

***Formula
SAE
'85***



FORMULA SAE COMPETITION RULES



TEXAS REGION SCCA, INC.

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FORMULA SAE COMPETITION BOOKLET

CONCEPT OF THE COMPETITION	1
RULES	2
ELIGIBILITY	2
CAR RESTRICTIONS	2
Wheelbase, Track, and Clearance	3
Suspension	3
Roll-Over Protection	3
Driver Protection	3
Wheel Size	3
Brakes	4
Engine and Drivetrain	4
Fuel Allowed	4
Carburetor and Intake Restrictor	4
Kill Switch	5
Muffler and Exhaust System	5
Fasteners	5
Car Number	5
Fuel System	5
Fire Extinguisher	6
Modifications	6
COMPETITION EVENTS	7
INSPECTION	7
Conduct of the Inspection	7
Judging of the Inspection	7
Scoring of the Inspection	7
PRESENTATION EVENT	8
Conduct of the Presentation Event	8
Judging of the Presentation Event	8
Scoring of the Presentation Event	8
DESIGN EVENT	9
Conduct of the Design Event	9
Judging of the Design Event	9
Scoring of the Design Event	9
COSTING EVENT	10
Conduct of the Costing Event	10
Judging of the Costing Event	10
Scoring of the Costing Event	10
ACCELERATION EVENT	11
Conduct of the Acceleration Event	11
Judging of the Acceleration Event	11
Scoring of the Acceleration Event	11

SKID-PAD EVENT	12
Conduct of the Skid-Pad Event	12
Judging of the Skid-Pad Event	12
Scoring of the Skid-Pad Event	12
MANEUVERABILITY & FUEL ECONOMY EVENT	13
Conduct of the Maneuverability & Economy Event	13
Judging of the Maneuverability & Economy Event	13
Scoring of the Maneuverability & Economy Event	14
HIGH-PERFORMANCE TRACK EVENT	15
Conduct of the Track Event	15
Judging of the Track Event	15
Scoring of the Track Event	16
JUDGING, SCORING, AND AWARDS	17
JUDGING	17
SCORING	18
AWARDS	19
RULES OF CONDUCT	20
GENERAL RULES	20
PIT RULES	20
DRIVING RULES	21
SPECTATOR RULES	22
SCHEDULE OF EVENTS	23
APPENDIX: FORMS	
Eligibility Certification	25
Safety and General Inspection	26
Presentation Judging	27
Engineering Design Judging	28
Cost Guidelines	29
Cost Analysis Form	31
Subassembly Cost Form	32

PREFACE

This competition is hosted by the University of Texas at Arlington and is sanctioned by the Society of Automotive Engineers (SAE) through the student membership office (John Casker). In addition to this sponsorship which has existed for several years, this year is the first year that the Formula SAE competition is fully sanctioned by the Sports Car Club of America (SCCA) through national and local levels (Texas Region). Additional support is being provided through the Equipe Rapide Sports Car Club (E/R).

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.

These rules represent an outgrowth of the rules and traditions that have evolved over the past few years at the University of Texas at Austin under the direction of Professors Mathews and Wood.

The writing of these rules is deeply indebted to the careful scrutiny of past competitors and judges.

Robert L. Woods
Arlington, Texas
September 1984

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 comparison with approximately 15 other cars from across the nation. The end result is a fantastic 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 \$4500 so that the challenge to the design team is to design and fabricate a prototype car that best meets these goals and intents. Your design will be compared and judged with other competing designs to determine the best overall car.

The cars will be judged in three different categories: 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	Maneuverability Event
50	Fuel Economy Event
350	High-Performance Track Event
<u>1000</u>	Total

This competition is similar 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, Mini Indy, 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

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.

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 that the students must incorporate in their car. Professionals may not make decisions of design, drawings, or fabricate parts for the competition team. The 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.

In order to compete, the team must submit an entry fee of \$150 by 1 March 1985. This fee will include five tickets to the banquet; additional tickets may be purchased at the competition.

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.

A 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.

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 mandatory restrictions will be enforced by the judges. Noncompliance must be corrected and pass a reinspection 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 and at least two wheels must affect the propulsion and 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-over angle of the car with driver will be measured. From this, the judges can determine the roll-over safety of cars. A tilt angle of 57 degrees should be used as a minimum guideline. The judges reserve the right to disqualify entrants with an unsafe tilt angle in consideration of the tires and suspension.

Suspension

The car must be equipped with a front and rear suspension system having a usable wheel travel of at least 2 inches. Due to the difficulty of accurately measuring this, the judges' opinion of the capability of the car to have this much travel will be used.

Roll-Over and Crash Protection

All parts of the driver must be protected from contact with the ground in any roll-over attitude. The car must have a roll bar extending above the helmet of an average driver (5' 10") or the tallest team member by at least 2 inches. This roll bar must be constructed of mild steel with 1.00 inch O.D. by .060 inch wall or alloy steel with 1.00 inch O.D. by 0.049 inch wall 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.

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 at least 8 inches but cannot exceed 13 inches in diameter.

Brakes

The car must be equipped with a brake system acting upon at least two wheels and should be capable of providing 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 or aviation fuel). No other fuel or additives will be allowed. Nitrous oxide or other oxidizing agents will not be allowed due to safety considerations.

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 at the competition.

This restrictor must be placed between the carburetor or throttle and the engine. If the carburetor 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.

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. The measurement will be made at the midpoint of the 100 foot run 20 feet away at 3 feet above the ground. The sound level must not exceed 105 dB on the 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 from 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 to confirm compliance with this rule.

The fuel system must be designed such that 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 deceleration in the performance events. This is a concern since motorcycle carburetors normally are not designed for lateral accelerations. A good test is to tip the car to a 45 degree angle to observe possible spillage.

Fire Extinguisher

The car must be equipped with at least a 2 pound halon or class B and C dry chemical fire extinguisher. The fire extinguisher must be mounted a safe distance from the carburetor and must be easily removable from inside or outside the car. As an alternative, a fire control system may be used. This system must use at least a 2 pound halon or B & C fire extinguisher mounted at any location as long as the actuation point is a safe distance from the carburetor and can be operated from inside and outside of the car.

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 after those repairs.

COMPETITION EVENTS

The competition is divided into three categories: (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 HIGH-PERFORMANCE TRACK EVENT that tests the performance, endurance, and reliability of the car in wheel-to-wheel racing on a track 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, 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 (particularly 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 audience and formality will be dispensed and 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 evaluate the team's ability to give a technical presentation only. 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 question answers as a basis for evaluating the engineering effort. The design judges will also inspect the car at some detail to determine 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 understanding question 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 will 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 similar 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 \$4500, then \$4500 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.

$$\text{ACCELERATION SCORE} = \frac{T_{\text{max}}/T_{\text{your}} - 1}{T_{\text{max}}/T_{\text{min}} - 1} \times 100$$

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 cornering ability will be expressed in lateral g's. The car having the largest lateral g capability 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.

The cars will enter the skid-pad at speed and will take one full lap to establish the turn. The next two laps will be timed and the car will exit the circle after one more quarter turn. The circle will be marked with a chalk line having a diameter of 50 feet. Sixteen cones will be placed just inside of the circle. The car can run at any diameter outside of the circle within 10 feet of the line. A penalty 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 the inner or outer circle. The skid-pad will be timed in one direction and then the other to make one run. The time for each direction will be added together and recorded on the heat card. The run with the best combined time will be used to compute the score.

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 ($g = 0.613 \text{ diameter}/\text{time}^2$).

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.

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

In the case that the maximum time for the four laps exceeds 26 seconds (corresponding to 0.8 g's), then 26 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 Maneuverability and Fuel Economy Event

There will be two heats. Each heat must have a different driver and each driver can have two runs. During the event, there will be one car on the course at a time. The course will be a combination of straightaways, tight turns, chicanes, button-hooks, etc. The longest straightaway will be less than 150 yards. 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 Maneuverability 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 both 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.

$$\text{MANEUVERABILITY SCORE} = \frac{T_{\text{max}}/T_{\text{your}} - 1}{T_{\text{max}}/T_{\text{min}} - 1} \times 150$$

In the case that the maximum time exceeds 480 seconds (corresponding to 15 mph), then 480 seconds 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.

$$\text{FUEL ECONOMY SCORE} = \frac{V_{\text{max}}/V_{\text{your}} - 1}{V_{\text{max}}/V_{\text{min}} - 1} \times 50$$

In the case that the maximum volume of fuel used exceeds 1080 cc (corresponding to 7 miles per gallon), then 1080 cc will be used as the maximum in the above equation; however, negative points will not be given.

HIGH-PERFORMANCE TRACK EVENT

The concept for the high-performance 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, 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 High-Performance 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 consist of tight turns, slalom, chicanes, hair-pin turns, and straightaways. The longest straightaway will be less than 100 yards. The total length will be approximately 15 miles which will require an even number of laps. One four-lap practice run for each driver of this event will be allowed prior to the heat. During the heat, there will be groups of 4 to 6 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 with the fastest cars running first. The heats will be of 50 minutes duration; each car may start at anytime during that time period but will not be allowed to continue after the end of the 50 minutes. The car must finish the required number of laps during the 50 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 4 to 6 cars on the track continuously during the heat. The second heat will have 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 High-Performance Event

The high-performance track event will be judged upon the average speed obtained during the heat. The time will start when the car enters the track. The times of each lap will be recorded and the time will stop when the car has finished the required number of laps. 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 over 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 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 High-Performance Event

The score for the high-performance event will be based upon the average speed obtained during the best heat. The 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 points will be spread between 0 and 350 based upon average speed which can be expressed in terms of the adjusted time. The following equation will be used to determine the scores for the high-performance event.

$$\text{HIGH-PERFORMANCE SCORE} = \frac{T_{\text{max}}/T_{\text{your}} - 1}{T_{\text{max}}/T_{\text{min}} - 1} \times 350$$

A car must complete the required number of laps in order to have a time to be scored. In the case that the maximum adjusted time exceeds 45 minutes (corresponding to 20 miles per hour), then 45 minutes will be used in the equation; however, negative points will not be given.

JUDGING, SCORING, AND AWARDS

At the start of the competition, the host will transfer all matters of judging, scoring, and conduct of the events to the race officials.

JUDGING

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 race officials from the local SCCA (Sports Car Club of America) to help with the actual conduct of the race events, the timing, flagging, and safety. The following is a list of the expected judging staff.

Chief Engineering Judge and Event Director

- inspection judges (2)
- measurements crew (2)
- design judges (2)
- presentation judges (2)
- cost judges (2)

Race 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 \$4500. Negative points will be given.
ACCELERATION	100	upper limit of 9 seconds elapsed time. Solo racing.
SKID-PAD	50	lower limit of 0.8 g's. Solo racing.
MANEUVERABILITY	150	lower limit of 15 mph. Solo racing.
FUEL ECONOMY	50	lower limit of 7 mpg. Solo racing.
TRACK	350	lower limit of 20 mph. Wheel-to-wheel racing.
total	1000	

It should be understood that some of the lengths in the competition and the limits in the scoring equations might have to be adjusted during the competition. For example, on the High-Performance Track Event, the number of laps will be the closest even number required for approximately 15 miles; thus, the actual distance might be 14.8 miles.

The intent of the bottom limit to the scoring on all events is to discard so-called bad data points that are reasonably beyond the limits of competitive efforts, 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 \$4500, 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 or done; but the chief judge has the right to do so if it is clear that adjustments are necessary.

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.
PERFORMANCE 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 Performance Track events.
TOP DRIVER	The individual driver that has the highest number of points counting his scores on both runs in the three driving events that he enters (neglecting fuel economy).
TEAM SPORTSMANSHIP	The team that receives the most ballot votes at the banquet based upon their team unity and teamanship, 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 simply a race. The competition teams should always keep in mind that the events will be conducted with engineering ethics rather than the race ethics of some forms of racing. 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 Race Director and the decision will be final.

GENERAL RULES

This event is being hosted by a state institution and the judges and teams are representatives of other institutions; as such we must all keep in mind the reflections on our institutions. Alcoholic beverages will not be allowed at any place on the campus by competitors or spectators (except for the after-banquet party!). 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 in 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 familiarization practice for the High-Performance 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 race 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 performance 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 race 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 performance track 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 racing 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 racing.
WHITE (motionless)	Corners	Slow car ahead.
WHITE (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 racing cars.
YELLOW (waved)	Corners	Great danger ahead; slow down and be prepared to stop. Do not pass racing cars.
RED	Corners	Race halted; stop racing and proceed around the track at slow speed until the problem is corrected, or go to the pit as directed.
BLACK (furled & pointed)	Corners	Warning; you are driving in an unsafe manner. If continued, you will get a black flag.
BLACK (waved)	Corners	Stop racing 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 racing 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 will not be allowed in the pits during the performance events. Participants and spectators may not enter the track areas during performance events. During the High-Performance 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 Race Director for 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

10:00	Organizational meeting	auditorium
10:00	Submission of COST ANALYSIS REPORT	cost judge
1:00-7:00	INSPECTION	display area
1:00-7:00	PRESENTATION and DESIGN EVENT	display area
1:00-5:00	Measurements	display area
1:00-5:00	Demonstration of Muffler and Brakes	track

Friday

8:00	Assembly and inspection verification	track
9:00	ACCELERATION EVENT	track
10:30	SKID-PAD EVENT	track
12:00	lunch	
1:30	MANUEVERABILITY & FUEL ECONOMY EVENT	track

Saturday

8:00	Assembly and inspection verification	track
8:30	High-Performance practice	track
10:00	HIGH-PERFORMANCE TRACK EVENT - I	track
12:00	lunch	
12:30	High-Performance practice	track
1:30	HIGH-PERFORMANCE TRACK EVENT - II	track
7:30	Banquet	Student Center
9:00	Social	Dry Gulch

Appendix: FORMS

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. _____

Number of additional banquet tickets needed (beyond the 5) _____

SAFETY AND GENERAL INSPECTION

_____	Formula-Style Body	_____	Steering Fasteners
_____	(in) Wheelbase	_____	Suspension Fasteners
_____	(in) Front Track	_____	Braking Fasteners
_____	(in) Rear Track	_____	Control Fasteners
_____	(in) Ground Clearance	_____	Car Numbers
_____	(in) Front Wheel Travel	_____	(gal) Fuel Tank Capacity
_____	(in) Rear Wheel Travel	_____	Refueling Spillage
_____	Roll-Over Protection	_____	Fuel Vent Leakage
_____	(in) Head Clearance	_____	Fire Extinguisher
_____	Roll Bar Braced	_____	Sprocket/Gear Ratios
_____	Safety Belts	_____	(lb) Weight
_____	Safety Helmet	_____	(deg) Tilt Angle With Driver
_____	(in) Wheel Size	_____	Fuel Spillage In Tilt
_____	(in) Tire Size and Type	_____	Safety Wire/Lock Nuts
_____	Brake Skid Demo	Additional Comments:	
_____	Brake Line Protection		
_____	(cc) Engine size		
_____	Oil Leaks		
_____	Scatter Shields		
_____	Kill Switch		
_____	(mm) Carburetor Size		
_____	Throttle Return Springs		
_____	(mm) Restrictor Size		
_____	(dB) Muffler Sound Level		
_____	Exhaust Gas Fumes		

PRESENTATION JUDGING

Score the following categories on the basis of 0-10 points each according to the following scale:

- 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 visible 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:

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 appropriate 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 (i.e., did these members design this car or its systems)?
- _____ 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 techniques that would be used in production. For example, a part might have been machined and welded on the prototype; whereas, the part 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 possible.

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 \$1.00/cc for a high-performance engine (e.g., motorcycle) and \$0.50/cc for an average-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 \$0.80/cc and the external transmission must be figured separately. Engines that come equipped with an integral transmission, differential, and u-jointed axles will be computed based upon \$1.25/cc. 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	\$0.75/weld
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")

COST ANALYSIS

CAR # _____

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
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Total Subassembly Cost _____
