The 2005 Solar/Electric Boat Project

The College of New Jersey
Department of Engineering

The 2005 Solar/Electric Boat Team at Hoyte Lake in Buffalo, New York. From the left: Dr. Norm Asper, advisor; Jim Giachi, (junior mechanical) volunteer; Dave Ullman, (senior mechanical) steering designer and fabricator; Nick Ginga, (senior mechanical) hull manufacturing engineering; Mike Current, (senior electrical) energy management systems designer and fabricator; Tara Keohane, (junior electrical) volunteer electrical systems fabricator; Alex Michalchuk, (senior mechanical) endurance power system designer and fabricator; Mark Johnson, (senior mechanical) sprint power system designer and fabricator; Brad Lynch, (senior mechanical) hull design and manufacturing; Sean Elmes, (senior electrical) energy management systems designer and fabricator.

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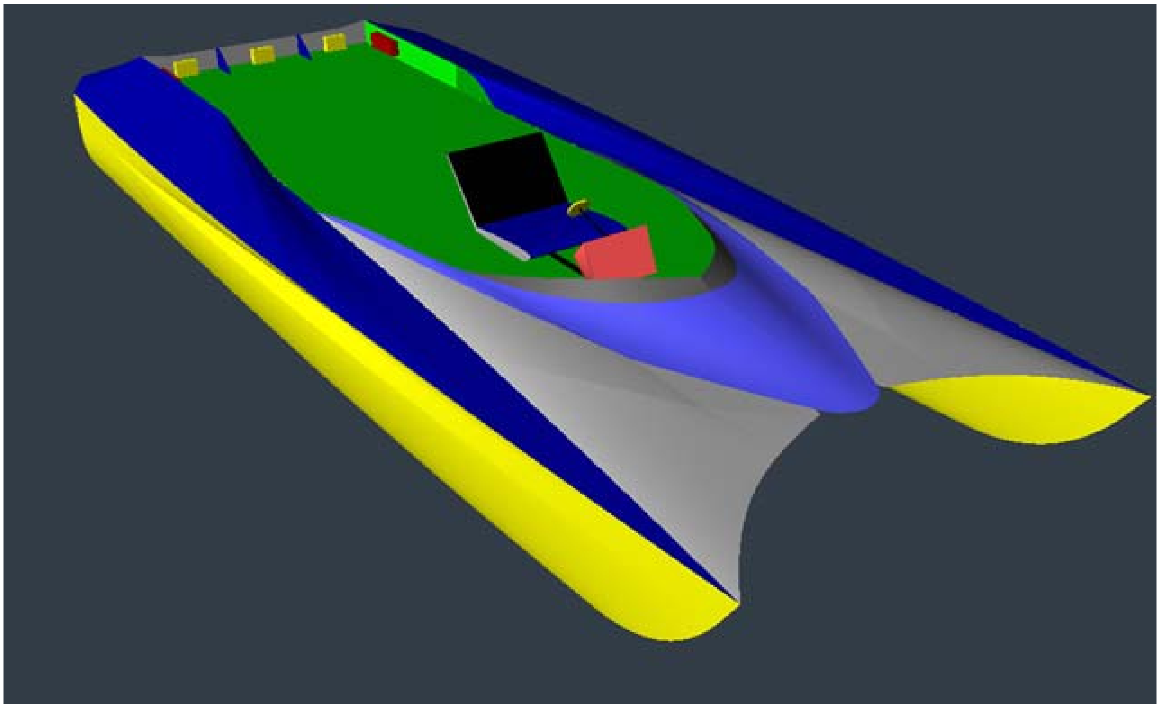


During the summer months of 2004, the team decided to completely redesign the Solar/Electric Boat for 2005. In an attempt to increase performance it was decided to design an outboard catamaran that could be easily changed from the high speed sprint event to the low speed endurance event. The first step was to analyze the hydrodynamic effects on a catamaran hull of this size, weight, and at these speeds. AeroHydro's MultiSurf software was used to develop the above design. Analysis showed that it would indeed be an improvement over previous boats.

Full sized plots of the hull forms were laid out on MDF board, and rib stations were cut out to form a full sized plug for the hulls

When assembled, the shape became an exact replica of the inside of the hulls.

Thin wood strips were applied to the framework to form the smooth lines of the narrow hulls.

Nick and Brad were responsible for the hull design and manufacture. Here they are helped by Mike from Electrical Engineering, and Dave the steering designer.

Styrofoam was used to form the complex shapes of the aft section of the hull.

The entire plug was then sanded to smooth out irregularities in the surface.

It was then possible to see the final shape of the two hulls that would make up the catamaran.

Tests were conducted to determine the temperatures and times necessary for forming the new thermal formable, 3/8 inch, Corecell styreneacrylonitrile (SAN) foam that would make up the core of the fiberglass sandwich construction.

The foam had to be cut into sizes that would fit into our largest oven. Here, Ed the team manager helps in the cutting process.

After being heated to the correct temperature and for the proper amount of time, the pieces were formed to the shape of the plug. Mike, the sprint power designer. also gets into the forming process.

The entire plug was then covered with polyethylene plastic sheeting. This would separate the plug from the epoxy resin.

The preformed polystyrene sections were then clamped to the plug.

The foam sections were glued together, and the seams between the sections were filled with epoxy resin and an ultra light weight microbaloon filler.

A large bag was created with another sheet of polyethylene film and packaging tape. The bag was large enough to fit the entire hull. The bag was then reopened to allow for the fiberglass lay-up.

The plug was covered with 6 ounce fiberglass cloth and soaked with epoxy resin. This lay-up was covered with a strippable fabric that would release from the epoxy resin. On top of that, a breather fabric was applied to offer an even vacuum pressure and absorb excess resin.

The bag was sealed with packaging tape, and a partial vacuum was applied to draw the foam, fiberglass, and resin down tight to the plug. The vacuum bag was left overnight to allow the resin to cure.

The vacuum bag and molding fabrics are removed and the shell is popped from the plug. The edges are trimmed to protect the workers from sharp edges.

The inside seams were filled just as they were on the outside of the hull shell.

The inside of the hull was also fiber glassed in the same manner as the outside.

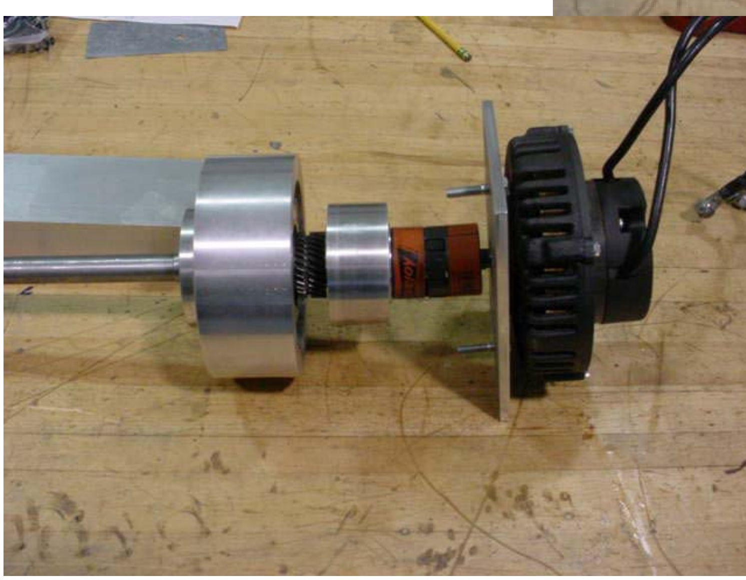
The excess glass and cloth was trimmed to complete one hull section.

Then the whole process started again to fabricate the second hull for the catamaran.

The foam was heated and formed around the plug, and the second hull began to take shape.

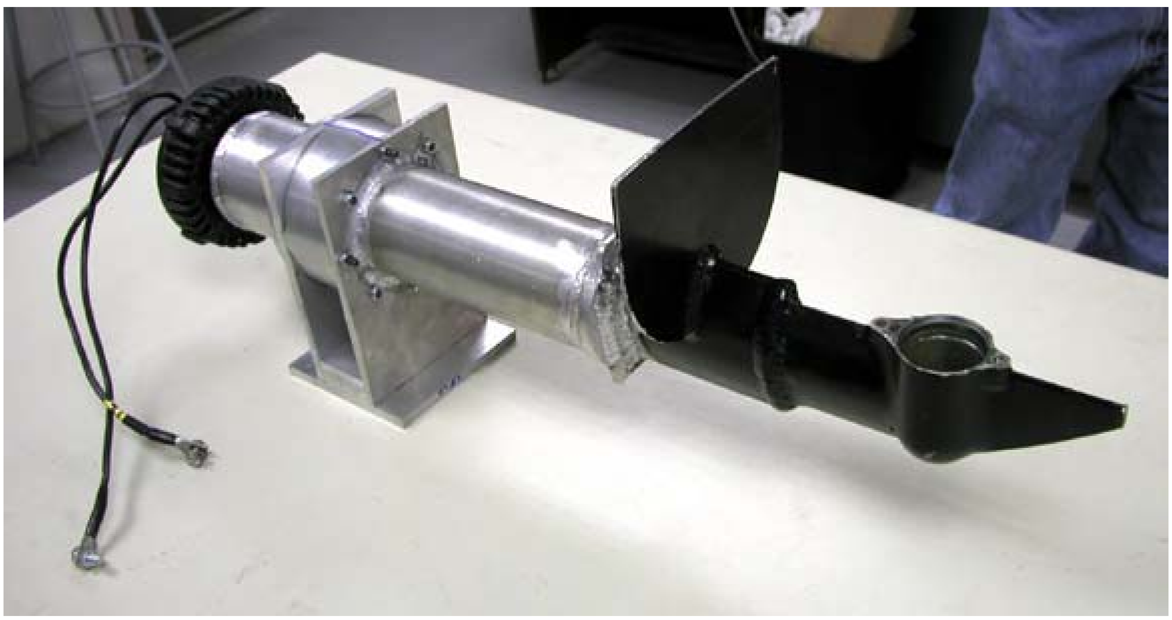
As the hulls were being built, work was beginning on the power units. The endurance power system came together early in the process. The lower unit is based upon a highly modified 2.5 hp unit provided by Mercury Marine.

In order to achieve the 600 rpm required by the 12 x 12 carbon fiber propeller, a planetary gear set from a Chrysler automatic transmission was highly modified. With the 1.85 to 1 reduction provided by the lower unit, the 3,000 rpm provided by the Perm PMG-080 brushed permanent magnet motor was matched to the slow (560 rpm) turning propeller.



For ease of service, the motor was attached to the gear case through a Lovejoy Connector.

The opening in the motor support bracket is used to mount the optical tachometer. Lines were applied to the lower Lovejoy connector which were read by the optical sensor as revolutions per minute.



With the final assembly of the bevel gears and propeller shaft, the endurance unit is ready to be drilled and mounted to the steering system.

Also progressing at the same time was the development of the sprint power system. Two LEM-200 D126 motors were selected to drive two 7.2” dia x 8.7 pitch drag racing propellers through two Konig/Koony 14:15 ratio racing lower units. Here, Mike checks the fit of the motor to the motor mount assembly.

The racing lower units were very difficult to obtain, and were eventually imported from the Czech Republic.

The sprint units eventually came together late in the developmental process which left only a few days for testing. This lack of testing, modification, and retesting would come to haunt us as we approached the Solar Splash event.

The powerhouse sections underwent several modifications as a result of the testing. Once again, for ease of service, the motors were connected to the drive shaft with Lovejoy connectors.

For transport and ease in handling at the event, all three motors were mounted to a custom outboard hand truck. Here, Mike ensures that all the motors will fit the hand truck. Notice that, for protection, no propellers are mounted to the sprint drive units, and a backup conventional aluminum propeller is mounted to the endurance unit.

In order to mount the motors and steering to the catamaran, the two hulls had to be connected with a platform. The 2004 launching dolly was modified to serve as both the launching dolly for the catamaran as well as an assembly jig for gluing the platform to the hulls.

Alignment of the three cradles was critical since this alignment will determine the parallel alignment of the two hulls.

Here, Nick and Brad place the carefully trimmed hulls into the jig in preparation for positioning the platform

The first layer of the platform consisted of 1 1/2 inch polystyrene insulating foam fiber glassed to a 1 x 3 wooden frame.

A second layer of 3/8 inch Corecell (SAN) high density foam (the same foam as used for the hulls) was fiber glassed to the wood/foam base structure.

Bulkheads had to be glued and fiber glassed into the hulls to provide strength. They also served as mounting points for glassing the platform in place.

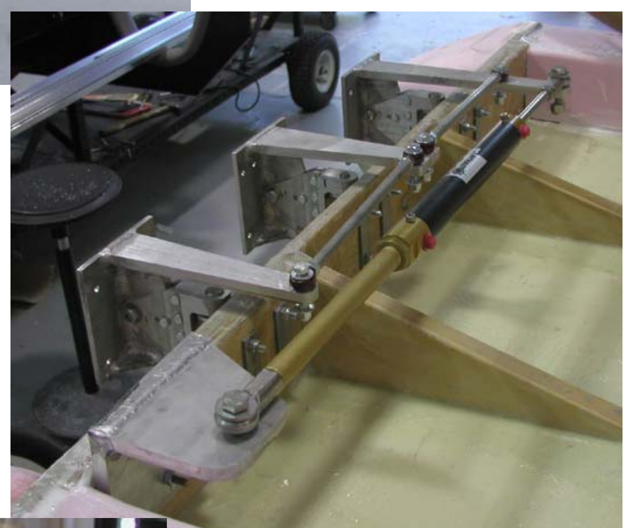
Locating and trimming the platform to fit the hulls was the next critical task.

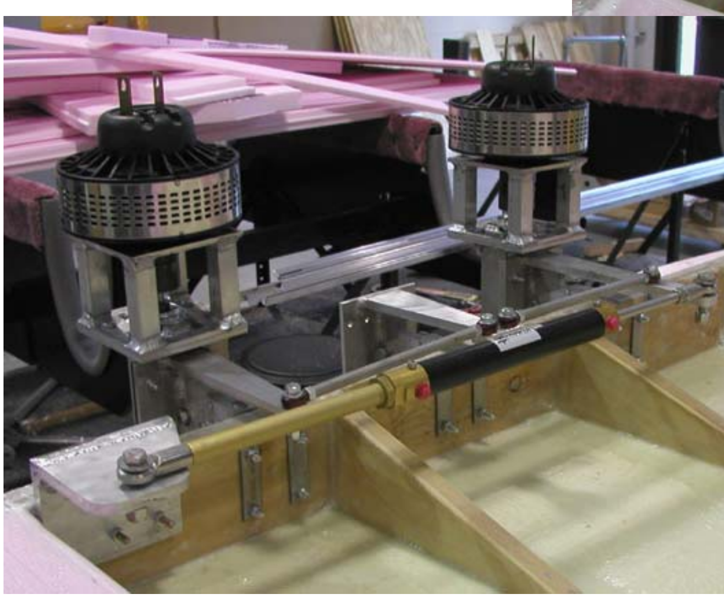
The platform, the transom, and the hulls were all screwed and fiber glassed together at the same time.

Once the transom was in place, the transom knees could be screwed and fiber glassed to the transom and to the wood structure inside the platform.

With the catamaran platform and transom in place, the hydraulic steering provided by Teleflex could be installed. The motor mounts and steering assemblies had been in development for more than a semester. They offer a thirty degree turning angle both port and starboard as well as a 10 degree tilt adjustment both fore and aft.

The steering viewed from the starboard side shows the hydraulic cylinder mounted to the steering assembly. For the endurance event, the single endurance outboard motor is mounted to the center steering motor mount.



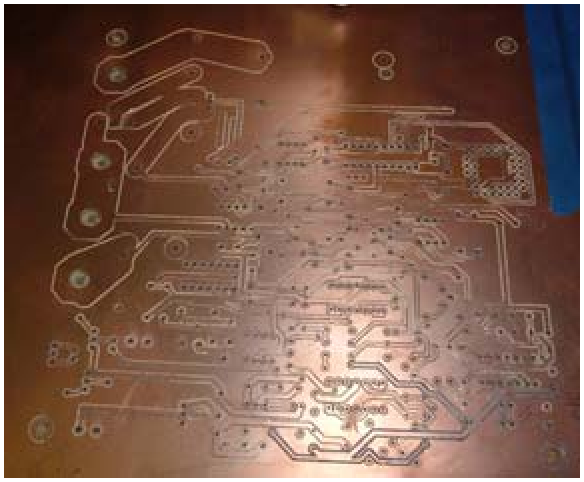


For the sprint event, the two sprint motors are mounted to the two outside motor mount/steering assemblies.

The steering console supporting the hydraulic steering pump will also enclose some of the electrical components.

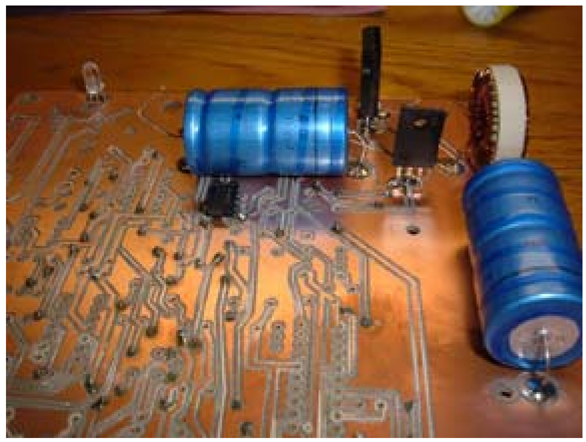
The steering console and the seat are mounted on a set of tracks to allow for adjustment. The weight distribution is considerably different between the sprint and the endurance events. The tracks also provide for minor adjustments in center of floatation.

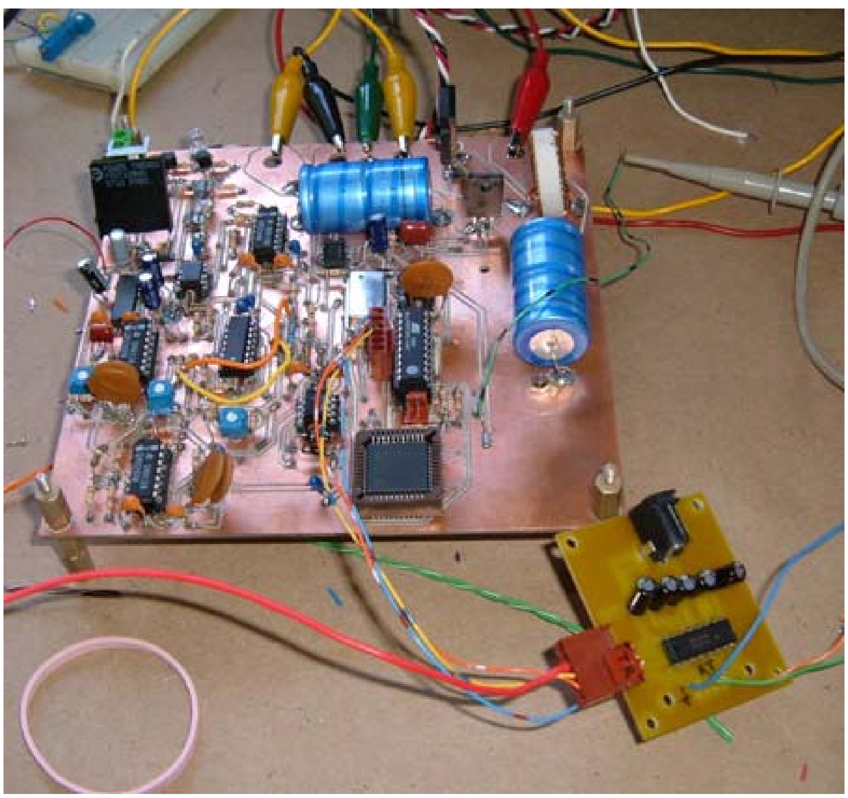
The front and top panels of the console are held in place with Zeus fittings. Removing the front panel allows for easy access to the instruments and switches. The top opening provides access to the instrument batteries and several electronic components.



The plan from the beginning was to build Peak Power Trackers (PPT) for each of the 16 solar panels. The first prototype circuit board was designed using Eagle software, and machined using a computer assisted milling machine.

The machining process was difficult and time consuming, but much less expensive than etching prototype boards.

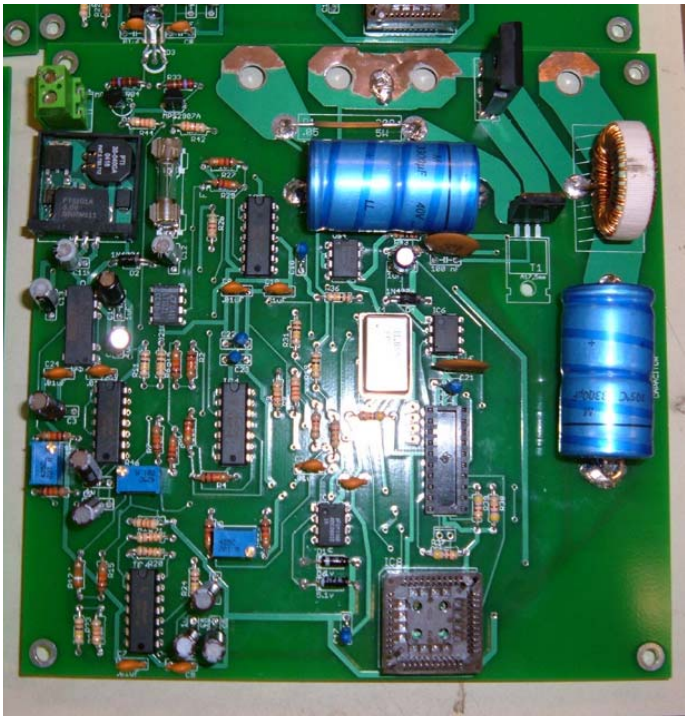


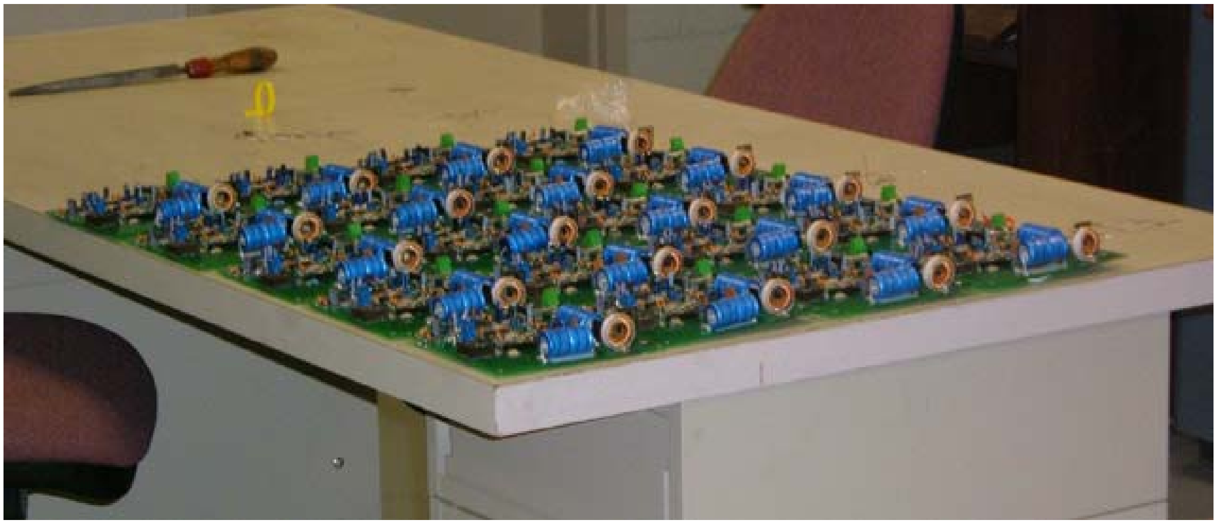


The prototype Peak Power Tracker survived rigorous testing, and the final circuit program was sent to Advanced Circuits for etching 20 boards.

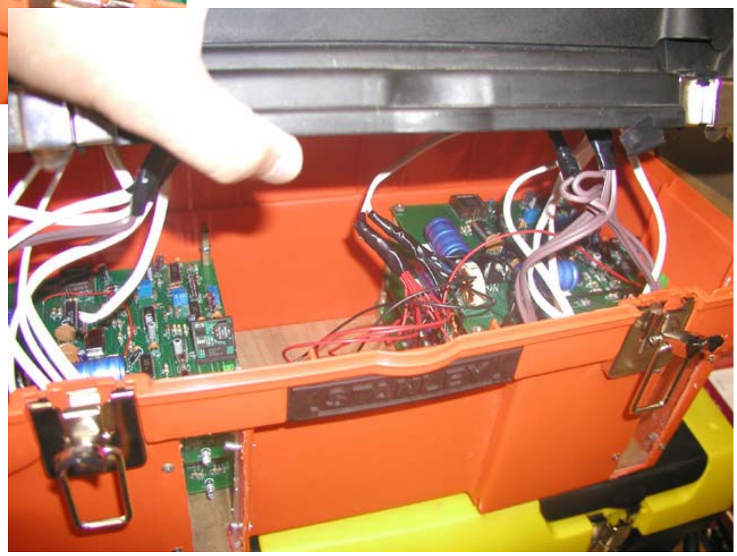
Once the PPT boards arrived, they all had to be assembled. Everyone on the team spent a weekend soldering the parts to the 20 boards

Each board was subjected to the same tests as the prototype board. With minor corrections (mostly polarity), the team ended up with 20 Peak Power Trackers (four extras).

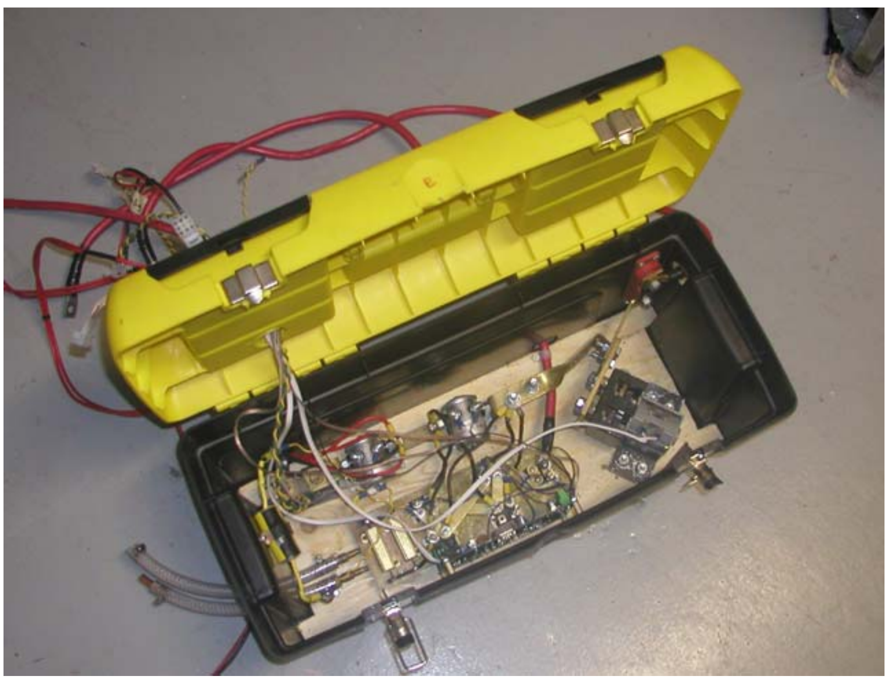




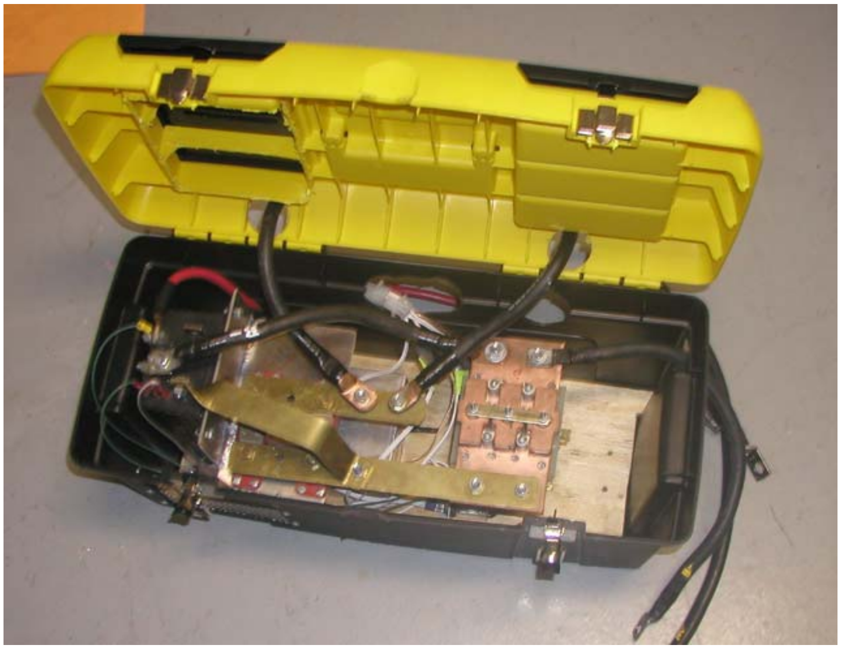
The peak power trackers were mounted in two tool boxes for ease of installation, protection from splashed water, and quick changeover from the sprint to the endurance configuration.



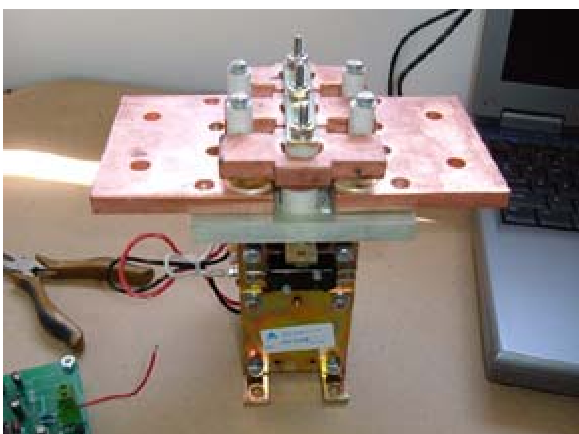
Each tool box held eight peak power trackers. One box served the front array, and the other served the rear array.



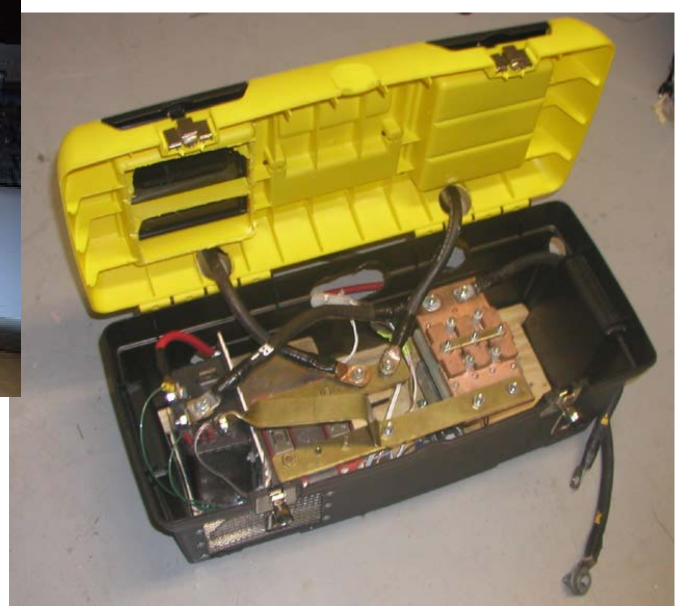
The solar arrays were connected to the endurance control box.
The ;motor controller (designed and built by the team) is in the front with tubes providing water cooling. The large solenoid on the right is the master disconnect switch, and the two solenoids at the rear allow the driver to disconnect the batteries from the circuit.



The sprint/slalom controller is mounted in a similar tool box. To the left side of the box is a commercial motor controller used for the varying speeds required by the slalom event. Since the 400 amp output of the commercial controller was not near enough for the sprint event, the large solenoid on the right was used to bypass the controller for the sprint. However, since there was a huge power spike at the bypass time, and the motors would only tolerate 800 amps each, a delay was built into the circuit. When the driver depressed the accelerator to the “floor”, the motor controller had three seconds to ramp the output up to 400 amps, then the bypass would activate. The resulting spike was lowered to 1,515 amps.



The high power bypass solenoid is shown above.



The final shape of the catamaran was developed using extruded polystyrene (insulating) foam. The material is light weight, provides excellent floatation, and is very strong when used as the core of a fiberglass sandwich.

The openings in each of the two hulls provide access to the bilge pumps, and one hull has a water inlet and pump used to water cool the electronics.

With the shape completed and the surface prepared, the Epoxy Primekote could be applied. All of the finishes were supplied by Interlux Yacht Finishes.

All finishes were applied with a fine foam roller followed by a foam brush used to remove bubbles left by rolling. The excellent flow characteristics of the Brightside Interlux Finishes provides excellent results even with semi-skilled workers.

At this point it becomes obvious how closely the final product resembles the original design concept.

Following two coats of black paint, the boat is ready for the first series of on-the-water testing.

The testing site is Core Creek State Park in Bucks County PA, just across the river from the campus . Although we have lakes on campus, none of them are large enough for testing the sprint motors.

The catamaran easily floats off of the launching dolly.

The first test was of the sprint configuration. The three battery boxes located just in front of the motors house three Optima SC7-SU batteries. Solar Splash rules limit the source voltage to 36 volts from less than 100 pounds of lead-acid batteries.

There was a concern for the depth of the lower units. Too much of the power house was under water even in the static condition. With Nick at the helm, the boat levels out perfectly.

Even at the beginning of the design work , there was one big unknown, the shape of the bow wake between the hulls. This shape could severely effect the depth of the sprint drive units. It turned out that this concern was well founded. There would need to be modifications.

With the solar array framework completed, the endurance configuration could be tested

A new platform and additional bracing was added to the 5 year old trailer designed especially to hold the launching dolly.

Sixteen 30 watt solar panels make up the total array. The Solar Splash rules limit solar output to 480 watts.

Back at Core Creek, the endurance systems were tested. Unlike the sprint systems, the endurance systems worked perfectly.

The endurance system had two deep cycle batteries on board for a maximum source voltage of 24 volts from 66 pounds of lead-acid batteries. These batteries however, could only be charged using solar energy. Sean, who designed the energy management system, takes the helm.

The exciting part of this testing was the realization of how well the boat performed using only the output of the solar panels.

Arriving in Buffalo NY late Tuesday evening, June 21st, it wasn't until Wednesday morning that we could begin setting up our paddock area.

The first task was to unload the boat, and prepare it technical inspections and qualifying.

All of the tools and parts had to be laid out in the paddock area in preparation for the first events.

The boat was then moved down to the launching area in preparation for the first on-the-water inspections and qualifying events.

Six people could easily lift the boat from the dolly and carry it down the steps to the water.

The boat was placed between the docks in order to install the batteries and solar arrays.

It was the responsibility of the electrical engineers to supervise the installation of the batteries, the peak power trackers, and the motor controller.

Once everything was installed, it was simply a matter of waiting our turn to qualify.

At the high line, Nick gets instructions from the starter boat.

The endurance qualifying event was a timed effort showing how well the boat could maneuver with the weight of the solar arrays and the power supplied by the endurance motor. The boat performed exactly as expected, and we placed forth in the number points generated by the qualifying events.

The slalom event was performed in the sprint configuration. It was a point generating event in which the boat had to prove that it was controllable at the higher speeds.

The boat handled perfectly in this event taking second place, 0.37 seconds behind the first place University of Arkansas boat.

Nick at the helm, and the team were particularly happy with this performance.

The first sprint heat pitted us against the only other catamaran in the competition.

We gained the advantage at the start, and increased that lead throughout the run.

This is a view of Nick approaching the finish line from the opposite side of the lake.

In the sprint finals, we were defeated here by the University of Arkansas, who was then beaten by the event winner, the University of New Orleans. The needed modifications that arouse during our testing sessions were just too extensive to be accomplished during the short testing period before the competition. We started the day in first place, but slipped from that position with this event.

In the endurance event, half of the boats leave the high line to begin the first heat . The second half of the boats join the event in thirty minutes. The entire field runs for two hours with a similar 30 minute staggered finish.

The boat ran exactly as designed. It was a sunny day, and the boat would perform on solar power alone (without batteries) as well as many boats working on both electrical systems together.

In the first heat, it was decided to run the backup propeller designed to shed weeds. The boat was not as fast as some of the competitors, so it was decided to change over to the primary propeller for the second heat to gain back some speed. We could stop in the pits to clean off the propeller if it became necessary.

To avoid dropping hardware in the lake, the rear solar array and the endurance motor was removed from the boat and the new propeller installed on the dock. Here Alex prepares to install the five bladed carbon fiber propeller.

The efficiency of the new propeller was obvious from the start. There were however, several boat that were faster. Another area that will need to be redesigned for next year.

The University of New Orleans, in the background, was the fastest boat in the endurance, (and the sprint) but burned out two motor controllers in the process and finished well back in the standings.

Removing the boat from the lake and loading it on the launching dolly one last time.

Although the team was disappointed in the overall 6th place finish, they were happy to have won the “Outstanding Electrical System Award”, and were also very happy with their very close second place finish in the slalom event. They were also happy with their tying for third place in their, ASME judged, Technical Report submission. The 2006 team is busily determining how to recover our dominance of the sprint event, and how to further improve our performance in the endurance events. 2006 is indeed a new year with a new team, and new engineering problems to solve. What a great learning experience this project has become.

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