# The College of New Jersey

## 2012 Solar Electric

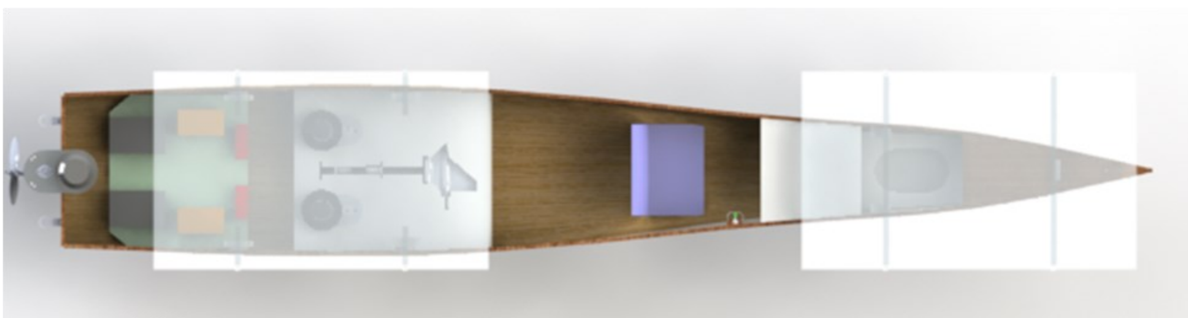
## Boat Construction

The team from left to right: The advisors; Dr. Norm Asper, Professor Emeritus, Interdisciplinary Advisor; Dr. Anthony Deese, Asst. Prof., Electrical Advisor; and Dr. Karen Yan, Assoc. Prof., Mechanical Advisor. The team members continuing from the left: Glenn Reese, Electrical Engineering, Power Management, and Motor Control; Steven Voinier, Mechanical Engineering, Team Captain, Propeller Design and Manufacturing; Christopher O'Mullane, Mechanical Engineering, Design and Manufacturing of the Sprint drive train and integration of the Steering System; Steven Stockhamer, Computer Engineering, Team Manager, Design and Manufacture of Data Acquisition and Telemetry; and Patrick Dougherty, Mechanical Engineering, Design and Manufacture of the Endurance Drive Train, and Reconfiguring the 2009 hull..

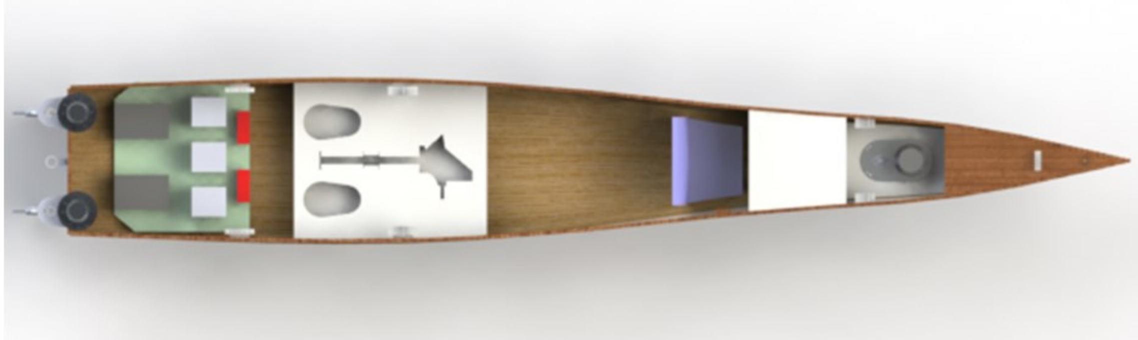

Having decided to re-use the hull designed and manufactured for the 2009 event, the Electrical and Computer Engineering members of the team were able to concentrate their efforts on the redesign of the power management, motor control, data acquisition, and telemetry systems. The Mechanical Engineering members of the team could then concentrate on the redesign of the propellers, sprint and endurance drive systems, steering, and reconfiguring the hull to accept these changes as well as a new solar array, and adherence to the new rules changes.

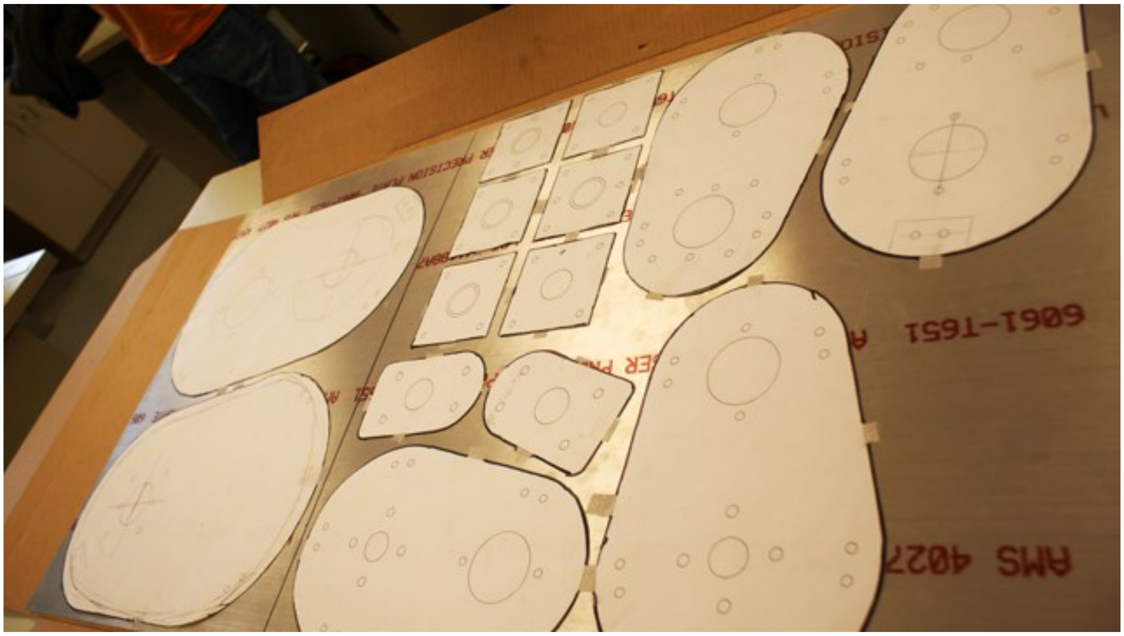

The helm and its bulkhead had to be removed and replaced further aft in the hull which meant the skipper also had to be moved back. The bulkhead directly behind the driver also had to be removed. Here Pat prepares to replace the bulkheads with solid Styrofoam bunks routed to accept the drive system parts. Because of the rules change, these parts had to be stored on the boat at all times. The weight distribution calculations also had to consider two new larger/heavier solar panels provided by the Schott Solar Corp.


Here the helm is being repositioned further aft, and fiber glassed into place. All of these location/weight changes within the hull required the team to re-calculate the centers of buoyancy, floatation, and balance for both the endurance configuration and the sprint configuration.



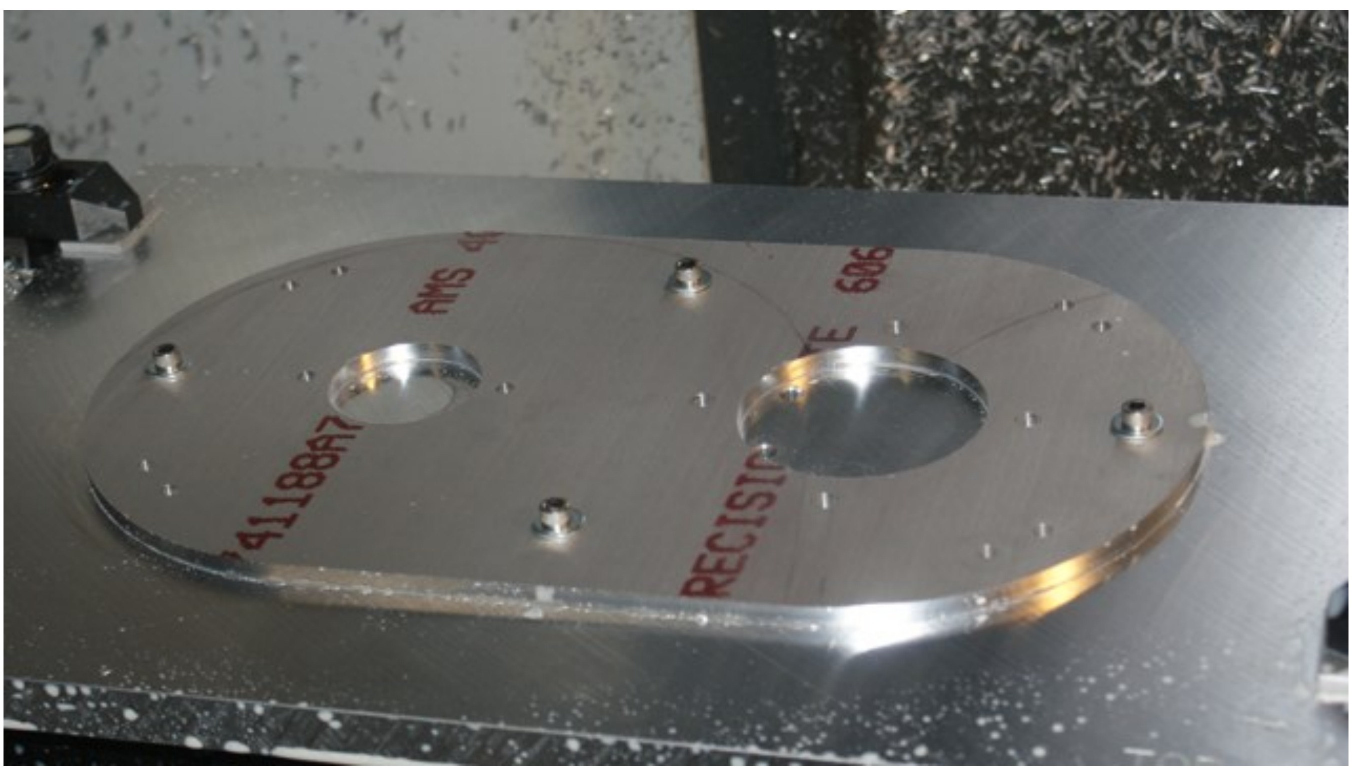
The final arrangement placed one solar panel forward the helm, and one aft the helm with room for the driver to move the seat either forward or aft between them to achieve optimal weight distribution. The heaviest elements to consider in weight distribution were the driver, the batteries, and the solar panels. For the endurance event, the center of gravity needed to be located further forward than the evenly displaced hull's center of flotation to take advantage of the displacement hull form of the forward hull section. In the sprint of event, it was necessary to place the center of gravity far enough aft to allow the hull to climb the bow wake, but still forward enough to limit the drag, allowing the hull to plane most efficiently on the planning hull form at the aft section.

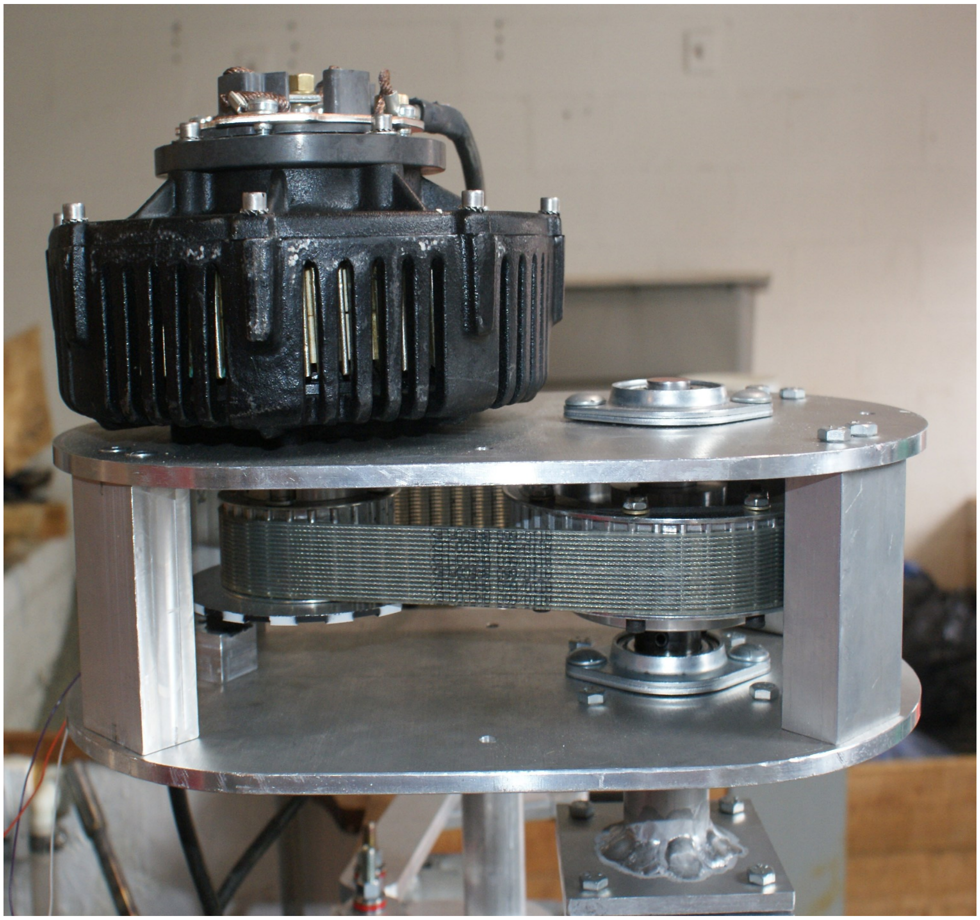




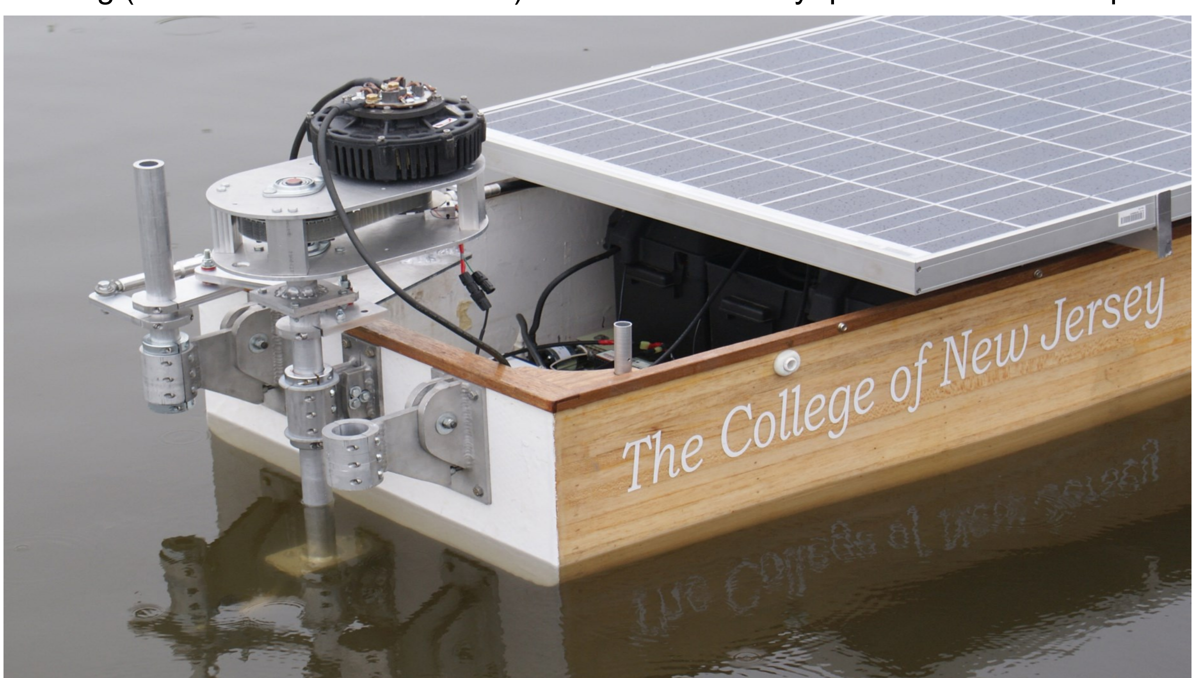

As the hull layout progressed, the motor mounts and transmission housings were being laid out on 1/4 inch Aluminum plate. Also shown here are couplings that will eventually be welded to the Powerhouse to mount the lower units and the transmission housings.

With the CNC programs written, the roughed out parts could be machined—no problems with exact duplicate parts.





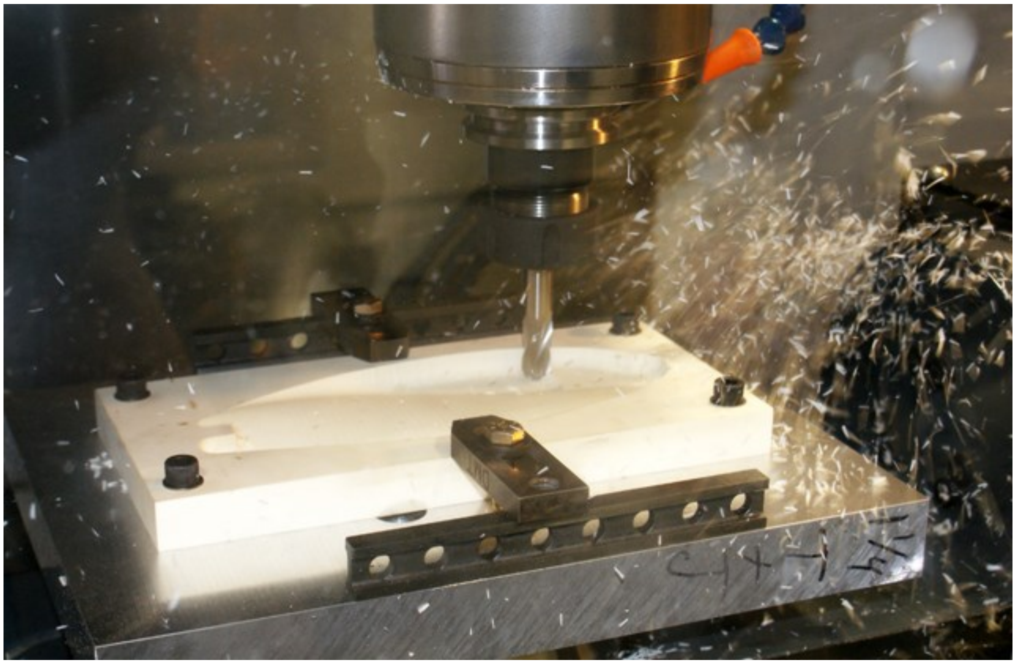
The PMG-132 endurance motor used in the 2009 competition was reused in 2012.The peak efficiency occurred at 1080 RPM while delivering 128 in-lbs. of torque. The propeller designer requested a rotational speed of 550 RPM, so a speed reduction would be necessary between the motor and the powerhouse. The team's decision to share powerhouses and lower units between the sprint and endurance drive trains eliminated the use of the Mercury lower unit used in 2009. Because the Konny lower units offered a nearly 1:1 gear ratio, the endurance drive train could no longer be a direct drive system. BreccoFlex belt and pulleys were chosen to reduce the rotational speed of the system. 24 tooth and 44 tooth pulleys were used to achieve a speed of 589 RPM. A 660 mm AT series timing belt was selected for this purpose. Below, the assembly installed ready for testing (without the driver on board). Notice the "dummy" powerhouse on the port side of the transom. The steering system will be discussed later.



The shaft couplings were machined from 1018 plain carbon steel. The square receiver was machined to match both the motor output shaft and the lower unit input shaft.

A hole was bored into the other end of the coupler to accept the W1 tool steel (drill rod) shaft. The couplings were then pinned and brazed to each end of the shaft.

Since it was decided that the endurance propeller could not be manufactured from a single stock piece of aluminum, It was proposed the propeller could be constructed as an assembly with individual blades connected to a central hub.



After completing the endurance propeller design, to prove the G&M codes for the CNC program, the first blade was cut in Butter-board®.

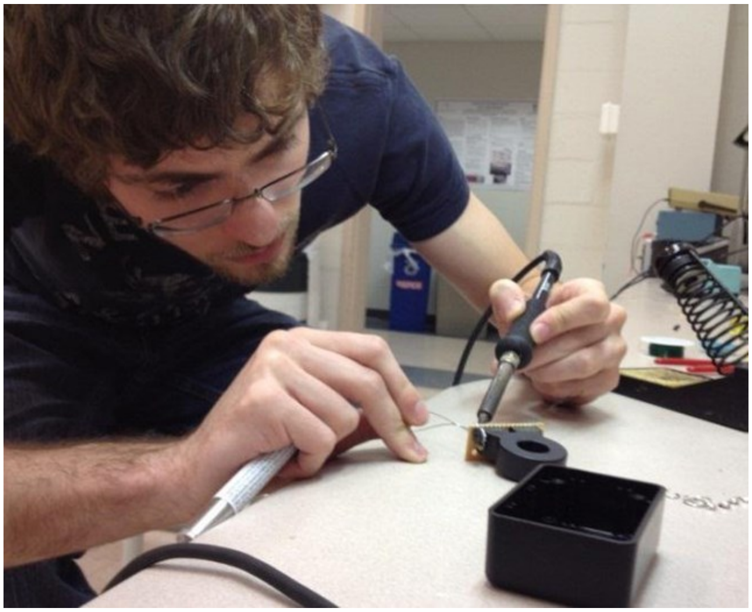
Indexing grooves were machined into the mounting hubs on each of the blades. The six bolts used to assemble the two halves of the center hub also served to index each blade into the proper orientation. These indexing/assembly bolts also served to resist the centrifugal forces exerted on the blades.

Final assembly of the endurance propeller..

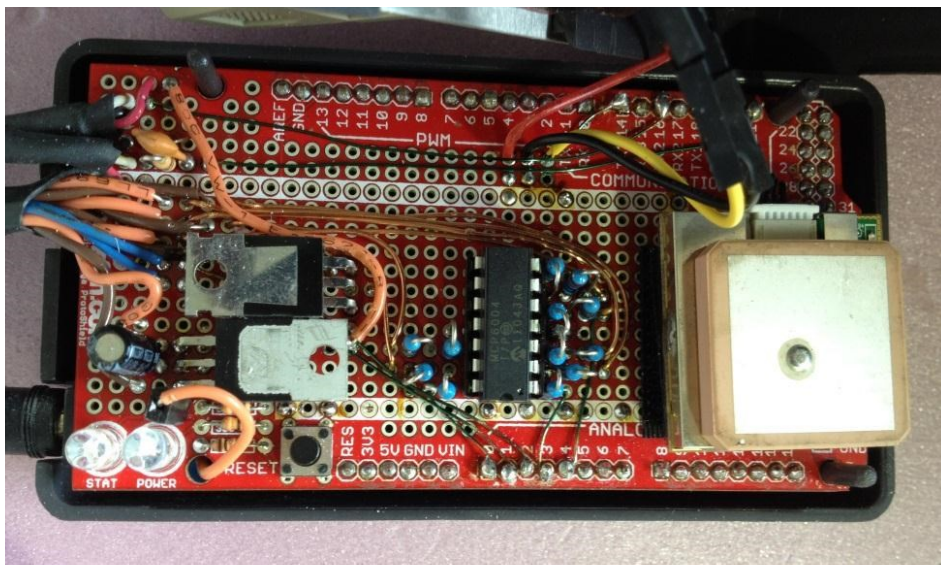
For the sprint configuration, the Lynch LEM-200-D216 motors used on the 2009 boat were re-used. Again, BreccoFlex belts and pulleys were selected in this case to increase the speed of the propellers up to 5375 RPM. A comparison of the sprint and endurance propellers is shown below.

The dual sprint outboard assemblies are shown at the left—mounted in this case to prove the action of the steering mechanism. Notice that the “dummy” powerhouse has been moved into the center endurance location. This design allows the same steering mechanism to be used, without modification, in both the dual-motor sprint and the single-motor endurance configurations.

The illustration at the left shows the extruded polystyrene “bunks” for stowing the sprint motors and one powerhouse/lower unit during an endurance event. Below shows the parts neatly stowed under the solar panel. The arrangement was later modified to refine the center of balance. These bunks also served to add floatation well beyond the 120% minimum requirements.



In order to collect data for the telemetry, Steve is soldering a perforated board and potentiometer to a current sensor. After calibration, the sensors were enclosed in waterproof containers before mounting in the boat. All electronics, except for the switches on the dashboard, the solar panels, and the RPM sensor are mounted on the endurance electrical panel shown on page 12.

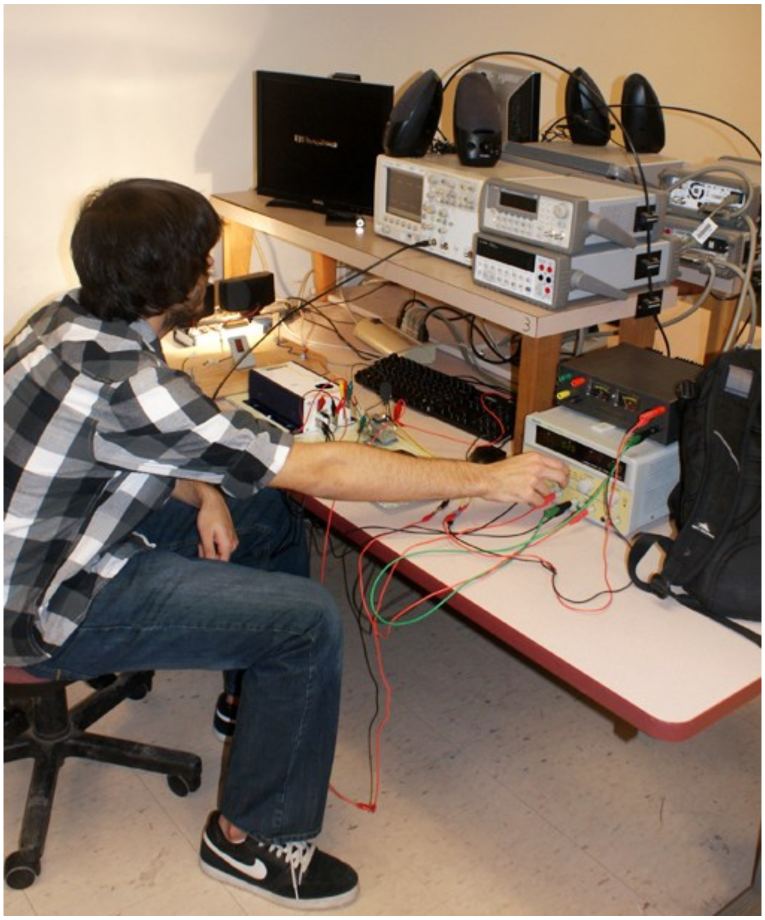



An Arduino Mega 2560 prototyping board was developed for the purpose of connecting all necessary circuitry to the Arduino.


The RF module that is used in the solar boat telemetry system is the MaxStream XStream-PKG-R 900MHz Stand-Alone Radio Modem. This unit transmits the data to the team on shore.

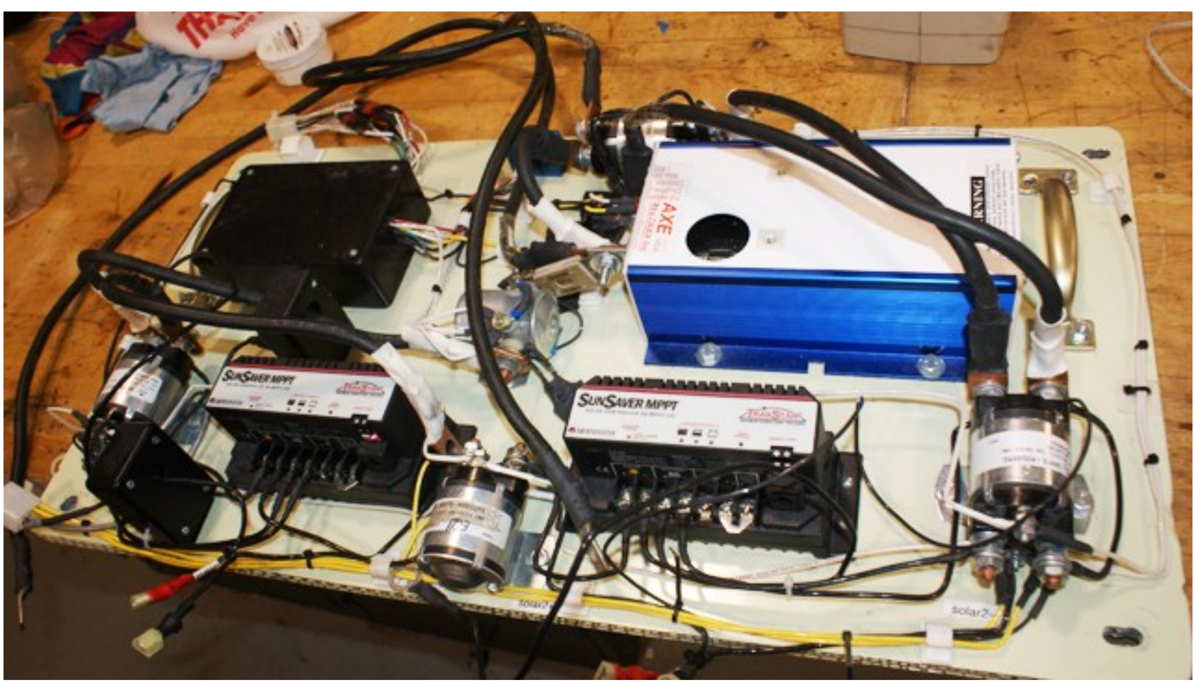
A Serial Adapter was all that was needed to connect the Radio Modem to the Lap Top computer on shore. Although the XStream transceiver  has a dipole antenna which serves well for the on-board leg of the data communication loop, the on-shore unit took advantage of a larger antenna mounted to an enclosure containing the transceiver and battery.

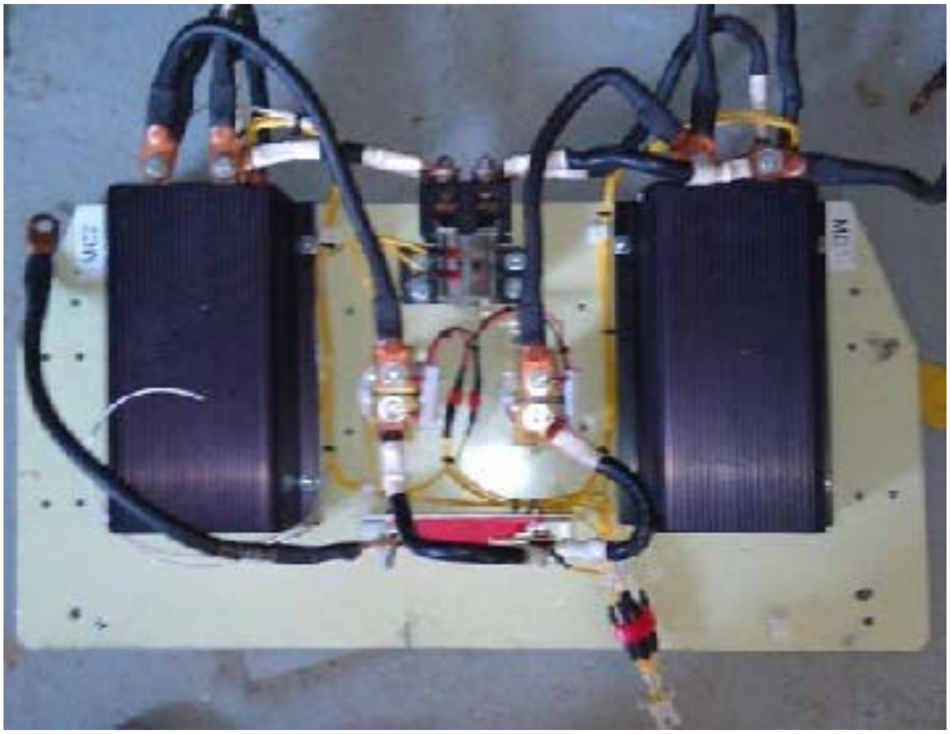

With the aid of Photoshop (to avoid screen glare), the “LabVIEW Virtual Instrument Panel” screen that Steve viewed on shore is shown at the left.



Here Glenn is designing the “Smart Controller Board” to provide the signal  to the AXE 4844 motor controller. The board shown below is an Arduino Protoshield, which will plug directly into an Arduino. The output of the Arduino powers the throttle, the smart motor control bypass switch, the RPM sensor, and the current sensor.

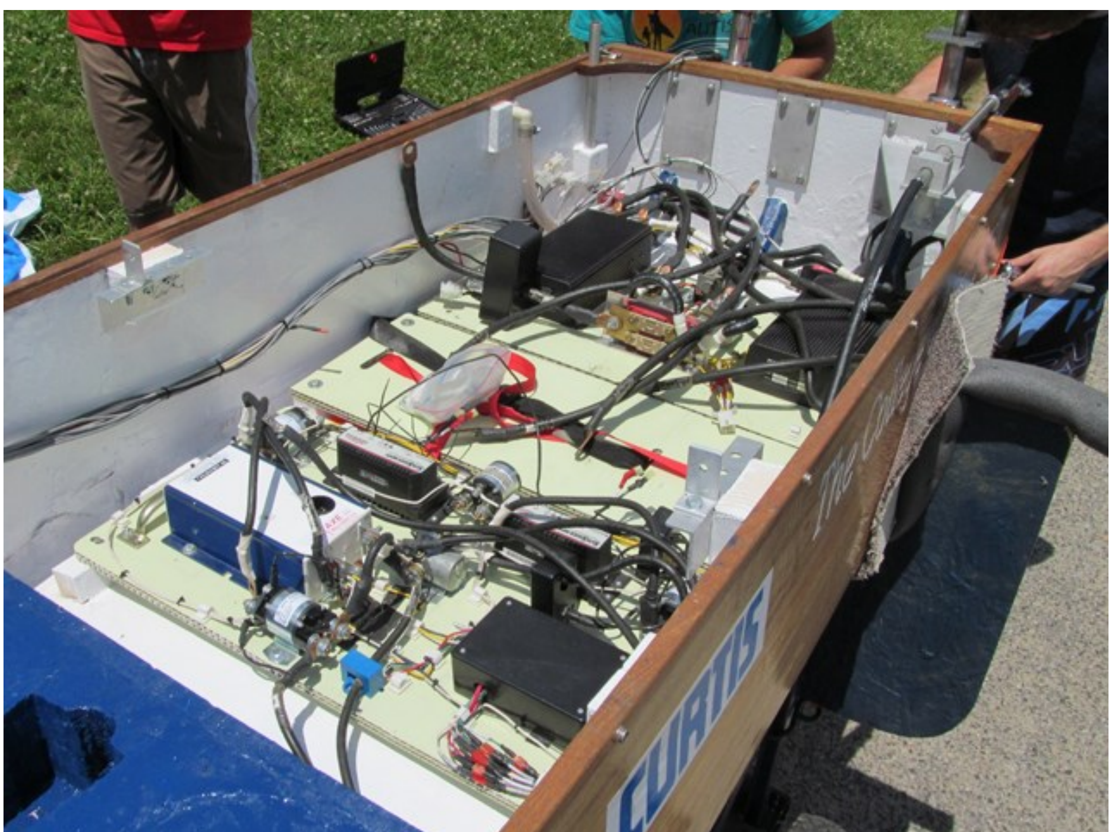
The illustration below shows the completed endurance electrical panel. All electronics, except for the switches on the dashboard, the solar panels, and the RPM sensor are mounted on this board. The batteries are mounted on a separate board in battery boxes.

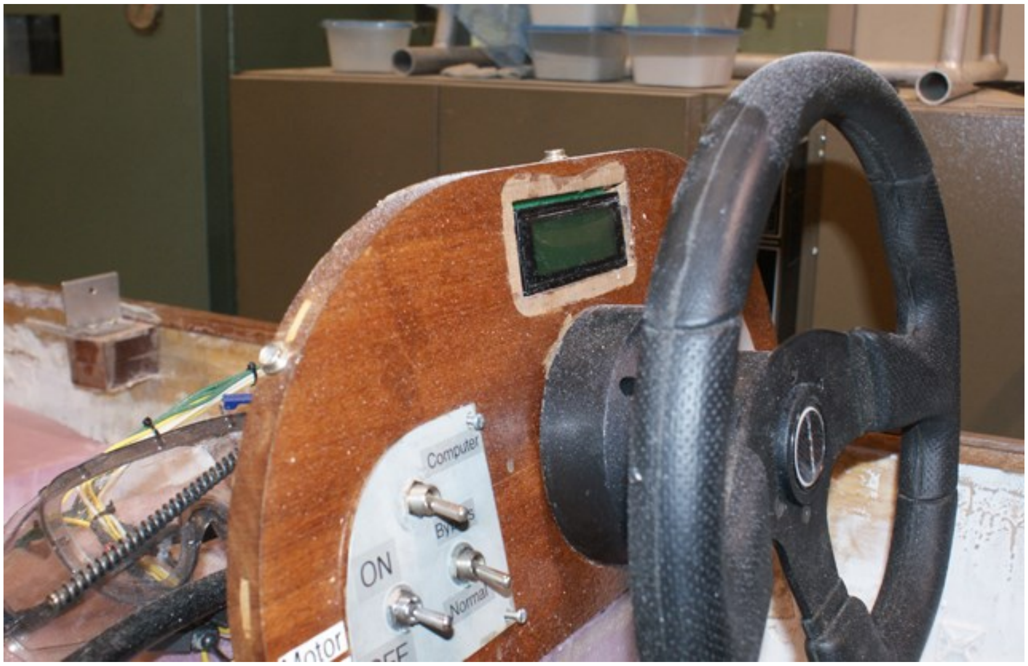




The illustration at the left shows an earlier version of the Sprint Electrical System Panel. Later the main contactor, the bypass contactors and sensors were added. The completed board is shown below installed in the boat.

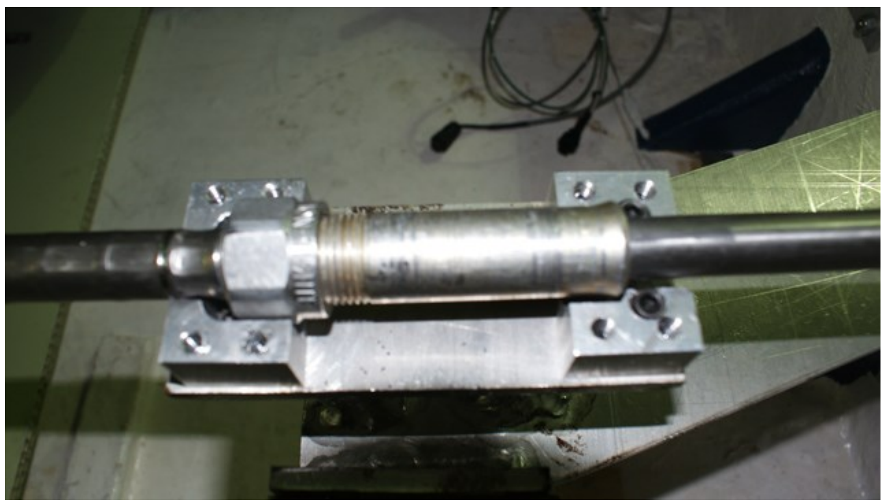
Below, both electrical system boards are installed in the boat. The Sprint Panel is aft, and the Endurance Panel is mounted forward. The panel board between the two will hold the batteries selected for the system in use at any given time. The electrical panels exchange positions depending on the event. This reduces the length (weight and resistance) of the high current cables needed to run the motors yet doesn't change the location of the center of balance.

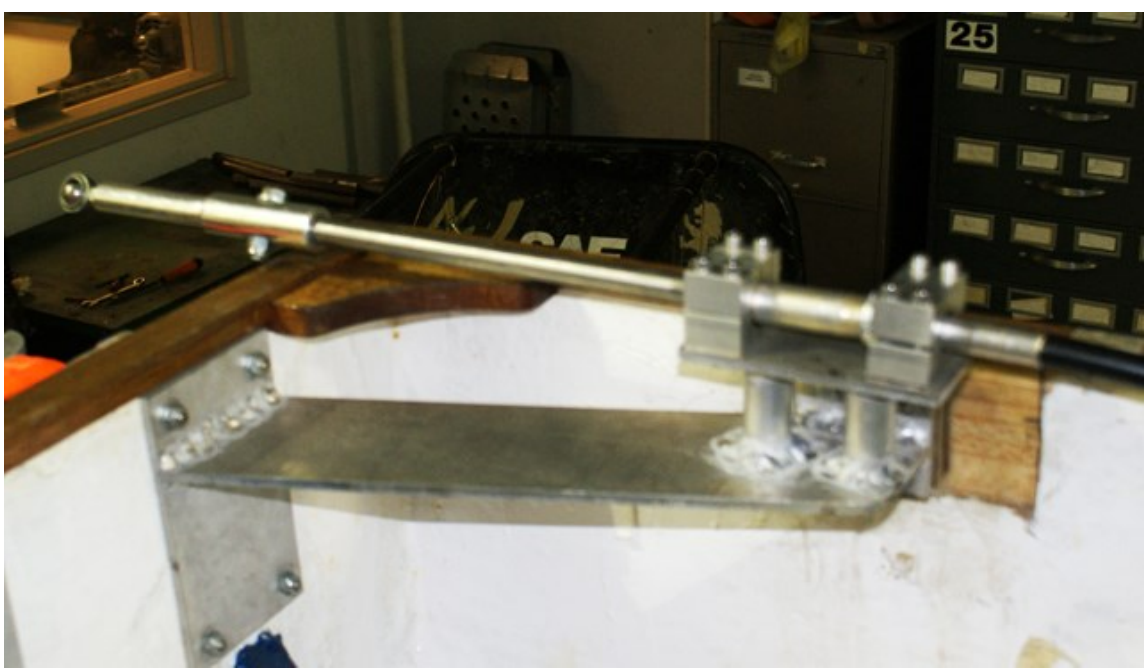


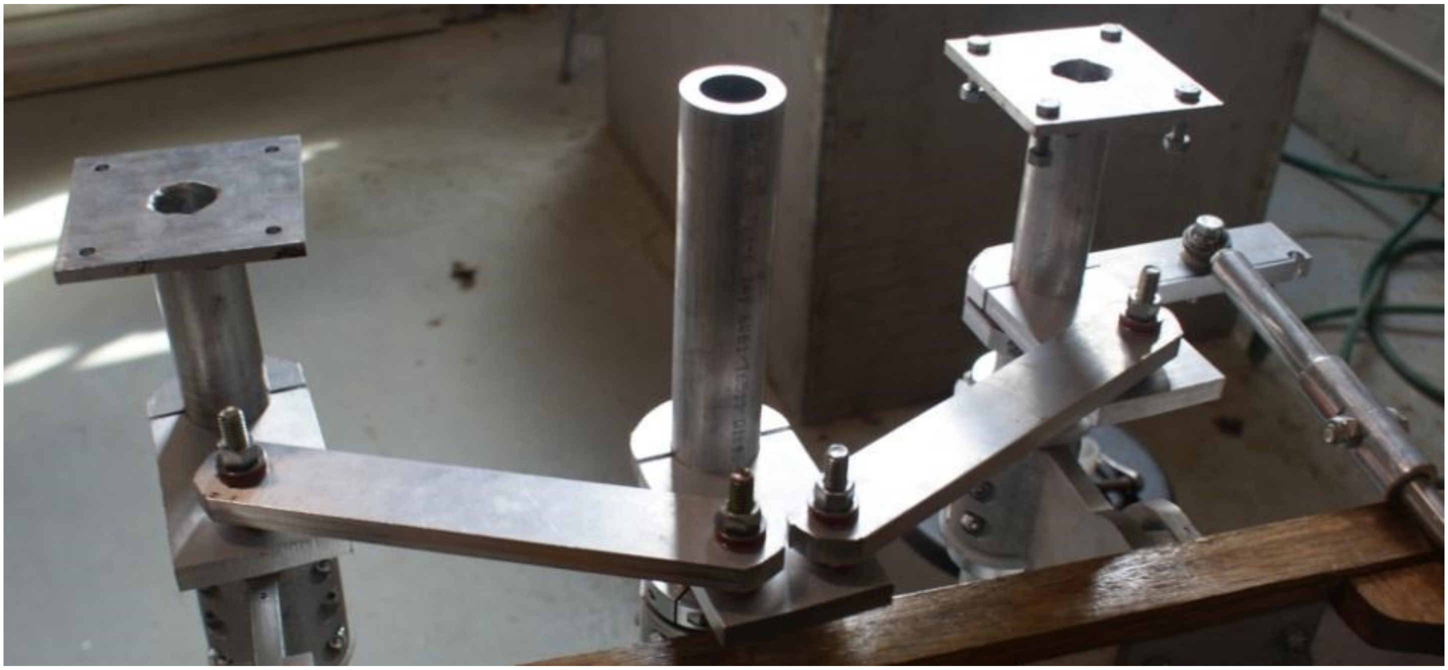



The helm featured a standard marine steering wheel and flex cable. The switch panel shown in this illustration went through several iterations during the development and testing periods.

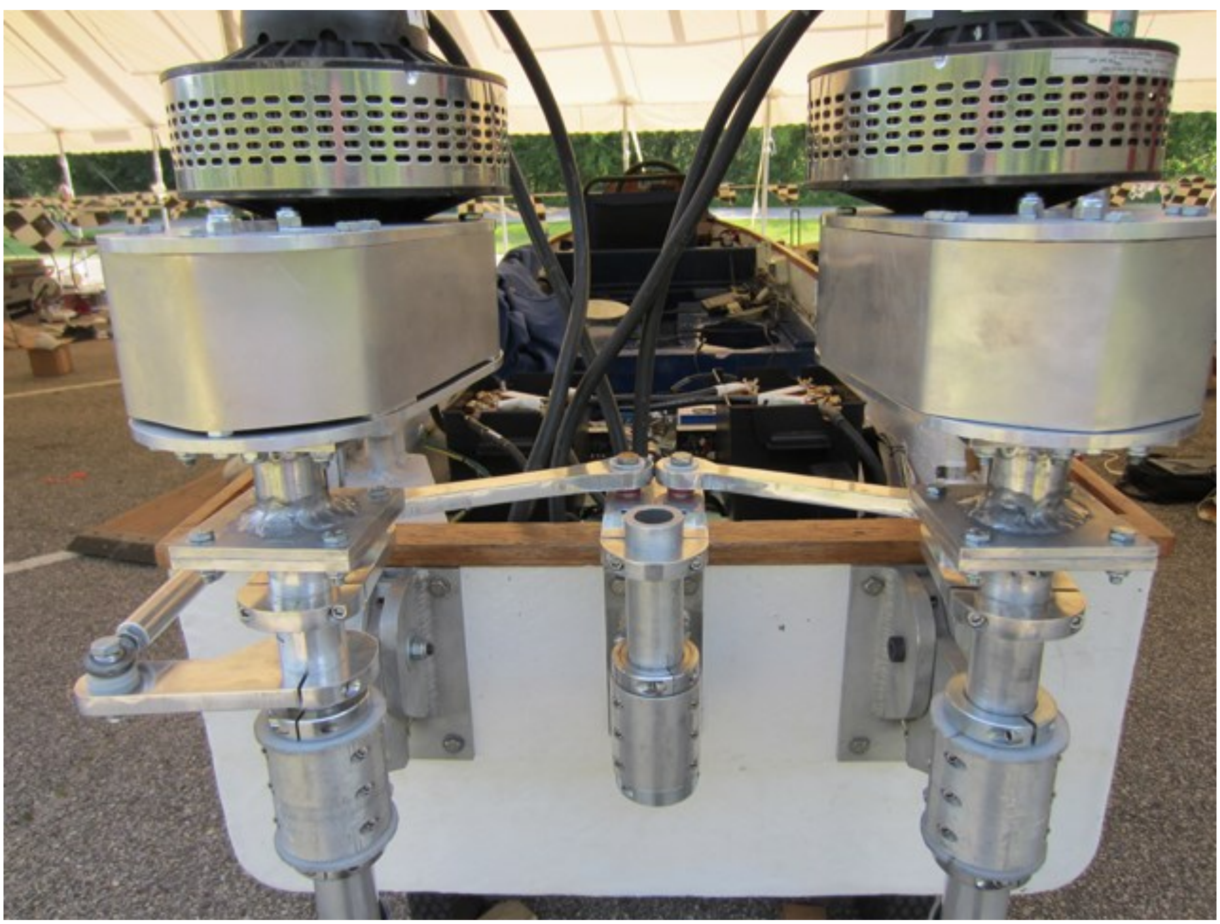
The Uflex Push/Pull Cable Steering System had to be anchored  to the hull in order to restrain the cable housing. One of the motor support plates on the transom served as a mounting point for this bracket. The other end of the bracket was simply a wood plate “fierglassed” to the starboard freeboard.







The final steering mechanism appears above. The exceptionally long dummy power house in the center was left this length to allow for last minute adjustments to the depth of the outboard units. The final assembly of the dual sprint outboards is shown below.




After the very long drive to Cedar Falls IA, we arrived at the George Wyth State Park the venue for the Solar Splash Event. Unloading the boat and unpacking the parts was the first order of business.

The Electrical Power Panels, the motors, the Power Houses and Lower units, and especially the Solar Panels all made the trip in fine shape. After being assigned our paddock space and boat number, our display area had to be set up and the boat readied for technical inspections.


David Luneau from the University of Arkansas provided the Electrical Technical Inspection as Steve S. and Glenn the electrical engineers answer questions. Below, waiting for  the mechanical inspection, Steve V, Chris, and Patrick watch the proceedings.


Steve V., Chris, and Patrick, the mechanical engineers on the project, respond to questions posed by the Mechanical Systems Technical Inspector Richard Burat, a design engineer from Portsmouth ME.  Richard and I have worked together with mechanical inspections several times in past years, and it was good to catch up after our not being here for the past two years.

With the endurance motor and propeller installed, and all technical inspections successfully completed, it was time to launch for first on-the-water qualifying events.

The first qualifying event  was the course designed to show that the boat could maneuver through a complex course at moderate speeds with the solar array installed.

Following a dreadful “hole-shot” in the first sprint event, we were able to redeem ourselves in the second and third heats of the event. The seeding worked out that we were matched against the only two other “wood boats” at the competition for the second heat. We were eventually ranked forth in the sprint competition.

Because of the weather, the two endurance events were run on Sunday. These are much more relaxed events because they are based on energy management.  How far can the boat go in two hours using just the energy from the sun, and the solar energy stored in lead-acid batteries of a restricted weight? Steve V. drove both endurance events. He is in constant contact with Steve S. who is monitoring telemetry from the boat on-shore.


The team was obviously thrilled with their overall fourth place finish, but were also very proud of receiving the Outstanding Hull Design Award, and the Outstanding Workmanship Award. Our Third place in both the Slalom Event and in the Technical Report judging helped in attaining the fourth place overall finish, but it also helped that we finished just outside the top three rankings in several other events.


Overall a good effort after an absence from the competition for the past two years. The feeling of the team, and especially next year's team, is that we must break away from this long narrow compromise hull design to which many teams are turning. This hull was designed and fabricated by the 2009 team; met with reasonable success that year, and sat dormant for the next two years. There must be design alternatives out there that will better handle the new rules of the competition. Everyone is looking forward to a drastic change in design approach for 2013. We now have a year to get this done. We will see everyone in Iowa for the 2013 event.