MOTORSPORTS 1: INTRODUCTION TO MOTORSPORTS

Joseph P. Howard[1] and Joseph F. Kmec[2]

Abstract *--- The Mechanical Engineering Technology (MET) Department at Purdue University's School of Technology is developing an upper-level automotive motorsports course for undergraduate students. The course will introduce, inform, and provide students with a theoretical and technical understanding for career entry-level opportunities in CART (see Figure I below), IRL, NASCAR, F1, and related automotive motorsports areas.*

Course topics will include applied selections linked to core MET disciplines such as mechanics, fluid mechanics, thermodynamics, instrumentation, and controls. Topics such as racing engine technology, vehicle dynamics, aerodynamics, and racing strategies, will focus solely on "fundamentals". Because the entire racing "know-how" is not available in-house, use of outside help ranging from guest lecturers to visits of racing and support team facilities is planned. Lab experimentation, some involving full-scale equipment, will be an integral part of the course. It is the author's intent that upon completion of "Motorsports 1," MET students will have the ability to define, describe, and apply, fundamental motorsports/vehicle principles and practices. The purpose of this paper is to describe various aspects of the proposed course, including rationale for developing a course such as Motorsports 1, teaching strategies, and course content.

Index Terms --- MET: Mechanical Engineering Technology; CART: Championship Auto Racing Teams; IRL: Indy Racing League; NASCAR: National Association of Stock Car Automobile Racing; F1: Formula One

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FIGURE I
2002 CART CHAMP CAR DESIGNED AND BUILT BY LOLA CARS OF ENGLAND.

INTRODUCTION "WHY MOTORSPORTS 1?"

The justification behind developing an automotive motorsports course at Purdue University stems from a simple reason: growth. The automotive motorsports industry, both nationally and internationally, is respectably approaching the popularity levels of some of the world's most heavily-watched sports. Interest in automotive motorsports as well as the industry supporting motorsports, is growing.

When interest grows, support for such interest must also grow. Automotive motorsports is extensively supported by a seemingly behind-the-scenes network of sponsors, manufacturers, and highly trained support teams. Engineering, technology, business, and racing know-how are necessary tools that support the industry. Clearly, the basics of such tools are acquired at the university level.

Automotive motorsports is a profit-driven business selling "entertainment" as the product. However, this business of entertaining requires quite a different lot of performers; instead of actors or singers, engineers, engineering technologists, and technicians, are used. The end product, or entertaining principle, is essentially a fully functioning, advanced, high-tech automobile; not unlike the end product of the world's major automobile producers whose support can be traced to advanced education programs like those in Purdue University's School of Technology. The Mechanical Engineering Technology (MET) department within Purdue's School of Technology has in the past been a starting ground for engineering technologists planning to enter the world of automotive design, development, and production. Corporations such as General Motors (GM), Ford Motor Company, and Daimler Chrysler, have recruited students with MET degrees. With continuing improvements in present MET courses and the development of new courses such as *Motorsports 1*, there is good reason to believe that the MET department will continue to serve the engineering technology needs of the entire automotive industry.

Thus, the intent of *Motorsports 1* is not only to meet the needs and interests of automotive motorsports teams and motorsports support industries, but also to act as a supplement to the core practices and tools already in place for supporting world automobile production. To build upon such fundamentals as statics, dynamics, fluid mechanics, and thermodynamics from a performance (motorsports) perspective, will only improve the understanding and

[1] Joseph P. Howard, Dept. of Mechanical Engineering Technology, 1417 Knoy Hall of Technology, West Lafayette, IN 47907-1417, howardjp@purdue.edu
[2] Joseph F. Kmec, Dept. of Mechanical Engineering Technology, 1417 Knoy Hall of Technology, West Lafayette, IN 47907-1417, jfkmec@tech.purdue.edu

application of such topics. In short, knowledge gained from the design, development, and production of high performance automobiles, is transferable to the design, development, and production of street vehicles.

It is the mission of *Motorsports 1: Introduction to Motorsports,* to further support Purdue University's mission of discovery, learning, and engagement. Using this mission, the course will introduce, inform, and provide MET students with a technical and opportunistic understanding of present and future professional employment needs in CART, IRL, NASCAR, Formula One, and other forms of automotive motorsports in Indiana, the United States, and the rest of the world. A summary of these and other course goals are presented in Table I below.

TABLE I
THE 6 GOALS OF MOTORSPORTS 1

Num.	Goal
1	Introduce, convey, and apply fundamental technical principles and practices in current use by professional motorsports companies and industries.
2	Inform students of present and future job area niches for MET graduates in professional motorsports. Briefly explore job opportunities, geographic location, working conditions, and salaries of the motorsports industry.
3	Prepare students for employment in professional motorsports by offering relevant assignments, research topics, and company and team tours.
4	Provide insight into motorsports involvement today and in the future for the state of Indiana, the rest of the United States, and other heavily motorsports-populated countries like England, Italy, Australia, and Japan.
5	Explore, via an independent study, the potential for further motorsports studies (*Motorsports 2: Advanced Topics in Automotive Motorsports*).
6	Deliver MET undergraduates with fundamental theoretical and applications knowledge necessary to succeed in entry-level positions in professional automotive motorsports.

MOTORSPORTS 1: COURSE OUTLINE

Table II below outlines twelve relevant components for the first semester offering of the proposed *Motorsports 1* course. The components were selected based on discussions with representatives from the racing and automotive industries, web-searches of similar programs offered at other universities, and in keeping with the mission of the technology program currently offered at Purdue University. Collectively the components represent a starting point for which further modifications, additions, and subtractions are expected. At this time, no provision for time allotment to each component has been determined. Experience gained and lessons learned from the first offering will influence the time to be allotted to each component.

TABLE II
THE 12 COMPONENTS TO MOTORSPORTS 1

Num.	Component
1	The Role of Automotive Motorsports in the Undergraduate Curriculum
2	History of Automotive Motorsports
3	Automotive Motorsports Classifications: Styles and Racecourses
4	Vehicle Materials
5	Racing Engines
6	Drivetrain: Engine Output Shaft to Wheels
7	Suspension Systems
8	Vehicle Aerodynamics
9	Vehicle Dynamics
10	Data Acquisition and Analysis
11	Racing Theories and Strategies: Calculations
12	Factory Involvement in Automotive Motorsports

Component 1: The Role of Automotive Motorsports in the Undergraduate Curriculum

This first component of *Motorsports 1* will simply introduce the general idea of what the MET department has deemed "automotive motorsports" to mean, and how that topic fits within the MET Bachelor of Science (BS) elective curriculum. The intent here is to convey course content to the students, and to inform the students of the relevancy and importance of the course in the program of study. This component will also present to the students the intended mission, objective, and goals of the course, along with opportunities in automotive motorsports for MET graduates.

At present, "automotive motorsports" is viewed primarily as high performance automobile racing, and is thought to be directly linked to core principles and practices used in street vehicle design, development, and production, but not always identical. One important aspect of the course is to identify differences between the racing and street vehicle designs, while presenting basic concepts using racing vehicle concepts.

The direction of the course will be further expanded upon with presentations on how and where MET graduates fit into the motorsports industry. Potential positions of interest to MET students upon completion of Motorsports 1 (and the MET B.S. degree), will also be explored.

[1] Joseph P. Howard, Dept. of Mechanical Engineering Technology, 1417 Knoy Hall of Technology, West Lafayette, IN 47907-1417, howardjp@purdue.edu
[2] Joseph F. Kmec, Dept. of Mechanical Engineering Technology, 1417 Knoy Hall of Technology, West Lafayette, IN 47907-1417, jfkmec@tech.purdue.edu

Component 2: History of Automotive Motorsports

Component two will deliver historical information. The rich history of automotive motorsports, both in the United States and abroad, will be presented. Subtopics of importance will include the invention of the automobile, design and layout of world-famous racecourses such as the Indianapolis Motor Speedway and the Daytona International Speedway, the birth of motorsports divisions or leagues, and technical milestones that greatly affected the growth and development of motorsports engineering.

A biographical account of the engineers and business leaders contributing to the invention and development of motorsports, and justification behind the building of the Indianapolis Motor Speedway and the Daytona International Speedway will be presented. A more in-depth look into the early years of the automobile, and the test tracks used, will include a study of some foreign racecourses and testing facilities, in addition to their domestic counterparts. The majority of automotive motorsports divisions and the racecourses built, were the direct offspring of manufacturer development projects. Using this approach, an appreciation and understanding of both how, and why, automotive motorsports came to be and what it is today, should follow.

Technical topics linking the racecar and road vehicles will also be presented. Innovations such as the internal combustion engine turbocharger, overhead camshafts, the use of airfoils to create aerodynamic downforce, turbine engine usage, vehicle shape, and lightweight composite materials, will be presented. The important and continuing evolution of safety and safety equipment throughout the history of the automobile, will also be examined.

In general, all relevant historical aspects of automotive motorsports will be presented. A visit to the Indianapolis Motor Speedway Hall of Fame Museum is also planned.

Component 3: Automotive Motorsports Classifications: Styles and Racecourses

The automotive motorsports classifications component will focus primarily on the more popular racing styles and racecourse types. Racing styles include road racing, oval racing, drag racing, off-road racing, endurance racing, land-speed racing, and rally racing. Racecourse types include those circular in nature, straight-line courses, and combination of both of the two.

The selection of racing styles is seemingly infinite. Given the constraints of course delivery time, the intention is to cover the above-mentioned professional racing styles. Although there are numerous other non-professional automotive racing styles or classes, these will be included if time permits. Governing theories for each style of racing will be presented. Such theories or elements include engine performance, handling concepts, and chassis design and construction. At this point, the treatment of such theories will be minimal since such highly technical course components like "Racing Engines," "Vehicle Dynamics," and "Vehicle Materials" have yet to be covered. A more in-depth consideration of such theories and elements will be discussed in their representative component slot.

The racecourse type, whether it be circular, straight-lined, or a combination of both, for each style of racing is to be presented and described as well. The circular nature of left-hand turning ovals (both short and long in circumference) and relevant vehicle set-up and design parameters will be presented. The same will be accomplished for ¼ mile and 1/8 mile straight-line drag racing. The complexities of road and street courses will be explored, taking vehicle set-up and design into consideration for all presentations. As added detail, course banking (grading), course width, course material construction, and spectator safety are topics that will be examined.

Relevant sanctioning bodies and their roles for the many racing styles, as well as common sanctioning rules are to be presented. Rule content will include vehicle design restrictions, development windows, on-track testing, off-track development, competition rules, and typical series practices and standards (regarding the events and happenings of a typical "race weekend").

Again, content limitations of component three will be driven solely by the factor of allotted time. The quantity of and complexity of material for this component alone is extensive. The challenge will be to present the content by drawing upon knowledge that students already have and apply it to a high speed racing environment.

Component 4: Vehicle Materials

Component four will cover materials commonly used in today's top-level automotive motorsports. The materials themselves, construction techniques, and vehicle applications will be discussed. Possible subtopics to this component include design analysis, such as finite element analysis (FEA) and non-destructive testing and inspection. The utilization of existing welding and composite labs is also planned.

Commonly used racecar materials will be introduced. Students will study and understand the material properties for aluminum, magnesium (as shown below in Figure II), titanium, steel alloys, plastics, carbonfiber composite (also shown in Figure II), Kevlar composite, and others. Students will learn why and how specific materials are utilized in certain applications. Students will also learn why and how both parts and components are constructed in the manner they are. In other words, reasons for some designs are based

[1] Joseph P. Howard, Dept. of Mechanical Engineering Technology, 1417 Knoy Hall of Technology, West Lafayette, IN 47907-1417, howardjp@purdue.edu
[2] Joseph F. Kmec, Dept. of Mechanical Engineering Technology, 1417 Knoy Hall of Technology, West Lafayette, IN 47907-1417, jfkmec@tech.purdue.edu

not only on the property of the materials, but on unique outside influences such as the possibility of destruction in a collision, and the effect that collision may have on the occupant. Examples of parts applications may include the use of aluminum as a reinforcing structure (bulkheads) for carbonfiber-composite vehicle body shells. Another example is the use of lightweight steel alloys in vehicle suspensions.

Numerous "example" or "model" vehicle parts are to be utilized in lecture exemplifying the high performance characteristics of such materials. Classroom sample parts shall include (at minimum) a cross-section of carbonfiber honeycomb composite, lightweight steel alloy suspension components, magnesium wheels, and even a plastic driver's helmet. Plans are underway to obtain these items for the first offering of the course.

Construction or fabrication methods for such materials will also be presented and practiced in existing welding and composite labs. Students will have the opportunity to practice skills such as mig welding, tig welding, spot welding, composite lay-ups, and composite repairs.

Lastly, use of an available analysis tool, such as finite-element analysis (FEA) will serve to complete the design, analysis, and fabrication cycle. Present non-destructive testing methods such as magnafluxing shall be introduced. In addition, experts in the field of non-destructive testing will serve as invaluable sources of information as guest lecturers.

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FIGURE II
MAGNESIUM RACECAR WHEEL MANUFACTURED BY O-Z WHEELS, WITH ADJACENT CARBONFIBER BODY PARTS MANUFACTURED BY REYNARD OF ENGLAND.

Component 5: Racing Engines

Component five of *Motorsports 1* will simply build upon pre-existing knowledge gained in MET 426: *Internal Combustion Engines*. With continued offerings of the Motorsports 1 course, representative engines from each of such series as CART, the IRL, NASCAR, NHRA, and F1, will be studied. Studies shall focus on overall engine geometry, such as bore, stroke, compression ratio, air/fuel ratios, and related mechanical systems. Assignments will include comparisons between street and racing engine operation characteristics such as thermal efficiency, valve timing, fuel consumption, pressure vs. volume (P-V) diagrams, and power output. Other major design considerations, which contrast that of a street vehicle, will be discussed. This component will cover topics such as fuels, turbocharging, supercharging, lubrication, and engine control units (ECU's). Lastly, the component will explore common manufacturing practices and the use of tight tolerances and fits associated with racing engine components.

Sandcasting, vertical milling, and lathe machining will be studied from the standpoint of constructing engines and engine parts. Representatives from the field of designing and manufacturing racing engines will also aid in presenting the latest and most innovative methods for manufacturing racing engines. Manufacturing similarities and differences for racing engines and street-vehicle engines will also be explored.

Distinguishing differences and similarities between the engines of professional motorsports will be emphasized. Instruction will focus on major engine features (both similar and contrasting) between the IRL's normally aspirated engine, and F1's normally aspirated engine. And as stated earlier, the engines of CART, the NHRA, and NASCAR will also be explored. Horsepower and torque outputs will be presented, as well as operating speeds and engine geometry. The question of, "How are they producing so much power?" will be studied.

Fuels such as methanol, gasoline, and alcohol will be included. Operating characteristics, properties, and make-up of fuels will also be presented. Forced induction systems like turbocharging and supercharging will be analyzed from the basis of CART and the NHRA. Again, operating characteristics will be considered, as well as specifications of such performance parts to a given engine. Lubrication theories and practices will be presented to contrast and parallel those of street vehicles. Engine control from the standpoint of the ECU will be explored as well.

[1] Joseph P. Howard, Dept. of Mechanical Engineering Technology, 1417 Knoy Hall of Technology, West Lafayette, IN 47907-1417, howardjp@purdue.edu
[2] Joseph F. Kmec, Dept. of Mechanical Engineering Technology, 1417 Knoy Hall of Technology, West Lafayette, IN 47907-1417, jfkmec@tech.purdue.edu

Component 6: Drivetrain: Engine Output Shaft to Wheels

Mechanisms transferring power from the output shaft of the engine to the wheels, commonly referred to as drivetrain, will be incorporated into this component. The gearbox / transmission and the differential will be described, analyzed, and disassembled. Figure III below shows a CART Champ Car in various stages of disassembly. Note the cover placed on the engine section. The racing community is very competitive and takes active measures to protect its won innovations. This practice presents a challenge to introduce new technology in an academic setting. Nevertheless, efforts to present the latest engine and transmission know-how will be made. Students will study typical gear ratios and gear ratio selection, both within the gearbox, and differential. It is anticipated that two or three example gearboxes will be available for student inspection and/or disassembly and reassembly.

Typical gear ratios, at given engine speeds, will be presented for both the gearbox and differential. Necessary skills and calculations will be presented to choose proper gearing, given such inputs as engine speed, racecourse configuration, racecourse low and top speeds, and any other necessary input parameters.

In addition, common practice regarding gearbox builds and rebuilds will be discussed. This will include approaches and methods used in assembling and disassembling gearboxes, as well as items of interest like part materials, design configurations, and lubrication requirements.

Lastly, a gearbox mechanic or gearbox manufacturer representative is planned to serve as a guest lecturer.

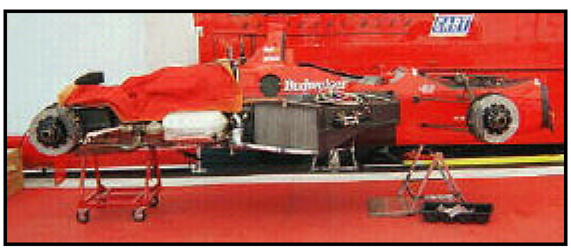

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FIGURE III
PARTIALLY DISASSEMBLED 1999 CART CHAMP CAR DESIGNED BY SWIFT ENGINEERING.

Component 7: Suspension Systems

Component seven will introduce aspects of suspension systems such as tuning and development, and the cause and effect relationships associated with adjustments. Suspension system tuning will include a working knowledge of camber, toe, caster, ride height, and anti-roll bars. The effects of tires, shock absorbers, and springs will also be studied. Further study may involve suspension geometry design such as motion ratios, and even steering geometries. Passive and active suspension systems, as well as semi-active suspension systems, will be introduced as well.

Fundamental suspension tuning will be analyzed and demonstrated. Example problems regarding which suspension parameters are to be tuned in given vehicle situations, and to what extent, will be demonstrated. Students will be able to demonstrate such problem-solving abilities on available lab automobiles, or on an available lab racecar. Plans to secure a fully equipped racecar are being pursued.

Tire operating characteristics and tire construction will be introduced. Along with tires, springs and shocks will be studied in detail. The working relationship between tires, springs, and shocks, will be covered. Adjustment options, tuning procedures, and overall working-theory fundamentals, will be presented from the basis of statics and dynamics. Fluid dynamics will be used to study the inner workings of the shock absorber. A “shock absorber dynamometer” for use in a lab setting within the MET department will be explored. Here, shock absorber performance curves can be studied, as well as advanced testing through “discover tuning.” A guest visit to the Auto Research Center’s (ARC) seven-post vehicle dynamics rig in Indianapolis is also planned.

A guest lecturer or in-house specialist on active, semi-active, and passive suspension systems will be sought. In some forms of motorsport and some street vehicles, active suspension is an important consideration of handling. An expert from this field will be sought.

Component 8: Vehicle Aerodynamics

General vehicle / racecar aerodynamic theory shall be presented based on related coursework offered in the course MET 313: *Fluid Mechanics*. Mechanisms of vehicle aerodynamics are to be introduced, defined, and manipulated. Aerodynamic enhancements such as airfoil, airfoils with endplates, vehicle undertrays (which includes entryway vortex generators and exitway diffusers), and vehicle center of pressures, will be studied. Aerodynamic lift and drag will also be defined and utilized. Vehicle stability and handling will be discussed as a direct correlation with vehicle aerodynamics. Additional topics will include the fluid mechanics and aerodynamics surrounding radiator cooling, aerodynamic tire drag, and “drafting.”

[1] Joseph P. Howard, Dept. of Mechanical Engineering Technology, 1417 Knoy Hall of Technology, West Lafayette, IN 47907-1417, howardjp@purdue.edu
[2] Joseph F. Kmec, Dept. of Mechanical Engineering Technology, 1417 Knoy Hall of Technology, West Lafayette, IN 47907-1417, jfkmec@tech.purdue.edu

Airfoils, or "wings," are a large factor in creating both downforce and drag in automotive motorsports. Many motorsports classifications allow the use of both front and rear "wings" (airfoils). Overall vehicle aerodynamics are constrained by the operations of both the front and rear wings. Their influence on vehicle stability, handling, and engine output, is significant, and will be studied.

The study of vehicle undersides, or "undertrays," shall be introduced. Entryway vortex generators and exitway diffusers will be studied from the basis of creating vehicle downforce. The combination or corollary relationships between undertrays and airfoils will also be studied. Vehicle ride heights, also a key factor in developing downforce via the use of the undertray, will be explored.

The term, "center of pressure," will be defined and later calculated. Adaptation of such practices will be utilized in predicting /developing improved vehicle handling and stability theories.

Advanced topics, including the effects of aerodynamics on engine / radiator cooling, and vice-versa, will be presented. Further aerodynamic considerations will involve such mechanisms as flugels, sidepods, multiple airfoils in "wing" use, and the aerodynamic effect of tires on wheel design. Common practices in aerodynamic testing will also be described as shown below in Figure IV.

FIGURE IV
AEROMDYNAMIC TESTING OF A 40% SCALE MODEL RACECAR AT THE AUTO RESEARCH CENTER (ARC) IN MOORESVILLE, NC.

Component 9: Vehicle Dynamics

General knowledge gained in MET 111: *Statics*, and MET 213: *Dynamics*, is to be used for further study under component nine, Vehicle Dynamics. General topics in vehicle performance, handling, stability, and ride will be covered. Using fundamental analysis tools such as free-body diagrams, vehicle forces and moments will be analyzed for vehicles in motion. Topics such as acceleration, road-load horsepower, center of gravity location, cornerning, ride height, tires, spring and shock absorber selection, and tire performance will be presented. Both racecars and street vehicles will be studied in this component.

A computer model of the combined engine and transmission unit will be introduced. The model will be used to simulate vehicle acceleration and deceleration on track straights and banked turns. Such a model will also be used to predict fuel consumption. A long-term goal of the vehicle simulation exercise will be to compare computer model performance with that of an actual vehicle.

Advanced topics of study shall include presentation and study of how vehicle handling parameters, such as shock absorbers, are tuned in common developmental practices. The "seven-post vehicle dynamics rig," as shown below in Figure V, will be used as a source of developmental reference for study in this area.

Although this component of *Motorsports 1* is invaluable for working engineers in the field, again, development of expertise in this component is not the intention. This component is intended to serve as a sound baseline for further study in vehicle dynamics. One such possibility is a course presently offered in Mechanical Engineering at Purdue University, ME 565: *Vehicle Dynamics.*

FIGURE V
SEVEN-POST VEHICLE DYNAMICS RIG AT THE AUTO RESEARCH CENTER (ARC) IN INDIANAPOLIS, IN.

Component 10: Data Acquisition and Analysis

Data acquisition is a commonly used tool in tuning and developing racecars and street vehicles. Instrumentation, data gathering methods, and analysis, are all relevant skills for such development. Building upon past knowledge gained in the required course, MET 382: *Controls and Instrumentation for Automation*, much of the learning is intended to be hands-on using available lab space, computers

[1] Joseph P. Howard, Dept. of Mechanical Engineering Technology, 1417 Knoy Hall of Technology, West Lafayette, IN 47907-1417, howardjp@purdue.edu
[2] Joseph F. Kmec, Dept. of Mechanical Engineering Technology, 1417 Knoy Hall of Technology, West Lafayette, IN 47907-1417, jfkmec@tech.purdue.edu

(or laptops), and data acquisition software similar to LabView.

The analysis of engine data, aerodynamic data, and shock absorber data, is relevant to both racecar and street vehicle development. Before analysis however, an understanding of instrument or sensor operation, and proper methods of implementation, will be explained. Emphasis will be given to sensors and measurement. Potential sensors to be examined include linear potentiometers, rotary potentiometers, thermocouples, pitot-static tubes, ride-height laser sensors, as well as others.

A majority of the time will be spent analyzing actual recorded data, as well as drawing conclusions from the data. It is intended that knowledge gained in component nine, Vehicle Dynamics, will only be built upon once the students begin analyzing recorded data from real racecars and street vehicles.

Commonly used motorsports data acquisition software is to be implemented for educational use in a lab environment; more specifically, data acquisition software such as that developed by Pi Research. A working knowledge of such commonly used motorsports software will only add to the overall value of a graduating MET student.

Component 11: Racing Theories and Strategies: Calculations

Component eleven will address what actually happens at the track (on-track) on a race weekend, and how development / vehicle tuning decisions are made. Vehicle preparation, on-track engineering decisions, qualification tuning, pitstop / fuel strategies, telemetry analysis, and a handful of other on-track duties will be presented. Because actual on-track experience is not planned at this point in the course's developmental stages, guest speakers such as track engineers, team managers, and crew chiefs, will be utilized.

Some of the topics these individuals will address include first-hand experiences dealing with issues such as: Who makes what decisions? How many engineers are used per racecar? Is a translator needed to communicate with the foreign racecar driver? Will the gearbox mechanic have adequate time to change the gearing before qualifications begin? How much fuel should the team keep in the car while tuning for predicted raceday conditions? Should the assistant engineer be moderating tire pressures, or brake caliper temperatures on a 90°F July afternoon? Who monitors fuel mileage? Will elevation be a factor on engine performance in a street race in Denver, Colorado? Finally, the difference between "practice" and "qualifying" rounds will be explored. The intent is to provide students with as much on-track knowledge, before they actually encounter such a working environment, as shown below in Figure VI.

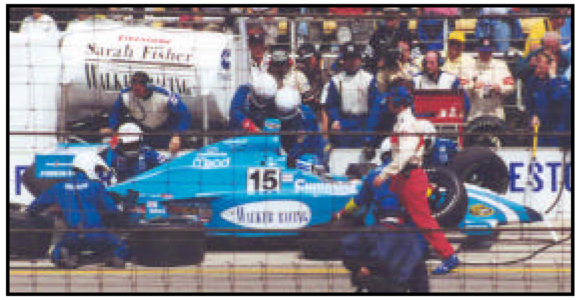

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FIGURE VI
DALLARA INDY CAR IN THE PITS AT THE 2000 INDIANAPOLIS 500.

Component 12: Factory Involvement in Automotive Motorsports

This last component will entail the working relationships between major automobile manufacturers and automotive motorsports. Sometimes, the working relationship between teams and corporations is directly linked through ownership and engineering. Still other times, the only relationship that exists lies in the swapping of equipment and cash.

There are situations where corporations have actually owned complete race teams, and operated the team with individuals (engineers and managers) handpicked directly from industry. Other arrangements include a working relationship between the corporation and the team, where team engineers and company engineers actually collaborate. In addition, the management of the team also collaborates with advisors sent from corporate headquarters.

Thus, corporations act as sponsors, providing funding in exchange for advertising. Corporations use motorsports as "developmental programs" as well, where, for example, a corporate engine manufacturer will build race-winning engines to signify competitive dominance among its competitors. Still other relationships may involve a corporation supplying equipment to every racecar within a given race series, such as a tire company providing the same make of tires to every race team in the pit. Providing students insight into what can be an endless number of arrangements is an important aspect of the course.

Lastly, the influence of unexpected outside factors will be presented. Such factors include the influence of the economy on corporate / team relationships, the threat of war, tobacco legislation, alcohol laws, television programming, and even celebrity involvement. All these factors and a handful of others are significant catalysts in corporate / team

[1] Joseph P. Howard, Dept. of Mechanical Engineering Technology, 1417 Knoy Hall of Technology, West Lafayette, IN 47907-1417, howardjp@purdue.edu
[2] Joseph F. Kmec, Dept. of Mechanical Engineering Technology, 1417 Knoy Hall of Technology, West Lafayette, IN 47907-1417, jfkmec@tech.purdue.edu

relationships and have had an influence on the success and/or demise of racing teams.

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[1] Joseph P. Howard, Dept. of Mechanical Engineering Technology, 1417 Knoy Hall of Technology, West Lafayette, IN 47907-1417, howardjp@purdue.edu
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