THE COLLEGE OF NEW JERSEY
DEPARTMENT OF ENGINEERING

2003 Solar/Electric Boat Project

For the "Solar Splash 2003" World Championship Solar/Electric Boat Regatta

The team at the launching area of Hoyte Lake, Delaware Park; adjacent to the campus of Buffalo State University. From the left Tim Fodor, alumni volunteer; Megan Fankhanal, senior team manager and steering designer; Carrie Johnson, junior telemetry programmer; Mike Brazinski, senior motor controller designer/builder; Nick Ginga, junior helm designer/builder; Chris Jaworowski, senior sprint controller designer; Marion Labos, senior energy management system designer/builder; Matt Hennessee, senior endurance drive system designer/builder; Andrew Tom, senior telemetry designer; Tim Naples, senior steer-by-wire designer/builder; Paul Tarnow, senior sprint drive system designer/builder, and Dr. Norm Asper, advisor. Not shown, Mr. Jay Ross, President Protocol Electronics, electrical advisor.

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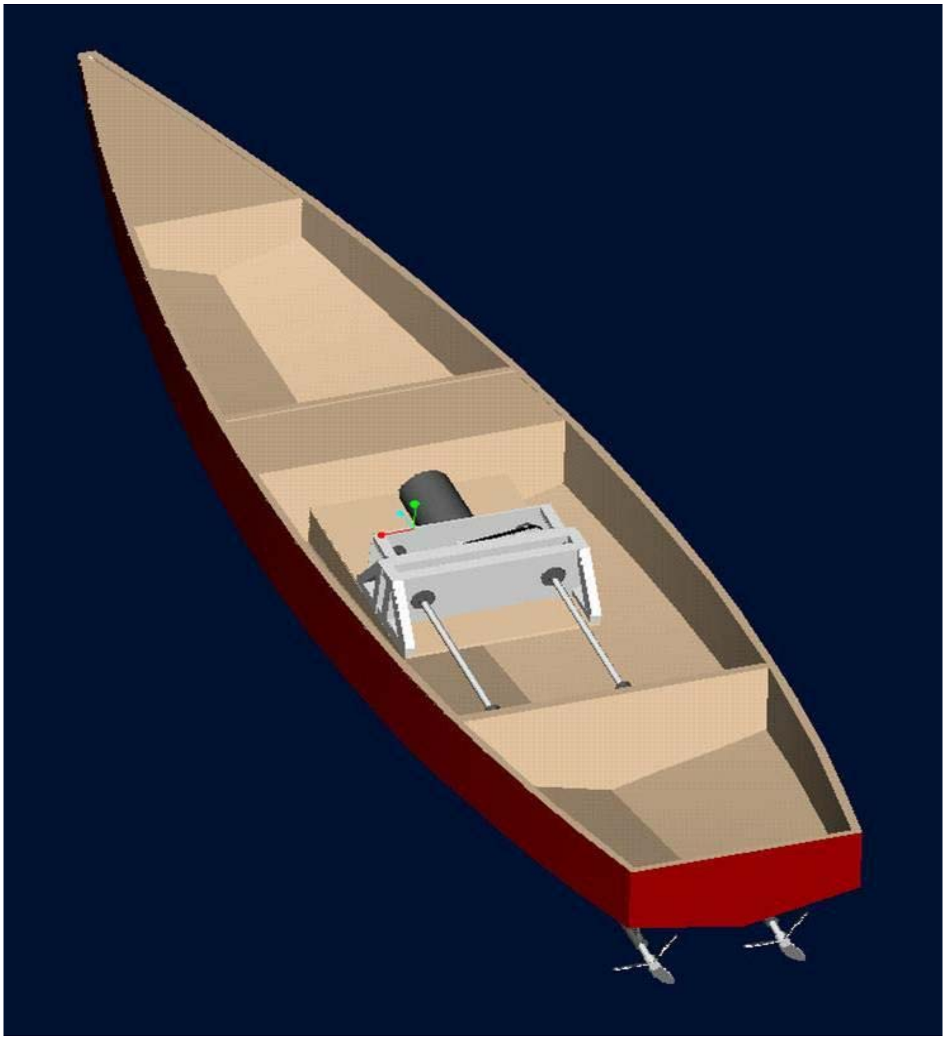
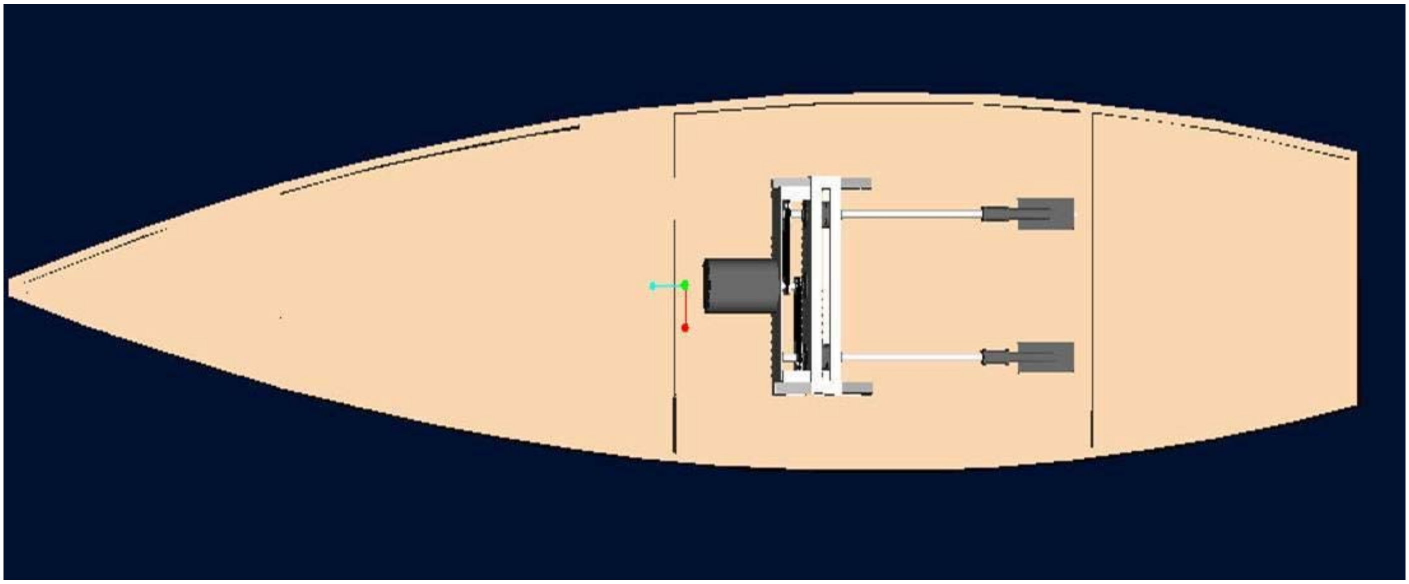
The first task performed in designing the 2003 boat was to determine the drag of the existing hull. Sand bags were loaded into the hull to simulate the weight of batteries, motors, and related hardware. The

The drag was measured at several speeds and a graph developed to

One of the last on-the-water days before cold weather sets in.

The team's analysis led them to decide on a twin-screw arrangement, primarily for the counter-rotating capability of the high torque sprint configuration. A Pro-E, 3-D model was developed for both the sprint and endurance configurations. Shown here is the model of the endurance configuration. This low speed, low power, arrangement used only one motor and did not require the counter-rotation desirable for the sprint configuration. In this case both propellers were turning clockwise. The sprint used two motors spinning in opposite directions utilizing both clockwise and counter-clockwise rotating propellers.





The twin-screw decision, combined with the decision to use the 2002 hull, required that the team fabricate struts to support the propeller shafts. No manufacturer offered struts that would match the motor angles to the hull bottom angles. At the left, Matt is machining a sleeve to accept a standard shaft bearing.

At the right Paul is machining the support brackets that will match the propeller shaft angles to the bottom of the boat.

The parts at left are ready to be welded at mirror image angles. One will be welded for the port side bottom angle, and one for the starboard side bottom angle.

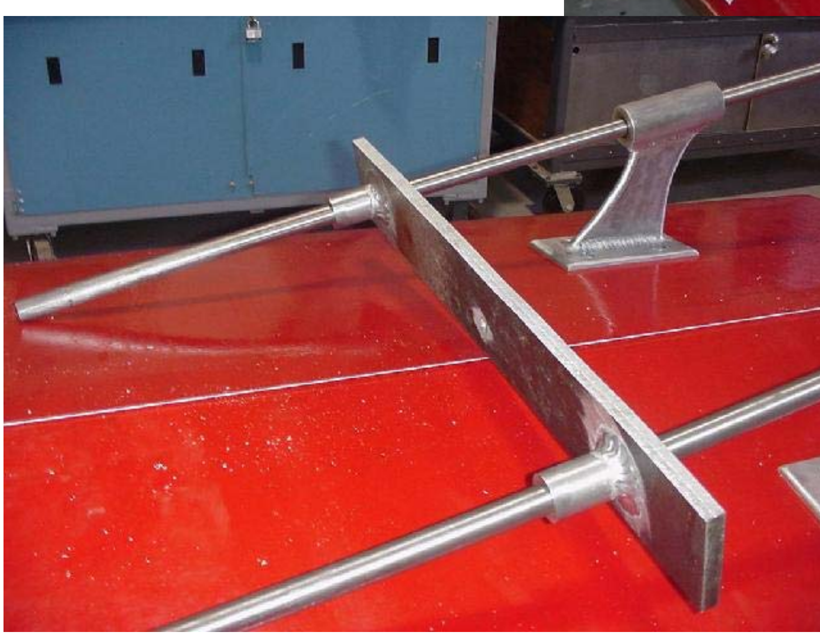
Standard, water lubricated, shaft bushings were purchased to match the 3/4 inch propeller shafts.

At the right, Paul is pressing these bushings into place with a hydraulic press.

The result of these efforts are two ,professional quality, propeller shaft struts, fabricated at the exact compound angles specified by the teams design.

With the new struts in hand, the bottom of the boat could now be drilled for mounting the shaft supports.

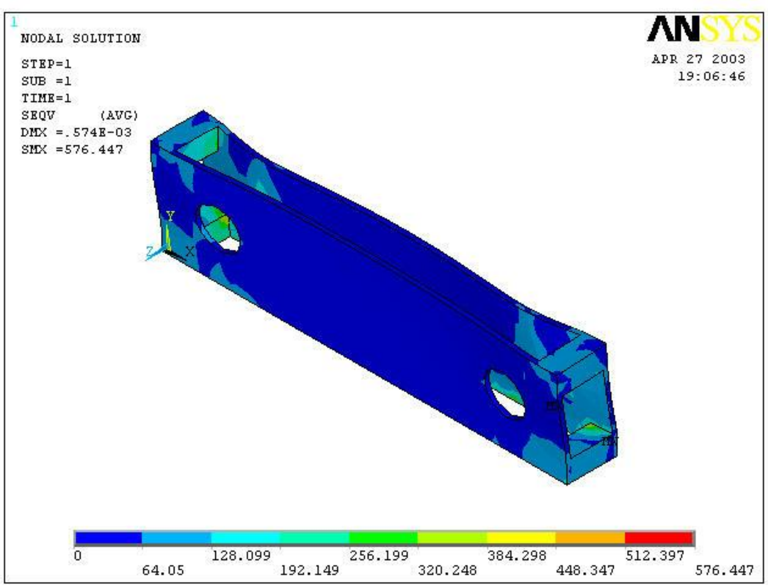
In these illustrations Matt and Paul are locating and drilling mounting holes for the struts. In order to locate the motors in their precise positions, the struts needed to be located precisely each side of the centerline keel, and forward the transom.



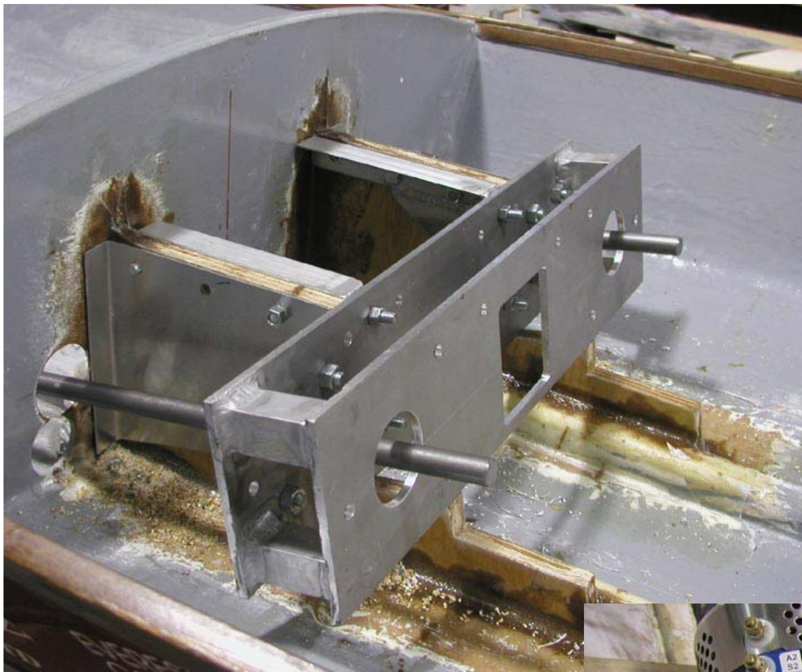
A jig was fabricated to perfectly align the propeller shafts so that shaft holes could be bored through the bottom of the hull. The illustration at the left shows the jig in place with dummy 2/4 inch shafts. One of these shafts was then modified by mounting a 2 inch hole saw on one end, and using the shaft as a very long drill bit. An electric drill was mounted to the other end of the shaft, and shaft holes were bored through the bottom of the boat.

As with the strut design, no manufacturer had a shaft log available that matched the angles defined by the team's design. In these illustrations, Matt and Paul are fabricating a custom shaft logs using the dummy shafts, the struts, and the alignment jig to locate the fiberglass tubes used to make the shaft logs.

After the fiberglass tubes were cut to the correct angle, they were epoxied and fiberglassed into place. Conventional stuffing boxes, and couplers completed the waterproof installation.

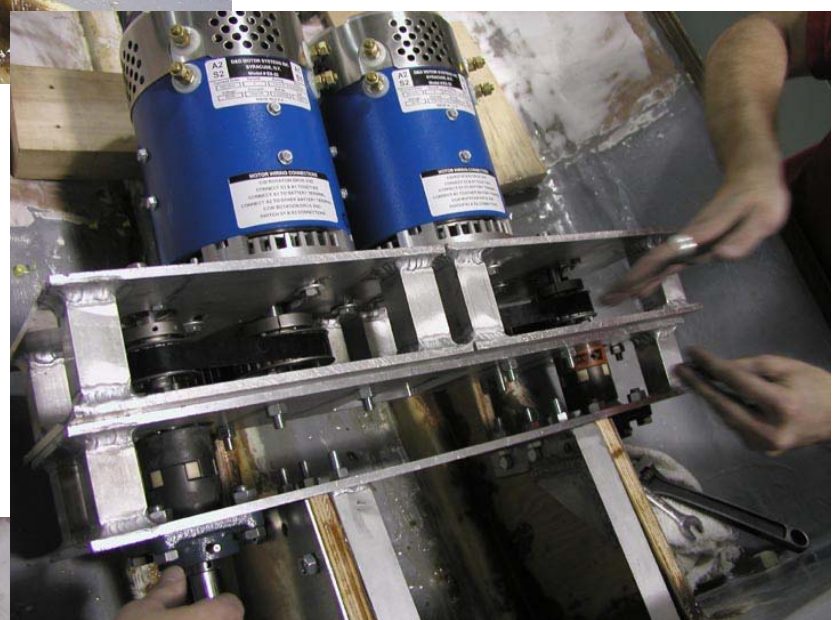


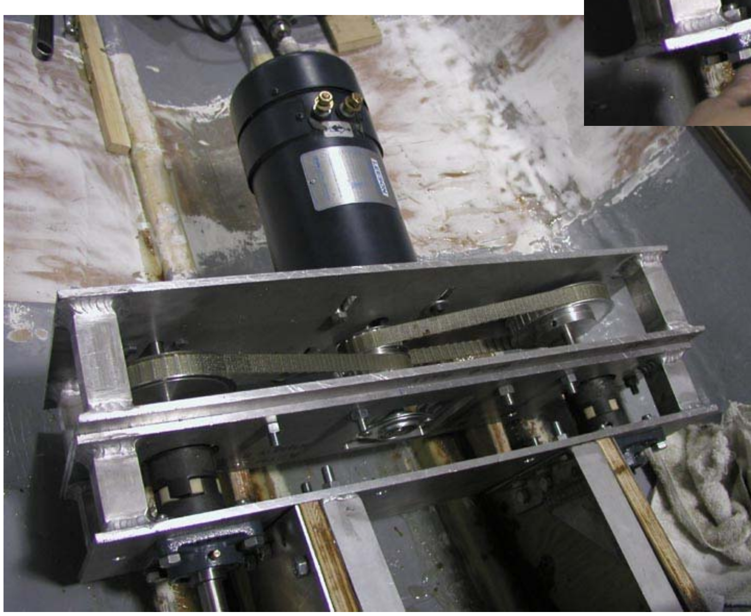
To complete the drive system up to the motors, a motor mount had to be designed to accept both the endurance, and sprint configurations. The illustration at the left shows an ANSYS analysis of the loads expected on this motor mount. The holes in the motor mount are for the shafts with the thrust bearings mounted on the back side.



The final motor mount assembly was then bolted to an engine (motor) bed that was fiberglassed to existing bottom stringers and an existing bulkhead. During testing, it was concluded that the motor mount still had excessive deflection, and an additional support was welded into the top center of the assembly.

The motor adapter plates with their gearing assemblies were then bolted to the motor mount. The "Lovejoy Couplers", shown in the lower left corner of the illustration at the right, made changing motors a relatively quick and easy task. The sprint motors used a 1:1.5 ratio notched belt to match optimum motor to optimum propeller speed.





The endurance motor mount assembly also used notched belts to optimize the motor/propeller speed ratio. Once again "Lovejoy Couplers" were used for quick motor change. Also shown in these two illustrations are the thrust bearings mounted to the aft side of the motor mount.

In addition to Megan's managerial duties, and reflecting her Mechanical Engineering concentration, she took on the design of the mechanical elements of the steering system. Combining standard rudder design techniques with NACA Symmetrical Air/Hydrofoils designs, she settled on the NACA 0012. At the left, she is using station profiles to make negative profile patterns for several stations along the foil.

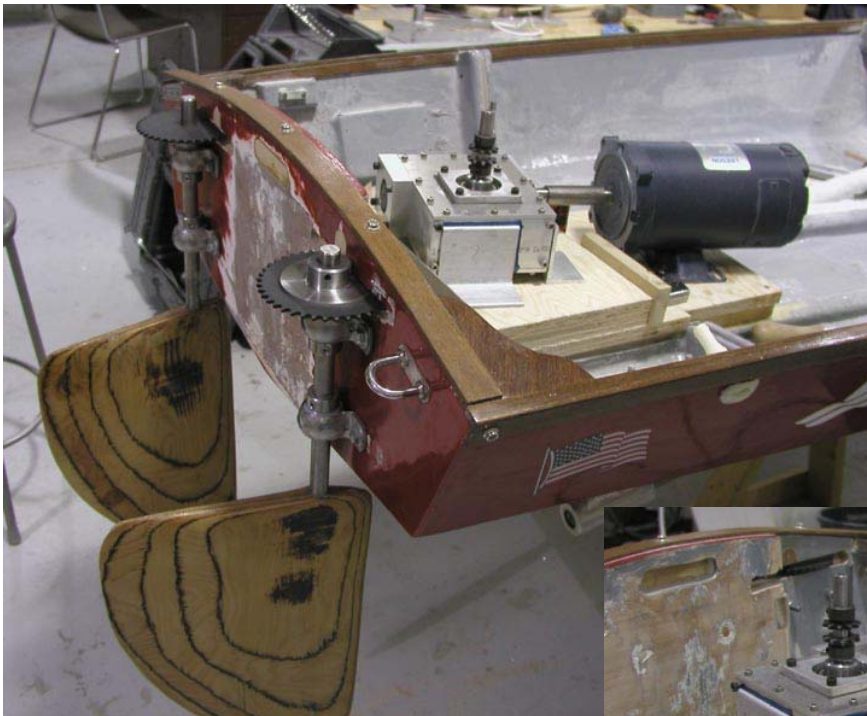
In the illustration below, stainless steel plates have been welded to stainless steel rudder shafts to provide lateral support for the rudder in high speed turns

The Styrofoam pattern at the left was developed from the 1/4 ellipse rudder design technique. This pattern was then combined with the NACA profile and the final rudder design was established.

Two layers of 3/4 inch marine plywood were laminated with fiberglass cloth over the rudder shaft and welded plates. The two pieces of plywood were routed out to accept the shaft assemblies.

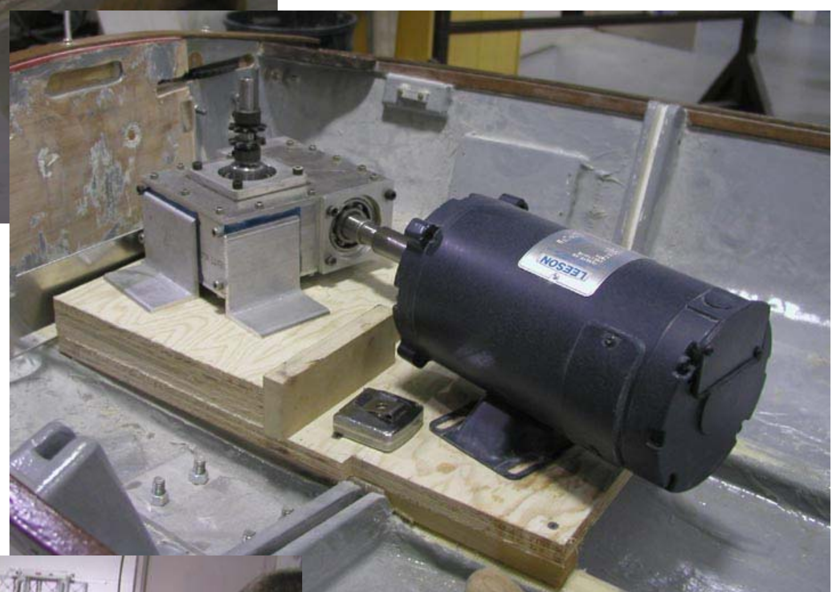
The rudders were cut to the 3/4 ellipse pattern, and then ground to the symmetrical foil shape

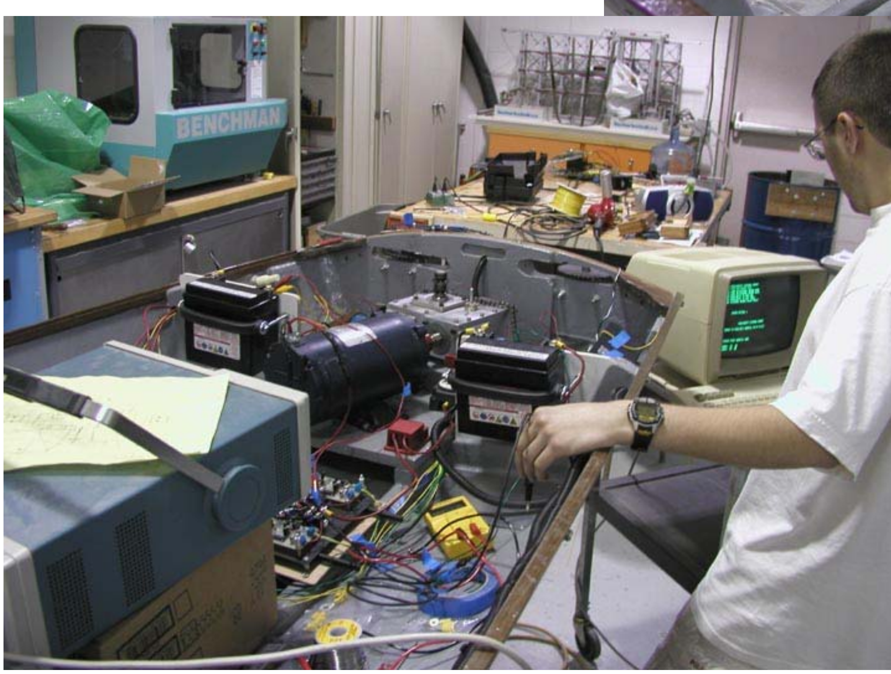
The negative profile patterns were used to check the progress of the grinding process. When completed, the rudders were covered in a 3 oz. Fiberglass cloth and epoxy resin.



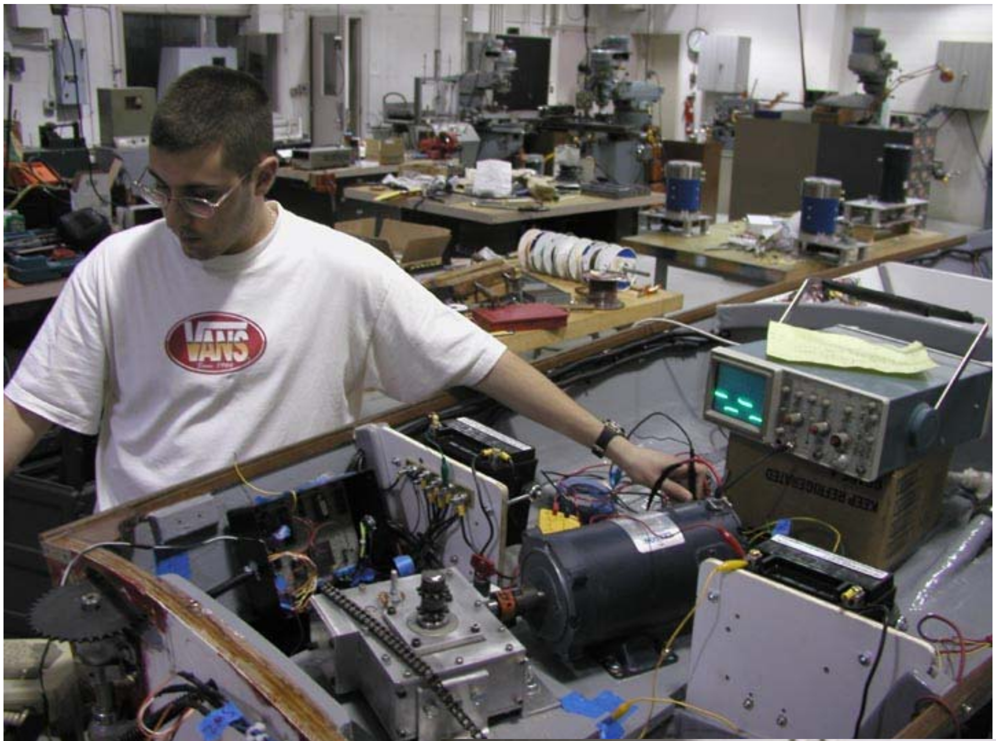
When mounted the two rudders are moved in exact parallel fashion by a chain assembly. The unique part of this steering assembly is that it was designed after the “Fly-by-Wire” technique used in aircraft.

A 1/2 horse motor is coupled to a worm gear assembly which rotates the chain sprockets and rudders.





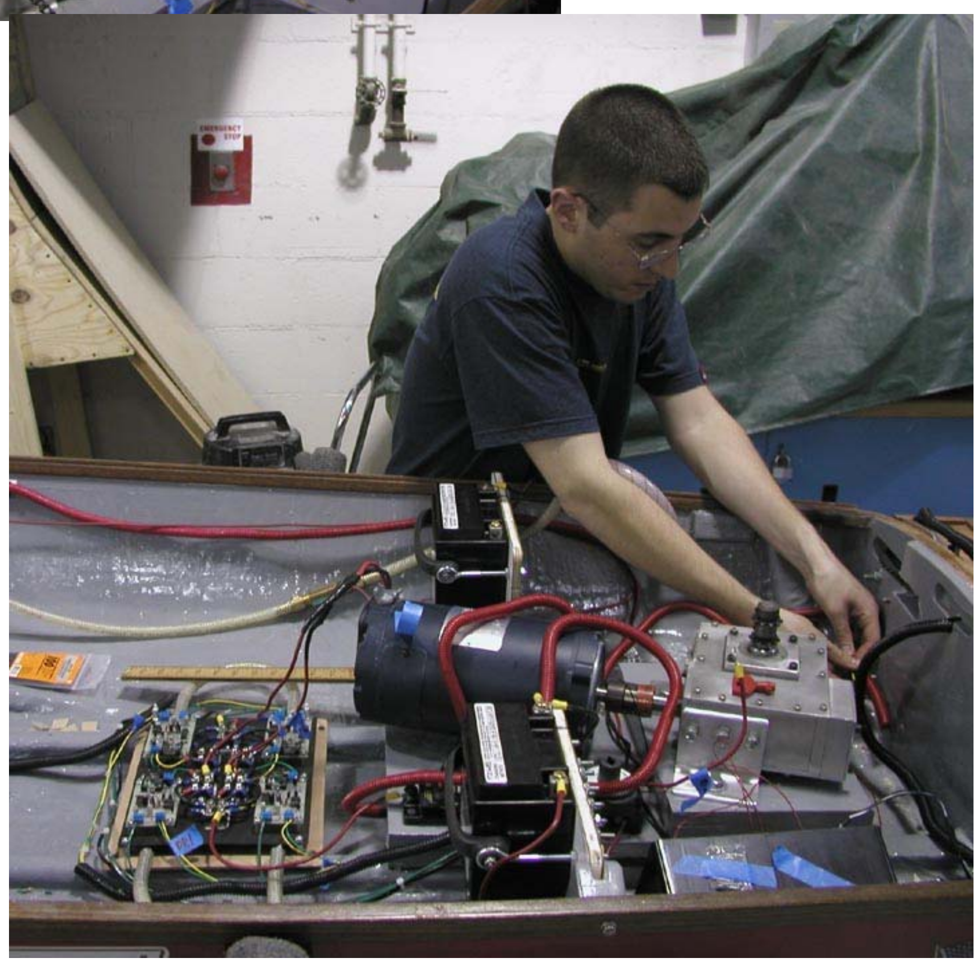
Tim designed and fabricated the computer interface with the steering wheel, as well as the motor controller. One of the two batteries shown at the left runs just the steering motor. The other battery runs all of the electronics in the boat as well as his steering.



Tim built a pulse-width-modulator to control the steering motor. The pulse signal can be seen on the scope at the right.

The computer interface is mounted on the gunwale just below the sheer.

At the right, Tim is organizing the complex wiring system. Resting on the bottom of the boat, in the lower left, is the pulse-width motor controller for the steering. The unit will be mounted upright just in front of the motor to make room for additional floatation. The motor controller, and all the rest of the electronics, are mounted on a copper plates and cooled with fresh water pumped in from the lake.



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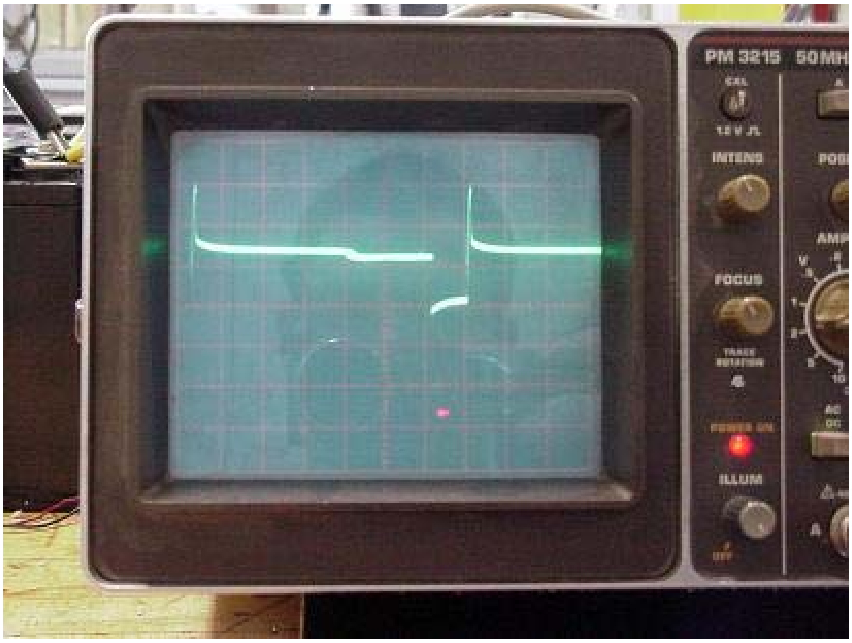
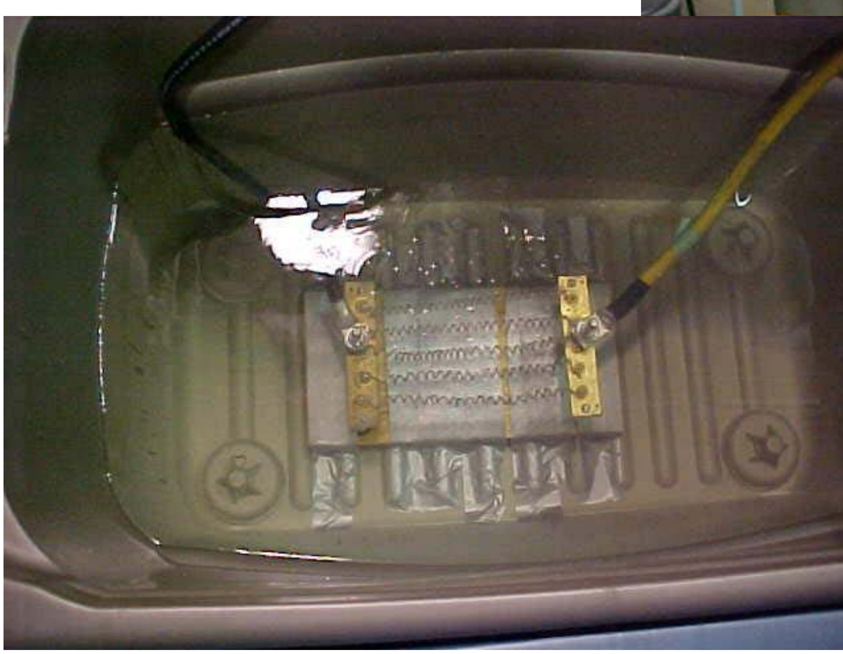
Our motor controllers in the past have been vulnerable to excessive loading. It was suspected that a voltage spike might very well be the culprit. Mike assembled a prototype controller, and using an endurance configuration, tested the system for ampere load and battery longevity.

During the test, he hooked up a scope to view the pulse signal, and indeed found 1.6 kw spike at the turn-off time. This spike could very well have been burning out previous controllers. A diode mounted to each motor should alleviate the problem.



In order to simulate the load of a sprint motor in the laboratory, a 36 volt, 800 amp load had to be developed.

Three 12 volt cranking batteries were connected in series to a Nichrome wire load. Jay Ross supervises the test



To withstand 800 amps, without burning out, the load had to be submerged in a tank of water. At the right, the water can be seen boiling from this much current.

Nick and Sean lay out an instrument panel for the helm which will also incorporate the steering electronics.

The layout was first prepared in a “Foamcore” mockup. All switches and displays had to be accounted for.

The electronic steering module also had to be accounted for in the panel design. The electronic steering module was adapted from an arcade video game.

Even as a volunteer, Nick spent many hours fabricating the aluminum instrument panel. The entire three piece assembly was machine polished.

A new bulkhead was glassed in place to accept the new instrument panel. The panel was hinged at the bottom, and attached at the top with thumb screws so that it could be easily opened to service the wiring.

The lights and switches on the panel were then “appropriately” labeled.

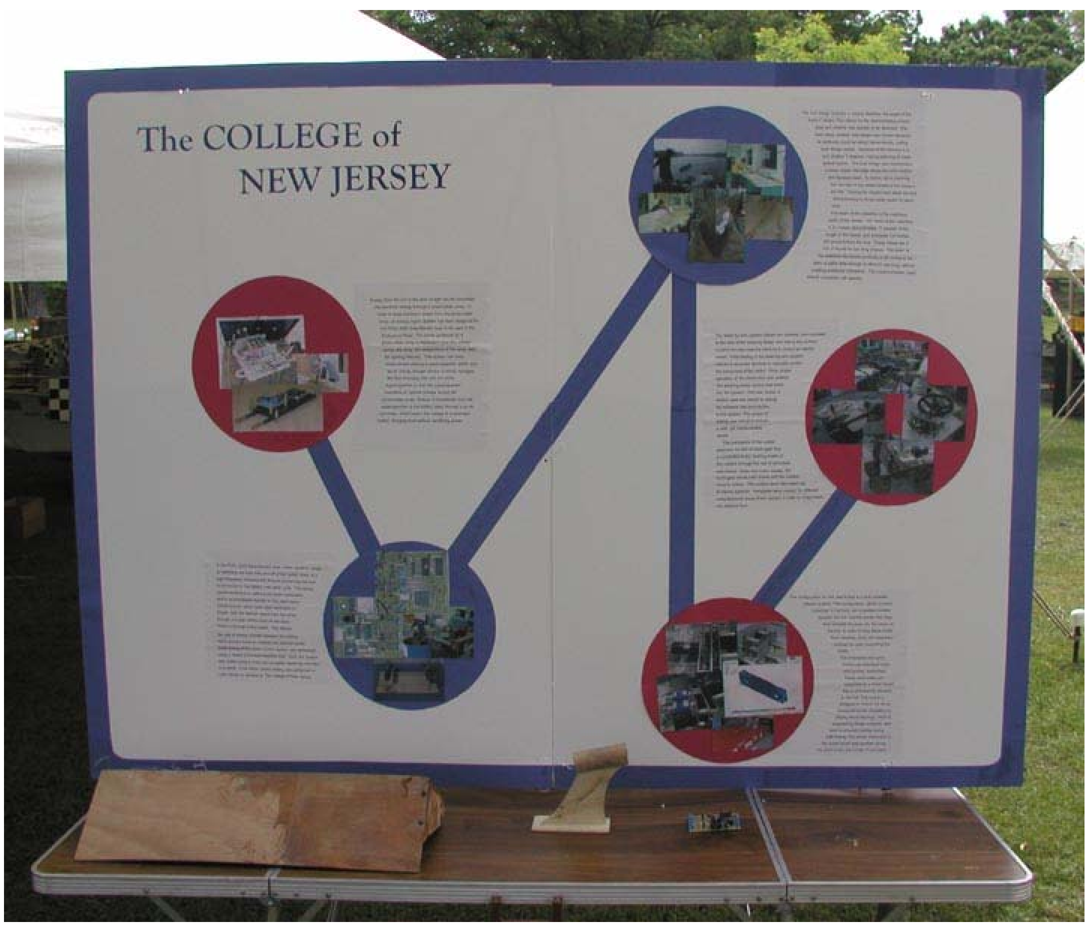
With everything finally in place, it was time for the first on-the-water test. The launching dolly had to be modified to accommodate the new inboard configuration. Launching is always difficult into the campus Lake Silva.

It is always a tense time when all the switches are turned on together for the first time. In this case, the sprint configuration at a lowered voltage. The lake is not large enough for a high speed run.

It is also always a relief when everything works as expected.

In Buffalo, the first task is to set up our paddock area. Sth solar array charging stand in front hold such necessary elements as a football and a water bottle.

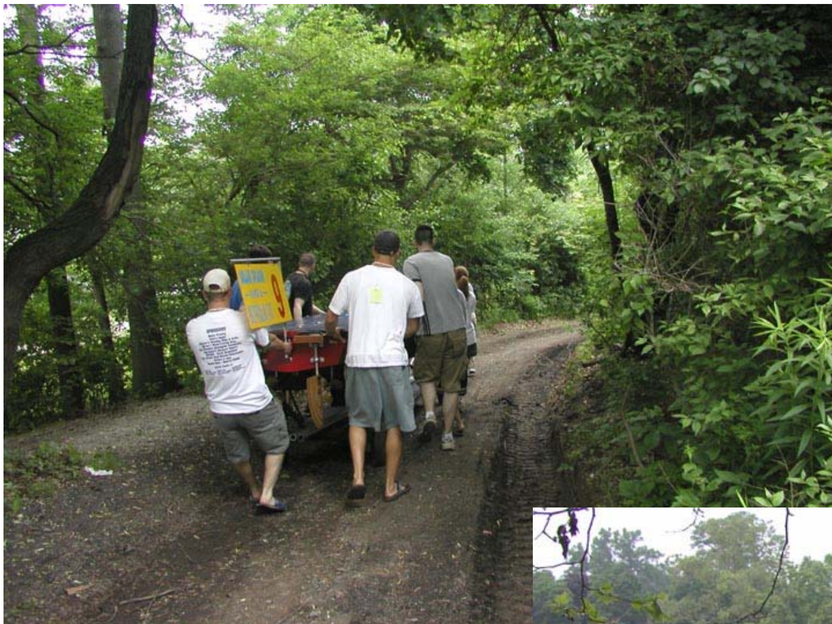
This is also the time to set up our display for the poster session. With a technical level geared to the general public, the poster generated the third highest points awarded at the event.



Even with the cold rainy days of Thursday, Friday, and Saturday, the boat had to be set up for qualifying. Sweatshirts and hats were the order of the day.

At the right, Mike checks out the installation of his motor controller for qualifying in the sprint configuration.

The Pulse Width Modulation pattern on the screen is exactly what he wanted to see.



Although still no sun, the rain stopped periodically, and qualifying could continue. To get the boat from the tent/paddock area to the launch area, it had to be rolled down a steep dirt path.

The launching dolly proved up to the task of navigating the muddy path.

This was the first time that most of the team had even seen the competition site.

Since we were one of the first boats to qualify, there were not very many spectators or other team members to help launch the boat.

To make the job easier, the batteries and solar panels were added after the boat was in the water. Here Mike connects the batteries while Marion and Tim hold the boat.

Occasionally, the sun did come out, but was of little help in these short qualifying events.

Here, Mike takes the helm and confers with Tim about the switching process for “turning on” the boat.

Below, Mike is pushed out to the high line for staging.

Below, and to the left on the dock, Jay Ross has arrived to help the team. As the electrical advisor for the team, and president of Protocol Electronics, he continues to be the strongest corporate supporter of the project. In his facilities, he provided space, equipment and supplies for the fabrication of all of the electronics on the boat. Without his support, much of this project could not have happened.

Mike is now on the high line in preparation for the maneuverability test. The starter in the chase boat just behind Mike is George Ettenheim, the originator, and coordinator of the event. Notice, coming from Phoenix Arizona, that he is still wearing a parka.

The boat handled perfectly in this qualifying event.

Tim takes the helm for qualifying in the slalom event. Notice that there are no longer solar panels covering the rear deck.

This is strictly an electric boat event in which the boat must show that it can also handle properly at higher speeds. Here Tim crosses the finish line in fine shape.

Retrieving the boat, and placing it on the dolly, following the various events was always an event in itself. After the qualifying days, and during the competitive events, there was always help from other teams to load the boat. Besides, many of the teams wanted to borrow our poles.

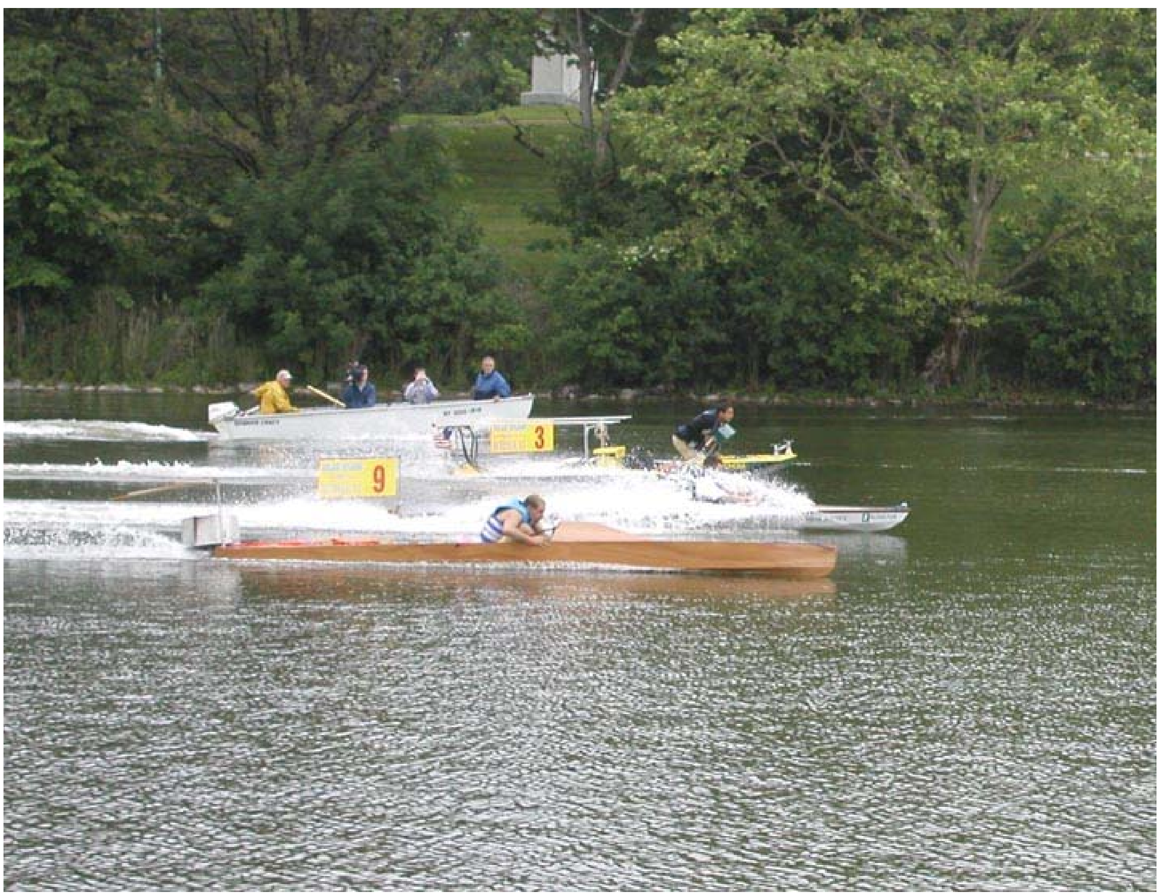
And then the boat had to be brought back up the gravel trail to the paddock area. At least now, the mud seems to be gone.

Back up at the paddock area, the solar charging station had to be set up. Once the event starts, batteries could only be recharged using solar energy. Carrie, Mike and Rich look on as Matt and Paul connect the solar arrays to the charging stand.

The panels simply unplugged from the boats charging system and plugged into the system on the charging stand. The solar arrays can then be tilted to follow the sun. Whenever the arrays are not on the boat, they are on the stand topping off batteries.

Based on the seeding established in the qualifying events, the fastest boats were run against each other. At the left, the three fastest boats from qualifying run head-to-head. In the center lane, Tim gets the "hole shot". In the near lane is the Univ. of Ark, and in the far lane is Cal Poly – Pomona.

At the halfway mark of the 300 meter course, Tim still holds the lead. Notice that the 25 horse chase boat in the background is being left behind. Tim was eventually nosed out by Arkansas. In the final standings, the Univ. of New Orleans bettered the times of all three of these boats.



Finally, Sunday dawned a bright sunny day, perfect for a solar boat race. At the left, Tim takes the first heat on Sunday morning. The purpose of the endurance event is to determine how far the boat can go in two hours with a solar array charging a 24 volt battery pack.

Although the speeds in this event are not great, we found that were drawing excessive current in the turns. At the right, Tim leans into the turn to help the boat turn to avoid using too much rudder. Here he has just passed the U.S. Naval Academy.

Mike took the afternoon heat, Tim could just not see another two hours in the sun following his morning stint.

By the end of the event, the battery pack was essentially dead. The solar array was still providing 12 amps of power at 24 volts which still provided a little over 0.3 hp. We were not going fast, but we were still moving while a number of boats were dropping out. At the very least, it shows that a boat can be run on solar power alone.

Although, in the final analysis, the team slipped to a disappointing ninth place overall, we won the ASME “Outstanding Systems Award”, and we took the third highest points on our technical report as judged by an ASME jury. We also took the third highest points for our poster session display, and the second highest ASME “Workmanship Award”. Not bad for one of the few colleges at the competition that does not have a Marine Architecture School.

As we packed up late Sunday afternoon for the trip home, one team member seemed to sum up the feelings of the group – “In spite of the struggles and trials of the previous year, I would do it again in a heartbeat”. It was disappointing that so many schools had to pull out at the last minute due to financial problems, and particularly disappointing that the Coast Guard Academy had to pull out do to homeland security responsibilities. They have always been a wonderful competitor.

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