Official newsletter of the University of Illinois at Urbana-Champaign Formula Hybrid Team

ILLINI HYBRIDRACING Newsletter

June 2011

ILLINI HYBRID RACING TEAM EXCELS at Formula Hybrid International Competition

- Illini Hybrid Racing team places 8th out of 34 teams
- Wins GM Engineering Design award for innovative battery design
- Places 4th in Design event
- Confident of contending for 1st next year!

After a year's hard work, the Illini Hybrid Racing team hit the road toward New Hampshire with a completely revamped vehicle. Thanks to all the team's devoted sponsors, the 2011 vehicle featured a high voltage system that was truly a force to be reckoned with, and this showed in the dynamic and static events, as the team returned home with multiple awards, including an 8th place overall finish.

The first two days of the competition were completely devoted to passing technical inspection, and competing in the business and design competitions. Because of the complexity of the hybrid systems, and the many rules that govern them, just passing technical inspection is a huge accomplishment in itself. In fact, at the end of the third day, the University of Illinois was one of only seven teams to have passed all the inspections, which allowed the team to compete in the autocross and endurance events. Unfortunately, only one team was able to get through tech in time to compete in both acceleration events, which gave them a huge leg-up on the competition. Although it may have been logical to extend the acceleration event so that more teams could compete, the organizers decided to close the event as scheduled, even cutting one team off in the middle of a run.

When the GM engineers presented the award, they were quoted as saying "We would be proud to put these (battery modules) on one of our production vehicles."

The Illini Hybrid Racing team also put up great performances in the business and design events. The team placed 5th in the business presentation after receiving complements from the judges on the team's marketing strategy. The design judges were also very impressed, and selected the University of Illinois to compete in the design finals on the third day of competition. The judges men-

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The team presents their vehicle to Formula Hybrid competition judges

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Illini Hybrid Racing Team Excels

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tioned that the high voltage system design carried the team into the finals. In particular, the modular battery packs made a huge splash with the judges. The team constantly had judges coming over to the pit asking to see the battery modules, and was even awarded an engineering design award from GM for the batteries. When the GM engineers presented the award, they were quoted as saying "We would be proud to put these on one of our production vehicles." At the end of design finals, the Illini Hybrid Racing team was awarded 4th place in the event.

In the final two days of competition, the team was able to compete in the last two dynamic events: autocross and endurance. Despite having very little time to test and tune the vehicle before competition, the team was still able to take 7th place in Autocross, and 7th in Endurance. With a proven, top of the line high voltage system, and a mechanical system to match currently in the process of development, the Illini Hybrid Racing team is confident that they will contend for 1st place in next year's competition.

The team would like to extend their thanks to all the sponsors and supporters who made this all possible. It was only with all this generous support that the University of Illinois could place 8th out of 34 registered teams. Thank you!

AO Smith Donates Two Performance Induction Motors

Last season, AO Smith provided the drive motor for the Illini Hybrid Racing team. The AO Smith E317 motor is rated for 22.7 ft -lbs of torque at 1760 RPM, but with some high efficiency SKF bearings, and the help of a Yaskawa A1000 motor drive, the motor can be driven up to 96 ft-lbs at 8,000 RPM. This performance is achieved by selecting a 115/230 motor winding and using the low voltage delta configuration. AO Smith was so pleased with last year's partnership that they kindly decided to more than double their support for the team this year. They have shipped two new endplates for last year's motor and have committed two brand new E317s.

Dave Nickel, Sr. Product Manager, has helped the team make some notable improvements for the two new motors. They have larger diameter shafts to better manage the increased torque output, and secondary shafts for rear mounting our Dynapar optical encoders. The team would like to extend a huge thanks to Dave and AO Smith for their continued support!

Yaskawa Representative Visits

On March 4th 2011, the Illini Hybrid Racing Team enjoyed a visit from Edward Tom, an application engineer at Yaskawa Electric and University of Illinois alumn. After touring the team's powertrain testing labs in Everitt Lab, Ed treated a number of members to lunch, and then visited the Engineering Student Project Lab where systems integration takes place. Ed also discussed the different overcurrent protection devices on the Yaskawa A1000 motor drive, and explained how the team can push the limits without damaging the drive. It was both an educational and enjoyable visit for everyone involved, and the team would like to thank Ed for making the trip!

Team Lightens and Shrink Yaskawa A1000 Package

YASKAWA
The Drive for Quality™

Yaskawa may sell the best performing industrial motor drives that money can buy, but they are still *industrial* motor drives. In other words, they are optimized for performance in stationary applications where size and weight are non-issues. In a racecar, however, size and weight are major liabilities. The team, therefore, reduces the size and weight of the drive through some "slight modifications."

Dylan Erb holds up the significantly lighter and smaller Yaskawa A1000 Motor Drive

The first step in the repackaging process is to remove the front-end AC-DC rectifier. This converter is designed to take 3-phase current from the wall and charge the DC bus of the drive. Because we hook our battery pack directly into the DC bus, we don't require this equipment. The second step is to convert the drive from air-cooling to water-cooling to decrease the size of the heat sink. The heat sink accounts for a significant portion of both the physical size and the weight of the air-cooled industrial drive. Finally, all the components must be reoriented and repackaged into a polycarbonate housing that reduces the final volume of the drive. Once complete, the repackaged drive fits in 23% the volume and weighs 30% of the original unit. The end product is the same size as 4 of our custom battery modules stacked face-to-face, which makes it fit nicely into the vehicle's side pods. Thanks again to Yaskawa for all the in-kind and technical support!

The modified AO Smith E317 motor

AO Smith.

Engineering Open House

On March 11th and 12th, team members participated in the 2011 University of Illinois Engineering Open House. EOH is an annual college event in which engineering organizations have the option of showcasing their research with the local community. The two day event takes place all across the engineering campus with exhibits captivating the general public by demonstrating how science and engineering play a role in our everyday life. The event attracts thousands of visitors to the Illinois campus each year and stands as the largest event of its kind in the country.

Many members of the Illini Hybrid Racing team interacted with numerous primary and secondary education students, informing them of the benefits and rewards of engineering. The car used in this year's competition was on display allowing viewers to ask questions regarding engineering aspects of the project. The team also displayed a few other devices such as a regenerative braking model and the engine/generator assembly to help primary and secondary students get a better understanding of the key concepts that help power our car. Engineering Open House provides a great experience for both the team members and the general public as ideas were exchanged as well as the promotion of science, technology, math, and engineering.

Illini Hybrid Racing has grown since its inception in 2009 to become an outstanding educational extra-curricular activity for University of Illinois students. The team has grown to more than 100 active members from nearly every engineering and numerous non-engineering departments. We hope our participation in such outreach events helps inspire young students to pursue education in science and engineering related fields. Should those students choose to attend the University of Illinois, we hope they provide the foundation and inspiration that will keep the Illini Hybrid Racing team at the forefront of outstanding student extra-curricular activities.

Future Illinois students take a look at the Hybrid vehicle

Illini Hybrid Racing Goes to the Indianapolis Motor Speedway!

The vehicle at the Indy 500 Emerging Tech Day. Photo courtesy of Roland Photo.

Two days after the Formula Hybrid International Competition, the Illini Hybrid Racing team brought the 2011 hybrid vehicle to the Indy 500 Emerging Tech Day at the Indianapolis Motor Speedway. The team enjoyed the chance to showcase the sheer power of the University of Illinois electric powertrain by competing in the all-electric division of the autocross event. Drivers were given unlimited runs around the track to best showcase their technologies to the general public. The team was extremely pleased to take 2nd place. Going into the summer off-season, the team is excited to continue improving and tuning the 2011 car, while continuing development of the 2012 vehicle, beginning with a completely new chassis. Thanks again to all the sponsors who made this season possible!

National Instruments Provides Compact RIO 9074 Controller

The Illini Hybrid Racing team would like to extend special thanks to National Instruments for their continued support. National Instruments representative Andrew Watchorn generously arranged for the donation of a number of components for the control system of the 2011 vehicle including another cRIO 9074 controller, 2 USB Data Acquisition units, and multiple cRIO interface modules. The additional hardware accelerated the team's testing and integration schedule by providing redundant systems. Last year's controller was implemented as a test bed for component testing, code development, and debugging, while the newly donated equipment was simultaneously being integrated and tested in the 2011 vehicle. Having multiple vehicle controllers also benefit the team at competition by providing easily accessible spare parts to resolve last minute technical issues. Again, thank you to both National Instruments and Andrew Watchorn for the continued support, this new hardware greatly increased our productivity and led us to a very successful competition!

NATIONAL INSTRUMENTS

Gates Corporation Donates Drivetrain Components

The 2011 Illinois hybrid drivetrain encompasses many standard components that transfer torque form the drive motor to the wheels, including shafts, sprockets, chains, hubs, and the differential. This season's single speed transmission, with an overall gear reduction of 6.4:1, is accomplished using a two stage system. The first stage, a 2.4:1 reduction from a max 8K RPM and 96 ft-lbs to an intermediate shaft, challenges the use of conventional roller chain, ultimately resulting in the teams selection of a Gates Poly Chain Carbon belt. The Poly Chain specifications promised a smoother and more durable high speed chain without the usual stretch and chatter of traditional roller chains. Power from the intermediate shaft is then transferred to the differential via a 428 roller chain on the low speed sprockets. This mix of roller chain and Gates Poly Chain Carbon allowed the 2011 team to best gauge the benefits of both systems as we overhaul the drivetrain design for 2012.

The 2011 Formula Hybrid Competition as well as testing, before and after competition, left the team highly impressed with the Gates Polychain alternative. At competition, the roller chain required repeated tightening at often the most inconvenient times and was the source of most drivetrain failures during testing. The Gates Polychain once tightened, stayed tight, and performed as advertised. Next year, the team is considering eliminating roller chain completely and relying solely on the Gates PolyChain.

Gates Corporation sponsors key components

Once the decision to implement a Gates PolyChain was made in late January 2011, the team contacted Gates Sales Manager Gavin Johnson and Illinois Field Representative Steve Small. On February 4th, 2011, Mr. Small visited the team at the University of Illinois Engineering Students Project Lab and provided invaluable feedback to help us best ascertain what Gates products would best meet our needs. We cannot thank enough both Mr. Johnson and Mr. Small for arranging for the belts, bushings, tools, and sprockets desired by the team to be 100% donated. Thank you Gates for being a 2011 Illini Hybrid Racing sponsor!

Battery Module Design Support Provided by Tyco Electronics and Littelfuse

With frequent stories of lithium-ion batteries in laptops and cell phones overheating and resulting in fires, public concern reasonably exists regarding their use in automotive applications. The conditions that a vehicle battery endures can be much harsher than that of a laptop or cell phone, thus a very safe and robust implementation must exist in order to minimize the likelihood of accidents pertaining to battery misuse or failure. Therefore, this season our team presented a drastically improved modular battery system with a layout that incorporates numerous safety features without sacrificing significant space or weight, while substantially increasing ease of use.

The accumulator pack was assembled using high power batteries manufactured by A123 Systems (ANR26650M1A), which are widely known for their reliability. An important characteristic of the batteries is the flat voltage curve, providing a predictable and consistent nominal DC voltage. The number of batteries was reduced from 360 cells to 336 cells, 84 in series and 4 in parallel. This provides a nominal voltage of 277 volts, nominal capacity of 9.2 Ah, and a maximum continuous current of 240 amps.

In order to create an environment that best balances safety and ease of maintenance, last season's battery pack was replaced with a modular design. The batteries were assembled into 8 separate modules, each consisting of 42 cells in series, a fuse and a contactor. Each fuse is a 450 volt, 50 amp semiconductor fuse manufactured by Littelfuse while the contactors are Tyco's LEV100 rated at 900 volt, and 100 amps. These contactors were designed specifically for automotive applications, and are therefore compact, lightweight, and robust. Including a contactor in each battery pack allows for each module to be de-energized individually to reduce risk of electrical shock while the system is idle or under maintenance. Individually fusing each module not only protects the vehicle from the dangers of component short circuits, but also provides the module with overcurrent protection resulting from incorrect installations or improper use. The modular design also provides improved structural support for the batteries so that they can endure high acceleration events such as physical shock from uneven pavement or collision.

The batteries are oriented side-by-side, providing a dense packaging arrangement while simultaneously permitting evenly distributed forced air cooling across the entire pack through perforated front and back face plates. Carefully located Nomex paper and Kapton tape throughout the module minimize the likelihood of internal shorts, without significantly reducing forced-air cooling. Each of the 42 cells is individually monitored for temperature and voltage by a low-profile Elithion Lithiumate Pro battery management board. Utilizing CAN communication and a convenient Tyco circular plastic connector (CPC), each module is monitored by a system controller during charging and discharging for a variety of faults including low voltage limit, high voltage limit, high temperature limit, discharge current limit and others. The Tyco Series 1 CPC connectors were chosen for their high voltage rating (600V), wide variety of current ratings, and their compact and lightweight design. The cell-by-cell monitoring provides a critical safety feature able to detect individual cell failures before advancing into a cascading failure damaging the entire pack, vehicle, or operator. Other benefits of the modular design include easy installation and extraction from the vehicle, allowing for quicker servicing should batteries malfunction in one or more modules. Overall, the move to a modular design has greatly improved the safety and serviceability of the Illini Hybrid system while adding a more professional finish to the end product.

Custom Battery Module

The battery modules were a subject of great discussion amongst automotive representatives at competition, providing considerable positive feedback. The team also received 4th place in design at the Formula Hybrid International Competition, in addition to a 3rd place design award distributed by the General Motors Corporation. The battery module design is believed to be a substantial factor in the team's success in these design events.

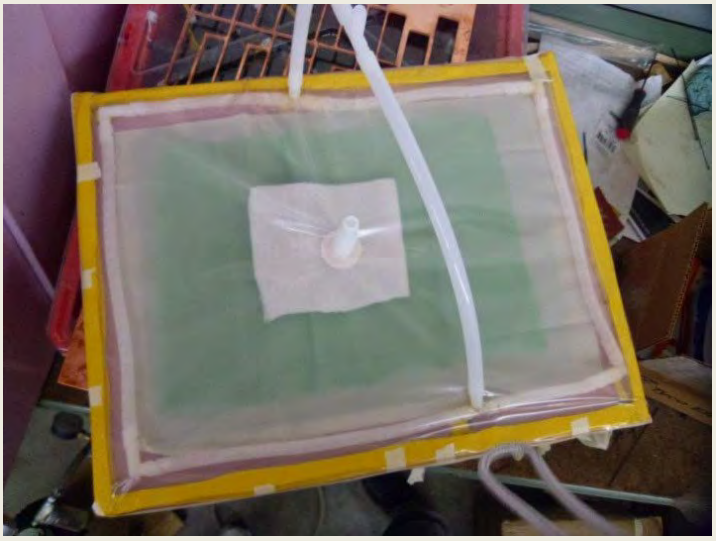
We would like to thank Tyco Electronics, who provided support through the donation of high voltage contactors, countless connectors, connector accessories, and associated tooling. We would also like to thank Littelfuse for providing generous support of their fusing products and technical assistance. Littelfuse has maintained a R&D center in the University of Illinois Research Park since 2010. Our sponsors are vital to the success of our team and we are grateful for all their assistance.

Airtech International Contributes to the Body Team

The Illini Hybrid Racing body team recently completed its body for the 2011 Formula Hybrid Competition. Our team initially planned to use the VARTM (Vacuum Assisted Resin Transfer Molding) process for manufacturing carbon fiber panels. The VARTM process allows for a consistent, strong and lightweight carbon fiber part because, unlike the traditional wet- layup, the resin is evenly distributed and the amount of resin added to the part can be more easily monitored. In the VARTM process, resin is induced into a sealed mold. The center hose is attached to a resin trap and then a vacuum pump, while periphery hoses are connected to a resin bucket. This setup allows resin to be induced into the mold when the vacuum pump is started. With wet layup, resin is painted on in a far less controlled fashion and then optionally vacuum-bagged.

However, we encountered some novice mistakes when making practice parts using the VARTM process. One of the main issues we found was that the viscosity of the resin we purchased was much heavier than required. Unable to find a fast source for epoxy resin with a viscosity less than 250cps our layups were not reproducible and of adequate quality with frequent resin starved regions. Due to time and funding limitations, we decided to fall back on the more easily implemented wet-layup method. While a little heavier than originally desired, the carbon fiber provided by Airtech International resulted in structurally stiff and lightweight body panels for our 2011 vehicle.

We would like to thank the team at Airtech International for recently providing the hoses, spiral tubes, elbows and tee-fittings used in the VARTM process. Without these essential parts, carrying out the VARTM method of making carbon fiber would not have been possible. Though the process was not used in the final parts this season, we look forward to attempting the VARTM process again and slowly gaining the necessary experience and supplies for next season. Again, thank you Airtech for your consistent support to our team!



VARTM practice part setup

Bender, Graybar Electric, and Omron Send In-Kind Support

The Illini Hybrid Racing team fulfills about two-thirds of its annual needs through in-kind donations. Without the generous companies who donate products, the project would be nearly impossible. The team is very pleased to announce three returning sponsors who once again provided some great products, and even offered to expand their support. **Bender** provided an IR155 ground fault detector for no more than the shipping cost, **Graybar Electric** sent out 20 feet of orange conduit, and **Omron** contributed three A22E-LB-01 push buttons for use as emergency shut-offs. All three companies are official sponsors of the Formula Hybrid International Competition. A special thanks to all three companies for not only helping make Illini Hybrid Racing possible, but for supporting all 34 teams registered for the 2011 Formula Hybrid International Competition!

BBS of America

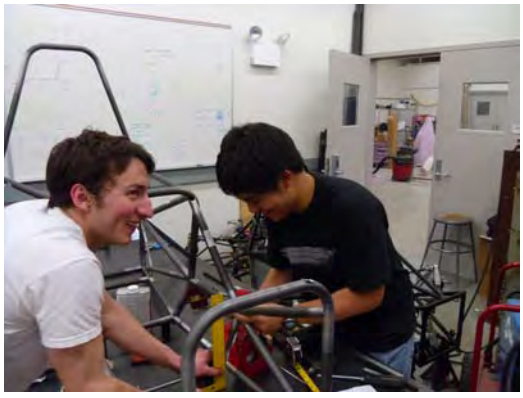
Thank you to BBS of America and Eric Niconovich for supporting our cause. We greatly appreciate your quick action and concern for our team's success.

Chassis Fabrication Process

Supported by Cartesian Tube, Plymouth Tube, SKF, and Wicks Aircraft

Last February, the chassis design for the 2012 car was completed and verified for strength and torsional stiffness using an ANSYS computational model. The Illini Hybrid Racing team began the process of profiling each tube individually in Unigraphics and exporting them to separate files. After all of the files were complete, a final assembly diagram with a bill of materials was created to identify each tube and its respective properties. This information was sent to Cartesian Tube in Stratford, Ontario, for CNC tube profiling. The Illini Hybrid Team would like to thank **Cartesian Tube** for the donation of all the tube programs and for the extremely quick production of the tube kit. From submittal of our order, it took only approximately one week to receive the finished product in Illinois. Cartesian tube made the whole process very straight forward and was a pleasure to work with. Upon receiving the kit, it was assembled in about three days. We started by creating jigs from 1 inch square tube that the **Plymouth Tube** (Streator, Illinois) mill donated. These jigs held the lowest horizontal tubes at the correct height and position on our framing table and from there the rest of the chassis fell into place. Thank you Plymouth Tube for providing not only the Illini Hybrid Racing team with a supply of chromoly tubing, but also our sister teams at the University of Illinois, the Formula SAE and Baja SAE teams.

We would also like to thank **Wicks Aircraft Supply** for the chromoly tubing and plate sold at cost which will be used in the creation of our a-arms, push/pull rods, and tie rods for the 2012 car.



Putting together the chassis

Along with the new chassis for 2012, many suspension and drivetrain components are currently in the works for 2012. Along with this comes a need for an array of different bearings for the differential housing, the bell cranks, wheel bearings, and other moving components. The Illini Hybrid Racing team would like to once again thank **SKF** for their continued support of our team through its many bearing donations. SKF continually provides our team and countless others with generous contributions from some of their highest quality product lines.

Fuel System Upgrade

For the 2010-2011 UIUC Hybrid car the fueling system was completely redesigned from the 2009-2010 vehicle. Last season's design consisted of two 64oz stainless steel water bottles modified and welded to be used as fuel tanks. While this design was simple, quickly built, and inexpensive, the fuel line plumbing was extremely complicated to allow for the proper draining of two tanks, the mounting was flimsy, and the aesthetics of the system were poor.

The new design uses a single pyramid shaped tank precisely designed using Siemens Unigraphics NX and welded from 0.065" 304 stainless steel sheet metal. The tank was built to hold the required minimum capacity of three liters. However, given the small quantity of fuel to be used at competition (approximately 1.5 liters) the fuel pickup point and baffling was immensely important in the design. As a result, a small reservoir was built into the front of pyramid. This separate section is exposed to the primary tank via three half inch milled channels in the bottom of the pyramid. As a result of this channeling and the small reservoir, fuel will always be exposed to the fuel pickup nipple even when the fuel level is very low and the g-forces on the car are high.

The final product has a far more finished appearance and a significantly more secure mounting compared to last year's design. In all aspects, the new fuel tank is a higher performing, better built, and more attractive package. We look forward to seeing what further improvements the team undertakes in designing the 2011-2012 fuel system!

(Above) Last season's design
(Right) New custom tank

Huntsman Advanced Material Donates RenShape Boards

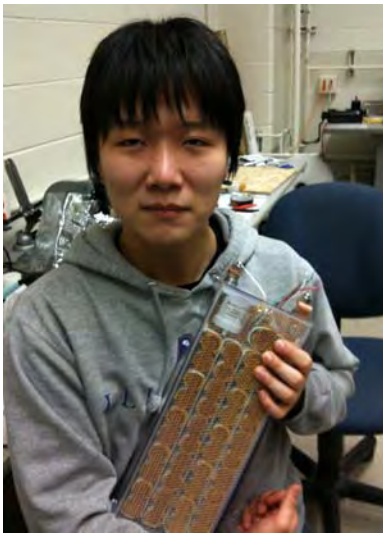
The Illini Hybrid Racing team would like to thank Huntsman Advanced Materials for donating two pallets of their RenShape 5008 Epoxy tooling boards. In order to make a cost effective mold for a composite body, SAE teams might cut low-density foam cross-sections of their CAD models, adhere them and sand to a semi-smooth finish. However, doing so is very time consuming, labor-intensive, and inaccurate. While more expensive to process, the advantage of using RenShape boards is their high density, durability and machinability; thus increasing the accuracy of the final part while significantly reducing the time needed to hand-work the final mold. Furthermore, since the RenShape 5008 boards have a low coefficient of thermal expansion, they can be used for room temperature layups and autoclave cures. Unfortunately we received the material too late in the season to use with the 2011 carbon fiber layup; however, we look forward to making use of their incredible product next season. We would like to thank Huntsman Advanced Materials for their generous donation and support!

Team member profile

Minku Kim

Name: Minku Kim
Subsystems: Power Electronics, Electric Machinery, Batteries

Hometown: Toronto, Ontario
Major: Undergraduate Electrical Engineering



Minku Kim joined the Illini Hybrid Racing Team at the beginning of the 2010-2011 season as a junior in Electrical Engineering. Although he had never worked on a vehicle team before, he had a great deal of hands on experience, and was looking for an opportunity to do more. He started work with the Power Electronics and Electric Machinery teams, helping to disassemble the Yaskawa A1000 for repackaging, but soon found himself getting drawn into additional subsystems. Though he tried, he just couldn't stay away from the other subsystems. He was soon a key member of the battery team, working long hours on the assembly of the battery modules, staying true to his high standards for quality, and ensuring that each module was made right. It is because of his high standards for quality in engineering and knack for leadership that Minku will be taking over as the Team Captain of the 2012 Illini Hybrid Racing team.

Outside of classes and the hybrid team, Minku enjoys playing tennis with friends, playing his electric guitar that he made himself, teaching tennis lessons at a local club, and honing his aim with his home-built bow and arrow set. He's one of the more rare engineering students who has chosen the profession not for a steady job, but because he has a passion for building new and useful products. With his passion, great work ethic, and talent, Minku will certainly go far. Congratulations Minku Kim on being the Illini Hybrid Racing's featured student!

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Why you should support Formula Hybrid

The automotive industry has sought after students participating in Formula SAE since its conception in 1978. Qualifying for an internship at Ford Motor Company and Honda Motor Company specifically requires Formula SAE involvement. The competition has acknowledged educational value.

With an annual budget in excess of $110,000, the Illini Hybrid Racing Team at the University of Illinois seeks out funding from a variety of resources in order to keep the team rolling. Monetary and in-kind donations made by our corporate sponsors are often matched by either the University of Illinois College of Engineering or College of Engineering departments. The donations that our sponsors provide are essential to the team's success. The team expresses deep gratitude to our sponsors for making the whole project possible.

ALL DONATIONS ARE FULLY TAX DEDUCTIBLE

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