

THE 2002 SOLAR/ELECTRIC BOAT PROJECT

The College of New Jersey
Department of Engineering



The 2002 Solar/Electric Boat Team at Hoyte Lake in Buffalo, NY. From the left: Nick Ginga (Sophomore) volunteer; Jay Ross (President of Protocol Electronics) technical advisor; Marian Labos (Senior) motor controller/energy management designer and fabricator; Phil Aiello (Senior) project manager; Dan Bischoff (Senior) power system designer and fabricator; Joe Balesterri (Senior) hull designer and fabricator; Norm "Doc" Asper project advisor. Not shown, Kristin Harz (Senior) trailer designer and fabricator.

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The original design work started during the summer of 2001. The team members divided their efforts into the areas of ***hull design, power system design, and motor control/energy management.***



The early design discussions resulted in decisions to utilize the “stitch-and-glue” hull construction technique. Strength and impact analysis led to the selection of 4mm Okoume marine plywood as the core of a fiberglass sandwich utilizing 6oz glass on each side.

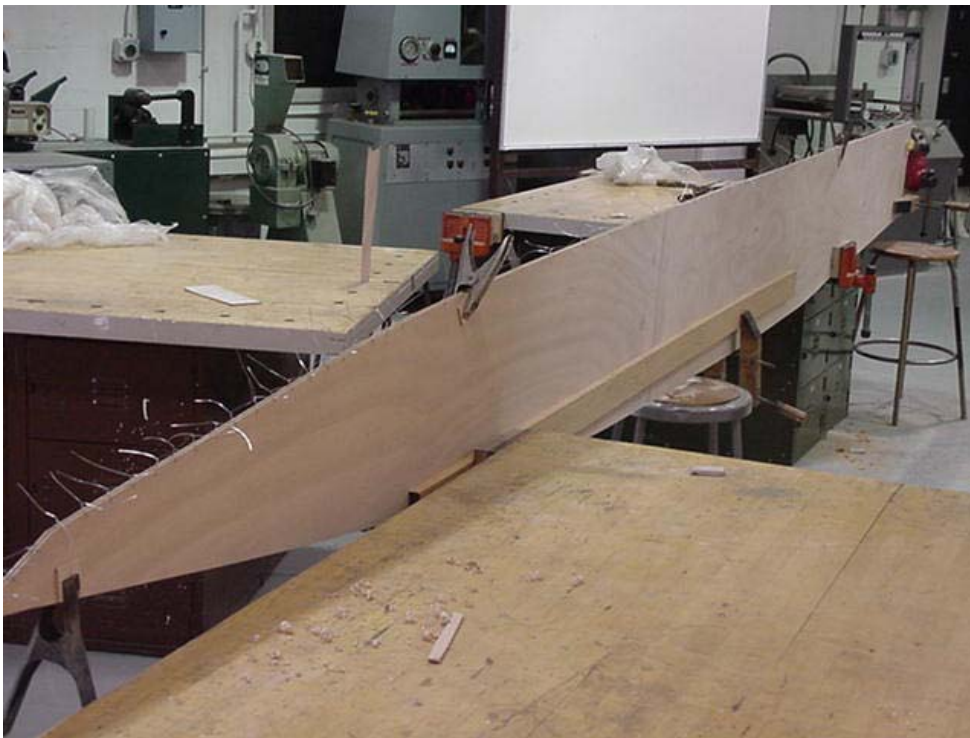
Human factors requirements of the driver, and the solar array requirements determined the size of the boat (within the limits of the competition rules). **AeroHydro’s MultiSurf** Computer program was used to determine the hydrodynamics of several design options. **Edensaw Woods** supplied the core material, and **Mahogany of Mays Landing** supplied the glass and Epoxy resin.

The photo at the left shows Joe and Phil creating the scarf joints on the ends of the 10ft sheets of plywood, to make sheets long enough for continuous sides and bottom sections for the boat.

The scarf joints then were used to assemble the 4mm Okoume panels into sheets that were 20ft long.



Utilizing the "Hulls" software package, Joe was able to rotate the curved hull panels, derived from the "MultiSurf" analysis, into flat surface panels. The cost of paper for our large plotters forced us to revert to traditional lofting techniques. At the right, Joe lays out each of the panels on a 20ft table.



Once the panels were cut, the two bottom panels were stitched together along the keel.



The bottom panels were then spread open and the side panels were stitched to the bottom creating a hard chine.

Although this job could have been done by one or two people, it is good to have extra hands at this point. Kristin takes time away from the trailer to help in the stitching process.



The transom was then temporarily fitted to the panels. It was later screwed and epoxied in place.



The wire stitches at the bow were about 2in apart, while the remaining stitches were about 4in apart. The edges were beveled to reduce the open areas at the joint.

The spaces between the stitches were filled with a mixture of epoxy and "Q-cell-400 Microspheres" provided by **Mahogany of Mays Landing**.





Once all of the spaces between the stitches were filled, the stitches could be removed and the hull would retain it's shape. Temporary bulkheads were installed to keep the twist out of the long narrow hull – over 18ft long, and less than 3ft wide. In the picture below, the scarf joints can be seen on the starboard bottom and port gunwale.





With the temporary bulkheads in place forming a “strongback”, the boat was turned over and one layer of 6oz glass was applied to the bottom. A heat gun was used to help the epoxy resin flow to a smooth surface.





Each seam in the hull was filleted with a paste mixture of epoxy and 50 mesh wood flour. The wood flour was supplied by **P. J. Murphy Forrest Products Corp.** These fillets were then covered with three, progressively wider, layers of fiberglass tape.

The entire inside of the hull was then covered with one layer of 6oz fiberglass cloth.



This technique resulted in a very strong, lightweight fiberglass/wood sandwich structure.



The Mahogany sheer was fitted to the hull structure. Joe is seen here hand cutting the compound angle at the bow. The photo below shows the number of clamps required to hold the sheer pieces in place while the epoxy hardened. The sheer joint at the bow fit perfectly.





Bottom stringers were added to distribute load from the transom, and to provide mounting points for seat and equipment. The bulkheads have been constructed but not yet mounted.

At the right, the bulkheads have been located to provide space for the driver and support for the solar array. In this photo they have been epoxied to the hull, and will be glassed in place using 3in fiberglass tape.



ANSYS analysis of the transom flexure indicated that we should add transom knees to accommodate these loads. This photo shows the hardwood frame covered with a plywood skin. These transom knees were then fiberglassed to the transom, bottom, and bottom stringers.



First coat of primer is applied to the bottom of the hull. **Interlux "Brightside"** enamels were applied with a foam roller, and the bubbles were brushed out with a foam brush. The finish is outstanding, and part of the reason why we won the **Craftsmanship Award**.

Foam flotation was cast-in-place in the closed bulkhead section of the bow. Another enclosed foam section was installed in the center of the boat. Final flotation calculations exceeded the required 110%.



The flotation was covered with a mahogany deck.



As the hull was progressing, Dan was busy preparing the power units. The 740x series starter motor provided by **Prestolite Electric** was modified as shown at the left. The parts below were removed from the motor case, and the end plate machined to retain the shaft bushing. The Prestolite motor was prepared to become part of the sprint configuration.

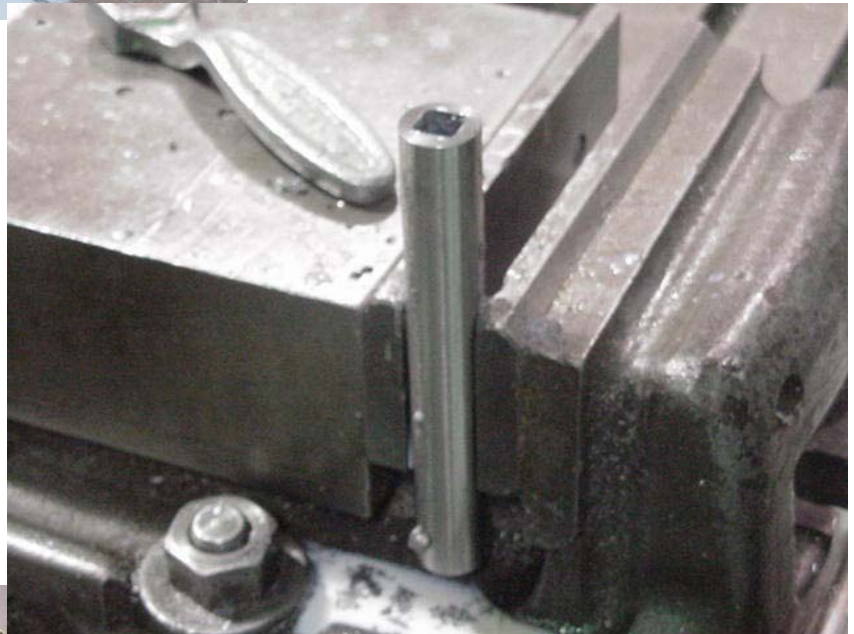


The 25hp lower unit provided by **Mercury Marine**, also destined to be part of the sprint configuration, received minor modifications. The water pump and cooling system chambers were removed and filled with expanding foam as were the exhaust ports. In the photo at the left, Dan is sanding the fiberglass filler used to close the water inlet ports. The reverse gear selector was also removed, and a spacer was machined to hold the bevel gears in the forward position.



In order to match the motor RPM range with the lower unit gearing and propeller selection, it was necessary to select a gear ratio that would make this match. A chain and sprocket arrangement was selected to make this match. At the left, Dan is removing material in order to lighten the drive sprocket.

It was also necessary to machine an adapter to extend the 2.5hp Mercury lower unit drive shaft to the mounting plate and power head. This then became part of the endurance motor configuration.



Part of Dan's responsibility was also the steering. Shown at left is a part of the tiller assembly designed to steer the outboards.



The photo at the left shows how the Mercury lower unit for the sprint configuration was mated to the motor adapter plate and steering mechanism. The steering mechanism was designed to remain undisturbed on the boat while the motors could be changed by removing four bolts.

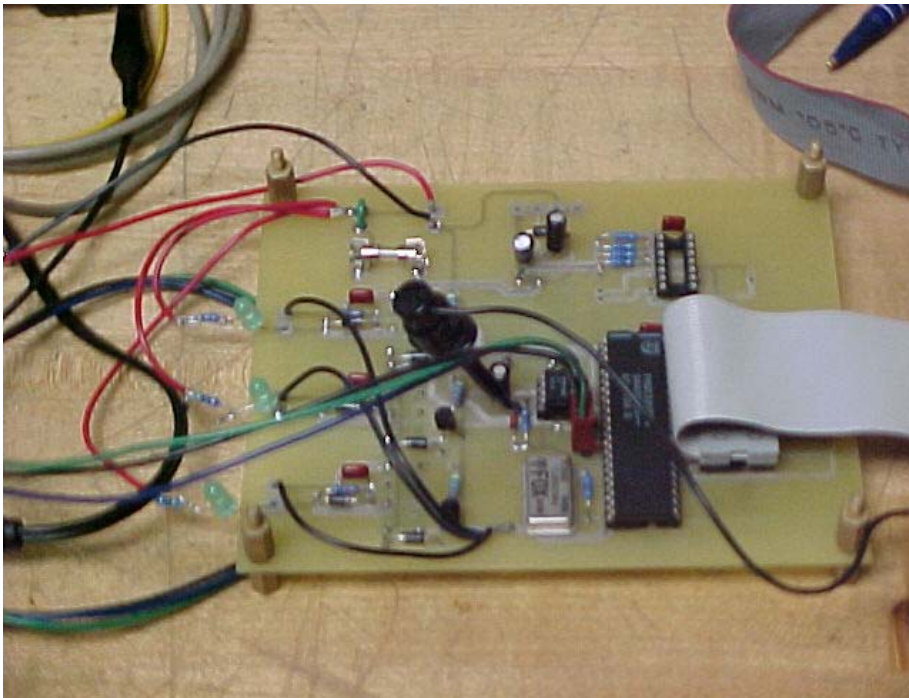
The two motors began to get difficult to move around the lab, so a motor dolly was built to make this task easier. The dolly was used to perform the same task at the competition. The endurance motor mounted on the dolly shows that no gearing was necessary to match the motor to the lower unit gearing because a custom carbon fiber propeller was developed to match the output shaft speed with the desired boat speed. A Lovejoy connector made motor head changes a quick five minute job.





While the hull, power, and steering elements were being developed, Marian was deeply involved with the development of the control systems for both the endurance motor and the sprint motor. Above, the prototype elements of the endurance controller are mounted on a piece of plywood. The setup is being used to test their effectiveness controlling the endurance motor which is mounted to a Prony Brake (below). The test provided Torque, RPM, and Amperage. Above, Jay Ross (left) president of **Protocol Electronics**, and technical advisor, oversees the test. Marian (center) supervises the test and reads data. Water cooling allowed for miniaturization of parts, but after all, the unit will be on a boat.



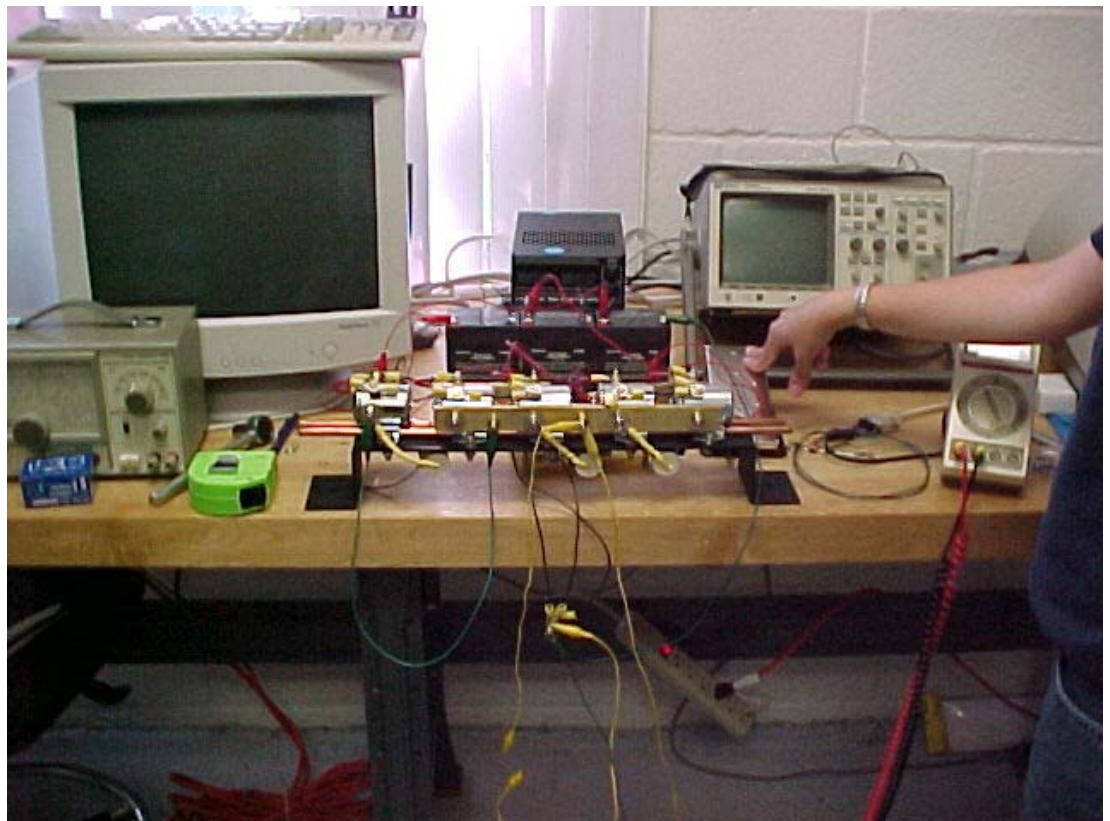


This is the prototype controller (above) that is used for the sprint and slalom runs. It has an 8051 microcontroller programmed in assembly language to interpret the position of a foot pedal. Shown below is Marian assembling the high current contactor array. At this point, we are pushing the limit on the current specification for continuous operation of these contactors. Therefore, they are also being water cooled.





Above, Marian is machining one of the several circuit boards for the two controllers. The proof is in the testing.
Below, Marian presses on the foot pedal switching the solenoids through the three different voltages.





During this same period of time, Kristin had designed an over-the-road trailer to transport the boat and launching dolly. In the past years, we had to decline invitations to display and demonstrate our boats because of the prohibitive cost of renting a truck for each show. This trailer will provide us with the opportunity of accepting more of these invitations as well as reduce future transportation costs to the competition.

Kristin provided all the design work and much of the welding fabrication. The MIG welder was portable enough to move around this 16ft trailer.



The “**Torflex**” axel provided by **Dexter Axle** was mounted to the trailer frame. The frame was designed to accept the finished boat (without motors) mounted on it's launching dolly.



Above, the longitudinal supports for the plywood (carpeted) decking have been welded in place. The spacing of these supports were dictated by the location of the wheels on the launching dolly. Pockets were cut into the decking to accept the dolly wheels. This design "locked" the dolly into position so that minimal straps were required to hold the boat and dolly in position. Below, the trailer has been primed, and Phil is applying the first finish coat of black. The black frame will be highlighted by polished Diamond Plate Aluminum fenders, and a matching **Weather Guard toolbox** provided by **Knaack Manufacturing Company**.





“First Launch” is always an exciting time. The location is Lake Silva on the TCNJ campus. Boat is in a temporary sprint configuration.

Marian is first at the helm. She wanted to be sure that the boat is pointing away from shore before she turned on any of the electrical systems – probably a good thought.



Then Phil gets the chance to try his hand at the helm.



The boat is finally painted, registered, and the graphics applied. The trailer is also complete and registered as a state vehicle – no simple task. Here everything is loaded to head for a larger lake and more extensive testing.





In Buffalo, the first task was to set up our assigned tent area. Registration had to be completed, and the boat had to pass the technical inspection. At the left, the solar arrays are being installed for the electrical inspection.

At registration each driver had to be weighed. Each driver had to weigh 70kg, or carry ballast to achieve that minimum weight. Obviously Marian had to carry considerable ballast to achieve that minimum weight. Phil met the minimum easily.



Throughout the technical inspection period, Marian's electrical system received a great deal of attention. The IEEE judges were so impressed that they awarded the TCNJ entry "**The Best Electrical System**" trophy.



When the solar array was not mounted on the boat, it was mounted on an array stand charging batteries for the next event. All of the elements became part of our display package.

A major part of our display was the poster that depicted each step of the development process. The key was the Gantt chart of the project with lines leading to photographs of that step, and samples of the parts. The judging of this display yielded the second highest number of points awarded for the activity.

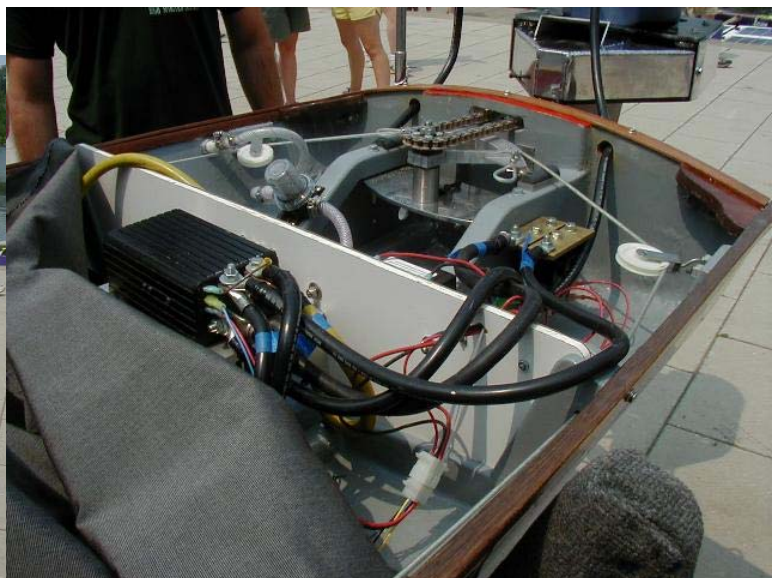


Also, a part of our display included the motor stand holding the motor not mounted on the boat. Shown here is the endurance motor (without propeller). When the endurance motor was mounted on the boat, the propeller was not mounted until after the boat had been moved to the "on deck" area.



View of the helm from the driver's vantage. Tillers offer one or two hand steering. The GPS is located in the center. Volt and Amp meters are located at the starboard side. The knob to the left of these meters is the "cruise control" for the endurance event. The meter on the port side is the charging indicator for solar array, and the panel of switches control solenoids and cooling pumps. This view illustrates one of the reasons why the TCNJ boat was awarded the **Craftsmanship Trophy**.

In the photos below, Dan inspects the sprint wiring and steering.





Marian qualifies the boat in the endurance configuration. Not a great deal of sun this day, but qualifying was only one lap around the course. In these photos, she is going faster than she would normally for seeding purposes.





Phil prepares to qualify in the sprint configuration. No solar array, power only from batteries. This is essentially a 300 meter drag race. Qualifying times result in seeding for the sprint heats.





Bringing the boat on the launching dolly down to the "on deck" area for launching.

Phil, Doc, and Nick await launching instructions. Nick (at the right) is the sophomore volunteer who was always there when we needed help. Perhaps a member of a future boat development team.



Launching was a relatively simple task, usually because there were always a number of volunteers willing to help.



Above, Phil is buttoned up for a sprint heat. Unfortunately both sprint heats were plagued with mechanical failure. In both heats, the boat left the high line and accelerated just as expected. At about the halfway point in the first heat, the motor simply shut down. After a tow back to the launching area, it was discovered that a battery terminal had completely melted away. It was concluded that the terminal type could not withstand the nearly 800 amp draw. The terminals were changed for the second heat, and again the boat left the high line and accelerated just as it should. Again, at about the halfway point, the motor stopped. This time the cause proved to be an under rated fuse. It proves that no parts are minor or insignificant. These two DNF's were too much to overcome in the final scoring, dropping us to 11th place overall. A disappointing finish, but a fantastic learning experience.





The boat performed much better in the endurance events. After repairing malfunctions resulting from the qualifying events, Marian's motor controller worked perfectly. The fact that it is still not a bright sunny day may have helped us, since a stuck relay stopped the solar array from charging the batteries about half way through the event. Below, Marian passes the host school, Buffalo State, as they round a marker buoy.





An impressive package designed and built by five senior engineering students with the help of one volunteer. The boat goes on now to public displays and demonstrations to school groups and civic organizations. The initial thinking of students interested in next year's competition is to retain the hull (as well as the trailer and dolly), and modify the drive train. The prospects are exciting!





The project would not have been possible without the support of our many fine sponsors who provided both money and materials. A special thanks goes to Mr. Jay Ross, President of Protocol Electronics, who provided guidance as a technical advisor and the use of his company's equipment and materials. The benefit of his presence and help at the competition was immeasurable.





The trailer and launching dolly were the final touches that made this the most visible package at the competition. **Weather Guard** and **Dexter Axle** provided the materials that made the trailer possible.



The College of New Jersey has established a reputation for winning the "Technical Writing Competition". Below is the cover of the report of the project submitted in early May. The report was judged by a jury appointed by ASME, and team was awarded the trophy for submitting the "Most Outstanding Technical Report".

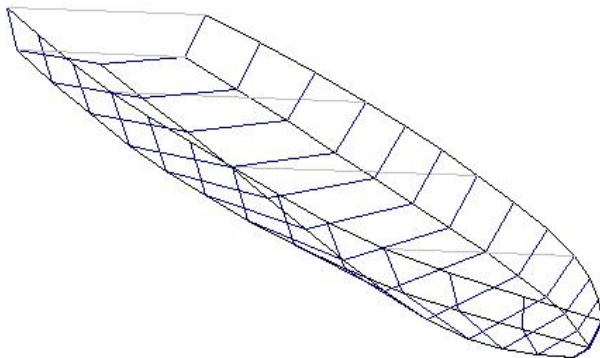
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2002 Team Members

Boat #7

Technical Report



Wire frame of the final boat design

Solar Splash

Date: June 19-23, 2002

Location: Buffalo, NY

Phil Aiello,
Project Manager
Marian Labos,
Motor/Power
Controller Design
Joe Balesterri,
Hull Design
Dan Bischoff,
Power System Design
Kristin Harz,
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