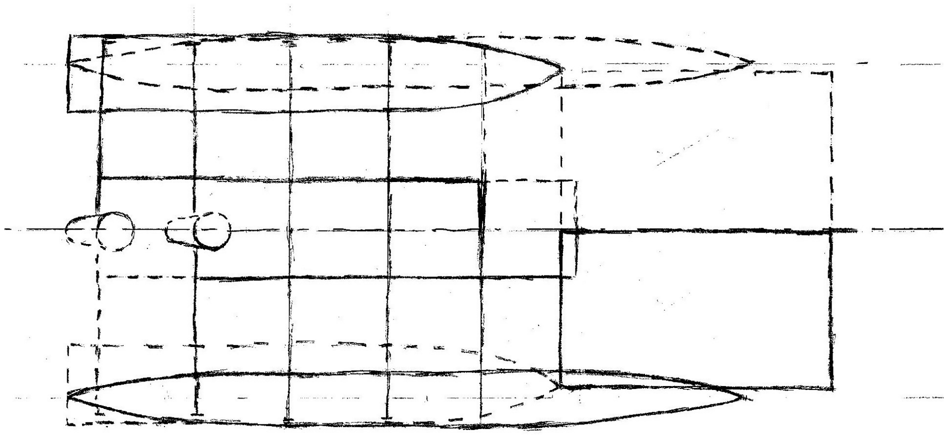
The College of New Jersey Engineering

Solar Electric Boat Project 2013

The team in the early planning stages. From left to right; Dr. Norm Asper, Professor Emeritus, mechanical engineering & technical advisor; Dr. Anthony Deese, Asst. Professor, electrical/ computer engineering advisor; Manthan Kothari, senior mechanical engineer, propeller designer and fabricator; Kyle Orr, senior mechanical engineer, steering designer and fabricator; Brian Graham, senior mechanical Engineer, hull designer and lead fabricator; Thomas Burns (TJ), senior mechanical engineer, team captain and team manager, designer and fabricator of drive systems; and (back to camera) Dr. Karen Yan, Assoc. Professor, mechanical engineering advisor. Dr. Yan left for a sabbatical in China during the spring and summer sessions. Missing from the photo is Prof. Bijan Sepahpour, Professor and Chair of Mechanical Engineering. Also missing from photo is Tyler Wardlow, the senior computer engineer responsible for the telemetry and power systems. Late in the spring semester, Mr. Wardlow was replaced by Mike Bauer, a mechanical engineer with extensive electrical and computer experience.



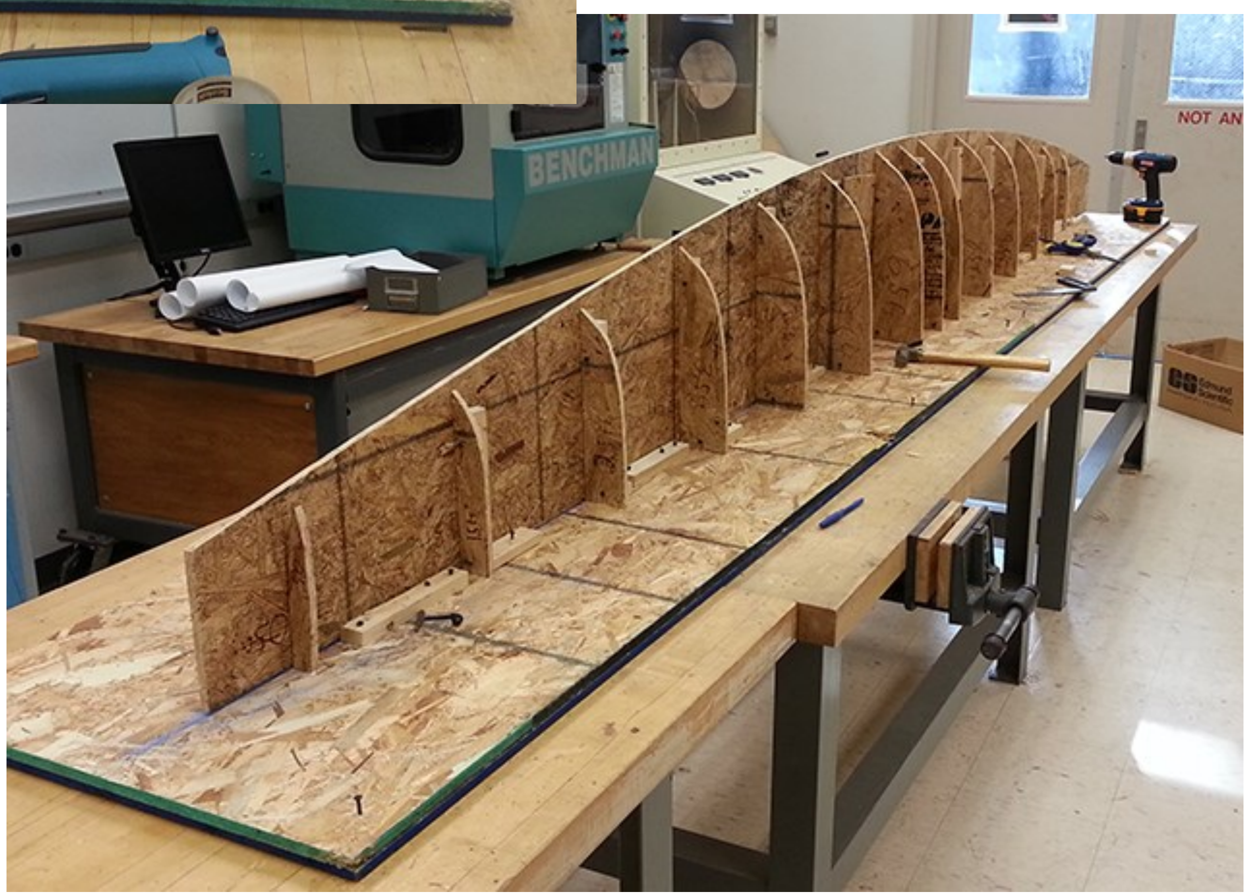
The team accepted Brian’s radical new hull design concept which involved building four (4) hulls. Two planning hulls and two displacement hulls. Each planning hull would be mounted upside down on a displacement hull. The two assemblies would then be attached on an “8020” Aluminum frame to form a catamaran. The sketch above shows two longitudinal frame members on each side of the center line. These members will support the seating, steering and power units. Also shown are the four (4) lateral frame members that are attached to each set of double hulls. To achieve an appropriate center of floatation for the two (sprint and endurance) configurations and to provide room for the solar array, it would be necessary to move the frame rearward 24 inches for the planning/sprint hull and then 24 inches forward for the displacement/endurance configuration. These two configurations are shown on the sketch above and below the horizontal centerline. Above the center line the frame is mounted (object lines) to the planning hull mounting points. The relative position of the displacement hull is shown in hidden lines. Below the horizontal center line, the frame is mounted to the displacement hull (object lines) and the relative position of the planning hull is shown in hidden lines. Kyle and TJ came up with one motor/transmission system for both configurations, and the computer/electrical engineers came up with a single motor control/energy management system that could also be used for both configurations.

For the endurance events the hulls were mounted, as in the photo at the right, and the solar array was added. In the high speed events, the hull units were turned upside down, the frame was moved back to the rearward mounting point, and the solar array was removed. This will become more obvious as we get further into the report.

Above, Kyle, Brian, and Manthan layout rib stations to be used in building the hull plugs. At the right, Manthan simply cuts out the 5/8 inch OSB stock for each rib.

For the planning hull, a keelson former was mounted to the hardback, and the rib formers were mounted to both the hardback and the keelson. Notice that the spacing of the rib formers needed to be much closer in the curved bow area than in the straight stern area. A chine former still needs to be mounted before the foam can be applied to the plug.

The same process was followed for the displacement hull, but with a rounded chine and freeboard, a chine former was unnecessary. It was simply necessary to remember that two (2) hulls had to be made from each of these plugs.



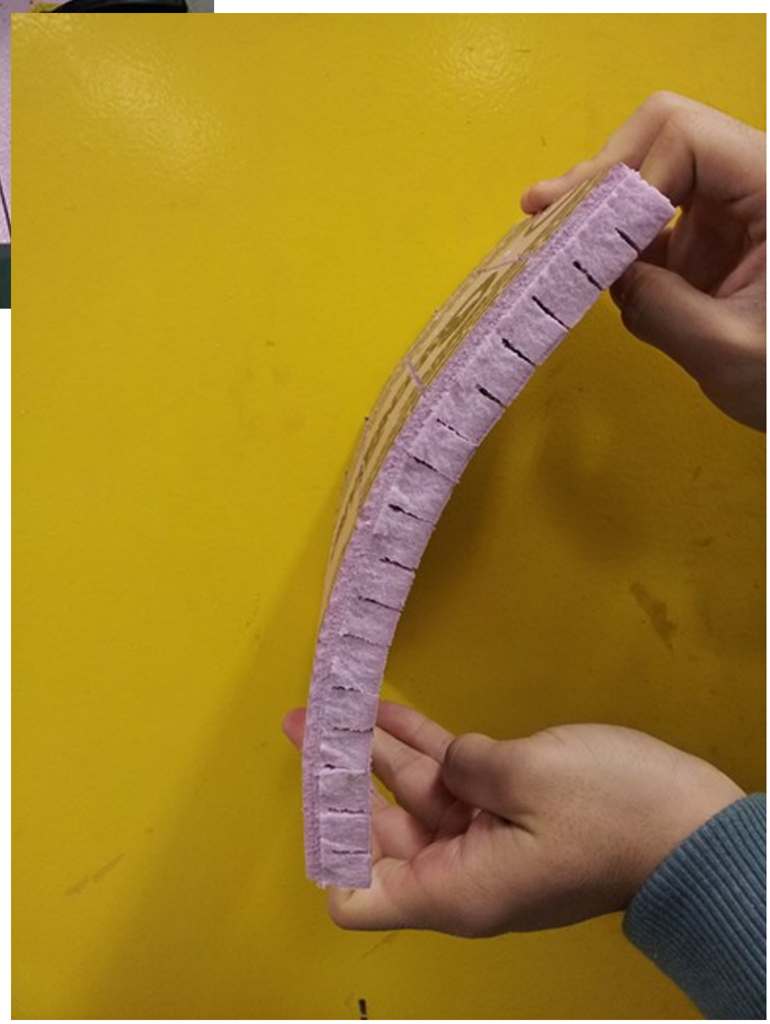
We started forming the 3/4 inch extruded polystyrene foam over the planning hull first because it would be easier with many more straight lines. The plug was protected with regular construction Visqueen to keep from gluing the foam to the plug. A Japanese fine cut pull saw was used for the initial shaping.

Epoxy resin was applied to all of the foam joints and the joints were held closed with straps, clamps, and weights. The aft section of the planning hull was much easier to hold in place than the curved bow section.

The whole process was repeated to construct two identical planning hulls.

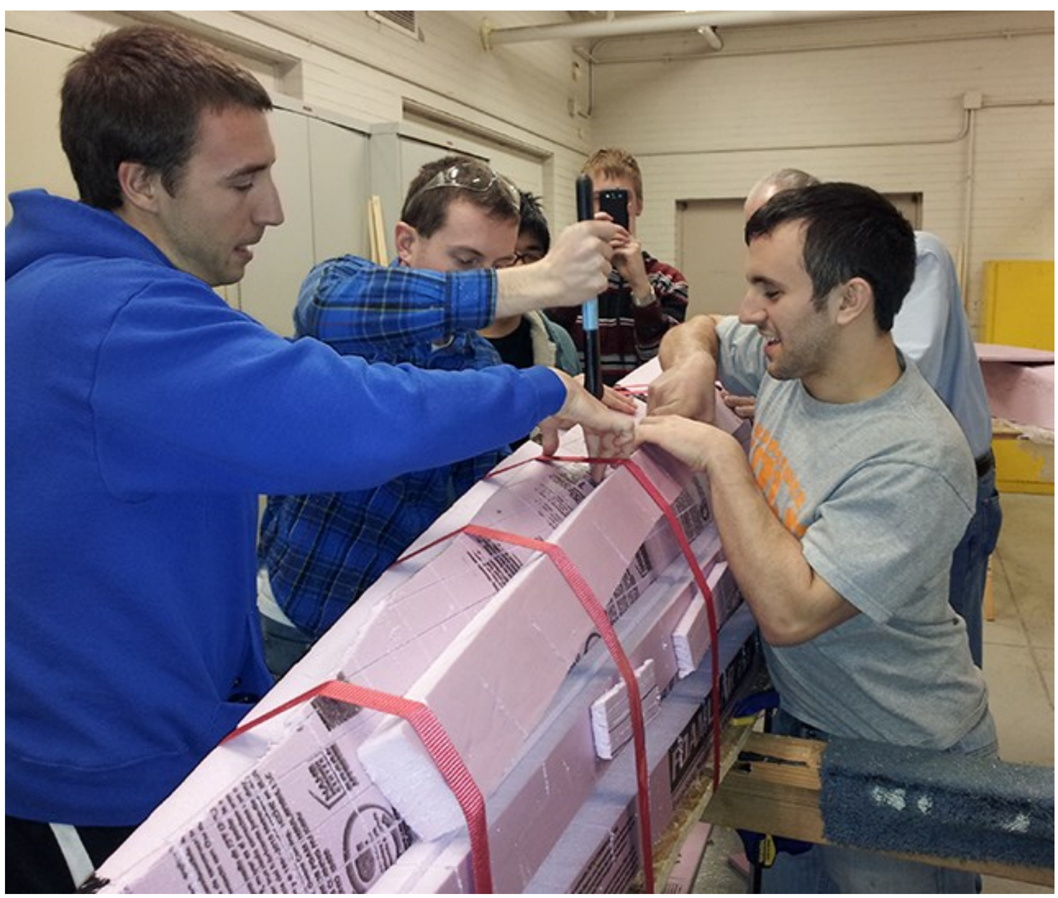
The process for covering the displacement hulls with the extruded polystyrene panels was much more difficult. The hull shape had no straight lines. With the curved freeboard and rounded bottom, the curves turned out to be tighter than the Styrofoam could be bent.

It became necessary to cut saw kerfs into the 3/4 inch Styrofoam to make the bends required by the displacement hull shape.



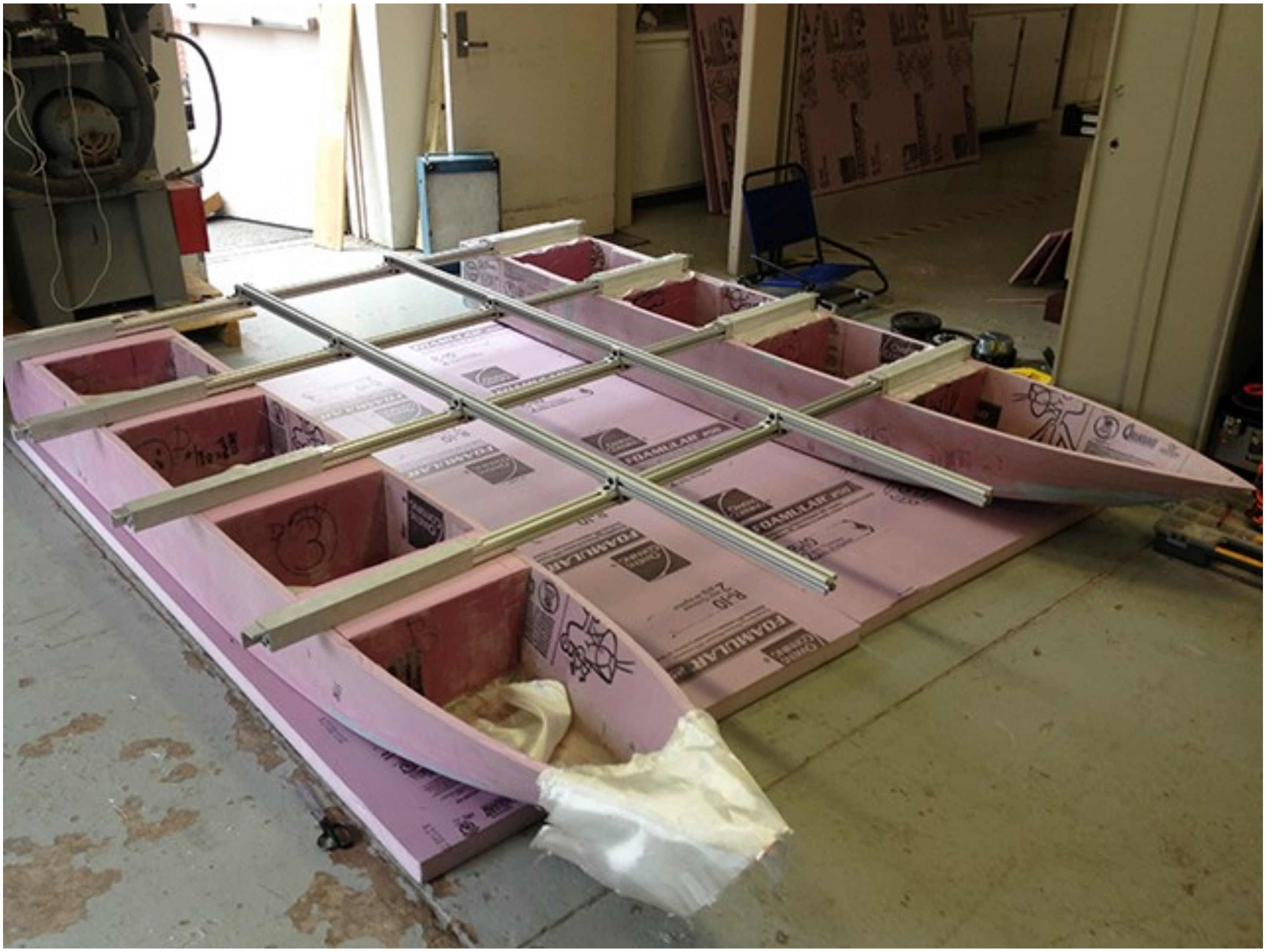
The team recognized that these kerfs would have to be filled with a light weight “microbloon” epoxy filler, and the whole hull would have to be sanded smooth, before the fiber-glass could be applied.

To glue the foam to the displacement hull plug, a complex assembly of straps and spacers was necessary to hold the Styrofoam in place. It was then necessary to find ways of filling the kerfed areas to keep the hull in shape when the straps were removed. Once all of the clamping material was removed, the remaining kerfs could be filled and sanded. Many volunteers were recruited to accomplish these tasks.



All four hulls were then fiber glassed on the outside. Two sprint/planning hulls and two endurance/displacement hulls.

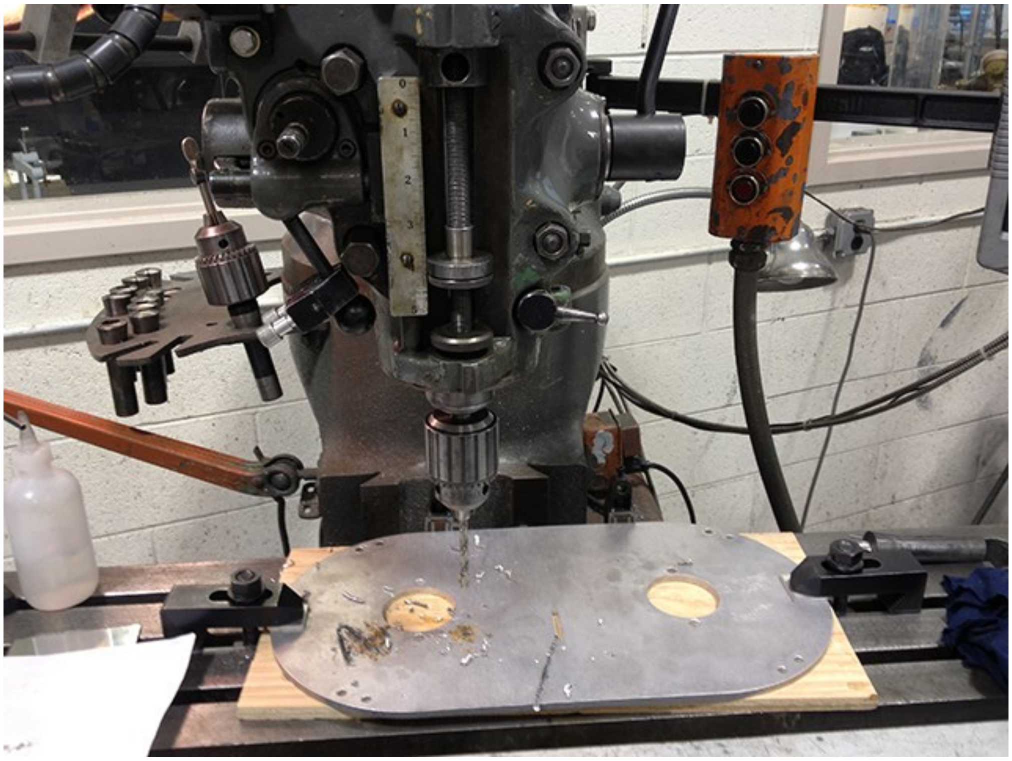
After all the hulls were glassed on the inside, bulkheads were glassed into place. These bulkheads not only gave lateral support to the hull, but provided mounting points for the "8020" lateral deck support tubes.



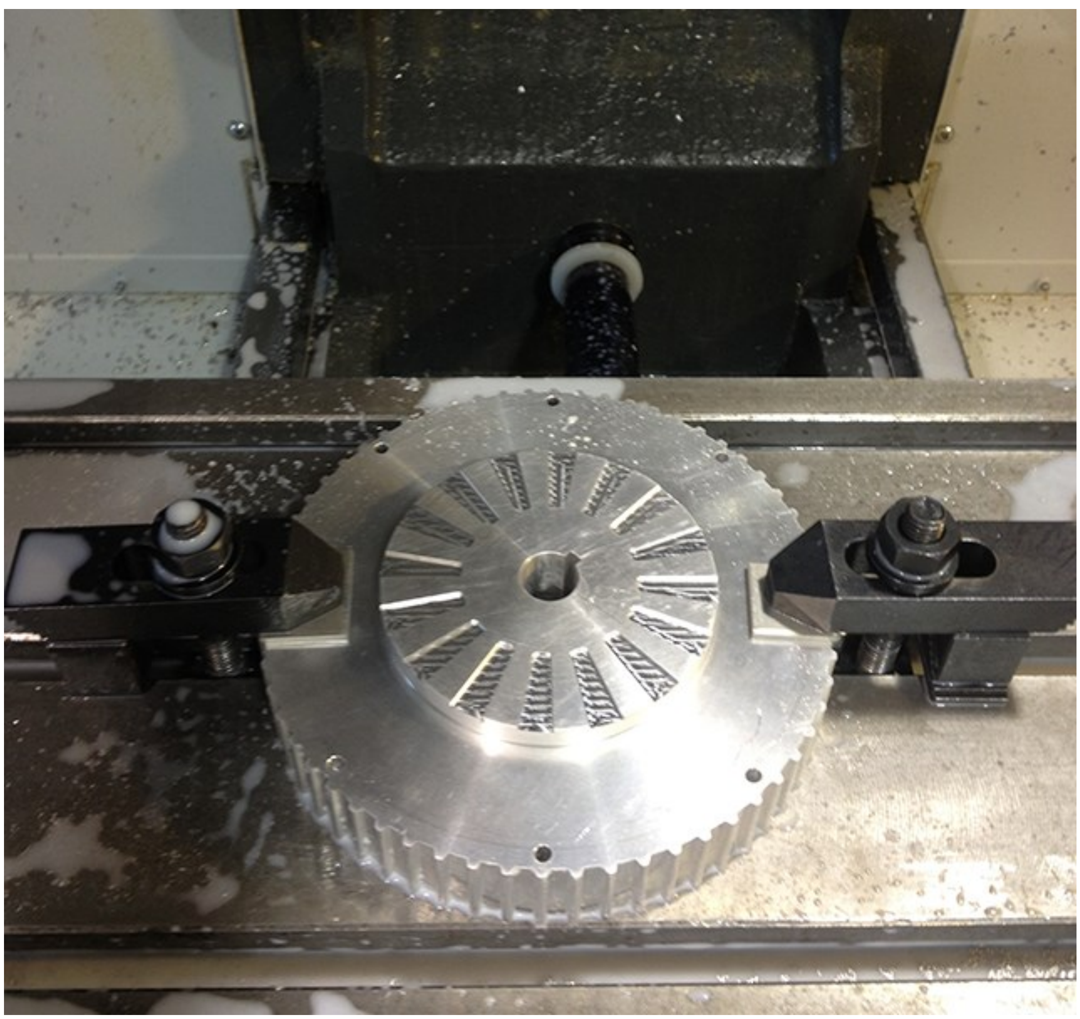
The photo above shows the “8020” deck frame “dry mounted” to the sprint hulls. Once located and marked, slots were cut into the bulkheads to accept the 6061 T6 Aluminum tubes that would serve as “receivers” for the “8020” decking tubes. At the right, obviously the launching dolly had to be modified to accept this new hull configuration.

When the hulls were finally fiber glassed together, the finished hull shape became very evident .

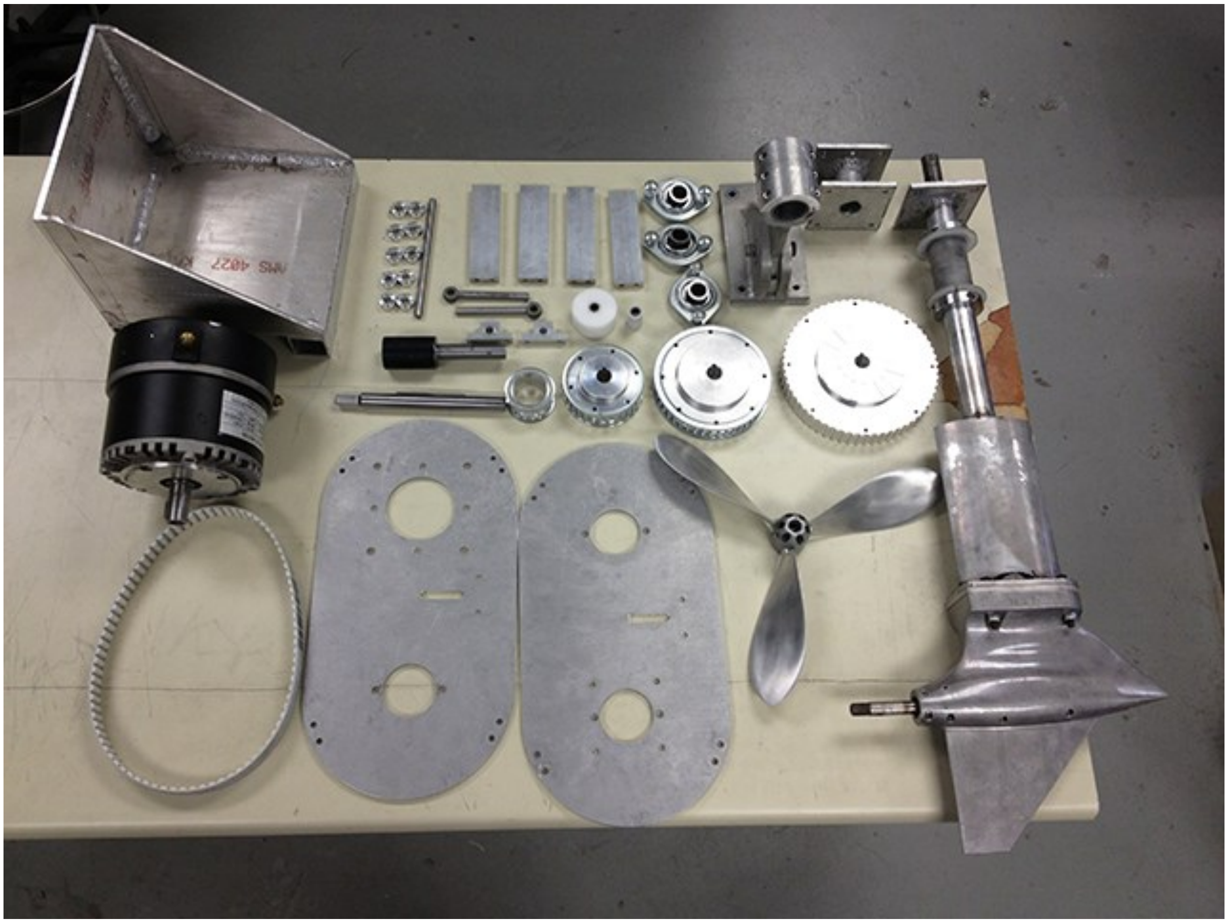
When it was time to mount the hulls to the aluminum frame, the launching dolly became an important part of the final assembly process. In these two photographs, the displacement hulls are down (as in the water), and the helm, seat, and power unit have been located.



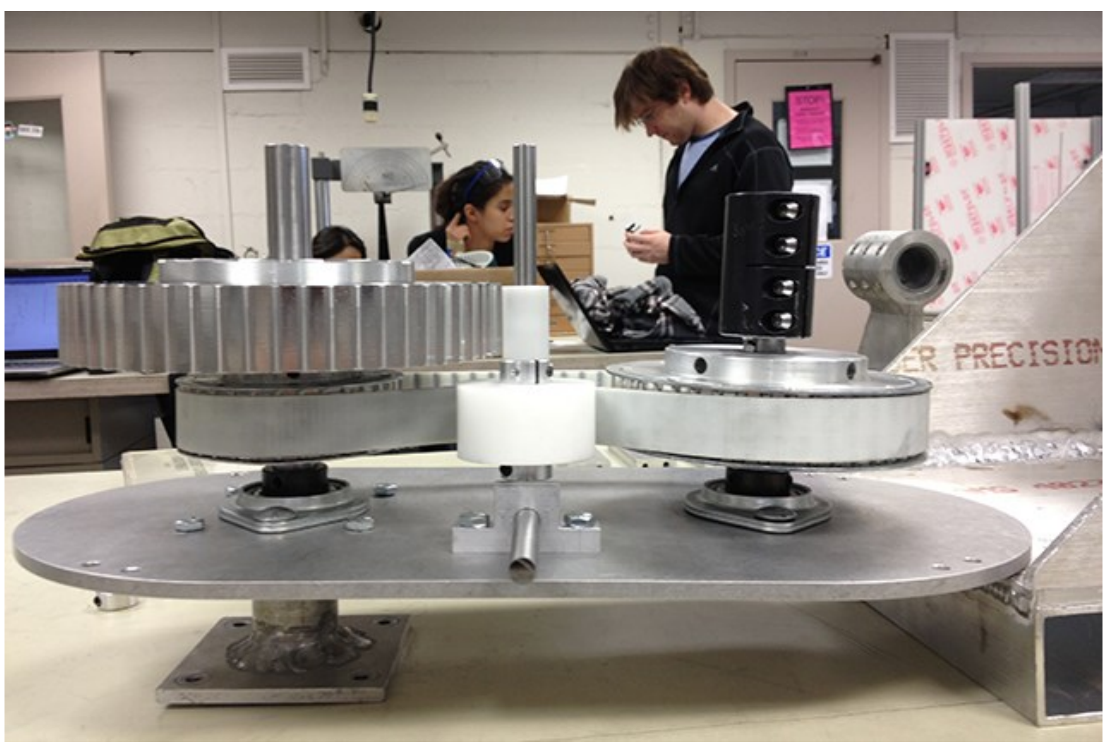
During this same period, TJ has been machining the power unit that he designed during the fall semester. The top photo shows one of the motor/transmission mounting plates being prepared on one of the 3 axis milling machines.

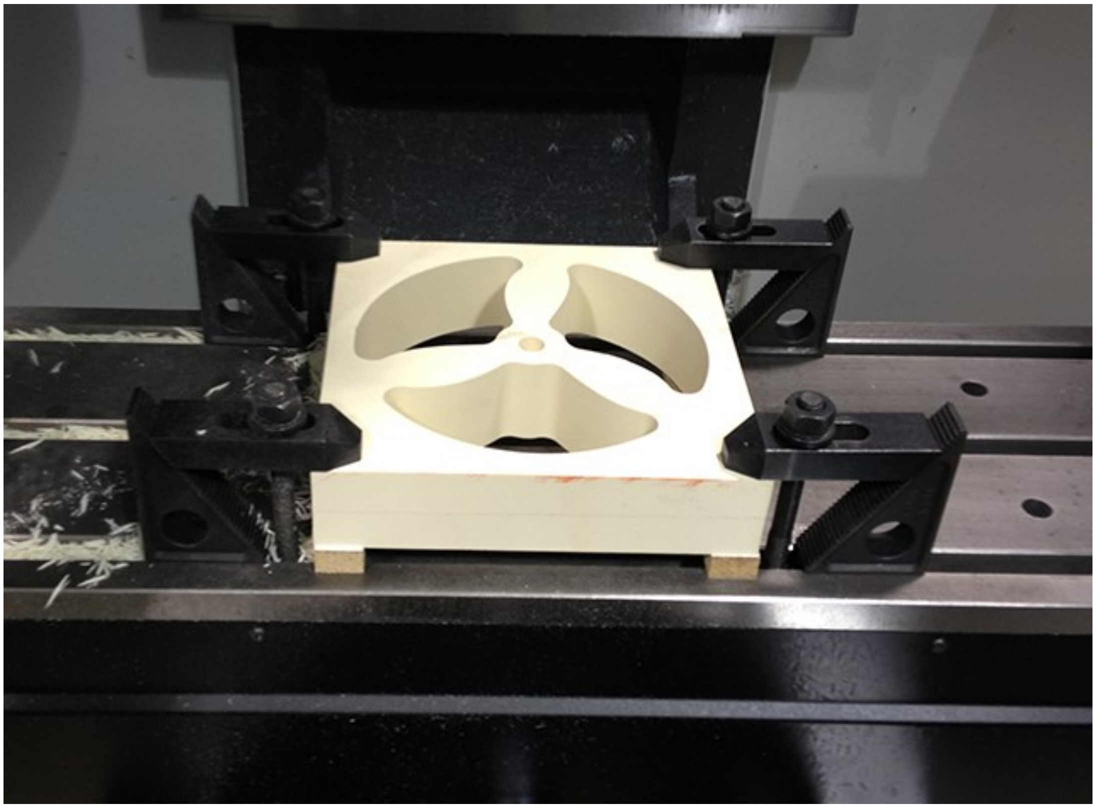


The lower photo shows the “BERKOflex” driven endurance pulley being machined on the 5 axis milling machine. Much of the back side of this pulley was also removed to reduce weight. Note the timing segments machined on the top of the pulley. An optical sensor will be mounted just above this pulley, and the lower machined segments will be painted black to become the RPM sensor.



As the machining of the parts came to a close, the assembly could begin. In the lower photograph, the driven pulleys are on the left with the endurance pulley on the top. The lower pulleys with the belt and idler in place are the sprint pulleys. Notice that there are two (2) idlers, one in the current sprint position, and one for the endurance gear ratio. The endurance drive pulley is yet to be installed.

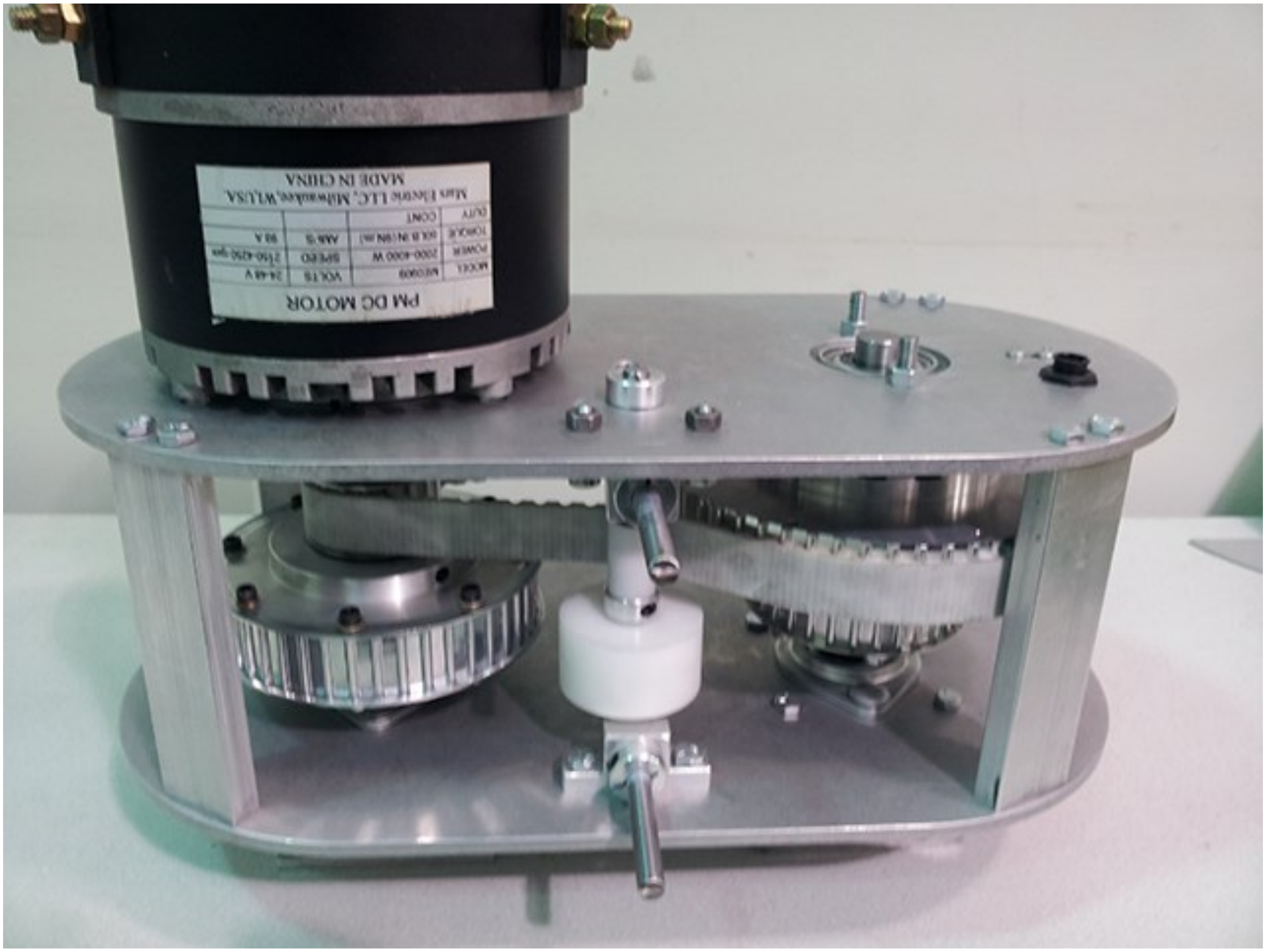




Manthan, in order to prove his CAM software development of the sprint propeller, first machined the propeller machine in “butterboard” material. Since our manufacturing lab no longer has casting capabilities, it became necessary to machine the propeller from a solid block of aluminum. Below, the block has been turned over for the second roughing pass.

The fore and aft profiles of the sprint propeller in the semi-finish cut and the finish cut condition can be seen above and below.

With the new GeoPeak Energy solar panels on hand, and the mounting brackets installed, the boat could be assembled for static waterline tests. Below, the displacement calculated center of flotation was very close. Only minor adjustments needed to be made in the location of equipment on the deck.



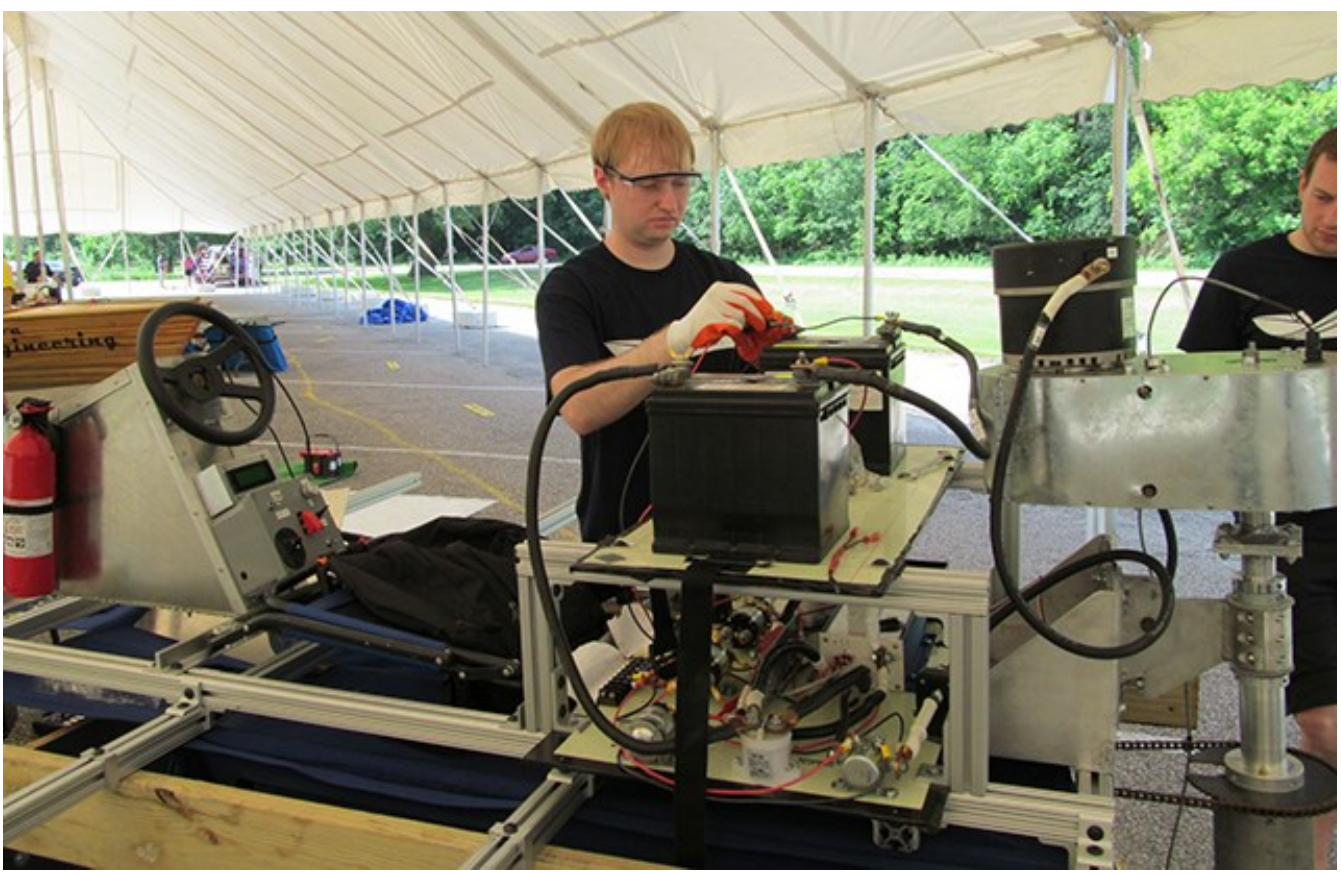
After an extend discussion with Manthan and his “right handed” propeller development, and a discussion with the motor manufacturer, TJ reversed the motor/transmission mounting plates so that the idler would be on the return side of the belt if the polarity of the motor was reversed. The motor manufacturer indicated that there would be no reduction in motor output. This photo shows the belt on the upper pulleys with the endurance idler in place. To change to the sprint configuration, the idler will be loosened and the belt will slide down to the lower pulleys where the larger idler pulley can take up the return slack. An elegant solution to the problem.

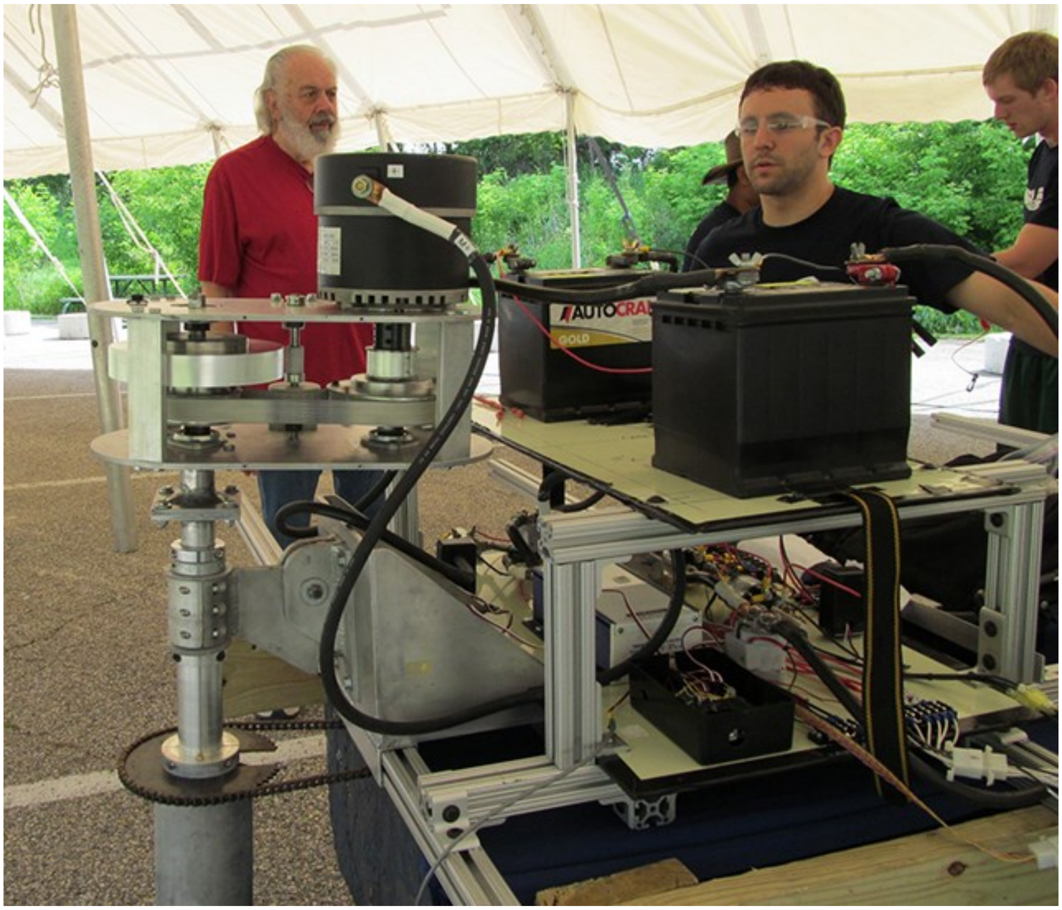
The changeover to the sprint configuration also confirmed the need for the major change in center of flotation. Not only did the deck need to be moved back 24 inches, but everything on the deck would also have to be moved back an additional 24 inches. This required a new position for the batteries, the motor control equipment, the seat, and the entire helm and steering. Luckily, the use of the 8020 framework for the deck, provided infinite adjustment for all of the parts mounted on the deck. Another elegant solution.

After sixteen hours of driving (two 8 hour days by college rule) from The College of New Jersey to the University of Northern Iowa, we finally arrived at George Wyth State Park. This is the third year that Solar Splash has been held at this Iowa venue, and hosted by the University of Northern Iowa. This has been an excellent venue, only a short drive from campus, and the university has been an excellent host.

While the team begins setting up their area in the paddock, I find time to renew old friendships. On the right is David Shaw, the advisor from Geneva College in PA. On the left is Dr. Jeff Morehouse from the Mechanical Engineering Dept. at the University of South Carolina. Jeff has been a long time supporter and participant in Solar Splash, and with the untimely death of George Ettenheim (the event founder and original organizer), Jeff took over as the event director.

Below, Mike makes final preparations for the mechanical technical inspections. The deck is now set up in the sprint configuration. Mike was a fantastic last minute addition to the team filling the slot of the electrical/computer engineer called away by work responsibilities. While Mike is really a mechanical engineer, he has extensive knowledge and experience in electrical/computer engineering. He completely redeveloped the motor control system, the energy management system, and the telemetry system in three weeks.





Everything was unpacked from the truck, reassembled, and thoroughly tested. The paddock area behind us was quite empty as many boats had not yet checked in. That made it a good time for the team to register — publicity release forms, insurance forms, ID badges, meal tickets, etc.

Richard Burat, a design engineer from Portsmouth ME, has been doing most of the mechanical technical inspections for a number of years. Here, TJ explains the motor and steering setup. Below, everyone gets involved in explaining the hull designs and the various configurations.

During the electrical technical inspection, Mike answers questions posed by David Luneau. David is the Solar Splash Technical Manager, and has also provided the electrical inspections for a number of years. David is from the University of Arkansas.

There were a seemingly endless stream of judges stopping by to look at all aspects of the boat. There were also members of the public and members of other teams who wanted to stop and talk about the boat. Whenever the boat was in the paddock area, it was always necessary that some team members were there to talk about the project.

The judging also included our display poster - - - and there was always time for lunch.

In preparation for the on-the-water events, the boat had to be assembled into the proper configuration. Because of the limited space within the paddock area tent, it was easier to assemble the hulls to the deck by moving the launching dolly outside. Above, the starboard hulls are slid onto the lateral 8020 decking tubing. Once in place, a collar with a “T Bolt” was slid into place to space the hulls correctly from the deck. On the outer end of the lateral tube, a collar with a through bolt (at the right) held the hulls in place.

Since the next event required the endurance configuration, the solar panels with their peak power trackers had to be installed—only five (5) bolts were necessary to hold the assembly in place. Then the solar array was connected to the power management system and the batteries.

The boat was then brought up to the “On Deck” position to be launched as soon as the previous boat was out of the way. This is when Mike would set up the telemetry monitoring system. Mike and the team on shore could see exactly what the driver was seeing on the helm monitor. The team was always in voice contact with the driver via a radio system.

The rest of the team had to be involved in the launching process. This required at least one member to be in the water guiding the boat to the dock where the driver/pilot could board.

Lauri Dann (in the red shirt) has served as the launch master for several years. Above, she actually rechecks each boat at each launch to assure that it still meets the technical and safety requirements for the event. In this case, the above photo shows one of the initial tests to assure that the boat does not have excessive healing. The bag of stones is draped over the freeboard, and the amount of tilt is measured with a protractor level mounted on the deck. Our boat's heel was 0 degrees. Below, Jeff the event director (also in the red shirt) serves as the official starter.

The qualifying and slalom events were held on Thursday afternoon and Friday morning. With threatening weather (a hurricane watch and expected flash flooding) the endurance event was moved to Friday afternoon.

Even with threatening weather and little sun, the entire first heat of the endurance event was completed. As weather reports got more ominous, the event organizers decided to run at least one heat of the sprint races in the evening. This way, every boat would have a chance to compete at least once in every event, even if the flash floods materialized over night.

As the evening skies got darker, the boats quickly changed over to the sprint configuration and staged for the sprint/drag race. The event organizers brought in pizza for everyone, so no one went completely hungry. Below we are staged at the highline with the beautiful boat from Tennessee, who beat us handily in this event.

These two photographs show us returning to the dock from the finish line, and loading the boat onto the dolly. As it turned out, this would be the final time that we would retrieve the boat from the lake at Wyth State Park. The predictions of flash flooding proved accurate.

We had become used to the exceptionally high water level in the lake, but as the evening wore on, the water level began to rise even further. As we left the park Friday evening, part of the access road was already under water. The park ranger indicated that by midnight they would be able to tell if we needed to completely evacuate the park. At about 12:30 the “calling tree”, that had been established at check-in, went into affect. Each team was notified that they had two hours to evacuate the park. When we arrived, the generator that had been supplying power to the paddock area had already been evacuated. Packing the truck would have to be done in the dark.

With light from several car headlights, all of the teams were able to get everything into their trucks and trailers. By 2:00 the paddock tent area had been cleared—even the trash had been cleaned up.

On Saturday, the 2013 Solar Splash was declared complete. It didn't take much to see that we couldn't get back to the Wyth Park Lake, and we were happy to have everything out. However, we now had no venue for the awards banquet.

During each of the previous event days, Hansen's Dairy had been providing free ice cream as a mid-afternoon break. The dairy also had a conference center on the farm that they offered for our awards ceremony. Since our lunch had already been contracted for, it was simply brought to the dairy and our ceremony was back on.

So once again we were eating. One of our goals for this year was to improve our endurance distance, and we did that. Unfortunately at the expense of our sprint times. We did however maintain our engineering design standing winning both the Outstanding Systems Award and the Outstanding Hull Design Award.

In the end we brought home our share of the trophies with a very unique boat that turned a lot of heads. I'm sure that many members of the public and even members of other teams who viewed this boat in the paddock area, or watched it perform on the water, did not realize that these five students completely designed and manufactured this entire boat in one year. Everything was designed and manufactured by these students "in house" - a phenomenal feat. I'm looking forward to the chance to do it again for 2014.