University at Buffalo
The State University of New York

Solar Splash: Technical Report

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EXECUTIVE SUMMARY

The University at Buffalo has a long history of competing in the Solar Splash Competition, going back to the early 2000's. After several consecutive entries, and hosting the competition the team graduated and the project was dropped. Last year the university entered the competition for the first time in over a decade. It was a great learning experience for everyone involved, and the team had great time. With the knowledge gained from previous competition and more assets, this year will be more result focused. After getting last place year, the main goal this year is to rank in the top half of the competition. Several major changes were made the boat that will help us at the event.

First, the old boat hull was completely scrapped and a wood-fabric hybrid hull will be used. This hull is a third of the weight of the hull used last year due to its unique utilization of sail cloth instead of solid material to reduce weight. The hull is also longer and thinner, which will help during the sprint race.

New solar panels that are twice as efficient and 1/5th of the weight as the previously used panels were acquired through an academic grant. Last year bulky residential panels were used on the boat. This year semi-flexible lightweight panels with 23.5% efficiency are utilized.

New marine batteries will replace the 7 year old batteries previously used. The team will utilize two different batteries for the endurance and sprint race. The endurance battery pack is deep cycle batteries while the sprint race pack will contain crank batteries that have high outputs.

A new inboard motor design is also utilized to reduce weight and friction caused by the drivetrain. Last year the outboard motor was one of the heaviest components on the boat. This new inboard allows the boat to hold the motor instead of adding a separate mount.

We expect to perform in each race: the slalom, endurance, and sprint race. As of this writing so in-water tests have been done so it is difficult to determine if we will perform stronger in one event over another. The one limiting component on the boat is the electric motor. It is over five years old and its efficiency is questionable. This is something we wish to address by next competition.

Overall, the team is very excited and confident due to the many improvements between competitions.

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I. OVERALL PROJECT OBJECTIVES

The main focus of this boat is to be more competitive in the 2017 competition than the 2016 entry. To accomplish this goal, several goals have been set. Our primary improvements were made in weight, technology, and in general knowledge.

First, this entry will be a remarkably low weight. This is accomplished by a hybrid hull comprised of wood, fiberglass and Dacron sail fabric. These materials all have high strength-weight ratios that allow for a low density hull.

Several high performance equipment was also acquired for this project that will attribute to the success of the project. Four new 120W solar panels were acquired, each highly efficient (23%) and extremely low weight (4.86 lbs. each). New set of batteries were another important acquisition for this project. These will allow for maximum utility, as they have never been used before. An inboard drive system was designed and implemented this year, to center the weight of the boat and increase stability.

As last year was our team's first entry, many lessons were learned. This new information will be utilized to better perform at the 2017 competition. There are many small details, too many to name in this report, that were picked up not only during the previous design and construction process but at the competition itself. This culmination of general knowledge allowed our team to take a better approach to this competition by being better informed. The team also plans to put more emphasis on the technical report and project visuals as these negatively affected our score in the past.

Overall, the team feels much more confident with a better hull, new equipment and the knowledge of the 2016 competition.

II. SOLAR SYSTEM

A. Design

Previously the team had used four 120 W Kyocera panels. These panels were designed for long-term use on a residential building, and therefore were robustly designed. They weigh just over 26 pounds each, for a total of about 104 pounds for the array. The current system consists of two units of two panels wired in series. These units are then wired in parallel with each other before feeding into the solar controller, a Blue Sky Solar Boost 3024i. This controller is capable of charging 12V and 24V battery packs.

There are many major issues with the team's current design of the solar array, many of which originate from how outdated it is. The main concern of the team this year was the weight of the watercraft. The old 104-pound array would easily make up a majority of this year’s weight due to the upgrade to a lighter hull. Another issue concerning the age of the panels, is that the efficiency is not competitive with new panels. In addition, an easier connection of wires from the panels to the solar boost would be helpful. Previously, all of the connections were made with ring lugs and bolts, which left exposed connections.

B. Analysis of Design Concepts

With one of our main goals being to shed weight this year, the team researched lighter and more efficient panels. A decision matrix was used to compare panels as seen below. Many of the panels still had the aluminum framing used for residential installation which is heavy. The few that were promising were the monocrystalline, semi flexible solar panels which stood out due to their low weight and efficiency.

The panels that were eventually chosen were the KingSolar 120W monocrystalline Semi Flexible panels. Each of these output 120 W of power and weigh just under 5 pounds each. This allowed the team to drop 95 lbs. from the boat just in the solar panels while increasing the efficiency from 14% to 23%. The panels can also be attached to the boat using aluminum L-beams across the boat and Velcro on the panels and beams. The Velcro will allow easy installation and disassembly of the panels.

The same configuration will be used where panel pairs are wired in series and then the series pairs are wired in parallel (Fig. 1). This allows double the voltage and current to go into the solar charger. All of the wiring was done using MC4 connectors which is the solar industry standard now. This allows for quick installation and removal of the entire array by via the simple plug connection.

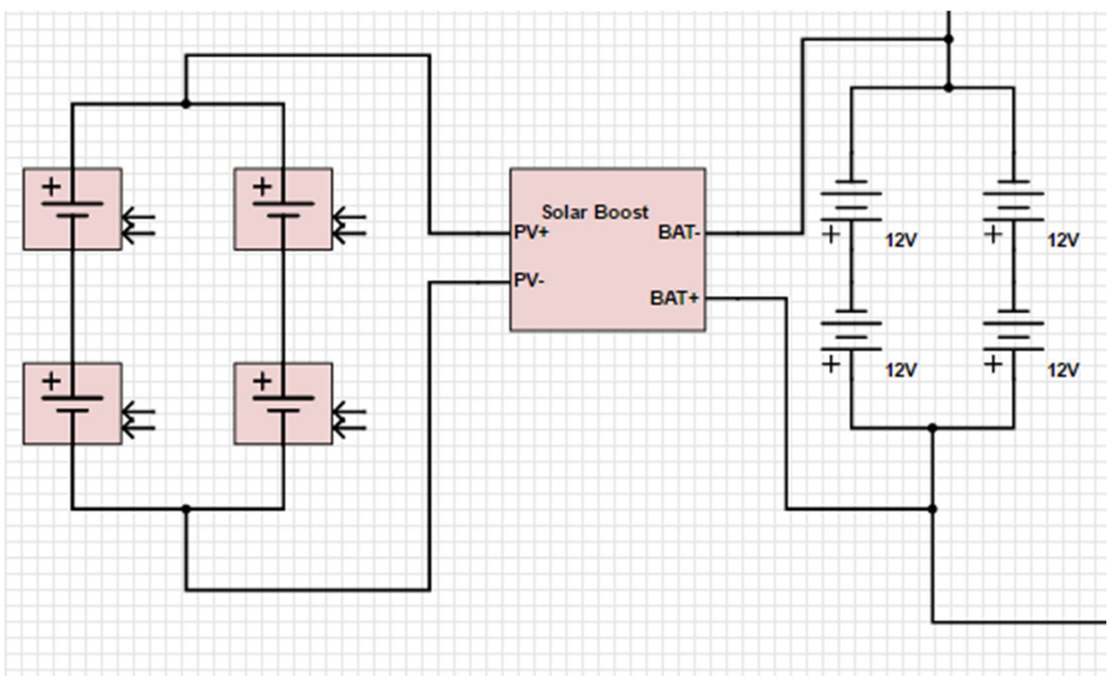


Fig. 1: Solar Configuration

Brand	Power (W)	Weight (lbs.)	Area (in²)	Cost (USD)	W/USD	W/(in²)	W/lb.	Efficiency	Type
Panasonic HIT	240	33.00	1953.1	$464.00	0.517	0.123	7.576	19%	Monocrystalline
Trina	240	43.00	2536.3	$223.00	1.076	0.095	5.581	14.66%	Polycrystalline
P-Maxx Series	120	5.00	1500.4	$394.00	0.305	0.080	24.019	-	-
ApolloFlex	120	4.00	1092.0	$240.00	0.500	0.110	30.000	22%	Monocrystalline
King Solar	120	4.83	977.3	$240.00	0.500	0.123	24.691	23%	Monocrystalline

Fig. 2: Solar Panel Decision Matrix

Several of the panels that were researched were put into a decision matrix (Fig. 2). They were compared by several quantities including weight, size, cost, power and efficiency. As seen above, the polycrystalline material is low cost for its power output but it really lacks in efficiency and is quite heavy. Above that is a more efficient monocrystalline version but it is large and heavy due to its aluminum frame. Also researched was the idea of building our own panels with singular cells. This is seen in the P-Maxx Series. The weight is low but the array would be quite large and costly to build ourselves. The idea of the team building the panels was out performed by the following two monocrystalline panels. These two were similar panels in almost every aspect and outperformed the other choices by quite a bit in most categories. The choice to go with the King Solar had to do with the fact that the vendor was easier to buy from through the University at Buffalo Student Association as well as the fact that the others were sold out. Also King Solar panels are slightly more efficient but a little heavier. This 0.83 pounds per panel will be negligible compared to the final weight of the boat though. This matrix helped to make the team's decision clear as to which panels should be purchased.

C. Design Testing and Evaluation

These panels will last for a few years, allowing future teams to use them and the MC4 connectors give the team the chance to easily change the configuration.

III. ELECTRONICS SYSTEM

A. Design

The design from last year is similar to the design from this year with a few changes that involved the batteries and solar panels. These changes are documented in the solar power and power electronics section.

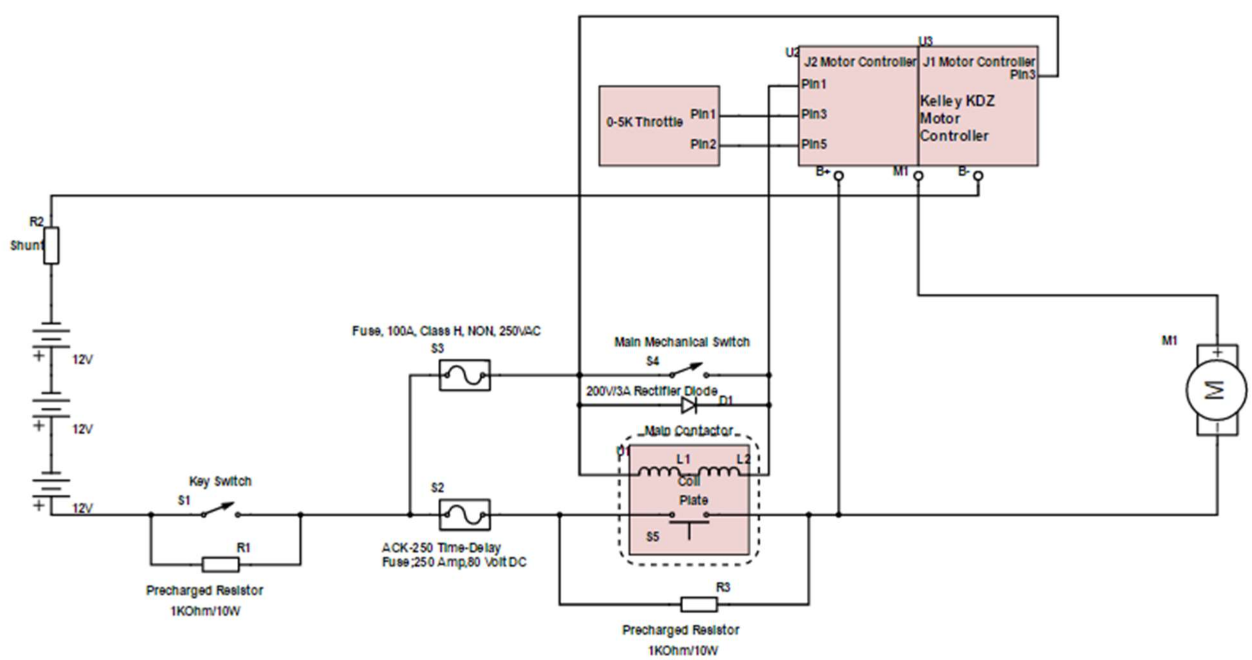


Fig. 3: Main Circuit Diagram

Most of the issues that arose from the electrical system last year had to do with poor labeling and organization of cabling as can be seen in Fig. 4. There was also an issue with a malfunctioning main contactor, due to low voltages. A low budget and short time constraints were responsible for most of last year's issues. The throttle was also an issue, with it being difficult to set at a specified position and have it remain there.

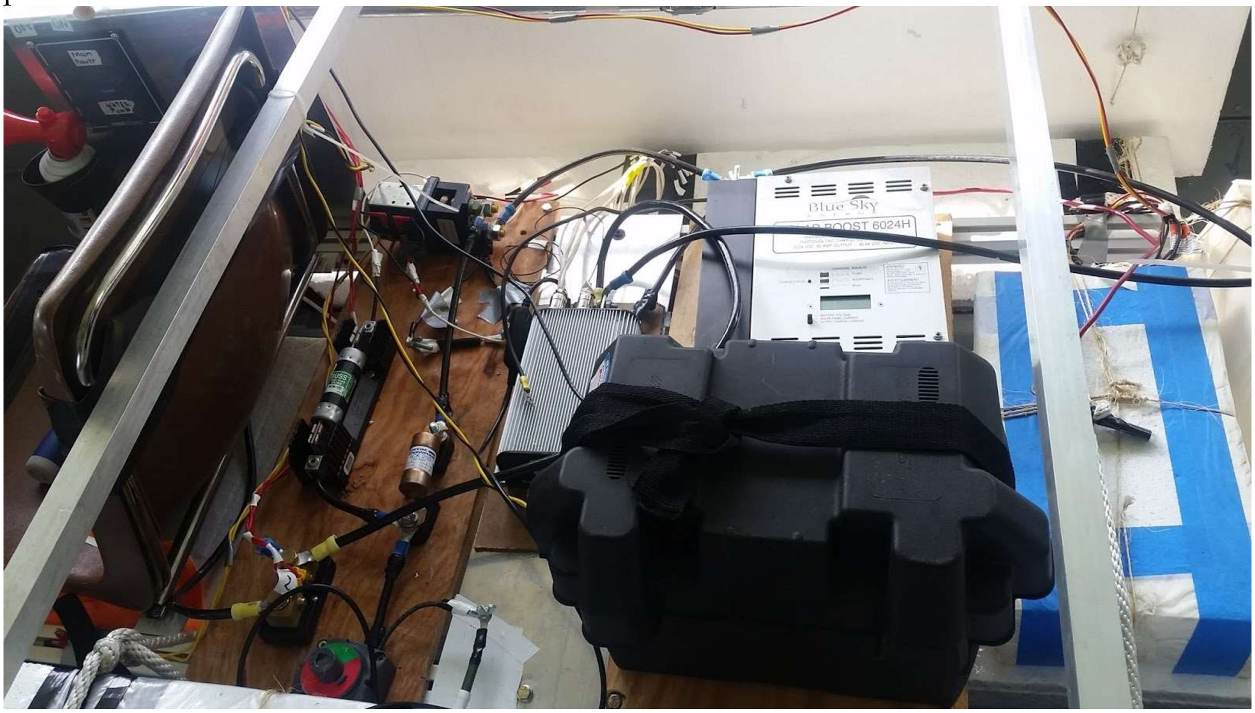


Fig. 4: Previous Circuit Board

This year the emphasis was to eliminate the time constraints with better planning, improve the aesthetics of the circuit, and to fix the issue with the main contactor. A throttle box was also built to alleviate the aforementioned issue. The rest of the circuit performed as expected last year without any issues.

B. Analysis of Design Concepts

The power to the system is provided by three 12V batteries in series for 36V in the sprint race. For the endurance race, four batteries in a 24V configuration are used to power the system. These feed into the motor controller which is a KDZ48400 rated for a 400A burst or 160A continuously running, as well as feed into the motor. The current motor that is being used is a 48V 150A motor which runs 3600 RPM unloaded. The motor is old and heavy, but there was not enough money this year to replace it. No issues with too much current to the controller were dealt with last year so the decision to use the same controller was made. This controller takes inputs from a 0-5k throttle which uses a potentiometer to vary the resistance across the input and output pin from 0 to 5kΩ (Fig. 3).

A throttle box then houses the throttle. Using sheet metal throttle housing brackets, the throttle is sandwiched on either side by a bracket. The brackets have rubber stripping on the edges that butt up against the throttle. This creates a force to hold the throttle in place while still allowing the skipper to move the throttle to a new position. Fig. 5 is a model of a simplified throttle design. The final will have a hand grip for the skipper.

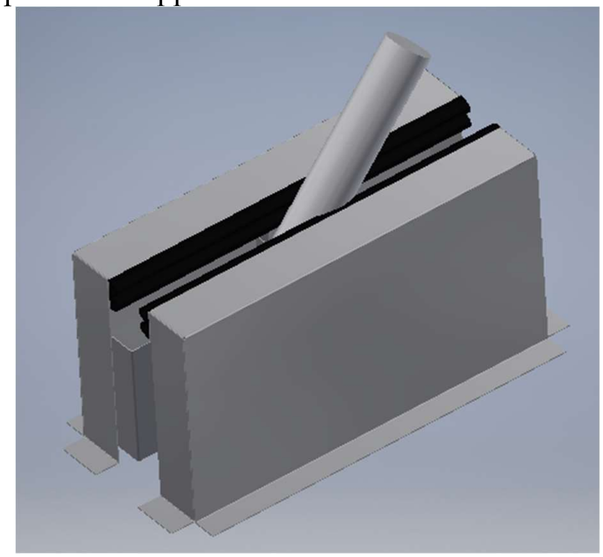


Fig. 5: Throttle Design

To protect the controller, several fuses have been put in place in the main power lines of the circuit. There is also a main contactor. The issue last year was that this contactor was rated for 48V and 400 A. Our batteries in the endurance race were only 24V so they could not put out enough power to close the contactor. Therefore, the skipper had to use a nonconductive rod to press the bus bar against the magnetic contacts in the contractor where it would stay. Any time the battery power dropped low enough the contractor could open up again though. This problem was fixed by choosing a lower voltage contactor, 36V, that could then be used for both races and would eliminate the issue.

A control panel next to the skipper housed a mechanical flip switch to cut power if needed, as well as the power switch for the bilge pump. A dead man’s switch was installed to cut power in case the skipper left the boat for any reason as well.

Most auxiliary wiring was done with 16 gauge wires. The main power cables are using gauge 3 wire and between batteries is 1 gauge wires to accommodate the amperage maximums of the circuit put in place by the fuses and controller

IV. POWER ELECTRONICS SYSTEM

A. Design

The original design from the previous year was to use four unmarked batteries, from previous years, for the endurance race and three of those for the sprint race. For the endurance race the batteries were connected in a 24V arrangement. This was done because the solar charger that the team had could only charge up to 24V. The sprint, where the solar panels were not used, the team went for a 36V configuration to get more power out of the motor. The solar panels, as stated above, were four 120W panels connected in series and parallel before being fed into a Blue Sky Solar Boost to charge the battery pack.

The main issues with last year had to do with a lack of experience with the competition and old components. When our team got to the competition, it came to our attention that the batteries that were going to be used no longer could hold a charge. A team donated batteries to use for the competition so that our team could still compete. The solar system also added a considerable amount of weight to the boat which slowed us down a great deal. The panels were also large and bulky, making it hard to install and uninstall.

The main goal at the beginning of this year was to replace the solar panels, batteries and the solar charger, if the old one was not compatible with the new panels. Research on the batteries and solar panels was initiated at the beginning of the semester to upgrade the components as soon as possible. For the panels, the goal was to decrease weight and increase efficiency. For the batteries it was to find ones that would give us the large power storage needed for the endurance race, as well as a high current discharge for the sprint event.

B. Analysis of Design Concepts

The new design for the batteries took many specifications into account including weight, amp-hours, voltage, current draw and cost. After much research the four endurance batteries that were chosen were the MightyMax ML35-12 batteries. The weight to Ah ratio could not be matched anywhere else for the cost. Many teams have used the Genesis EP batteries but for the same weight just 26 Ah batteries could be purchased. The cost was also around triple the cost of the MightyMax batteries. Due to the fact that these batteries do not last many seasons, the choice was made to purchase lower cost endurance batteries as well. For the sprint event it was recommended to use crank batteries to for the quick amp draw required in the short sprint race. This led to the selection of three 12 V Optima Red-Top batteries which will provide the quick burst needed for the sprint. Here the batteries cost more than other crank batteries but provide a much larger amount of cranking amps.

To save money, the old solar charger will be used. The downside to this is that we can only charge a 24V battery pack so the charging of batteries between events must be done in shifts. This charge controller implements MPPT technology to increase charge current. The controller can deliver up to 30 amps to 24 volt systems. It runs a completely automatic 3-stage charge cycle which includes bulk charging for when the battery voltage is low, and the charger delivers as much current as possible. Then it switches to acceptance charge where current is reduced until fully charged. Then float charge will be initiated to keep the battery fully charged without damaging it.

V. HULL

A. Design

Last year's hull was a 12 foot aluminum row boat that was refitted for the 2016 competition. That hull has been discarded, and a new hull was sourced. The hull we will be using for the 2017 competition is one that was donated to us by Buffalo Maritime Center (BMC), which was also used by the University at Buffalo's 2004 Solar Splash Team.

The hull is over 10 years old; this is not an issue in itself, however, there are some damages that have occurred over time. Multiple support ribs were detached from the walls; we had to remove the old, cracking glue, prepare the two surfaces and apply fresh adhesive. There were a few tears in the side Dacron; these were repaired with Dacron adhesive tape. Since the hull was not built explicitly for this year's use, multiple adjustments had to be made in order for the hull to accept our new steering system. The slot in the back of the boat was expanded to accommodate for the quadrant. The old steering components were all removed; however, some of them were epoxied or screwed into the support ribs. This required extra caution and consequently more time. The old motor mount, the steering "dash board" and all the previous circuitry was removed. One difficulty we face with our hull is the location of the motor shaft opening. It is not in an ideal location, however, moving the location would compromise the integrity of the hull since the main supports would have to be removed in that area. This has required the team to perform much more research into placement of all of our components, including the skipper, pulleys, steering components, and seating.

As mentioned earlier, the Dacron on the side has multiple tears in it. These tears were patched, however it does not compare to a brand new sheet of Dacron (Fig. 6). We are working on improving the Dacron, in order for the boat to function better and be more aesthetically pleasing. The bottom of the hull has a few imperfections in the form of cracks, chips, and peeled paint. The team will be sanding and refinishing in order to achieve a smoother hull and a lower friction coefficient (Fig. 7).

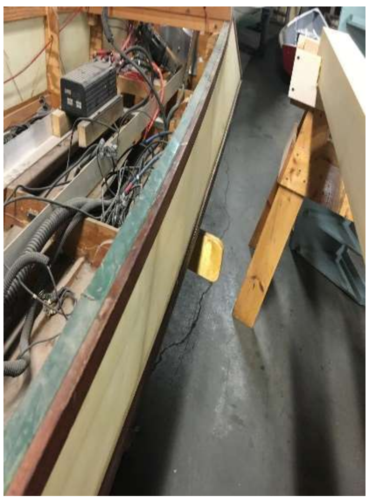


Figure 6: Dacron Sheet

Figure 7: Bottom of Hull

B. Analysis of Design Concepts

A hybrid hull of hard wood and Dacron sail cloth creates a lightweight and strong boat. The main portion of the hull is constructed from Maple wood, and in order to decrease the weight of the hull, the side panels are made out of Dacron sailcloth. The bottom of the hull has a three-millimeter layer of plywood and several layers of fiberglass. The Dacron side paneling is heat shrunk over the side of the boat, and tensioned in place with wood paneling and brass nail and screws.

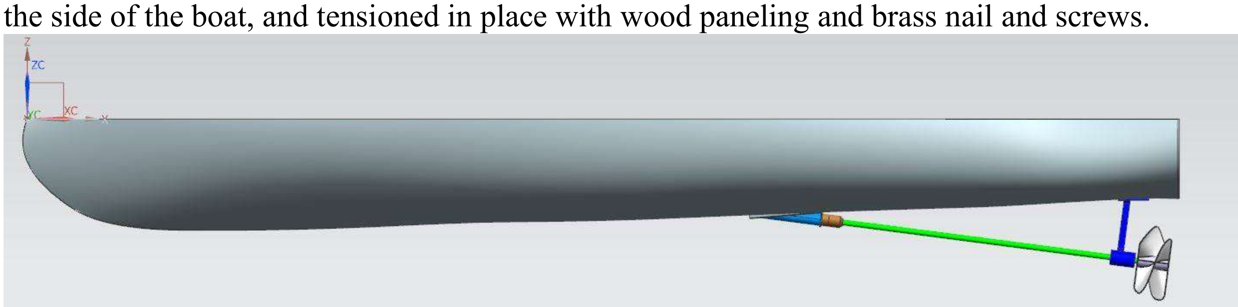


Fig. 8: Side View of Hull

Being narrow, the hull does not allow for transporting heavy loads or persons in the water as well as sacrificing stability. However, it does greatly reduce the drag (from water) acting on the hull. It does force the solar panels to overhang, which will increase the drag from air. It also creates the risk of damage to the panels. This made the placement of the panels a difficult decision. Having a wider hull would be more stable in the water, but a narrower hull is faster. This boat is a mix of both and is projected to perform well at the competition.

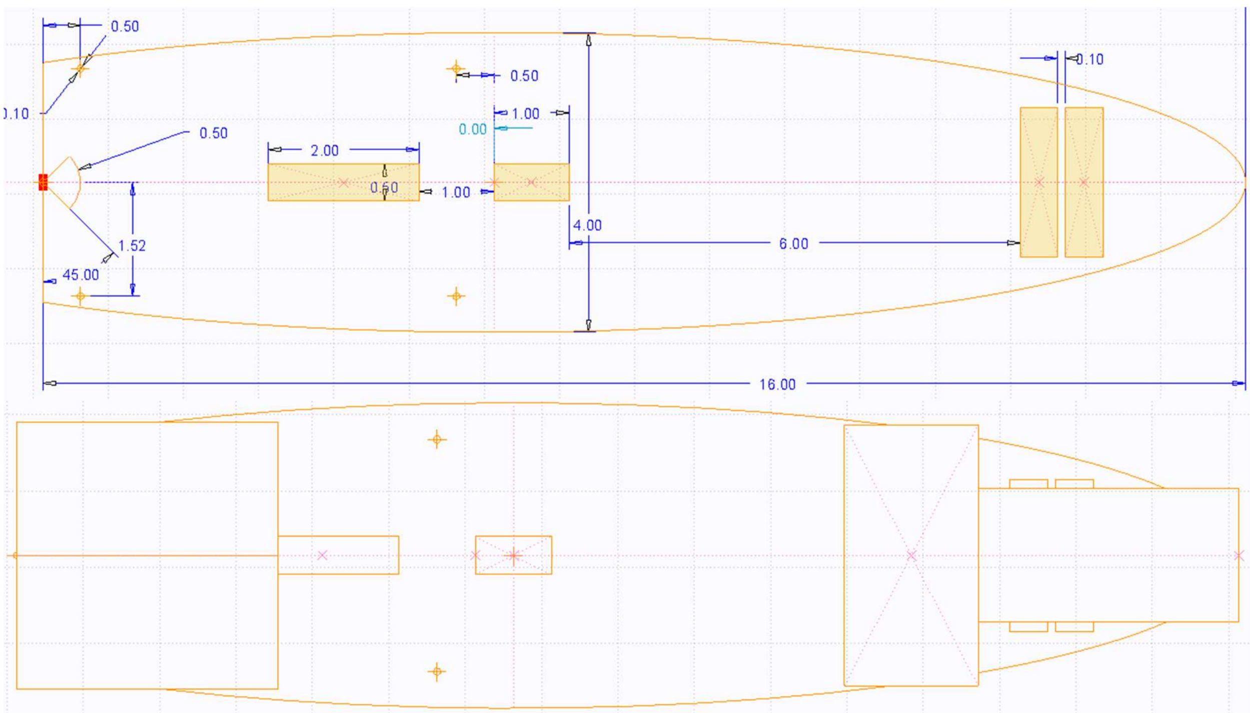


Figure 9: Top View of Component Arrangement

We decided to use this hull because it is much lighter than the one used last year. Our previous hull was constructed solely out of Aluminum, and weighed about 160 lbs, whereas our current hull weighs around 60 lbs. This 100 lb reduction coupled with higher performing solar panels and higher capacity batteries will enable the boat to achieve faster lap times and lower energy consumption. In Fig. 9, we have a design layout of all the components. Factors like trim angle, weight distribution and sizing of components were taken into consideration when making the layout.

C. Design Testing and Evaluation

Since the boat was donated to us by the BMC, there was no need for a prototype construction. Though it did come damaged it was easily repaired. We did do some analysis on adding an extra twelve inches to the back end of the boat. By adding that extra twelve inches it would add to the water line length and ultimately add some speed. Plus, it would allow some wiggle room for driver placement and weight distribution.

The boat at its current state is not operational though once it gets to a point where water testing is plausible we will be performing them. We will test if it floats, and the ideal placement of the batteries and skipper for the perfect trim angle. We will also do a visual inspection to see if there are places where it seems drag is being created. Based on this design, we can approximate the maximum hull speed that the boat is capable of.

Hull Speed

$$V_{hull} = 1.34 * \sqrt{waterline\ length\ in\ ft.}$$

$$V_{hull} = 1.34 * \sqrt{15} = 5.3\ knots = 6.1\ mph$$

Overall the boat is making good progress and is on track to being completed by the end of May. The design was solid, and thanks to the members of Buffalo Maritime Center, we have managed to take an old hull, and make it more efficient and faster than it was previously.

VI. DRIVE TRAIN

A. Design

The current design is the outboard engine design, shown in Fig. 10. The problem for this design is that the speed and stability of the solar boat does not meet the standard set by other teams. Therefore, the goal for this project is to improve the speed, the stability and the endurance of the solar boat by making reasonable revisions.

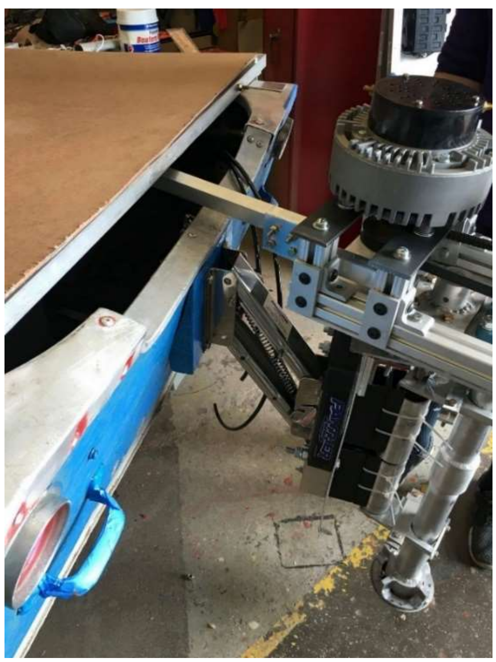


Fig. 10: Previous Drive Train

B. Analysis of Design Concepts

We plan to solve those problems by using the inboard engine design. This design is a popular design for both commercial and family use. The main idea for this design is to mount an engine inside the boat. With a shaft going through the bottom of boat into water (Fig. 11). More commonly known as an inboard motor. This kind of design can reduce friction more than an outboard motor. Also, this design can make balancing boat easier versus an outboard configuration. Drilling a hole in the boat requires many calculations to prevent boat damage. We also need to do design a shaft housing such that leakage is prevented. The technical analysis focus on FEA, the friction reduction compared to the outboard, and the balance of the boat. The validation method includes actual data of the measurement and calculation, and the performance of the boat in the actual environment.

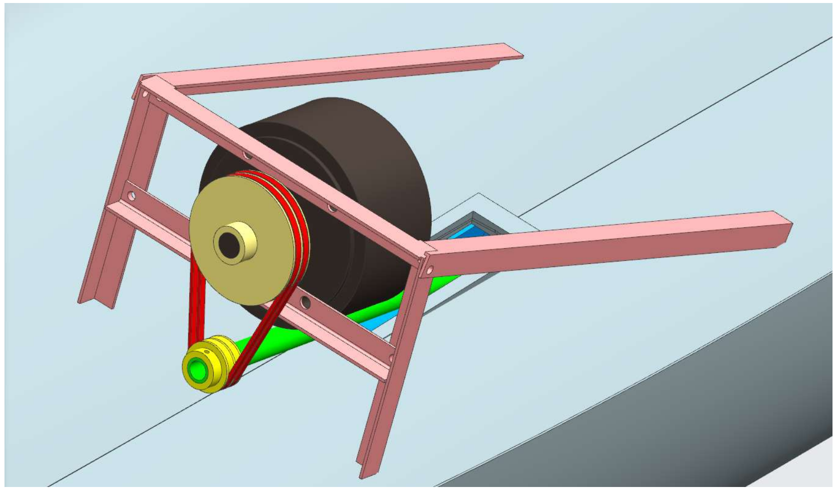


Fig. 11: Motor Mount

C. Design Testing and Evaluation

We did the FEA test for this inboard engine drive train design. This is the key step for verifying if our previous design works. Stress, strain and displacement are calculated in Creo. FEA is performed for strut, shaft, motor mount and motor mount plate based on calculated/estimated force and torque. Fig. 12 is the test result for this design.

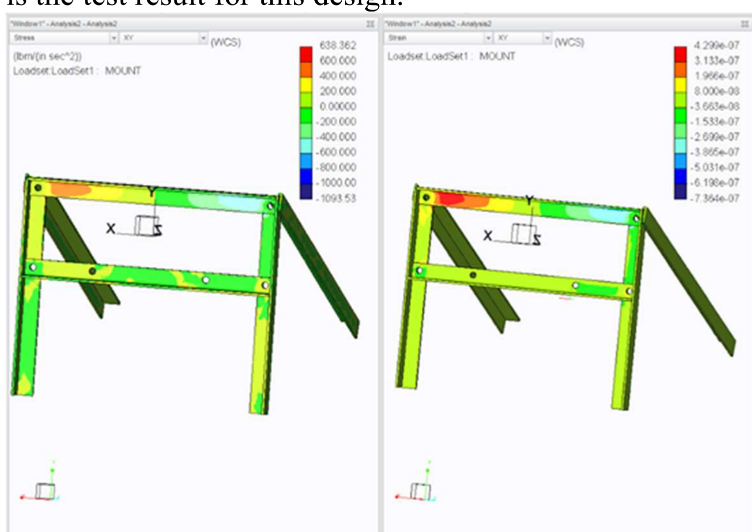


Fig. 12: FEA Results

The FEA results shows that there are some existing weak sections along the part. Therefore, we have to revise the thickness of some parts to satisfy the FEA test. Also since the boat is a complex system, many of our previous calculation and simulation may not work. We will directly test the whole boat in water and improve it.

VII. STEERING

A. Design

The current steering system is split into 3 parts. The first part of the system is between the steering wheel and the steering column where a wire is wrapped around pulleys of equal size on the steering wheel and the steering column. The second part is the steering system is the steering column that runs from the cockpit of the boat to the stern. The third and final part is a pulley system that runs from the steering column to a moment arm consists of two pulleys, one free spinning the other attached to the steering column with a moment arm in the middle. This moment arm rotates the entire drivetrain as a single unit.

With the system we currently have, there were problems that rose amidst the competition. For example, there was slippage between the steering wheel and steering column. That came with the inability to crimp and wrap the cables tight enough around the steering wheel and the first pulley. With this intricate system not only was it heavy from the steel pipe used for the steering column, but it was inefficient. There was a large amount of time wasted trying to alleviate the issues of that system, that it was detrimental to the entire competition.

This year there are many improvements that are needed to be successful in the 2017 competition. This year, a more efficient design is being created. This is achieved by making the system as simple as possible. A reduction in weight is needed as well, last year's boat took seven men to lift onto the trailer, and five people to get into the water. This was an unnecessary hassle and that is one of the man goals for improvements throughout all systems.

B. Analysis of Design Concepts

The new hull and propulsion design has an inboard motor. So that means that the entirety of the steering system needs a redesign. Using the improvements stated above as the guidelines to the redesign, we were able to create a lean steering system.

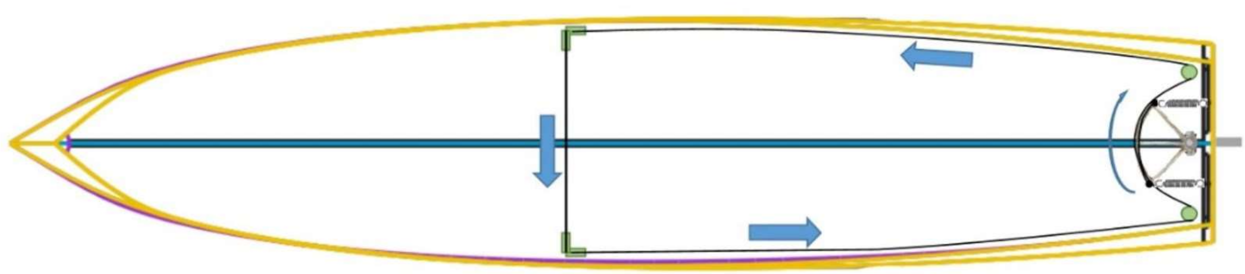


Fig. 13: Cable Steering Diagram

Fig. 13 is a top view of the new system. It contains two main parts, the quadrant system and the pulley system. The pulley system is used to translate rotation to the quadrant. By pulling on the cable in the pulley system, it results in the rotation in the quadrant. To decrease sensitivity in the movement of the quadrant we used a 4:1 ratio in the system. The quadrant is commonly used in many different types of boats, at its core a quadrant acts as a lever. In the quadrant system the quadrant is directly attached to a shaft. Which is attached to the rudder [1]. So as the quadrant turns so does the rudder (see Fig. 14). Since the quadrant acts as a lever, it doesn't take much force to steer the boat. Also, in the quadrant system there are springs, those springs are used to aid the skipper in maintaining a straight direction when piloting.

The Pulley-Quadrant was not the only system considered for steering. Our team seniors did a design project which involved a fully electronic steering system. That system used pistons, sensors and potentiometers to steer the boat. Along with, an Arduino attached to distance sensors that would help the skipper avoid obstacles. That system was overkill and required many expensive parts. Something that our budget could not spare.

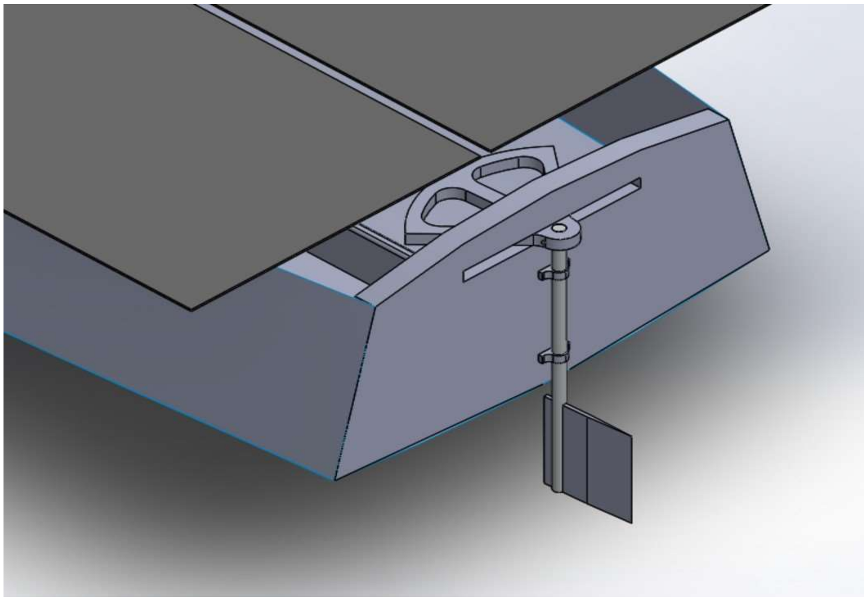


Fig. 14: Quadrant and Rudder Model

To have a boat that can turn properly, we need 80 degrees of rotation from the rudder. Originally we had a 1:1 ratio of turning (As the cable is displaced in one direction, the quadrant moves equal to the amount of displacement), although 80 degrees of movement was achieved with a 1:1 ratio, we realized that it was too sensitive. After some deliberation we assessed that a 4:1 ratio is needed to achieve 80 degrees of rotation, and decrease sensitivity. So a level of complexity needs to be added into the design. The 4:1 ratio was achieved by attaching the cable system to a 4 inch sprocket, which is attached to a 1in pulley. That pulley then translates the rotation to the quadrant. This assessment was based on simple geometry and a quadrant with a 8 inch diameter.

C. Design Testing and Evaluation

The steering system is currently being assembled on the actual hull in the Buffalo Maritime Center. We plan to do on water testing by the end of May. For the on water test we will assess the validity of the steering systems. Seeing if the skipper is able to pilot of the boat for long a duration, and that the boat is able to make the turns a competition.

VIII. DATA AQUISITION

The communication system is place is basic, consisting of a pair of 22-channel two-way radios. This system was implemented in the previous competition and worked well, however there are limitations. First, no live data can be received by the team on shore to analyze performance or troubleshoot issues. This could be done by using a series of microcontrollers transmitting live performance and system condition data to the support team on shore. Important system condition variables like battery levels, power consumption, and circuit temperatures could then be tracked during trials. Another downfall of the two-way radios is the fact that they require one the skippers' hands. When the skipper is using one hand for steering and one hand for power control this can become an issue. A way to relieve this problem is having a headset style radio that is hands-free and easy to use.

The team chose to use a set of two-way radios is because of price, reliability and ease of implementation. Overall, the communication system was not a priority therefore not much effort was spent on communication development.

Data acquisition can be a powerful asset if implemented. Unfortunately, this year this capability will not be added, in the future it may be a part of this boat. There a several functions a data acquisition system could have. For example, microcontrollers could be used to process and display data to the driver and team concerning the critical on-board systems. Or more simply, a small data acquisition system could log performance information to be processed after the race. Overall, this is an area for our team to grow into as the main systems become more reliable.

IX. PROJECT MANAGEMENT

Each year brings new challenges. Last year, our team faced all the problems of starting a project from scratch. This year, with more experience and project infrastructure, the issues faced were different. The main challenges during this year can be boiled down to the finances, time, workspace, and procurement. However, using what we've learned in the past, we were able to make better decisions throughout the year to improve our outcome at the competition.

A. Leadership and Members

The project efforts are led by Senior Andrew Tillinghast (ME). The electrical team is led by Senior Christopher Hannah (ME), the propulsion team by Senior Yingkai Yang (ME) and the chassis team by Andrew Tillinghast. Within each sub-team there are 4-6 active members.

B. Organization

The project is part of the on-campus ASME club. Within our project, there are 3 sub-teams: electronics, propulsion, and chassis team. Each sub-team meets regularly, generally once or twice each week. The entire project meets bi-weekly. During the project meetings teams give short updates on their progress and coordinate with others teams.

C. Finances

The majority of the funding towards this project came from grants the team applied for throughout the year. During the fall of 2016, the team put together a sponsorship package providing all the details of the project and sent the packages to grant foundations and related product companies. Overall, we received two $2000 grants awarded to us for these efforts. As a school club, we were awarded a $450 budget. We were also awarded $1200 from the department of mechanical engineering. There was also an individual donor who gave $700. Next year, the project will receive more awards by the school due to forward progress. This was an appropriate amount of money, but the financial issues are with spending the money. The Student Association makes it difficult to spend the money in our budget easily.

D. Sustainability

Many project members are graduating in May; this makes it difficult to ensure sustainability of the project. However, several underclassmen are active in the project and plan to continue the project. The team has already made decisions for next year's leadership. This will give the upcoming leaders time to prepare and learn about the responsibilities involved.

X. CONCLUSIONS AND RECOMMENDATIONS

The goal of this project was to learn from our mistakes, and create a more competitive entry than last year. So far, the team has done just that. The biggest improvements we have seen are in technology and weight. The fact that we have new solar panels, batteries and chassis will truly enhance our performance at the competition. However, there remains room for improvement. Currently, the team is working on setting goals for the future teams to have guidelines to follow. These involve fortifying the hull, upgrading the motor, enhancing the circuit, data acquisition systems, and more.

In the beginning of the project, the team got together and completed a Gantt Chart that would be used by each sub-team to follow throughout the year. This proved helpful in the first half of the project, but component procurement issues slowed the entire project down and suggested objectives times were being passed. In the end, procurement processing time was the biggest issue during the project. As a club, the Student Association (SA) handles all club money. If the project needs anything, it must go through SA. This usually takes 4-7 business days before the order can be placed. Overall, it may take 2-4 weeks between deciding on what part to buy and actually getting the part. This obstacle is tough to get around, so plans must be made far in advance to counteract this time penalty.

In the future, we wish to make our team aware of the long order time so they can plan around it. Every year thus far, this process has slowed us down the most. Any methods to minimize this time would be considered a great investment. Another piece of advice for future teams would be to seek a more active advisor. Currently, our "advisor" signs the entry form, and that's it. He is not involved whatsoever in the any part of the project. A helpful advisor could get us more resources, finances, and technical insight. All of these would allow us to be more competitive during the competition.

XI. REFERENCES

[1] Rudder Design Tips. *Competition Composites Inc.* <http://www.fastcomposites.ca/site/marine/design-tips-fabrication-overview/design-tips/?doing_wp_cron=1494261882.4509301185607910156250

Appendix A: Battery Documentation

Battery Model: RT U 3,7
Part Number: 822 255 000 888 2
Nominal Voltage: 12 volts
NSN: 6140 01 475 9361
Description: High power, sealed lead acid, engine starting battery

Physical Characteristics:

Plate Design: High purity lead-tin alloy. Wound cell configuration utilizing proprietary *SPIRALCELL*® technology.
Electrolyte: Sulfuric acid, H_2SO_4
Case: Polypropylene
Color: Case: Dark Gray
Cover: “OPTIMA“ Red
Group Size: BCI: 75/25

	Standard	Metric
Length:	9.313”	237 mm
Width:	6.813”	172 mm
Height:	7.625”	197 mm (height at the top of the terminals)
Weight:	33.1 lb.	15.0 kg

Terminal Configuration: SAE / BCI automotive and GM style side terminal (3/8 – 16 UNC – 2B, threaded nut).

Performance Data:

Open Circuit Voltage (fully charged): 12.8 volts
Internal Resistance (fully charged): 0.0030 ohms
Capacity: 44 Ah (C/20)
Reserve Capacity: BCI: 90 minutes
(25 amp discharge, 80°F (26.7°C), to 10.5 volts cut-off)

Power:

CCA (EN -18°C): 730 amps
MCA (BCI 0°C): 910 amps

Recommended Charging:

The following charging methods are recommended to ensure a long battery life:
(Always use a voltage regulated charger with voltage limits set as described below.)

Model: RT U 3,7
These batteries are designed for engine starting applications. They are not recommended or warranted for use in deep cycle applications.

OPTIMA® RedTop U 3,7

Recommended Charging Information:

Alternator: 13.3 to 15.0 volts; no amperage limit

Battery Charger: 13.8 to 15.0 volts; 10 amps maximum; 6-12 hours approximate

Float Charge: 13.2 to 13.8 volts; 1 amp maximum current (indefinite time at lower voltages)

Rapid Recharge: (Constant voltage charger) Maximum voltage 15.6 volts. No current limit as long as battery temperature remains below 50°C (125°F). Charge until current drops below 1 amp.
All limits must be strictly adhered to.

Recharge Time: (example assuming 100% discharge – 10.5 volts)

Current	Approx. time to 90% charge
100 amps	35 minutes
50 amps	75 minutes
25 amps	140 minutes

Recharge time will vary according to temperature and charger characteristics. When using Constant Voltage chargers, amperage will taper down as the battery becomes recharged. When amperage drops below 1 amp, the battery will be close to a full state charge.

(All charge recommendations assume an average room temperature of 25°C, 77°F)

Always wear safety glasses when working with batteries.

Always use a voltage regulated battery charger with limits set to the above ratings. Overcharging can cause the safety valves to open and battery gases to escape, causing premature end of life. These gases are flammable! You cannot replace water in sealed batteries that have been overcharged. Any battery that becomes very hot while charging should be disconnected immediately.

Not fully charging a battery can result in poor performance and a reduction in capacity.

Shipping and Transportation Information:

OPTIMA batteries can be shipped by AIR. The battery is nonspillable and is tested according to ICAO Technical Instructions DOC. 9284-AN/905 to meet the requirements of Packing Instructions No. 806 and is classified as non-regulated by IATA Special Provision A-48 and A-67 for UN2800. Terminals must be protected from short circuit.

Manufacturing Location:

OPTIMA Batteries
17500 East 22nd Avenue
Aurora, CO 80011
United States of America
Phone: 303-340-7400
Fax: 303-340-7474

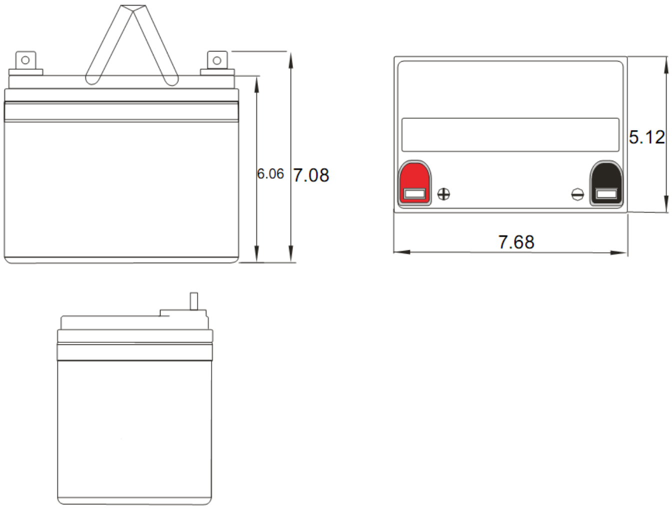
BCI = Battery Council International

PRODUCT INTRODUCTION

MIGHTYMAX SEALED LEAD-ACID BATTERIES

ML35-12 12V35AH

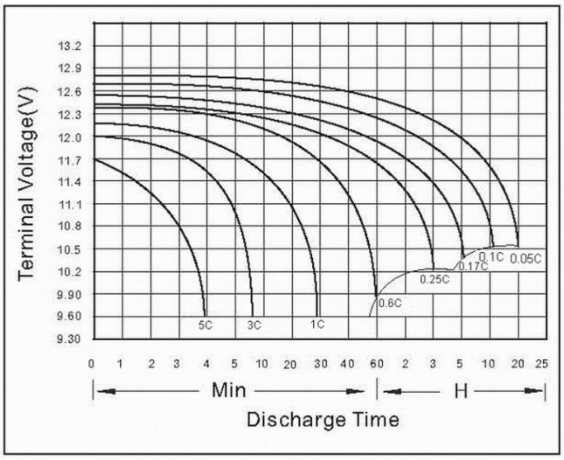
· **Outer dimensions(inches)**



Specification

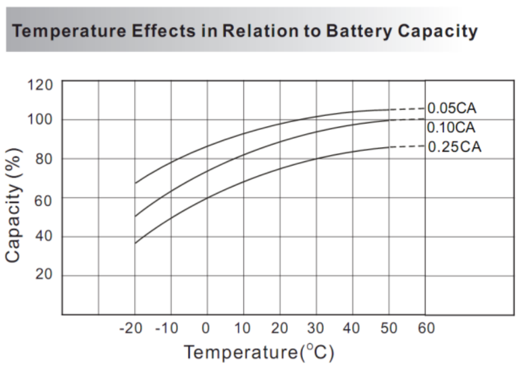
Nominal voltage		12V	Rate Capacity (20 hour rate)	35AH
Dimensions	Length	7.68 inches	Weight Approx	21 lbs
	Width	5.12 inches	Standard Terminal	F5
	Height	6.06 inches		
	Total Height (With Terminals)	7.08 inches	Optional Terminal	N/A

· **Discharge Characteristics(25℃/77F°)**



Electrical Specifications

Capacity 77° F(25℃)	20 hour rate(1.75A)	35AH	Internal Resistance Full charged battery	15mΩ
	10 hour rate(3.15A)	31.5AH		
	5 hour rate(5.95A)	29.7AH		
	1 hour rate(21A)	21AH		
Capacity Affected by Temperature (20hour rate)	104° F(40℃)	102%	Self-discharge 77 °F(25℃)	Capacity after 1 month storage 90%
	77° F(25℃)	100%		Capacity after 3 month storage 75%
	32° F(0℃)	80%		Capacity after 6 month storage 65%
	5° F(-15℃)	50%		Capacity after 12 month storage 55%
Charge Constant Voltage	Cycle use: Initial Charging Current less than 9.9A; Voltage 14.20~15.00V 77° F(25℃) Standby use: Voltage 13.50~13.80V 77° F(25℃)			



Appendix B

Sprint Configuration		Endurance Configuration	
Components	Weight (lbs)	Components	Weight (lbs)
Solar Panels	0	Solar Panels	20
Drive Train	20	Drive Train	20
Batteries	100	Batteries	100
Skipper	150	Skipper	150
Hull	65	Hull	65
Steering System	15	Steering System	15
Motor	30	Motor	30
Electrical Systems	40	Electrical Systems	40
Cockpit System	10	Cockpit System	10
Total	430	Total	450 (Max)

The displacement due to the wall thickness of the wood that the hull is made out of, will account for some buoyancy force. It is calculated as follows.

Density of Water = 62.41 lbs/ft^3	Max Weight = 450 lbs
Density of Polystyrene = 1 lbs/ft^3	Factor of Safety = 1.2

Buoyancy Force $F_{b,hull} = \rho_{water} \cdot \text{Thickness} \cdot \text{Surface Area}$ $F_{b,hull} = 62.41\ lbs/ft^3 \cdot 0.0098\ ft \cdot 43.72\ ft^2$ $F_{b,hull} = 26.73\ lbs$	Thickness = 3mm = 0.0098 ft Surface Area* = 43.72 ft^2

We still need a factor of safety of at least 1.2. So by subtracting the buoyancy force from the total maximum weight from the endurance configuration, we can use that value to calculate the volume displaced (V_{Disp})

$F_{remain} = F_{b,max} - F_{b,hull}$ $F_{remain} = 450lbs - 26.73\ lbs$ $F_{remain} = 423.27\ lbs$	$V_{Disp} = \frac{F_{remain}}{\rho_{water}}$ $V_{Disp} = \frac{423.27\ \text{lbs}}{62.41\ lbs/ft^3}$ $V_{Disp} = 6.782\ ft^3$	$V_{final} = V_{Disp} \cdot FoS$ $V_{final} = 6.782\ ft^3 \cdot 1.2$ $V_{final} = 8.134\ ft^3$

V_{Disp} is the amount of volume displaced by the boat, V_{final} is the amount displaced by the boat after the factor of safety is included in the calculations. So we need displaced approximately nine cubic feet in order to maintain a minimum factor of safety of 1.2. This is achieved by using Cellofoam EPS (polystyrene) insulation. With a density of 1 lbs/ft^3, EPS provides an excellent buoyant force per cubic-foot. Nine cubic feet of EPS will be distributed at two critical locations, the bow and the stern. At the bow EPS will be distributed around main electrical components, and the batteries. At the stern the remaining EPS is placed behind the driver

Appendix C: Insurance

SUBBOAR-01 JGUSTAFSON

ACORD

CERTIFICATE OF LIABILITY INSURANCE

DATE (MM/DD/YYYY) 05/02/2017

THIS CERTIFICATE IS ISSUED AS A MATTER OF INFORMATION ONLY AND CONFERS NO RIGHTS UPON THE CERTIFICATE HOLDER. THIS CERTIFICATE DOES NOT AFFIRMATIVELY OR NEGATIVELY AMEND, EXTEND OR ALTER THE COVERAGE AFFORDED BY THE POLICIES BELOW. THIS CERTIFICATE OF INSURANCE DOES NOT CONSTITUTE A CONTRACT BETWEEN THE ISSUING INSURER(S), AUTHORIZED REPRESENTATIVE OR PRODUCER, AND THE CERTIFICATE HOLDER.

IMPORTANT: If the certificate holder is an ADDITIONAL INSURED, the policy(ies) must have ADDITIONAL INSURED provisions or be endorsed. If SUBROGATION IS WAIVED, subject to the terms and conditions of the policy, certain policies may require an endorsement. A statement on this certificate does not confer rights to the certificate holder in lieu of such endorsement(s).

PRODUCER
Walsh Duffield Companies, Inc.
801 Main St.
Buffalo, NY 14203

CONTACT NAME: June S. Gustafson, CPCU, AAM
PHONE (A/C, No, Ext): (716) 362-7374 FAX (A/C, No): (716) 847-1360
E-MAIL ADDRESS: jgustafson@walshins.com

INSURER(S) AFFORDING COVERAGE	NAIC #
INSURER A : Philadelphia Indemnity Ins Co	18058
INSURER B :	
INSURER C :	
INSURER D :	
INSURER E :	
INSURER F :	

INSURED
Sub Board I, Inc.
William Hooley
PO Box 602100
Buffalo, NY 14260-2100

COVERAGES CERTIFICATE NUMBER: REVISION NUMBER:

THIS IS TO CERTIFY THAT THE POLICIES OF INSURANCE LISTED BELOW HAVE BEEN ISSUED TO THE INSURED NAMED ABOVE FOR THE POLICY PERIOD INDICATED. NOTWITHSTANDING ANY REQUIREMENT, TERM OR CONDITION OF ANY CONTRACT OR OTHER DOCUMENT WITH RESPECT TO WHICH THIS CERTIFICATE MAY BE ISSUED OR MAY PERTAIN, THE INSURANCE AFFORDED BY THE POLICIES DESCRIBED HEREIN IS SUBJECT TO ALL THE TERMS, EXCLUSIONS AND CONDITIONS OF SUCH POLICIES. LIMITS SHOWN MAY HAVE BEEN REDUCED BY PAID CLAIMS.

INSR LTR	TYPE OF INSURANCE	ADDL INSD	SUBR WVD	POLICY NUMBER	POLICY EFF (MM/DD/YYYY)	POLICY EXP (MM/DD/YYYY)	LIMITS	
A	X COMMERCIAL GENERAL LIABILITY; CLAIMS-MADE; X OCCUR			PHPK1529656	08/01/2016	08/01/2017	EACH OCCURRENCE	$ 1,000,000
							DAMAGE TO RENTED PREMISES (Ea occurrence)	$ 100,000
							MED EXP (Any one person)	$ 5,000
							PERSONAL & ADV INJURY	$ 1,000,000
	GEN'L AGGREGATE LIMIT APPLIES PER: POLICY; PRO-JECT; LOC						GENERAL AGGREGATE	$ 2,000,000
	OTHER:						PRODUCTS - COMP/OP AGG	$ 2,000,000
								$
	AUTOMOBILE LIABILITY						COMBINED SINGLE LIMIT (Ea accident)	$
	ANY AUTO						BODILY INJURY (Per person)	$
	OWNED AUTOS ONLY; SCHEDULED AUTOS						BODILY INJURY (Per accident)	$
	HIRED AUTOS ONLY; NON-OWNED AUTOS ONLY						PROPERTY DAMAGE (Per accident)	$
								$
A	X UMBRELLA LIAB; X OCCUR			PHUB550633	08/01/2016	08/01/2017	EACH OCCURRENCE	$ 3,000,000
	EXCESS LIAB; CLAIMS-MADE						AGGREGATE	$ 3,000,000
	DED; X RETENTION $ 10,000							$
	WORKERS COMPENSATION AND EMPLOYERS' LIABILITY Y / N						PER STATUTE; OTH-ER	
	ANY PROPRIETOR/PARTNER/EXECUTIVE OFFICER/MEMBER EXCLUDED? (Mandatory in NH)	N / A					E.L. EACH ACCIDENT	$
	If yes, describe under DESCRIPTION OF OPERATIONS below						E.L. DISEASE - EA EMPLOYEE	$
							E.L. DISEASE - POLICY LIMIT	$

DESCRIPTION OF OPERATIONS / LOCATIONS / VEHICLES (ACORD 101, Additional Remarks Schedule, may be attached if more space is required)
Proof of coverage Solar Splash 2017

CERTIFICATE HOLDER

Solar Splash
% Jeff Morehouse
309 Newridge Road
Lexington, SC 29072

CANCELLATION

SHOULD ANY OF THE ABOVE DESCRIBED POLICIES BE CANCELLED BEFORE THE EXPIRATION DATE THEREOF, NOTICE WILL BE DELIVERED IN ACCORDANCE WITH THE POLICY PROVISIONS.

AUTHORIZED REPRESENTATIVE
Edward F. Walsh Jr.

Appendix D: Team Roster

	Name	Degree Program	Year	Team Role
1	Andrew Tillinghast	Mechanical Engineering	4th	Team Leader
2	Jerasak Manivong	Mechanical Engineering	3rd	Chassis Team
3	Chris Hannah	Mechanical Engineering	4th	Electronic Team Leader
4	Morgan Henry	Electrical Engineering	2nd	Electronics Team
5	Nicholas Viola	Mechanical Engineering	4th	Electronics/Chassis Team
6	Ramzy Abu-Ramadan	Mechanical Engineering	1st	Chassis Team
7	Shivron Sugrim	Mechanical Engineering	2nd	Chassis Team
8	Yingkai Yang	Mechanical Engineering	4th	Propulsion Team
9	Ian Tillinghast	Computer Science	2nd	Electronics Team
10	Henry Fleischut	Mechanical Engineering	2nd	Chassis Team
11	Adekunle Samuel	Mechanical Engineering	3rd	Chassis Team
12	Mohmed Abdelkarim	Mechanical Engineering	3rd	Chassis Team
13	Yankun Lin	Mechanical Engineering	4th	Propulsion Team
14	Pengfei Yang	Mechanical Engineering	4th	Propulsion Team
15	Cesar Arevalo	Mechanical Engineering	2nd	Chassis Team