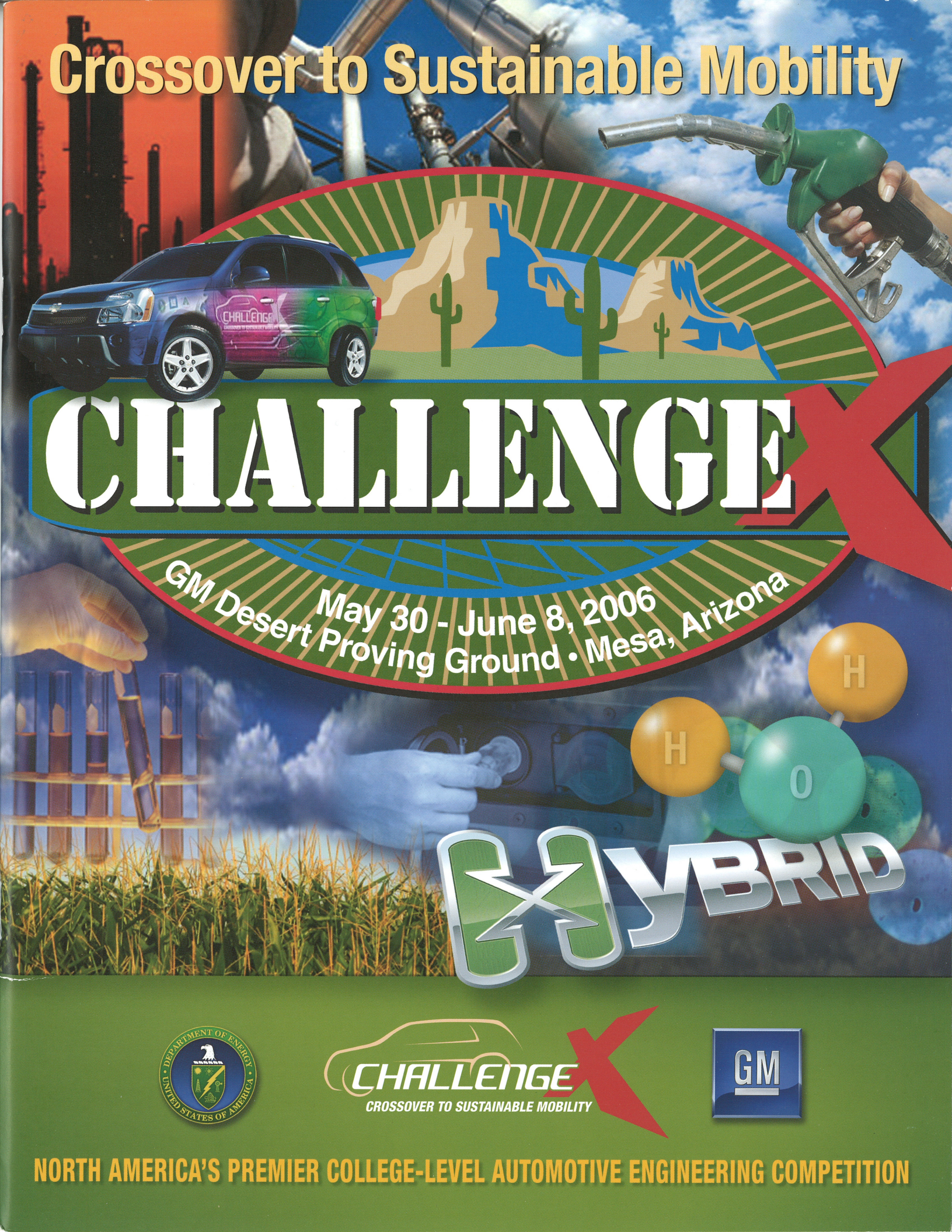
Crossover to Sustainable Mobility



DEPARTMENT OF ENERGY • UNITED STATES OF AMERICA •

CHALLENGE X
CROSSOVER TO SUSTAINABLE MOBILITY

GM

NORTH AMERICA'S PREMIER COLLEGE-LEVEL AUTOMOTIVE ENGINEERING COMPETITION

CHALLENGE X
CROSSOVER TO SUSTAINABLE MOBILITY

Dear Year Two Competitors and Friends of Challenge X,

We are pleased to welcome you to the General Motors Desert Proving Ground for the 2006 Challenge X competition.

With concern over prices for petroleum at high levels, it has never been more important to develop sustainable mobility technology. We owe it to ourselves and future generations to find creative and affordable ways of improving energy efficiency and reducing the environmental costs of personal mobility. Those of you who are participating in Challenge X find yourselves on the leading edge of a technology development challenge to provide the attributes and functionality that consumers demand while shifting the automotive paradigm towards sustainability. Getting to this point in the Challenge required very serious hard work, dedication, and a real sense of responsibility to this competition and to the future. We salute and congratulate all of you who have reached this milestone!

As a member of a Challenge X university team, your hard work in academics and practical hands-on learning in engineering has provided you with an unparalleled experience that paves the path for your career in engineering with a real competitive advantage. This is experience money can't buy. Challenge X gives you the tools you need to pursue your personal goals while working to address North America's pressing need for improved energy efficiency. This competition allows you to make engineering decisions in the context of a realistic industry procedure, GM's Global Vehicle Development Process, and equips you with a wide range of skills that you'll need in order to be a successful engineer.

In the first year of competition, you used math-based modeling to compare and select the advanced technologies that you have chosen for your propulsion and supporting subsystems. As a team, you made the tough trade-offs, decided on a direction, and started to implement that design into your "dream machine." Now in Year Two of Challenge X, that machine is ready to be put to the test.

Your unique and innovative design approaches to reengineer the 2005 Chevrolet Equinox will be challenged and scrutinized this week. Meeting the three goals of increasing energy efficiency, reducing the environmental impact, and maintaining the performance and utility features of the stock vehicle is the essence of the vision for this three-year competition. This year's competition focuses on powertrain integration and development, and determining how closely your vehicle comes to the energy use and emissions goals of the competition. Your team vehicles will be tested extensively in categories such as braking, acceleration, greenhouse gas impact, total well-to-wheels fuel economy, emissions, and towing capacity. You will also be required to give technical presentations on your overall vehicle design as well as your control strategy, pass through a Vehicle Design Review with some of GM's top engineers, and submit an SAE-style technical paper detailing your overall design. The results of this second year of Challenge X will let you know how much farther you have to go to achieve your team's goals in the final year of competition.

Although what the organizers and sponsors have asked you to do is difficult, we are impressed with the high level of effort that you have put into this project thus far and are looking forward to seeing what great things you accomplish this year on your drive to develop the vehicles that will carry us to a sustainable mobility future. Good luck to all of you as you compete in this year's rigorous competition!

To our friends in government, industry, and academia who have supported the hundreds of students involved in this project, we salute you, too. Your mentoring, advising, guidance, and sponsorship have been exceptional and have helped these students learn not only about real-world engineering design and development, but also how a partnership of committed companies and organizations can successfully join together to solve issues of interest to all. Crossing over to sustainable mobility is truly a challenge that we can be proud to take on together!

Tom Stephens, Group Vice President,
GM Powertrain and
Chair of GM's Energy and
Environmental Strategy Board

Alexander Karsner,
Assistant Secretary
Energy Efficiency and Renewable Energy,
U.S. Department of Energy

THE CHALLENGES

The ***freedom*** *that personal* ***mobility*** *provides is a building block of North America's culture and strength. Over the last decade, the United States automotive market has trended toward purchasing larger vehicles. At the same time, there has been an increased emphasis on* ***reducing vehicle emissions*** *and a growing concern over petroleum consumption. The issues of* ***energy efficiency****,* ***global climate change****, and cleaner air pose challenges not only in the United States, but across the globe. To address these challenges, government, industry, and academia have sponsored* ***Advanced Vehicle Technology Competitions*** *aimed at college and university engineering students to extend the progress toward and demonstrate the feasibility of achieving a common goal:* ***sustainable mobility****.*

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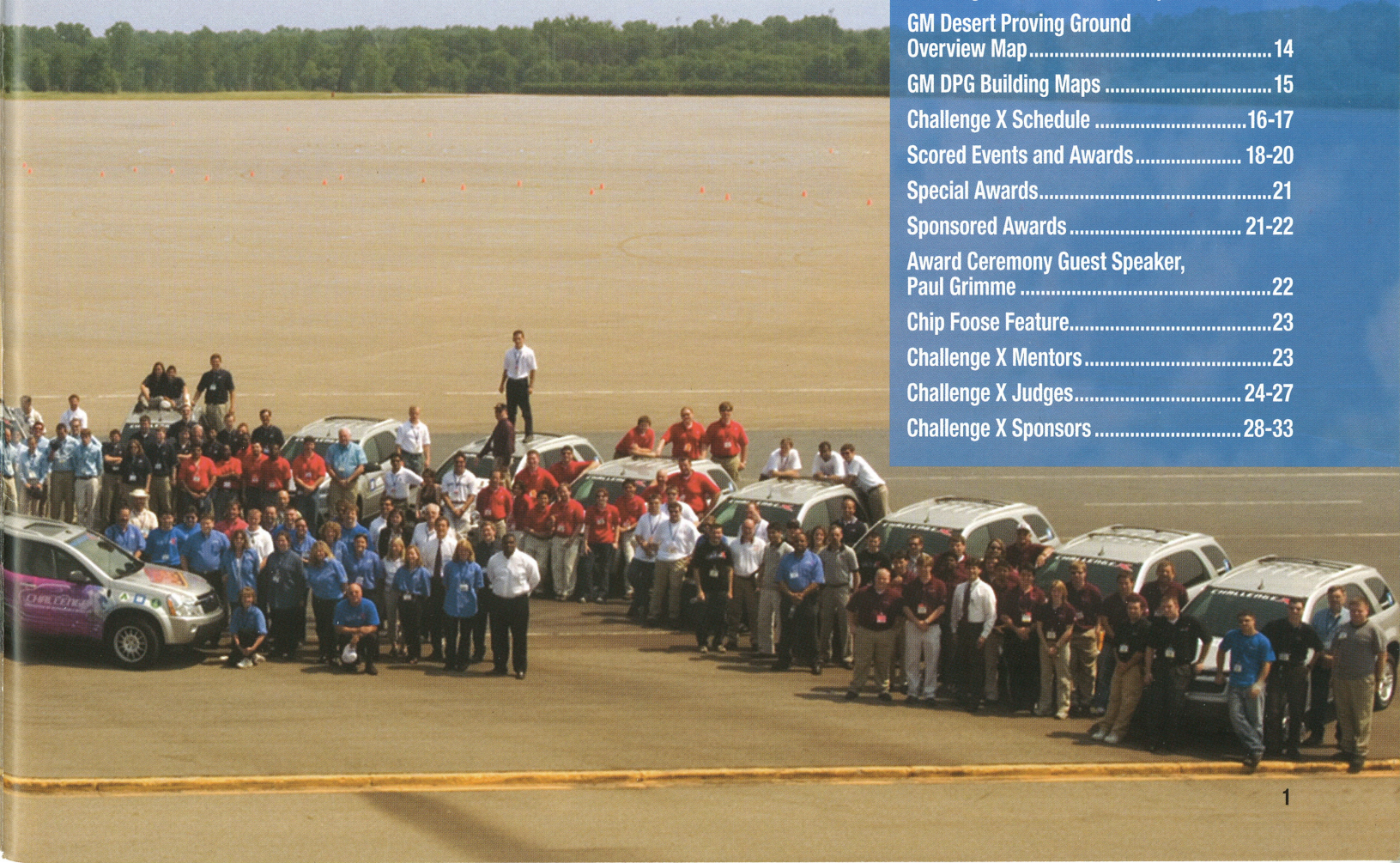


INTRODUCING CHALLENGE X

Since 1987, the U.S. Department of Energy (DOE), Natural Resources Canada, and various academic and industry partners have sponsored more than two dozen university-level advanced vehicle student engineering competitions. Building on the success of these programs, DOE has partnered with General Motors Corporation (GM) as the headline sponsors of Challenge X: Crossover to Sustainable Mobility.

Students are following GM's real-world Global Vehicle Development Process (GVDP) to design, develop, and integrate their advanced technology solutions into a Chevrolet Equinox, a GM crossover vehicle. Each of the seventeen university teams selected through a competitive proposal process has an opportunity to participate in hands-on research and development with leading-edge automotive propulsion, fuels, materials, and emissions-control technologies. GM has provided 2005 Chevrolet Equinoxes, $425,000 in additional production parts, $220,000 in seed and prize money, engineering mentoring, competition facilities and operation support. DOE provides competition management, team evaluation, and technical support. More than 300 univerisity participants and more than 30 private and public organizations have joined with DOE and GM to support this innovative engineering program.

Turning a paper design into a functioning prototype vehicle is the goal of the teams in this second year.

Each of the three years of Challenge X emphasizes one of the three distinct phases of the GM GVDP. Year one focused on the use of math-based modeling tools for vehicle design and vehicle and subsystem control. Through the use of these tools, teams spent their first year of competition researching and comparing advanced technologies, and by the end of the first year, each team had chosen their own unique powertrain architecture. Now in the second year, teams have been integrating, controlling, and testing their powertrain designs. Turning a paper design into a functioning prototype vehicle is the goal of the teams in this second year. As they transform their virtual design into reality, students continue to use the computer-based math modeling tools developed in year one to assist with the refinement and calibration process of their Challenge X entry. With the help of Challenge X sponsors, many different products and solutions were made available to enable and support the students' integration efforts of year two. For the final year of Challenge X, teams will continue to develop and calibrate their vehicles, refining them to pre-production concept vehicle levels while realizing their full performance potential.

This year's competition, held May 31 – June 8, at GM's Desert Proving Ground in Mesa, Arizona, is the setting for an extensive set of events designed to measure the vehicles' performance and how much the teams have learned. Teams are required to pass a rigorous safety and technical inspection prior to participating in the competition's dynamic events. From there, a demanding set of events will measure each vehicle's capabilities in braking, handling, acceleration, fuel economy, criteria tailpipe and greenhouse gas (GHG) emissions, drive quality, and trailer towing performance. Teams will also be judged through technical design presentations, a vehicle development review, an assessment of their control strategies, and a variety of written reports.

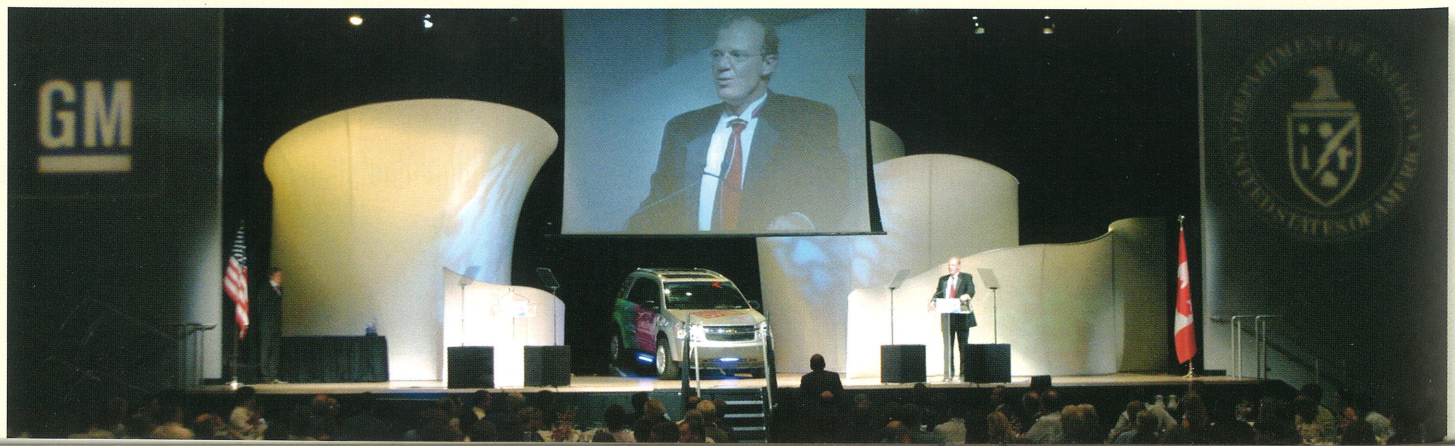
CHALLENGE X TECHNOLOGIES

The teams in the Challenge X competition are employing many novel ideas, approaches, and technologies that (1) provide near-term and long-term solutions to significantly reduce wells-to-wheels energy consumption, (2) reduce petroleum energy consumption and emissions (on a total fuel cycle basis), (3) significantly reduce criteria tailpipe and GHG emissions, and (4) increase pump-to-wheels fuel economy. All the teams selected hybrid vehicle designs—some of which go beyond those being considered by original equipment manufacturers—for their student-modified vehicles, spanning the gamut of parallel, through-the-road, and series hybrid electric vehicle (HEV) configurations. These HEVs employ state-of-the-art nickel metal-hydride and lithium-ion battery packs. One team has chosen a "charge-from-the-wall" plug-in hybrid electric vehicle HEV configuration to extend the electric vehicle range of its Equinox to over 40 miles. A variety of advanced electric drive systems are employed by the teams to enable HEV features—such as regenerative braking, high-load electric assist, and engine transient smoothing—to improve vehicle-level efficiency and driveability.

Engine selections in Challenge X have been dominated by highly efficient diesels and turbocharged spark-ignited engines operating on bio-based fuels, such as E85 (85% ethanol) and B20 (20% biodiesel), representing near-term approaches to improved efficiency. More advanced engines, such as highly dilute and boosted spark ignition engines and hydrogen-assisted ultra-lean burn combustion strategies, represent more long-term approaches. The teams are combining these advanced power units with emerging exhaust gas after-treatment technologies to reduce criteria emissions and total GHG production (such as selective catalytic reduction to control oxides of nitrogen emissions and catalyzed particulate filters).

In addition, there are five teams whose designs include the use of Hydrogen as a second fuel, and one team employing a fuel-cell as its primary propulsion system. The other teams are using fuel cell auxiliary power units to power air conditioning and other parasitic loads as well as aid in HEV propulsion.

From the wealth of advanced technologies employed in the Challenge X vehicles, it is apparent that these student-designed approaches truly represent the future of automotive powertrain development.



Challenge X 2006 Team Technologies and Configurations

TEAM	HEV ARCHITECTURE	ENGINE	FUEL	TRANSMISSION	ENERGY STORAGE	MOTOR
Michigan Technological University	Through-the-road Parallel Hybrid	2.0-L Ford Spark Ignited	Reformulated Gasoline	Ford Getrag MMT6 6 Speed Manual	COBASYS Nickel Metal Hydride - 336V	50 kW Solectria AC Induction
Mississippi State University	Through-the-road Parallel Hybrid	1.9-L GM Direct Injection Turbodiesel	Bio Diesel (B20)	GM F40 6 Speed Manual	Johnson Controls Nickel Metal Hydride - 330V	67 kW Ballard AC Induction
Ohio State University	Through-the-road Parallel Hybrid	1.9-L GM Direct Injection Turbodiesel	Bio Diesel (B20)	AISIN 6 Speed Automatic	Panasonic Nickel Metal Hydride - 345V	67 kW Ballard AC Induction
Pennsylvania State University	Continuously Variable Power Split Hybrid	1.3-L GM Direct Injection Turbodiesel	Bio Diesel (B20)	GM Continuously Variable Power Split	Lithium Tech Lithium Ion - 316V	21 kW Solectra AC Induction
Rose-Hulman Institute of Technology	Power Split Hybrid	2.5-L VM Motori Direct Injection Turbodiesel	Bio Diesel (B20)	Power Split Gearbox	COBASYS Nickel Metal Hydride - 336V	(2) Azure 78 kW AC Induction
San Diego State University	Through-the-road Parallel Hybrid	1.9-L GM Direct Injection Turbodiesel	Bio Diesel (B20)	GM F40 6 Speed Manual	Hawker Lead Acid - 336V	150 kW AC Propulsion AC Induction
Texas Tech University	Through-the-road Parallel Hybrid	2.2-L GM 100 kW Spark Ignited/10 kW Fuel Cell	E85/ Hydrogen	GM 4 Speed Automatic	COBASYS Nickel Metal Hydride - 336V	45 kW Ballard Integrated Power Transaxle
University of Akron	Through-the-road Parallel Hybrid	1.9-L VW Direct Injection Turbodiesel	Bio Diesel (B20)	VW 6 Speed Direct Shift Gearbox	Johnson Controls Nickel Metal Hydride - 165V/ Maxwell Ultracaps	21 kW Siemens AC Induction
University of California, Davis	Through-the-road Parallel Plug In Hybrid	1.5-L Toyota Atkinson Cycle Spark Ignited/ 10 kW Fuel Cell	E85/Hydrogen	Nissan Continuously Variable	LIthium Tech Lithium Ion Nickel Metal Hydride - 350V	30 kW Unique Mobility AC Permanent Magnet
University of Michigan	Series Hydraulic Hybrid	1.9-L GM Direct Injection Turbodiesel	Bio Diesel (B20)	Hydraulic Pump	15 gal. Hydraulic Accumulators	Hydraulic Motor
University of Tennessee	Through-the-road Parallel Hybrid	1.9-L GM Direct Injection Turbodiesel	Bio Diesel (B20)	GM F40 6 Speed Manual	COBASYS Nickel Metal Hydride - 336V	67 kW Ballard AC Induction
University of Texas at Austin	Belt-driven Alternator/Starter	1.9-L GM Direct Injection Turbodiesel	Reformulated Gasoline/Bio Diesel (B20)	GM F40 6 Speed Manual	Johnson Controls Nickel Metal Hydride - 40V	5 kW Hitachi AC Induction BAS
University of Tulsa	Through-the-road Parallel Hybrid	1.9-L GM Direct Injection Turbodiesel	Bio Diesel/ Hydrogen	GM F40 6 Speed Manual	COBASYS Nickel Metal Hydride - 288V	67 kW Ballard AC Induction
University of Waterloo	Series Fuel Cell Hybrid	65 kW Hydrogenics PEM Fuel Cell	Hydrogen	Fixed Gear Reduction	COBASYS Nickel Metal Hydride - 336V	67 kW (2) Ballard AC Induction
University of Wisconsin – Madison	Through-the-road Parallel Hybrid	1.9-L GM Direct Injection Turbodiesel	Bio Diesel (B20)	GM F40 6 Speed Manual	Johnson Controls Nickel Metal Hydride - 330V	45 kW Ballard Integrated Power Transaxle
Virginia Tech	Split Parallel	2.0-L GM Saab Turbo Spark Ignited	E85/Hydrogen	GM 5 Speed Manual	COBASYS Nickel Metal Hydride - 336V	67 kW Ballard AC Induction
West Virginia University	Through-the-road Parallel Hybrid	1.9-L GM Direct Injection Turbodiesel	Bio Diesel (B20)	AISIN 6 Speed Automatic	Maxwell Ultracap 750 kJ	(2) 13 kW AC Induction Wheel Hub Motors




CHALLENGE X TEAM DESCRIPTIONS

Michigan Technological University

Faculty Advisor: John Beard
Team Leaders: Chad Morrison, Todd Cimermancic

Team Structure The MTU Team is led by two team members who are responsible for overseeing the project and delegating responsibilities. Beneath the two team leaders are several project leaders in charge of subgroups, including Modeling, Powertrain, Vehicle Build, Cooling, Electrical, Weight Savings, and Consumer Acceptability. Each week, a general meeting is led by both team leaders, followed by a technical meeting where project leaders can discuss work in progress as well as weekly goals. The entire team relies on a Gantt chart for completing semester- and year-long goals, and weekly tasks are put on a team action list.

Overall Design Strategy The MTU Challenge X Equinox is a through-the-road parallel hybrid. The front wheels of the MTU Equinox are powered by a Ford 2.0-L gasoline engine mated to a 4-speed automatic transmission. The gasoline engine is assisted by a Solectria electric motor that powers the rear wheels. The combination of gasoline and electric power allows the MTU team to improve fuel economy, reduce regulated emissions, and maintain drivability. The vehicle will retain all the comfort features of the stock Equinox while utilizing advanced technology and lightweight components, including composite brake rotors, lightweight GM seats, and polycarbonate windows. The goal is to maintain the functionality of the stock Equinox while improving its appeal to consumers.

Mississippi State University

Faculty Advisors: Marshall Molen, Hossein Toghiani, Bill Jones
Staff Advisors: Bob Kirkland, Zach Rowland
Team Leader: David Oglesby

Team Structure The Mississippi State University Challenge X Team members are divided among administrative and technical areas. The administrative side of the team consists of a business group lead by David Oglesby and Bill Bain, an outreach activities group lead by Amanda McAlpin, and a safety group led by Christy Burton. The technical side of the team consists of an electrical group led by Ron Lewis, a powertrain group led by Christopher Whitt, a mechanical group led by Brian Christian, and a modeling & controls group le d by Jimmy Mathews and Kennabec Walp.

Overall Design Strategy The MSU cX Team's design strategy consists of building a split-parallel, through-the-road, hybrid electric Equinox that is charge sustaining, consumer acceptable, production feasible, and capable of meeting both the team's and competition's performance requirements. The MSU Equinox will incorporate a 1.9-L GM Diesel engine fueled with B20 biodiesel powering the front axle and a Ballard AC induction electric drive and Johnson Controls NiMH battery pack driving the rear axle.

Ohio State University

Faculty Advisors: Dr. Giorgio Rizzoni, Dr. Shawn Midlam-Mohler, Frank Ohlemacher
Team Leader: Courtney Coburn

Team Structure The Ohio State University Challenge X team is organized into several subgroups that focus on a particular aspect of the vehicle. These subgroups include Powertrain, Electrical Systems, Control Strategy Development, Systems Integration, Modeling and Simulation, and Telematics. Each subgroup has a leader that reports to the team leader. Comprised of mostly undergraduate students, the majority of the team members are studying either mechanical or electrical engineering. With the guidance of faculty advisors, the team utilizes numerous pertinent contacts within industry and the university.

Overall Design Strategy The Ohio State University Challenge X Team has developed a power-split hybrid electric vehicle. Powering the front axle is a downsized diesel engine coupled with a starter/alternator, while a larger electric motor powers the rear axle. A NiMH battery pack provides the necessary 345 nominal voltage to the powertrain. With this configuration, start/stop, electric launch, load shifting, traction control, regenerative braking, as well as other unique modes of operation are realized to increase the fuel efficiency of the vehicle. To reduce emissions, a unique system using lean nitrogen oxide traps (selective catalytic reduction) developed at Ohio State is employed. A unique supervisory control strategy centered around equivalent consumption, battery state-of-charge, and drivability appropriately manages all vehicle components to meet the team's desired technical and performance specifications.

Pennsylvania State University

Faculty Advisors: Dr. Dan Haworth, Gary Neal
Team Leaders: Matt Shirk, Brian Herrold, Haftay Hailu

Team Structure The PSU Advanced Technology Vehicle Design team is divided into six substructures: Engine, Emissions, Electric Drive, High Voltage Electronics, Transmission, and Controls & Electronics. Each group is responsible for designing and manufacturing systems within each specific project. One group leader from each substructure reports to the advisors and team leaders.

Overall Design Strategy The PSU Advanced Technology Vehicle Design team designed the Chevy Equinox Hybrid with the goal of improving fuel economy and "wells-to-wheels" greenhouse gas and criteria emissions. This goal was considered in every aspect of design while maintaining the performance, utility, safety, and features demanded by the consumer.

CHALLENGE X TEAM DESCRIPTIONS

Rose-Hulman Institute of Technology

Faculty Advisors: Dr. Zac Chambers, Dr. Marc Herniter
Team Leaders: Clint Hamme, Brian Roser, Matt Devries, Todd Richard, Javid Khan

Team Description Rose-Hulman's team consists exclusively of undergraduate students working with our two faculty advisors. In terms of class year, our team has 59 students with 26 seniors, 22 juniors, and 11 sophomores. We have 30 Mechanical Engineers, 20 Electrical Engineers, and 9 students of other majors at Rose-Hulman. We actively recruit sophomores, juniors, and seniors of all majors.

Our team is divided into five groups, each led by a student project leader: Mechanical Systems Integration, Electrical Systems Integration, Control Systems Integration, Engine & Emissions Systems Integration, and Administration. The five project leaders work closely with the faculty advisors. Finally, a rigorous implementation of a Gantt chart has been adopted to keep the team on track.

Overall Design Strategy Rose-Hulman is using a power-split architecture. We have two Azure 78 kW Electric Machines connected to a transfer case with a 2.5-L VM Motori Diesel engine that are all connected to a Planetary Gear Set, which serves as an electrically variable transmission. This system is hooked up to the road through a Pontiac GTO suspension using exclusively rear wheel drive.

San Diego State University

Faculty Advisor: Dr. Jim Burns
Team Leader: Frank Falcone

Team Description The San Diego Sustainable Mobility Team has adopted a fairly conventional structure utilizing one team lead and several smaller self-directed teams of two to three. For example, engine integration, motor design/integration, and controls are handled by three separate defined teams, with the team lead being part of the controls team. Given the small size, the mid-management layer, which consisted of team coordinators, was eliminated. Other peripheral tasks (such as energy storage packaging) are typically handled by volunteers with varying levels of time investment. Remaining tasks are assigned to existing teams.

Overall Design Strategy The vehicle architecture supports a high (power-ground) coupled diesel electric hybrid. The engine is a GM 1.9-L turbo diesel coupled with a 150kW AC Propulsion AC induction motor and Mototron controller for higher level logic and control. The GM ECU is retained. The SDSMT's strategy is two tiered for years two and three.

In year two, a low-risk standard stick shift strategy will be implemented. The engine will be assisted by the motor. The primary focus is to recapture braking energy to then return it to the system, thus boosting over all efficiency. Performance will be enhanced and emissions offset as recaptured energy displaces that of the chemical nature. In year three, as we integrate deeper energy storage and more advanced controls, off idle and electric-only functionality will further increase efficiency and emissions reduction. Shifting will be automated.

Texas Tech University

Faculty Advisors: **Dr. Tim Maxwell and Dr. Michael Parten**
Team Leaders: **Brion Owens, Thomas Gates**

Overall Design Strategy The TTU Challenge X team will convert a Chevrolet Equinox into a hybrid electric vehicle powered by the GM 2.2-L I–4 (L61) SI engine fueled with both hydrogen and E85. The vehicle will have a 2–by–2 or through-the-road hybrid configuration, with the engine powering the front axle and the Ballard electric motor powering the rear axle.

The COBASYS NiMH battery pack will provide energy storage and electric power to the motor. The Hydrogenics 10-kW proton exchange membrane (PEM) fuel cell will provide power for any electrical accessories and will charge the batteries as needed. To maintain the high-voltage battery pack's state of charge, the pack will be charged primarily through the road with some help from the fuel cell.

University of Akron

Faculty Advisors: **Dr. Iqbal Husain, Dr. Joan Carletta, Dr. Jerry Drummond, Dr. Jon Gerhardt, Dr. Richard Gross, Dr. Tom Hartley, Dr. Robert Veillette**
Team Leaders: **Angelina Bellino, Joe Bisbing, Jim Faucett, Nayeem Hasan, Rob Paciotti, Nathan Picot, Brian Porto, Mike Roblin, Chuck Van Horn, Donald Whitmore**

Overall Design Strategy The University of Akron Zips consist of undergraduate and graduate students primarily in the Departments of Electrical & Computer Engineering and Mechanical Engineering. The team also has students and faculty involved from the Communications, Marketing, and Chemical Engineering Departments. Team members contribute to subsystem teams, such as Control Systems, Engine & Transmission, Emissions, Communications, Packaging and Integration, Outreach, etc., which are each headed by a student Team Leader.

The University of Akron's Equinox, affectionately nicknamed Joey, uses a series-parallel 2x2 hybrid system. This architecture features a unique control system that allows for the vehicle to operate in a full range of hybrid capabilities, from 100% electric-only to 100% mechanical-only and anywhere in between. The goal is to maximize the benefits of series, parallel, and split operations through drivetrain component selection and control system design. Joey's 1.9-L VW engine with a DSG transmission provides high efficiency and reliability. The vehicle uses B20 biodiesel with after-treatment technologies to reduce emissions. Emphasis is also placed on performance capabilities and drive quality for an enjoyable consumer experience.

CHALLENGE X TEAM DESCRIPTIONS

University of California, Davis

Team Advisors: Professor Andrew A. Frank Ph.D, Professor Paul A. Erickson Ph.D
Team Leaders: Terrence K. Williams, Bryan D. Jungers

Team Description 5 Graduate students and 20 Undergraduate students—85% are Mechanical Engineers, 10% Electrical Engineers, 5% Civil/ Materials Engineers. Some team tasks include work on the chassis/body modifications, powertrain integration, engine controls calibration and tuning, CVT modifications and controls, advanced battery monitoring and integration, school and community outreach, and various other administrative duties.

Overall Design Strategy Plug-in Hybrid Electric Vehicle Tri-fuel using gasoline/ethanol, hydrogen and solar electricity Parallel Configuration: dual electric motors, a Prius 2004 Engine, modified Nissan 2.0-L CVT, 350 V Lithium-ion battery pack from Lithium Technology Corporation.

The vehicle runs for the first 50 miles in all-electric mode at speeds of up to 60 mph (assuming a fully charged battery pack). Additional range and acceleration are provided by operating the vehicle in hybrid mode, with an estimated fuel economy of 35 mpg and 40 mpg for city and highway driving, respectively. The vehicle's batteries can be recharged using grid electricity (from a 110 V outlet), or distributed renewable energy systems, such as micro wind and solar.

University of Michigan

Ann Arbor Faculty Advisor: Albert Shih
Dearborn Faculty Advisor: Keshav Varde
Ann Arbor Team Leader: Steve Dockstader
Dearborn Team Leader: Pavan Potluri

Team Description The University of Michigan Challenge X Team is split between the Ann Arbor and Dearborn campuses. Each campus has one faculty advisor and one team leader. The Ann Arbor campus has focused on the hydraulic and control subsystems. The Dearborn campus has focused on the diesel engine and control subsystems. Both campuses have contributed to vehicle integration and fabrication activities. The University of Michigan currently has 10 team members.

Overall Design Strategy The University of Michigan's Challenge X vehicle is a series hydraulic hybrid. A 1.9-L GM diesel engine has replaced the stock V6 gasoline engine and is directly coupled to a variable-displacement, bent-axis hydraulic pump rated up to 80 CC/rev at 2200 rpm. The diesel engine and 80 CC/rev hydraulic pump are utilized to manage the state of charge of a high-pressure (18,000 psi to 5,000 psi) accumulator. The high-pressure accumulator is coupled, in parallel to a low-pressure accumulator (300 to 800 psi), across two variable-displacement, bent-axis hydraulic pump/motors rated up to 55 CC/rev at 2500 rpm. One of these 55 CC/rev pump/motors is coupled to each axle. Vehicle motion is controlled by using electromechanical valves to vary the displacement, based on operating conditions, of the front and rear axle pump/motors.

University of Tennessee

Faculty Advisor: David "Butch" Irick
Team Leader: David Smith

Team Description A team is a collection of individuals with different assigned functions and/or abilities that allows them to accomplish tasks that would be overwhelming for fewer individuals. Each person on the team should know what their role is and should have the necessary training to accomplish it. Each team member is responsible for the completion of their task as the completion of the overall project hinges on the completion of its separate parts. Every team needs a responsible leader who has a clear vision of the goal and who will hold the team accountable for their work. He is also accountable to the team for bringing all the parts together to complete the task.

Overall Design Strategy The problem at hand was to create a more efficient hybrid car. The team working on this solution was consisted of Mechanical, Electrical, Mechatronic and Computer Engineers working as a group, giving input from their fields of specialization. The team has been working for 9 months to resolve problems associated with the goals for improvements to the vehicle. The two major goals of this project were to make the vehicle as lightweight and fuel efficient as possible without compromising safety. The focus of the fuel efficiency problem was experimentation with alternative energy sources, including bio-diesel fuels and a battery charging electrical system.

University of Texas at Austin

Faculty Advisors: Dr. Ron Matthews, Dr. Matthew Hall
Team Leaders: Brian Novoselich, Lev Shuhatovich, Ted Kane, Patti Hightower

Team Description The University of Texas at Austin Challenge X team consists of 35 members, including 4 graduate students, from the disciplines of Mechanical and Electrical Engineering. Our team is divided into thirteen subsystem areas: Safety, Engine Calibration, Controls, Vehicle Packaging, Engine Cooling, Climate Control, Vehicle Networking, Dual Fuel System, Belt Alternator-Starter, Data Acquisition, Air Handling, Outreach, and Logistics. A weekly team forum is held to discuss progress and pitfalls of each specific group and to flow down important challenge information. Overseeing the efforts are our two team co-captains under the accommodating guidance of our two faculty advisors.

Overall Design Strategy The University of Texas Challenge X team plans to implement a mild hybrid with a strong focus on improving engine efficiency through implementation of the HEDGE (High Efficiency Dilute Gasoline Engine) strategy. Our goal with HEDGE is to combine the high efficiencies associated with compression ignition engines with the lower emissions of standard spark ignition (SI) engines for typical driving conditions. HEDGE will be achieved through the use of exhaust gas recirculation (EGR) and a chemical ignition source during low engine loads, creating a high-compression SI engine for most of the operating range the consumer would use the vehicle. In addition, a belt driven alternator/starter (BAS) will be integrated into our design. This will allow for idle off operation, resulting in increased fuel economy.

CHALLENGE X TEAM DESCRIPTIONS

The University of Tulsa

Faculty Advisors: Dr. Christi Patton Luks, Dr. Daniel Crunkleton, Dr. John Henshaw, Dr. Robert Strattan, Mr. Douglas Jussaume, Mr. Matthew Roberds
Team Leader: Joshua Buck

Team Description The University of Tulsa Challenge X Team is a Hurricane Motor Work (HMW) project that has produced award-winning vehicles at the Tour de Sol and Mini-Baja competitions. During year two of the Challenge X competition, the Tulsa team has divided the major tasks of modifying a Chevrolet Equinox into an alternative energy vehicle into four build teams. The Front End Build Team is responsible for assembly of the GM diesel engine, the Rear End Build Team is responsible for inserting the Ballard IPT electric motor, the Energy Storage Systems Team is responsible for the two Ballard Nexa fuel cell and vehicle accessories, and the Controls Team is responsible for the operation of all the new components in a working hybrid electric vehicle. The Tulsa team is truly interdisciplinary, with faculty advisors from 3 engineering disciplines and students from 9 major departments.

Overall Design Strategy Tulsa's HMW has moved in a new direction by producing its first parallel through-the-road hybrid electric vehicle. The front wheels are driven by a 1.9-L Common Rail Direct Injected GM diesel engine through a 6-speed manual transmission. The diesel engine is fueled with B20. The rear wheels are driven by a 65 kW Ballard Integrated Powertrain electric motor, which is powered by a 60 kW, 288 V Cobasys NiMH battery pack. Always pushing the integration of new technologies, the Tulsa team has included the use of two Ballard Nexa 1.2 kW fuels for charging and accessory power. The entire vehicle is controlled by National Instruments' LabView programming software running on NI's cRIO.

University of Waterloo

Faculty Advisors: Dr. Roydon Fraser, Dr. Michael Fowler, Dr. Stephan Lambert, Dr. Mehrdad Kazerani
Team Leaders: Matt Stevens, Chris Mendes

Team Description UWAFT's team structure is divided into five main subteams: mechanical, electrical, controls, hydrogen, and business. The core team of approximately 30 members—7 graduate students and 23 undergrads—is divided among these five subteams. A weekly meeting updates all members on the past week's successes and less-than-successes and identifies key action items for the upcoming week. This approach ensures that the team's efforts are cohesive and that any design issues are identified and reviewed immediately.

On a side note, UWAFT is considering the inclusion of a "Coffee Brewmaster" position in the org chart. Selection criteria will be strict, as this would be the most important team position.

Overall Design Strategy UWAFT's design philosophy focused on combining model-based design principles with a well-defined physical integration plan. For the mechanical integration, three major phases were identified. The alpha phase focused on the evaluation of temporary support framing required during the replacement of the frame rails and cross members in a test body. The beta phase consisted of the integration of a frame design and all major components into the actual vehicle and low-speed testing. The final phase of mechanical integration required the replacement of the frame and mount structures with improved designs and to perform high-speed testing for control strategy tuning. Model-based design allowed UWAFT to implement a near-final solution in the alpha phase, thereby minimizing the modifications required in subsequent phases.

University of Wisconsin - Madison

Faculty Advisor: Glenn Bower
Team Leader: Liz Casson

Team Description Mainly comprised of undergraduate students, the University of Wisconsin - Madison Challenge X Team is subdivided into 5 groups led by a single team leader. These five groups are Controls, Electrical, Drivetrain, Mechanical, and Outreach. The tasks and responsibilities that go into building a hybrid vehicle are broken down respectively between these five groups to efficiently divide the workload. Although the tasks may be divided, the team collaborates nicely to build a complete and safe working vehicle. Weekly meetings are held so that group leaders can inform the team of the current status of the vehicle and update everyone on the upcoming tasks.

Overall Design Strategy The University of Wisconsin - Madison Challenge X Team is implementing a through-the-road parallel biodiesel electric hybrid design for their entry into the 2006 Challenge X competition. The drivetrain consists of a GM Diesel 1.9-L Turbo Charged engine supplemented with an Extengine SCR catalyst system coupled to a GM F40 6-speed manual transmission. Mounted in the rear is a Ballard 45 kW electric transaxle supplied by a 316V nominal Johnson Controls High Voltage Battery Pack. A MPC555 controller is programmed to integrate the engine and electric motor assist for smooth driving. Using PSAT, this design is estimated to achieve over 36 mppge with emission levels lower than the tier 2 bin 5 category.

Virginia Tech

Faculty Advisor: Doug Nelson
Team Leader: Steven Boyd

Team Description The Hybrid Electric Vehicle Team of Virginia Tech (HEVT) is made up of 30 seniors in Mechanical Engineering working on the project to fulfill the college's capstone design project requirements. In addition, approximately 15 volunteers are working with the team. To manage the team, HEVT has chosen to break the team into seven different sub-teams, focusing on the engine, transmission, rear traction motor, belted alternator/starter, high-voltage battery, 12 V systems, and controls. Each of these sub-teams has chosen a sub-team leader to organize the group and communicate with other groups. Our team leader oversees each sub-team to keep the team as a whole on the proper path to success.

Overall Design Strategy Through extensive computer modeling, HEVT determined that a split parallel hybrid architecture powered by E85 was the best fit for the Equinox REV_{LSE}. E85 was chosen as the fuel to meet an HEVT VTS of reducing well-to-wheels petroleum use by 80%. HEVT achieves a split parallel architecture (SPA) by utilizing two electric motors. The belted alternator-starter (BAS) is belted directly to the engine, while the rear traction motor (RTM) drives the rear wheels to maintain all-wheel-drive capabilities. This architecture allows for two parallel power paths when the RTM and BAS assist the engine and a series power path when the BAS is used to generate electricity to charge the high-voltage battery.

CHALLENGE X TEAM DESCRIPTIONS & MAPS

West Virginia University

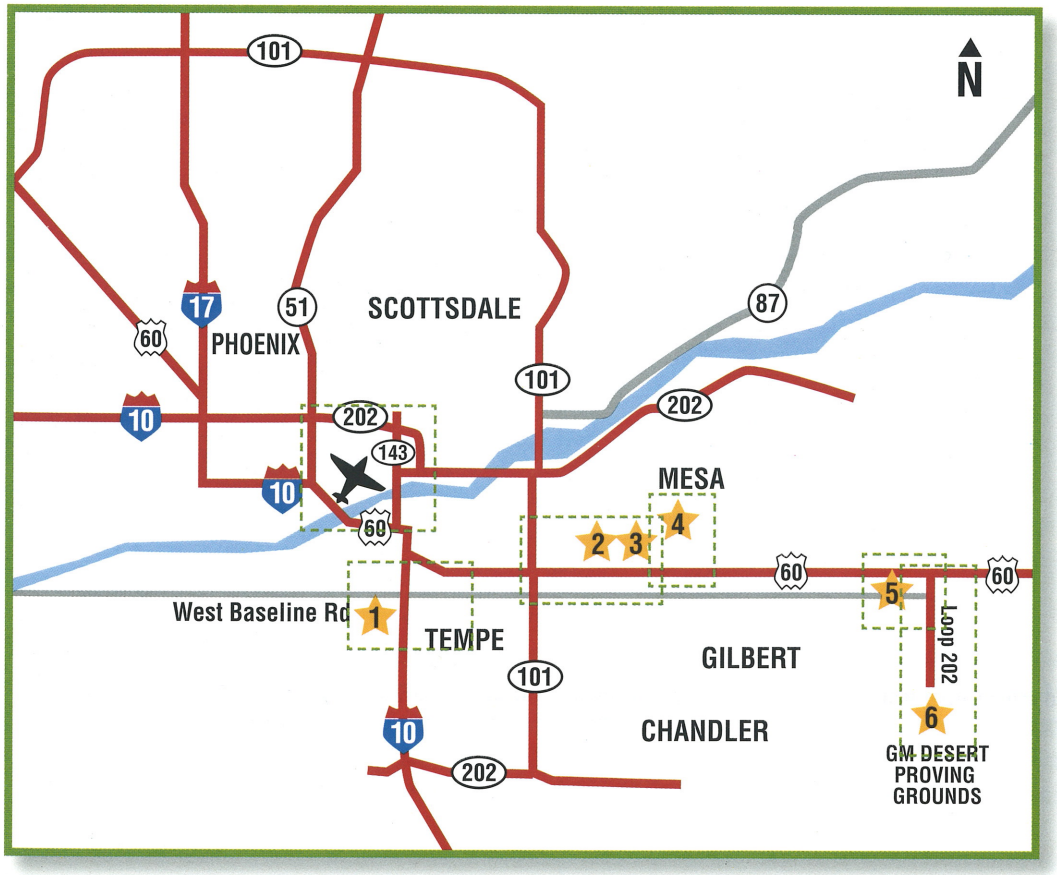
Faculty Advisor: Dr. Nigel Clark
Team Leader: Dan Gesiert

Team Description The West Virginia University Challenge X team structure can be described as a distributed organizational structure, where students are assigned to work on separate project teams and report to a project manager. The team consists of 3 subgroups, which include Powertrain, Hybrid, and Controls. Each group has a leader who acts as a liaison to the team captain and other executive members. The team also has an executive board which consists of a captain, a co-captain, a radar, a treasurer, an outreach coordinator, a technical advisor, group leaders, and a mentor.

Each team is responsible for the design, development, selection, and acquisition of components; integration of the components into the vehicle, and interaction with the other teams.

Overall Design Strategy The WVU team will replace the six-cylinder gasoline engine with a 1.9-L GM diesel engine. The stock GM diesel particulate filter will be used for PM reduction, and a selective catalytic reduction system will be implemented for NOx reduction. Two PML Flightlink permanent magnet electric wheel motors will be implemented for the hybrid powertrain. The pack of 115 ultra-capacitors will be used to store braking energy. A High-Performance Golf Cars electric motor will provide AWD capabilities. The control strategy will be separated into drive, brake, and traction modes that handle control of the hybrid system under those conditions. The control strategy will be implemented by three Mototron MotoHawk controllers.

PHOENIX AREA MAP



Phoenix Sky Harbor International Airport
3400 E Sky Harbor Blvd
Phoenix, AZ 85034

1 Skit Night RUSTLER'S ROOSTE
8383 South 48th Street
Phoenix, AZ 85044

2 Team Hotel Residence Inn-Mesa
941 West Grove Avenue
Mesa, Arizona 85210

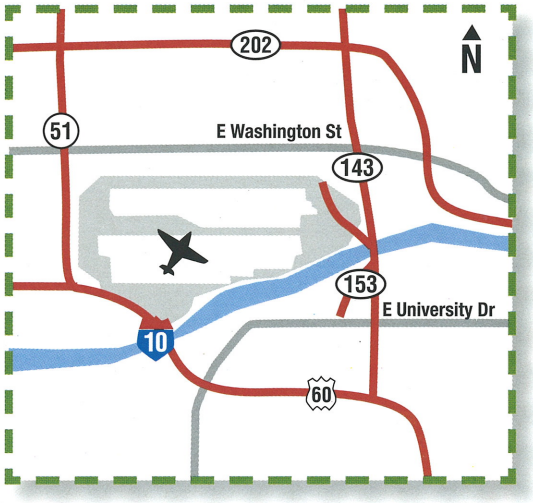
3 Organizer/Judge Hotel/ Sponsor Social/Faculty Dinner
Hilton Phoenix East/Mesa
1011 West Holmes Ave.
Mesa, AZ 85210

4 Award Ceremony
Mesa Arts Center/Ikeda Theater
1 East Main Street
Mesa, Arizona 85211-1466

5 Team Hotel Country Inn & Suites
6650 E. Superstition Springs Blvd
Mesa, AZ 85206

6 Competition Events
GM Desert Proving Ground
13303 S. Ellsworth Rd.
Mesa, AZ 85212

Phoenix Sky Harbor International Airport

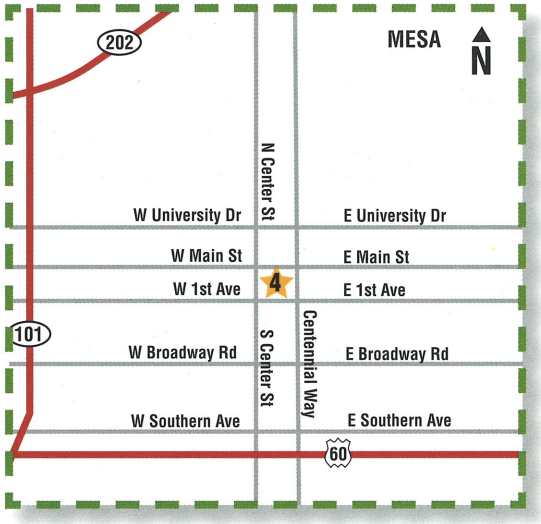


1 Rustler's Rooste

2 Residence Inn-Mesa

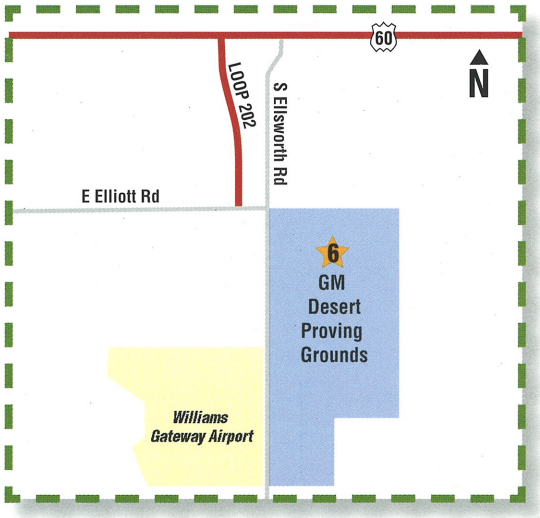
3 Hilton Phoenix East/Mesa

4 Mesa Arts Center

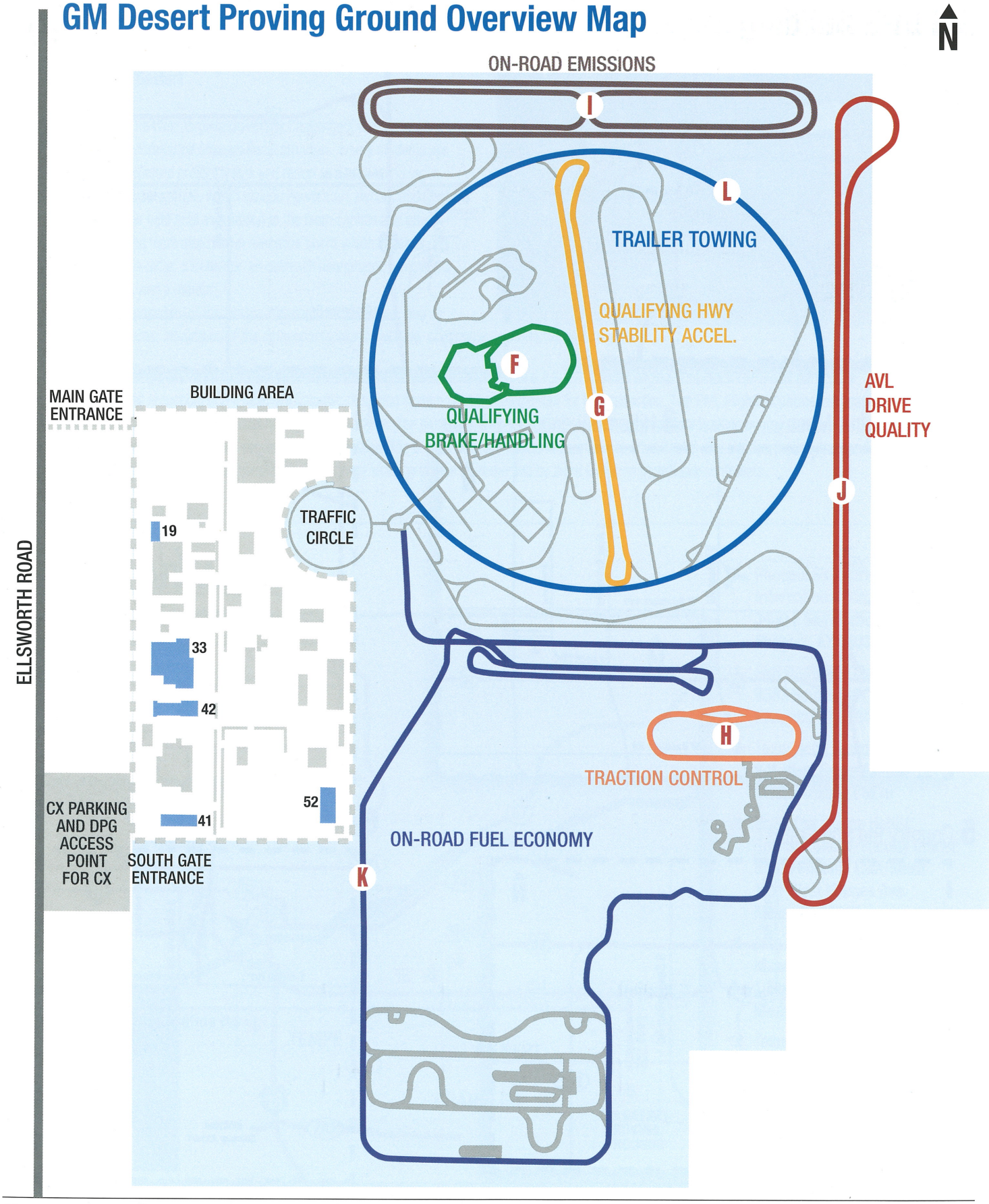


5 Country Inn and Suites

6 GM Desert Proving Grounds

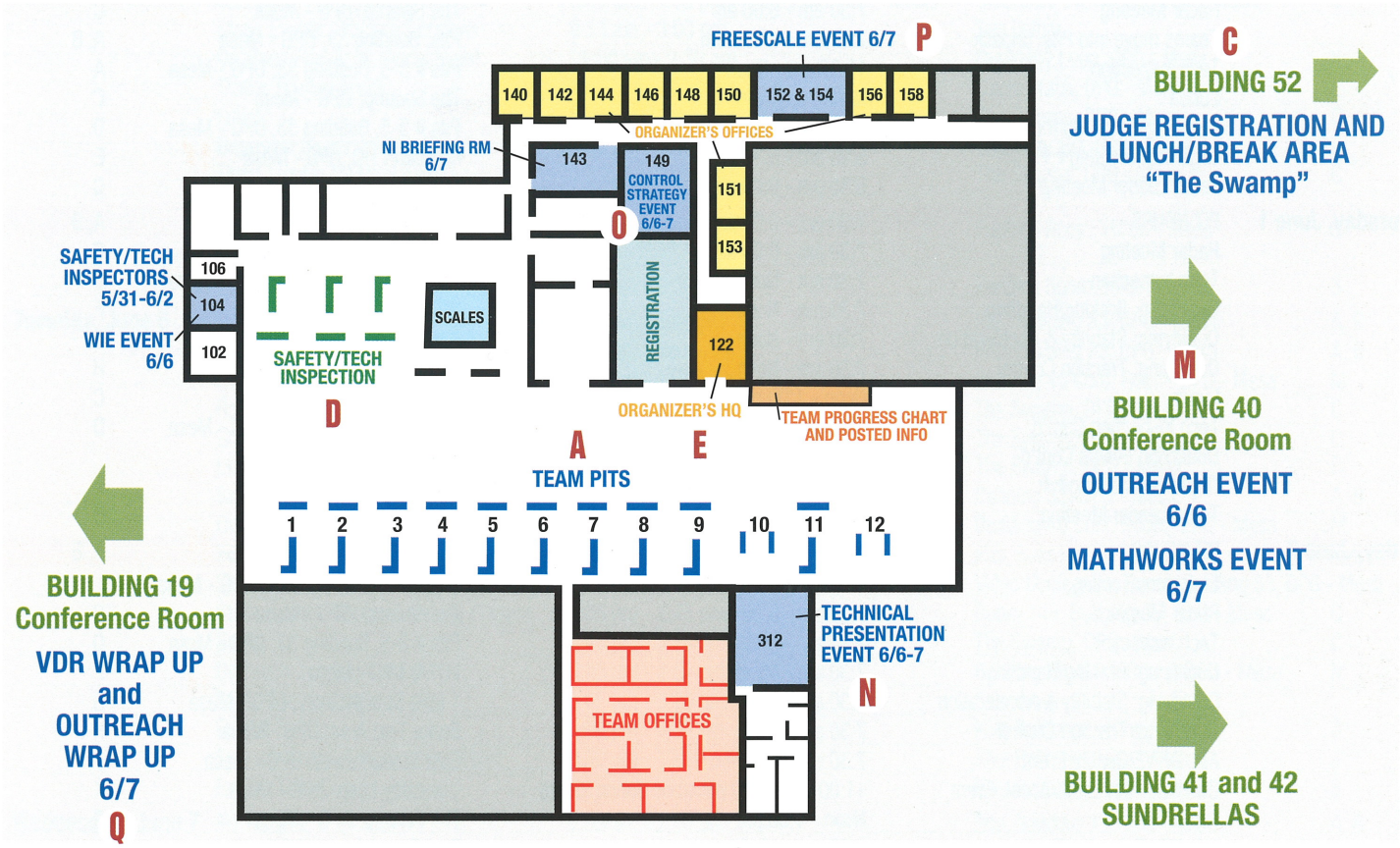


GM Desert Proving Ground Overview Map

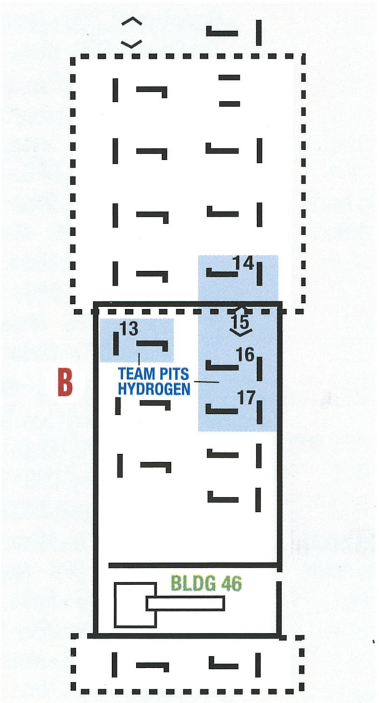


GM DPG Building Maps

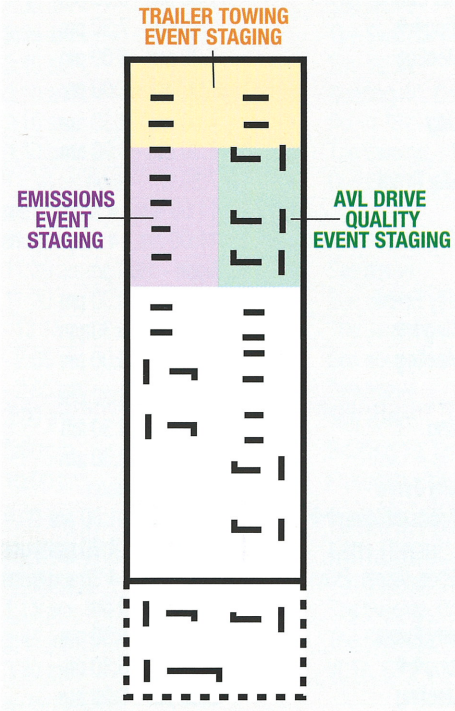
BUILDING 33



BUILDING 42 SUNDRELLA



BUILDING 41 SUNDRELLA



CHALLENGE X SCHEDULE

DATE	EVENT	TIME	LOCATION	MAP KEY
Tuesday, May 30	Team Registration	2:00 pm - 5:30 pm	Hilton - Mesa	3
	Skit Night & Team Orientation	6:00 pm - 10:00 pm	Rustler's Rooste - Phoenix	1
Wednesday, May 31	PIT HOURS	7:00 am - 6:00 pm	Pits, Building 33, DPG - Mesa	A, B
	Radar Meeting	7:30 am - 8:00 am	The Swamp, DPG - Mesa	C
	Teams move into Pits, unpack	7:30 am - 10:30 am	Pits, Building 33, DPG - Mesa	A, B
	Tech Inspection	10:30 am - Noon	Pits # 3-5, Building 33, DPG - Mesa	A
	Lunch	Noon - 1:00 pm	The Swamp, DPG - Mesa	C
	Tech Inspection Cont'd	1:00 - 4:30 pm	Pits # 3-5, Building 33, DPG - Mesa	D
	Organizer Meeting++	5:00 pm - 5:30 pm	Organizer HQ, DPG - Mesa	E
	Team Leader Meeting	5:30 pm - 6:00 pm	The Swamp, DPG - Mesa	C
Thursday, June 1	PIT HOURS	7:00 am - 8:00 pm	Pits, Building 33, DPG - Mesa	A, B
	Radar Meeting	7:30 am - 8:00 am	The Swamp, DPG - Mesa	C
	Tech Inspection	7:30 am - Noon	Pits # 3-5, Building 33, DPG - Mesa	D
	Qualifying: Braking/Handling	7:30 am - Noon	VDTA, DPG - Mesa	F
	Qualifying: Stability & Acceleration	7:30 am - Noon	1 Mile Straightaway, DPG - Mesa	G
	Qualifying: Traction Control	7:30 am - Noon	Brake Test Area, DPG - Mesa	H
	Lunch	Noon - 1:00 pm	The Swamp, DPG - Mesa	C
	Tech Inspection Cont'd	1:00 pm - 6:30 pm	Pits # 3-5, Building 33, DPG - Mesa	D
	Qualifying Events Cont'd	1:00 pm - 6:30 pm	See above	
	Organizer Meeting++	7:00 pm - 7:30 pm	Organizer HQ, DPG - Mesa	E
	Team Leader Meeting	7:30 pm - 8:00 pm	The Swamp, DPG - Mesa	C
Friday, June 2	PIT HOURS	7:00 am - 8:00 pm	Pits, Building 33, DPG - Mesa	A, B
	Emissions Testing	4:00 am - 8:30 am	Ride and Handling Loop, DPG - Mesa	I
	Radar Meeting	7:30 am - 8:00 am	The Swamp, DPG - Mesa	C
	Tech Inspection	7:30 am - Noon	Pits # 3-5, Building 33, DPG - Mesa	D
	Qualifying: Braking/Handling	7:30 am - Noon	VDTA, DPG - Mesa	F
	Qualifying: Stability & Acceleration	7:30 am - Noon	1 Mile Straightaway, DPG - Mesa	G
	Qualifying: Traction Control	7:30 am - Noon	Brake Test Area, DPG - Mesa	H
	AVL DRIVE Quality Event	7:30 am - Noon	East Straightaway, DPG - Mesa	J
	On-Road Fuel Econ./Accel. Event	11:00 am - 6:30 pm (runs during lunch)	Durability Loop, DPG - Mesa	K
	Lunch	Noon - 1:00 pm	The Swamp, DPG - Mesa	C
	AVL DRIVE Quality Event	1:00 p.m. - 3:00 pm	East Straightaway, DPG - Mesa	J
	Tech Inspection Cont'd	1:00 pm - 3:00 pm	Pits # 3-5, Building 33, DPG - Mesa	D
	Qualifying Events Cont'd	1:00 pm - 6:30 pm	See above	
	Organizer Meeting++	7:00 pm - 7:30 pm	Organizer HQ, DPG - Mesa	E
	Team Leader Meeting	7:30 pm - 8:00 pm	The Swamp, DPG - Mesa	C
Saturday, June 3	PIT HOURS	7:00 am - 6:00 pm	Pits, Building 33, DPG - Mesa	A, B
	Emissions Testing	4:00 am - 8:30 am	Ride and Handling Loop, DPG - Mesa	I
	Radar Meeting	7:30 am - 8:00 am	The Swamp, DPG - Mesa	C
	AVL DRIVE Quality Event	7:30 am - Noon	East Straightaway, DPG - Mesa	J
	Trailer Towing	11:00 am - 4:30 pm (runs during lunch)	Circle Track, DPG - Mesa	L
	On-Road Fuel Econ./Accel. Event	11:00 am - 4:30 pm (runs during lunch)	Durability Loop, DPG - Mesa	K
	Lunch	Noon - 1:00 pm	The Swamp, DPG - Mesa	C
	AVL DRIVE Quality Event	1:00 pm - 4:30 pm	East Straightaway, DPG - Mesa	J
	Organizer Meeting++	5:00 pm - 5:30 pm	Organizer HQ, DPG - Mesa	E
	Team Leader Meeting	5:30 pm - 6:00 pm	The Swamp, DPG - Mesa	C
Sunday, June 4	PIT HOURS	7:00 am - 6:00 pm	Pits, Building 33, DPG - Mesa	A, B
	Emissions Testing	4:00 am - 8:30 am	Ride and Handling Loop, DPG - Mesa	I
	Radar Meeting	7:30 am - 8:00 am	The Swamp, DPG - Mesa	C
	AVL DRIVE Quality Event	7:30 am - Noon	East Straightaway, DPG - Mesa	J
	NSF Faculty Advisor Judging++	8:00 am - 11:00 am	Room 149, Bldg 33, DPG - Mesa	0
	Trailer Towing	11:00 am - 4:30 pm (runs during lunch)	Circle Track, DPG - Mesa	L
	On-Road Fuel Econ./Accel. Event	11:00 am - 4:30 pm (runs during lunch)	Durability Loop, DPG - Mesa	K
	Lunch	Noon - 1:00 pm	The Swamp, DPG - Mesa	C
	AVL DRIVE Quality Event	1:00 pm - 4:30 pm	East Straightaway, DPG - Mesa	J
	Organizer Meeting++	5:00 pm - 5:30 pm	Organizer HQ, DPG - Mesa	E
	Team Leader Meeting	5:30 pm - 6:00 pm	The Swamp, DPG - Mesa	C

DATE	EVENT	TIME	LOCATION	MAP KEY
Monday, June 5	PIT HOURS	7:00 am - 4:00 pm	Pits, Building 33, DPG - Mesa	A, B
	Emissions Testing	4:00 am - 8:30 am	Ride and Handling Loop, DPG - Mesa	I
	Radar Meeting	7:30 am - 8:00 am	The Swamp, DPG - Mesa	C
	Caterpillar Facility Student Tour◆	8:00 am - 4:30 pm (Pick up at Hilton - Mesa)	Caterpillar Proving Ground - Tucson	3
	Static Events: Practice Sessions	9:15 am - 3:00 pm	See below	
	On-Road Fuel Econ./Accel.Event	11:00 am - 2:30 pm	Durability Loop, DPG - Mesa	K
	Trailer Towing Event	11:00 am - 2:30 pm	Circle Track, DPG - Mesa	L
	Lunch	Noon - 1:00 pm	The Swamp, DPG - Mesa	C
	Organizer Meeting++	3:00 pm - 3:30 pm	Organizer HQ, DPG - Mesa	E
	Team Leader Meeting	3:30 pm - 4:00 pm	The Swamp, DPG - Mesa	C
	Faculty Advisor Reception and Competition Discussion◆	5:00 pm - 7:00 pm	Pueblos Room, Hilton - Mesa	3
	Maxwell Technologies Faculty Dinner & Round Table◆	7:00 pm - 9:30 pm	Pueblos Room, Hilton - Mesa	3
Tuesday, June 6	PIT HOURS	7:00 am - 6:00 pm	Pits, Building 33, DPG - Mesa	A, B
	Teams Pack Up Pits	7:00 am - Noon	Pits, Building 33, DPG - Mesa	A, B
	Outreach Judging	7:30 am - 11:30 pm	Building 40 Conf. Room, DPG - Mesa	M
	Radar Meeting	7:30 am - 8:00 am	The Swamp, DPG - Mesa	C
	Static Events: Judge Registration	11:30 am - 12:30 pm	The Swamp, DPG - Mesa	C
	Lunch	11:30 am - 12:30 pm	The Swamp, DPG - Mesa	C
	Static Events: Judge Briefings	12:30 pm - 1:00 pm	Building 33, DPG - Mesa	A, B
	Outreach Judging Cont'd	1:05 pm - 2:45 pm	Building 40 Conf. Room, DPG - Mesa	M
	Static Events: Vehicle Devel. Review	1:05 pm - 2:45 pm	Pits, Building 33, DPG - Mesa	A, B
	Static Events: Technical Presentation	1:05 pm - 2:45 pm	Video Conference Room, Building 33, DPG - Mesa	N
	Static Events: Control Strategy Present.	1:05 pm - 2:45 pm	Room 149, Building 33, DPG - Mesa	O
	Break	2:45 pm - 3:05 pm	The Swamp, DPG - Mesa	C
	Outreach Judging Cont'd	3:05 pm - 4:50 pm	Building 40, Conf. Room, DPG - Mesa	M
	Static Events Cont'd	3:05 pm - 5:20 pm	See above	
	Exhibit Set Up	5:00 pm - 6:30 pm	Kiva Ballroom, Hilton - Mesa	3
	Sponsor Social & Networking Event	6:30 pm - 10:00 pm	Kiva Ballroom, Hilton - Mesa	3
	Exhibit Take Down	10:00 pm - 10:30 pm	Kiva Ballroom, Hilton - Mesa	3
Wednesday, June 7	PIT HOURS	7:00 am - 3:30 pm	Pits, Building 33, DPG - Mesa	A, B
	Breakfast	7:00 am - 7:30 am	The Swamp, DPG - Mesa	C
	Radar Meeting	7:30 am - 8:00 am	The Swamp, DPG - Mesa	C
	Static Event Judging Cont'd	7:30 am - 9:30 am	See above	
	Sponsored Awards: Registration	7:30 am - 8:05 am	The Swamp, DPG - Mesa	C
	Sponsored Awards: Judge Briefings	8:05 am - 8:40 am	See below	
	Sponsored Awards: The MathWorks	8:40 am - 9:10 am	Building 40, Conf. Room, DPG - Mesa	M
	Sponsored Awards: Freescale	8:40 am - 9:10 am	Room 152-154, Bldg 33, DPG - Mesa	P
	Break	9:10 am - 9:30 am	The Swamp, DPG - Mesa	C
	Outreach Judging Wrap Up++	9:30 am - 11:30 am	Building 19, Conf. Room, DPG - Mesa	Q
	Sponsored Awards: National Instruments	9:30 am - 11:30 am	Pits, Building 33, DPG - Mesa	A, B
	Static Events Cont'd	9:30 am - 11:30 am	See above	
	Sponsored Award Judging Cont'd	9:30 am - 11:30 am	See above	
	Lunch	11:30 am - 12:15 pm	The Swamp, DPG - Mesa	C
	Static Events Cont'd	12:25 pm - 2:05 pm	See above	
	Sponsored Award Judging Cont'd	12:25 pm - 2:05 pm	See above	
	Judges Final Wrap Up	2:05 pm - 3:00 pm	See above	
	Vehicle Development Review Wrap Up++	2:05 pm - 3:00 pm	Building 19, Conf. Room, DPG - Mesa	Q
	Freescale EE Student Tour & Dinner◆	3:30 pm - 10:00 pm	Freescale FAB Facility - Chandler	
Thursday, June 8	Breakfast Reception	8:00 am - 9:00 am	Ikeda Theater, Mesa Arts Center - Mesa	4
	Award Ceremony	9:00 am - 11:45 am	Ikeda Theater, Mesa Arts Center - Mesa	4
	Lunch	12:30 pm - 2:00 pm	The Swamp, DPG - Mesa	C
	Press Conference	1:00 pm - 1:15 pm	The Swamp, DPG - Mesa	C
	Ride and Drive	1:15 pm - 2:45 pm	The Swamp, DPG - Mesa	C
	Panoramic Photo	2:45 pm - 3:30 pm	VDTA, DPG – Mesa	F

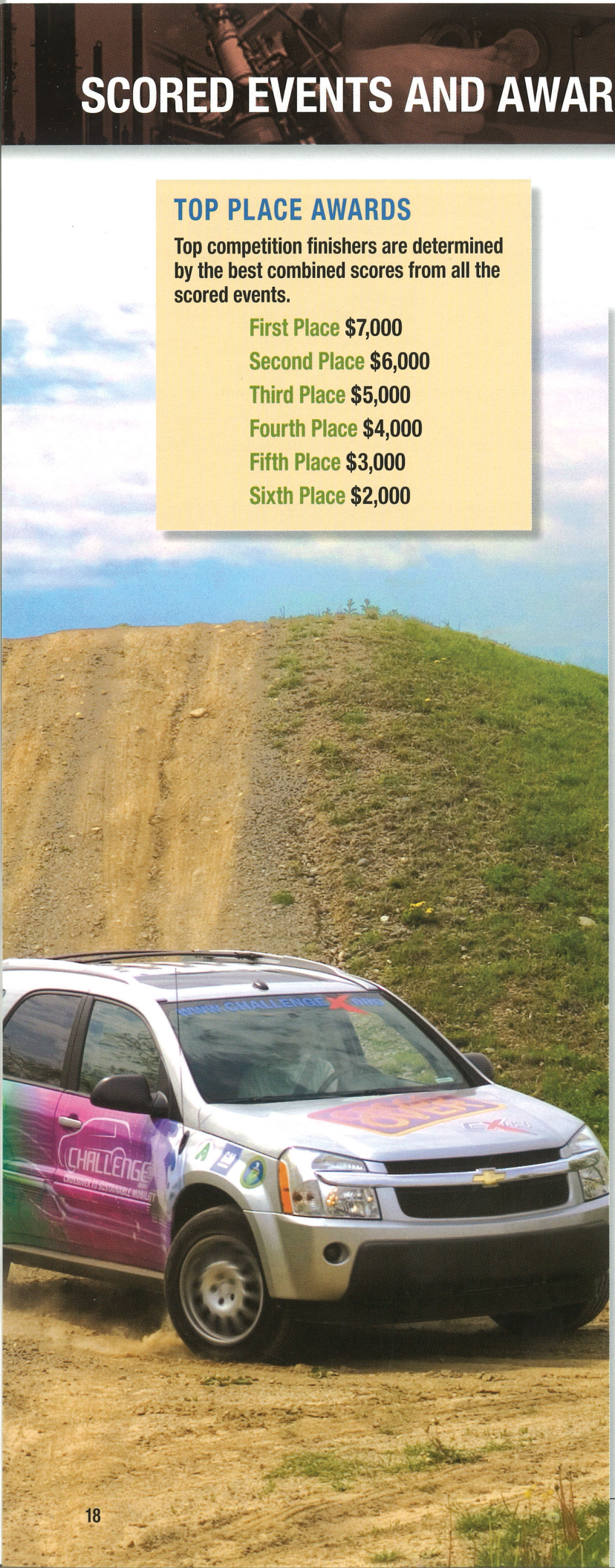
LEGEND HQ = Headquarters ++ = Organizers Only ◆ = Advance Sign Up Required

SCORED EVENTS AND AWARDS

TOP PLACE AWARDS

Top competition finishers are determined by the best combined scores from all the scored events.

First Place $7,000
Second Place $6,000
Third Place $5,000
Fourth Place $4,000
Fifth Place $3,000
Sixth Place $2,000



SCORED EVENTS

REPORT #1

YEAR TWO FALL TECHNICAL REPORT

40 points

Event Captain: Forrest Jehlik – Argonne National Laboratory

Challenge X Teams submitted a 10-page SAE-format report documenting the final changes to the design and vehicle technical specifications from the first challenge year's analysis. Teams were required to document and describe the powertrain architecture integrated into the vehicle for the June 2006 competition. Utilizing completed modeling and component testing, Teams updated their vehicle technical specifications. From this analysis, Teams provided insight into how their Vehicle Technical Specification (VTS) was developed, the changes that occurred to the original VTS, and presented the information to substantiate their selections.

REPORT #2

YEAR TWO SPRING TECHNICAL REPORT

70 points

Event Captain: Forrest Jehlik – Argonne National Laboratory

Considered the final written technical document for the competition's second year, Challenge X Teams submitted a final 15-page SAE-format report. The purpose of the spring technical report was to document how the components and control system were able to meet the energy efficiency, emissions, and performance/utility capabilities of the vehicle as determined in the first year's modeling analysis. Teams presented test data from their vehicle to support claims of energy efficiency, emissions, and performance. The broad range of topics covered in the report consisted of their selected powertrain and hybrid control strategy, powertrain control and operation capabilities of vehicle compared to the production vehicle, validation of results that substantiate the VTS design, and specifics of the vehicle unique and important not covered in any of the previous topics.

Best Written Technical Reports ($1,000) is awarded to the team with the highest total score for both reports.

PRE-COMPETITION TECHNICAL INSPECTION

40 points

Event Captain: Steve Gurski – Argonne National Laboratory

Prior to the competition, Challenge X mentors and organizers visited teams for a pre-event inspection of the completed competition vehicles. At this pre-competition event, a critical review of a vehicle's compliance to the safety and technical guidelines was held. Teams were evaluated with an all-encompassing safety and technical checklist and provided feedback by mentors and organizers with regards\ to a team's design. As part of this inspection, teams were awarded points for displaying complete integration of their powertrain, as well as demonstrating vehicle operation.

QUALIFYING: BRAKING AND HANDLING

30 points

Co-Event Captains: Jace Petersen and Jim Trout – General Motors

The braking and handling events are the first of the dynamic qualifying events of the Challenge X competition. To ensure the vehicles maintain the appropriate amount of stopping performance, teams are required to undergo a braking test. Teams will receive a pass or fail based on their demonstrated performance. After passing the braking event, teams will then demonstrate their vehicle's ability to navigate a serpentine cone-lined course and test the vehicle's handling capabilities. Teams will be given multiple attempts to drive their vehicle through the handling course in the shortest time possible.

The team that is able to achieve the lowest time possible through the handling event will receive the trophy and a check for $500.

QUALIFYING: ACCELERATION

35 points

Co-Event Captains: Dave Gerber, Dan Molnar, and Debbie Yee – General Motors

The Acceleration Event evaluates the ability of the vehicle to accelerate in two different metrics. Initial vehicle movement to 60 mph and 50 to 70 mph. Teams will be challenged to demonstrate the best acceleration possible given their vehicle architecture design.

The team demonstrating the highest score based on their acceleration times will receive the award for the Best Acceleration and a check for $500.

QUALIFYING: LIMITED TRACTION CONTROL

55 points

Co-Event Captains: Jeff Hengesh and Jim Hamilton – General Motors

This event will demonstrate the "All Weather" capability that customers expect of SUVs. This event will evaluate the capabilities of the Challenge X vehicles to maintain launch traction during acceleration on low coefficient-of-friction surfaces. Subjective and measured data will be used to rate the performance of the vehicles.

QUALIFYING: HIGHWAY STABILITY

Pass/Fail

Event Captain: Shan Smith – General Motors

The purpose of the highway stability event is to evaluate the ability to control the competition vehicles at highway speeds. The event will utilize tests that are currently used in real-world vehicle design programs to ensure that vehicles are safe to operate at highway speeds.

AVL DRIVE QUALITY

65 points

Co-Event Captains: Randy Yost, Steve Baldus, and Dave Evans – General Motors

The balance between fuel economy and drivability is one of the most difficult and important tasks in the Vehicle Development Process. The objective of this event is to assess the vehicle's drivability through objective on-road evaluation. AVL DRIVE is the enabling technology that will be used to objectively evaluate the drive quality of each of the competition vehicles. The event will evaluate a set of driving "modes," such as acceleration, cruising, and braking, and develop a score that will be used for the final comparison and award for the event.

The team with the highest drive quality score will receive the trophy for the Best AVL DRIVE Quality and a check for $1,500.

TRAILER TOW

55 points

Event Captain: Frank Witt – General Motors

The goal of this event is to demonstrate towing ability at a reasonable speed over a given grade. This drive schedule will be indicative of real-world conditions that the production vehicle may experience. The event will be performed over the road and, where applicable, demand zero net on-board energy storage change (i.e., charge sustainability) over the towing drive cycle. Distance traveled and the time taken to complete the event will be the metrics used to judge the event.

The team that is able to travel the fixed distance of the towing cycle the quickest without exceeding the maximum speed will receive an award for Best Trailer Performance and a check for $500.

ON-ROAD EMISSIONS TESTING

65 points

Co-Event Captains: Rachel Gerver and Jim Tulpa – General Motors

Chassis dynamometer testing has traditionally been used for measuring tailpipe emissions from automobiles and light trucks. This approach provides a controlled environment and the ability to use large and accurate emissions sampling systems. However, recent developments in emissions measurement technology have given way to the opportunity of measuring tailpipe emissions from a vehicle as it is driven on-road, with the Semtech emissions sampling systems from Sensors, Inc., located aboard the vehicle. In Challenge X, competing vehicles will be driven over a pre-defined drive schedule that is similar in nature to laboratory-based emissions testing. Teams are required to demonstrate simultaneous control of key criteria emissions and will be scored based on an emissions bin structure.

The team that achieves the highest score based on the Challenge X emission bin structure will receive a check for $2,000 and a trophy for Lowest Regulated Tailpipe Emissions.

SCORED EVENTS AND AWARDS

WELL-TO-WHEELS GREENHOUSE GAS EMISSIONS
65 points
Event Captain: Steve Gurski – Argonne National Laboratory

The objective of the well-to-wheels greenhouse gas event is to reduce greenhouse gas (GHG) emissions relative to a production vehicle based upon emissions measurements. The GHG emissions of each vehicle will be attributed to two components: (1) upstream fuel-cycle emissions and (2) tailpipe emissions measurements. The maximum points for this event will be awarded to the vehicle with the lowest GHG score. Each vehicle will be assigned upstream GHG emissions based on the type and amount of fuel used during the on-road emissions event, according to a peer-reviewed analysis of GHG emissions contained in the Greenhouse Gas, Regulated Emissions and Energy Use in Transportation (GREET) model.

The team with the lowest GHG score will receive a check for $2,000 and a trophy for the Lowest Well-to-Wheels Greenhouse Gas Emissions.

ON-ROAD ENERGY USE AND CONTROL STRATEGY PRESENTATION
65 points
Co-Event Captains: Cheryl Clark and Jim Contes – General Motors

The purpose of the on-road energy use event is to determine the energy use and fuel economy of participant vehicles. Vehicles will be driven over a closed-loop road circuit with varying speeds, accelerations, and start/stops. The type of driving over the closed loop is designed to simulate normal real-world driving conditions.

The team that achieves the highest gasoline equivalent fuel economy will receive a check for $2,000 and a trophy for the Best On-Road Energy Use.

WELL-TO-WHEELS PETROLEUM ENERGY USE
65 points
Event Captain: Steve Gurski – Argonne National Laboratory

The well-to-wheels petroleum energy use event will determine a team's impact on the petroleum energy use of the vehicle. The reduction of petroleum energy usage on a well-to-wheels basis is a focus of the competition and is evaluated by this event. Petroleum energy use will be determined from the fuel use demonstration during the on-road energy use event. Each competition vehicle consumes petroleum energy, either during vehicle operation (tank-to-wheels) or during the production of the fuel (well-to-tank).

The team that uses the lowest amount of petroleum energy during the event will receive a trophy for the Lowest Well-to-Wheels Petroleum Energy Usage and a check for $2,000.

TECHNICAL PRESENTATION
65 points
Event Captain: Connie Bezanson – U.S. Department of Energy

The vehicle overview presentation event is designed to evaluate the effectiveness with which the team executed the second-year deliverables of Challenge X. In a technical presentation format, teams articulate their technical accomplishments and lessons learned from year two, along with future challenges for the final year of Challenge X. Particular emphasis is placed on understanding how teams have realized their overall design strategy, vehicle technical specifications, and vehicle architecture. Each team will make a technical presentation addressing key categories and then answer questions from a panel of industry and government experts. Scoring is based on presentation style and technical content.

The Best Technical Presentation Award ($1,500) is presented to the team with the highest score in the Technical Presentation event.

VEHICLE DEVELOPMENT REVIEW
65 points
Event Captain: Bob Larsen – Argonne National Laboratory

The Vehicle Development Review (VDR) is a combination vehicle inspection and team presentation designed to evaluate the level of engineering design and execution of that design commensurate with a prototype vehicle in the second year of the Challenge X development process. Following the general outline of the GM Vehicle Development Process, the VDR seeks to determine the degree to which the team's vehicles exhibit the level of component integration and functionality expected as the result of their stated design goals and VSTs.

The Best Vehicle Development Review Presentation ($1,500) is awarded to the team with the highest scores in the Vehicle Development Review event.

CONTROL STRATEGY PRESENTATION
75 points
Event Captains: Chuck Folkerts and Kent Helfrich – General Motors

After developing a vehicle control strategy to utilize advanced vehicle technologies, each team gives a presentation, then answers questions from a panel of government and industry experts. The control strategy presentation is a focused technical presentation detailing the hybrid powertrain control strategy demonstrated for the competition in each team's vehicle. The presentation includes information on the controls hardware architectures and software strategies chosen, as well as details on the overall strategy employed to provide the required control of the hybrid powertrain system, such that the safety, fuel economy, and performance targets are met.

The Best Control Strategy Presentation Award ($1,500) is presented to the team with the highest score in the Control Strategy Presentation event.

SPECIAL AND SPONSORED AWARDS

SPECIAL AWARDS

DR. DONALD STREIT SPORTSMANSHIP AWARD

This award is presented to the team that offers the highest level of assistance and support to other teams and organizers despite their own circumstances. This award is presented in honor of Dr. Donald Streit, who served as a dedicated faculty advisor to the Pennsylvania State University FutureTruck team and embodied the true meaning of sportsmanship. Although Dr. Streit's life ended prematurely, his memory and his example are carried on by the students who have and will continue to participate in advanced vehicle technology competitions for decades to come.

The winning team will win a trophy and check for $500.

BEST ENGINEERING & FABRICATION WORKMANSHIP

This award is presented to the team with the best combined interior and exterior vehicle presentation, based on the scores and input from the judges in the Vehicle Development Review event.

A trophy and check for $500 will be awarded to the winning team.

SPIRIT OF THE CHALLENGE AWARD

This award, presented by the competition organizers, is given to a team that exhibits the following characteristics: displaying exceptional perseverance in the face of adversity, maintaining a positive attitude throughout the competition despite significant challenges and obstacles, and pursuing exceptionally high technical standards for their team that best represent the spirit of the Challenge X competition.

The winning team will win a trophy and check for $500.

MOST IMPROVED TEAM AWARD

This award is presented to the team that demonstrates the most improved overall performance over last year's Challenge X competition. Improvement may be determined by performance in individual events or the overall competition.

The winning team will win a trophy and check for $500.

OUTSTANDING RADAR AWARD

The Challenge X Outstanding Radar Award was developed this year to recognize the significant contributions of the Team Radars—an important but sometimes overlooked role in the competition. The Radar program, instituted for the 1998 Ethanol Vehicle Challenge, was modeled after Radar O'Reilly of M.A.S.H. 4077. The main purpose of a Radar is to coordinate the team logistics and communications, both within the team, as well as with the organizers.

The winner of the Outstanding Radar Award will receive special recognition from the organizers.

SPONSORED AWARDS

NATIONAL SCIENCE FOUNDATION OUTSTANDING FACULTY ADVISOR AWARDS

Event Captain: Don Senich – National Science Foundation

It takes an enormous amount of time and energy for a faculty advisor to pull together a team of students to participate in an engineering competition, and professors may be reluctant to undertake such a time-consuming project such as Challenge X. Yet, most participating students claim that Challenge X is one of the highlights of their university experience. Since 1997, the National Science Foundation-sponsored faculty award has provided recognition to the faculty advisors who, through their leadership and research, are advancing the frontiers of science and engineering while passing on a legacy to their students that extends throughout the automotive industry.

Two awards will be presented to the faculty advisors who best incorporate the Challenge X goals, objectives, and activities into the undergraduate engineering curriculum and who have had the most significant impact on the engineering education of their students or have used advanced vehicle technology competitions (AVTCs) to enhance the engineering education experience. These funds are placed into a university account to be used to enhance the integration of the AVTC experience into the undergraduate curriculum for the benefit of the students.

National Science Foundation Outstanding Incoming Faculty Advisor Award – $15,000
National Science Foundation Outstanding Long-Term Faculty Advisor Award – $15,000

GMability OUTSTANDING OUTREACH AWARDS

Event Captain: Lynda Palombo – Natural Resources Canada

Sponsored by GM's K-12 Education Program, the Challenge X Outreach Program encourages teams to use various outreach strategies to raise awareness about critical energy and transportation-related issues throughout North America. The Outreach Program specifically challenges teams to focus their outreach efforts on the following audiences: K-12 students, local communities (community groups, professional organizations, etc.), and local media. This year, particular emphasis was placed on securing media coverage in the team's local markets. Teams will submit a written summary of their outreach activities to be eligible for up to 20 competition points. Teams may also compete for several sponsored outreach awards by giving an oral presentation to a panel of government and industry judges.

Outstanding Outreach, First Place ($1,500); Outstanding Outreach, Second Place ($1,000); and Outstanding Outreach, Third Place ($500) are awarded to teams based on additional outreach activities. Most Improved Outreach Program ($500), K-12 Educational Outreach ($500), Best Community Outreach ($500), Best Media Relations Award ($500), and Best Web Site Award ($500) are awarded to the teams that go above and beyond the minimum point requirements in these categories.

CHALLENGE X SPONSORED AWARDS

CHALLENGE X OUTSTANDING WOMEN IN ENGINEERING AWARD

Event Captain: Lyn St. James

The Lyn St. James Foundation is sponsoring an award to honor women engineering students who are demonstrating outstanding technical excellence and accomplishments through the Challenge X automotive engineering program. The award is intended to encourage more women to study engineering and pursue a career in automotive engineering after graduation.

The Lyn St. James Foundation is a 501 (c) 3 non-profit educational organization that provides leadership, vision, resources, and financial support in order to create an open environment for women's growth in automotive fields.

The winner will receive $1,000 for her university's Challenge X program.

THE MATHWORKS: CROSSOVER TO MODEL-BASED DESIGN AWARD

Event Captain: Paul Smith – The MathWorks

This award recognizes Challenge X teams that exhibit the most creative application of The MathWorks software products, including MATLAB and Simulink, to help achieve the overall competition objectives for the second year. Teams will be evaluated on how well they applied model-based design with The MathWorks' toolset to help achieve the overall competition objectives in the areas of plant modeling, controls design and tuning, data analysis and visualization, hardware implementation, the overall development process they followed, the quality of their presentation, and lessons learned.

First Place – $1,000, Second Place – $750, Third Place – $500

NATIONAL INSTRUMENTS: MOST INNOVATIVE USE OF VIRTUAL INSTRUMENTATION AWARD

Event Captain: Jeff Meisel – National Instruments

Virtual instrumentation is the combination of industry-standard computer technology with powerful application software and cost-effective hardware to perform the functions of traditional control or measurement devices. In Year 1, the National Instruments Award was given for the most innovative use of virtual instrumentation for control design and simulation. For Year 2, the National Instruments award will be given for the actual implementation of that strategy in the vehicle.

This award encourages Challenge X teams to use PC-based technology in creating sophisticated measurement, control, simulation, prototyping, and testing applications. Teams will be scored on design philosophy and control strategy, implementation of virtual instrumentation solution(s), how they overcame the challenges encountered during implementation, their schematic diagrams of the NI products in the vehicle and the systems/subsystems that they are measuring/controlling, and screen captures of major VI block diagrams and VI hierarchy.

First Place – $1,000, Second Place – $750, Third Place – $500

FREESCALE SEMICONDUCTOR: SILICON ON THE MOVE AWARD

Event Captain: Ron Stence – Freescale Semiconductor

This award recognizes the Challenge X teams that exhibit the best design and use of microprocessor hardware and software. The intent of this award is to identify the teams that have designed and developed their own hybrid electronics control system and can clearly explain the features and functions of the control systems necessary to develop a Hybrid Electric Vehicle. The teams that can demonstrate innovative uses of embedded processors and other silicon devices and have the ability to clearly identify and explain the student-developed control strategy elements (S/W and H/W) are encouraged to compete.

First Place – $1,000, Second Place – $750, Third Place – $500

Award Ceremony Guest Speaker, Paul Grimme

Paul Grimme is senior vice president and general manager of the Transportation & Standard Products Group at Freescale Semiconductor, the world's No. 1 supplier of semiconductors to global auto manufacturers and the No. 2 supplier of microcontrollers.

Since joining Motorola's semiconductor business in 1981, Paul has held positions in the areas of product engineering, marketing, and operations management. Prior to his current position, he served as corporate vice president and general manager of the 8/16-bit Products Division. In 1999, Paul was promoted to vice president and general manager of the Advanced Vehicle Systems Division. In this role, he led the division's 32-bit microcontroller thrust into the automotive powertrain and chassis markets—one of the most commercially successful architecture adoptions in the automotive segment.

Paul earned a bachelor's degree in electrical engineering from the University of Nebraska. In 1992, he received his master of business administration degree from the University of Texas.

Chip Foose

In a relatively short career, Chip Foose has created a legacy of designs and accomplishments that are well beyond his years. Chip was born and raised in Santa Barbara, California, and automobiles were definitely in his blood. Chip's first job was working for his father's company and by age twelve, Chip already had five years experience under his belt and had painted his first car: a Porsche 356. Early on, a chance meeting with Alex Tremulus, the designer of the "Tucker," was actually Chip's motivation to attend Art Center, where he majored in automotive product design. That was the start of a career that has taken him from various design positions at Asha Corporation, Stehrenberger Design and, notably, at Baker Sportronics, where he served as chief designer and fabricator of both models and prototypes of electric vehicles to be used in the NFL and NBL.

Chip also continued his work with his father, designing and building street rods, customs, studio vehicles, and show cars for films such as Blade Runner, Robo Cop, and Gone in 60 Seconds, which featured "Elinor." Chip also partnered with Boyd Coddington and Hot Rods by Boyd, eventually becoming President of Hot Rods by Boyd. Chip, who is widely acclaimed for his "Boyd Look" design and creative skills, was responsible for many internationally-known vehicles, such as: Roadster, Sportstar, Boydster I and II, and Boyd Air.

In 1998, Chip and his wife, Lynne, started their Huntington Beach, California-based company, Foose Design, an automotive and product design development company, specializing in illustration, graphics, ideation model making, surfacing, and complete construction of automobiles and automotive-related products for individuals, television, film, and automobile manufacturers.

Chip has been inducted into the San Francisco Rod and Custom Motorcycle Hall of Fame, the Darryl Starbird Rod & Custom Car Museum Hall of Fame, and the Hot Rod Hall of Fame. The later induction made history for Chip, being the youngest member ever inducted. Chip was also honored as the first recipient of the Good Guys Trendsetter Award and has won several America's Most Beautiful Roadster Awards and the coveted "Ridler" Award.

Chip Foose, however, may be best known for his role as host of the television series "Overhaulin'," which airs on the TLC network. **Chip will be a guest speaker at the 2006 Challenge X Award Ceremony and Ride and Drive on June 8, 2006.**

Challenge X Mentors

At the beginning of Challenge X, a GM engineer was assigned to each team to provide technical mentoring. Throughout the three-year program, these committed mentors are helping to guide the teams through the vehicle design process and provide an industry perspective on their design approach. GM mentors have also helped the teams explore the benefits of their chosen technologies, to help them produce the most efficient, consumer-acceptable vehicle possible.

Michael Abowd	Engineering Group Manager – Telematics Software	University of California - Davis
William Beggs	Performance Engineer – Full-size Truck Energy and Drive Quality	Mississippi State University
Rayel Booth	Lead Engineer – Mid-size Car HVAC and Powertrain Cooling	Ohio State University
Thomas Ender	Engineering Group Manager – Vehicle Controls	University of Waterloo
Matthew Galligan	Engineering Specialist – Cross Platform Electrical Validation and Diagnostics	University of Michigan
Christopher Graham	Engineering Specialist – Engine Calibration and Emissions	University of Texas at Austin
Fred Hohnstadt	Performance Engineer – Two-mode Hybrid Noise and Vibration	University of Tennessee
Cassandra Hughes	Design Engineer – Concept Vehicle Electrical Architecture	Pennsylvania State University
Kevin MacFadden	Development Engineer – Diesel Engines	University of Tulsa
Art McGrew	Design Manager – Transit Bus Hybrid	Rose Hulman Institute of Technology
Scott Otterson	Electrical Strategist – Common Body Control Module	University of Akron
Jon Stec	Engineering Specialist – Electronic Returnless Fuel System Calibrator	Texas Tech University
Aaron Sullivan	Performance Engineer – Small SUV Ride and Handling	University of Wisconsin
James Sydenstricker	Lead Calibrator – Two-Mode Hybrid RWD Transmission	West Viginia University
Keith Van Houten	Performance Engineer – Luxury/Performance Car Noise and Vibration	Virginia Polytechnic Institute and State University
Bill Venner	Performance Engineer – Full-size SUV Noise and Vibration	San Diego State University
Jeremy Worm	Development Engineer – Two-Mode Hybrid RWD Engine	Michigan Technological University

CHALLENGE X JUDGES

JUDGE BIOS

Written Technical Report

Gary Baker is a vehicle efficiency engineer for the CANMET Energy Technology Center of Natural Resources Canada (NRCan), which conducts R&D and related technology transfer activities related to efficiency technologies for the industrial and buildings sector, vehicle and engine efficiencies, and alternative transportation and renewable energy technologies.

Frederick M. Cartwright is the Director of Technology Planning for Global Planning and Program Management for GM Powertrain, where he has responsibility for the development of integrated technology plans for gasoline, diesel, and hybrid powertrains.

Roger A. Clark serves as Senior Manager for Energy, Mass, Drive Quality, and Environment for GM. His position includes leadership in vehicle performance, fuel economy, and mass requirements development; Corporate Average Fuel Economy (CAFÉ) strategy development; and the Fuel Economy Learning Vehicle innovation program.

Forrest Jehlik is Technical Coordinator for the Challenge X program, where he is responsible for the technical execution of the competition from the competition logistics to team support. Forrest is formerly a General Motors powertrain research and development engineer and is a proud veteran of the student competitions.

Steve McConnell is a Research Engineer in the Center for Transportation Research, Energy Systems Division at Argonne National Laboratory. Previously, Steve was a Project Engineer at Automotive Testing Laboratories. He graduated from West Virginia University with a B.S. and M.S. in Mechanical Engineering and served as Ergonomics and Controls Team Leader and Crew Chief for WVU's SAE Formula Team.

Chuck Risch has extensive experience with advanced automotive technology and alternative fuels from his more than twenty years at Ford Motor Company. A pioneer in developing and commercializing these technologies, Chuck joined Argonne National Laboratory after his recent retirement from Ford.

Technical Presentation

Don Baldwin is Director of OE Technical Marketing, Michelin North America. He has 25 years with Michelin and is currently responsible for technical marketing and communications for the Michelin Automotive Industry Division.

Micky Bly is Director of Hybrid Vehicle Integration at GM's Milford Proving Ground, where he is responsible for the overall vehicle integration of the GM Hybrid and Two-Mode Hybrid Systems. Micky is also one of the GM Co-Executive leads for Challenge X.

Debbi Bourke is a Project Engineer at COBASYS LLC working in the transportation department. She has worked on a wide variety of projects, including a hybrid electric locomotive, an all-electric bus, a hybrid electric transit bus, and a hybrid electric bus.

Joe Cargnelli is Chief Technology Officer of Hydrogenics, one of the company's founders in 1995 and has served as a director since January 1996. Joe has led the evolution of the company's broad technology portfolio over the years and has been a key contributor in the alignment of technology development with Hydrogenics leading hydrogen and fuel cell product development.

John Cotner is a Senior Applications Engineer for the Field Automotive Systems Team of Freescale Semiconductor, where he works on hybrid vehicle control electronics and the implementation of advanced powertrain control algorithms on Freescale 32bit processors. John has worked in the automotive electronics industry for 17 years, managing Digital Radio and In-Vehicle Communication for Ford as well as Anti-Lock Brakes, and Vehicle Stability Control and Adaptive Cruise Control for Kelsey-Hayes. John received both B.S.E. and M.S.E. degrees in Electrical Engineering from the University of Michigan.

Ted Grey is Manager of Fuel Cell Stack and Power Module Design in GM's Advanced Product Engineering department, where he is responsible for the stack design and components.

Jon Heidorn is VP, Business Strategy & Marketing for UGS Corporation, where he is responsible for marketing all UGS product lines within the Americas. He has over 20 years of enterprise product design, manufacturing, and data management experience in the product lifecycle management industry. Previously, he held positions with Schlumberger Technologies Applicon, Halliburton, and P.C. Dynamics. Mr. Heidorn earned a bachelor's degree from Eastern Michigan University and an MBA from the University of Illinois-Chicago in marketing and finance.

Larry Johnson has more than 30 years of transportation research experience and is the author or co-author of more than 70 publications and conference presentations on transportation topics. He serves as the Director of the Transportation Technology R&D Center at Argonne National Laboratory.

John Kluza is a Consulting Engineer for The MathWorks, specializing in Controls, Modeling, and Rapid Prototyping. He has a M.S. from Penn State and a B.S. from Lehigh University—both in Mechanical Engineering. Previously, John worked on a number of electro-mechanical systems, including all-electric and electronically controlled air powered gantry cranes at Ingersoll-Rand, a robotic cargo handling system for the U.S. Navy at Penn State and prosthetic actuator devices at CyBotic Technologies.

Stanley Ludlow is Program Engineering Manager for the Theta Architecture, NAO Engineering, for GM. His position includes responsibility for engineering of the Chevrolet Equinox and the Pontiac Torrent.

Ricardo Martinez, Fuels Product Specialist, manages the Specialty Fuels Team within BP's Global Fuels Technology group. The Specialty Fuels Team supplies custom-blended gasoline and diesel to the automotive industry, laboratories, and academia for research purposes.

Mark Roberts is the Director of the Talent Acquisition Center at GM. He leads the overall salaried recruiting function and Academic Relations activities for GM in the United States and is the chairperson for GM's Global Talent Acquisition Roundtable.

Don Senich is the director of the grant program for "academic liaison with industry" at the National Science Foundation. He is responsible for implementing 22 million dollars in academic and industrial collaborative research in the Engineering Directorate and is the procurement interface with the Small Business Administration's Office of Government Contracting.

Dr. K. Thirumalai is Chief Engineer for RD&T with the U.S. Department of Transportation's (DOT's) Research and Innovative Technology Administration, a new administration created by DOT to focus on innovations and advanced technologies for transportation.

Control Strategy Presentation

Charles H. Folkerts is the Manager of the Model-Based Controls group within the Advanced Propulsion System Controls department of GM Powertrain. He leads the design and development of control systems, architecture, and algorithms for future powertrain systems.

Tim Grewe is the chief engineer for GM's AHS2 – EP40/50 parallel hybrid system. The EP40/50 is a parallel hybrid system for heavy-duty transit buses that entered production in 2003; the AHS2 will enter production in 2007.

Kent Helfrich is director of GM's Advanced Powertrain Control Systems, where he develops powertrain control systems for near-future vehicles through internal R&D and strategic industry and university partnerships.

Chris Hennessey is the Applications & Controls Group Engineering Manager for AVL Powertrain Engineering, Inc. He has over 10 years of Powertrain Development experience with vehicle level controls, calibration, and production engineering programs. Currently, he is focused on the expansion of AVL's globally based advanced powertrain development efforts, with specific focus on hybrid powertrain development.

Scott Kirchner is a Senior Manager in the Global Electrical Software and Controls Central Engineering Group at GM. His group is responsible for vehicle chassis and body software and controls, and Scott is the GM Liaison to Intrepid Controls for Challenge X.

James B. Kolhoff is the Director of Software Engineering for GM Powertrain. He is responsible for production software design and testing for embedded engine and transmission controls, system engineering for security-critical powertrain functions, and powertrain-to-vehicle electronic and software interface specifications.

Robert Leale is a Field Applications Engineer for Intrepid Control Systems, Inc.

Aymeric Rousseau is head of the Advanced Powertrain Vehicles Modeling Department at Argonne National Laboratory. After working for PSA Peugeot Citroen for 3 years, he joined Argonne, where he is responsible for the development of the Powertrain Systems Analysis Toolkit (PSAT).

Justin Shriver has experience designing, testing, and implementing algorithms for stability control and is currently part of The MathWorks Advanced Support Group.

Lee Slezak manages the Advanced Vehicle Simulation and Evaluation Activities for the Office of FreedomCAR and Vehicle Technologies Programs within DOE's Office of Energy Efficiency and Renewable Energy.

Richard Soja works for Motorola and is focused on system design and definition of new microcontroller products. He contributed to the architecture and design of the MPC5554.

John Theofanopoulos worked on multiple DOE-sponsored advanced technology vehicle competitions during college. He works at Cobasys as a software development engineer and is currently Manager of Software Development for Stationary Applications.

Andrew Watchorn is the Academic Product Marketing Engineer, Northeastern U.S., for National Instruments. During college, he worked for seven summers at GM in various roles — from manufacturing engineer on assembly lines to project engineer related to the Cadillac Night Vision Head-Up-Display System.

Vehicle Development Review Presentation

A. Harvey Bell IV is Executive Director of GM North America Advanced Vehicle Development. The Program Engineering Managers who report to him are responsible for the product and process engineering integration for all North America advanced vehicle programs, as well as the development engineering and validation associated with those programs.

Joseph Cargnelli is Chief Technology Officer for Hydrogenics, a leading global developer of hydrogen and fuel cell products. Joe was one of the company's original founders and has served on the board since 1996. He earned a Master's degree in Applied Science, Mechanical Engineering, from the University of Toronto, where he also received a Bachelor's in the same field. Previously, Joe served as a Research Engineer with the Laboratory of Advanced Concepts in Energy Conversion, Inc., a laboratory engaged in the research, development and demonstration of alkaline fuel cells and hydrogen storage methods.

Tom Carter has a bachelors and masters degree in mechanical engineering from Virginia Tech. He has worked 23 years for Michelin Americas Research Corporation including four years as a design engineer in Clermont-Ferrand, France, Michelin's international headquarters. His work experience includes tire testing, tire design, and business analyst for world wide testing.

Ray Corbin, president of AVL Powertrain Engineering, Inc., is responsible for the company's powertrain engineering consultancy activities and growth of the company's North American simulation software sales. Corbin is an active member of the Society of Automotive Engineers and the North American Defense Industry Association. Corbin holds a bachelor's degree from Kettering University (formerly General Motors Institute), Flint, Michigan, in mechanical engineering.

Jack Dawson manages Dana Corporation's Technology Resource Park in Ottawa Lake, Michigan, and is responsible for identifying and assessing emerging technologies that could disrupt Dana's current portfolio. Mr. Dawson is also responsible for the Dana India Technical Center, which is an engineering and IT organization supporting Dana globally. He has worked in the auto industry for more than 30 years in design and process engineering with General Motors, Ford, Volkswagen, and the Tier 1 supply base. He has a mechanical engineering degree from General Motors Institute (Kettering).

CHALLENGE X JUDGES

Don Hillebrand has over 20 years of experience in automotive engineering, research management, and government affairs and was a senior policy advisor to the Executive Office of the President, White House Office of Science and Technology. He is the Vehicle Systems section leader at Argonne National Laboratory's Center for Transportation Research.

Michael Iverson has worked for Johnson Controls, Inc. (JCI) Automotive Group for over 14 years and has experience in a variety of advanced battery products. As the Manager of Applications Engineering for the JCS Advanced Battery Solutions group, he is currently working on OE hybrid and plug-in hybrid vehicle programs using JCS nickel-metal hydride and lithium-ion battery technologies.

Robert Lawson is a recent graduate of Clemson University with a Master's degree in Mechanical Engineering. At Clemson, his research was focused on vehicle dynamics and included modeling and simulation of tractor-trailer rollover and on-center handling for passenger cars. He is currently employed with Michelin where he works to design and develop innovative run-flat solutions. He is also responsible for designing the PAX assemblies, which were supplied to each of the Challenge X teams.

Pete Maloney is a Senior Consulting Team Leader at The MathWorks, where he provides engineering consulting services to automotive and aerospace customers to help them apply model-based design practices using MathWorks tools.

Derek Matthews was the founder and team captain of the McMaster Formula SAE team. He has worked with Ford of Canada, Ecostar, and DaimlerChrylser. He is currently the Customer Service & Application Engineering Manager for Ballard Power Systems.

John M. Miller is VP, advanced transportation applications for Maxwell

Technologies, with primary responsibility for developing and promoting ultracapacitor-based solutions for the automotive and heavy vehicle industries. Previously, Mr. Miller spent 18 years with Ford Motor Company, where he led several auto motive electronics and electric and hybrid drive train development programs, and has also worked as an automotive industry consultant, author, and guest lecturer. He holds 50 patents and has written more than 100 scientific and technical papers and three books, including *Hybrid Vehicle Propulsion Systems*. Mr. Miller holds a BS degree from the University of Arkansas, an MS degree from Southern Methodist University, and a doctorate. Mr. Miller will be the host and guest speaker at the Maxwell Technologies Challenge X Faculty Advisor Round Table on June 5, 2006.

Larry Nitz is the Executive Director of GM's Hybrid Powertrain engineering team. He is responsible for the engineering execution of GM's hybrid powertains on a global basis.

Ed Wall is Program Manager of the FreedomCAR and Vehicle Technologies Program Office in DOE's Office of Energy Efficiency and Renewable Energy. He received a B.S. in Physics from Muhlenberg College and a Master's in Geology from the Johns Hopkins University.

Nicholas Zielinski is the Vehicle Chief Engineer for Advanced System Integration within the Advanced Vehicle Development Center of GM, where he is responsible for leadership of the vehicle integration and performance development of advanced propulsion systems, electronic controls, and by-wire systems prior to their implementation in volume production vehicles.

Outreach Presentation

Andrea Arnold is Public Relations Manager for AVL North America, which offers combined solutions of powertrain engineering, simulation software and testing, and instrumentation systems. Prior to this, Arnold was a Senior Account Executive at Eisbrenner Public Relations. Arnold has a Bachelor of Arts degree in Communication from Michigan State University.

Liz Callanan is the Community Relations Manager for The MathWorks, leading partnerships with worldwide universities, aerospace and automotive companies, and engineering organizations. She has managed product marketing programs and public relations for The MathWorks.

Betsy Creedon is Director of Business Operations in GM's Law and Public Policy Group.

Jane Dalziel is the Director of Communications & Government Liaison of Hydrogenics Corporation. Since joining Hydrogenics in 2000, Jane has been evolving Hydrogenics' communications and government relations efforts to position the company as a recognized leader in hydrogen and fuel cell technology and products, and to advance the industry sector as a whole across a wide range of stakeholder audiences. Jane graduated from Queen's University in Kingston, Ontario, with a Bachelors Degree in Chemical Engineering.

Matt Hartwig has been the Communications Director for the RFA since October 2005. Prior to working at the RFA, he served as a communications aide to Senator Tom Harkin on the Senate Agriculture, Nutrition and Forestry Committee and as a spokesman with Consumers Union. Matt hails from Thornton, Iowa, and is a graduate of Iowa State University.

Andy Mastronardi is Global Director of the Freescale University Program. Prior to Freescale, Andy spent 26 years in the education industry, both as a teacher and in educational publishing.

Roger Meyer is the team lead in the Office of Communications and Outreach for DOE's Office of Energy Efficiency and Renewable Energy. Previously, he served as a press secretary on both the House and Senate sides of Capitol Hill.

Lynda Palombo is Chief, Office of Coordination and Technical Information for the CANMET Energy Technology Centre (CETC) of NRCan. For more than 16 years, Lynda has been active in the marketing and promotion of efficient and alternative transportation technologies.

Jenny Rios is an account director with Strat@comm, a Washington, D.C.,-based public relations firm. She has a decade of public relations and strategic consulting experience, specializing in media relations, writing and editing, community outreach, grassroots mobilization, and special events work in the private and public arenas.

Freescale Silicon on the Move Award

Ted Bohn is a Research Engineer for Argonne National Laboratory's Advanced Powertrain Facility. He has more than 20 years experience in electrical engineering in industrial and research environments, with an emphasis in power electronics, electric machines, and control systems. Ted has been involved in HEV-related design projects and student vehicle design competitions for more than 15 years. Ted has a MS in Electrical Engineering from the University of Wisconsin – Madison.

Bruce Emaus is the President of Vector CANtech, a company that specializes in development tools and embedded software components for automotive distributed applications. Mr. Emaus is also the chairman of the SAE Embedded Software Standards Committee and co-chair of the SAE Distributed Embedded Systems Engineering Task Force. With over 30 years of product development experience covering embedded software, electronics hardware, systems and information engineering, he is a leading expert in the area of distributed embedded systems and small area network protocols.

Pete Savagian is Engineering Director of Hybrid Powertrain Systems for GM Powertrain. His group is responsible for hybrid powertrain architecture development and control, analysis, and simulation.

Ron Stence has more than 25 years of professional experience and holds nine U.S. patents in microprocessor architectures and systems. He is currently in the Microcontroller Division of Freescale's Transportation & Standard Products Group, working in a variety of embedded processor areas for the automotive industry.

Rich Swortzel, Director of Business Development for MotoTron, has a BSEE and MSEE and is a licensed engineer in the State of Ohio. Rich worked for General Motors 10 years and has spent the last 12 years in the embedded controls business developing solutions for the production implementation of model-based software, including the current MotoTron MotoHawk platform.

National Instruments Most Innovative Use of Virtual Instrumentation Award

Rodney Cummings graduated with a bachelor's degree in Computer Science from the University of Texas in 1990. Since that time, he has worked at National Instruments as a software architect and group manager on a variety of communications products spanning a variety of markets, including test instrumentation, industrial I/O and motion, telecom, and automotive. In recent years, Rodney has focused on National Instruments products for automotive communications, including CAN, GMLAN, FlexRay, and LIN.

Eric Gassenfeit is the Information Officer for GM Powertrain Product Development, where he has global responsibility for all IT systems, applications, infrastructure, and support services used in powertrain product development.

Becky Linton is a Field Sales Engineer for National Instruments in the state of Michigan. She works with all academic accounts in the state as well as General Motors and other automotive manufacturers. Becky started her career at NI in 2004 as a member of he Engineering Leadership Program. Becky is a member of IEEE and received a bachelors of science in electrical engineering from Kettering University, formerly GMI Engineering & Management Institute.

Jeff Meisel is the NI Sponsor for the ChallengeX program and Product Marketing Engineer for LabVIEW Real-Time and Embedded. Jeff started his career at NI in 2004 as a member of the Engineering Leadership Program. Jeff is an active member of IEEE and holds a bachelors of science in computer engineering from Kansas State University.

The MathWorks Crossover to Model-Based Design Award

Craig Borghesani has over 17 years of MATLAB experience. He ran his own consulting company specializing in MATLAB and Simulink development for 10 years. Some of his past customers include GM, Pratt & Whitney, and Otis Elevator. He joined the MathWorks in 2004 as an Application Engineer after moving to San Diego.

Jon Friedman is the Automotive Industry Marketing Manager at The MathWorks, leading the marketing effort to foster industry adoption of The MathWorks' tools and Model-Based Design. Previously, Jon held various positions at Ford, including software development research, product development, and Electrical Engineering Supervisor. Jon has also worked as an Independent Consultant for Delphi, General Motors, Chrysler, and the Armaments Command. Jon holds a B.S.E., M.S.E., and Ph.D. in Aerospace Engineering as well as an MBA—all from the University of Michigan.

Robin Lo is an Energy and Drive Quality Performance Engineer in GM's Hybrid Integration Group, where he works on the Saturn Vue Green Line hybrid. In this role, he has been integral in ensuring that this vehicle met its targets for fuel economy and vehicle performance. Robin also serves as the Lead Engineer for the Energy Hybrid Expert Team at GM.

Paul Smith is the Manager of North American Consulting at The MathWorks. His background includes serving as an automotive powertrain control design engineer at Ford Motor Company and as a nuclear propulsion officer in the U.S. Navy.

Outstanding Faculty Advisor

Connie Bezanson manages DOE's Advanced Vehicle Competition activities within the FreedomCAR and Vehicle Technologies Program Office. She received a B.S. in Mechanical Engineering from The Catholic University of America.

Forrest Jehlik (See bio on page 24)

Bob Larsen is a Senior Technical Advisor at Argonne National Laboratory. Bob initiated the Advanced Vehicle Technology Competition program in 1989 and was instrumental in the development of the Challenge X competition.

Cindy Svestka is an Energy and Drive Quality Performance Engineer in GM's Hybrid Integration Group, where she is responsible for meeting fuel economy vehicle performance targets through testing, development, and integration of a future hybrid application. She also serves as the GM Technical Lead for Challenge X and was active in student vehicle competitions when she was in college.

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Natural Resources Canada

Natural Resources Canada (NRCan) has been a long-time supporter of the U.S. Department of Energy's advanced vehicle technology competition program, providing technical and program support for more than 20 competitions over 16 years. Challenge X underscores NRCan's commitment to addressing greenhouse gas reductions and supporting sustainable energy policies and advanced automotive technologies.

NRCan provides knowledge, expertise, and program activities for the sustainable development and use of Canada's natural resources and to support the global competitiveness of its resource and related sectors. This includes energy activities that encompasses policy development, market development programs, and international activities in energy efficiency, renewables, transportation technologies, alternative fuels, and conventional fuels.

SPONSOR WEB SITE www.nrcan.gc.ca

The MathWorks

The MathWorks is the leading developer and supplier of technical computing software. Employing more than 1,000 people, The MathWorks was founded in 1984 and is headquartered in Natick, Massachusetts, with offices and representatives throughout the world. The MathWorks customers are over 500,000 of the world's leading technical people, in over 100 countries, on all seven continents. They work at innovative companies, government research labs, financial institutions, and at more than 3,500 universities. They rely on us because MATLAB and Simulink have become the fundamental tools for their engineering and scientific work. By sponsoring Challenge X, The MathWorks realizes its mission of support for math and science educational endeavors, fostering growth opportunities for those who will make contributions and discoveries in the future.

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NATIONAL INSTRUMENTS™

For 30 years, National Instruments has been a technology pioneer and leader in virtual instrumentation—a revolutionary concept that has changed the way engineers and scientists in industry, government and academia approach measurement and automation. Leveraging PCs and commercial technologies, virtual instrumentation increases productivity and lowers costs for test, control, and design applications through easy-to-integrate software, such as NI LabVIEW, and modular measurement and control hardware for PXI, PCI, PCI Express, USB and Ethernet. Headquartered in Austin, Texas, NI has more than 3,800 employees and direct operations in nearly 40 countries. For the past seven years, FORTUNE magazine has named NI one of the 100 best companies to work for in America.

In addition to providing an NI Application Engineer advisor to each team for product support and expertise through all phases of the competition, NI will also donate more than $750,000 in software, hardware, and training products to participating teams.

Through its support of the Challenge X competition, NI continues its commitment to education by providing tomorrow's engineering leaders with tools to be successful today and in the future.

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Freescale Semiconductor, Inc. is a global leader in the design and manufacture of embedded semiconductors for the automotive, consumer, industrial, networking, and wireless markets. Freescale became a publicly traded company in July 2004 after more than 50 years as part of Motorola, Inc. The company is based in Austin, Texas, and has design, research and development, manufacturing or sales operations in more than 30 countries. Freescale, a member of the S&P 500®, is one of the world's largest semiconductor companies with 2005 sales of $5.8 billion (USD).

Challenge X design teams will receive Freescale hardware development tools, software, and training based on our industry-leading PowerPC microcontrollers. Using the same products designed into General Motors powertrain engine control systems around the world, the Challenge X teams will gain real-world experience in real-time engine management applications, from fuel and spark control to emissions and vehicle diagnostics. Freescale is also providing each team with our CodeWarrior development studio, which provides state-of-the-art debugging technology with a highly visual and automated framework that accelerates design development.

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AVL

AVL, headquarted in Graz, Austria, is the world's largest privately owned and independent company for the development of gasoline, diesel, and alternative fuel powertrain systems, as well as fuel cell and hybrid technologies. The company, which also manufactures powertrain instrumentation and test systems, guarantees close cooperation with customers by affiliates and local offices worldwide. AVL's North American Headquarters is located in the Detroit suburb of Plymouth, Michigan.

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

EPA's mission is to protect human health and to safeguard the natural environment—air, water, and land—upon which life depends. For more than 30 years, the EPA has been working for a cleaner, healthier environment for the American people. Additionally, EPA supports environmental education projects (www.epa.gov/teachers/grants.htm) that enhance the public's awareness, knowledge, and skills to make informed decisions that affect environmental quality.

DEPARTMENT OF TRANSPORTATION UNITED STATES OF AMERICA

U.S. Department of Transportation (DOT) mission is to develop and administer policies and programs that contribute to providing fast, safe, efficient, and convenient transportation at the lowest cost consist with the national objectives of general welfare, economic growth and stability, the national security and the efficient use and conservation of resources in the United States. The R&D programs in DOT support the development and implementation of technologies to support this mission and improve the nation's transportation systems and ensuring safety of all transportation operations. DOT employs almost 60,000 people across the country, led by the Secretary of Transportation and the following operating administrations and bureaus: Federal Aviation Administration, Federal Highway Administration, Federal Motor Carrier Safety Administration, Federal Railroad Administration, Federal Transit Administration, Maritime Administration, National

Highway Traffic Safety Administration, Research and Innovative Technology Administration and Pipeline, Hazardous Materials Safety Administration, Saint Lawrence Seaway Development Corporation, and the Surface Transportation Board. The newly created Research and Innovative Technology Administration (RITA) enables the Department to more effectively coordinate and manage the Department's research portfolio and expedite implementation of cross-cutting innovative technologies.

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GOLD SPONSORS

The National Science Foundation (NSF) has been a long-time supporter of the U.S. Department of Energy's advanced vehicle technology competitions. In addition to providing financial support to Challenge X, each year the NSF provides two $15,000 awards to faculty members who have made significant contributions to the goals of the Challenge X program and to engineering education. This year will be the eighth year for the outstanding faculty advisor(s) award sponsored by NSF.

NSF is an independent federal agency that supports fundamental research and education across all fields of science and engineering, with an annual budget of nearly $5.58 billion. NSF funds reach all 50 states through grants to nearly 2,000 universities and institutions. Each year, NSF receives about 42,000 competitive requests for funding and makes about 9,800 new funding awards. The NSF also awards over $425 million in professional and service contracts yearly.

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BP has transformed: growing from a local oil company into a global energy group, employing over 100,000 people and operating in over 100 countries worldwide. In addition, the company is committed to making a positive contribution and has taken a leadership role toward a cleaner environment. BP delivers cleaner-burning and lower-emissions fuels to more than 115 cities worldwide that have serious air quality problems. As vehicle technology continues to advance, fuels and lubricants must also change to keep pace with the new technology. Several years ago, BP introduced ECD® an emissions control (ultra-low sulfur) diesel fuel that helps sulfur-sensitive control systems operate effectively. BP is supplying a wide spectrum of fuels to the Challenge X teams, including biodiesel (B20), ethanol (E85), and Hydrogen.

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Cobasys is committed to bringing advanced, integrated energy storage system solutions into widespread commercial production for transportation and stationary applications. Our vision is to be recognized as the world's most admired energy storage solutions company.

Cobasys offers complete plug-and-play NiMHax® system solutions for Hybrid Electric Vehicles (HEV), Electric Vehicles (EV), Heavy Duty Vehicles (HDV), and 42-volt applications. Our patented Nickel Metal Hydride (NiMH) technology and NiMHax(r) battery systems have been proven over millions of miles or real-world use in cars, trucks, and buses. Cobasys is also developing battery solutions for Uninterruptible Power Supply (UPS), Telecom stationary power systems, and Distributed Generation Systems. NiGUARD®, NiCOM®, and NiGEN® battery systems can be easily configured to provide the power and energy you require.
Our NiGUARD® solutions offer owners a durable, reliable back-up power system that provides long life over a wide range of environmental conditions and in one- third the space of conventional lead acid batteries.

Cobasys is a joint venture between Chevron Technology Ventures LLC, a subsidiary of Chevron Corporation and Energy Conversion Devices. Cobasys headquarters is located in Orion, Michigan, and our main facility for complete module manufacturing and system assembly is located in Springboro, Ohio.

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Chevron is an integrated global energy company participating in virtually all aspects of the global energy business. It is the second largest U.S.-based energy company and the fifth largest in the world. Chevron's 47,000 employees work in approximately 180 countries around the world, producing oil and natural gas and marketing fuels and other advanced energy products. Chevron, through Chevron Technology Ventures, is involved with identifying, developing, and commercializing new and emerging technologies and new energy systems that promise to play an increasingly important role in the world's energy mix and environmental stewardship. Such activities include fuel processing, hydrogen infrastructure, and advanced batteries. Technology Ventures is actively engaged in developing and commercializing several key enabling technologies through internal development, joint ventures, and equity investments to create new market opportunities for the next generation of clean, efficient energy systems.

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Ballard is working with many of the world's leading auto manufacturers to develop the next generation of efficient and clean engines for the world's vehicles. These include transit buses, automobiles, and trucks using Ballard® fuel cells, fuel cell engines, and electric drives to form complete fuel cell power trains. With extremely low, or zero emissions, Ballard® fuel cell engines are ideally suited to the environmental performance demanded of the new generation of automotive power, with the added advantage of being cleaner, quieter, and more efficient than the internal combustion engine.

Ballard's focus on the transportation market is to drive product innovation, cost reduction, and the development of volume manufacturing processes. Ballard, together with its customers, has demonstrated the suitability of proton exchange membrane (PEM) fuel cells as the best alternative to internal combustion engines for automotive power and reaffirmed Ballard's leading position in this large market.

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MICHELIN

The world's largest tire maker, Michelin manufactures and sells tires for every type of vehicle, including airplanes, automobiles, bicycles, earthmovers, farm equipment, heavy-duty trucks, motorcycles, and the space shuttle. The company also publishes travel guides, maps, and atlases covering Europe, Asia, Africa, and North America. Headquartered in Greenville, S.C., Michelin North America employs 23,920 and operates 21 plants in 17 locations.

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SENSORS' EMISSIONS MEASUREMENT TECHNOLOGY

Sensors, Inc., is the leading manufacturer of portable emissions test systems for real-world applications. Our products reflect an engineering focus on innovation, timeliness, and quality, as well as the latest manufacturing techniques. Sensors, Inc., also provides solutions for engine test cells, end-of-line testing, and comparison studies of after-treatment devices and fuel additives. Technologies include NDIR, NDUV, and FID for gaseous measurements; pressure differential for total exhaust flow and mass measurement of particulate using a quartz crystal microbalance technique; and partial dilution sampling systems. The SEMTECH product line includes in-use diesel and gasoline engine test systems (SEMTECH-D, SEMTECH-G, and SEMTECH EFM). Sensors' headquarters houses administrative, engineering, and manufacturing facilities and is located in Saline, Michigan.

SPONSOR WEB SITE www.sensors-inc.com

dSPACE

dSPACE is a market innovator and leading producer of engineering tools for embedded controller development. We provide integrated systems for prototyping control algorithms, automatic production code generation, controller testing, controller calibration, and engineering support services. We look forward to participating in the Challenge X competition as an opportunity to empower student engineers to quickly develop innovative solutions to the challenges of reduced emissions, increased performance, and driver satisfaction. Our robust and comprehensive ECU development environment can dramatically reduce development time and costs while providing increased flexibility for continuous modifications throughout the process. Today, more than 12,000 dSPACE systems are in use worldwide, serving customers in the automotive, aerospace, agricultural, educational, engineering, robotics, and noise & vibration industries.

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RFA
Renewable Fuels Association

As the national trade association for the U.S. ethanol industry, the Renewable Fuels Association (RFA) promotes policies, regulations, and research and development initiatives that will lead to the increased production and use of fuel ethanol. RFA membership includes a broad cross-section of businesses, individuals, and organizations dedicated to the expansion of the U.S. fuel ethanol industry.

Organized in 1981, RFA serves as the voice of the ethanol industry, providing advocacy, authoritative analysis, and important industry data to its members, Congress, federal and state government agencies, strategic partners, the media, and other opinion-leader audiences.

SPONSOR WEB SITE www.ethanolRFA.org

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Vector is a recognized pioneer in the development of CAN, FlexRay, and LIN development tools and embedded software components. Our tool suite includes CANoe for network development through testing; CANalyzer for network analysis; and CANape Graph for measurement, calibration, and diagnostics. Vector is also the official software provider of GMLAN, DC Embedded, and FNOS. With over 15 years of experience, Vector provides an international presence with offices in Europe, North America, and Japan.

Vector is proud to be a sponsor of the ChallengeX program. Universities use Vector tools throughout the world to educate the future engineering leaders for the industry challenges of today and the future.

SPONSOR WEB SITE www.vector-cantech.com

Dana Corporation is a global leader in the design, engineering, and manufacture of value-added products and systems for automotive, commercial, and off-highway vehicle manufacturers and their related aftermarkets. Delivering on a century of innovation, the company's continuing operations employ approximately 45,000 people worldwide dedicated to advancing the science of mobility. Founded in 1904 and based in Toledo, Ohio, Dana operates hundreds of technology, manufacturing, and customer service facilities in 30 countries. The company reported sales from continuing operations totaling $7.9 billion in 2003.

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For more than 80 years, Caterpillar, Inc., has been building the world's infrastructure and, in partnership with its worldwide dealer network, is driving positive and sustainable change on every continent. With 2005 sales and revenues of $36.34 billion, Caterpillar is a technology leader and the world's leading manufacturer of construction and mining equipment, diesel and natural gas engines, and industrial gas turbines.

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Intrepid Control Systems, Inc.
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Intrepid Control Systems, Inc., has been delivering vehicle development tools to major OEMs and their suppliers for over 10 years. Our premier products include neoVI, neoVI Pro, ValueCAN, and Vehicle Spy software. They have been helping vehicle, aeronautic, and marine engineers for over a decade. We pride ourselves on not only our products, but also the high level of service and support that we offer to our customers.

Intrepid Control Systems has put considerable time and effort into General Motors new higher level protocol called GMLAN. Our Vehicle Spy software includes many integrated diagnostic features that enable someone with little or no knowledge of GMLAN to complete highly complicated request and decoding of GMLAN diagnostics.

At Intrepid Control Systems, we make vehicle networks simpler.

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UGS is a leading global provider of product lifecycle management (PLM) software and services with nearly 4 million licensed seats and 46,000 customers worldwide. Headquartered in Plano, Texas, UGS' vision is to enable a world where organizations and their partners collaborate through global innovation networks to deliver world-class products and services while leveraging UGS' open enterprise solutions, fulfilling the mission of enabling them to transform their process of innovation.

SPONSOR WEB SITE www.ugs.com

MotoTron Corporation is the leader in production code generation on the target controller and is the supplier of MotoHawk model-based software development to many of the Challenge X teams.

MotoTron Corporation supplies electronic systems, tools, and controller hardware to the automotive, marine, industrial, recreational, power generation, and aviation industries. MotoTron enables its customers to use AV tools (including Moto-Haule) and be electronic system integrators for the following applications:

- Gasoline Engine and Transmission Control
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- Diesel Engine/Emissions Control
- Integration - Multiplexing/CAN Based Control
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- Autonomous Vehicles
- Small Engine management

MotoTron's key products include:

- MathTronics(tm) high-reliability control software development process
- MotoHawk(tm) model-based software development system
- ControlCore(tm) autocode-enabled embedded software framework
- Rugged ECUs (electronic control units) for rapid prototyping and production

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XM Satellite Radio, Inc., a publicly traded company headquartered in Washington, D.C., is the leading satellite radio provider with more than 1.6 million subscribers. General Motors was the first automaker to offer factory-installed XM Satellite Radio, which is currently available in more than 40 GM models for 2004.

Broadcasting live daily from studios in Washington D.C., New York City, and Nashville at the Country Music Hall of Fame, XM's 2004 lineup features more than 120 channels; 68 commercial-free music channels; 33 channels of premier sports, talk, comedy, children's and entertainment programming; and the most advanced traffic and weather information for major markets nationwide.

XM Satellite Radio programming, with more than 120 channels, CD-like quality, and coast to coast coverage, includes original music and talk channels created by the company's dedicated in-house programming team and by leading national brand-name content providers. XM Satellite Radio's programming partners

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include Sesame Workshop, NASCAR, MSNBC, Associated Press, CNBC, BBC World Service and BBC Concerts, Radio One, The Sporting News, CNN, Bloomberg, C-SPAN Radio, Clear Channel, Discovery, and MTV.

General Motors has produced more than one million XM Satellite Radio-enabled vehicles.

OnStar by GM

OnStar, a wholly owned subsidiary of General Motors, is the nation's leading provider of in-vehicle safety, security, and communication services using wireless technology and the Global Positioning System (GPS) satellite network. OnStar is available on more than 50 GM models for 2006. By the end of 2007, OnStar will be a standard feature for GM's retail customers in the United States and Canada, covering all segments and prices except for some commercial vehicles. OnStar safety and security services include automatic notification of air bag deployment, stolen vehicle location assistance, emergency services, roadside assistance, remote door unlock, and GM Goodwrench remote vehicle diagnostics. OnStar Hands-Free Calling allows drivers to make and receive hands-free, voice-activated calls from their vehicle. More information about OnStar can be found at www.onstar.com.

Gamma Technologies

Gamma Technologies is the developer of GT-SUITE, a top-quality CAE software for the engine, powertrain, and vehicle industries. GT-SUITE is an integrated CAE program for design analysis of engines. The most unique feature of this highly advanced tool is that it is contained in a single application—a new paradigm in engine simulations. There are six components in GT-SUITE with the following main capabilities:

- GT-POWER: Engine simulation for performance and acoustics analysis, with full control capabilites
- GT-DRIVE: Vehicle performance and cycle analysis for fuel economy and emissions, as well as driveline component dynamics
- GT-VRAIN: Valvetrain kinematics, dynamics and tribology, camshaft vibrations, chain/gear drives, cam design
- GT-FUEL: Injection system pressure and flow dynamics, hydraulic system analysis
- GT-COOL: Engine heat management and cooling system analysis
- GT-CRANK: Crankshaft dynamics and torsional vibrations, engine balance, block vibrations, mounts, bearing oil films

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Maxwell TECHNOLOGIES

Maxwell is a leading developer and manufacturer of innovative, cost-effective energy storage and power delivery solutions.

Our BOOSTCAP® ultracapacitor cells and multi-cell modules and POWERCACHE® backup power systems provide safe and reliable power solutions for applications in consumer and industrial electronics, transportation, and telecommunications.

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PRODUCTS

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Hydrogenics is a world leading developer and manufacturer of hydrogen and fuel cell systems and test equipment for fuel cells. Hydrogenics Power Systems group currently maintains an early market focus, offering high-performance HyPM® fuel cell power products for a range of applications that today target light mobility and backup and auxiliary power. As a pathway to tomorrow's larger commercial power markets, these early niche markets have the potential to change the way the world makes and uses energy for the benefit of future generations—offering clean and sustainable solutions that don't compromise the performance and reliability that our growing energy needs demand.

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First Technology
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First Technology's Automotive & Special Products division supplies inertia switches, sensors, and over-current thermal protection products to automotive and industrial customers worldwide. Our products focus on essential safety, performance, and driver convenience areas. We are pleased to support the teams of Challenge X with fuel cut off inertia switches. Visit us at www.1firsttech.com.

HEADLINE SPONSORS

The U.S. Department of Energy (DOE), through Argonne National Laboratory, provides overall competition management, team evaluation, and technical and logistical support. Challenge X is the premier DOE-sponsored student vehicle competition.

DOE launched its student vehicle competition program in 1989 to demonstrate and test technologies developed in laboratories. By combining the next generation of technical innovators with emerging advanced transportation technologies, the Challenge X competition helps ensure a sustainable, environmentally responsible transportation future. DOE and its network of national laboratories maintain an aggressive research and development program in advanced vehicle technologies, including fuel cells, energy storage, hybrid systems, advanced materials, alternative fuels, and heat engines. The Challenge X mirrors much of this research and demonstration activity.

DOE works to develop new technology to improve vehicle efficiency and lessen our dependence on foreign oil.

Close to 20,000 students have received hands-on engineering experience in these competitions. Many of them have moved on to take jobs in the automotive industry, bringing with them an understanding of and enthusiasm for advanced vehicle technologies.

SPONSOR WEB SITE U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, FreedomCAR and Vehicle Technologies Program – **www.eere.energy.gov/vehiclesandfuels**

Argonne National Laboratory Transportation Technology R&D Center – **www.transportation.anl.gov**

Over the past fifteen years, General Motors (GM) has joined the U.S. Department of Energy (DOE) to sponsor several successful student engineering competition programs. Recently, GM and DOE have teamed up as headline sponsors of Challenge X: Crossover to Sustainable Mobility, the latest advanced vehicle technology competition program.

The three-year competition, modeled after the General Motors global vehicle development process, brings students into the real world of vehicle development and better prepares to make a faster contribution to the engineering profession and the automotive industry. Each participating university team will re-engineer a new 2005 Chevrolet Equinox, with three basic goals: reduce energy consumption, decrease emissions, and maintain the performance and utility features of the stock vehicle.

GM donated a new 2005 Chevy Equinox crossover vehicle to each of the university teams at the end of the first year of the competition, plus two control vehicles. GM also provided each university team $10,000 in seed money and has donated use of its engineering, testing, and proving ground facilities for student workshops and competitions. Finally, GM has provided highly controlled access to its intellectual property, staff support (including a program manager, team mentors, and event judges) and communications support for the competition series.

General Motors Corp. (NYSE: GM), the world's largest automaker, has been the global industry sales leader for 75 years. Founded in 1908, GM today employs about 327,000 people around the world. With global headquarters in Detroit, GM manufactures its cars and trucks in 33 countries. In 2005, 9.17 million GM cars and trucks were sold globally under the following brands: Buick, Cadillac, Chevrolet, GMC, GM Daewoo, Holden, HUMMER, Opel, Pontiac, Saab, Saturn, and Vauxhall. GM operates one of the world's leading finance companies, GMAC Financial Services, which offers automotive, residential, and commercial financing and insurance. GM's OnStar subsidiary is the industry leader in vehicle safety, security, and information services. More information on GM can be found at **www.gm.com**

The U.S. Department of Energy and General Motors Take the Lead

The U.S. Department of Energy, GM, and the other industry and government sponsors are proud to support Challenge X: Crossover to Sustainable Mobility—a competition that challenges 17 universities across North America to explore vehicle solutions that will minimize energy consumption and reduce emissions. Students are following GM's real-world Global Vehicle Development Process and integrating their advanced technology solutions into a Chevrolet Equinox, a GM crossover vehicle that combines elements of both a sport utility vehicle and a passenger car.

Sponsor Benefits

Sponsors have the opportunity to meet, work with, and recruit hundreds of North America's most motivated and talented engineering students. They provide product donations, training, and support to the teams so students can integrate these technologies into their competition vehicles. As a result, sponsors are able to observe how their products perform during rigorous and innovative use, and students gain access to the latest software and newest vehicle technologies that might otherwise be unavailable or too expensive. Sponsors also gain international media coverage and develop partnerships with government, industry, and academia.

Student Perks

Unlike traditional textbook learning, Challenge X gives students hands-on experience in a real-world vehicle development process that will better prepare them for careers in the automotive industry. As students struggle to overcome significant program obstacles and technical challenges, they also build leadership and teamwork skills, not only in engineering, but also in business development, fundraising, and public relations.

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CHALLENGE X

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Challenge X is an advanced vehicle technology competition managed by Argonne National Laboratory for the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy

Argonne NATIONAL LABORATORY

WWW.CHALLENGEX.ORG