

REVOLUTION IN GEAR

It's sporty, it's red, and it's called

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PHOTOS BY
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ut on the taxiway of the deserted Lone Rock Airport, the command comes: “Hit it!” Danny Bocci '05 punches the gas on the brand new Chevrolet Equinox and accelerates hard into the deepening autumn night. The engine rushes, tires squeal, and the fluid lines of the vehicle recede into running lights. It all goes off like a scene from a slick TV ad, except that instead of a film crew, there is twenty-two-year-old Liz Casson '06 in a gray hooded sweatshirt, running a hand-held video camera. And instead of a catering spread, Dan Mehr '06 works a grill loaded with brats and burgers and ribs. Grocery bags of chips, cookies, and soda spill open at his feet, and students grab handfuls while manning the radar gun and the laptop and waiting for their turn at the wheel.

The group is festive, and no wonder: they've been waiting a year for this car, envisioning it in their heads and on computer screens. Now they can touch it, hear it, and gun it. The tires are still a glossy showroom black, the interior exudes that new-car smell, and the seats are a little stiff. For UW-Madison's hybrid vehicle team, it's time for rubber and muscle and steel.

This car is the heart of Challenge X, a national competition that pits teams from seventeen North American universities in a three-year quest to convert a standard-issue, gasoline-powered car into a hybrid that combines internal combustion and electricity for maximum efficiency. During the next nine months, the UW team will reimagine, re-engineer, and endlessly reassemble its vehicle, transforming it from an off-the-assembly-line

Equinox, with an average fuel economy of twenty-one miles per gallon, into a thirty-five-miles-to-the-gallon hybrid that team members have nicknamed Moovada. They will need to meet next-generation emissions standards, stay within budget, and maintain or exceed the utility and performance of the original car.

First came a facelift: students repainted the car with a modified DeWalt NASCAR scheme in red and black. The rest of the to-do list is formidable: design, build, and replace the front and rear subframes. Rebuild the electrical system for the higher voltage required by the electric motor and its \$2,000 battery. Fit the electric motor. Build the emissions system. Add a clutch and transmission. Swap the gasoline engine for a high-end diesel. Replace the gas tank. And write software to make everything work together.

Previous Wisconsin teams have done similar tasks, and done them well. During the past seven years of the competition, sponsored by the U.S. Department of Energy and the automotive industry, UW-Madison has won five times.

But things are different now. While the idea of building a hybrid car was once a novel engineering exercise, it's now an economic imperative for America's struggling auto industry. Even before the Iraq war and the effects of Hurricane Katrina sent oil prices soaring, General Motors and Ford teetered on the edge of bankruptcy, their imposing fleets of trucks and sport-utility vehicles seeming like dinosaurs in a new age of fuel efficiency. And while the market for hybrid cars is still small, companies such as Toyota, which sometime this year

Moovada.



*Could this car
designed and built by UW engineering students
change the way we drive?*

will pass General Motors as the world's largest automaker, are miles ahead.

In 2004, General Motors replaced Ford as primary sponsor of the hybrid-car competition and tailored it to fit its vehicle-development process. As a result, the rules changed, the vehicle changed, and Wisconsin's success changed. After the first year of Challenge X, which culminated in preliminary judging last summer, UW-Madison placed tenth. And now UW's proud vehicle-design program

faces a problem that significantly parallels the challenge for Detroit: how to engineer a comeback.

Glenn Bower has three rules: have fun, learn something, and don't hurt yourself. Bower, a faculty associate in mechanical engineering, advises some one hundred students who participate in the university's various auto-design teams, which also include groups working on Baja and Formula

race cars and one designing a more environmentally friendly snowmobile. Before any of those students roll up their sleeves and start tinkering, Bower insists on diversions — anything from a wheelbarrow race or a contest to suck down a stack of saltines and a soda — to build rapport and ease tension.

On a day last fall, not long after the Equinox landed, the exercise is to design a module to protect an egg from a twenty-foot drop, using only one piece of paper, a roll of Scotch tape, a few straws, and some rubber bands. Although not a single egg survives, the exercise does the trick, and the students are loose as they head into the garage, a sprawling, quadrilateral room in the Engineering Centers Building with vehicles propped up and popped apart in every corner.

Liz Casson, a senior in electrical engineering and the hybrid team's leader, sits cross-legged on the floor, struggling with the suspension on a five-year-old Baja car. Plenty remains to be done on the Moovada, but she wants to leave those opportunities for less-experienced team members. Besides, she plans to take the Baja for a spin around Bower's wooded lot during the team's fall bonfire.

"I've always liked to build stuff, ever since I was little," she says. "If something wasn't working, I wanted to know why."

Vehicle-design competitions exist to give students an opportunity to pursue that curiosity. In cooperation with the Department of Energy, the auto industry has sponsored dozens of contests since 1987, in part to showcase new technology, but also to offer college engineers a sample of the auto-design process.

Many, like Casson, have little

experience working on cars before they sign on. Casson was attracted as a freshman by a display of the UW's hybrid car — then a 2002 Ford Explorer — because it was the same model her dad drove back home in Potomac, Maryland. "The team was a family," she remembers. "I liked that, because as a freshman, you're looking for friends. It's a huge school."

With no mechanical experience, Casson started out working on the team's newsletter. In time, she learned to weld and made herself useful on the band saw. "Just hanging around the garage provided the opportunity to explore," she says. "I don't think you need to come in with the background of taking apart engines or building tractors. I just think you need to come in with the drive to figure out why something isn't doing what you think it should."

Students get to tinker with engines, but they're also tinkering with their career options. Many past participants have gone on to work in the auto industry. Julie Marshaus '99, MS'02, who designs exhaust gas recirculation valves for Delphi Corporation, says she owes her job to the hands-on experience she earned as a team member. "A lot of people in industry don't have a good grasp of the challenges of the future technology," she says, noting that she's met colleagues who didn't know that a hybrid vehicle uses a different voltage because "they've never been around it."

"This is your opportunity to make mistakes," says Casson. "So you can learn now, and you're going to be way ahead of your field."

Mistakes? Her voice shrinks and she looks embarrassed. "I've shorted batteries," she confesses. "I've never done anything that devastating, like blow up an engine — which we have done before. As long as you learn from your mistakes, we're happy."

That willingness to dive in has helped fuel the success of the UW design teams. Kristen De La Rosa of Argonne National Laboratory, which oversees the competition, says Wisconsin students are known for their outreach and their cooperation with other teams and that their domi-



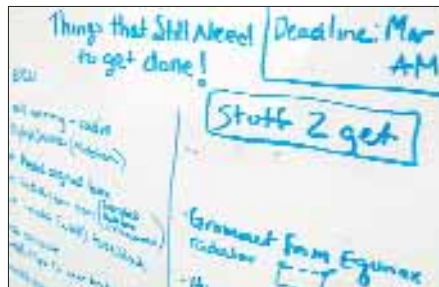
nance of the Ford-run FutureTruck challenge was no accident.

"That team in particular is very business savvy, and they have a very good reputation," she says.

Challenge X — so christened because the Equinox is a cross between a car and a sport-utility vehicle — was altered to mirror GM's vehicle-development process and now puts more emphasis on computer modeling and design in its early phases. "We had a monster garage approach to competitions in the past," says De La Rosa. "A lot of the engineering decisions were based on 'What can I get my hands on?' and 'What can I fit into the vehicle?'"

Now, in the first year, teams receive a disembodied engine compartment and a library of computer files. They design their vehicles entirely on computer. After passing that test, teams get the Equinox and turn it into a mule vehicle — a rough cut that tests the new drivetrain, but lacks polish. The final goal is a showroom-quality vehicle, down to the cup holders.

Last summer, teams traveled to GM's offices in Auburn Hills, Michigan, to present the results of the design phase. Not surprisingly, judges selected the most conceptually advanced plan — a fuel-cell-powered hybrid designed by the University of Waterloo in Ontario,



Getting the Moovada in gear takes more than just gears. Clockwise from upper left: students install newly modified engine components under the hood; programmers sift through thousands of lines of computer code that help run the car's dual engines; a crowded to-do list reminds the team of looming deadlines; sparks fly as a student uses a grinder to hone a part to be installed in the car; and the team blows off steam by racing mechanic carts across the terrazzo tile floors of the Engineering Centers Building lobby.

Canada — as the winner. Though disappointed by their tenth-place result, UW students are more confident of their chances now that the competition has moved on to the nuts-and-bolts work.

"We've developed a strategy over the years for setting goals for ourselves that are realistic," says Casson. While other teams opted for more experimental approaches, she says Wisconsin has a design it can build.

As the semester progresses, the pace in the Engineering Centers garage slowly picks up. It's a free-form choreography, with small teams tackling tasks that, when combined in proper

order, will equal a finished vehicle. On a Friday in October, several students are retrofitting a clutch, while three others scan a printout, trying to master the five thousand lines of code that will eventually run the Moovada.

Meanwhile, another group of students works on the task of mounting the Moovada's rear electric motor. They have uncovered a problem with their strategy and now must reconfigure a two-hundred-pound jig of welded, one-inch angle iron. Two men with a sledge hammer and a grinder tackle that indelicate job.

In the final car, this and other subframe elements will be made of

aluminum, to shave pounds and enhance fuel efficiency. But because aluminum fabrication is expensive and less forgiving, they first perfect the design in steel, which has its frustrations. "You get the feeling for the real thing here, and you sense other potential problems, too," says Dave Ahlman x'06. But, he confesses, "I'd rather be doing it on a computer."

"It's just not the same," counters Kevin Stutenberg x'08. "If you're designing something on a computer screen, it's not nearly the same as going out and pulling it off or machining it on the lathe. That's where you learn all the little things, like [that] you have to add a little tolerance."

Stutenberg, a certified helicopter mechanic, has a little more perspective than the average undergrad. Deployed to Iraq as a flight engineer for the massive Chinook helicopter, he eventually became a door gunner. "I think one great reason for advancing the hybrid program is that we are less dependent on the Middle Eastern countries, because they do tend to be a little less stable than we are," he says.

On screen or under the hood, Ahlman and Stutenberg embody the spirit of engineering, but it's not the only factor at play in the making of a successful vehicle. Technology often takes a back seat to economic reality, and those tensions are already showing up in the market for hybrids, which account for less than 2 percent of all automobile sales in the United States. With two engines instead of one, hybrids cost several thousand dollars more than similar gasoline-powered cars, and automakers aren't likely to stick with them unless they sell within broader market segments.

"Unfortunately, we have to have an economic incentive," says Bower. "Right now, it's people interested in high technology — engineers — and environmentalists buying [hybrids]."

In fact, a sleek red car right in the hybrid team fleet offers a perfect lesson in these automotive economics. Dusty and partially disassembled, with a library of technical manuals scattered on the

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rear dash, few people might recognize it as a billion-dollar car. But that's how much money General Motors spent developing the notorious EV1.

Still touted as the most efficient production vehicle ever made, the all-electric EV1 was created in the late 1990s to meet California's strict environmental regulations. But even as GM was pouring resources into the car's development, the industry was battling California in court, a legal maneuver that ultimately toppled the standards. GM pulled the plug and recalled the eight hundred experimental vehicles, much to the anguish of a small cadre of fans. Former *Baywatch* star Alexandra Paul chained herself to an EV1 junkyard in protest.

Although it may have been a financial boondoggle, the EV1 is a foundation for the automotive future. Without its innovation, the U.S. hybrid effort would be even further behind companies such as Toyota and Honda, which have the best-selling models. GM is gambling that lessons learned in building the EV1 will help minimize its hybrid investment and shift the paradigm to an all-electric car powered by a fuel cell.

Meanwhile, Challenge X gives the industry seventeen different solutions to the basic engineering problem of making hybrids work. Mark Johnson, a director in GM's product development group, says that the competition "allows us to leverage some of the best and brightest and most technologically capable young minds in North America. This generation is totally in tune with sophisticated software tools, computers, math modeling, and simulations, and they're undoubtedly going to take this industry on its next technological leap."

To Casson, however, the EV1 isn't a harbinger or history lesson. "It's just an engineering challenge," she says. "When you come up with an idea to do something, and you work through it, and you get stuck, and you keep working on it and keep working on it ... when you're done, the feeling you have of accomplishment is incredibly rewarding." That's what keeps her plugging away at the

Moovada — it's another engineering challenge to be mastered.

"Who took off the Big ass nuts on the end of the half shafts in the

rear???? We cannot find them and have looked everywhere. Give us ... " The hurried e-mail from Danny Bocci stops in mid-sentence, then screams: "WE NEED THESE SO WE CAN DRIVE TOMORROW!!!!!!!!!!!!!"

It's a Monday night in late February, and crunch time for the Moovada. The car needs to be operational by Thursday, when the team is to demonstrate it at a press event in Milwaukee. Executives from Johnson Controls, which is donating a battery to the team, and from GM will be on hand. But Bocci, a computer engineer who has been working to perfect the Moovada's control software, needs a working vehicle before he can test the code.

Bocci is the senior member of the crew and the only one who has experienced an entire vehicle build. His dad was an engineer for Motorola and a ham radio enthusiast, and ever since Bocci could pull up a chair, he's spent hours at his dad's side. "I always thought I'd work at Motorola, but my real passion is vehicles," he says. He once built a racing tractor that did thirty-five miles per hour. "That was an experience," he laughs. "A lot of the first-generation design only lasted four or five blocks."

Even since Bocci joined the team, the atmosphere around the garage has changed. While it was once the playground of habitual shop rats, technology has altered people's relationship with cars. "Ten years ago, people still had vehicles that were eight or ten years old, and they had to replace distributor caps and spark plugs. People still did timing lights," says Bower. "Now, you just plug it in, and the computer tells you what's wrong." The trend has hurt the UW's vehicle teams: where once Bower had sixty to eighty students working on the hybrid car, it's down to a core group of about twenty students.

For that reason, Bower isn't thrilled


by the new Challenge X format. "We already have enough book work and computer work here," he says. "The accreditation boards are saying we need more hands-on [activities]." The opportunity to get under the hood, he says, has been a big reason these contests have thrived at Wisconsin. "When it gets to the grease monkey stage, or just the grunt stage, our team has been more willing to get dirty, get in the shop, stay in long hours, forgo the parties."

But the message of Challenge X is that the auto industry — and those who work in it — must adapt to new environments. And for Wisconsin, there are promising signs that more than just a vehicle is coming together.

Bocci's next e-mail to the team comes at 5:45 on Tuesday morning, and it begins: "It's alive!" The calibration is still pretty rough, but the initial conversion from gas-guzzling Equinox to Moovada is done.

"I have a very realistic sense of how much work is left," Bocci says. But as the team prepares for the next round of judging this June, he and others are pleased by the progress.

"I saw people working as a team for the first time this year, with ten or twelve people working toward the same goal," says Bower. "Before, two or three people were doing all the work."

"I've been learning over the years to make them struggle," he admits. "They have to get upset and realize that there is a better way." It's a lesson that is beginning to sink in, both for the students and for the auto industry at large. The students have something to teach us all about the challenge of our automotive future: instead of all the environmental hand-wringing, the political grandstanding, and the relentless failure of Detroit to forge a path beyond our gas-addicted plight, it's simply time to pull a few all-nighters and get the job done. 

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