- Other_____
- Other_____

Comments:_____

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MANUFACTURABILITY / FIELD SERVICEABILITY (0-15pts) Score:_____

Can the team efficiently build more than one car? Can it be fixed it in the field?

This category addresses the ability of a reasonable manufacturing facility to construct the vehicle *as presented* and for teams campaigning the vehicle to perform maintenance and repairs. Considerations may include:

- Are unusual, or specialized, machining operations required? Exotic / expensive materials?
- Are fasteners standardized (SAE or Metric?) throughout vehicle?
- Have the number of fastener sizes been minimized?
- Are components from various corners of the car interchangeable?
- Can all areas of vehicle be accessed without major component (engine) removal?
- Can components be substituted in field with conventionally available items?
- Is special training or equipment required to service subsystems? Will this prove unreasonable as the car is campaigned outside the university environment?
- Other_____
- Other_____

Comments:_____

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AESTHETICS & STYLE (0-5pts) Score:_____

Is the car appealing?

This category may not seem engineering / design oriented, but is an important reflection of the professionalism and seriousness of the team. It is the first impression of the vehicle, and often influences the ability of the team to diagnosis emerging problems (leaks, cracks, etc.) before they become catastrophic.

- Is the overall appearance attractive?
- Does the car look fast?
- Does the car exhibit high levels of fit and finish?
- Is the car clean (washed, free of oil, grease, debris, etc.)?
- Does the car instill pride in driver/owner/team/sponsors? Or apologies…?
- Other_____
- Other_____

Comments:_____

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CREATIVITY (0-10pts) Score:_____

Is the design and execution of this car going to cause a rule change?

Strictly speaking, innovation is extremely rare in FSAE. It implies a marketing success coupled to a new paradigm. Creative interpretation or adoption of ideas in new ways is certainly encouraged in this competition, however: If it makes us go redress the rule-book, then perhaps it is even better!

- Are any components or systems unique or unusual, due to special analytical finding?
- Has there been creative use of materials, manufacturing processes, or test procedures?
- If so, do the creations contribute to the potential performance of the vehicle or to its overall effectiveness? (Creativity that does not have a function is “art”.)
- Do the students understand why and how their idea is better than the classic method?
- Other_____
- Other_____

Comments:_____

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