STONY BROOK
SOLAR RACING

Solar Seawolf Boat #5

May 1st, 2023

Team Members:

Andy Lin, Frank Lin, Andrew Mathew, Vikash Ramharack, Kumpu Ide, Wesley Ng, Dominic Del Toro, Sherin Davis, William Winters, Angela Tom, Vanessa Man, Dakota Levermann, Chenhao Lyu, Dylan Harrinarine, Tami Takada, Max Manoach, Shafayat Alam, James Jung, Steven Chen, Jinheng Zhang, Zheng Chen, Md Zaman, Matthew Leo, Abraham Mendoza, Jake Lin, Soyun Lee, Josh Levykh

Faculty Advisors:

Professor David Westerfeld, Austin Giordano

Executive Summary

The Stony Brook Solar Racing Team is a student-run club that is supported in many ways by the university. The primary goal of the Stony Brook Solar Racing Team this year is to make improvements to old designs and ensure the changes work properly. The team is dedicated to improving upon its performance at Solar Splash 2022 and competing against other teams at the event. The Solar Racing Team is sub-categorized into three main groups: Mechanical Engineering, Electrical Engineering, and Programming.

The mechanical group oversaw the mechanical aspects of the boat such as power transmission, propeller studies, drivetrain, motors, steering system, hull design, and boat assembly. The goals of the mechanical team for this year are mounting and improving the drivetrain assembly; mounting the solar panel array, batteries, and electrical system; designing and manufacturing a boat dashboard, mounting the skipper seating, pitch actuation, and modifying the hull design. These systems are mounted onto a semi-displacement hull designed by the team in 2019.

The electrical group is responsible for the power distribution from the solar charging to motor control systems, the design of sensor hardware to integrate with main boat circuitry, and the selection of parts such as batteries, solar panels, and sensor components. This year, work was focused on redesigning the motor control circuit and assisting the mechanical group in waterproofing electrical components, managing wiring within the hull, and mounting the solar panel array.

The software group works primarily on data acquisition and display. The projects this year include the development of an off-shore analytics platform and a new design of the data acquisition system and sensor in collaboration with the electrical team.

The team faces considerable challenges due to the changes that we have made to our boat to conveniently progress on it. Our administration has also faced difficulty in ensuring funding and resources for the continued success of the team and meeting deadlines in a hybrid work environment.

Table of Contents

I. Project Objectives

The goals of the mechanical team for this year include tasks such as reconstructing the hull of the boat, optimizing its weight distribution, reconfiguring the drivetrain and gearbox system for a fully submerged propeller, and redesigning the steering and throttle systems. Due to some issues with the workspace we previously used, we had to separate the boat into two halves which had to be rejoined. Although deconstructing and reassembling of the boat is an critical task that can pose many points of failure, it also allowed for us to take advantage of the deconstruction to reconfigure some systems we deemed were previously inefficient or unoptimized for this year's goals.

The electrical team has worked on redesigning our solar panel configuration to be more aerodynamic. The layout was originally planned to maximize the potential solar power output but resulted in a large amount of overhang over the edge of the hull. Without change, the boat would have been much more difficult to handle and posed more safety risks for the skipper exiting the craft. Additionally, the motor control circuit was redesigned to have one motor controller for each motor that we have.

The electrical and programming teams have also been collaborating on developing our data acquisition system, as this was not emphasized in previous years, which resulted in a lack of knowledge transfer and difficulty knowing where improvements needed to be made. The parameters we found most vital to record were battery charge and discharge power, battery state of charge percentage, boat speed, and propeller positioning with respect to the waterline. Developing an analytics platform to easily assess the boat's performance over time will hopefully mitigate this issue and benefit the team in future years. Displaying this data in real-time onboard will also assist the skipper during competition races.

II. System Design

A. Solar System

1) ***Current Design:*** Our system consists of R28 Powerfilm rollable solar panels and a 60A Renogy Commander MPPT charge controller. Although the selected components and mounting have not changed, the configuration of solar panels has been updated to consider skipper safety. There were originally 16 panels, arranged in 2 sets of 8 in parallel connected panels. These were mounted to 3 frames that encompassed the cockpit, as shown in **Fig. 1**. This specific layout of panels was chosen to maximize power output within Solar Splash regulations. One panel weighs 0.8kg and has dimensions of 79.6 inches by 14.6 inches. The electrical and physical characteristics of the panels are shown in **Fig. 2**. However, this design made the boat feel bulky and unsteady because the parts of solar panels were overlaying the boat frame. The design of the frame that the solar panels were mounted onto did not secure the panels as well as we wanted and resulted in a flimsy setup.

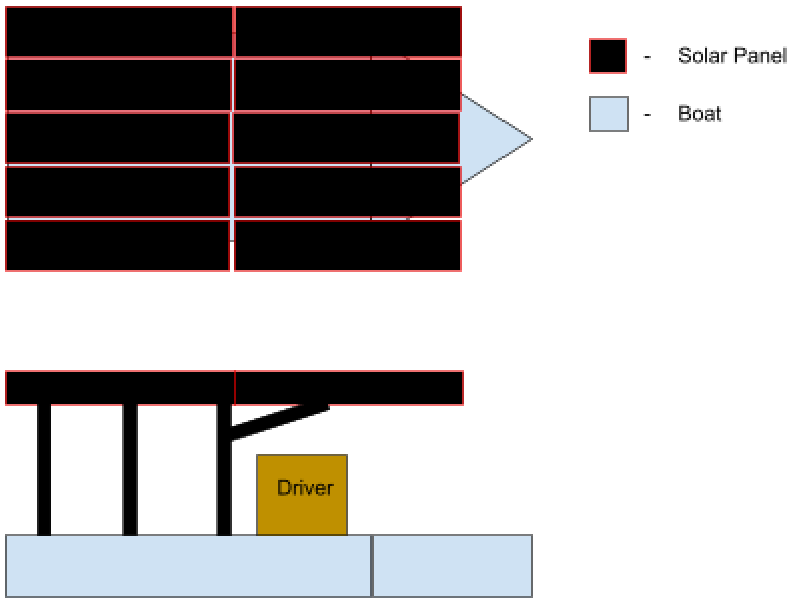


Fig. 1. *Solar system setup with extrusion supports.*

Rated Voltage at Pmax	15.4V
Rated Current at Pmax	1.8A
Open Circuit Voltage	21.9V
Short Circuit Current	2.3A
Rolled Dimensions	14.6 x 3.0 inches 370.8 x 76.2 mm
Unrolled Dimensions	79.6 x 14.6 inches 2,021.8 x 370.8 mm
Weight	1.7 lbs 0.8 kg

Fig. 2. *Electrical and physical specifications of solar panels.*

2) ***Analysis of Design Concepts:*** Our system now consists of twelve solar panels divided into two sets of six. The six panels within each set are wired in parallel while the two sets themselves are wired in series. Our system now has solar panels on top of the boat and the skipper, sort of like a roof. This was challenging to mount securely while keeping the skipper safe while maintaining a clear line of sight, so we are using aluminum extrusion as pillars and supporting structures to mount it. However, the challenge with this was that the front part of the solar panel structure was flimsy. Thus, we are further securing the solar panel mount on the top and front of the skipper with additional aluminum to enhance structural integrity. This layout best optimizes the total voltage and current output. The previous design gave 448W, while our newer design gave 336W. The 112W loss of power will affect the battery's charging, but is something we need to sacrifice. We organized the panels by open-circuit voltage as shown in **Fig. 3** and grouped similar performing ones to each frame.

Tier 1	Volts	Tier 2	Volts	Tier 3	Voltage
2	19.99	4	19.39	1	18.64
3	20.08	8	19.07	7	18.98
9	20.14	10	19.9	17	18.85
12	20.27	14	19.1	18	18.9
16	20.8	15	19.1		
20	20.25	19	19.2		

Fig. 3. *Table of solar panel open circuit voltages.*

B. Electrical System

1) ***Current Design:*** The skipper was able to control several systems on the boat from switches mounted on the dashboard. The most important of these are the electrical interlocks that deactivate the motor controller. The control signal for the main contactor is interrupted by the main motor switch and the deadman switch. A foot pedal was used because a hand throttle would not provide enough physical resistance and hold its position. The propeller height was controlled by a three-position switch which controlled a linear actuator. The auxiliary battery is a 12V nominal battery that powers the bilge pump, lights, and data acquisition components. There are switches controlled by the skipper to engage the lights and change the bilge pump operation mode between automatic and manual.

2) ***Analysis of Design Concept:*** Using a switch located in the back of the boat, the electrical system can be converted between Sprint mode and Endurance mode. This involves connecting the solar charge controller to the main battery and changing which contactors are actuated by the kill switch. This is necessary, because the different contactors have different coil voltages. Previous iterations of the boat only used one contactor and one motor controller for both motors. Also connected between is the deadman switch which was moved from the dashboard to inside the boat, beside the skipper. Additionally, the foot pedal was replaced with the hand throttle. Besides the main three batteries, we have a small 12V auxiliary battery which powers the bilge pump, lights, and data acquisition components. It was determined that running an individual motor at 12V is more efficient than running two motors slowly at 36V for Endurance. This is due to the motor controller not having to step down the voltage as significantly. We were concerned about the safety of our old kill switch setup, so the new deadman's switch location allows the lanyard to disconnect easier compared to if it was mounted to the dashboard. The foot pedal proved to be strenuous to the skipper during Endurance where a certain position had to be held for extended periods of time, so the hand throttle should allow for more accurate control and will be more convenient.

   The solar charger we used last year was oversized for our application. We would have liked to purchase Genasun brand solar charge controllers as these were recommended to us by the panel manufacturer, but uncertainties about the endurance system voltage and budgetary constraints related to attending competition prevented this. As a stopgap measure, we purchased an inexpensive MPPT solar charge controller which can be used for either 12 or 24 volt battery systems, which was much smaller and lighter than the existing unit.

3) ***Design Testing and Evaluation:*** We have made an attempt to make the wiring more neat and professional, and have avoided using daisy chained crimp connectors to the extent we did last year. We are instead using terminal blocks and WAGO connectors, and have tried to make most of the junctions inside of boxes in the rear of the boat above the batteries. We will either bundle and secure all of our wiring or run it through conduit, to protect it from water and abrasion. We want to make the system as fool-proof as possible, because

connecting the wrong system voltage for the current configuration could lead to permanent damage. We plan to test the electrical system for reliability at a local lake, but at the time of writing this has not been done. Wiring diagrams for our current electrical system can be seen in Appendix E.

C. Power Electronics System

1) ***Current Design:*** The existing design consisted of two Agni 95R permanent magnet axial flux motors driven by a single Alltrax AXE 7245 motor controller. Similar motors are used by many teams at Solar Splash due to their efficiency and power density. The motor controller was provided with a system voltage of 36 volts for all events, and had a rated current of 300 Amps. System power was provided by three XS Power lead-acid AGM batteries, either an older set of three (3) with model number D1200 or a newer set of three (3) with model number PS925L. These are not deep cycle batteries, and each set was well below the battery weight cap.

2) ***Analysis of Design Concepts:*** The old system worked and proved to be very reliable, but had considerable room for improvement. On-water testing with improved instrumentation showed that the motor controller was undersized for our application, and was operating in current limit mode while delivering well below the system voltage to the motors. This meant that not only was the boat going slower than it could be for Sprint, but that the motor controller was stepping down voltage for Endurance, which decreases efficiency. We have responded by switching to a system with two motor controllers, one per motor, changing gear ratios so that the propeller will spin at the target speed for each event when the motors are receiving close to system voltage, and using a single motor with a different system voltage for Endurance. The new motor controllers are an Alltrax AXE 4845 which we had on hand, and an Alltrax SR 48400 which we received as a donation. The SR 48400 will be used for Sprint and Endurance, and the AXE 4845 will only be used for Sprint, in conjunction with the SR 48400. The motor on the AXE 4845 will be disconnected for Endurance. At the power levels we estimate to be needed for Endurance, our motors achieve the highest efficiency when the system voltage is lower, according to graphs provided by the manufacturer. Efficiency at these power levels seems to be similar for 12 or 24 volts, but we have decided on 12 volts, because it is easier to configure batteries for that system voltage.

   We had intended to purchase new batteries that would allow us to make use of more of the battery weight allowance, were rated for deep cycling, and allowed more flexibility in configuring system voltage. However, unexpected expenses related to attending the competition prevented this. Therefore, we will most likely use 36 volts for Sprint (all batteries in series) and 12 volts for Endurance (all batteries in parallel). Although using non deep cycle batteries for an electric vehicle application may seem like a poor choice, they will theoretically provide higher short term power for Sprint, and faster recharging. Additionally, we do not put many charge-discharge cycles on the batteries each year, so battery life is less of a concern. Since the batteries are well below the weight cap, we may experiment with adding smaller batteries in series with the main pack for Endurance, as a stopgap measure to achieve maximum energy storage.

3) ***Design Testing and Evaluation:*** We plan to test a number of configurations on the water before competition. However, we have been unable to do so at the time of writing. We plan to test speed and current consumption in the Sprint configuration, and adjust our gear ratios based on the results, so that we can drive the motors with the most power possible. We also plan to test different system voltages in the Endurance configuration to find the most efficient configuration at a competitive Endurance speed.

   We conducted bench tests of our motors and motor controllers by chaining the motors together and using one to spin the other. A passive load was placed across the terminals of the motor being spun which allowed us to test the motors under load. The results were interesting, and showed that efficiency increased with increasing power, which matches the graphs provided by the manufacturer for the low amounts of power that we were able to sink in a benchtop environment. It also showed that the motor controllers have incredibly variable efficiencies depending on the amount of step down, varying from as low as 40% to as high as 98%.

D. Hull Design

1) ***Current Design:*** The hull is a design created in 2018 for the 2019 Solar Splash, and measures 14 feet in length, 40 inches across, and has a waterline 14 inches below the top-most surface. It was designed to be more well-rounded, being longer than previous iterations for a higher hull speed for Endurance, having underside geometry that would assist in getting onto plane in Sprint, and handles well in corners for Slalom. The hull is fitted with 10 foot lengths of 1.5 inch wide aluminum slotted extrusions, which allows for flexibility in mounting components around the boat.

   While it did perform admirably last year, there was no surviving documentation regarding its properties on the water, leading to many critical design decisions made mostly on assumptions. Notably missing was its drag coefficient in the water, which would allow us to calculate adequate motor power and reduction for a given speed. The hull could not fit in our workshop or the building as a whole, having been assembled at a facility off campus made for large structures, leading to cancellation of work hours due to inclement weather and occasionally uncomfortable or even unsafe working conditions in being forced to work outdoors. The weight distribution for the boat was also not taken into consideration in last year's design, leading to the boat having a slight but constant nose-down trim, and being unable to get onto plane.

   For the 2023 iteration, we would like to reduce our drag coefficient for this hull, and as such, it must be measured. The hull must also be made to fit into the Heavy Engineering building where our workshop is, such that work can be performed indoors. The internal positioning of components should also be reworked to promote getting onto plane.

2) ***Analysis of Design Concepts:*** Due to our lack of experience in working with composites and limited budget, the team opted not to redesign the hull from scratch, but to keep the current design. Where a new hull would have given us flexibility in design, there would be no quantitative proof of improvement without first testing the original design. The current design was thus modified to fit into the building, by means of separating the boat into two distinct parts. The frontmost 6 feet of the boat (hereinafter referred to as the "bow section") would be separated from the remaining rear 8 feet of the hull ("stern section") so that both sections can fit into the freight elevator in front of our shop, which has a max length of only 10 feet. The two halves would then be designed to bolt back together, with a silicone gasket layer in between to prevent water ingress.

   The structure needed to bolt the halves together is twofold. For the bow section, a foam core composite bulkhead with one side of 1/32" structural fiberglass and the other side of ¼" aluminum is added, which is to be watertight and structurally sound; for the stern section, the bulkhead in place was reused and reinforced with the same 1/32" structural fiberglass and ¼" aluminum. The bolts used to secure the front in place were eight (8) ⅜"-16 carriage bolts to hold together the aluminum panels, and four (4) longer ⅜"-16 bolts passing through both bulkheads to secure them in place. 3M Scotch-Weld Epoxy Adhesive DP420 is used to bond all layers together and to the hull on each half. This is all depicted in **Fig. 4** below.

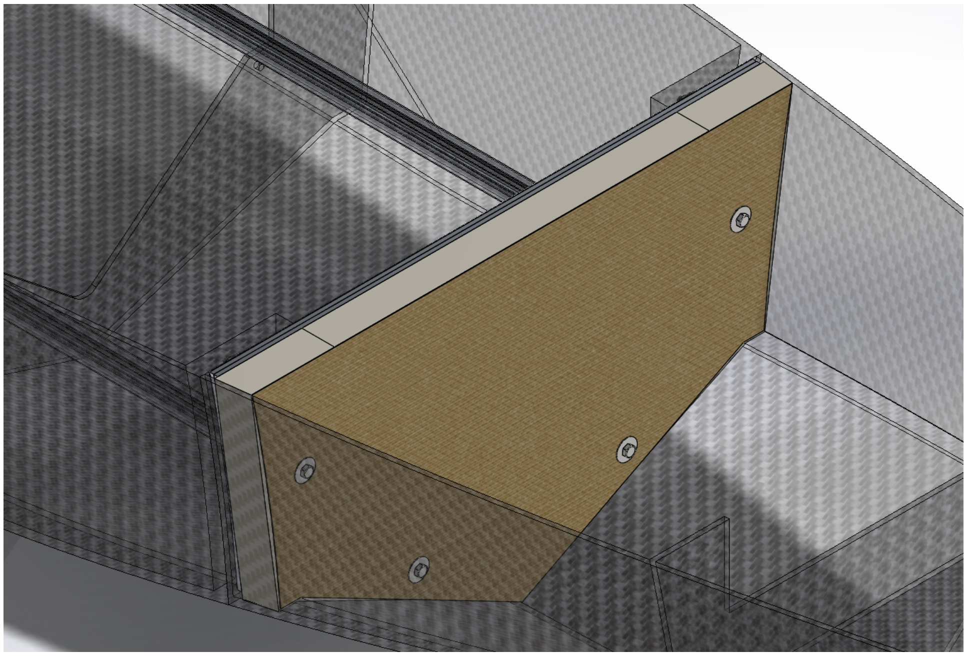


Fig. 4. *New bulkhead in Solidworks that will be attached to the bow section.*

   This would add weight to the fore, so changes were made to move as much weight aft as possible, and reduce weight where deemed necessary. In removing all subsystems for the hull cutting operation, the weight and center of mass of the bare hull and frame could be measured, and its condition inspected. If repairs were required, it would be significantly easier to do with the hull in its lightest configuration. As there is proof of significant efforts made for optimizing the performance of the hull at the originally intended waterline, the overall weight of the boat was kept nearly the same, but the center of mass was shifted backwards for the Sprint and Slalom races to get onto plane faster.

3) ***Design Testing and Evaluation:*** Prior to cutting the boat in half, the hull was tested for a drag coefficient by a pull test on the water. The hull was towed through the water at a known constant speed, and the force required to pull it at that speed was recorded. The hull drag coefficient was calculated to be 0.446, provided an average velocity of 1.16 m/s and an average drag force of 26.55 N.

   The adhesive and composite materials used were evaluated for shearing performance, due to most adhered surfaces, if not in compression, being shear on this part. A sample of foam was adhered with strips of carbon fiber laminate, and tested for three point bending as seen in **Fig. 5**. The Ncorr program, a MATLAB program for 2D image correlation, was utilized to analyze the sample before and after loading, and shear strain was calculated, as can be seen in **Fig. 6**. The shearing modulus was then calculated to be 1.1×10^6 PSI.

Fig. 5. *Test sample for adhesive with foam core composite in three point bending.*

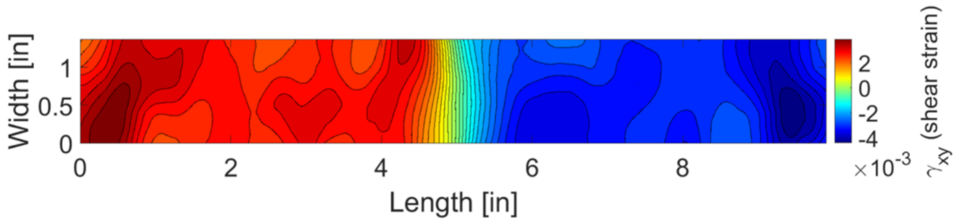


Fig. 6. *Shear strain plot in relation to location across the face of the test sample in bending.*

With this data in hand, we moved on to produce the final assembly. The boat was cut using a reciprocating saw, and after cutting, all damage to the hull was patched with TotalBoat TotalFair Fairing Compound mixed with graphite. An additional layer of epoxy was used to resurface the hull, but its effect on drag is not yet tested.

With the hull emptied, the weight and location of the center of mass could be measured. The whole hull turned out to weigh close to 115 lb, which is 30 lb heavier than the 2019 estimate, but included parts of the rail frame and not just the bare hull. The bulkhead would add an estimated 6 lb, so the frame was lightened by removing the inner set of rails, moving the top rails to the inside, and cutting the new inner rails down 2 feet to only be 8 feet long. The resulting changes made the frame 23 lb lighter, bringing the total weight of the complete hull to 98 lb. The center of mass was also found to be directly above the center of buoyancy when the hull was level, which is approximately 52 inches from the transom, so the weight can be distributed evenly for Endurance, and made to be tailheavy for Sprint and Slalom.

With the halves reattached as shown in **Fig. 7** , the boat was loaded in three point bending where the frontmost portion of the boat and the transom were supported by the ground, and the entire boat rested atop it, and was empirically loaded. The attachment points were secure enough to support the whole weight of the boat plus skipper and extra load for safety factor in three point bending.

Fig. 7. *Bow and stern sections reattached and free-floating.*

E. Drivetrain and Steering

1) ***Current Design:*** The current drivetrain was a design brought over from the 2015 boat, and can be broken down into two key components, the inner and outer drivetrain. The inner drivetrain consisted of two AGNI 95r motors chained to a single shaft that leads to the outer drivetrain, which was supported by a separate flange mounted bearing and a bearing pressed into the hull. The outer drivetrain takes the power through a double-Cardan joint and gimbal unit, and to the final inner propeller shaft, which passes through a sleeve assembly and turns the propeller. A render of the whole drivetrain assembly is shown in **Fig. 8**. A linear actuator is also attached to the sleeve from the transom, which allows for the skipper to trim the position of the outer drivetrain until the optimal position of the propeller is reached. Ideally, half of the propeller should be submerged in the water and the other half should be above the water level to achieve the best performance. However, upon testing, observations were made that the propeller should be farther submerged just below the water surface for maximum speed, and closer to parallel with the surface of the water to get onto plane faster. For the 2023 iteration, we would like to modify the location of the propeller shaft, lowering it to fully submerge the propeller for increased power and increased maximum speed.

Fig. 8. *Inner and outer drivetrain unit for the 2022 boat.*

The current steering system design adopts a rack and pinion mechanism in the front of the boat to convert the rotation of the steering wheel to a linear pushing and pulling force, as can be seen in **Fig. 9**, which is transferred to the back of the boat by means of push-pull (control) cables. These cables are ideal for a steering system, as they can exert force in both directions, so whenever the steering wheel is turned, one cable is pushing on the drivetrain while the other is simultaneously pulling the drivetrain in the opposite direction. In our current setup, the skipper only needs to rotate the steering wheel 1.5 times to go from one extreme to the other, and uses clamps and J-hooks to hold the steering cables rigidly in place. However, the whole system was redundant, was heavy, bulky, and was determined to impede skipper egress. For the 2023 iteration, the main components should be kept the same, but the whole system should be made more compact and lighter.

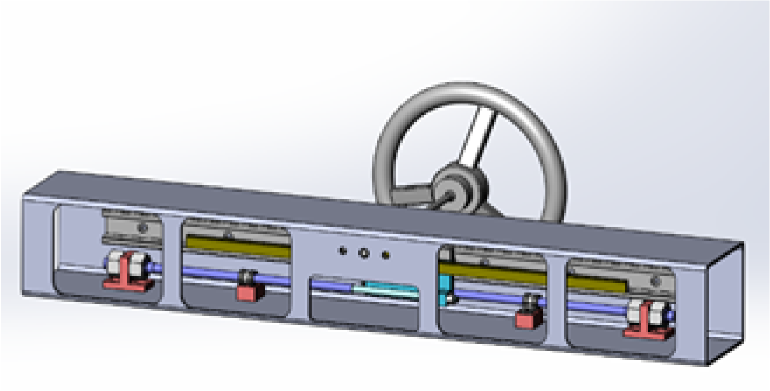


Fig. 9. *Rack and pinion steering system used in the 2022 boat.*

The current design for the throttle is a foot actuated pedal salvaged from an electric golf cart. The team found later that the foot pedal did not actuate fully from 0 to 5 kΩ, instead stopping short, thus not allowing the boat to reach 100% throttle. The pedal was also difficult to hold at a constant speed, while it was suitable for fine control such as needed in Slalom. For the 2023 iteration, the throttle should be changed to a system that is actuated by hand.

2) ***Analysis of Design Concepts:*** This year, the team opted to not change the inner drive train as it still functioned at the desired efficiencies. The team also chose not to redesign the entire outer drivetrain system and decided to design a drop-down gearbox to mount to the motor output, lowering the propeller shaft's centerline and fully submerging the propeller. In previous years, we utilized a surface piercing propeller system, but the team found that we would benefit from a fully submerged propeller. To do so, we constructed a gearbox that will move the shaft centerline down by 4 inches and uses a 1:1 gear ratio. The gearbox utilized a clamshell design and was machined using 6061 alloy aluminum for ease of machining. Within the gearbox walls, the team designed bores to fit R10-2RS ball bearings for the gears and their shafts to fit onto. Sprockets and chains were considered for this purpose, but there was not a suitable combination of chain and sprocket that would endure the peak power output of nearly 30 HP from the motors within the space constraints. The gearbox will be assembled onto the back of the boat bridging the inner and outer drivetrains. The gearbox is then filled with oil and sealed. Below in **Fig. 10** is the CAD of the gearbox.

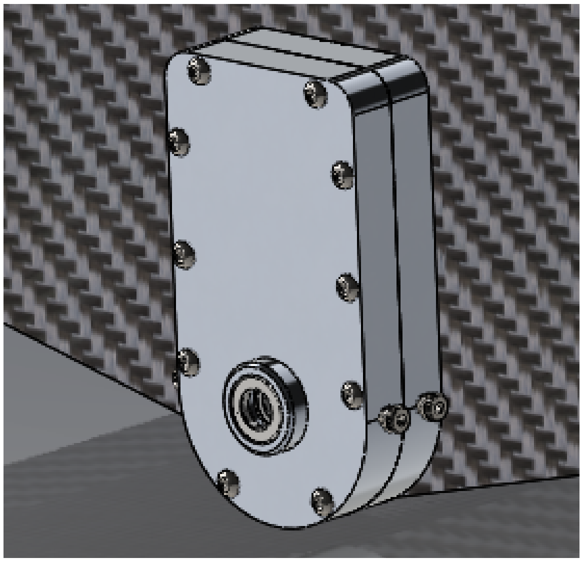


Fig. 10. *CAD rendition of the drop-down gearbox unit in Solidworks.*

The redesigned steering system would reuse many of the same components from the original steering system, but critically would eliminate the steel box frame, and no longer straddle the skipper. Instead, the steering system would be entirely mounted to one side of the boat on the inner rails and use a single push-pull cable. The steering would also rotate the pivot of the linear actuator, instead of directly moving the sleeve, as this would reduce the length of cable needed. A tiller was considered for this application, being that it is the simplest solution with hardly any moving parts, but the fine resolution control this system could not afford for the skipper was a major factor in its decision to not adopt it.

We have redesigned the throttle from a foot pedal to a hand based slide throttle. The throttle has an impedance range from 0 to 5 kΩ. One benefit of this throttle design is that it does not require constant skipper attention, since there is no return spring that pushes the throttle back to a home position, or 0% throttle. It will be beneficial for Endurance since a constant speed will allow the skipper to reduce the amount of systems that require attention. Since we are also wiring a motor controller for each motor, two potentiometers were needed, one for each motor controller. It was needed for them to maintain similar or equal resistance for proper motor throttle percentage, therefore a handle was added that moves both slides in tandem. We also had considered a previous throttle design which used a gear pair and a knob potentiometer, as seen in **Fig. 11**. However, due to the change to separate motor controls for each motor, we had to scrap this idea since it was not feasible for controlling two potentiometers. The idea was scrapped in favor of the newest iteration, **Fig. 12**.

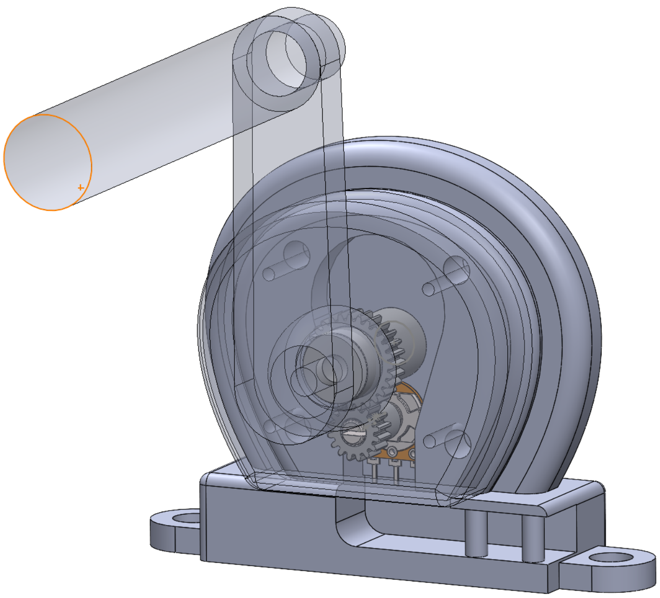


Fig. 11. *Gear pair and potentiometer knob throttle (previous iteration).*

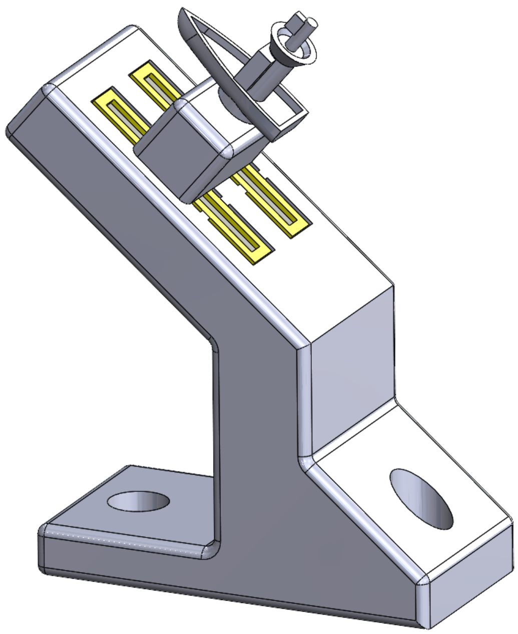


Fig. 12. *The slide potentiometer with mount & slider handle.*

3) ***Design Testing and Evaluation:*** Our system has yet to be tested in an active environment where the boat is running on water. The new gearbox is currently being machined due to compounding delays in production, but is expected to be ready for the 2023 Solar Splash. If in the event it cannot be manufactured in time, the gearbox is simply a bridging unit, so it can be omitted and the progress can be reversed to revert the boat back to its original state in 2022. The steering unit likewise faces similar manufacturing hurdles, but the core components have not changed, and thus it is not a concern if they do not get finalized in time. The throttle could be better optimized by changing the potentiometers used. Currently, the potentiometers are exponentially tapered, meaning that the motor activation will not be proportional to the displacement of the throttle. Instead, we could use linear taper potentiometers to allow for more consistent and accurate motor control.

F. Data Acquisition and Communications

1) ***Current Design:*** The data acquisition system that was to be used in the 2022 Solar Splash competition consisted of a Raspberry Pi as the central server for data aggregation. The data was displayed to the skipper via a touch-screen display which contained a GUI developed from Python. The system was powered by a buck converter which dropped the voltage from the 12V auxiliary battery to 5V. A low dropout regulator was used to smooth out ripple voltages and provide a stable voltage reference to the ADS1115 ADC breakout board. Two shunt resistors, consisting of a 2:1 differential multiplexer and an instrumental amplifier, were in place to measure the current delivered by the solar panels to the system and the current delivered to the load. The total battery charge current could be calculated by finding the difference between these currents. The DAQ set out to measure boat velocity through a mini-GPS breakout board from Adafruit, using the difference in position relative to time elapsed. The Raspberry Pi would gather data through sensors via I2C or ADC channels and then send them every second to a MongoDB database for storage.

   Ultimately, the data acquisition system failed and we were unable to collect data remotely from the boat or display information to the skipper. This was caused by overall design flaws and the Pi's inability to send messages back to the shore due to radio range inadequacies. In the next iteration of the data acquisition system, we would like to take a different approach to its design and attempt to simplify the hardware used.

2) ***Analysis of Design Concepts:*** The data acquisition system that was designed and implemented this year consists of relaying information to both the skipper and an offshore laptop, where data can be viewed in real time and stored for analysis. The system measures solar charging current and voltage, motor current and voltage, battery current and voltage, prop shaft RPM, motor temperature, motor controller temperature, and GPS location. The LCD screen on the dashboard will display voltage, current, and speed, information considered most vital to the skipper, while the offshore laptop will receive all data collected. The data collected is displayed on a GUI as well as saved into a csv file.

a) **Sensor interface:** The overview of the new DAQ can be abstracted into the first diagram, found in Appendix F, **Fig. F1,** which shows the initial logical data flow block diagram of the new DAQ for sensor data. There are six total aspects of the DAQ design referenced by this diagram.

1) ***Power regulation:*** The battery output is fed into a switching buck converter which will efficiently reduce the voltage down to 5V to make it compatible with the rest of the digital electronics. It is followed by a low dropout regulator which will smooth out any ripple and provide a stable reference voltage.

2) ***Current preprocessing:*** We used a series of L37S600S05Ms by Tamura, a hall effect sensor, to measure current from the various points of the boat's electrical and solar system. The analog data is then filtered and then fed to an external ADC. Further testing is needed to evaluate whether we will use an active or passive low pass filter. From the ADC, the digital data is sent to the STM32F072's I2C bus to be processed.

3) ***State of charge:*** The battery voltage is taken as either S1- or S2+ and digitized through the ADC, then read directly by the STM32F072. The state of charge is calculated via a lookup table for lead-acid batteries. To prevent damage, we should consider a SOC (state of charge) of 30% to be empty. See the reference table in Appendix F, **Fig. F2**, which shows the relationship between a battery's state of charge and its voltage level at various current draws.

4) ***I2C bus devices***: The STM32F072 communicates through I2C with the external ADC and LCD display. The ADC converts all input currents from the power electronic circuitry to digital signals to be read by the STM32F072. Another benefit of this design is that no special protocol like CAN/LIN (controller area network/local interconnect network) is required, which is often used in automobiles. However, only a few select microcontrollers have the serial hardware built-in.

5) ***SPI bus devices:*** The STM32F072 uses SPI to communicate with the MAX31865 RTD-to-Digital Converter. The MAX31865 converts the input resistance received by a platinum tipped 1000Ω resistance temperature detector into digital signals that can be easily read by the STM32F072. [10,11]

6) ***USART devices*****:** The STM32F072 communicates through USART with the Air530 GPS which sends serial data that gives information about positioning. The microcontroller also communicates with the Reyax RLYR896 in a similar manner. The RYLR896 uses the LoRa protocol and

AT Commands to send low byte data over far distances. [12] Another radio will receive the data and relay it to a laptop.

b) **Data aggregation:** The STM32F072 Discovery Board is our main system that serves as the skipper of all data aggregation. Raw data is received directly from the sensor interface by reading the ADC channel while selecting GPIO pins for the multiplexer. For the raw GPS values, the STM32F072 receives them via USART. While the data is being received as a continuous stream, the raw data values are sent to an external laptop GUI, using a Python script, every second with the data being saved in a csv file. An initial potential design for this GUI can be seen in Appendix F, **Fig. F3.** Thus, all our data can be saved in a centralized location.

A Data Analytics Platform is being developed for the new DAQ system which will provide a dashboard and analysis of data. Javascript is used both as a backend to collect and process the data, and as the frontend to display it. The front and backend are to be connected to each other through websockets built in Node.js. Data is stored in an SQL database & analyzed with Python. When the DAQ is unavailable, a mock data generator built using C++ may be implemented to simulate incoming data from the boat.

c) **Display:** There is a LCD display that is connected to the STM32F072 running our software, a C program to show the skipper the most recent values from the aggregated data.

3) ***Design Testing and Evaluation:*** Our system has yet to be tested in an active environment where the boat is running on water. We were able to test data acquisition when the boat's systems were running on land and found that the data collected in the STM32F072 was highly accurate in comparison to measurements gathered using off the shelf instruments.

III. Project Management

A. Team Organization

The 2022-2023 Stony Brook Solar University Solar Racing team continues to be led by our Executive Board who handles the administrative duties of the team. This ranges from maintaining the club's budget, to increasing membership, to overseeing the three sub-teams, and more. These subteams are mechanical, electrical, and software, each managed by their own team lead who are responsible for their portion of the boat. Projects and deadlines are assigned by leads to their respective sub-teams each week. Sub-teams meet once a week similar to last year's structure, however we now have two days instead of one where all sub-teams come in to collaborate with one another. This change allowed the team to complete bigger projects while encouraging more interaction between sub-teams.

B. Project Plan and Schedule

For the 2022-23 school year, the team has had a series of both land and wet tests prior to the competition. Land tests were conducted to ensure the functionality and successful operation of all mechanical and electrical systems before the boat is tested in water. This year, the team has had two scheduled wet tests at Lake Ronkonkoma: one early in the Fall 2022 semester and one late in the Spring 2023 semester. Tentatively, there are plans to conduct another wet test in the summer right before competition. The objective of these west tests include floating tests, stability tests, speed tests using various propeller designs, as well as testing newly integrated mechanical systems and data acquisition systems . The team's designated skippers also use this time to familiarize themselves with the boat. During the wet tests, members of each subteam are present to assist with preparing and lowering the boat into the water as well as observing and troubleshooting issues during the tests. After each wet test, the team reviews and analyzes the retrieved data to optimize various subsystems in the boat.

C. Finances and Fundraising

The Stony Brook Solar Racing Team receives a large portion of its funding from the university's Undergraduate Student Government (USG), which attains its funding for clubs like ours from the Student Activity Fee. For the 2022-2023 academic year, we fully utilized a ~$4300 budget which went towards boat materials, tools, and other equipment for our shop as well as school events which helped with the promotion of our club and its purpose.

In addition, Solar Racing receives funding from Stony Brook's College of Engineering and Applied Sciences (CEAS), which funds Solar Racing on a request-by-request basis. Solar Racing also has funds donated by recent alumni. Furthermore, the establishment and preservation of relationships with sponsors and alumni are essential to the continued growth and success of the team. Reflecting the importance of this is the Solar Racing Team's Business Lead, who is responsible for updating and distributing a quarterly newsletter, which updates sponsors on team progress.

D. Team Continuity and Sustainability Strategy

With over half of this year's competition-going members consisting of seniors, team continuity and sustainability has become a primary focus for the team and the incoming executive board. We do not expect many new members to get the chance to compete at Solar Splash due to housing and financial constraints of the team every year, so to ensure growth even in the event that the team does not compete, we are pursuing the idea of an internal competition that will teach the basics of competition and its rules on an accelerated time scale, and give our members a competition experience based on Solar Splash. Running a large-scale event on campus will ensure longevity of the program, so long as there are members excited to participate in it, and will use these opportunities to teach our members the skills they need to succeed, and will be in conjunction with our team leads who mentor their members using projects on the boat.

The incoming executive board has been joining the current executive board's meetings to understand what their roles will be going forwards, and how to undertake them. Each member of the board is mentoring their successor directly to ensure the transition process after the competition is as smooth as possible. This will allow the team to immediately be able to start working for next year's competition.

E. Discussion and Self-Evaluation

Because the team had attended the competition last year, we attempted to improve on the systems that we had tested in competition for the first time last year. In the beginning of the year, we had many ideas about what we wished to change about the system. As the year went on, we realized that we were unsure about how to actually implement the changes that we wanted to accomplish. The first semester, we were mainly doing design work and not too much physical work on the boat, other than determining how to properly cut the boat. We were a bit overwhelmed by the amount of work the goals we set for ourselves had. After the boat was cut at the end of the first semester, we were able to start working on the boat in earnest due to the fact that it was more convenient for us. We contacted a few companies of components that we had and got supplies donated to us, such as a new motor controller from Alltrax. The electrical team was able to work on the motor circuit because it was rebuilt outside of the boat. However, because the mechanical team's main focus was reassembling the boat, the other projects had to be set aside until the main focus was finished. This caused updates to the mechanical systems to be slower than we expected which set back testing the whole system. We may have been a bit too ambitious with all our initial ideas, but we will have a finished updated boat for competition.

IV. Conclusions and Recommendations

The mechanical team had a critical task this year of reassembling the boat after cutting it apart. This task was monumental since it required a design that would allow for the boat to separate and reattach without taking on too much water. However, it also gave the whole team a huge opportunity to reconfigure some designs as well as to optimize the weight distribution of the boat. Moving the batteries aft allowed for the boat to not pitch forwards as it did the year before. There was a heavy emphasis this year on optimization of the mechanical systems, such as redesigning the gearbox and drivetrain mechanisms for a fully-submerged dropdown propeller as well as improved mounting of the steering system for improved feedback. The team worked tirelessly to reconfigure the boat for improved performance and the changes should be evident in the competition results. If in the event that the hull does not perform optimally at competition, there should be ample budget next year to facilitate a whole hull redesign. Scheduling should be done in advance for all machining tasks, as this turned out to be a large hurdle in producing many parts on time. While impractical at some times, prioritize acquisition of parts rather than their production.

The electrical team should focus on replacing components, such as batteries and solar chargers, and improving cable management. New batteries should be purchased so that all 100 lbs of batteries may be used in all configurations, and there can be more flexibility in selecting battery system voltage. Design work should be completed before the end of the fall semester if possible so that the spring semester can be spent assembling and testing the boat and making changes based on the data that is collected. We received valuable information by contacting the manufacturers of our components, and future teams should not hesitate to reach out to these companies with questions. Better collaboration between teams is always needed, and should be a priority in the future. The possibility of using more power dense solar panels, or using a design that better makes use of the unique properties of our current sensors should be investigated.

The software team should improve upon the data analytics platform that was developed this year when the system is tested in an active environment with the boat running in water. While the team has filtering and amplification put into place to anticipate electrical noise, further testing should reveal areas of inadequacy. We can expand upon our telemetry system with additional measurements such as throttle position, other useful metrics may reveal themself as we further test the boat. The display on the skipper dashboard display as well as the off-shore laptop can also be improved upon when the observers view live data.

Overall the entire team should learn from our experiences at competition this summer and work to identify and remove performance bottlenecks. We should also make an effort to make the club engaging for new members, and to provide more hands-on engineering experience. Our club has also made and will make future efforts to promote the usage of solar energy as a viable energy source in the future, as well as renewable energy and sustainable transportation as a whole. Placing well in the Solar Splash competition and hosting renewable energy themed events will contribute to increased member retention and the legitimacy of our club's and Solar Splash's purpose at Stony Brook University.

V. References

[1] "Guidelines for Writing the Solar Splash Technical Report." *Solar Splash,* 17 June 2017, https://solarsplash.com/wp-content/uploads/2014/10/TechReportGuidelines_2017_06_17.pdf

[2] "Technical Report 2022." *Stony Brook Solar Racing Team,* https://docs.google.com/document/d/1YwrTb8HOoiZmt4qtorCETlvvIlF3eRMnr1ILCXk6akI/edit?usp=sharing

[3] "Axe to Permanent Magnet Motor." *Alltrax,* https://alltraxinc.com/wp-content/uploads/2017/03/Doc100-047-A_DWG-AXE-PermMag-wire-dia.pdfS

[4] "SR Series Controllers" *Alltrax,*

https://alltraxinc.com/sr-series/#model

[5] "High-Current Vehicle Relay." *McMaster-Carr,* https://www.mcmaster.com/7995K24/

[6] "Performance Graphs 95 Series." *Agni Motors,* https://drive.google.com/file/d/0B7_0vIYZo8L9M2tJbzRYZV94bFU/view?usp=sharing&resourcekey=0-qq_J8aBTKzlVFeQDqsllxA

[7] "L37S600S05M" *Digikey*

https://www.digikey.com/en/products/detail/tamura/L37S600S05M/11696424

[8] "INA128PA." *Mouser Electronics,* https://www.mouser.com/ProductDetail/Texas-Instruments/INA128PA?qs=VBduBm9rCJQJnrDRwX514g%3D%3D

[9] "109020022" *Digikey*

https://www.digikey.com/en/products/detail/seeed-technology-co-ltd/109020022/12323450?s=N4IgTCBcDaIOYCcD2A3ApgAgIYEsEFYBmABhAF0BfIA

[10] "Adafruit PT1000 RTD Temperature Sensor Amplifier - MAX31865" *Adafruit*

https://www.adafruit.com/product/3648?gclid=EAIaIQobChMIzrzGyez8_QIVKcmUCR1SEA4_EAQYAyABEgL0L_D_BwE

[11] "3984" *Digikey*

https://www.digikey.com/en/products/detail/adafruit-industries-llc/3984/9808307

[12] "RYLR896" *Reyax*

https://reyax.com/products/rylr896/

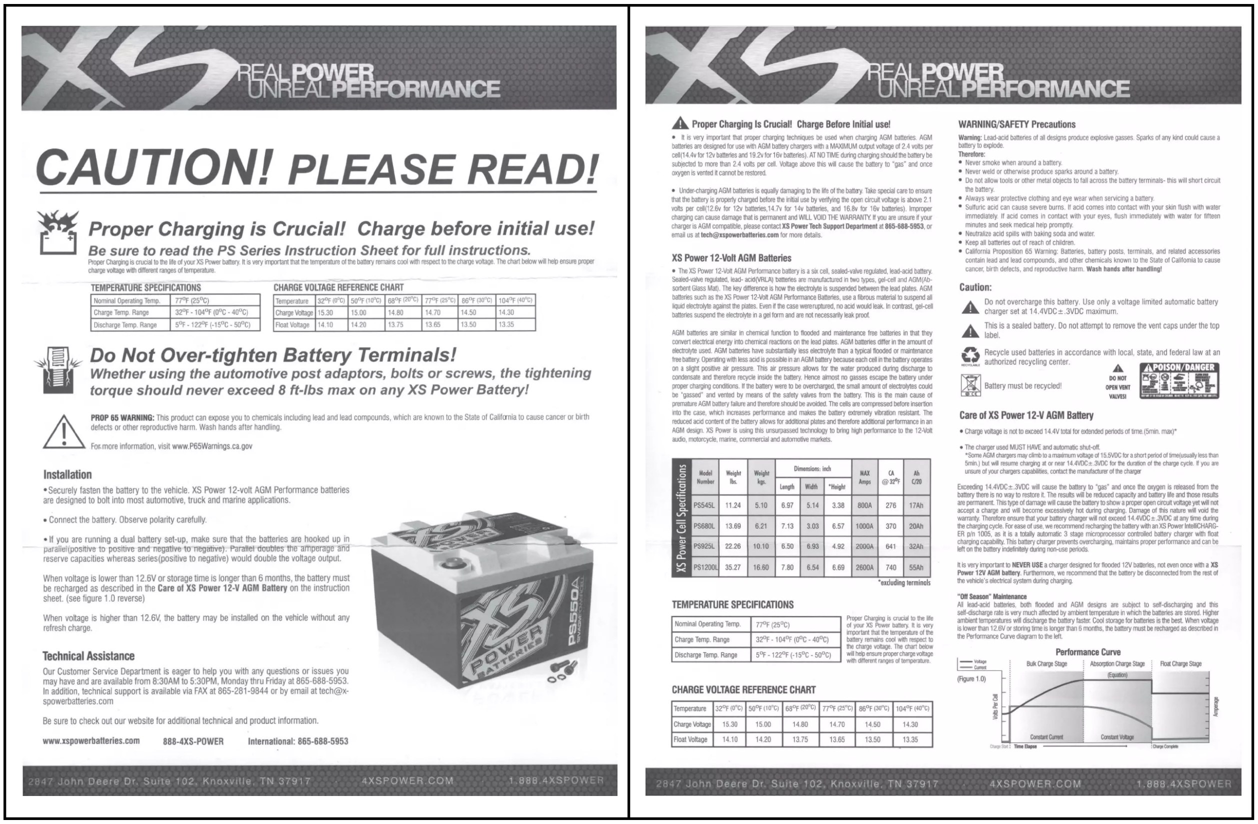
[13] "stm32F072B DISCOVERY" *STMicroelectronics*

https://www.st.com/en/evaluation-tools/32f072bdiscovery.html

VI. Appendices

Appendix A: Battery Documentation

Documentations of the two different sets of batteries that will be used during Solar Splash.



REAL POWER UNREAL PERFORMANCE

CAUTION! PLEASE READ!

Proper Charging is Crucial! Charge before initial use!

Be sure to read the PS Series Instruction Sheet for full instructions.

Proper Charging is crucial to the life of your XS Power battery. It is very important that the temperature of the battery remains cool with respect to the charge voltage. The chart below will help ensure proper charge voltage with different ranges of temperature.

TEMPERATURE SPECIFICATIONS

Nominal Operating Temp.	77°F (25°C)
Charge Temp. Range	32°F - 104°F (0°C - 40°C)
Discharge Temp. Range	5°F - 122°F (-15°C - 50°C)

CHARGE VOLTAGE REFERENCE CHART

Temperature	32°F (0°C)	50°F (10°C)	68°F (20°C)	77°F (25°C)	86°F (30°C)	104°F (40°C)
Charge Voltage	15.30	15.00	14.80	14.70	14.50	14.30
Float Voltage	14.10	14.20	13.75	13.65	13.50	13.35

Do Not Over-tighten Battery Terminals!

Whether using the automotive post adaptors, bolts or screws, the tightening torque should never exceed 8 ft-lbs max on any XS Power Battery!

PROP 65 WARNING: This product can expose you to chemicals including lead and lead compounds, which are known to the State of California to cause cancer or birth defects or other reproductive harm. Wash hands after handling.

For more information, visit www.P65Warnings.ca.gov

Installation

• Securely fasten the battery to the vehicle. XS Power 12-volt AGM Performance batteries are designed to bolt into most automotive, truck and marine applications.

• Connect the battery. Observe polarity carefully.

• If you are running a dual battery set-up, make sure that the batteries are hooked up in parallel(positive to positive and negative to negative). Parallel doubles the amperage and reserve capacities whereas series(positive to negative) would double the voltage output.

When voltage is lower than 12.6V or storage time is longer than 6 months, the battery must be recharged as described in the **Care of XS Power 12-V AGM Battery** on the instruction sheet. (see figure 1.0 reverse)

When voltage is higher than 12.6V, the battery may be installed on the vehicle without any refresh charge.

Technical Assistance

Our Customer Service Department is eager to help you with any questions or issues you may have and are available from 8:30AM to 5:30PM, Monday thru Friday at 865-688-5953. In addition, technical support is available via FAX at 865-281-9844 or by email at tech@xspowerbatteries.com

Be sure to check out our website for additional technical and product information.

www.xspowerbatteries.com **888-4XS-POWER** **International: 865-688-5953**

2847 John Deere Dr. Suite 102, Knoxville, TN 37917 · 4XSPOWER.COM · 1.888.4XSPOWER

REAL POWER UNREAL PERFORMANCE

Proper Charging Is Crucial! Charge Before Initial use!

• It is very important that proper charging techniques be used when charging AGM batteries. AGM batteries are designed for use with AGM battery chargers with a MAXIMUM output voltage of 2.4 volts per cell(14.4v for 12v batteries and 19.2v for 16v batteries). AT NO TIME during charging should the battery be subjected to more than 2.4 volts per cell. Voltage above this will cause the battery to "gas" and once oxygen is vented it cannot be restored.

• Under-charging AGM batteries is equally damaging to the life of the battery. Take special care to ensure that the battery is properly charged before the initial use by verifying the open circuit voltage is above 2.1 volts per cell(12.6v for 12v batteries,14.7v for 14v batteries, and 16.8v for 16v batteries). Improper charging can cause damage that is permanent and WILL VOID THE WARRANTY. If you are unsure if your charger is AGM compatible, please contact **XS Power Tech Support Department** at **865-688-5953**, or email us at **tech@xspowerbatteries.com** for more details.

XS Power 12-Volt AGM Batteries

• The XS Power 12-Volt AGM Performance battery is a six cell, sealed-valve regulated, lead-acid battery. Sealed-valve regulated, lead- acid(VRLA) batteries are manufactured in two types, gel-cell and AGM(Absorbent Glass Mat). The key difference is how the electrolyte is suspended between the lead plates. AGM batteries such as the XS Power 12-Volt AGM Performance Batteries, use a fibrous material to suspend all liquid electrolyte against the plates. Even if the case were ruptured, no acid would leak. In contrast, gel-cell batteries suspend the electrolyte in a gel form and are not necessarily leak proof.

AGM batteries are similar in chemical function to flooded and maintenance free batteries in that they convert electrical energy into chemical reactions on the lead plates. AGM batteries differ in the amount of electrolyte used. AGM batteries have substantially less electrolyte than a typical flooded or maintenance free battery. Operating with less acid is possible in an AGM battery because each cell in the battery operates on a slight positive air pressure. This air pressure allows for the water produced during discharge to condensate and therefore recycle inside the battery. Hence almost no gasses escape the battery under proper charging conditions. If the battery were to be overcharged, the small amount of electrolytes could be "gassed" and vented by means of the safety valves from the battery. This is the main cause of premature AGM battery failure and therefore should be avoided. The cells are compressed before insertion into the case, which increases performance and makes the battery extremely vibration resistant. The reduced acid content of the battery allows for additional plates and therefore additional performance in an AGM design. XS Power is using this unsurpassed technology to bring high performance to the 12-Volt audio, motorcycle, marine, commercial and automotive markets.

XS Power Cell Specifications

Model Number	Weight lbs.	Weight kgs.	Dimensions: inch Length	Width	*Height	MAX Amps	CA @ 32°F	Ah C/20
PS545L	11.24	5.10	6.97	5.14	3.38	800A	276	17Ah
PS680L	13.69	6.21	7.13	3.03	6.57	1000A	370	20Ah
PS925L	22.26	10.10	6.50	6.93	4.92	2000A	641	32Ah
PS1200L	35.27	16.60	7.80	6.54	6.69	2600A	740	55Ah

*excluding terminals

TEMPERATURE SPECIFICATIONS

Nominal Operating Temp.	77°F (25°C)
Charge Temp. Range	32°F - 104°F (0°C - 40°C)
Discharge Temp. Range	5°F - 122°F (-15°C - 50°C)

Proper Charging is crucial to the life of your XS Power battery. It is very important that the temperature of the battery remains cool with respect to the charge voltage. The chart below will help ensure proper charge voltage with different ranges of temperature.

CHARGE VOLTAGE REFERENCE CHART

Temperature	32°F (0°C)	50°F (10°C)	68°F (20°C)	77°F (25°C)	86°F (30°C)	104°F (40°C)
Charge Voltage	15.30	15.00	14.80	14.70	14.50	14.30
Float Voltage	14.10	14.20	13.75	13.65	13.50	13.35

WARNING/SAFETY Precautions

Warning: Lead-acid batteries of all designs produce explosive gasses. Sparks of any kind could cause a battery to explode.

Therefore:

- Never smoke when around a battery.
- Never weld or otherwise produce sparks around a battery.
- Do not allow tools or other metal objects to fall across the battery terminals- this will short circuit the battery.
- Always wear protective clothing and eye wear when servicing a battery.
- Sulfuric acid can cause severe burns. If acid comes into contact with your skin flush with water immediately. If acid comes in contact with your eyes, flush immediately with water for fifteen minutes and seek medical help promptly.
- Neutralize acid spills with baking soda and water.
- Keep all batteries out of reach of children.
- California Proposition 65 Warning: Batteries, battery posts, terminals, and related accessories contain lead and lead compounds, and other chemicals known to the State of California to cause cancer, birth defects, and reproductive harm. **Wash hands after handling!**

Caution:

Do not overcharge this battery. Use only a voltage limited automatic battery charger set at 14.4VDC±.3VDC maximum.

This is a sealed battery. Do not attempt to remove the vent caps under the top label.

Recycle used batteries in accordance with local, state, and federal law at an authorized recycling center.

Battery must be recycled!

DO NOT OPEN VENT VALVES!

POISON/DANGER

Care of XS Power 12-V AGM Battery

• Charge voltage is not to exceed 14.4V total for extended periods of time.(5min. max)*

• The charger used MUST HAVE and automatic shut-off.
*Some AGM chargers may climb to a maximum voltage of 15.5VDC for a short period of time(usually less than 5min.) but will resume charging at or near 14.4VDC±.3VDC for the duration of the charge cycle. If you are unsure of your chargers capabilities, contact the manufacturer of the charger

Exceeding 14.4VDC±.3VDC will cause the battery to "gas" and once the oxygen is released from the battery there is no way to restore it. The results will be reduced capacity and battery life and those results are permanent. This type of damage will cause the battery to show a proper open circuit voltage yet will not accept a charge and will become excessively hot during charging. Damage of this nature will void the warranty. Therefore ensure that your battery charger will not exceed 14.4VDC±.3VDC at any time during the charging cycle. For ease of use, we recommend recharging the battery with an XS Power IntelliCHARGER p/n 1005, as it is a totally automatic 3 stage microprocessor controlled battery charger with float charging capability. This battery charger prevents overcharging, maintains proper performance and can be left on the battery indefinitely during non-use periods.

It is very important to **NEVER USE** a charger designed for flooded 12V batteries, not even once with a **XS Power 12V AGM battery**. Furthermore, we recommend that the battery be disconnected from the rest of the vehicle's electrical system during charging.

"Off Season" Maintenance

All lead-acid batteries, both flooded and AGM designs are subject to self-discharging and this self-discharge rate is very much affected by ambient temperature in which the batteries are stored. Higher ambient temperatures will discharge the battery faster. Cool storage for batteries is the best. When voltage is lower than 12.6V or storing time is longer than 6 months, the battery must be recharged as described in the Performance Curve diagram to the left.

Performance Curve

(Figure 1.0)

2847 John Deere Dr. Suite 102, Knoxville, TN 37917 · 4XSPOWER.COM · 1.888.4XSPOWER

Fig. A1. *XS Power PS925L Battery Documentation Sheet*

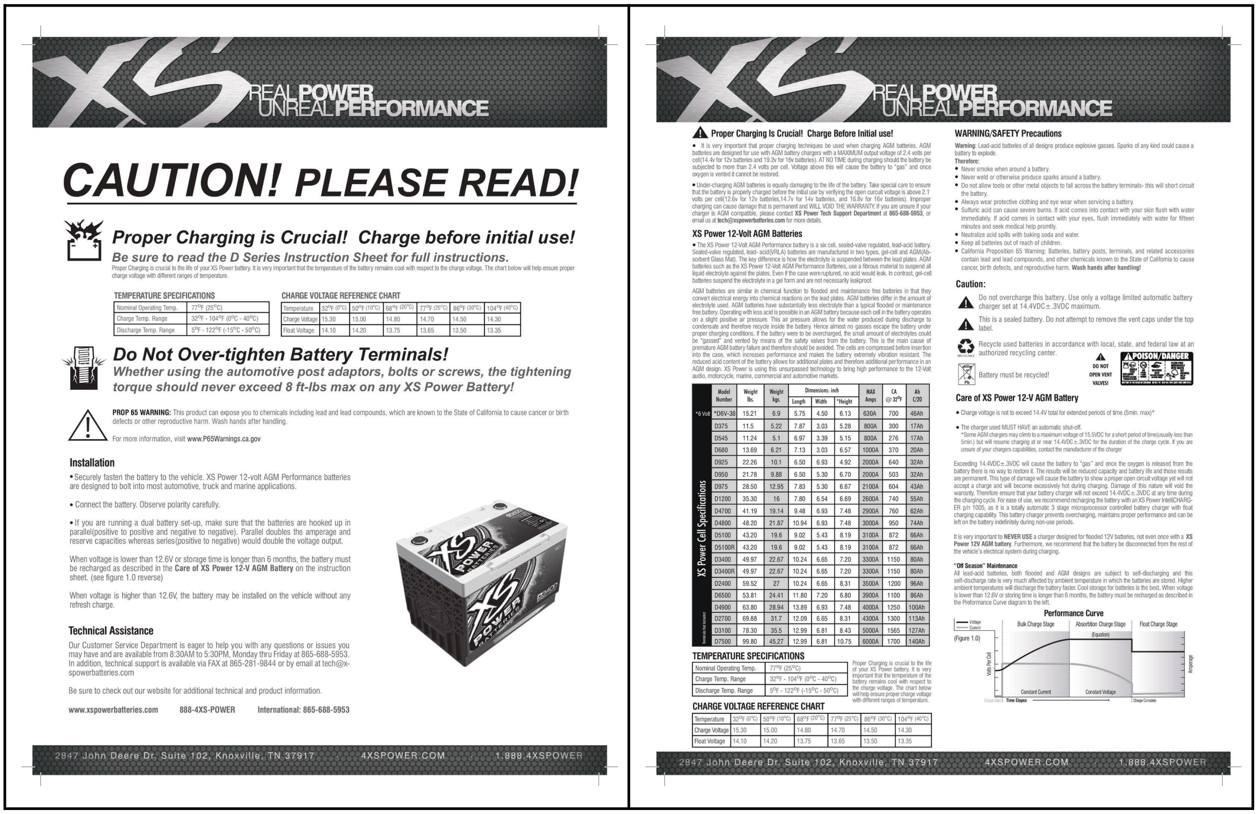


Fig. A2. XS Power D1200 Battery Documentation Sheet

Appendix B: Flotation Calculations

Our boat weighs approximately 342 lbs across all sections, with the weight distribution among systems and items shown below in **Table B.1**.

The means of flotation are separated into two parts, one for each section of the boat. The bow and stern portions of the boat, due to being possible to separate into two distinct units, will each have their own means of flotation in the event of separation that will still satisfy the requirements of Rule 7.14.2. The weight distribution for both sections is seen below in **Table B.2**. For all calculations, the specific weight of water, γ_W, will be 62.4 lb/ft^3.

In the bow of the hull is an enclosed volume V_{Bow} of 2.47 ft^3 filled with closed-cell expanding polyurethane (PU) foam with a specific weight γ_{PU} of 2 lb/ft^3. Multiplying V_{Bow} by the difference of specific weights of water and foam, we get a buoyant force $F_{b,\,Front}$ of 149.188 lb.

$$\begin{aligned} F_{b,\,Front} &= V_{Bow} \cdot \left(\gamma_W - \gamma_{PU}\right) \\ &= 2.47\, ft^3 \cdot \left(62.4\, lb/ft^3 - 2\, lb/ft^3\right) \\ &= 149.188\, lb \end{aligned}$$

The weight of the bow is 36 lb, and with the additional 20% safety factor, results in a minimum required buoyant force of 43.2 lb. Due to the buoyant force for the bow exceeding the minimum required flotation of the boat section with additional safety factor, Rule 7.14.2 is satisfied for the bow.

Along the sides of the stern section, there are four (4) foam blocks made of Owens Corning FOAMULAR 250 extruded polystyrene (XPS) foam and four (4) flotation airbags made of a durable polymer. A single flotation airbag displaces a volume V_{Airbag} of 0.6 cu. ft. and has a weight w_{Airbag} of 0.33 lb. Floatation force can be calculated by subtracting the weight of the airbag from the weight of water it displaces, resulting in a total buoyancy contribution of 148.436 lb from the four airbags alone, as can be seen below.

$$\begin{aligned} F_{b,\,Airbags} &= 4\left(\left(V_{Airbag} \cdot \gamma_W\right) - w_{Airbag}\right) \\ &= 4 \cdot \left(\left(0.6\, ft^3 \cdot 62.4\, lb/ft^3\right) - 0.33 lb\right) \\ &= 148.44\, lb \end{aligned}$$

All foam blocks, combined, make up for a displacement volume V_{Blocks} of 5.10 ft^3. With a specific weight γ_{XPS} of 1.55 lb/ft^3, by multiplying the volume by the difference between specific weights of water and foam, we get a contribution of 310.335 lb of buoyancy force for all foam blocks.

$$\begin{aligned} F_{b,\,Blocks} &= V_{Blocks} \cdot \left(\gamma_W - \gamma_{XPS}\right) \\ &= 5.10\, ft^3 \cdot \left(62.4\, lb/ft^3 - 1.55\, lb/ft^3\right) \\ &= 310.335\, lb \end{aligned}$$

The weight of the stern is 294 lb, and with the additional 20% safety factor, results in a design weight of 352.8 lb. The combined buoyancy force of both the airbags and foam blocks is 458.775 lb. Due to the combined buoyancy force exceeding the design weight of the boat section with the safety factor, Rule 7.14.2 is satisfied for the rear section.

Table B.1: *Weight distribution for the boat across all systems.*

System/Item Name	**Weight (lb)**
Hull and Frame	98
Drivetrain and Steering	86
Electronics and Solar Array	37
Batteries	100
Accessories and Equipment	9
Total	*330*

Table B.2: *Weight distribution for the distinct separable sections of the boat.*

Hull Section Name	**Weight (lb)**
Bow Section	36
Stern Section	294
Total	*330*

Appendix C: Proof of Insurance

OFFICE OF GENERAL SERVICES
BUREAU OFRISK AND INSURANCE MANAGEMENT

TO: Whom it may Concern

FROM: Tomlynn Yacono
Director, Bureau of Risk and Insurance Management

SUBJECT: *Statement of Self Retention*

The General Liability exposures of the State of New York as well as those of the State Agencies are self retained. Suits for bodily injury and property damage are brought in the NY State Court of Claims, which is supported by a multi-million dollar annual appropriation.

Employees are protected against suits under Public Officers Law Section 17 for actions or alleged actions that occur while they are acting within the scope of their employment.

If there are any questions or further information is needed, please do not hesitate to contact the OGS Bureau of Insurance at (518) 474-4725.

Appendix D: Team Roster

The list of members that have contributed to the creation of the boat.

First Name	Last Name	Major	Year	Team Role
Andrew	Mathew	Electrical Engineering	Senior	President
Andy	Lin	Mechanical Engineering	Senior	Vice President
Vikash	Ramharack	Electrical Engineering	Senior	Treasurer
Kumpu	Ide	Mechanical Engineering	Junior	Shop Manager
Wesley	Ng	Electrical Engineering	Sophomore	Secretary
William	Winters	Electrical Engineering	Senior	Electrical Team Lead / Business Lead
Angela	Tom	Computer Science	Senior	Computer Science Team Lead
Frank	Lin	Mechanical Engineering	Senior	Mechanical Team Lead
Sherin	Davis	Mechanical Engineering	Junior	Webmaster
Vanessa	Man	Mechanical Engineering	Senior	Member
Dominic	Del Toro	Business	Sophomore	Member
Tami	Takada	Undeclared	Junior	Member
Dakota	Levermann	Computer Science	Freshman	Member
Chenhao	Lyu	Applied Math and Statistics	Senior	Member
Dylan	Harrinarine	Mechanical Engineering	Junior	Member
Max	Manoach	Mechanical Engineering	Junior	Member
Shafayat	Alam	Mechanical Engineering	Freshman	Member
James	Jung	Mechanical Engineering	Junior	Member
Jinheng	Zheng	Electrical Engineering	Freshman	Member
Zheng	Chen	Mechanical Engineering	Freshman	Member
Steven	Chen	Mechanical Engineering	Freshman	Member
Md	Zaman	Undeclared	Sophomore	Member
Matthew	Leo	Electrical Engineering	Sophomore	Member
Abraham	Mendoza	Mechanical Engineering	Sophomore	Member
Soyun	Lee	Technology Systems Management	Senior	Member

Appendix E: Schematics

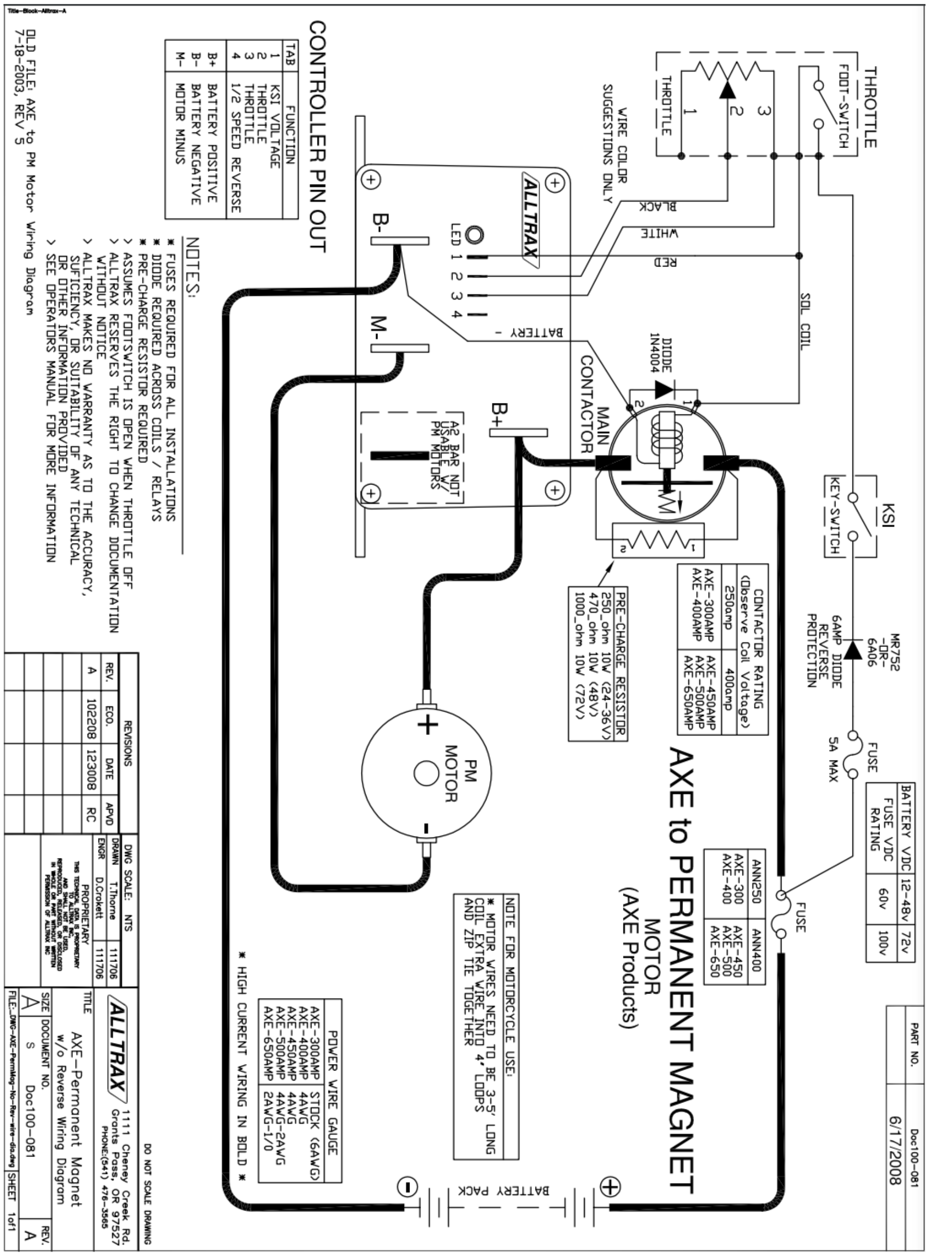


Fig. E1. *Alltrax AXE motor controller wiring diagram for Permanent Magnet DC Motor [3].*

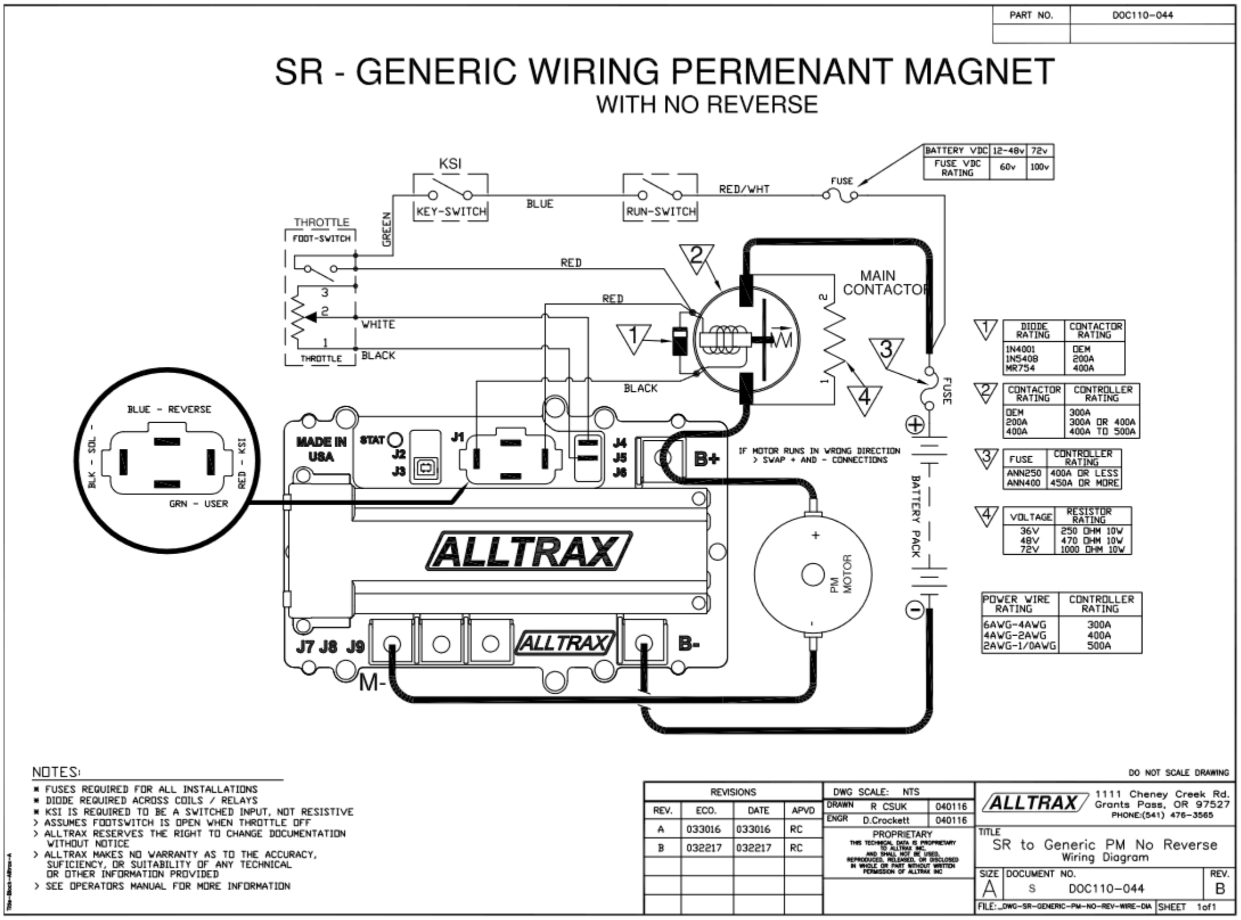


Fig. E2. *Alltrax SR motor controller wiring diagram for Permanent Magnet DC motors.*

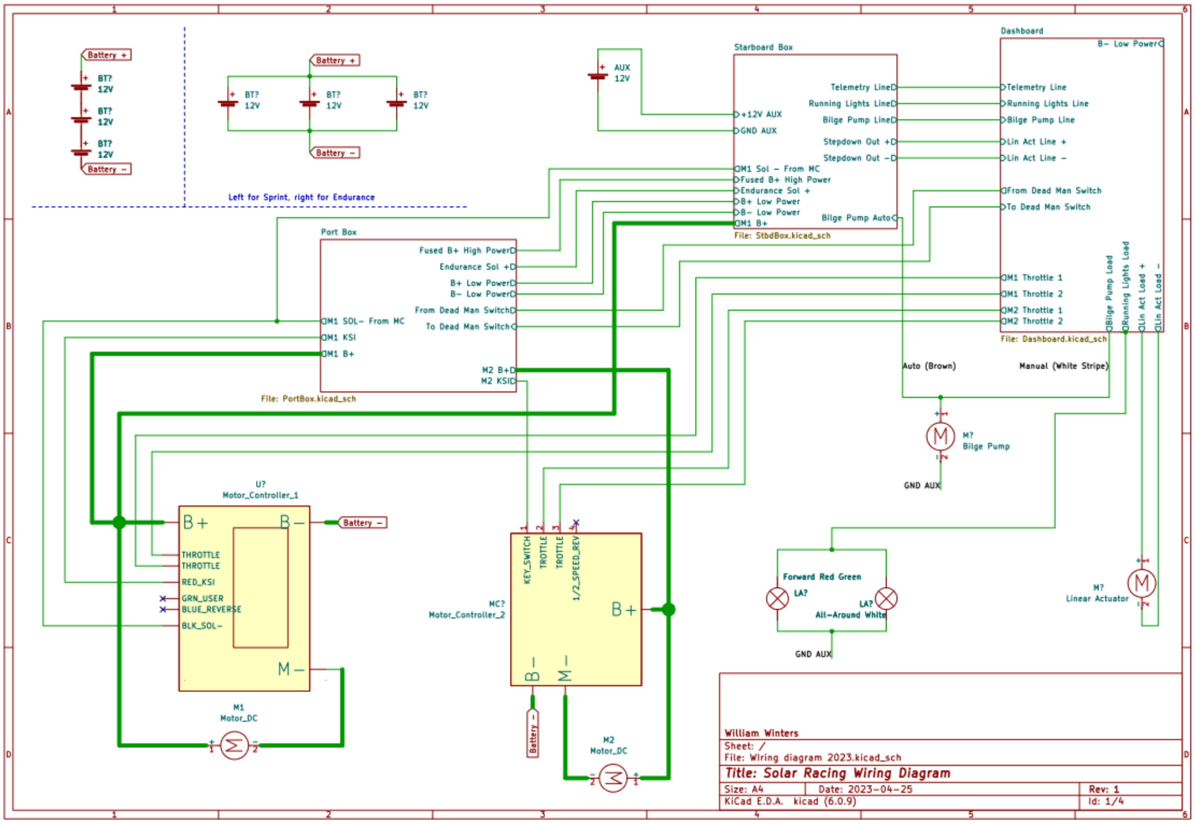


Fig. E3. *System Overview Wiring Diagram.*

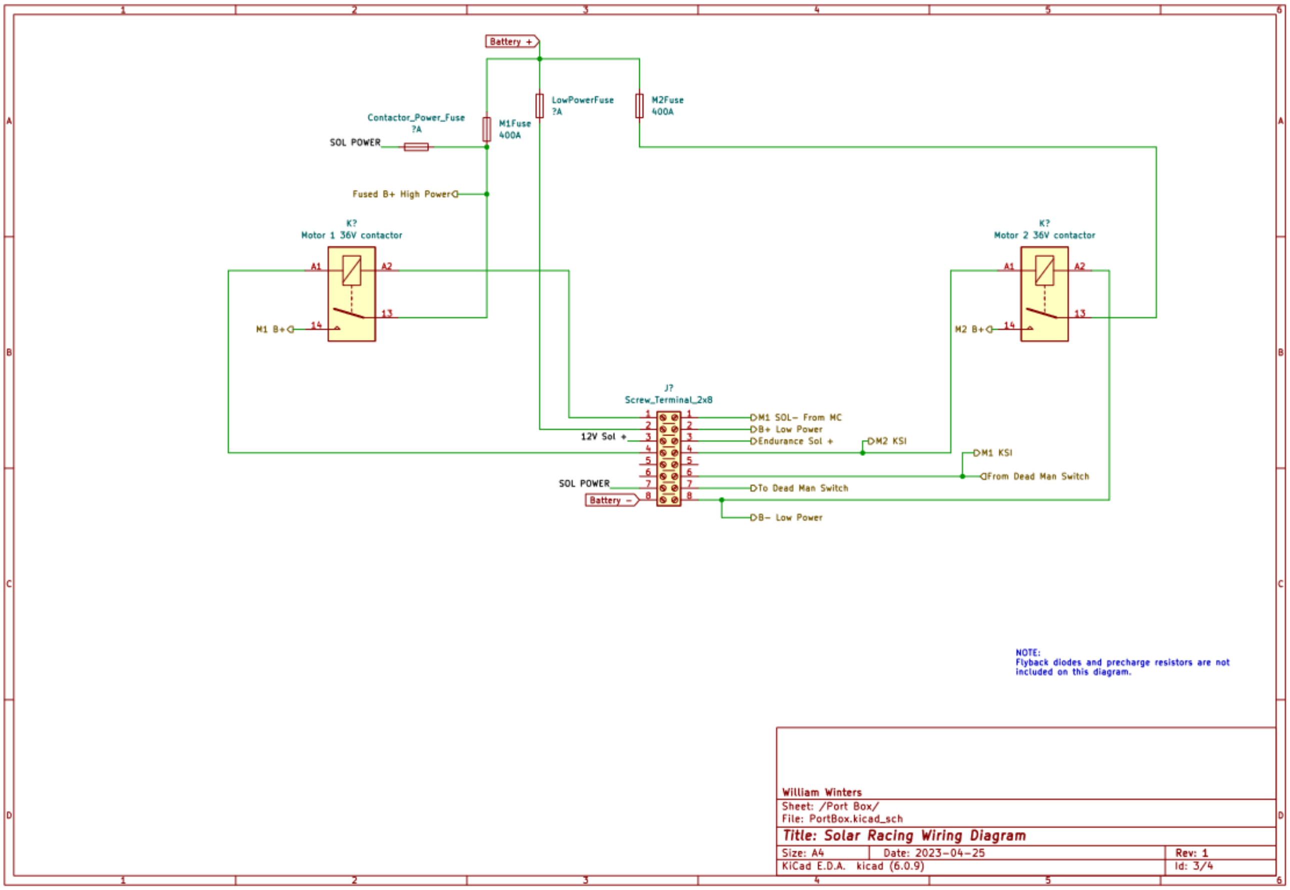


Fig. E4. *Port Electrical Box Wiring Diagram.*

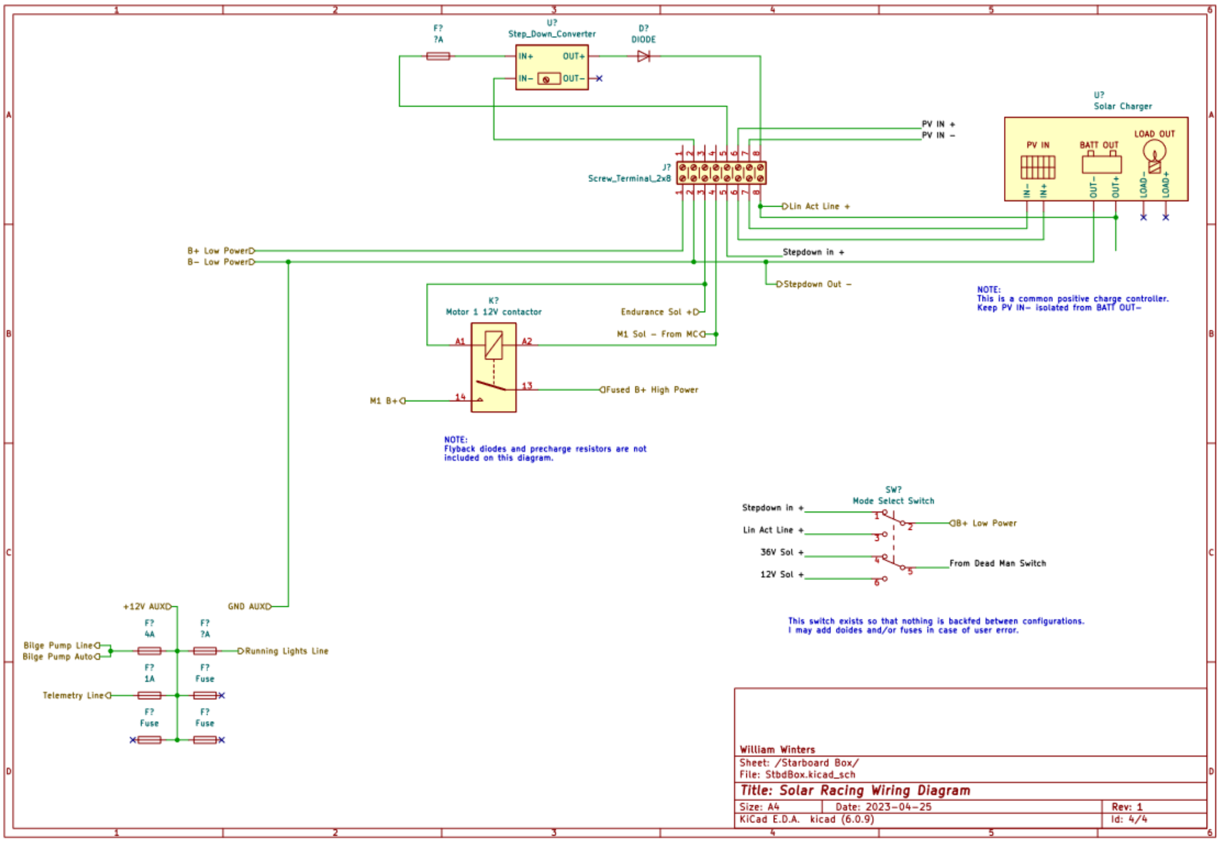


__Fig. E5.__ Starboard Electrical Box Wiring Diagram.

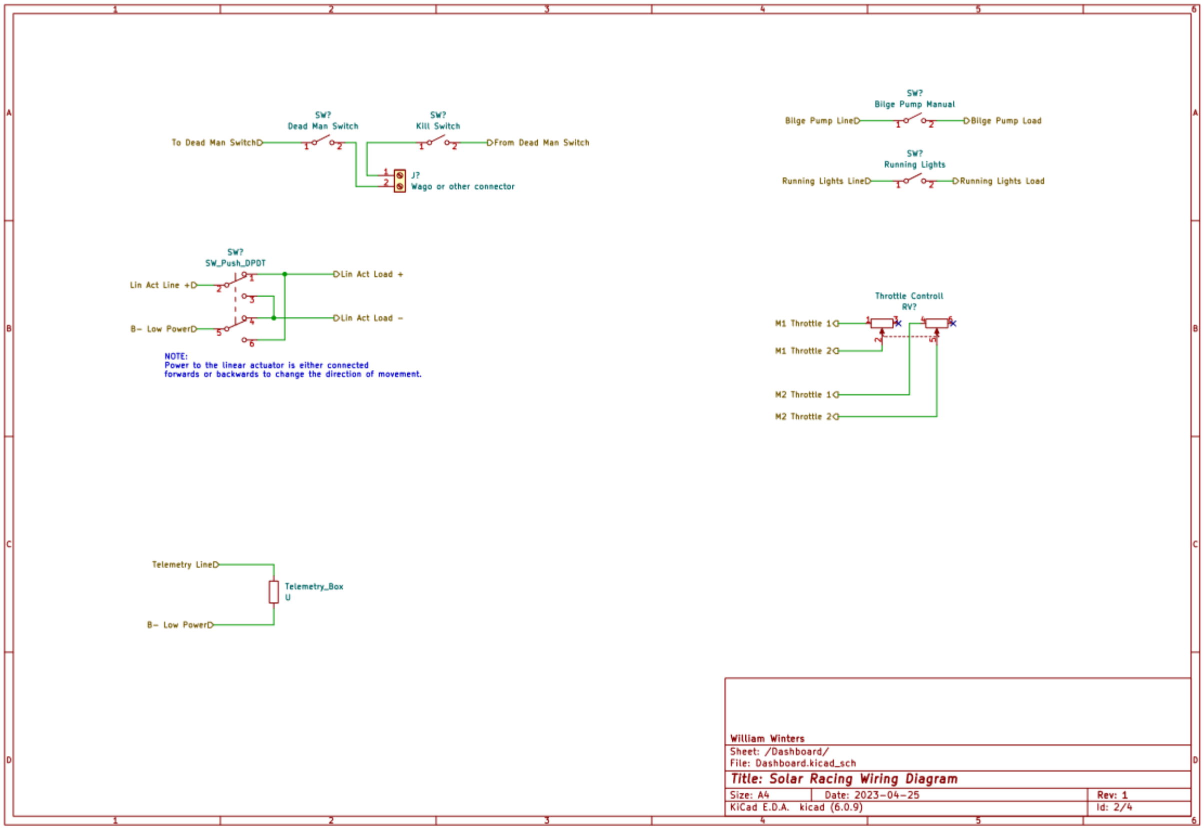


Fig. E6. Dashboard Wiring Diagram.

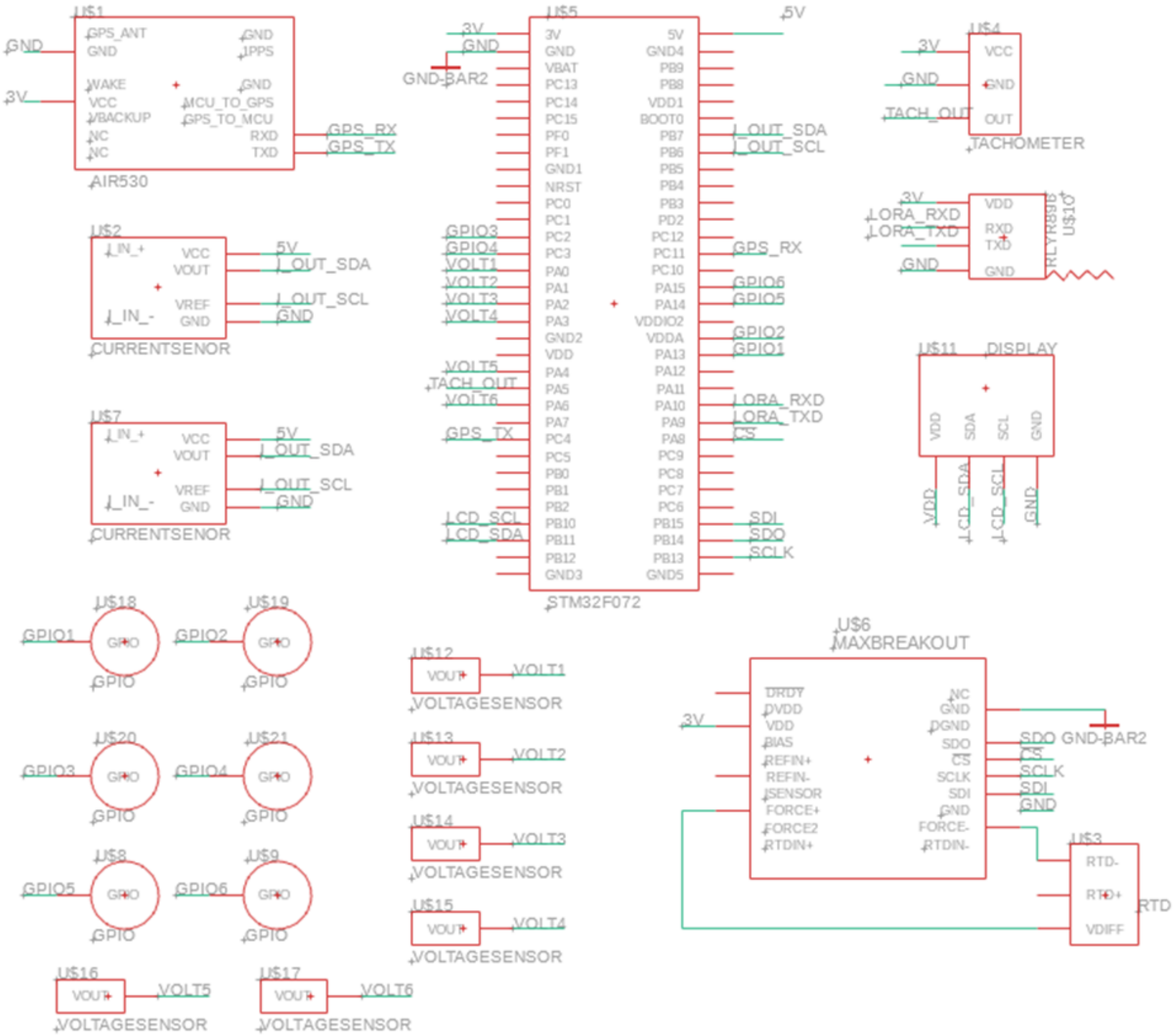


Fig. E7. Data Acquisition Hardware Schematic.

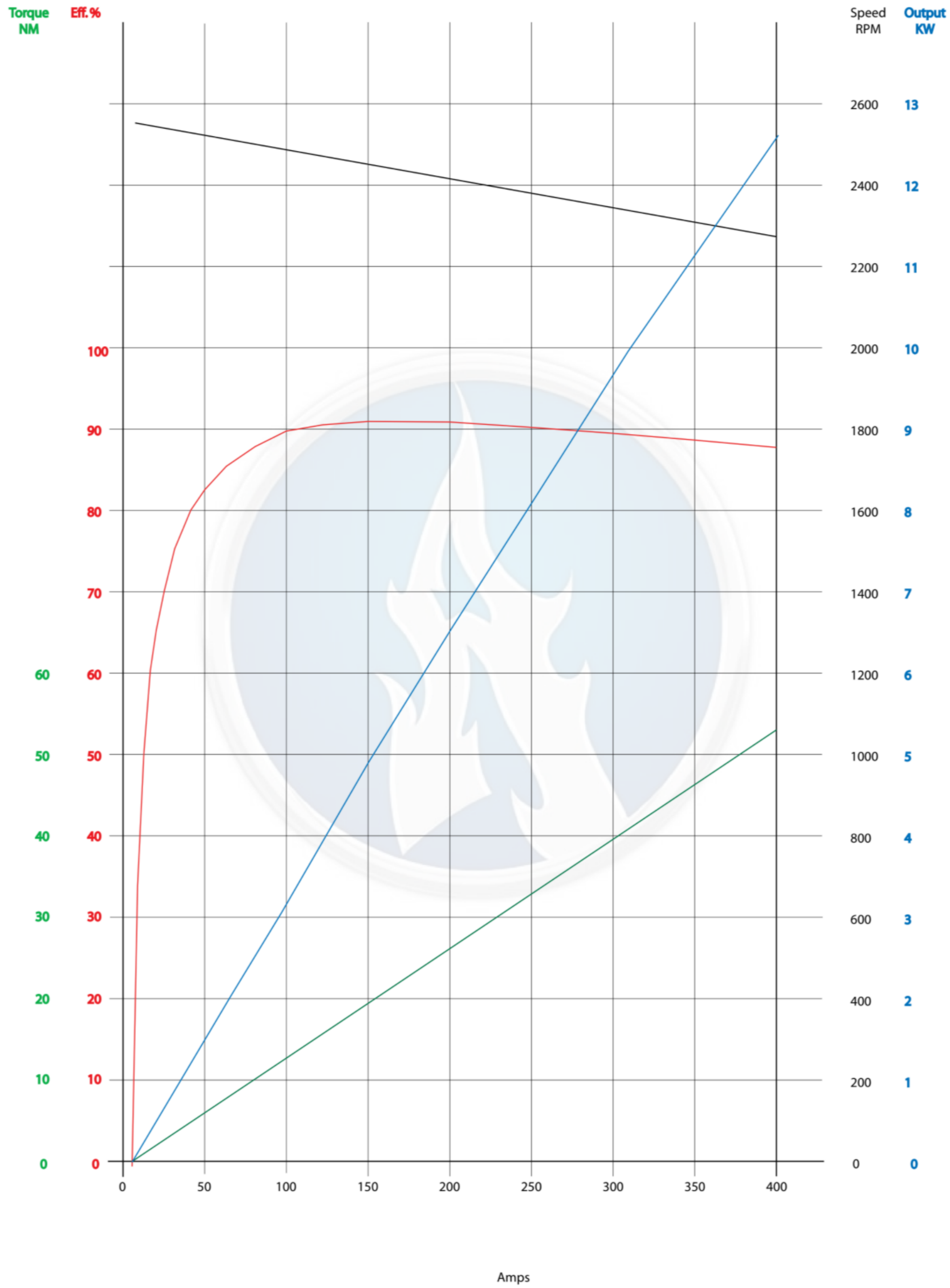


Fig. E8. *Performance graph of the AGNI 95r Series Motor [5].*

For the mounting of the motor system, we are making use of the rails that line the inside of the hull. Currently, we are using plywood to mount all of the parts that will be kept near the motors, including the solar charger, motor controller, main contactor, and DAQ system. The motor switch and throttle will be mounted separately in front of the skipper, so they have not been attached to this piece. While mounting most of the electrical components to a separate platform adds some weight, it makes it easier to mount the whole system and minimizes the amount of components we attach directly to the hull. We have also chosen to rewire the entire system using fuse blocks and bus terminals to make the wiring cleaner.

In the **Fig. E9** below, the aforementioned plywood mount that currently is housing all of the motor electrical components is shown. The connection to batteries and motors on both sides of it also replicates how these sections will be placed in the hull.

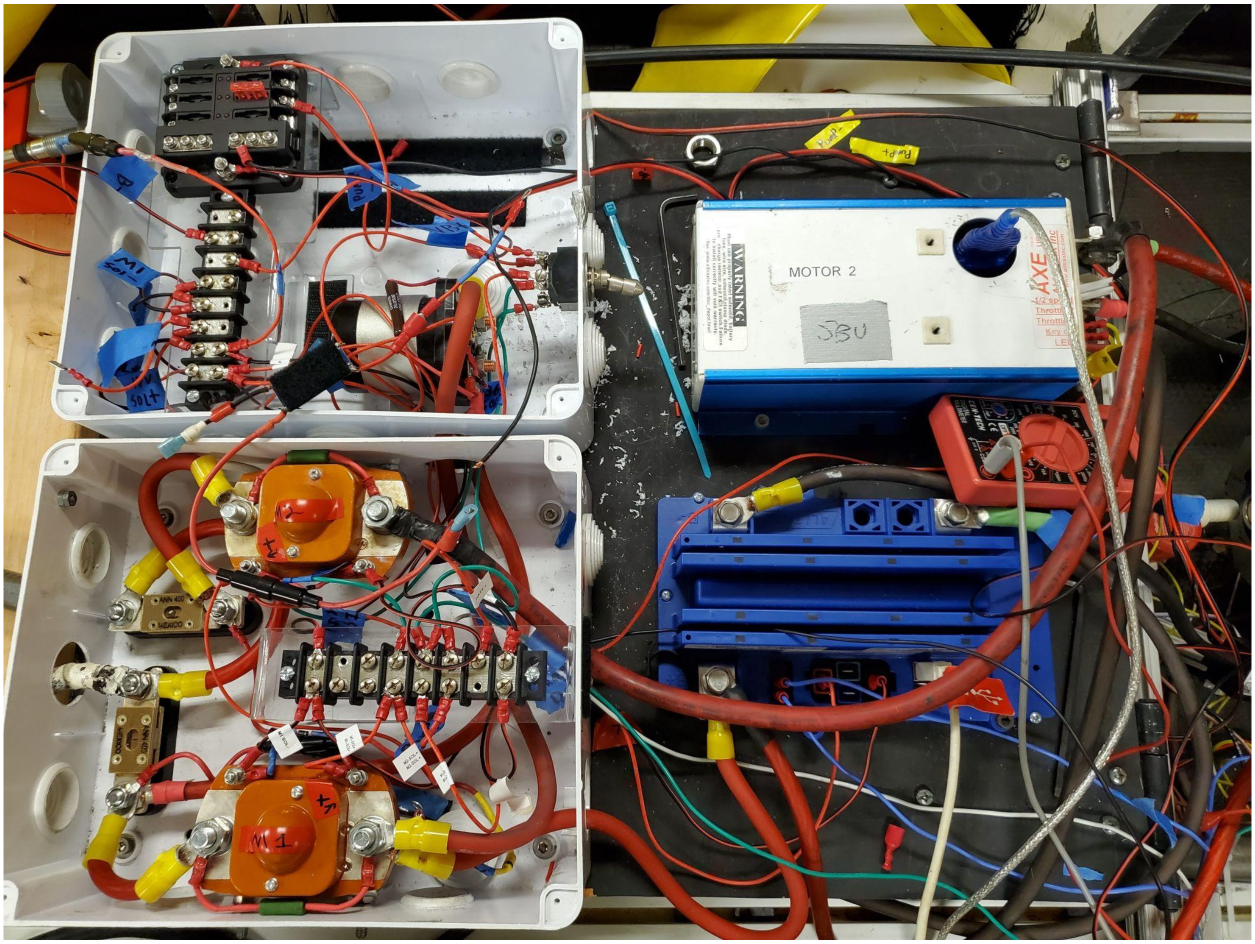


Fig. E9. *Motor Controller & Solar Charging Module*

Appendix F: DAQ Diagrams

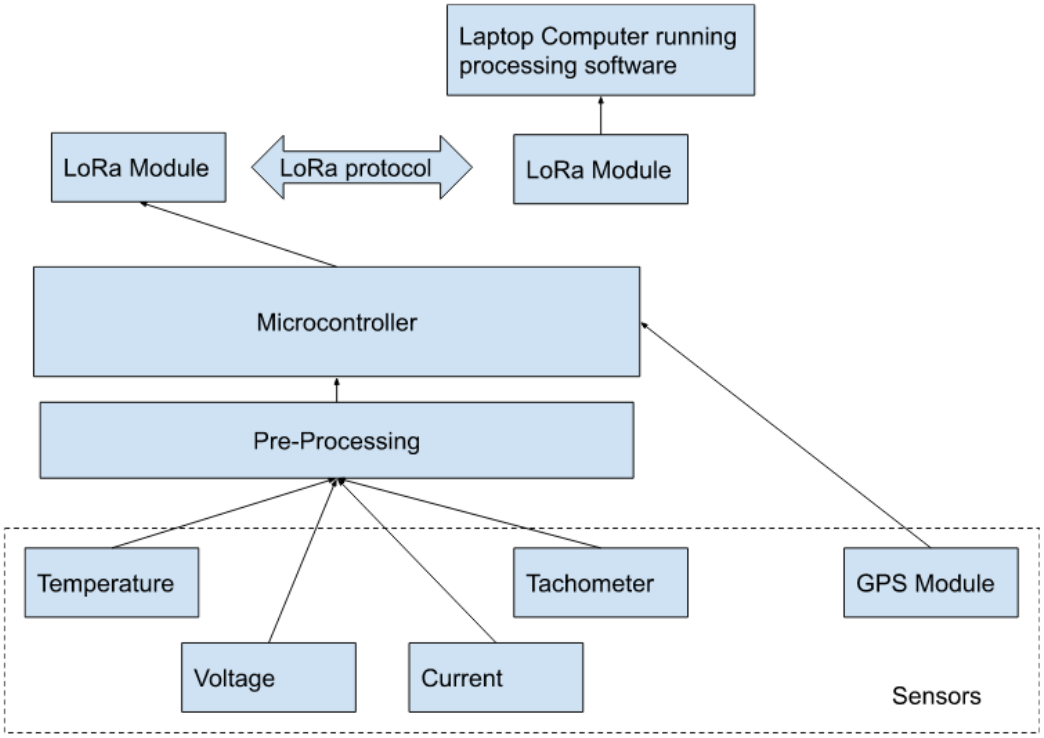


Fig. F1. *The block diagram of the sensor interface.*

State Of Charge (%) versus Voltage for various battery conditions											
SOC (%)	**100**	**90**	**80**	**70**	**60**	**50**	**40**	**30**	**20**	**10**	**0**
V, Rested	12.8	12.7	12.6	12.5	12.4	12.3	12.2	12.1	12.0	11.9	11.8
V, at 0A	**12.5**	**12.4**	**12.3**	**12.2**	**12.1**	**12.0**	**11.9**	**11.8**	**11.7**	**11.6**	**11.5**
V, at 5A	12.4	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.6		
V, at 10A	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.5			

Fig. F2. *Battery State of Charge Determined by Voltage and Current.*

Fig. F3. *Potential Design of GUI for Data Acquisition System.*