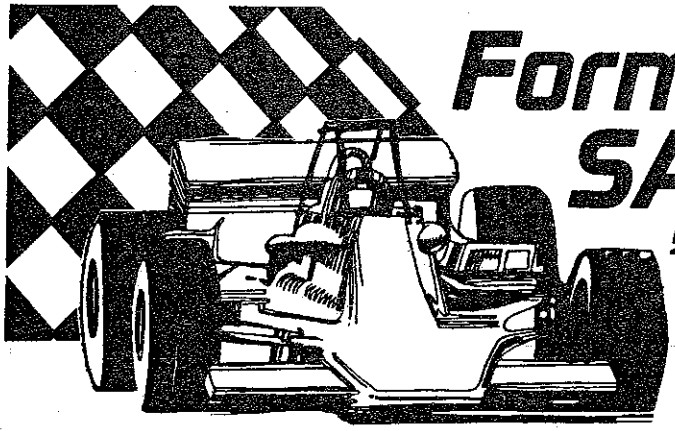

Formula SAE '86

Formula SAE Competition Rules

SCCA
Sports Car Club of America

Detroit Region, SCCA, Inc.

Hosted by

Lawrence
INSTITUTE OF TECHNOLOGY

Southfield, Michigan

May 22-24, 1986

PREFACE

This competition is hosted by the Lawrence Institute of Technology and is sanctioned by the Society of Automotive Engineers (SAE) through the student membership office and by the Sports Car Club of America (SCCA) through national and local levels.

Membership in SAE and SCCA is strongly encouraged for reasons of professionalism as well as insurance concerns. In addition to the desires of these national organizations for all competitors to be members, membership carries several benefits that are in themselves enough reason to join.

This competition is similiar to other competitions held across the nation such as the various Mini Baja off-road vehicle design competitions, the Super Fuel Economy, Human-Powered Vehicle, and others. These rules and traditions for the Formula SAE competition are indebted to the efforts of the previous hosts of Formula SAE:

1981	University of Texas at Austin
1982	University of Texas at Austin
1983	University of Texas at Austin
1984	University of Texas at Austin
1985	University of Texas at Arlington
1986	Lawrence Institute of Technology

David R. Hubbs
Southfield, MI
October 1985

FORMULA SAE COMPETITION BOOKLET

CONCEPT OF THE COMPETITION

The Formula SAE competition is an engineering competition for engineering students to conceive, design, fabricate, and race a small formula-style racing car. The limitations on the car frame and engine are very lenient so that the knowledge, creativity, and imagination of the students are challenged to the utmost. The cars will be built with a team effort over a period of about one year and the car will be taken to a host institution for judging and comparision with approximately 25 other cars from across the nation. The end result is a great experience for young engineers in a meaningful engineering project as well as the opportunity of working in a dedicated team effort.

For the purposes of this competition, the overall concept is that a manufacturing firm has engaged the student design team to produce a prototype car that meets the demands of the market place. The intended sales market is the nonprofessional weekend racer. Therefore, the car must be very high performance in terms of its acceleration, braking, and handling qualities. The car must be low in cost, easy to maintain, and reliable. In addition to these obvious factors, the car's marketability will be enhanced by other factors such as aesthetics, comfort, use of common parts, etc. The manufacturing firm is planning to produce 1000 cars per year at a cost below $5000 so that the challenge to the design team is to design and fabricate a prototype car that best meets these goals and intents. Each design will be compared and judged with other competing designs to determine the best overall car.

The cars will be judged in three different catagories: static inspection and engineering design, independent performance trials, and high-performance track competition. These events will be scored to determine how well the car performs. In each event, the manufacturing firm has specified minimum acceptable performance levels that are reflected in the scoring equations. The following points are possible.

50	Presentation
150	Engineering Design
100	Cost Analysis
100	Acceleration Event
50	Skid-Pad Event
150	Maneuverabiliy Event
50	Fuel Economy Event
350	Endurance Track Event
1000	Total

RULES

The competition will be governed by the following rules. Judges from automotive and engineering industries will be selected to confirm adherence to the rules and to determine the scores for the events. SCCA members will be used for the inspection and for the conduct, timing, and flagging all performance events

ELIGIBILITY

The competition is open to credit-earning undergraduate and graduate students of accredited engineering schools. The car must be conceived, designed, and fabricated totally by the engineering students without any direct involvement from professional engineers, automotive engineers, racers, or related professionals. The student competition team may use any literature or knowledge related to the design of the car. The students may use information from professionals or from professors as long as the information is given as a discussion of alternatives with their pros and cons; however, professionals may not make decisions-of-design, drawings, or fabricate parts for the competition team. Eligibility is limited to students to insure that this is an engineering competition rather than a race. Winning should be more related to engineering professionalism than to who crosses the finish line first.

It is intended that the competition team design and build a car and prepare the engine for the competition. To avoid the possibility of students merely bringing last year's car to race and therefore avoiding the engineering experience, no car will be allowed to race more than two years without penalty. If a team wants to continue with a car design for more than two years, a new car must be fabricated with photographic documentation that a new car was built and that improvements were made to the car. The judges will deduct design points from third-year cars.

The faculty adviser must accompany the team to the competition but is not allowed to provide hands-on help to the team or serve as a team member during the actual competition. The faculty adviser will serve as a liaison between the team and the officials and will make any communications of protest or complaints to the judges. The faculty adviser will oversee the school's responsibilities on and off the track.

CAR RESTRICTIONS

It is intended that all cars have approximately the same size and power in order to have a safe and fair competition. Thus, the following manditory restrictions will be enforced by the judges. Noncompliance must be corrected and and the car reinspected before the car will be allowed to compete in the performance events.

For the purposes of this competition, a car will be defined as a self-propelled land vehicle running on four wheels not in a straight line. At least two wheels must affect the steering, at least two wheels must affect the propulsion, and all four wheels must affect the braking. The car must have a formula-style body for aesthetic reasons.

Wheelbase, Track, and Clearance

The car must have a wheelbase of at least 60 inches. The wheelbase will be measured from the point of contact of the front and rear tires (both sides) with the wheels pointed straight.

The track and ground clearance of the car must combine to provide adequate roll-over safety. The tilt angle of the car with driver will be measured. A tilt angle of 57 degrees (corresponding to 1.5 g's) will be used as a minimum guideline. The judges have the right to disqualify cars with an unsafe tilt angle in consideration of the tires and suspension.

Suspension

It is intended that the car have a fully-operational suspension system with shock absorbers. The car must be equipped with a front and rear suspension system having a total usable wheel travel of at least 2 inches. The judges reserve the right to disqualify cars that have not made a serious attempt at an operational suspension system.

Roll-Over and Crash Protection

All parts of the driver must be protected from contact with the ground in any roll-over attitude. This will require roll bars next to the driver and in the front of the car. The driver roll bar must extend above the helmet of an average driver (5' 10") or the tallest team member by at least 2 inches. The roll bars must be a continuous tube constructed of 1.00 inch O.D. with .060 inch wall thickness mild steel, or alloy steel with 1.00 inch O.D. by 0.049 inch wall (or equivalent strength) as a minimum and must be securely attached to the frame. The roll bar must be braced in the fore-and-aft direction with braces attached within the top one-third of the roll bar at an angle of at least 30 degrees from the vertical.

The driver must be protected from a side collision by frame members extending to a level above his lap. The driver's feet must be protected from frontal collisions by surrounding frame members. The brakes and other critical components must be protected from rear collisions. The judges reserve the right to disqualify cars that are deemed unsafe, uncrashworthy, or do not have adequate structural soundness. As a guideline, a tube frame using 1.00 x .060 mild steel tubing with proper layout and fabrication will provide structural soundness.

Driver Protection

The car must be equipped with a safety belt system that is capable of restraining the driver to a safe position in any roll-over attitude. A four-point lap belt with shoulder harnesses is required as an absolute minimum. A five-point or six-point system is recommended.

A safety helmet with a Snell-75 safety rating must be displayed with the car and worn anytime that the car is driven under its own power. Eye protection is required to drive the car.

Wheel Size

The wheels of the car must be between 8 and 13 inches in diameter (inclusive). The tires can be any size or type.

Brakes

The car must be equipped with a brake system acting upon all four wheels and should be capable of providing four-wheel lockup on dry asphalt at any speed. The brake system must be protected from failure of the drivetrain or from minor collisions.

Engine and Drivetrain

The engine used to power the car may be any four-cycle piston engine with less than 610 cc displacement per cycle. Rotary engines are classified on the basis of double the displaced volume per cycle; therefore, rotary engines with less than 305 cc will be allowed. Two-cycle engines are prohibited. The engine can be modified to any extent desired.

In order to insure that oil will not be spilled on the track during the performance events, the engine (and transmission) must be sealed to prevent any leakage. If the judges suspect the potential for leakage, the team must take the necessary precautions.

Any transmission and drive train may be used. Any exposed drive train parts must be shielded or covered to protect the driver from flying debris in case of drivetrain failure. Exposed high-speed equipment such as torque converters, clutches, and flywheels must be shielded by a scatter shield of at least a 12 gauge mild steel or documented equivalent. Lower-speed equipment such as chains, sprockets, belts, and gears must be shielded by 18 gauge mild steel or documented equivalent. Guards for finger protection may be made of lighter material.

Fuel Allowed

During all performance events, the car must be operated with gasoline (auto gas, aviation fuel, or racing gas). No other fuel (such as nitro methane or alcohol) will be allowed. Nitrous oxide or other oxidizing agents will not be allowed.

Carburetor and Intake Restrictor

The car must be equipped with a single carburetor or a single throttle body if fuel injected. The carburetor may be of any size or design, and must have at least two springs to independently return the throttle to an idle position.

In order to limit the power capability from the engine, a circular restrictor must be placed in the intake system. The diameter of the restrictor must be no larger than 23 mm (0.866 inch). This restrictor will be checked with a circular go/no go plug on a rod during the inspection.

This restrictor must be placed between the carburetor or throttle and the engine. If the carburetor exit (not venturi) or intake manifold has a diameter of equal or smaller diameter than the restrictor, then a restrictor will not be required.

Turbochargers or superchargers will be allowed if the competition team designs the application. Engines that have been designed for and originally come equipped with a turbocharger will not be allowed to compete with the turbo installed. The restrictor must be placed upstream of the compressor but after the carburetor or throttle body. Thus, the only sequence allowed is throttle, restrictor, compressor, and then the engine.

Kill Switch

The car must be equipped with a positive toggle-type kill switch. It must be within easy reach from inside or outside the car.

Muffler and Exhaust System

The car must be equipped with a muffler in the exhaust system to reduce the noise to an acceptable level. The noise level will be measured with a sound level meter as the car accelerates at full power along a straight line for a distance of 100 feet or more. The measurement will be made at the mid point of the run at a distance of 20 feet from the car at 3 feet above the ground. The sound level must not exceed 105 dB on the A weighting band at any time during the test.

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

Fasteners

All critical bolts, nuts, and other fasteners on the steering, braking, and suspension must be secured from unintentional loosening. This can be accomplished best with safety wiring or cotter pinning; however, nylon lock nuts, locktight, and other forms deemed appropriate by the judges will be considered.

Car Number

Each car will receive a number at the time of its entry in the competition. This number must be displayed in 6 inch letters that are clearly visible form both sides of the car.

Fuel System

The car must be equipped with a fuel tank having a volume of no more than one gallon. During the inspection, the judges will drain the tank and refill it with a calibrated gallon.

The fuel system must be designed such the spillage during refueling cannot contact the driver position, exhaust system, or the ignition system.

The fuel tank and carburetor venting systems must be designed such that fuel cannot spill during hard cornering or decceleration. This is a concern since motorcycle carburetors normally are not designed for lateral accelerations. During the inspection, the car will be tilted to a 45 degree angle to observe possible spillage.

Fire Extinguisher

The car must be equipped with a fire extinguisher mounted a safe distance from the carburetor and fuel tank and must be easily removable from inside or outside the car. As an alternative, a fire control system may be used if the actuation location meets the intents above.

Modifications

Modifications to the car of any sort will not be allowed after the inspection and engineering judging. This includes modifications that affect the overall speed reduction, power transfer system, safety, or aesthetics of the car. Tire changes that affect performance will not be allowed. Adjustments (e.g., tire pressure, brake balance, suspension adjustments, chain and belt tension, and carburetor jetting) will be allowed to the car after the start of the performance events. Necessary repairs will be allowed under the knowledge of the team steward and the car must pass a reinspection by the inspection judges.

COMPETITION EVENTS

The competition is divided into three catagories: (1) STATIC EVENTS that include a general inspection, the engineering design and presentation event, and the costing event; (2) INDIVIDUAL PERFORMANCE TRIALS that test the individual abilities of the car in acceleration, cornering, maneuverability, and fuel economy; and (3) the ENDURANCE EVENT that tests the performance, endurance, and reliability of the car in a track event with other cars. Each of these events are described below in terms of the concept and what is intended to be tested, how the event is conducted, the criteria used in judging, and the formula used for scoring.

An individual team member cannot drive in more than three events (the maneuverability and fuel economy event is considered as two events). It is the team's option to participate in any event. The team may forfeit their second heat on the performance events.

INSPECTION

The concept of the inspection is to insure that the safety and design requirements outlined in the rules have been met. For cases in which the rules are not perfectly clear, the intent of the rule should be met. Violation of the intent of the rule is considered a violation of the rule.

Conduct of the Inspection

The cars will assemble in the display area on Thursday afternoon. The judging teams will come to each car for the inspection, and for the design, presentation, and cost judging. The cars must go to the test area for the noise level measurements and brake demonstrations.

Judging of the Inspection

The inspection judges will inspect the car at its location in the display area and make the necessary measurements. Upon completion of the static inspection, the car must at some time report to the muffler and brake test area. The car will be accelerated at maximum power and the sound level will be measured by the specifications given in the rules. At the end of the sound test, the driver must demonstrate that the car has adequate brakes. The judges will complete the Safety and General Inspection Checklist form in the appendix. If the judges find any part of the car that does not comply with the rules or that does not meet their approval, then the team must correct the problem and request a reinspection before the car will be allowed to compete in any performance event. The inspection judges reserve the right to reinspect any of the specifications (particularily the brakes and muffler) at any time during the competition.

Scoring of the Inspection

The inspection event is not scored for team points; however, the car must pass the inspection before it will be allowed to compete and must remain in accordance with these rules.

PRESENTATION EVENT

The concept for this event is to evaluate the team's ability to present their car to the customer. The presentation judges will evaluate the organization, content, and delivery of the technical presentation. The team that makes the best engineering presentation will win the event.

Conduct of the Presentation Event

The presentation, design, and costing judges can attend the presentation. The judging team will assemble with the competition team in front of the car in the display area. One (or more) team member(s) will give the presentation to the judging team and any other interested audience. The presentation cannot last more than 10 minutes and should not be interrupted by questions. After the presentation there will be approximately 5 minutes of questions. Only judges are permitted to ask questions. The audience may not ask questions or make any comments or distractions. During the question period, team members other than the presenter are encouraged to answer questions.

After the official question period, the design and costing judges can continue to ask clarification questions about the components, fabrication techniques, design, etc. that they need for their evaluations. In addition, the design and costing judges may come back at any time for further inspections and clarifications.

Judging of the Presentation Event

The presentation judges will consider the content, organization, and delivery of the presentation and will only evaluate the team's ability to give a technical presentation. The judges will use the evaluation form given in the appendix.

Scoring of the Presentation Event

The scoring of the event will be based on total points from the Presentation Judging Forms. The presentation points will be the average of the totals from the judges' forms. There is a maximum of 50 points from the Presentation Judging Form.

In order to provide more difference between the highest and lowest presentation scores, the scores will be spread from 0 to 50. The following equation will be used.

$$\text{PRESENTATION SCORE} = \frac{\text{your points} - \text{minimum points}}{\text{maximum points} - \text{minimum points}} \times 50$$

In the case that the minimum number of presentation points is below 20, then 20 will be used in the formula for the presentation score; however, negative points will not be given.

DESIGN EVENT

The concept of the design event is to evaluate the engineering effort that went into the design of the car and how the engineering meets the intent of the market. The car that best meets the design goals and engineering design concepts will win the design event.

Conduct of the Design Event

The design event will be initiated by the team's formal presentation. In addition to the presentation, design judges are encouraged to ask the penetrating questions relative to the team's understanding and level of analysis of the car. After the formal presentation and question period, the design judges may remain at the car to ask informal questions of the team members in order to make their evaluations. The judges reserve the right to return to the car at a more convenient time for further questions.

Judging of the Design Event

The design judges will use the presentation and answers as a basis for evaluating the engineering effort. The design judges will also inspect the car at some detail to form their own opinions if the design concepts are adequate and appropriate for the application. The judges have the responsibility to not award full credit (50 points) on the question about understanding (third from the last in the form) and to deduct up to an additional 100 points if they feel, based upon their questions and the photographic or substantiated evidence, that the car has competed in two previous competitions. The judges will use the Engineering Design Form in the appendix for their evaluation.

Scoring of the Design Event

The scoring of the design event will be based upon the points obtained on the engineering design judging form in the appendix. The average of the points from the judges will be used. There is a maximum of 350 points on the form. In order to provide more difference in the maximum and minimum scores, the design score will be spread between 0 and 150 by the following equation.

$$\text{DESIGN SCORE} = \frac{\text{your points} - \text{minimum points}}{\text{maximum points} - \text{minimum points}} \times 150$$

In the case that the minimum points is below 100 points, then 100 will be used as the minimum points in the above equation; however, negative points will not be given.

COSTING EVENT

The concept of the costing event is to obtain an accurate estimate of the cost of the car in limited production. This will evaluate not only the actual cost of the car, but also the team's ability to prepare an accurate engineering cost estimate. The car with the lowest corrected cost and the best report will win the event.

Conduct of the Costing Event

The team will submit their cost report to the cost judge as soon as possible upon arrival with an absolute deadline of one hour before the presentation. The costing judges can use the presentation as an introduction to the components and fabrication techniques of the car. After the presentation and questions, the costing judges may remain at the car to locate parts or ask questions. The costing judges must determine that a reasonable estimate of all parts and operations are included in the cost analysis. The costing judges retain the right to return to the car any time for inspections or for clarifying questions.

Judging of the Costing Event

The costing event will be judged on the basis of the cost of the car and the accuracy of the costing report. The cost of the car will be determined by the cost of the parts and fabrication for a production rate of 1000 cars per year using conventional manufacturing practices. The team will prepare a detailed engineering cost analysis using the guidelines and forms given in the appendix. From this analysis, the cost judges will determine if all parts and processes were included in the analysis and if unreasonably low costs were used. In the case of any omission, error, or cost below reasonable estimates are used, then the judge will add double the error. For example, if a car has tires listed at $10 whereas other teams list the same or similiar tires at $50, then the judge will add 2 X $40 for each tire to the cost. The adjusted price of the car will be used to determine the costing score.

Scoring of the Costing Event

The score for the costing event will be based upon the adjusted price of the car and the appropriateness of the costing report. The scores for the costing will be spread between 0 and 80 based upon the price of the car, a score of 0 to 20 will be based upon how detailed and appropriate the costing report is and if it was submitted on time. The following equation will be used to determine the costing score.

$$\text{COSTING SCORE} = \frac{\text{maximum price} - \text{your price}}{\text{maximum price} - \text{minimum price}} \times 80 + \text{report points}$$

In the case that the maximum price exceeds $5000, then $5000 will be used as the maximum price; and, negative points will be given. If a costing report is not submitted, or if the negative points would exceed -50, then -50 (plus report points) will be used as the costing score.

ACCELERATION EVENT

The concept of the acceleration event is to evaluate the car's acceleration ability in a straight line on flat pavement. This event rewards cars that are lightweight and can deliver power efficiently to the ground. The car that has the lowest elapsed time will win the event.

Conduct of the Acceleration Event

There will be two heats. Each heat must have a different driver and each driver can have two runs. The cars will accelerate from a standing start over a distance of 100 yards on a flat surface. The cars will be staged a few inches in front of the starting line and will be timed individually from the start to the finish line. If possible, dual timers will be used so that two cars can run against each other to increase the excitement. A green flag will be used to indicate the approval to begin, however, the timers start only after the front tires cross the lights at the start line. There will be no particular order of the cars in each heat; however, cars that have not run in the appropriate amount of time will be disqualified for that run. The elapsed time will be recorded on the heat card and the best time of the runs will be used.

Judging of the Acceleration Event

The acceleration event will be judged upon the amount of time it takes to accelerate from the start line to the finish line. Speed can be calculated by distance/time.

Scoring of the Acceleration Event

The score for the acceleration event will be spread between 0 and 100 based upon the average speed obtained during the best run rather than the time it takes. This technique of scoring based on speed rather than time for the point spread will increase the difference between the top few places so that there is a bigger difference between the winners. Since average speed is related to the inverse of time, the scoring equation can be reduced to one involving time. The following equation will be used to determine the scores for the event.

$$\text{ACCELERATION SCORE} = \frac{\text{Tmax/Tyour} - 1}{\text{Tmax/Tmin} - 1} \times 100$$

In the case that the maximum time (the slowest car) exceeds 9 seconds, then 9 seconds will be used as the maximum; however, negative points will not be given.

SKID-PAD EVENT

The concept of the skid-pad event is to measure the cornering ability of the car on a flat surface while making a constant-radius turn. The car having the best lateral acceleration will win the event.

Conduct of the Skid-Pad Event

There will be two heats. Each heat must have a different driver and each driver can have two runs. The Skid-Pad event will be conducted on a flat dry surface. There will be no particular order of the cars in each heat; however, cars that have not run in the appropriate amount of time will be disqualified for that run.

There will be two circles of 50 foot diameter in a figure eight pattern. The circle centers will be separated by 60 feet, and a driving path 10 feet in width will be marked. The cars will enter perpendicular to the figure eight and will take one full lap on the right circle to establish the turn. The next lap will be timed and the car will enter the left circle. One lap will be taken to establish the turn and the next lap will be timed. The car will exit at the intersection moving in the same direction as entered. The driving path will be marked with chalk lines of 50 and 70 feet diameter. Sixteen cones will be placed just inside of the inner circle and outside of the outer circle. A penality of 0.1 seconds will be added to the total time for every cone that is touched by the car. The run will be disqualified if a car's wheel crosses over the chalk lines. Cars that spin-out can continue as long as they don't cross either circle. The skid-pad will be timed in both directions and added together on the heat card to make one run.

Judging of the Skid-Pad Event

The skid-pad event will be judged on the lateral g's exhibited by the car considering penalty points. Lateral g's can be computed based upon the diameter of the path of the center of the car (55 feet will be assumed) and the time for one revolution (g = 0.613 diameter/time**2).

Scoring of the Skid-Pad Event

The score for the skid-pad event will be based upon the lateral g's exhibited by the car. The scores will be spread between 0 and 100 based upon lateral acceleration of the best run. Since lateral acceleration is inversely related to the square of the lap time, the equation used to compute the scores can be expressed in terms of time. The following equation will be used to determine the scores for the skid-pad event.

$$\text{SKID-PAD SCORE} = \frac{(Tmax/Tyour)^2 - 1}{(Tmax/Tmin)^2 - 1} \times 50$$

In the case that the maximum time for the two laps exceeds 13.4 seconds (corresponding to 0.75 g's), then 13.4 seconds will be used as the maximum time; however, negative points will not be given.

MANEUVERABILITY AND FUEL ECONOMY EVENT

The concept of the maneuverability and fuel economy event is to evaluate the car's maneuverability and handling qualities on a tight course with no other cars on the track. This track will combine the performance features of acceleration, braking, and cornering in one solo event. In addition to this handling test, the car's fuel economy will be tested. The fuel economy under racing conditions is important in most forms of racing and also shows how well the car has been tuned for the competition. The handling and fuel economy will be determined simultaneously so that this is a compromise event. The car with the fastest track time will win the maneuverability event and the car with the smallest volume of fuel consumed will win the fuel economy event.

Conduct of the Maneuvrability and Fuel Economy Event

There will be two heats. Each heat must have a different driver but each driver can have only one run. During the event, there will be one car on the course at a time. The course will be tight enough to limit the maximum speeds. The following specifications should be expected.

straightaways: no longer than 250 feet with hairpins on both ends
no longer than 150 feet with wide turns on the ends
constant turns: 100 to 200 feet diameter
hairpin turns: minimum of 24 feet outside diameter
slaloms: cones in a straight line with 25 to 50 foot spacing
chicanes, multiple turns, decreasing radius turns, etc.

The total length will be approximately 2 miles which will require the driver to complete a specified number of laps. There will be no particular order of the cars to run each heat; however, cars that have not run in the appropriate amount of time will be disqualified for that run. The time required to complete all laps will be recorded on the heat card and the time of the best run (as explained below) will be used to determine the score.

Prior to the maneuverability run, the gas tank will be filled to a certain level (e.g., full). After the run, the tank will be refilled to the same level to determine the quantity of fuel used. The car will be pushed to the start line with a full tank and allowed to make the run. After the run, the car must cross the finish line under power with fuel pump and fuel valves on and stop at the finish location. The car will then be pushed to the initial fueling location to be refueled. The volume of fuel used will be recorded on the heat card. The volume of the best run (as explained below) will be used to determine the fuel economy score.

In order to select the run that will be used in the computation of the score, a preliminary score will be calculated using the absolute maximum and minimums determined from all cars and all runs. The team's run that would result in the best combined maneuverability and fuel economy score will then be selected as the run to be used to calculate the actual team score. The actual maximums and minimums from these selected runs will then be used to compute the team score.

Judging of the Maneuverabilty and Fuel Economy Event

The cars will be judged upon the average speed on the track and the mile per gallon fuel economy. On the track, hitting a cone or course marker such that it is moved outside its locating circle or is knocked over will result in a one second penalty to be added to the total time for each time it occurs. If the car leaves the track (i.e., if all wheels cross over the course boundary) then the car must reenter the track at the same point or some point prior the the location that it left the track or lose that lap (requiring an additional lap). Cars that stall on the track may restart as long as no forward motion occurs during the restart. If cars have to be push-started, then two team members may enter the track and push-start the car; however, the car must exit the track and reenter at a location prior to where the engine stopped. Coasting will be permitted as long as the engine remains running.

Scoring of the Maneuverability and Fuel Economy Event

The score for the maneuverability event will be based upon the average speed during the selected run considering penalties. The scores will be spread between 0 and 150 using the average speed technique. The following equation is a simplification of the average speed equation and will be used to determine the team score for the maneuverability event.

$$\text{MANEUVERABILITY SCORE} = \frac{Tmax/Tyour - 1}{Tmax/Tmin - 1} \times 150$$

In the case that the maximum time exceeds the time required to average 15 MPH considering the actual length of the track, then the 15 MPH time will be used as the maximum time in the above equation; however, negative points will not be given.

The score for the fuel economy event will be based on the mile per gallon fuel economy obtained on the maneuverability track. The volume recorded on the heat card of the selected run will be used to determine the fuel economy. The points will be spread between 0 and 50 based upon the fuel economy. The equation for the fuel economy spread can be simplified to one involving the volume of fuel used. The following equation will be used to determine the score for the fuel economy event.

$$\text{FUEL ECONOMY SCORE} = \frac{Vmax/Vyour - 1}{Vmax/Vmin - 1} \times 50$$

In the case that the maximum volume of fuel used exceeds the volume required for 7 miles per gallon considering the track length, then the 7 MPG volume will be used as the maximum in the above equation; however, negative points will not be given.

ENDURANCE TRACK EVENT

The concept for the Endurance Track Event is to evaluate the overall performance of the car and to test the car's reliability. This event is the highlight of the competition that combines all of the performance features of the car including acceleration, braking, and cornering, as well as a coordinated team effort. The car that can go the fastest speed with minimum time wasted due to breakdowns (thereby finishing all laps in the shortest time) will win the event.

Conduct of the Endurance Event

There will be two heats. Two drivers will be required for a heat and each heat must have a different set of drivers. The course will be tight enough to limit the maximum speeds. The following specifications should be expected.

straightaways: no longer than 200 feet with hairpins on both ends
no longer than 100 feet with wide turns on the ends
constant turns: 75 to 175 foot diameter
slaloms: 30 to 50 foot spacing
chicanes, turns, etc.

The total length will be approximately 15 miles which will require an even number of laps. One four-lap qualifying run for each driver of this event will be conducted prior to the event. The race officials have the right to disqualify any driver or car in the interest of safety. During the heat, there will be groups of 2 to 5 cars allowed on the track simultaneously depending upon the length of the track. The cars will be grouped according to their scores on the maneuverability event as a mix of the fastest, medium, and slower cars. Each car will have a 60 minute window for its run. The car may start at anytime after the opening of its window but cannot continue after the end of its window. The car must finish the required number of laps during its 60 minute period in order to have a time recorded for the heat. There will be a mandatory 5 minute pit stop when the first driver has completed one half of the total laps to allow for refueling and the required driver change. As soon as one car finishes its heat, the next car in line can start its run in order to maintain 2 to 5 cars on the track continuously during the heat. The second heat will have a qualifying practice and a fresh start. The times for each individual lap and the total time for the heat will be recorded on the heat card. The best heat will be used to determine the score for the event.

Judging of the Endurance Event

The Endurance Track Event will be judged upon the average speed obtained during the heat. After the window opens, the time will start when the car actually enters the track and will stop when the car has finished the required number of laps. The car will be called in if it hasn't finished its laps when the window closes. The time of day for each lap will be recorded by the judge for the car. Any unnecessary, aggressive driving behavior (such as forcing another car off the track, refusal to allow passing, or close driving that would cause the likelihood of car contact) will result in a black flag for that driver.

When a driver receives a black flag signal, he must proceed to the penalty box to listen to a reprimand for his driving behavior. The amount of time spent in the penalty box will vary with the severity of the offense. A penalty of two seconds will be added to the total time for every pylon or course marker that is knocked down or moved out of its circle. If the car leaves the track (i.e., if all wheels cross over the course boundary), then the car must reenter the track at the same point or some point prior to where it left the track or lose the lap (which will require a make-up lap). Cars that spin-out can continue under the pylon and track exit rules above. If a car stalls or experiences a breakdown, then the car must immediately exit the track to make repairs and reenter under the track exit rule above. If the car must be push-started, then two team members may enter the track; however, the team members must enter or cross the track only upon the approval of the race officials. The car must be restarted and reenter the track under the supervision of a race official. Minor repairs (5 minutes) can be done beside the track; however, the car should be pushed to the pits for more significant repairs. Each time that a car enters the pits during the heat, the car must stop at the entrance of the pits, shut-off the engine, and be pushed to the pit location. Further rules and the meaning of flags are discussed in the Driving Rules section.

Scoring of the Endurance Event

The score for the Endurance Track Event will be based upon the average speed obtained during the best heat. The average speed will be calculated using the heat time minus the 5 minutes for the pit stop plus any penalty times recorded on the heat card. The score will be spread between 0 and 250 based upon average speed plus 100 for finishing. The following equation will be used to determine the scores for the event.

$$\text{ENDURANCE TRACK SCORE} = \frac{\text{Tmax/Tyour} - 1}{\text{Tmax/Tmin} - 1} \times 250 + 100$$

A car must complete the required number of laps within its 60 minute window in order to have a time to be scored. In case the maximum adjusted time exceeds 55 minutes, then 55 minutes will be used in the equation; however, negative points will not be given.

JUDGING, SCORING, AND AWARDS

JUDGING

At the start of the competition, the host will transfer all matters of judging, scoring, and conduct of the events to the race officials. The judges will be selected from engineering and automotive industries in order to maintain high professional standards in their conduct and interpretations of these rules. In addition to the engineering judges, there will be several competition officials from the local SCCA (Sports Car Club of America) to help with the inspection, actual conduct of the competition events, the timing, flagging, and safety. The following is a list of the expected judging staff.

Chief Engineering Judge and Event Director

- inspection judges (3)
  - measurements crew (4)
- design judges (3)
- presentation judges (3)
- cost judges (3)

Competition Director

- acceleration event judge
- skid-pad event judge
- maneuverability event judge
- fuel economy event judge
- track event judge
- team stewards assigned to each car
  - timers
  - start/finish line workers
  - flag and corner workers
  - safety stewards

The judging staff will strictly enforce the intent of the competition in a fair and logical manner and will encourage a high level of professionalism and safety for the participants.

SCORING

The criteria and method of scoring the events are presented in the description of the events. A summary of the possible score available and the limitations on the events is summarized below.

event	score	limitations and comments
INSPECTION	no score	Mandatory compliance before performance competition.
PRESENTATION	50	Lower limit of 20 of a possible 50 points.
DESIGN	150	Lower limit of 100 points out of a possible 350 points.
COST	100	Upper cost limit of $5000. Negative points will be given.
ACCELERATION	100	Upper limit of 9 seconds elasped time. Solo event.
SKID-PAD	50	Lower limit of 0.75 g's. Solo event.
MANEUVERABILITY	150	Lower limit of 15 mph. Solo event.
FUEL ECONOMY	50	Lower limit of 7 mpg. Solo event.
ENDURANCE	350	Lower limit of about 16.4 mph. wheel-to-wheel event.
total	1000	

The intent of the bottom limit to the scoring on all events is to discard data that are reasonably beyond the limits of the expected performance, and to eliminate the bottom percentage of scores in order to provide a finer discrimination between the top few places. To further separate the top few places, the inverse spread technique is used; thus, instead of a linear spread based upon elapsed time, a linear spread based upon average speed (inverse of elapsed time) is used. This provides a higher slope around the top few places.

It should be understood that the chief judge might have to adjust the bottom limits in some events if the results are much worse than our predictions. For example, if no car costs less than $5000, then the upper cost limit should be moved up. On the other hand if no car costs more than $3000, then the upper cost limit could be moved down. It is

anticipated that these adjustments will not be necessary; but the chief judge has the right to do so if it is clear that adjustments are necessary. A recommended technique is to adjust the limit so that 50 % of the cars receive a score.

AWARDS

Based upon the scores obtained in the competition events, the following awards and recognitions will be given. In each event, the winner and the top five places will be announced.

Award	Criteria
PRESENTATION	Best oral presentation.
DESIGN	Best overall engineering and design.
COSTING	Lowest car cost and best report.
ACCELERATION	Lowest elapsed time.
SKID-PAD	Highest lateral acceleration.
MANEUVERABILITY	Fastest speed on track.
FUEL ECONOMY	Highest MPG under race conditions.
ENDURANCE TRACK	Fastest speed on track.
OVERALL EVENT	Highest combined score on all events.

additional recognitions:

HIGHEST PERFORMANCE CAR	The car with the highest number of points on the combined scores in the Acceleration, Skid-Pad, Maneuverability, and Endurance events.
TEAM SPORTSMANSHIP	The team selected by the safety steward (or that receives the most ballot votes at the banquet) based upon their team unity and teammanship, assistance and interaction with other teams, and their promotion of friendly, professional, and safe competition.

RULES OF CONDUCT

It should be noted that this is a design engineering competition that requires performance demonstrations of a vehicle and is not a race. The competition teams should always keep in mind that the events will be conducted with engineering ethics rather than those of some forms of competition. In all events, violation of the intent of the rule will be considered a violation of the rule. Any perceived loopholes or potential problems should be identified in writing to the host institution. The host will then clarify the matter and advise all participants. Any problems that arise during the competition will be resolved by the Event Director or the Competition Director and the decision will be final.

GENERAL RULES

This event is being hosted by a Technical Institute and the judges and teams are representatives of other institutions; as such we must all keep in mind the reflections on our instituitions. Alcoholic beverages will not be allowed at any place on the campus by competitors or spectators (except for the after-banquet party!). Disruptive parties at the lodging site should be discouraged by the faculty adviser. Clean-up of trash and debris will be the team's responsibility.

Parking of cars and trailers will be in the designated areas only and personal cars will not be allowed in the track area.

It is the responsibility of the teams to be in the right place at the right time. If a car is not ready to compete at the scheduled time, then the team forfeits the run or opportunity and will not be offered a late make-up.

PIT RULES

During any part of the competition, cars may not be driven in the pits under their own power. Team members must push the car in and out of the pit area. When the car is driven anywhere but the practice area or the competition tracks, the car must be driven at walking pace. Whenever at all possible, a team member must walk beside the car.

Smoking will be prohibited in the pit area. The team's work area should be some defined area and should be kept uncluttered. No more than five team members will be allowed inside the pit work area at a time. At the end of the day, each team will clean all debris from their area and help with maintaining a clean track area. Each team will be required to bring an extra fire extinguisher to keep in their pit area.

Refueling with the engine running or the driver in the car is prohibited. Refueling with a hot engine is discouraged. Refueling should be done in the pits and a person should be standing by with a fire extinguisher in hand.

DRIVING RULES

The cars may not be driven under their own power in the immediate pit area. Cars must drive at a walking pace when going from one area to another with a team member walking beside the car. The driver must be wearing a helmet, eye protection, and safety belts whenever the car is being driven under its own power.

Practice on any of the performance tracks will not be allowed except for the qualification and familiarization practice for the Endurance Track Event. A practice area (with slaloms, etc.) will be provided in order to test and tune the cars. The practice area will be supervised and the number of cars on the area will be controlled. The cars may not be driven fast anywhere except the practice area and during the actual events. The competition officials will give one warning to the team of any infraction and have the right to deduct points from the team score depending upon the severity of the infraction.

The safety of this competition and especially the wheel-to-wheel Endurance Track Event will be considered as the ultimate responsibility of the competitors. Thus, aggressive driving, running cars off the track, not yielding to passing signals, etc. will result in a black flag and a discussion of the driving behavior with competition officials in the penalty box. The time spent in the penalty box will serve as a reprimand as well as to inform the driver exactly what he did wrong. Drivers should be especially aware that open-wheeled cars are inherently dangerous due to the possibility of two tires touching and throwing one car into the air. The Endurance Event is a timed event; each driver is racing the clock and is not racing the other cars; therefore, aggressive driving is not necessary. A slightly slower car will allow faster cars to pass safely rather than trying to hold them back.

DRIVER SIGNALS

Hand Signal	Meaning
One fist raised	Driver intends to stop running and exit to the pits or off the course.
Finger pointed	An overtaken driver indicating the side he intends for the faster car to pass.
Both arms raised	A driver's car is stalled and he will not move it until the course is clear.

FLAG SIGNALS

Flag	Location	Meaning
GREEN	Start Line	Start competition.
BLUE (motionless)	Corners	A faster car is behind you. Prepare for a pass.
BLUE (furled & pointed)	Corners	A faster car is trying to overtake you. You must give way for passing.
YELLOW (motionless)	Corners	Caution ahead; slow down and do not pass moving cars.
YELLOW (waved)	Corners	Great danger ahead. Slow down and be prepared to stop. Do not pass moving cars.
RED	Corners	Competition halted. Stop running and follow the directions of the corner worker.
BLACK (furled & pointed)	Corners	Warning; you are driving in an unsafe manner. If continued, you will get a black flag.
BLACK (waved)	Corners	Stop running and proceed to the penalty box to be reprimanded for your driving or to be advised of a problem with your car to be corrected in the pits.
CHECKERED	Finish line	End of competition for your car.

SPECTATOR RULES

The host will have no direct line of communication with spectators other than on-the-spot at the competition; thus, the competitors and participants should inform the spectators and help to enforce the rules.

Spectators are also prohibited from drinking alcoholic beverages on campus. Spectators should not be in the pits during the performance events. Participants and spectators may not enter the track areas during performance events. During the Endurance Track Event, there will be an outer boundary a safe distance from the track that spectators may not cross. Special exceptions can be made by the Director for the persons wishing to take photographs from safe locations inside the track. A race track such as this is not a good place for children and unsupervised young people.

SCHEDULE OF EVENTS

Thursday

9:00	Organizational meeting	auditorium
9:00	Submission of COST ANALYSIS REPORT	cost judge
10:30-5:00	INSPECTION	display area
10:30-5:00	PRESENTATION and DESIGN EVENT	display area
10:30-5:00	Measurements	display area
12:00-5:00	Demonstration of Muffler and Brakes	track

Friday

8:00	Assembly and inspection verification	track
9:00	MANUEVERABILITY & FUEL ECONOMY EVENT	track
1:00-2:00	lunch	
2:00	ACCELERATION EVENT	track
3:30	SKID-PAD EVENT	track

Saturday

8:00	Assembly and inspection verification	track
8:30	Endurance qualification for I drivers	track
9:30	ENDURANCE TRACK EVENT - I	track
12:00	lunch	
12:30	Endurance qualification for II drivers	track
1:30	ENDURANCE TRACK EVENT - II	track
7:30	Banquet	Wayne Buell Bldg.
9:00-?	Social	Wayne Buell Bldg.

Appendix: FORMS

CAR #_____

ELIGIBILITY CERTIFICATION

I hereby certify that the team members listed below are students currently enrolled in engineering courses.

This team has designed and/or modified and prepared this car for the competition without direct assistance from professional engineers or racers. This car has not competed in two Formula SAE events.

_____
Signature of Faculty Adviser

Team Members:

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____
11. _____
12. _____

CAR #_____

SAFETY AND GENERAL INSPECTION

_____ Formula-Style Body

_____(in) Wheelbase

_____(in) Front Track

_____(in) Rear Track

_____(in) Ground Clearance

_____(in) Front Wheel Travel

_____(in) Rear Wheel Travel

_____ Roll-Over Protection

_____(in) Head Clearance

_____ Roll Bar Braced

_____ Safety Belts

_____ Safety Helmet

_____(in) Wheel Size

_____(in) Tire Size and Type

_____ Brake Demo

_____ Brake Line Protection

_____(cc) Engine size and Type

_____ Oil Leaks

_____ Scatter Shields

_____ Kill Switch

_____(mm) Carburetor Size

_____ Throttle Return Springs

_____ Restrictor

_____(dBA) Muffler Sound Level

_____ Exhaust Gas Fumes

_____ Steering Fasteners

_____ Suspension Fasteners

_____ Braking Fasteners

_____ Control Fasteners

_____ Car Numbers

_____(gal) Fuel Tank Capacity

_____ Refueling Spillage

_____ Fuel Vent Leakage

_____ Fire Extinguisher

_____ Sprocket/Gear Ratios

_____(lb) Weight

_____(deg) Tilt Angle With Driver

_____ Fuel Spillage In Tilt

_____ Safety Wire/Lock Nuts

Additional Comments:

CAR #_____

PRESENTATION JUDGING

Score the following catagories on the basis of 0-10 points each according the following scale (any number or fraction along this scale may be used).

0 = inadequate or no attempt
2.5 = attempted but below expectation
5 = average or expected
7.5 = above average but still lacking
10 = excellent, perfectly meets intent

_____ CONTENT	Were the concepts presented appropriate and adequate to explain how the car meets the intent of the customer? Were enough technical details presented without being boring?
_____ ORGANIZATION	Were the concepts presented in a logical order progressing from basic concept and showing how the engineering accomplished the concept? Was it clear to the audience what was to be presented and what was coming next? Were distinct introduction and overviews as well as summary and conclusions given?
_____ VISUAL AIDS	Were visual aids used or clear visual references made to the car? Were the illustrations visable to all of the audience?
_____ DELIVERY	Did the presenter speak in a clear voice? Did the presenter show enthusiasm and promote confidence in the technical aspects. Did he maintain eye contact?
_____ QUESTIONS	Did the answer illustrate that the team fully understood the question and the intent of the question? Is there a doubt that the team understood the answer? Did the team promote complete confidence in their response to the questions?

_____ Total = PRESENTATION POINTS (50 points maximum)

Additional Comments:

CAR #_____

ENGINEERING DESIGN JUDGING

Score the following questions on the basis of 0-10 points using the following scale (any other numbers or fractions along this scale may be used).

0 - inappropriate design or use
2.5 - workable but substandard design
5 - average or expected design
7.5 - superior or better than expected design
10 - excellent design; perfect match with the intent

_____ How well does the car meet the intent of the market?
_____ Does the car have good lines and aesthetic appeal?
_____ How appropriate are the components relative to the intended use?
_____ Are the components readily available or all specially built?
_____ Are the specially built components simple in terms of fabrication?
_____ Is the car easy to maintain (oil change, wheel bearings, brakes, etc.)?
_____ Comfort, ease of entry, emergency exit, adjustable seat, steering angle?
_____ Operator controls and instrumentation appropriate and well located?
_____ Are there safety features in addition to the minimum requirements?
_____ Are the drivetrain components well-matched in function and load ability?
_____ Is the suspension well designed considering angles, bearings, slop, etc?
_____ Does it appear that camber, toe-in, and track changes were considered?
_____ Is the steering technique approporiate and without slop?
_____ Was attention paid to Ackerman angles?
_____ Do the brakes and the brake distribution seem adequate and correct?
_____ Are the ground clearance, weight distribution, and C.G. optimized?
_____ Does the frame seem stiff and strong enough?
_____ Are there too many or too few frame members?
_____ Are the frame members over or under designed for their required loads?
_____ Are the major load points triangulated properly?
_____ Do added parts or brackets serve more than one purpose?
_____ Are the directions of loading coincident with the direction of strength?
_____ Was there a concern for ease of fabrication (i.e., castings, stampings)?
_____ Are the appropriate fasteners used?
_____ Evidence of creativity and innovativeness in new designs or fabrication?

Score the following questions on the basis of 0-50 points using the following scale (any other numbers or fractions along this scale may be used).

0 - not appropriate or adequate performance
25 - average or expected performance
50 - excellent, perfect match

_____ How well do the team members illustrate their understanding of the design (deduct if these members did not design or understand this car)?
_____ What level of engineering analysis did these team members put into the car (e.g., dyno engine, frame stress analysis, suspension & steering geometry, performance and handling analysis)?

_____ Deduction (100 points maximum) if the car has competed in two previous events without major modifications.

_____ Total = DESIGN POINTS (350 points maximum)

COST ANALYSIS GUIDELINES

The cost analysis for the car is based upon the estimated cost for parts, fabrication, and assembly of a car in limited production (1000 cars per year); the engineering cost estimate may have little relationship to the actual money spent for the prototype. The cost analysis should consider fabrication techinques that would be used in production. For example, a part might have been machined and welded on the prototype but might be cast in production; therefore, the part should be estimated based upon the cost of casting in the cost analysis.

The cost of the car will be itemized into the following subassemblies: engine and drive train (including drive axles and bearings); frame and body (including pedals, shifter and throttle controls and linkages); wheels, wheel bearings, and tires; suspension and shocks; steering system; brake system; instruments and accessories; and miscellaneous parts (e.g., seat and harness), finishing (e.g., painting) and final assembly. The cost of fasteners and brackets will be included in their respective subassemblies. The costs of the subassemblies will include labor as if each subassembly were bought from a separate supplier and the car were simply assembled to the finished product.

Parts and materials used in the car will be estimated based upon wholesale supplier's quotes (documentation would be helpful) in the quantities stated. If an accurate wholesale price is not available, then 60% of retail can be used. Costing based upon, and the use of, used parts in production is not permitted.

The time required to cut, machine, weld, paint, fabricate, etc. will be costed at $25/hour if it is not explicitly costed from the Operations Cost Table. This rate will include the labor and overhead costs. Overhead will include expendables, capital costs and depreciation of machine equipment. The table given on the next page provides some guidelines to the costs of various operations.

The cost of the engine with integral transmission will be computed based upon $1.50/cc for a high-performance engine (e.g., motorcycle) and $0.50/cc for a low-performance engine (e.g., industrial) without integral transmission. An engine will be considered to be high performance if it is capable (without single carb and restrictor) of producing more than 6 horsepower per 100 cc displacement. If the integral transmission is not used with the high-performance engine, then the engine cost will be $1.25/cc and the external transmission must be figured separately. Engines that come equipped with an integral transmission, differential, and U-jointed axles must estimate the cost of the differential and U-joints separately. Rotary engines will be figured based upon the double displacement rating.

The following table should be used in estimating some of the costs.

Operations Cost Table

labor	$25/hr
welds	$0.50/inch
saw or tubing cuts	$0.40/linear inch
tube bends	$0.75/bend
tube end preparation	$0.75/prep
drilled hole	$0.25/hole
tapping holes	$0.25/hole
sheet metal shearing	$0.20/cut
sheet metal punching	$0.10/hole
sheet metal bends	$0.05/bend
sheet metal stampings	$0.05/sq. in.
sand castings	$3.00/lb
die castings	$4.00/lb
plastic injection molding	$3.00/lb
fiberglass	$2.00/sq. ft. (1/8")

CAR # _____

COST ANALYSIS

Subassembly Identification	Cost
Engine and Drive Train	_____
Frame and Body	_____
Wheels, Wheel Bearings, and Tires	_____
Suspension and Shocks	_____
Steering System	_____
Brake System	_____
Instruments and Accessories	_____
Misc., Finishing, and Final Assembly	_____
Grand Total	_____
Judges Adjustments _____ x 2 =	_____
Total Adjusted Cost	_____

SUBASSEMBLY COST FOR _____

Part Identification	Source	Cost

Total Subassembly Cost _____