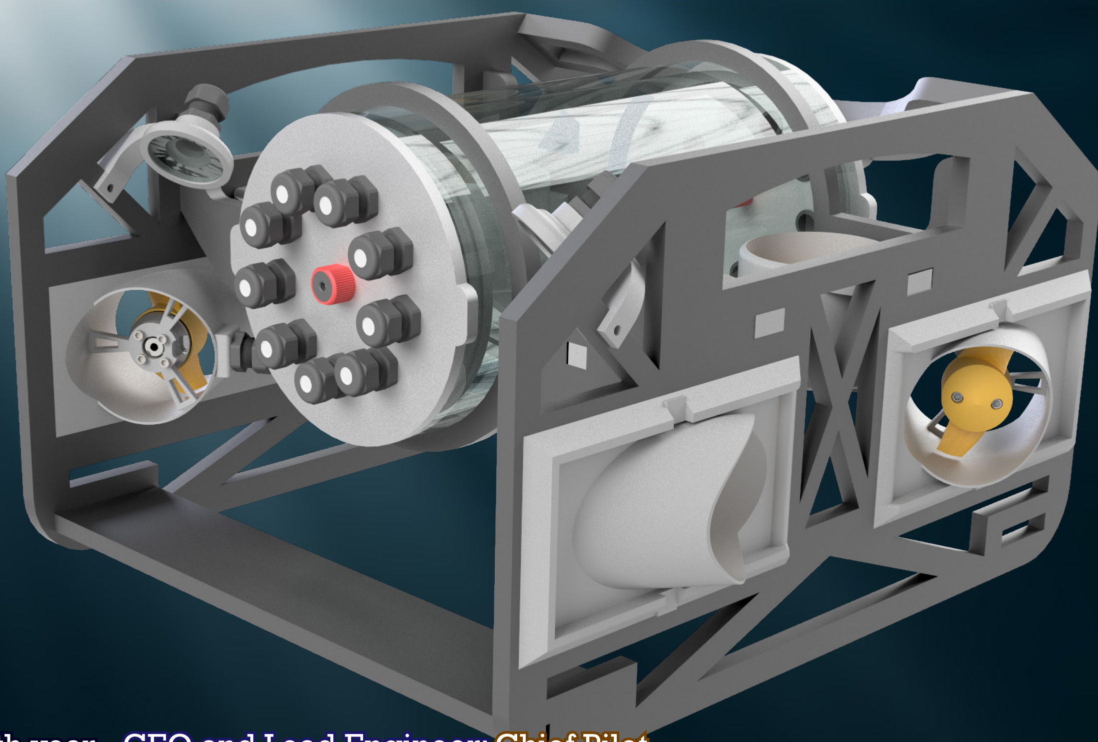
# Sea Sweepers

Highway 68 ROV Club
Salinas, CA, USA
Http://SeaSweepersROV.com

# B.R.I.A.N.

Technical Report

5/26/2017



JP O'Dell - 8th year - CEO and Lead Engineer; Chief Pilot
John Yeager - 8th year - COO and Systems Engineer; Mission Strategist
Michael Georgariou - 3rd year - Lead Electrical Engineer; Co-Pilot
Tyler Allen - 3rd year - Lead Mechanical Engineer; Poolside Assistance
Jack Hyland - 2nd year - Mechanical Engineer; Poolside Assistance
Kate Yeager - 1st year - Electrical Engineer; Tether Manager
Montana Sprague - 2nd year - Project Manager and Engineer
Hanna Hitchcock - 2nd year - CFO and Media Relations
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Mentored by: Kurt Yeager & Mike Allen

* Team Position
* Mission Position

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# Abstract

The Highway 68 ROV Club, known colloquially as the Sea Sweepers, was established in 2010 with the primary mission of providing students the opportunity to learn about engineering and entrepreneurship outside of the traditional classroom setting. The team is a student-run independent club, not affiliated with a school, and recognized by the IRS as a 501(c)(3) non-profit organization. This year the Sea Sweepers decided to advance to the Explorer class. The 2017 season competition theme is Port Cities of the Future, focusing on the harbor of Long Beach, California. From the beginning of this building season, the team designed the 2017 vehicle, BRIAN, to efficiently complete the mission tasks and to be easily operable by the client. BRIAN has a CNC-cut high density polyethylene frame, CAD designed and 3D printed thruster ducts and propellers, and a fully digital control system running off four arduino controller boards and a Raspberry Pi computer. The electronic boards, including the team's own custom designed circuit boards, are mounted in a custom built waterproof electrons housing in the center of the vehicle frame. The assortment of payload tools are easily mounted to a HDPE shelf on the front of the vehicle, and specifically tuned to complete missions in the port of Long Beach, and the vehicle has sufficient thrust for ocean operations. The Sea Sweepers have had a solid season and overcome numerous challenges. The team is pleased to present and demonstrate our product, BRIAN, at the 2017 international competition.

# Company History

Founded in 2010, the Highway 68 ROV Club consisted of four inexperienced, but ambitious fifth-grade boys. Eight years later, the Sea Sweepers are still alive and well, maintaining a team of nine members with two from the original team. Starting out in the Scout Class eight years ago, the team moved up through the divisions, taking first place in the Monterey Bay Regional in Scout, Navigator, and twice in the Ranger Class. In the Sea Sweepers' second appearance at the MATE International Competition, they took second place overall and won first place in the design and engineering category. This year, the team recruited new team members to expand its capabilities and build an elaborate vehicle using the different perspectives and knowledge of the new members combined with the experiences of the old members. A unique aspect of the Sea Sweepers is that the team is an independent club, which allows it to invite members from multiple schools. Building vehicles and pooling sponsorships have brought the club together and taught its members the importance of teamwork. Through challenging themselves to meet self-assigned deadlines and finish their work efficiently, the team members have learned how to juggle different commitments, complete their respective tasks, and have fun while working. The Sea Sweepers' work ethic translates into its continued success at the competition, and these experiences will help its members become the hardworking and dedicated engineers and programmers of the future.

**The 2017 Sea Sweepers**

# Safety

## Safety Philosophy

As an engineering and design team, the Sea Sweepers prioritize the safety of its members and clients. In order to maintain a safe learning environment, the team enforces strict rules in both the garage where they build and at the pool during practical use. The team protects its members and clients from any conceivable danger associated with underwater robotics and marine technology by taking every possible precaution.

Marco and John practice safe conduct with safety glasses.

First and foremost, the Sea Sweepers ensure the maintenance of an organized, orderly workspace, preventing workshop accidents. The team avoids tripping hazards and electrical mishaps by storing wires, parts, and tools in specifically marked locations in the garage. Safety glasses and other protective articles are mandatory when a team member is cutting, soldering, or using any other potentially dangerous tool. To guarantee the safety of the team, clients, and the vehicle, electrical components are stored away from the poolside. The team also created a JSA (Job Safety Analysis) to identify all safety hazard and guarantee safety during use. All of the electrical components on the ROV are carefully waterproofed. In addition to building the vehicle safely, the team also made sure to build a safe vehicle. All motors are shrouded, preventing damage or injury from the sharp blades of the propellers. Dangerous, rough, or sharp parts are filed or removed. All exterior parts of the vehicle are safe to touch, thanks to the Sea Sweepers' meticulous safety protocols. The team also uses checklists for operation and repair and can be found on the team website. By following these checklists carefully, the team remains safe whenever working on the vehicle.

## System Safety Features

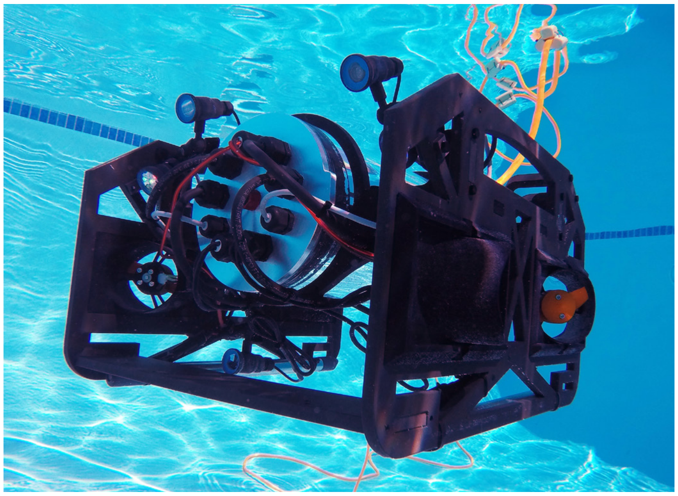
The electronics housing is equipped with moisture and temperature sensors that will alert the pilot in the event of a leak, catastrophic flooding, overheat, or electrical fire. Knowing immediately about a critical problem allows the pilot to shut down power to the vehicle and for the crew to swiftly remove it from the water. Damage will likely be minimized, as well as the chance of electrocution, and the possible cost of repairs is significantly reduced. All of the thrusters are covered by shrouds that are 3D printed into the frame, protecting the client from the spinning propellers and protecting the propellers themselves from objects that could damage them. The propellers are 3D printed in bright orange to increase visibility. All of the electrical connections and components on the vehicle are carefully waterproofed.

Inside the control box, all AC power is shrouded in green in order to alert the client to potential danger. Also, a circuit breaker is present so that the pilot can cut power to the vehicle immediately. Everything in the control box is securely mounted to the base, and the box case is weighted down to prevent tipping. All connections throughout the system are secure and no wire are exposed.

# Design Rationale

## Design Overview

BRIAN was engineered to be the most powerful and versatile ROV the Sea Sweepers have ever designed. BRIAN has eight brushless motors that use custom 3D printed propellers to achieve any axis of motion the client desires. All eight motors are discreetly mounted within the frame to minimize wasted space and reduce drag. BRIAN uses four wide angle cameras and two LED spot lights to aid the client in effectively completing the mission at hand. A variety of sensors including water temperature, leak detection, operating voltage, and AHRS (attitude and heading reference system) allow the operating party full oversight to the status of the vehicle. All communication and power is transmitted through an ultra thin, fifty foot tether which connects to BRIAN's control box. The control box is designed to be used by a two person crew. The main pilot drives the vehicle with two 3-axis joysticks, looking at the monitor displaying the four camera feeds. The co-pilot monitors sensors and vehicle status while assisting the pilot with the vehicle's manipulation attachments. BRIAN is the most reliable, multifaceted, and serviceable ROV on the market today and can fit any mission from repairing underwater pipelines to maintenancing light and water shows to reducing humans' environmental impact in the Port Cities of the Future.



**BRIAN in action**

## Design Process

When approaching the design challenge of the vehicle as a system, or any component of that system, the design team follows a series of steps to ensure an optimal product. First, the team creates a list of requirements that the component must meet, adhering to both mission necessity and competition rules. Once the functionality framework is established, the design team members each brainstorm solutions to the problem, and produce a sketch or some other proof of concept for their ideas. The best few ideas are prototyped, and the engineers then debate the pros and cons of each possibility. After both debate and pool testing, the winning idea is selected, produced, extensively tested, and then improved even further.


**Members of the team discuss vehicle design ideas and improvements**

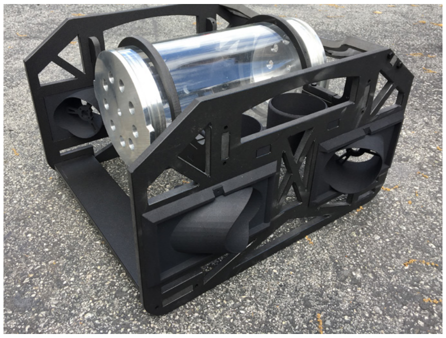
# Vehicle Components

## Build vs. Buy

This season, the Sea Sweepers worked especially hard to design the majority of BRIAN and minimize the use of commercial products. BRIAN implements a number of proprietary designs including an HDPE frame, motor assemblies, waterproof cameras, printed circuit boards, and control system. For example, BRIAN's thrusters are based on a basic Blue Robotics M100 motor. The Sea Sweepers then designed custom propellers, mounts, and thrust ducts. The Sea Sweepers combined some commercial components such as Arduino microcontrollers with custom designed printed circuit boards. By integrating these components, BRIAN's system is extremely reliable, yet very efficient. This approach allowed the team to custom build as many components as possible given the Sea Sweepers' skill level and financial capabilities.

## Frame

The Sea Sweepers' top priorities for frame design included lightweight design, ease of disassembly, structural strength, and hydrodynamics. For the frame material, the team selected high density polyethylene (HDPE) over acrylic because it is stronger, cheaper, and less dense than water. Having light material not only reduces dry weight for ease of use by the client, but requires no buoyancy foam to keep afloat. The panels of the frame are held together using a system of plastic bolts and notches, ensuring strong and stable joints, while still being easy to disassemble. The vehicle frame is as hydrodynamic as possible with the two largest panels oriented on the sides of the vehicle. In this setup, the two most important directions of motion (forward/back and up/down) will have minimal drag from the frame. Product demonstration tasks were addressed as well when designing the frame: every dimension of the frame was chosen to fit inside the 58 centimeter circle ensuring maximum ease for the client. In addition, the payload tools are modular and easily serviced. All these factors were attended to in order to develop a lightweight, strong, and modular frame.



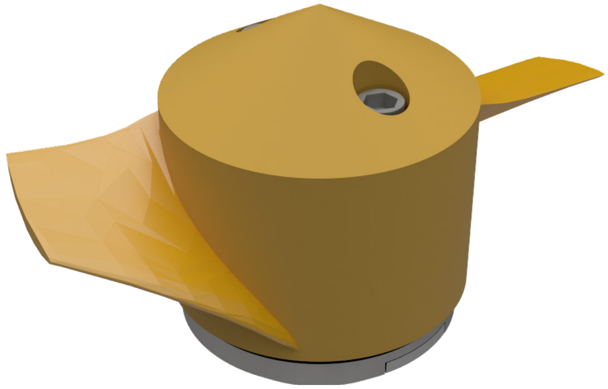
**BRIAN's frame**

## Buoyancy and Stability

The vehicle is designed for optimal stability for operational effectiveness and client convenience. The primary stability principle used is polarity; a polar vehicle has its more dense components located lower in the vehicle and its low density components located higher. This asymmetric density distribution maximized vehicle stability and reduces the amount of buoyancy and ballast required to ensure that stability. The component layout of the vehicle itself is naturally polar; the low density, air filled electronics housing is mounted as high up as possible, the medium density thrusters are mounted around the middle, and the high density ballast rebar is mounted in the bottom edge of the frame. This design ensures a stable ROV while also minimizing excess use of buoyancy and ballast. See Appendix A for additional information on vehicle buoyancy calculations.

# Motors

BRIAN implements eight brushless motors as its form of propulsion. Each motor is rated to 540Kv and is capable of .28 Nm of torque. The motors are run off of 12 volts DC and consume a maximum of 4 amperes each. With the custom 3D printed propellers, each motor assembly is capable of producing 1.2 kilograms of thrust. In fact, the motors were so powerful that they were limited by 40% to allow for more precise handling. Each motor's electrical connections are waterproofed with marine grade epoxy to ensure no water intrudes the vital parts of the motor.



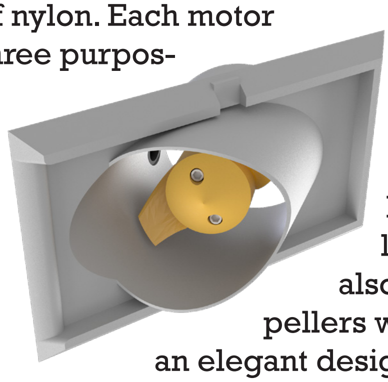
**Rendered image of propeller and motor assembly, displaying compactness of design**

# Propellers

BRIAN uses custom designed propellers to integrate perfectly with its motors to minimize extra space and maximize efficiency. The propellers are 3D printed in bright orange to increase visibility, which is an important safety feature of BRIAN. The Sea Sweepers decided to design and manufacture propellers despite the availability of commercial options for several reasons, the most prevalent of which being efficiency. The Sea Sweepers spent several months testing the different variations of the propellers to find the most efficient design. The propellers were tested by attaching a motor to a lever with a scale and measured thrust output. The Sea Sweepers found that two thin blades are more efficient than three or four blade propellers. Many off-the-shelf propellers mount on top of the motor; however, BRIAN's propellers mount around the motor, greatly reducing the surface area of motor assembly and allowing it to be mounted in a much smaller area. Additionally, the propellers were designed in counter rotating versions, effectively cancelling out any torque forces caused by the rotating propellers (this phenomenon is often referred to as "P-Factor" or "Propeller Walk").

# Motor Housings

One distinct feature of BRIAN is its motor housings. The housings are designed specifically for BRIAN and are 3D printed out of nylon. Each motor housing serves three purposes: mounting, ducting, and safety. The motor housings mount BRIAN's brushless motors and also shroud the propellers while maintaining an elegant design and maximum efficiency. The horizontal motor mounts are inserted into the side panels of the vehicle. This design allows for a minimum amount of drag and in turn makes the ROV more maneuverable. All eight motor mounts are also ducted to allow water to flow through them evenly. There are tolerances of less than one millimeter from the propeller to the wall of the housing to maximize the efficiency of the ducting. The third feature of the housings is safety. Each housing covers the propeller to minimize potential hazard and complication during an operation.



**Horizontal Motor Mount**

# Cameras

For the past three years, the Sea Sweepers have been slowly perfecting the camera system. The cameras used on BRIAN have been tested and perfected to the point that BRIAN has not had any leaks in two months of testing. In order to achieve optimal visibility during product demonstration, the vehicle has four cameras. Because commercially available options were too big, heavy, or expensive, the team decided to design waterproof enclosures for each camera. These housings were designed using CAD and 3D printed using a special acrylic material. The cameras are mounted to the frame using a unique ball mount system, allowing the client to move the cameras quickly during the mission. The camera signals are sent through the tether in a simple analog form and then run through a passive balun to clarify the signal. The four signals are then run through a multiplexer, which breaks and displays them on a single screen. By using a multiplexer, the co-pilot is able to enlarge a certain video feed or break them up in different arrangements on the screen. This complex video setup allows for greater multitasking for the client, providing him or her with the opportunity to maintain port cities and prevent potential environmental damage simultaneously.

**One of BRIAN's four cameras**

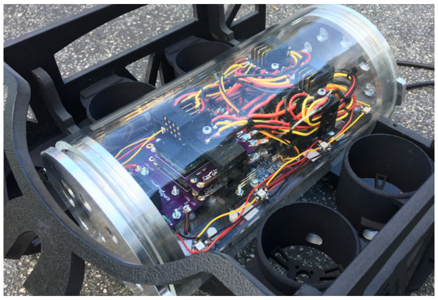
# Lights

The 2017 mission requires that the vehicle be able to not only illuminate sediment samples with white light but also activate various sensors using a colored light. The team decided to eliminate the need for two different kinds of light by utilizing current LED technology. The vehicle uses illumination spot lights that have programmed to change color at the flip of a switch, allowing red, blue, and white light. These spot lights are housed in custom 3D printed enclosures which ensure that the illumination floodlights will continue to work reliably in the low-light conditions underneath the Long Beach piers.

**BRIAN's lights**

# Waterproof Electronics Housing

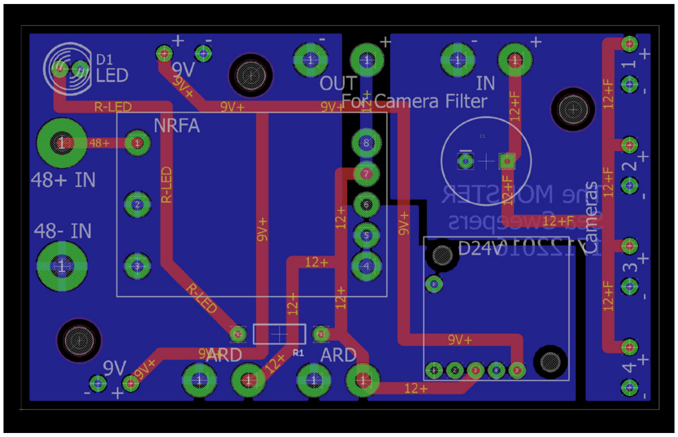
In order to minimize the number of wires in the tether, most of the electronics are located inside a six-inch diameter waterproof acrylic tube on the vehicle. This waterproof enclosure houses two Arduino Megas, eight electronic speed controllers, RS-232 converters, a series of custom power distribution circuit boards as well as various sensors that are mounted on a shelf inside the tube. The enclosure itself utilizes a double o-ring seal on both of the main endcaps. Each of the endcaps were designed and then engineered specifically for application on BRIAN using a CNC mill and lathe. Wires are brought in and out of the tube using removable waterproof cord grips. All aspects of the tube are designed to be easily serviceable.



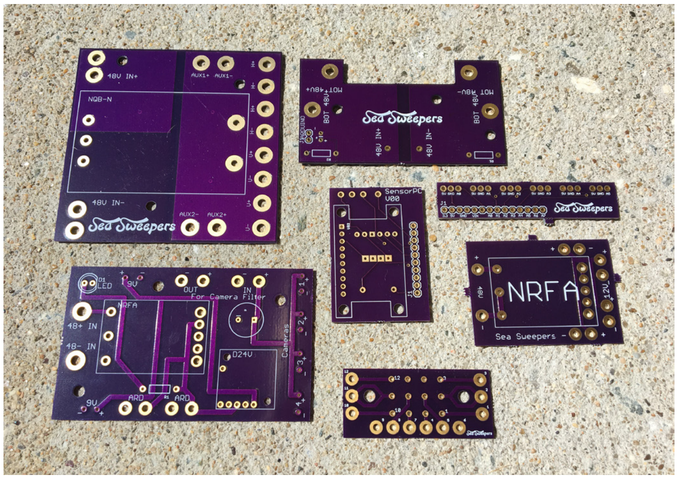
**The waterproof enclosure**

# Printed Circuit Boards (PCBs)

Oftentimes, designing and printing one's own circuit board is cheaper and more space efficient than using a commercial alternative. Using a CAD program called Eagle, the Sea Sweepers' electrical engineering team designed multiple PCBs (Printed Circuit Boards) with compact conductive tracks to maximize the efficiency of the electrical system inside the ROV, creating a more organized and serviceable electronics housing. There are a total of six unique PCBs inside the ROV that serve many functions, effectively consolidating many intricate connections and making them more clean, accessible, and modifiable. PCBs have been essential to the team's design this year and have allowed the team to plan ahead and create a design that allows for optimization of housing space and accessible and serviceable circuits within the housing. PCBs have allowed the team to take its electrical system designs to the next level.



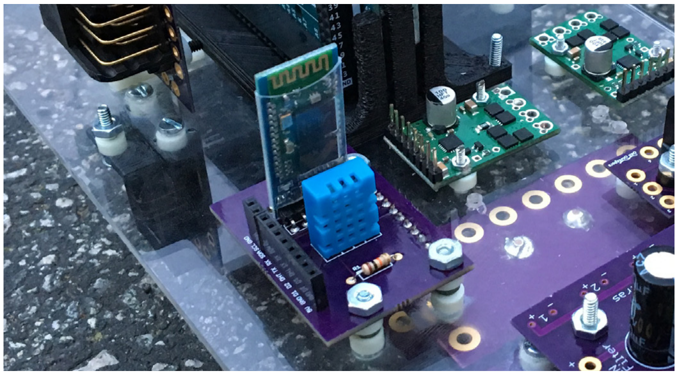

One of the Sea Sweepers' boards in Eagle




All of the Sea Sweepers PCBs

# Sensors

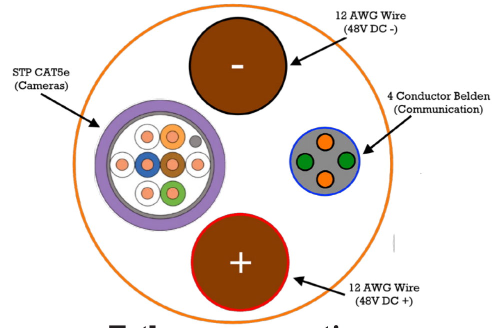
The vehicle has two Arduino Megas onboard, one of which reads values from multiple sensors including a depth sensor (Bar30), a temperature sensor (DHT-11), a leak sensor, a gyroscope (9DOF IMU), and a Bluetooth transmitter/receiver (HC-05). All of these aforementioned sensors communicate to the Arduino. Some, such as the Bar30, HC-05, and 9DOF, use I2C communication with the SCL and SDA pins. The other sensors use normal digital pin connection to transmit information. While most of the sensors onboard are not a required part of the mission, they are invaluable to ensuring safe and efficient operation of the ROV. Internal temperature and leak sensors provide information to the status of the inside of the waterproof housing and alert the crew to abnormalities such as leaks or high temperatures. The onboard depth sensor and AHRS (Attitude and Heading Reference System) provide situational awareness to the pilot. As seen below, all of the sensors are connected to PCB in order to optimize space and make all connections to the Arduino come from one board.



All the vehicle's sensors, attached to a custom PCB

# Tether

Weight was the primary consideration for the design of the tether. A lighter tether limits drag on the vehicle, is easier to manage, and is cheaper to transport, effectively lowering operating costs for the port of Long Beach. The tether contains two 12-gauge wires to power the vehicle, one STP CAT-5E cable for the video communication, and one 4-conductor cable for motor and sensor communication between the Arduino's in the control box and those on the vehicle. This four cable design keeps the tether light and flexible, allowing for a more agile vehicle. The aircraft avionics connector detaches the tether from the control box and is extremely durable, providing a reliable and safe connection. On the vehicle end of the tether, there are permanent waterproof connections with the electronics housing that pass through a strain relief built into the vehicle frame.




**Tether cross-section**

# Central Control System

## Power

The control box uses a combination of AC and DC power. The team's engineers specifically chose to power the Raspberry Pi, monitors, and video system using AC power, thereby removing them from the required DC amp limit. There are three switches to turn off various parts of the system: the DC ROV, DC to the control box, and AC to the control box. These switches allow for independent control of each of the different types of power the team is using. With this unique feature, BRIAN's clients are capable of safely cutting off power to the ROV while maintaining power in the control box in case of emergency. In addition, the team designed a switch to limit the power to the ROV so that BRIAN can maneuver more precisely for tasks such as turning the valve and plugging in the power connector. There is a circuit breaker on the box that is used to avoid blowing fuses and also as a main power switch for the control box.


**Assembled control box**

## Monitors

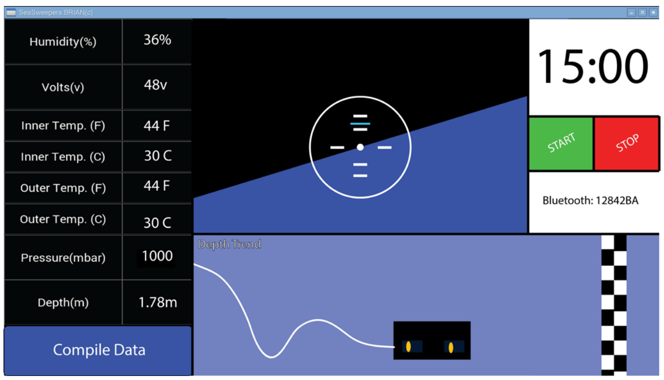
The team's engineers created a dual display consisting of the camera views and status displays. The design includes two large open frame LED monitors mounted in a Pelican Case. The Sea Sweepers opted for large, bright, LED monitors to allow the pilot to have a clear view under the water. The left screen displays the camera views, which show four camera feeds simultaneously. The right screen displays the telemetry data. The team uses a single wireless keyboard and trackpad in connection with a USB switch, allowing for control of both monitors with one keyboard.

# Camera Screen

The left screen in the control box displays the camera signals. The control system utilizes a video multiplexer that takes the four video signals and displays them on a single screen. This allows the pilot to change the layout of the video feeds during the mission and record operations onto a hard drive. The ability to record missions is beneficial to client for later review.

**The camera screen**

# Telemetry Screen




**A screenshot of our telemetry screen**

The right screen is used for BRIAN's status display. The Graphical User Interface (GUI) displays all of the necessary information to the pilot in an easy-to-understand format. The GUI has a simple layout. The most critical numerical information is lined up along the left hand side of the display. This important information includes the temperature, depth, pressure, voltage, and humidity inside of the tube. The right hand side of the display features a timer and the datum that the Bluetooth sensor is receiving. The upper-center section of the GUI displays an attitude heading reference system (commonly known as AHRS), which assists the client in understanding the orientation of the ROV. This section displays the AHRS according to the gyroscopic data collected by the onboard gyroscope. The bottom section of the screen displays a small scale model of the the ROV moving through the multiple tasks of the mission.

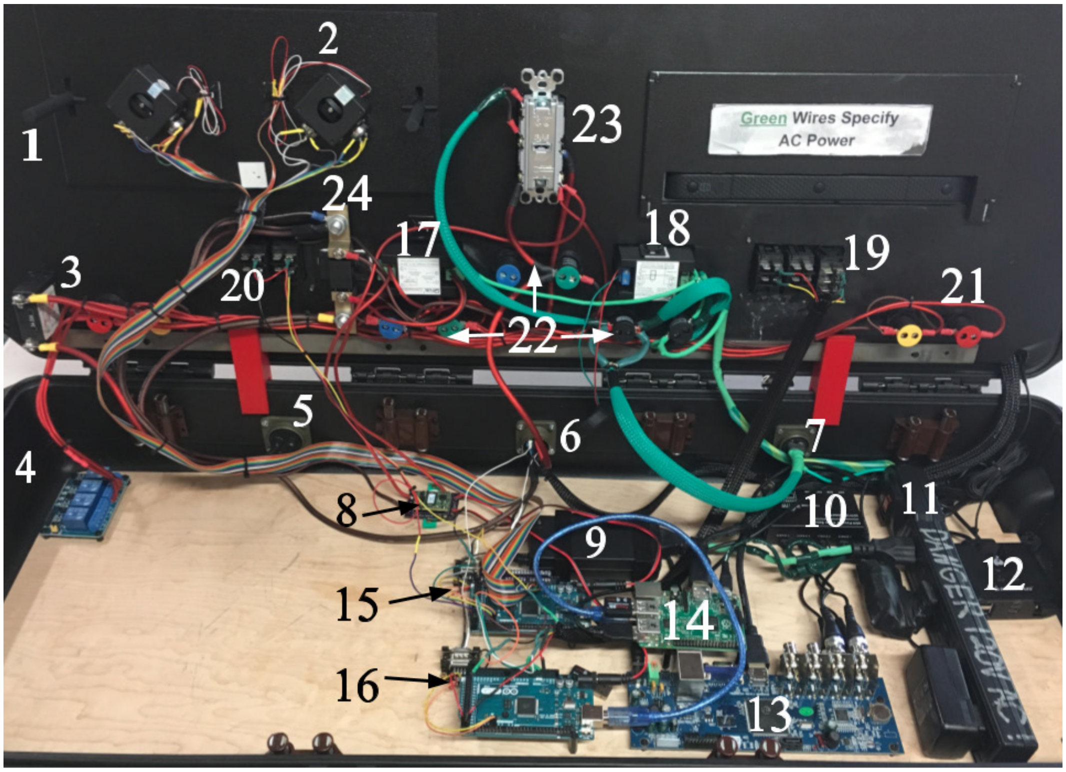
# Thruster Control Joysticks

For the control system, the team chose to use two three-axis potentiometers, all hooked up to an Arduino Mega in the control box. One switch in the control box changes how sensitive the joysticks are, in order to allow more precise controls for more sensitive parts of product demonstrations. This switch changes the motors to run at 40% of their normal power. This was essential to the pilot to perform the tasks as quickly and efficiently as possible. The Arduino in the control box consists of converting potentiometer values into bytes so it can be sent long distances through serial communication. In order to achieve the distances needed by the tether, transistor-transistor logic (TTL) serial is converted into RS-232 signals, which is run at 9600 bauds. The signal is then sent through wires in the tether to another Arduino onboard the vehicle. The code on the Arduino then assigns these reassembled bytes to the ESCs (electronic speed control boards). The control boards read pulse width modulation from the Arduino to change the speed and direction of the motors. This is done using the Sea Sweepers' code to assign these values accordingly.

# Other Special Features

The control system utilizes many other special features that increase the mission crew's performance and ability to address problems during the mission. For example, the control box includes a set of six blue and green LED lights that inform the pilot when the tethers are connected and functional. BRIAN's control system has three connectors: one for the tether to the vehicle, one for AC power, and one for DC power. Each blue LED is switched on when the corresponding tether is attached and functional. Each green LED is switched on when power is flowing through each circuit. The function of each system is independent and controlled by the main switches. The pilot and copilot have their own set of orange and red warning lights in clear view of their respective screens. If BRIAN's sensors detect any error, a red and/or orange light will engage depending on the severity of the problem. The situation can be looked into further by addressing the telemetry screen. These problems could include high voltage, high current, high temperature or humidity, or leaks.

Other features of the central control system include the auxiliary switches that engage certain functions specific to the mission. Two of these switches operate the lights on BRIAN, and they have three color options. One double-pole switch operates the valve-rotator, while another switch controls the electromagnet. The last switch limits joystick values in order to improve maneuverability during complex mission tasks. The keyboard mounted in the control box is flush with the top panel for a more elegant design.



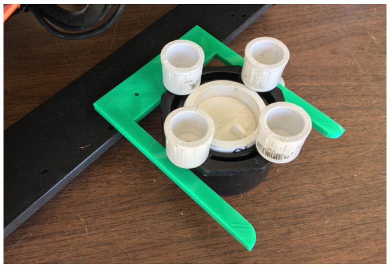

1 - Joystick pin lock
2 - Joystick
3 - Circuit breaker
4 - Relay control board
5 - Main DC connector
6 - Tether connector
7 - Main AC connector
8 - 48V to 12V DC converter
9 - Power supply for monitors
10 - Camera balun
11 - AC power strip
12 - USB switcher
13 - Video multiplexer
14 - Raspberry Pi
15 - Motor Arduino
16 - Sensor Arduino
17 - DC volt/ammeter
18 - AC volt/ammeter
19 - Attachment switches
20 - Light switches
21 - Warning lights
22 - Indication lights
23 - Main switch
24 - Shunt

# Payload Tools

The vehicle uses various specialized tools that were designed using CAD. Each tool has been through several renditions to ensure the final tool will be as efficient as possible. The tools are easily removable from the shelf, allowing for tool swapping during product demonstrations.

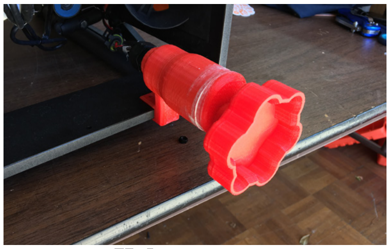
## All Purpose Hook

The vehicle utilizes a multi-purpose hook which has been designed for a large portion of the required tasks. The hook has two tapered prongs that can be used for skewering and retrieving the various samples. The prongs were spaced so that that same attachment would also be capable of removing and replacing the fountain cap.


All purpose hook

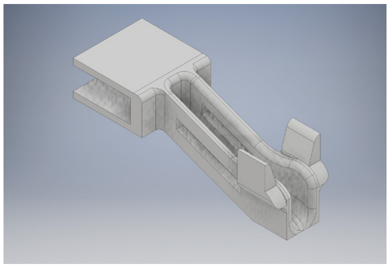
## Valve Turner

The valve turner attachment utilizes a lightweight and high torque motor placed inside a waterproof enclosure. Special seals were used to ensure that water would not breach the enclosure where the shaft protrudes. The attachment was designed with versatility in mind and utilizes a custom removable socket-like apparatus for use on different valve styles.


Valve turner

## Power Connector Grabber

The power connector attachment had to be able to pick up easily and maneuver the power connector. However, the attachment also had to be able to hold the connector steadily while it is being inserted into the port. The final rendition of this attachment was able to accomplish this simply by using wing-like guides to aid in the initial retrieval of the power connector. These guides then funnel the connector into a tight fitting chamber in order to hold the connector still for reinsertion into the port.


Power connector grabber

## Electromagnet

The vehicle utilizes a multi-purpose electromagnet for retrieval of metal objects. The magnet's housing has specially located guides to aid in the positioning of the objects. The magnet chosen is capable of handling objects up to 22kg. While there were stronger options on the market, these other options were too heavy for viable use on the vehicle.

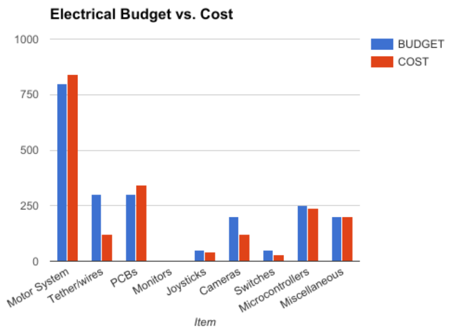

Electromagnet

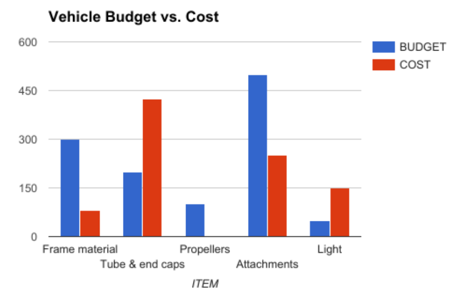
# Logistics

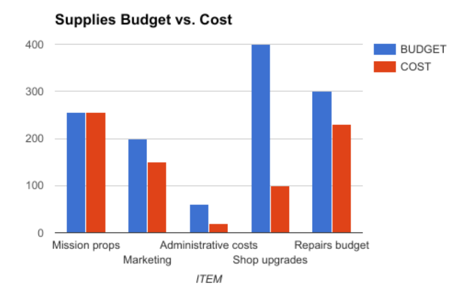
## Budget and Cost Accounting

Along with a company calendar, the Sea Sweepers set a budget for the 2016-2017 season. The budget is organized into three main categories: vehicle, electrical, and supplies; from there, it is further subdivided into specific items or item groups, giving each an estimated cost at the beginning of the season. After buying the items, the team recorded the actual cost and found the variance between cost and estimated cost, which will help to plan and save money in the future for the convenience of potential clients. In 2016, the team applied for and was granted 501(c)(3) status from the Internal Revenue Service, officially establishing the team as a non-profit organization. All of the team's sponsors that invest in the Sea Sweepers receive tax deductions for their sponsorships. All in all, the estimated budget that the team set for the year was $7,500, and in the end, the team spent $7,125. The team budgeted an additional $5,000 for expected travel expenses, which includes room and board for the nine team members at the international competition.

| Highway 68 ROV Club 2016-2017 Budget and Expenditure Sheet (USD) | | | | |
|---|---|---|---|---|
| ITEM | BUDGET | COST | VARIANCE | DONATED/DISCOUNTED/REUSED |
| **Electrical** | | | | |
| Motor System (motors, ESC) | 800 | 840 | -40 | |
| Tether/wires | 300 | 120 | 180 | |
| Custom-printed circuit boards | 300 | 350 | -50 | |
| Monitors | 0 | 0 | 0 | Reused |
| Joysticks | 50 | 40 | 10 | |
| Cameras | 200 | 120 | 80 | |
| Switches/potentiometers | 50 | 30 | 20 | |
| Microcontrollers | 250 | 240 | 10 | |
| Miscellaneous | 200 | 200 | 0 | |
| SUBTOTAL | 2150 | 1790 | 360 | |
| **Vehicle** | | | | |
| Frame material | 300 | 80 | 220 | Partially reused |
| Tube & end caps | 200 | 425 | -225 | |
| Propellers | 100 | 0 | 100 | Donated |
| Attachments | 500 | 250 | 250 | |
| Light | 50 | 150 | -100 | |
| SUBTOTAL | 1150 | 905 | 245 | |
| **Supplies** | | | | |
| Mission props | 250 | 250 | 0 | Reused |
| Marketing | 200 | 150 | 50 | |
| Administrative costs | 60 | 20 | 40 | |
| Shop upgrades | 300 | 100 | 200 | |
| Repairs budget | 1000 | 230 | 70 | |
| SUBTOTAL | 1810 | 503 | 407 | |
| | | | | |
| BUDGET SUBTOTAL | 5160 | | | |




TOTAL EXPENSES 7125

VARIANCE 375

# Fundraising

In terms of fundraising, the Sea Sweepers branched out and held fundraising events, such as organizing with local vendors to earn a portion of their profits if the team advertised for their restaurant. The team also began a yard work and junk hauling service in the local area, in which members cleared junk and debris for donations. It was a very profitable business that not only raised money for the team, but also acted as a team building activity. For the most part, the team reached out to the local community in a letter writing campaign and received support from a diverse group of sponsors, ranging from law firms to large agricultural corporations to individual sponsors and rotary clubs. Sponsors are organized into categories depending on how much they donate: Blue Whale ($1,000 and above), Humpback Whale ($500-$1000), Orca ($250-$499), Dolphin ($249 and below). All sponsors (listed below) are featured on the Sea Sweepers' website (www.seasweepersrov.com) and on a special poster that that is advertised at the competition; in addition, they receive a tax deduction due to the team's nonprofit status. Altogether the Sea Sweepers' raised $12,000 for the 2017 ROV season.

**Team members clear debris for donations**

# Sponsors

| | |
|---|---|
| El Camino Machine and Welding | 1500 |
| Stuart and Susan Smith | 1500 |
| Dole Fresh Vegetables | 1000 |
| Joe Pavek/Associates Logistics | 1000 |
| Monterey Pacific Rotary | 790 |
| John & Mary Avera | 650 |
| Tactical Wealth | 500 |
| A&V Aamodt | 500 |
| Colin & Marianne Horwitz | 500 |

*sponsors under 500 listed on website

**The Sea Sweepers visit Monterey Pacific Rotary**

# Project Management

At the beginning of the season, the returning members of the Sea Sweepers held a preliminary meeting to discuss the successes and failures of the previous year, along with plans for the new ROV and new members. Once the team lineup was set, the CEO shared a team calendar that set both tentative goals and hard deadlines that would keep us on course throughout the year in designing, building, and practicing the vehicle. The team communicated every day through a group text in order to stay on track and meet each deadline in the design and build process.

# Technical Challenges

During the early design phase, the team faced difficulty with the waterproof electronics housing. The new code motor control system being developed required a lot of electronics in the tube, such as voltage converters, electronic speed controllers, Arduino controllers, and lots of wiring. The original plan was to use the Blue Robotics electronics housing, which is four inches in diameter; however, it did not have sufficient volume to fit all of the required components. The mechanical engineering team could not find a larger, commercially available electronics housing, so the team decided to design and machine its own. The mechanical team purchased an acrylic tube six inches in diameter and an aluminum cylinder 6.5 inches in diameter. Meanwhile, the CAD team produced a design for the end caps, the caps being fused into the flanges, requiring only two O-rings per side to seal. We sent the design to a local machine shop to be produced. These were then drilled with the necessary holes to mount the waterproof wire connectors.

# Interpersonal Challenges

As a team, the Sea Sweepers faced personal challenges as well as technical challenges. With nine active team members, the biggest issues were project management and keeping everyone occupied with tasks to complete. To overcome these, the team created a detailed schedule with deadlines for the completion of each vehicle component and testing dates. We used this schedule to delegate tasks to specific team members or groups of members, and adjusted the deadlines as needed based on successes, failures, and workload. This way, members could work at meetings or at home, so no one had to attend every single meeting and the overall schedule did not have to be compromised for individuals. This master calendar was instrumental for the team staying focused and on schedule.

**The team solving a problem together**

# Vehicle Handling and Care

While BRIAN was designed to be durable and easily maintainable, there are certain actions that team members take to mitigate mechanical and electrical issues with BRIAN. During construction, taking extra care with soldering and waterproofing electrical connections reduces the risk of a short. Carefully handling and storing the tether reduces kinks, and strain on the connections at both ends of the cables. During the product demonstration, the team's designated tether manager is responsible for preventing issues with the tether in the pool and on the deck. BRIAN has been extensibly tested in both chlorine and saline pools, and after each practice run, a team member thoroughly washes the vehicle down with fresh water to help prevent corrosion. In addition, each motor is sprayed with an anti-corrosive oil that protects them from corrosion. This not only improves performance, but extends the life of the vehicle, making the ROV more efficient for the client. For transportation to and from any demonstration venue, both the vehicle and control system are packed into trunks and padded with liberal amounts of bubble wrap.

# TESTING

After all of the components were assembled into the complete vehicle, the Sea Sweepers began the extensive testing process. First, the team conducted the "bench testing". This consisted of running the motors and operating payload tools in the design shop to ensure the control console is properly communicating with the vehicle. Team engineers also used compressed air and a pressure gauge to test the O-ring seals on the electronics housing. Once this was sufficiently waterproof and the code was working properly, the team began running performance tests on the vehicle in the pool with the goal of adjusting the limits of motor power and trimming buoyancy and ballast. Next, the team entered the mission practice phase, where the poolside crew rehearsed the mission tasks and field tested BRIAN's payload tools. Poorly functioning or inadequate payload tools were modified, improved, or even redesigned.

**The many props the team designed and tested**

One important component that underwent an extensive testing process was the propellers. The propeller designers developed over fifteen distinct propellers, differing in mounting style, number of blades, blade length, and pitch angle. The goal of the project was to produce a propeller with a comparable thrust output to the Blue Robotics T-100. Sea Sweepers engineers used their M100 motor as a base and ran basic tests on all of the propeller designs, before selecting the top two contenders, a two-blader and a three-blader. With these, the team ran over fifty tests on each, using different amperage levels, thrust directions, and propeller mounting orientations. All of the data was compiled, and the design team analyzed the resulting graph, making the choice of simple propeller. The graph showed that while in the forward direction the two and three blade propellers were equivalent, the two-blader was superior in reverse. The choice to use a two bladed prop was clear after comparing the data. This data can be viewed in Appendix B (pg. 21).

**The team testing the vehicle**

# TROUBLESHOOTING

The team utilizes the NASA Engineering Design Process when problems arise. This process consists of the following steps: identify the problem, identify criteria and constraints, brainstorm possible solutions, generate ideas, explore possibilities, select an approach, build a prototype, and refine the design. When mechanical problems arise, the Sea Sweepers always reference this troubleshooting process. For example, while having issues with motor control, team engineers were able to identify a hardware problem by using a modified sample code to test individual motor control. Two motors were not functioning and the engineers identified that these two motors never functioned despite attempts to power the two motors independently. Because the motors would not function even when isolated, the team decided that the problem could either be a malfunctioning electronic speed controler or a bad motor. After swapping the motors engineers were able to determine that the problem was, in fact, the motors. The motors began to function normally after replacing them and using the finalized motor code.

# Team Member Reflections

My experience in ROV has been amazing. Being the only freshman, I thought it might take me some time to get used to everyone, but from day one it has felt like a cohesive team. Our love for robotics and technology helped us to connect immediately. The ROV experience has helped me to further develop my coding skills; I had so much fun finding new ways of achieving a goal while creating the sensor system and GUI. I sharpened my skills in the use of Python and Arduino. I also loved our lively team discussions as we learned the process of creating something as a group, and the give-and-take of ideas was really exciting! I learned so much from the entire process and from everyone on our team.

**Marco Pizarro**
9th grade

**Tyler Allen**
12th grade

After three years of the ROV experience, I have learned a lot about not only robotics but also myself. Prior to joining the team, I was a hands-on person that worked in the solitude of my grandparents' garage. In class, I was terrified of presentations and group assignments. When I first joined the team, I expected these fears to follow me; however, I found myself learning to work cohesively with people that soon become very close friends. The ROV experience has been a great opportunity to learn more about the field of robotics as well as gain valuable skills that will be necessary in the job market.

My ROV journey started eight years ago when I was in the fifth grade. I was a shy kid who loved science, but didn't know much about engineering and hands on skills. I competed with the team up through all four levels of the MATE competition and am confident that I am much more prepared for college with technical, design, problem solving, and leadership skills than I would have been otherwise. I've had an incredible experience with the Sea Sweepers and am grateful for all I've learned. I'll be able to take all these skills and experience with me when I attend the United States Air Force Academy in the fall.

**John Yeager**
12th grade

**Kate Yeager**
10th grade

My ROV experience has taught me many life skills, most importantly how to use creative thinking to solve seemingly impossible problems. I have learned how to collaborate, research, organize, and design. ROV has provided me with an experience unlike anything I could get in a classroom because it is hands-on and student-run, giving the team responsibility and independence. As a member of a Navigator class team last year, the jump to Explorer for this season seemed intimidating. However, joining the Sea Sweepers was anything but intimidating. The team immediately put me to work on the control box and that experience has taught me about electrical engineering and has made me consider more STEM fields for my future.

# Future Improvements

In hindsight, the team realized that it would have been better to take specific mission tasks into consideration before building and designing the vehicle. While we did pay attention to tasks in the design of the control box, we learned that we should focus on building mission-specific attachments and payload tools from the beginning of the design process. Last season, the Sea Sweepers learned the interpersonal lesson of organizing and scheduling for a team of nine busy people. To account for this in the 2016-2017 season, we scheduled more meetings in the beginning of the season, allowing for more free time and pool practice towards the end of the season. Over the past year, the team has honed a variety of different skill sets to address problems faced in the past. Last year, we faced problems such as finalizing vehicle designs, debating the use of certain parts (e.g. brushed motors versus brushless motors), and scheduling meetings. However, we have developed better management skills to finalize designs and make important executive decisions early on in the season.

# Acknowledgements

The Sea Sweepers would like to thank our loyal support system as well as all of our benevolent sponsors that made this vehicle and competition a possibility. We would like to thank Jill Zande, Matt Gardner, and the entire MATE organization for holding the ROV competition and giving students the opportunity to expand their skill sets and learn from hands-on experience in both engineering and business. The Sea Sweepers' sponsors, many of whom have sponsored the team in the past, are so incredibly generous and we thank them for their financial support, without which we would not have gotten off the ground. The team would like to thank our families for their constant love and support. In addition, the Sea Sweepers extend a special thank you to Kevin D'Angelo for his guidance and expertise in the area of software engineering. Finally, thank you to the team's faithful mentors Kurt Yeager and Mike Allen. Thank you, Kurt and Mike, for sticking with the team for eight long years, having a sense of humor, and always reminding us to wear safety glasses.

# References

Chuck Felice, Salinas High School woodshop teacher

James Nichols, Salinas High School drafting teacher

Jim Warwick, Salinas High School vocational teacher

Kevin D'Angelo, Robert Louis Stevenson School robotics teacher

MATE: *http://www.marinetech.org/*

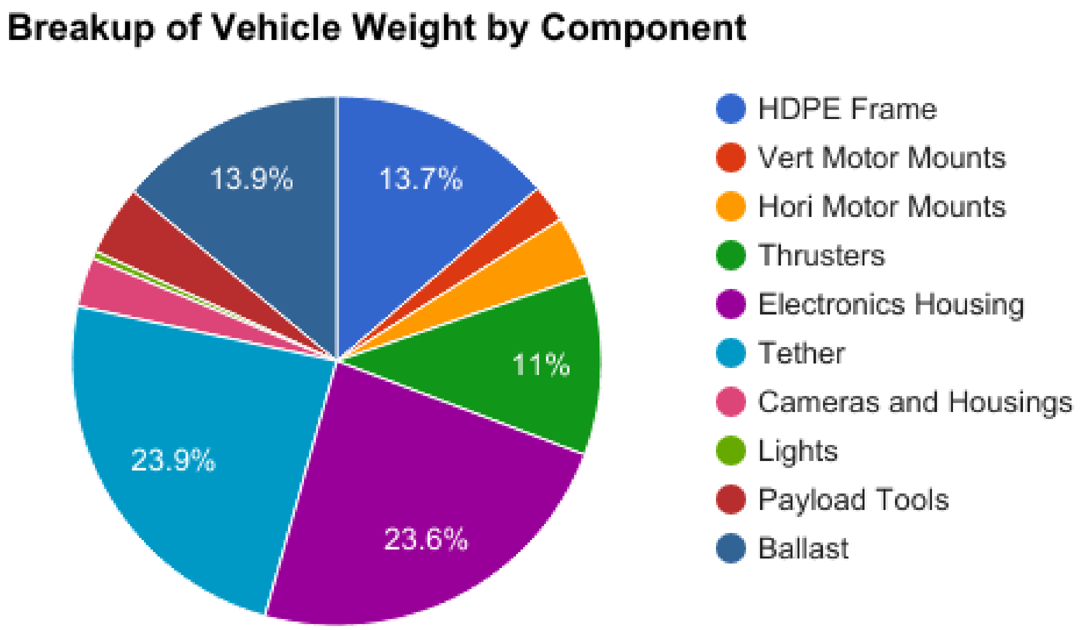
Arduino: *https://www.arduino.cc/*

Sea Sweepers ROV Facebook Page: *https://www.facebook.com/SeaSweepers/*

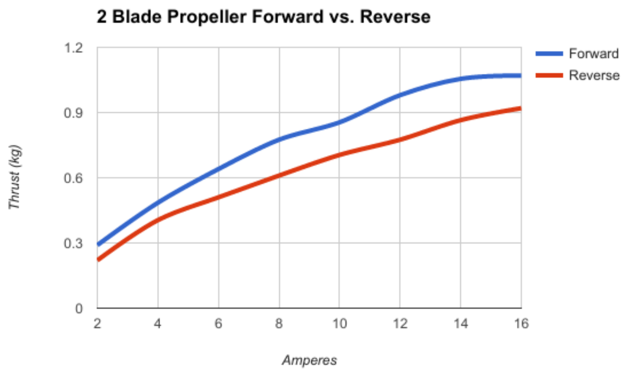
Sea Sweepers Website: *http://seasweepersrov.com*

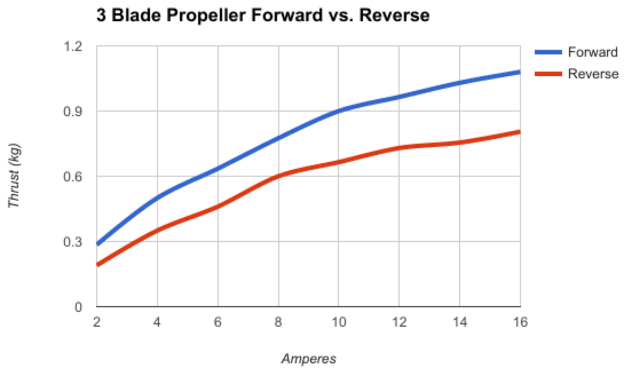
# Appendix A: Vehicle Weight Breakdown

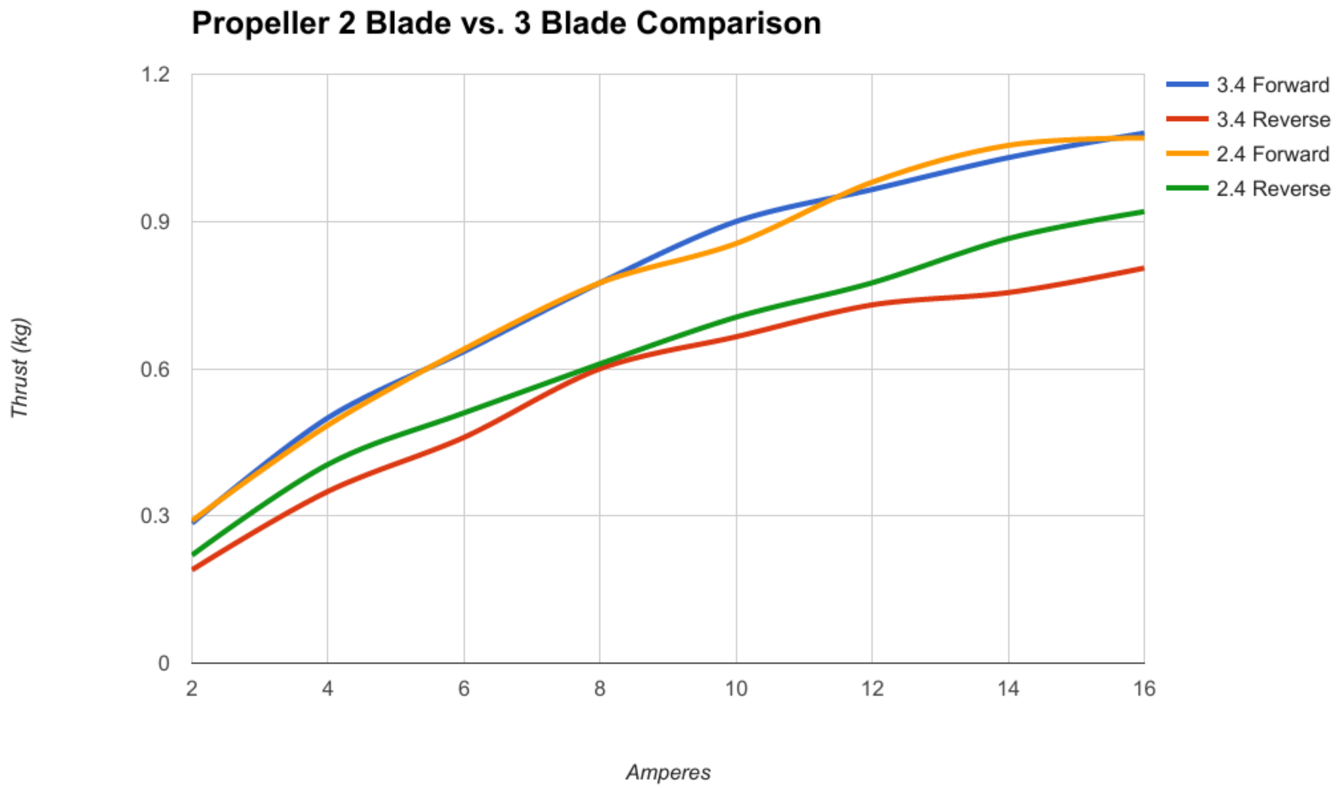
| Part | Part Weight | # of Parts | Total Weight (g) |
|---|---|---|---|
| HDPE Frame | 1475g | 1 | 1475g |
| Vert Motor Mount | 62g | 4 | 248g |
| Hori Motor Mount | 100g | 4 | 400g |
| Thrusters | 148g | 8 | 1184g |
| Electronics housing | 2540g | 1 | 2540g |
| Tether | 2575g | 1 | 2575g |
| Camera and Housings | 81g | 4 | 324g |
| Light Assemblies | 25g | 2 | 50g |
| Payload tools | 458g | 1 | 458g |
| Ballast | 1500g | 1 | 1500g |
| **Total Weight** | | | **12.477 Kilograms** |



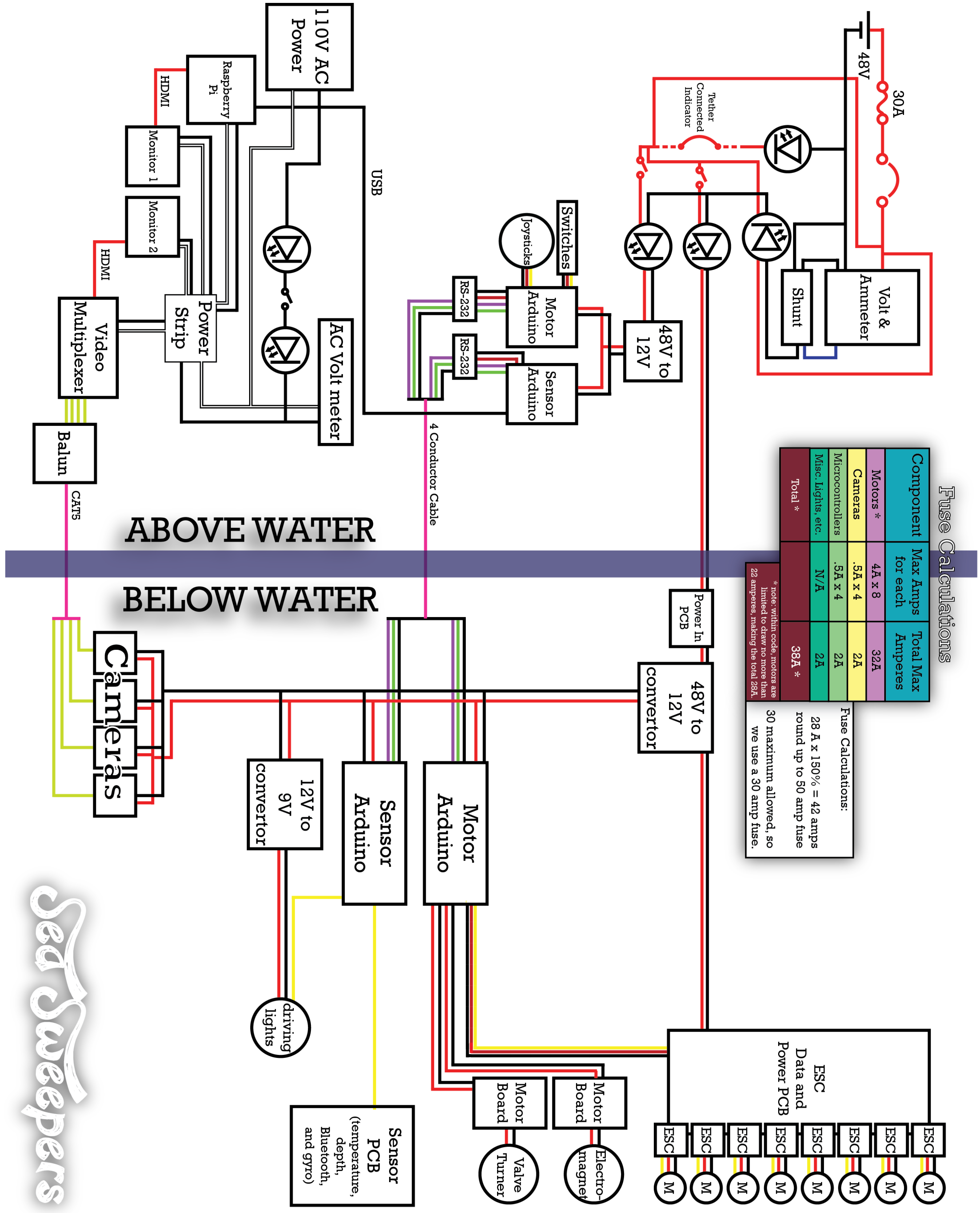
# Appendix B: Motor Testing Data



# Appendix C: System Integration Diagram




Fuse Calculations

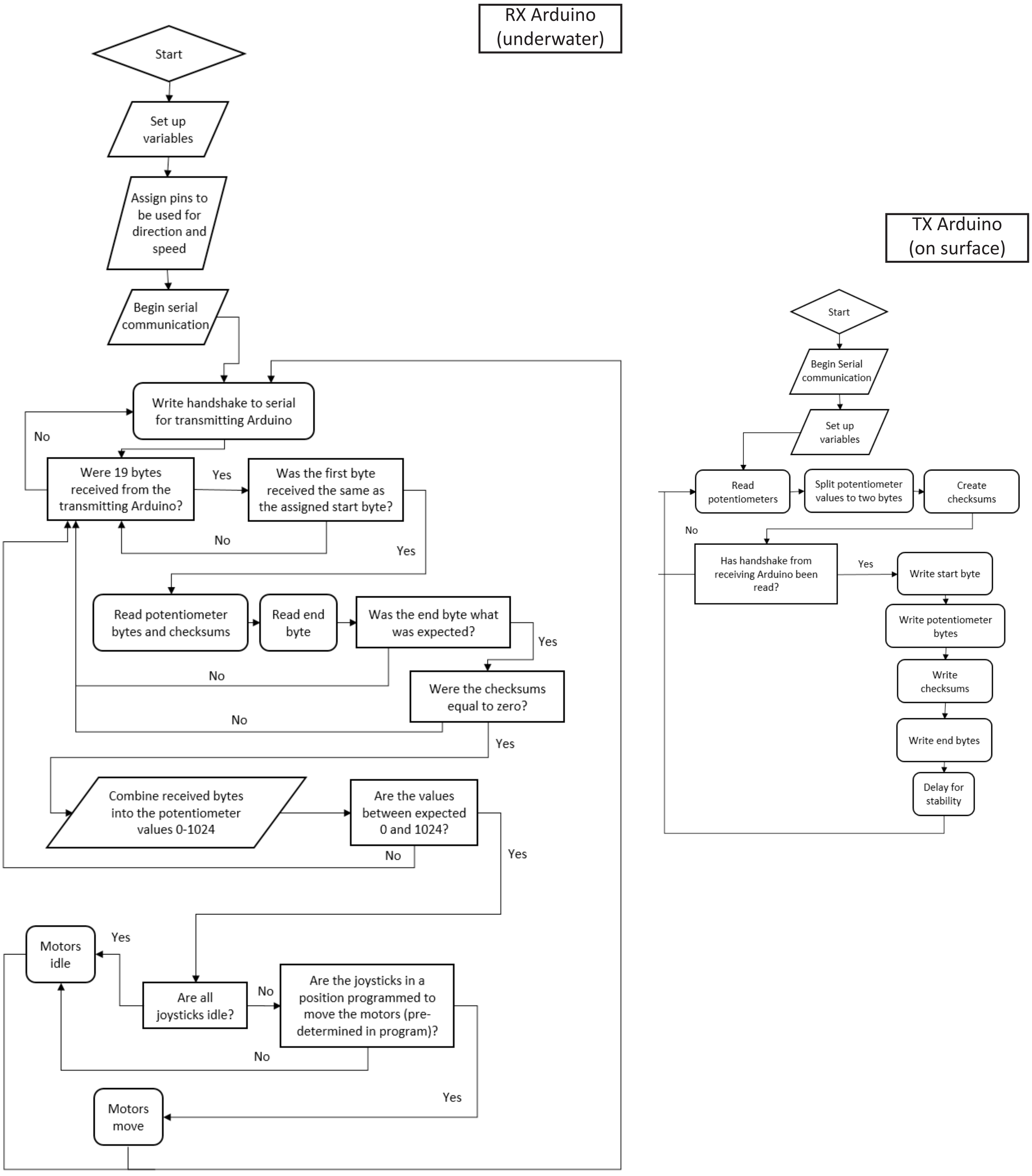
| Component | Max Amps for each | Total Max Amperes |
|---|---|---|
| Motors * | 4A x 8 | 32A |
| Cameras | .5A x 4 | 2A |
| Microcontrollers | .5A x 4 | 2A |
| Misc. Lights, etc. | N/A | 2A |
| Total * | | 38A * |

* note: within code, motors are limited to draw no more than 22 amperes, making the total 28A.

Fuse Calculations:
28 A x 150% = 42 amps round up to 50 amp fuse
30 maximum allowed, so we use a 30 amp fuse.

# Appendix D: Software Flowcharts

## Motors



# Appendix D: Software Flowcharts (cont.)

## Sensors