



# **The Inaugural 2011 TCNJ Electrathon Racing Vehicle**

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As Professor Emeritus, I not only continue teaching classes each semester but also continue to be involved in the most enjoyable part of the academic year – the Senior Design Project. For several years, on this web site, I have encouraged students to become involved with the Electrathon America competitive events. I see the goals and objectives of this competition fitting perfectly with the goals and objectives of our Technological Studies Department. With Electrathon's emphasis on secondary education Math, Science, and Technology, I can see this activity becoming a major recruiting tool for the School of Engineering. I can also see the School of Engineering working with New Jersey secondary schools in helping them develop Electrathon Vehicles with the intent of establishing a TCNJ sponsored competitive event for the State of New Jersey.

For the 2010/2011 academic year, three Mechanical Engineering seniors, and three Electrical/Computer Engineering seniors built the first TCNJ Electrathon Vehicle specifically for the Solar Class. This group competed successfully in the Connecticut Electrathon Challenge held at Lime Rock Park. The Connecticut event is sponsored by the Wicks Group with support and safety personnel provided by Central Connecticut State University and their Department of Technological Studies.

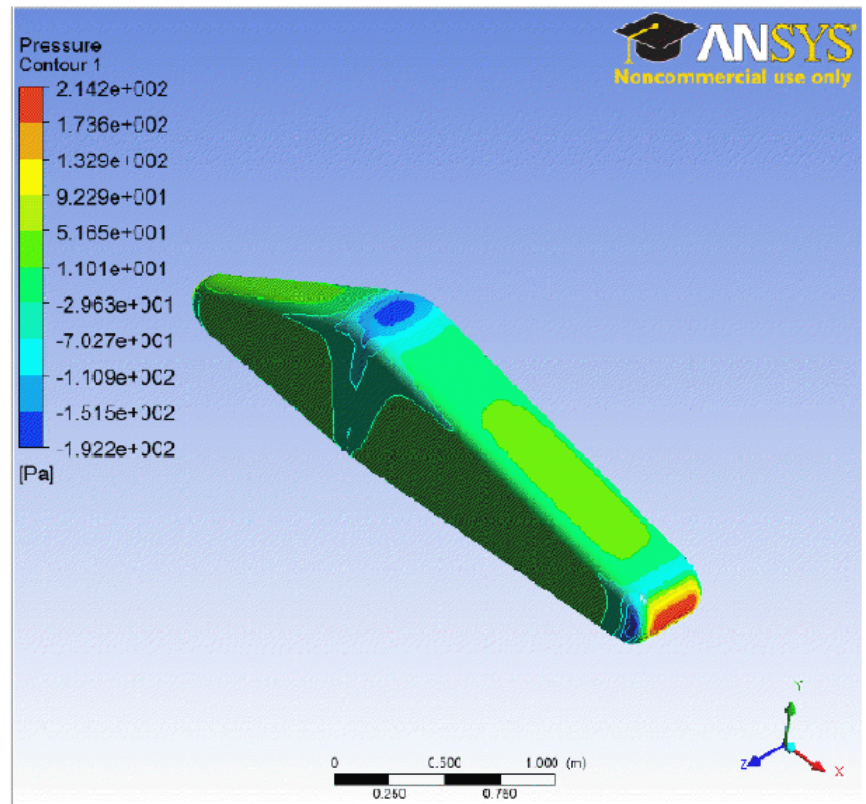


## The 2011 TCNJ Electrathon Vehicle Design Team

Standing from the left: Zach Esh, frame design and fabrication; Kyle Wilson, telemetry & instrumentation; Joe McCarty, motor & motor controller (design and fabrication); Justin (Maxx) Binger, project leader & solar power system; Hunter Carson, fairing and braking; Dr. Norm Asper, Professor Emeritus, secondary mechanical advisor. Kneeling from the left: Dr. Karen Yan, assistant professor, primary mechanical advisor; Jon Saia, steering & suspension. Not pictured: Dr. Anthony Deese, assistant professor, primary electrical advisor.

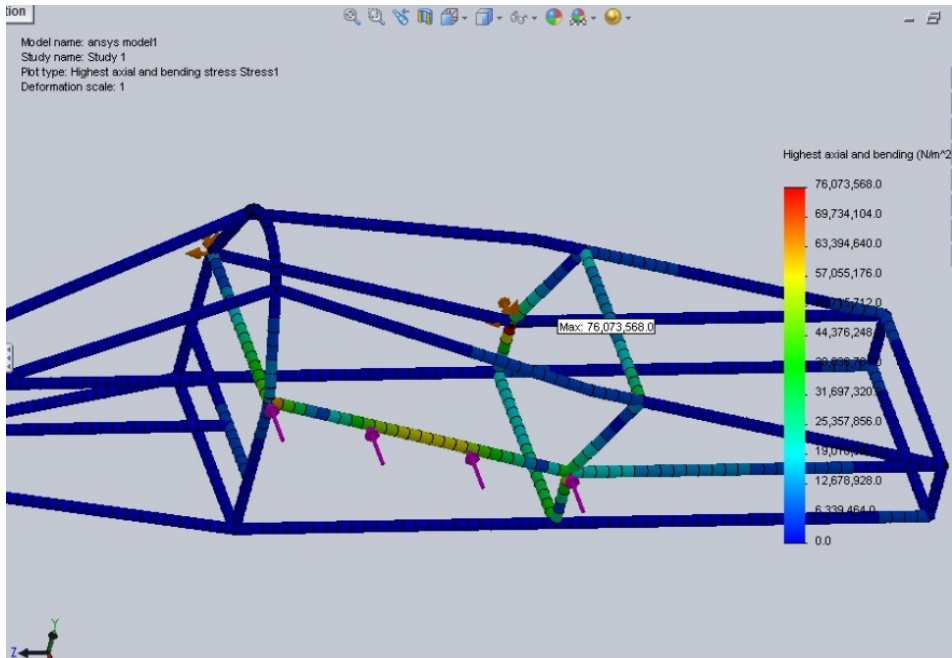


The early decision to compete in the solar division necessitated a design that included large surfaces for the mounting of solar arrays. The vehicle was designed in Pro/Engineer and loaded into Fluent to analyze aerodynamic drag. The design materials consisted of sheet aluminum body panels with polycarbonate windshield and side windows.



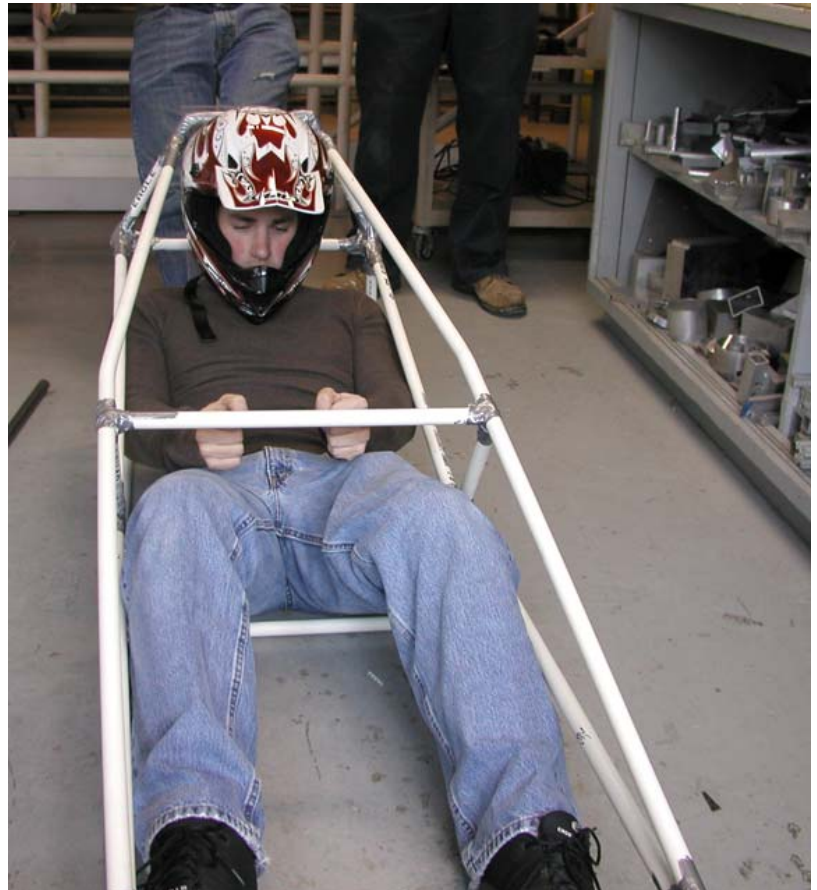
The same Pro/Engineer model was used to fabricate a 1/6 scale balsa model using a CNC router. The model was placed on a force balance in a wind tunnel to verify the Fluent data.



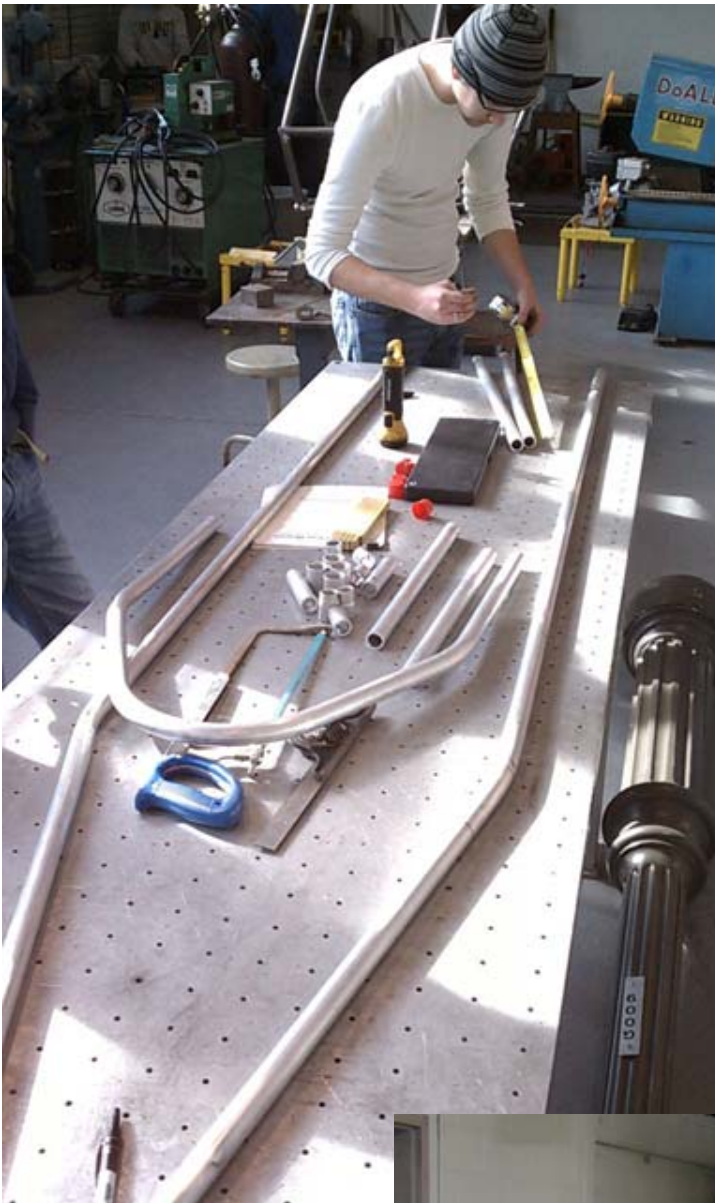


The selection of 6061 T1 Aluminum required an extensive ANSYS analysis of the frame and roll cage. The protection of the driver in the event of a frontal or side impact and roll-over were upmost in Zach's frame design analysis. Frontal and side impact ratings yielded a safety factor of 6 while the rollover safety factor yielded a safety factor of 14. The industry standard for a motorized vehicle is a safety factor of 5.

A full-size PVC mock-up of the frame was constructed to test the anthropometric viability of the frame design. In this illustration, Jon shows that the frame members at the shoulder are just too narrow, and the roll bar needs to be raised. As our two drivers, both Jon and Hunter will have to test a revised design of this of this frame.







With the frame members verified by the mock-up, Zach began cutting and forming the aluminum tube on the assembly table. The basic frame material size was 1 inch OD, while the side impact members were 1-1/4 inch OD tubing.

Zach took over the TIG welding responsibilities for the whole project—no small effort. Jon and Hunter set up milling machines to cut “fish mouth” joints on the end of the tubes. Each joint had to be mitered separately to match the angle of the adjoining tube.

Joe (on the left), Jon and Zach discuss the frame structure for the motor mount and rear wheel drop-out location. The frame members are now being clamped together and bolted to the assembly table.







Cutting the Aluminum tubing to length with the appropriate “fish mouth” joint angles, squaring and welding the frame took considerable time.





It always seems like a major milestone has been achieved when the basic frame finally comes together. It's easy to misjudge the myriad of details that still remain.



Now is the time to recheck the anthropometric changes that were made from the mockup. Notice the expanded side impact members at the shoulder area, and the raised roll bar. Now the front suspension and steering, drive train and rear wheel, seat, battery boxes, solar array, and body panels all need to be fabricated and mounted.



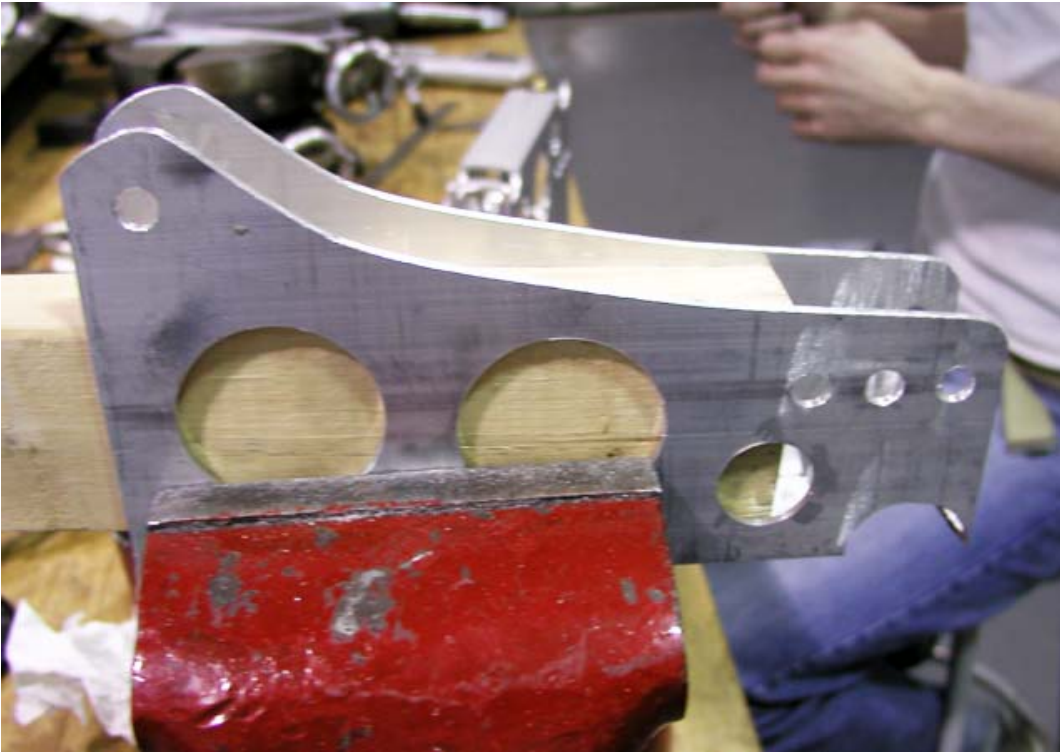


The front wheel location has already been established by the frame support members. The wire spokes of the selected bicycle rims were never designed to withstand the side loading that they will encounter in high speed turns. Negative chamber was needed to be designed into the front suspension. Some of this chamber could be achieved by an initial setting of the front suspension. Jon achieved additional “dynamic” negative chamber by designing an “Unparallel Equal Length Double A Arm” front suspension. As the car leans into a turn, the additional loading on the outside wheel creates an additional 3° of negative chamber.

Since both upper and lower A arms were identical, a welding jig facilitated their manufacture.

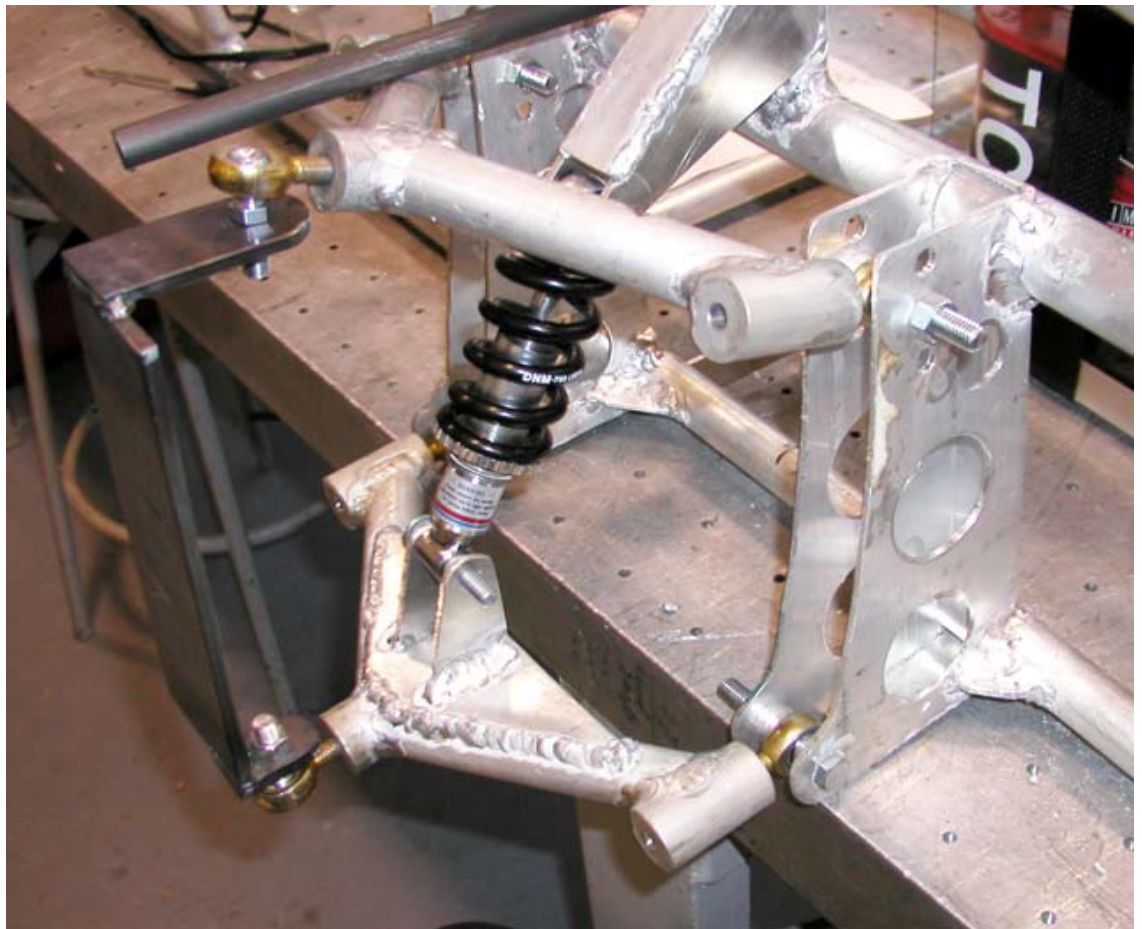






The A arm mounting brackets were fabricated from 6 x 2 in rectangular tubing. Initial mounting points were adjustable. The caster angle was established, and the mounting brackets were welded in place at the correct caster angle. Minor caster and chamber adjustments can still be made by turning the heim joints in or out.

With the A arm mounting brackets welded into place, the shock absorber mounting brackets could also be fabricated and welded into place. These brackets were designed to accept the 700 lb mountain bike “coil-over shocks” selected for this suspension system. The steel hub backing plates and A arm mounting tabs were fabricated and their installation was used to prove the suspension geometry.





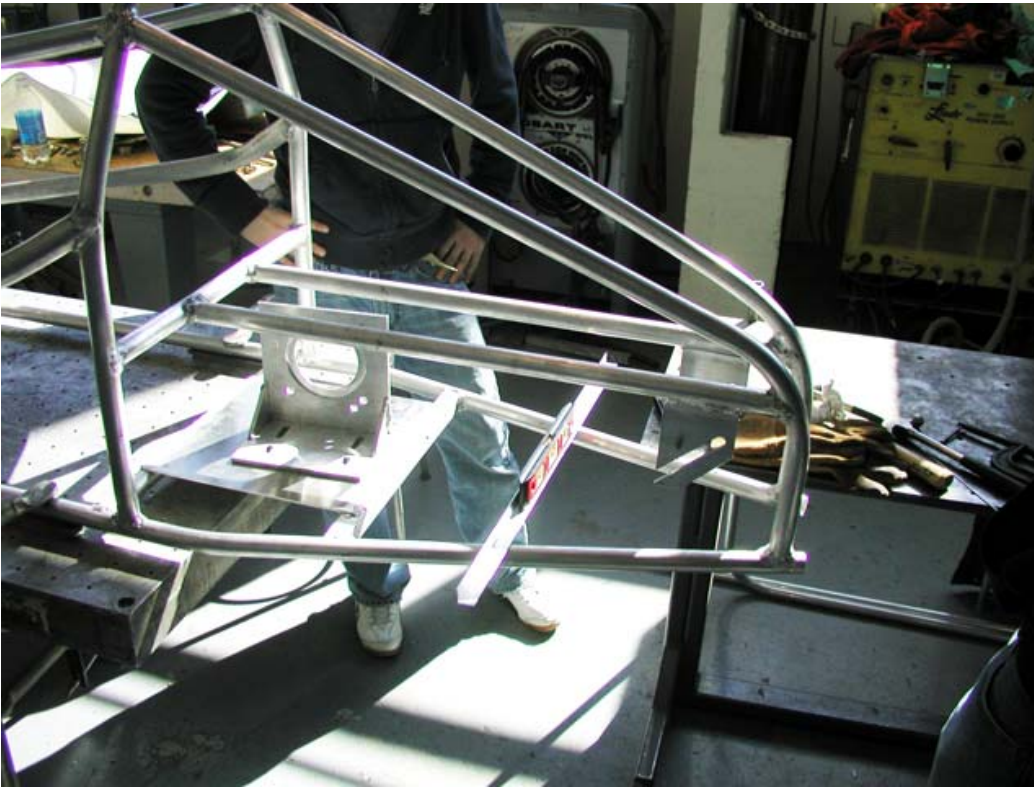


The steering column support bracket, the heim joint steering column supports, the pitman arm, and the tie rods were machined and welded into place. The original battery location can also be seen in this illustration. The battery location was later moved to the area behind the driver's seat in order to relocate the CG.

The steering column was intentionally left long until the ergonomics of the driver's seating position could finally be established.

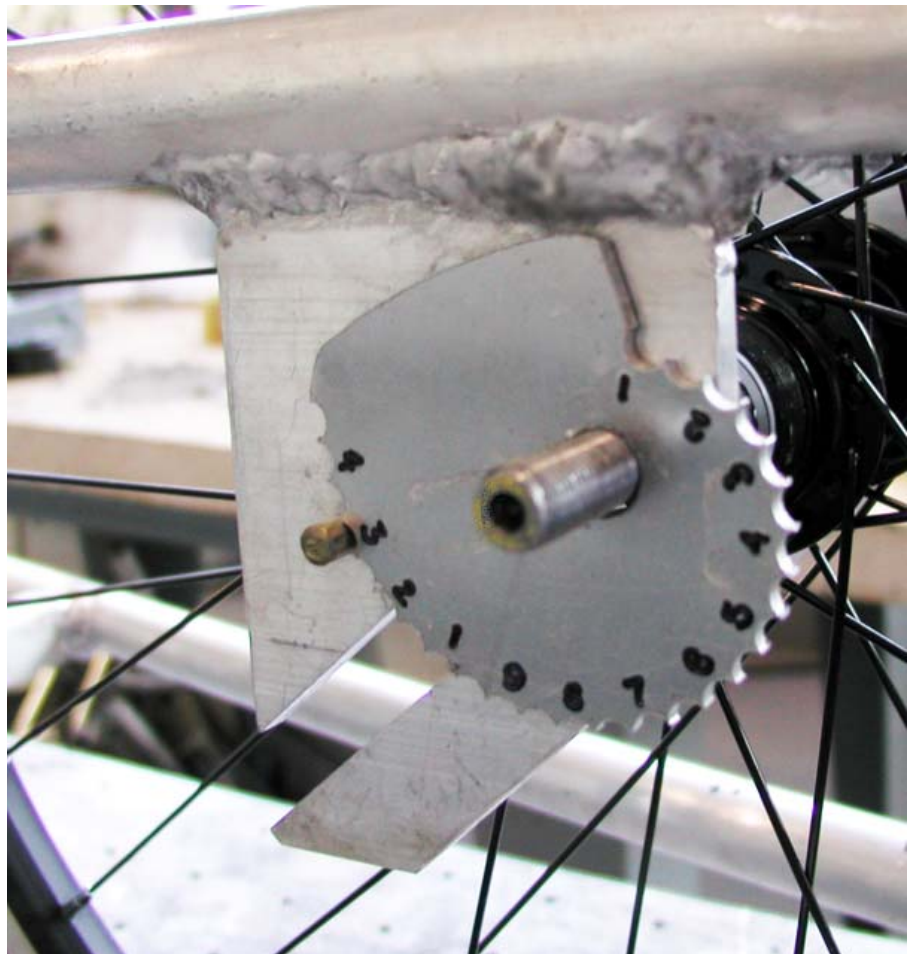






The tubes for the motor controller and the initial rear axel dropouts have now been welded in place. The mounting base for the motor mount bracket has also been welded in place across the base frame tubes. The level across the base frame tubes was used to correct for some minor bending which occurred during the welding process. The dropouts had to be perfectly level with the ground.

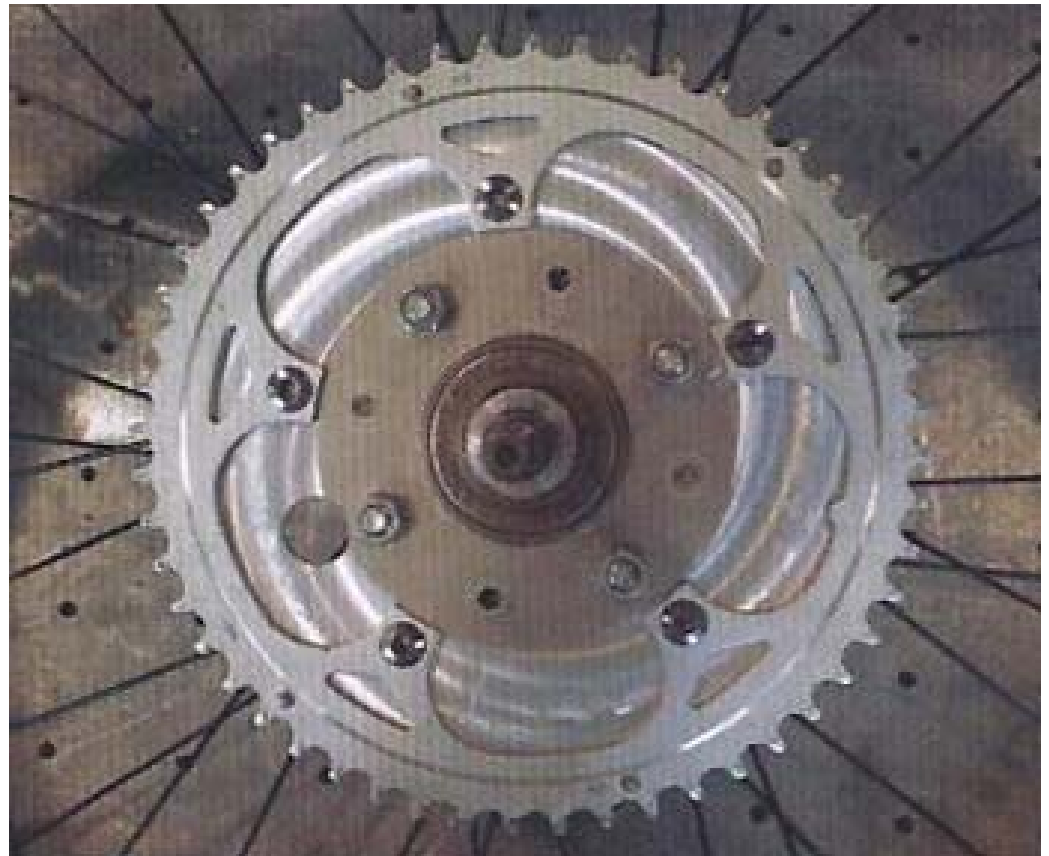
Zach designed a calibrated eccentric that will ensure the rear axel is always installed absolutely perpendicular to the centerline of the vehicle, even with a conventional bicycle rear axel dropout. The eccentric also serves to establish appropriate chain tension.



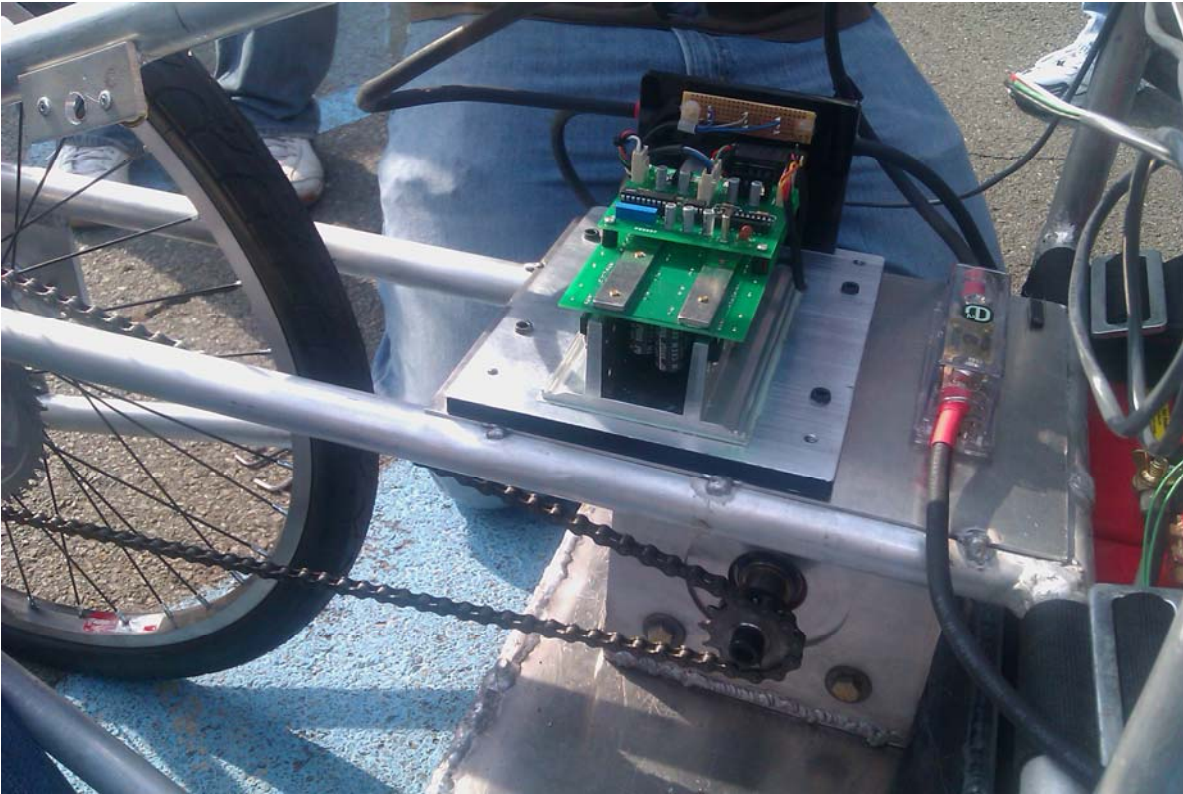


An adaptor was machined to mount a 12 tooth sprocket faced down to accept an ANSI standard #40 bicycle chain. The sprocket is mounted rigidly to the motor shaft.

A 22 tooth freewheel was used in conjunction with a 48 tooth front chain ring to provide an appropriate sprocket ratio. A 1/4 inch aluminum adapter plate was machined with mounting holes to bolt directly to the freewheel, and the face of the adapter plate was machined with a centering shoulder for mounting the chain ring.

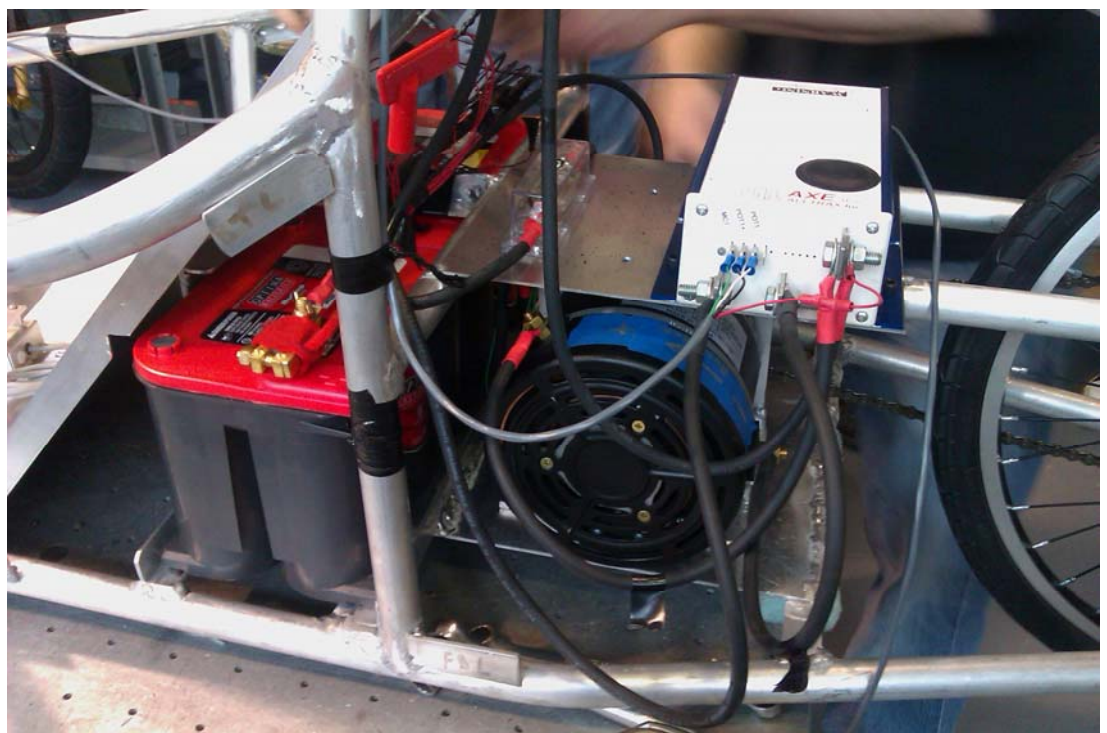


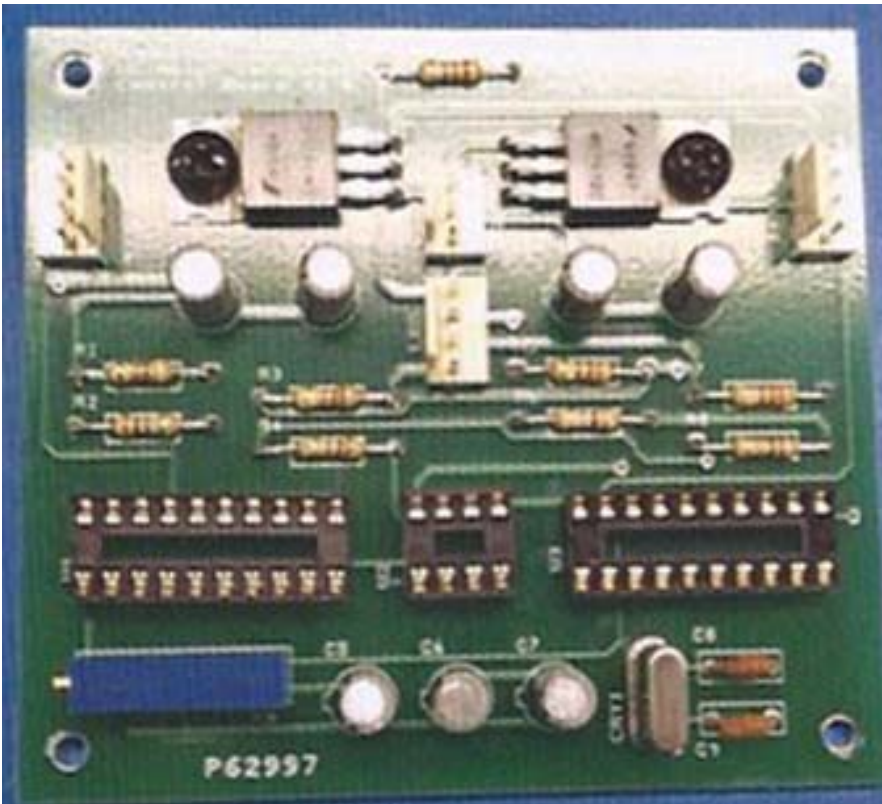




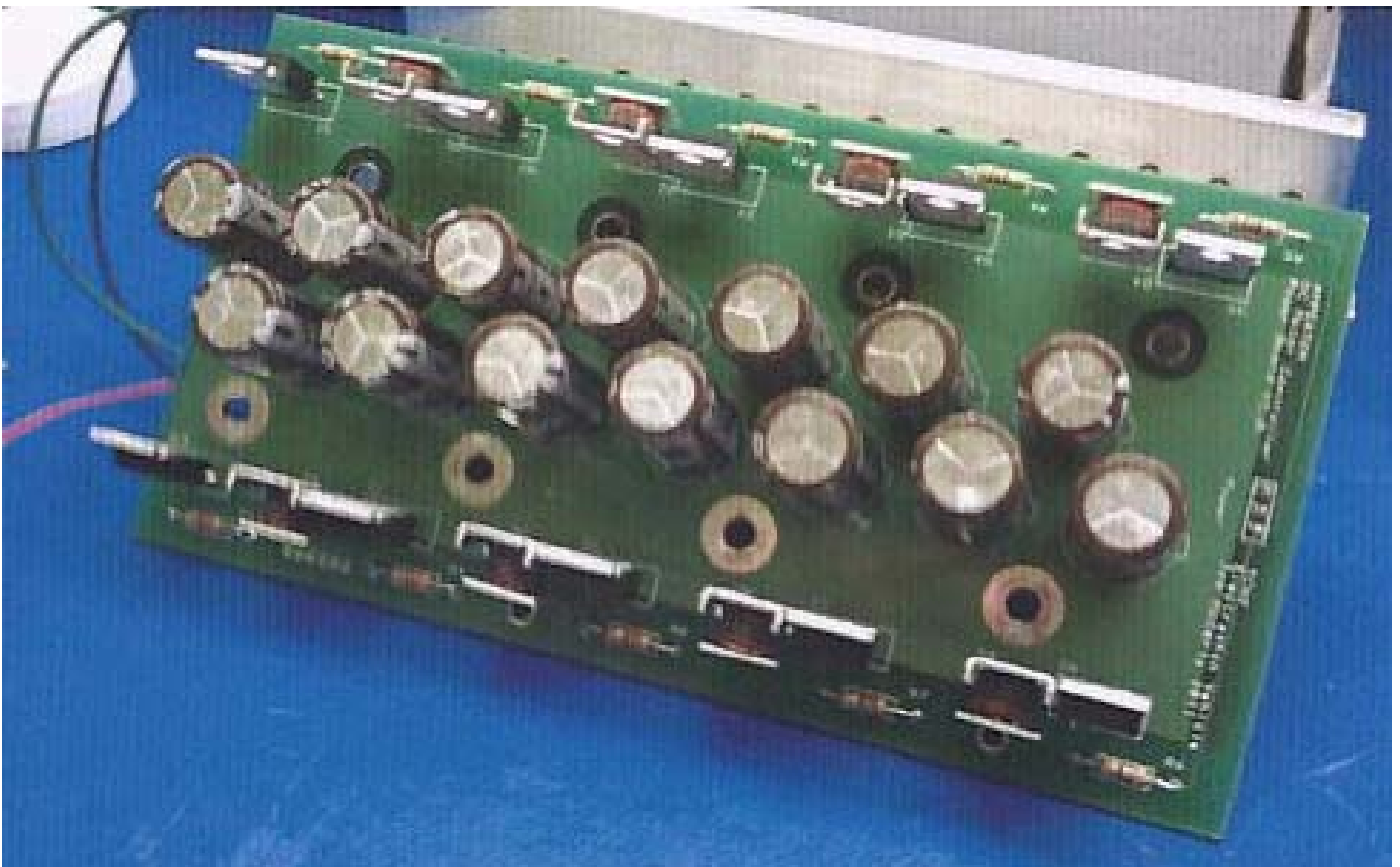
Above, Joe's motor controller (shown without cover and mounted on its heat sink) is mounted directly above the motor. His in-house designed and fabricated pulse-width modulated controller worked perfectly throughout several weeks of testing and the competition. Below shows the mounting of a commercial motor controller. Since one objective of this project was to show how local high schools could build a similar vehicle, we thought it unlikely that a high school would be building their own motor controller. A commercial controller of this type would be a viable option for a high school project.

Notice also the relocation of the batteries to behind the driver's seat. This change in weight distribution was necessary to achieve the appropriate stable "understeer" characteristic appropriate for a three-wheeled vehicle.





As for Joe's motor controller, after the boards were designed, Joe made full scale layout mock-ups to review the traces and to ensure that each component fit the footprint properly. Once the printed circuit boards arrived, the parts were soldered in place and the testing could continue. The upper picture shows the "Control Board", and the lower picture shows the "Power Board".

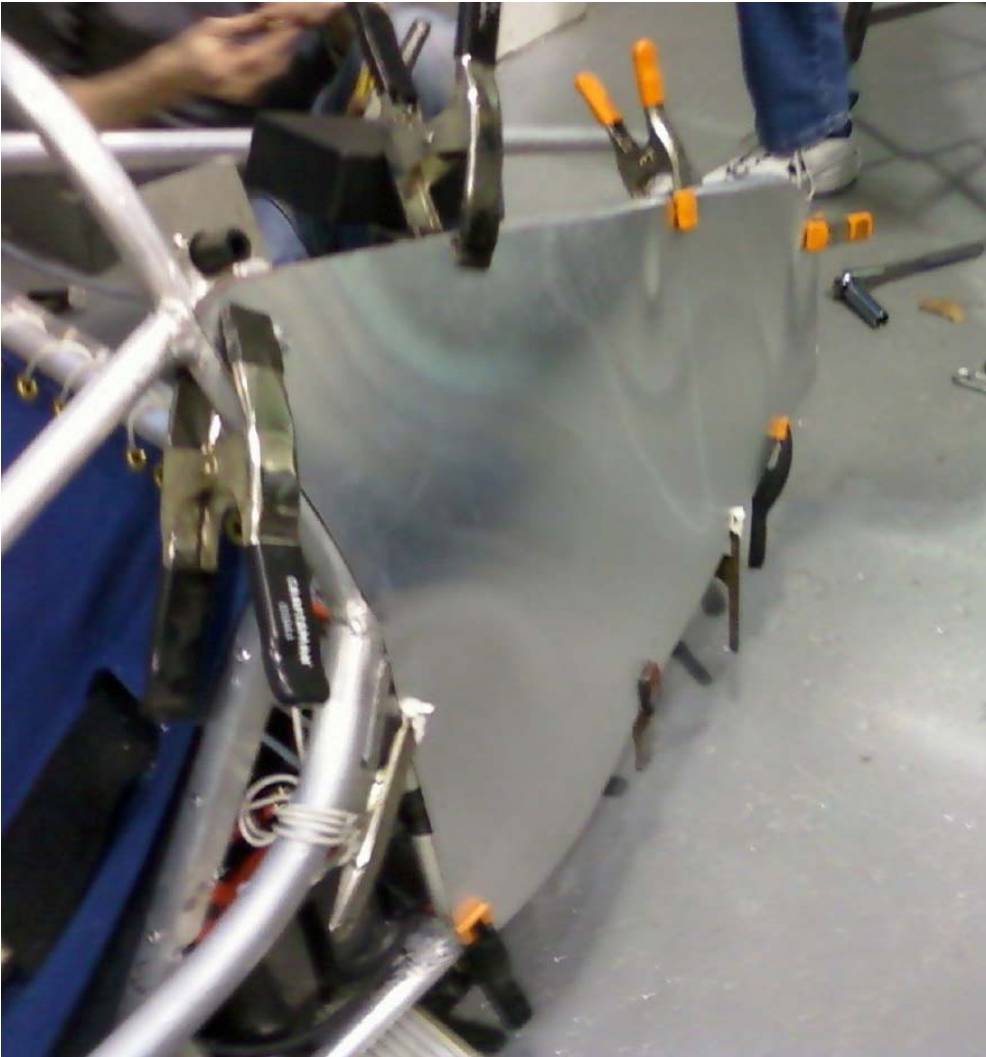






With everything assembled, it was time to begin the testing process. Any necessary modifications could be more easily performed without body panels in place.





The 0.024 inch thick aluminum sheet was shaped for the rear and side panels, and each panel was clamped into place to verify the fit. The rear panels shown here, the battery cover panels, and the solar array will all be mounted with dzus fasteners. These fasteners will provide quick access to the drive system and batteries.

With the dzus fasteners in place, the top Lexan cover can be fitted. The rear cover will be held in place with the same dzus fittings as the rear panels.

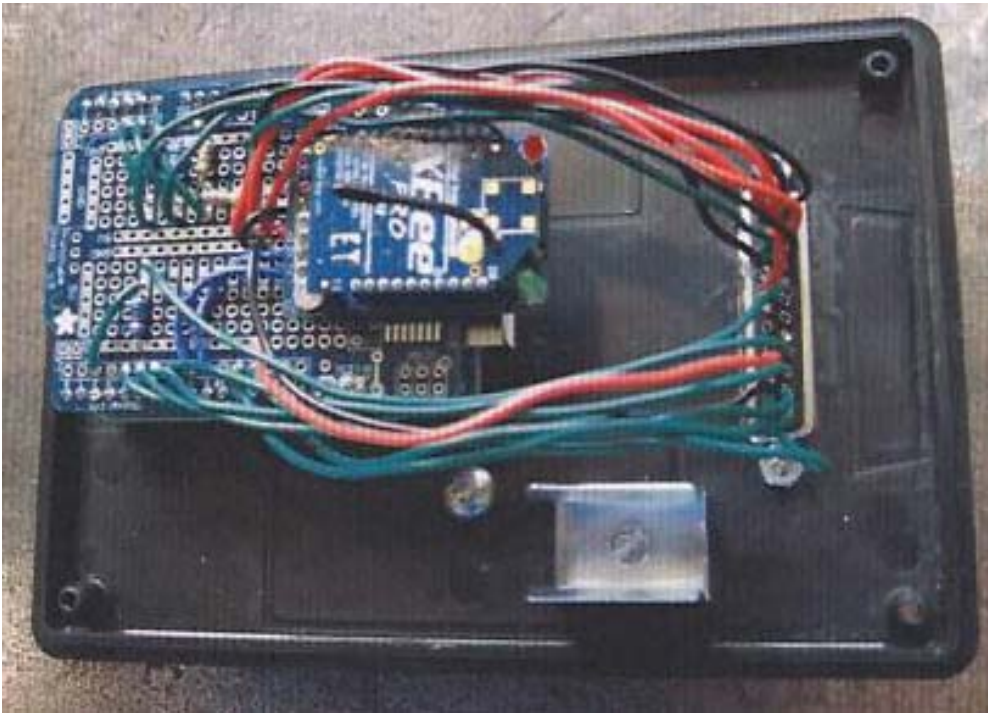






The Lexan polycarbonate cover (shown above with it's protective cover) is held in place in preparation for locating dzus fasteners for the rear side covers. The polycarbonate material was chosen for this rear cover area to insure that no interference would be created for the telemetry box mounted high in this area.





The in-vehicle instrumentation and telemetry box contained both an Arduino microcontroller board and an XBee transceiver. Therefore, information was hard-wired to an instrument box for the driver as well as being transmitted to the pits.

The cockpit display box was mounted on the handlebars directly in front of the driver. The 9-pin D-sub at the bottom connects the display directly to the telemetry box. The knob below the LCD screen is used to control display brightness.

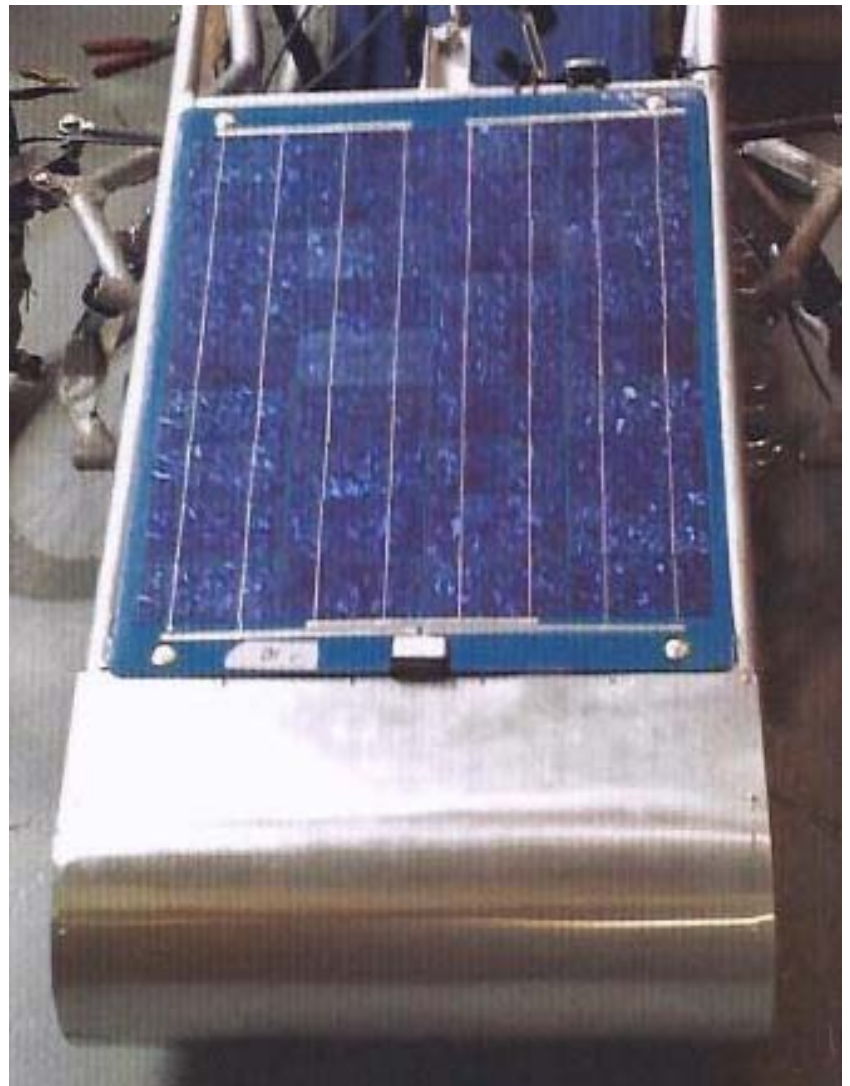






A change was made to the nose section. Hunter, being the taller of our two drivers, needed more room for his feet. We also needed an area to mount the peak power tracker for the solar array. Both were accommodated by extending and bending the roll cage tubes and welding them to extended bottom tubes.

Sheet aluminum was then rolled and pop riveted to the extended tubes at the nose section. Brackets were also welded into place for the dzus fasteners that hold the solar array in place. A sheet aluminum replacement panel was also made for the solar array panel in case we had to carry the car on our open trailer.





With all panels in place (except the solar array), full-hour test sequences could be performed. Even without the solar array in place, the one-hour tests (without driver change) yielded times faster than the winning times from the fall 2011 event. The team was happy with that data.







With only a minor tuning of the motor controller (a change in the ramp rate for acceleration), all of the electrical and mechanical systems were working perfectly. Obviously there was time out to paint the car and apply the vinyl lettering.





On June 3rd, at Connecticut's Lime Rock Park Raceway, Zach, Joe, and Maxx prepare the car for the first heat event. In each of the two heats, half of the registered cars will be on the track at the same time. Below, Zach talks to Hunter on the grid as the cars are being positioned for the first heat.







As the green flag drops, Hunter falls into line with the leaders. His stint as the driver can only last from 20 to 40 minutes. The Electrathon rules specify that there must be a driver change within that period.





Hunter selected a speed that would keep him running with the leaders but would not create an excessive current draw. He, and the pit crew, knew that he had enough energy to continue running with the leaders and still have enough power remaining to run much faster during the second half of the race.





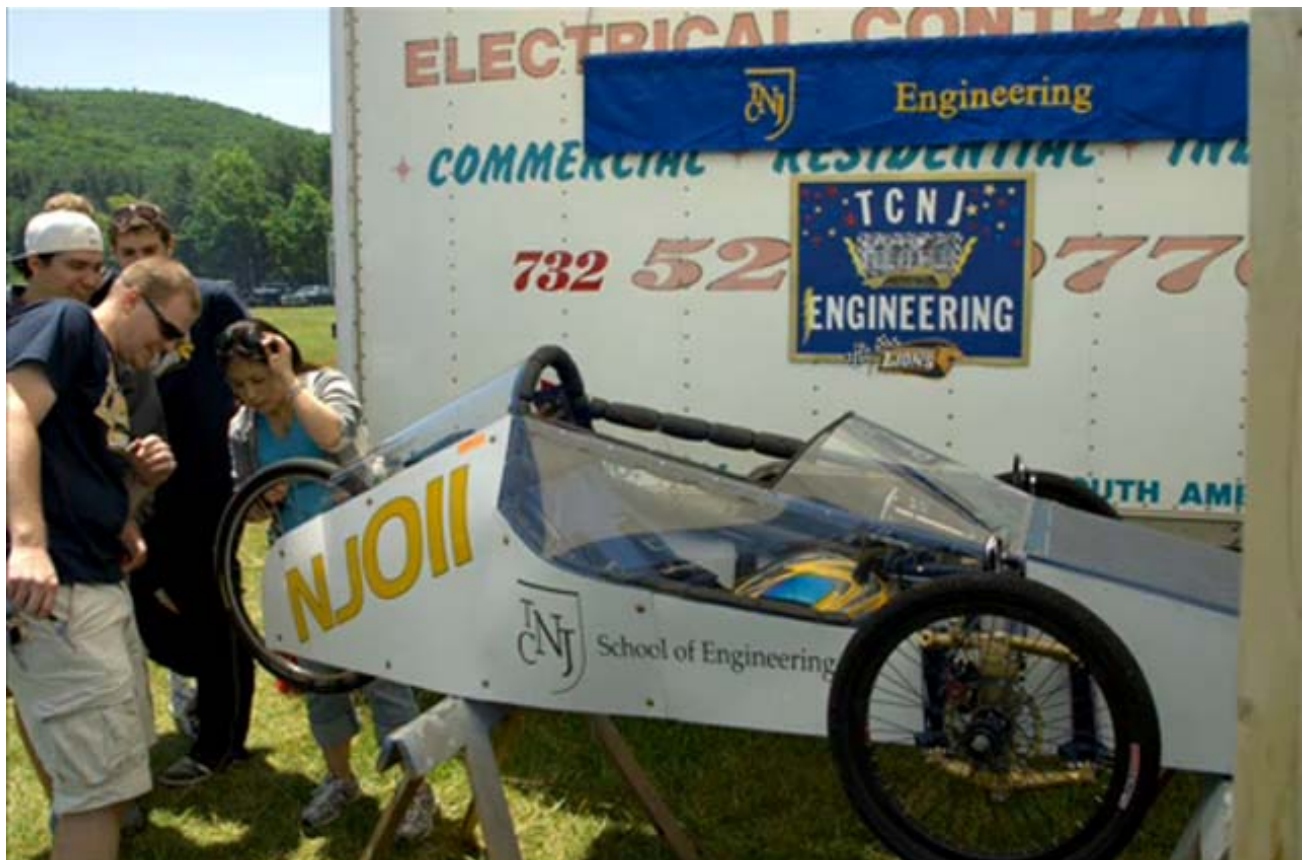


At the 35 minute mark, Hunter caught the left front wheel on the edge of the pavement and spun the car off into the infield. This turned his final lap, before the driver change, into a 5 minute ordeal, getting back onto the track and into the pits. The team's immediate concern was to inspect the car for damage and prepare to get Jon into the driver's seat. Both Hunter leaving the car and Jon entering the car had to be weighed again to verify that they still met the 180 pound minimum weight. Jon's arm-band verifies that he passed the initial weigh-in (with minimal ballast).





Into the pits following the spin, the car had to be inspected and a driver change had to be accomplished. The rear wheel was found to no longer be true. We could continue to run at the same speed as the leading cars, but a high speed finish was out of the question.







Jon finished the race with respectable lap times, but was disappointed by not being able to go all out in the closing minutes. We would just have to accept the fact that we were going to finish the race with considerable unused energy. Despite the mishap, the car ran perfectly the whole time finishing in a very respectable position.







The *NJ011* car completed 47 laps. Maxx describes the effort as “using less power than the average hair dryer with an equivalent energy consumption of *807 miles per gallon*\*! (\*One US gallon of gasoline contains an average of 36.6 kWh of energy)

This has been a great learning experience, and a great basis for future Electrathon projects, not only in The College of New Jersey’s School of Engineering, but also extended out into area high school technology programs.





Our most ardent supporter was Tracy McCarty (Joe's dad) on the right above and in the center behind the banner below. He went with us in the fall when we took our first look at an Electrathon event. He supplied the material for the frame as well as generous funding support and fabrication resources. He also provided the truck we used to haul the car and our supplies to the event. This type of support combined with the support of several local sponsors, and especially the extraordinary support provided by Dean Schreiner and the School of Engineering made it possible to create a high level project that reflected well on the students involved as well as the engineering program. I look forward to continued involvement in future School of Engineering Electrathon projects as well as the possible expansion of Electrathon projects into area high school Technology programs.

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