Mustang Robotics

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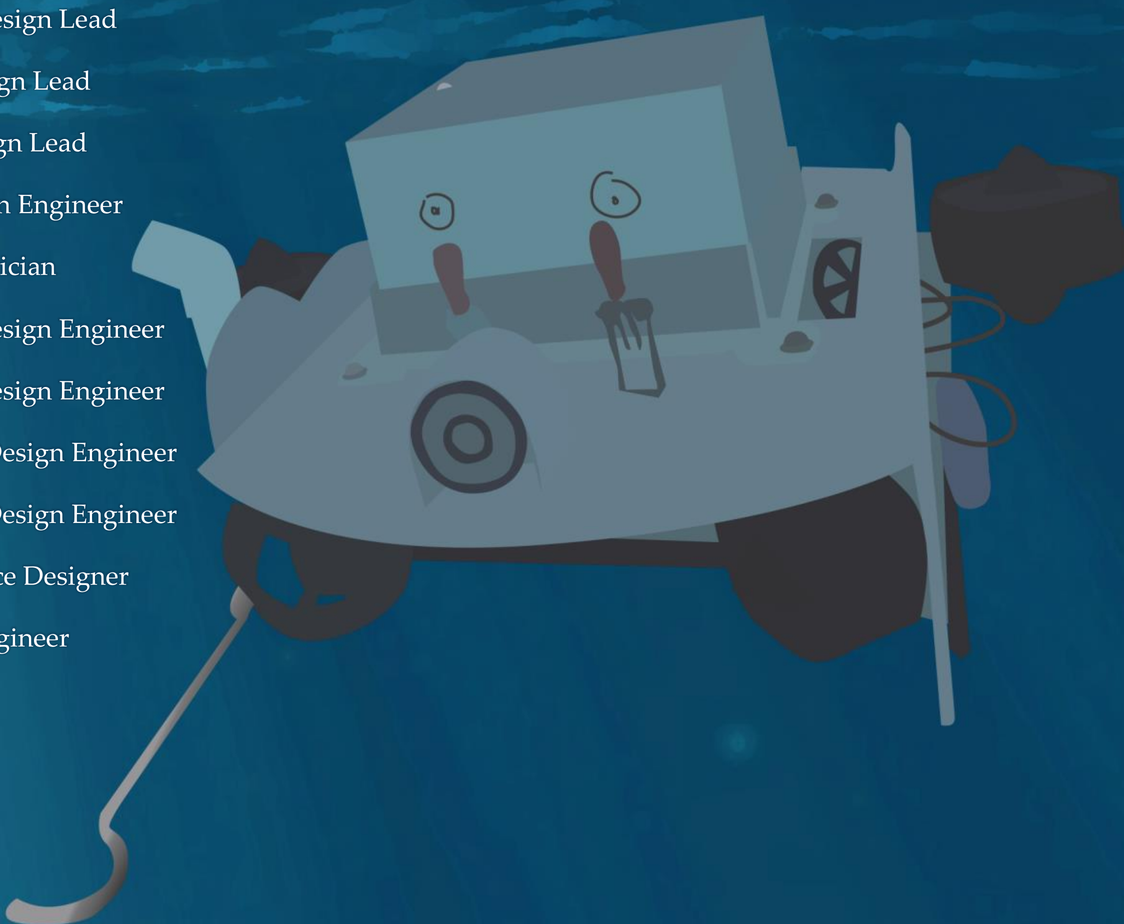
"Sebastian"



Abstract:

Mustang Robotics is proud to present Sebastian, an ROV designed to perform in both Earth's oceans and beyond, to the water moon of Europa. Sebastian was designed and built by the Mustang Robotics team over a period of nine months with a budget of five thousand dollars. This document details Sebastian's design, construction and testing, as well as the organization, procedures, and philosophy of Mustang Robotics.

Sebastian is designed to be compact, lightweight, and maneuverable, all without sacrificing any of the capability and accessibility necessary to complete the tasks presented by this year's mission. This design philosophy began with our electronics housing, which uses a gasket compression seal clamped by a series of toggle latches, allowing for quick access and a consistent seal. The frame of the vehicle is a polypropylene "H" design, which offers ample space for mounting mission tools and ease of accessibility to electrical connectors and mission tooling. To ensure the driver has excellent control, Sebastian is equipped with four cameras and six Blue Robotics T100 thrusters.

The control system of Sebastian utilizes an RS485 serial protocol with differential signaling and high voltage logic levels to ensure signal integrity for distances up to a thousand feet. Our asynchronous communications provide reliable data transfer without latency, reducing the learning curve necessary to use Sebastian. To provide the pilot and co-pilot with additional ROV information, sensors on Sebastian provide the user with power and temperature data from the inside of the electronics housing, along with attitude and depth.

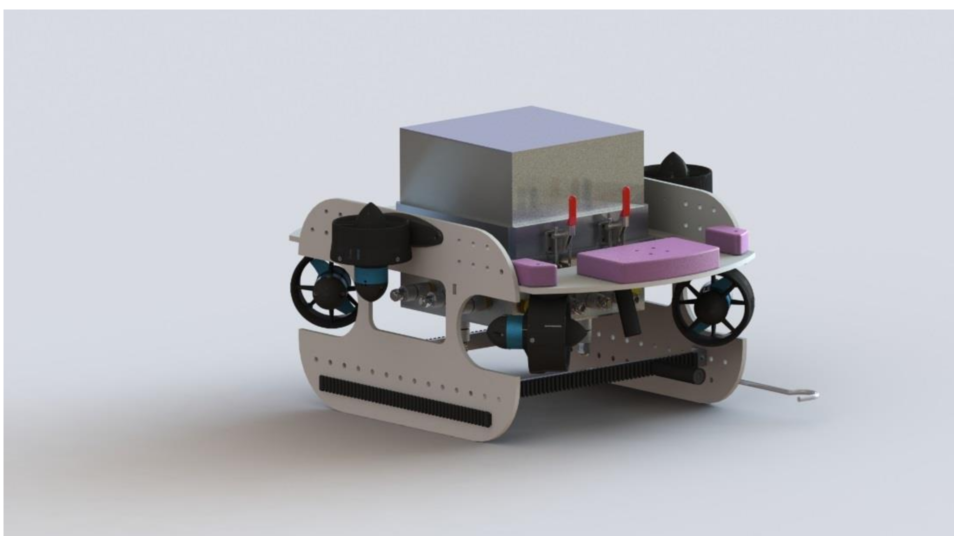


Figure 1: *A Solidworks rendering of Sebastian.*

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Design

Frame Design

Sebastian uses a ¼" polypropylene "H" shaped frame as opposed to last years aluminum box frame. This design allows us to easily prototype many modifications to the frame design as we are able to quickly cut out foam core mock ups with the aid of the laser cutter. The reasoning behind this is primarily for ease of production, as the laser cutter allows us to rapidly build and test various frame designs, as shown in Figure 2 below. Ultimately, the frame is consisted of a central plate that holds the electronics canister in the center via four bolts, and two vertical wings that the mounting hardware is attached to. The two wings were mounted perpendicular to the central plate to make the best use of the spherical mission size constraints. They were attached via mated slots that were then plastic welded through the use of a specialized heat gun. The result is an H shaped robot with our cube shaped electronics canister being mounted in the middle. For rigidity and additional mounting locations, two flat aluminum bars were bolted to the bottom of the H frame to prevent wobbling.

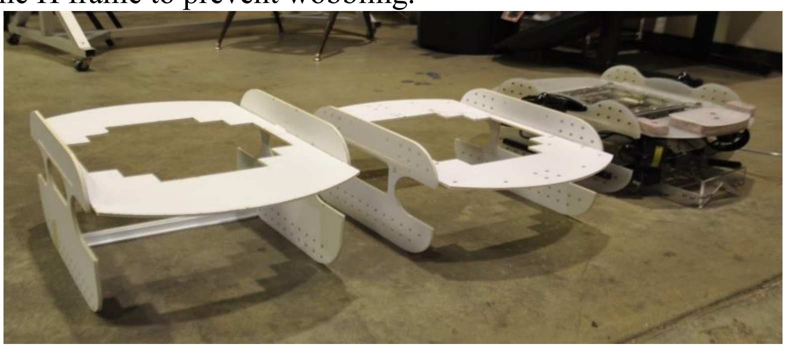

Figure 2: *comparison showing laser cut frame mockups next to our final frame*.

This shape offers numerous advantages, one of the biggest benefits is the easy mounting of mission tools. The frame is lined with holes that have threaded inserts in all of them. This allows for mission tools to be quickly screwed into the frame and many different points and without the hassle of dealing with lock nuts. Since the frame is mostly thin sheets of polypropylene, most of the available space constrained by the mission size envelope is left open to store tools. The relatively open design also makes accessing both the robot's electronics and mission tools fast and easy, allowing for quick maintenance and testing. Lastly, the minimalist frame design also cuts down on weight, allowing us to allocate more of the limited weight we are allotted towards mission tools and a robust electronics housing.

Connectors

This year, Mustang Robotics has built off of the experience we gained creating our own 8 pin connectors to design and manufacture a full set of connectors for our ROV. The connectors we have designed have similar size and capability to the industry standard, but at a fraction of the cost. This was possible through a small team of electrical and mechanical engineers studying the commercially available solutions while trying to develop a method to create something similar within the manufacturing capabilities of our team. Beyond providing a lower-cost alternative to commercial connectors, the design of these connectors has given many of our new company members invaluable experience with design for manufacturing, design troubleshooting, and machining experience. We chose to manufacture our own connectors rather than purchasing them because we can tailor the connector design to meet our changing needs, including features like pin number and orientation. The process was also a great learning experience. It helped us gain a better understanding of the importance of having connectors that are well-insulated, quick and easy to attach; while still being reasonably simple to manufacture. All of the connectors were manufactured in house using the Cal Poly machine shops.

Figure 3: *First article test of our waterproof connectors.*

The manufacturing process began with the machining of the aluminum shells and the brass bolts, which serve as structural basis of the connector. The next step in the process involved the manufacture of pin alignment plates and molds, which were cut by students on a small CNC mill, and hold the pins in place during casting and through operation. Next, we used pourable polyurethane rubber to fill the insides of the connectors as well as form an extruded surface which provides a sealing face between the connectors. The process of designing and building waterproof connectors further cements the ability of Mustang Robotics to be competitive in the expanding underwater technology market.

Power supply:

Mustang robotics uses a robust 48 V wall plug power supply. This topside supply uses a safe, polarized Anderson Connector as its power output, to prevent reversing the connections. It has a 12 amp fuse in-line to meet the MATE center safety requirements, as our power supply is not rated to exceed 600 Watts of power usage at any given time. The power is then sent down a 14 AWG, two conductor cable to a custom-made connector on the ROV.

Electronics trays:

Our ROV also has a clean, easy to maintain electronics tray. All of the electrical connections on the ROV connect to a single planar connection of several precision-aligned D-sub connectors, allowing the electronics tray to be removed from the inside of the ROV in under 10 seconds. This allows Mustang Robotics to quickly perform unpowered tests with the electronics removed, or to work on the electronics tray from the test bench power supply without the ROV present.

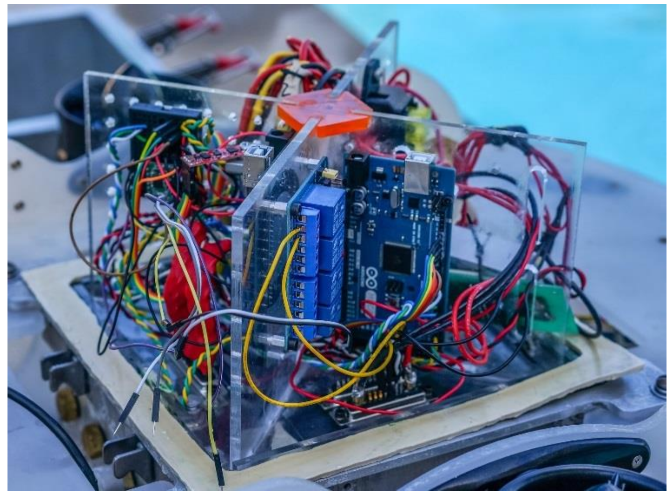

Figure 4: *The Main Electronics Housing*

Power Conversion:

Power conversion on the ROV is done on an in-house designed PCB. This quad power bus board not only converts the 48V input to 12 Volts at 96% efficiency, but also provides fault detection on the power system and temperature data for each power bus. It then supplies 12 Volts to the Electronic Speed controllers, the Camera systems, and the power sensing board. The power board can output up to 1200 Watts, but will only need to supply 800 Watts under normal conditions because of topside power limitations.

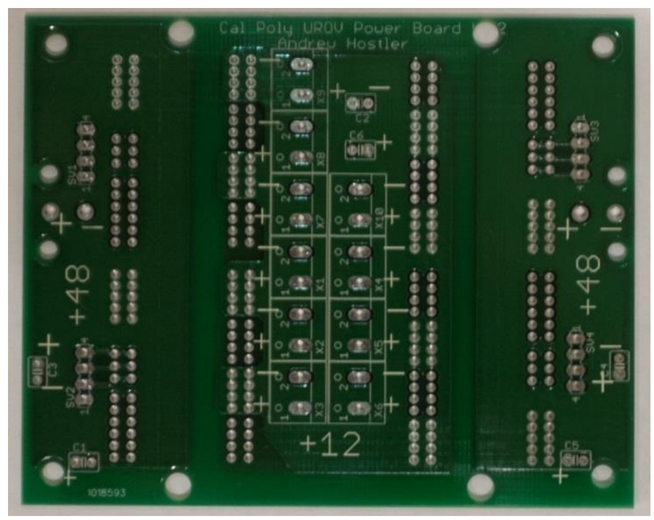

Figure 5: *A custom 1.2 kW power board for Sebastian. Using student made PCBs such as this allowed for a much smaller form factor in electronics mounting space.*

Video:

There are four cameras to help the user guide our company's ROV from many viewing angles. The cameras are positioned to help the user view the mission tools as they perform their purpose. This way, our product can perform precise maneuvers with instant feedback on each and every maneuver performed. The many visual feeds are managed through the video switching section of the Mustang Robotics accessory board, using GPIO pins to receive commands from the controller through the Master control module.

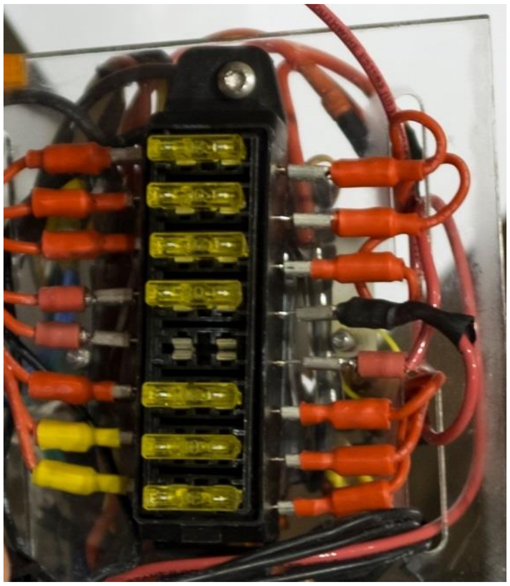

Figure 6: The array of fuses.

Fuses:

The ROV uses a bank of 8 automotive blade fuses to limit the current draw from the power supply. Our product is prepared for use in space, as well as the ocean. As such kelp beds may be a potential hazard. If the ROV runs through a kelp bed, the blade fuses will prevent any overcurrent in the motors without overheating or damaging the thrusters. Also, if the power systems on the ROV short circuit, the system will stop drawing power rather than destroying precious equipment.

The bank of fuses is also an effective use of space. It helps troubleshooting and is easily replaceable in case our product is put in unplanned circumstances. By limiting the power, it keeps the other parts of our company's ROV from exceeding their specified current and wattage limits. This preserves the functionality of the rest of the ROV in case of a single-subsystem malfunction.

Thrusters:

For ease of operation, four T100 thrusters were used to drive the robot. These thrusters improved over last year's design because the brushless motors operated more efficiently. They also have no air or oil filled cavities, allowing them to operate in seawater consistently without maintenance. With 130 Watt capabilities, the thrusters can provide 2.4 kg of diagonal thrust each- totaling 6 kg of thrust for the ROV in forward or sideways motion.

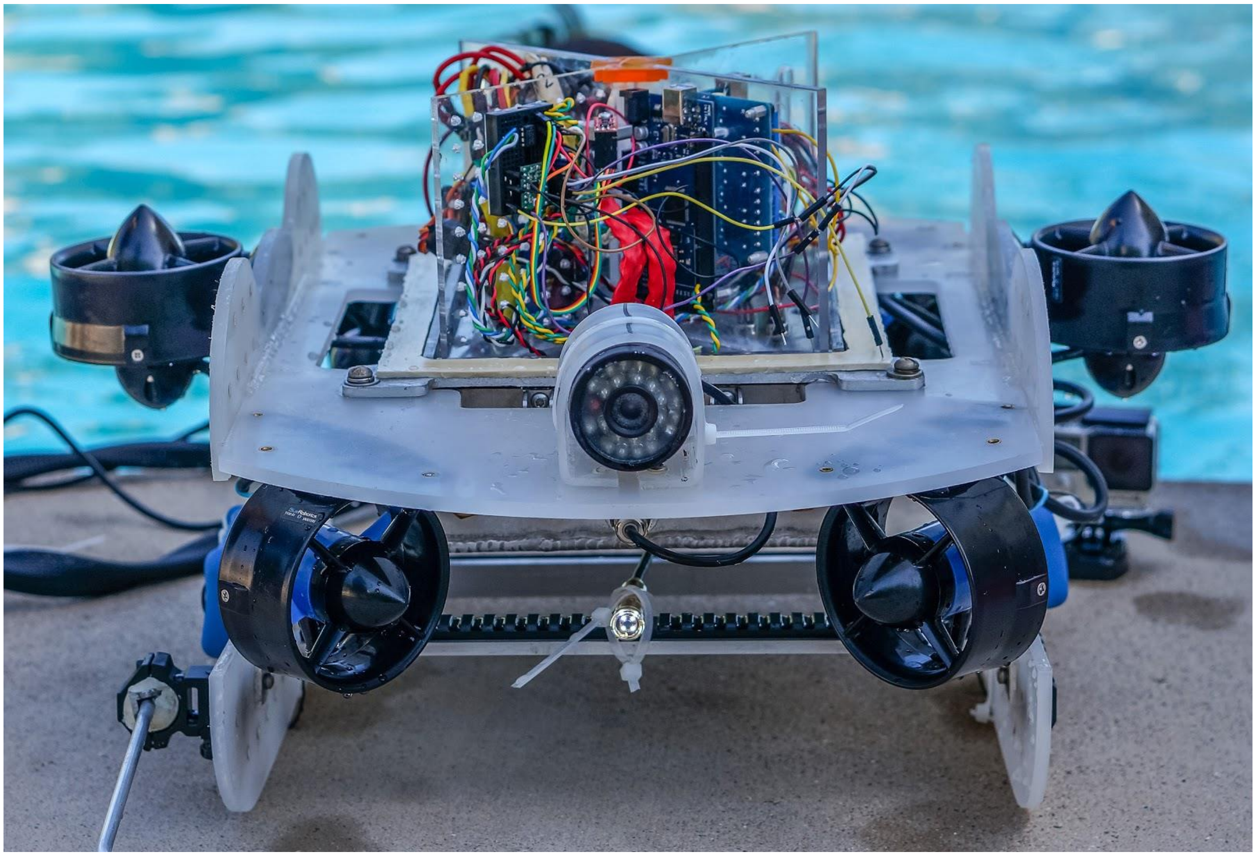

***Figure 7:** A front view showing our ROV's vector drive thruster mounts. This allowed the user to drive in both translational and rotational motion along a horizontal plane for intuitive mission task completion.*

Vector drive was implemented by angling the horizontal thrusters in a 45° diamond formation on the Polypropylene chassis. Placed at each of the four corners of the box, the thrusters can move the ROV in both the x and y direction. Movement in the z direction was achieved with two T100 thrusters facing vertically on the ROV, with 4.8 kg of upward thrust at peak output.

Using a vector drive system, controlling Sebastian is intuitive. The ability to both move and look in different directions enables users to draw on their experience using an xbox controller. It also is an essential for precise underwater applications, allowing for users to adjust their position while keeping visual reference to their objective.

Microcontrollers:

Sebastian is powered by two Arduino Mega microcontrollers. One is the master microcontroller, which communicates with the top side via RS 485 serial communication, and sends data to the thrusters. The other Mega board processes sensor data and communicates this information to the Master via I2C. The purpose of having two Arduinos with one as a master and the other slave is for both reliability and speed. Reading sensor data can use a considerable amount of processing power, so keeping this task on a separate microcontroller allows the Master to perform its tasks much faster. Additionally, this allows for isolation between the motor controllers and the sensors in case of an unfortunate event such as a program crash during sensor readings, which would prevent a crash on our Master Arduino and the communications.

Power Tracking:

In past years, power budget has been a challenge in ROV design. Some guesswork was involved in how much the ROV was actually using, as opposed to nominal values from datasheets. This lead Mustang Robotics to design a custom PCB for power monitoring. Our power budget tracking PCB was designed by company members using CadSoft Eagle, and manufactured by our sponsor Bay Area Circuits. This allowed the user interface to give the user feedback on how much power is being used by the ROV, thereby avoiding brownouts while on critical mission tasks.

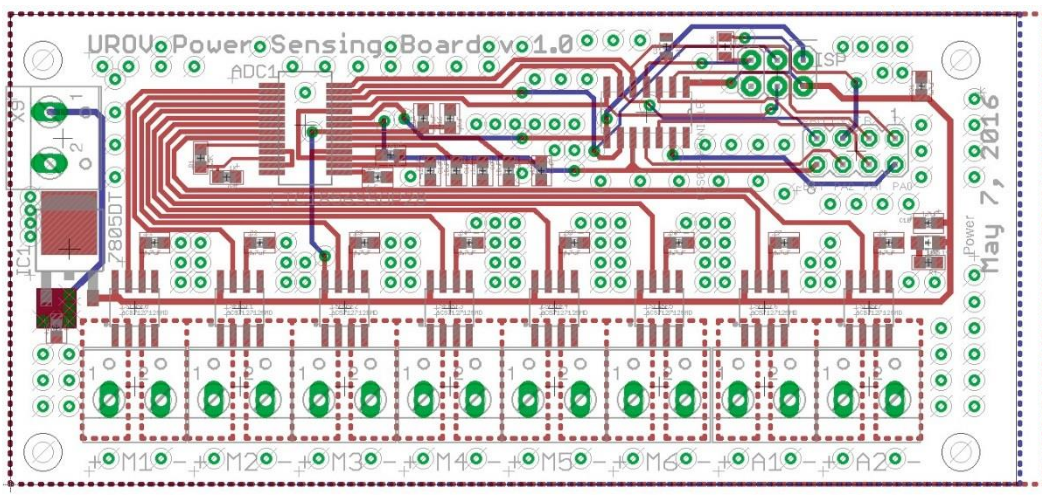

Figure 8: *The power measurement board for the ROV. It has 8 inputs for measuring up to the tether, six thrusters, and an extra mission tool.*

Sensors:

Sebastian has several sensors for gathering data on the external environment. There is a small pressure sensor mounted near the connectors that monitors the depth of the ROV. This can be used to measure the thickness of ice sheets, or measure the height the ROV is from a known depth seafloor.

Sebastian also has an accelerometer and gyroscope to track the orientation of the ROV. This data is sent topside and interpreted in the artificial horizon to notify the driver of the yaw, pitch, and roll of the ROV as it performs its tasks.

Finally, a one-wire protocol sensor is used to take temperature readings. The probe is aligned using mission tool hardware to properly read the temperature from a geothermal vent in its MATE specified mission task.

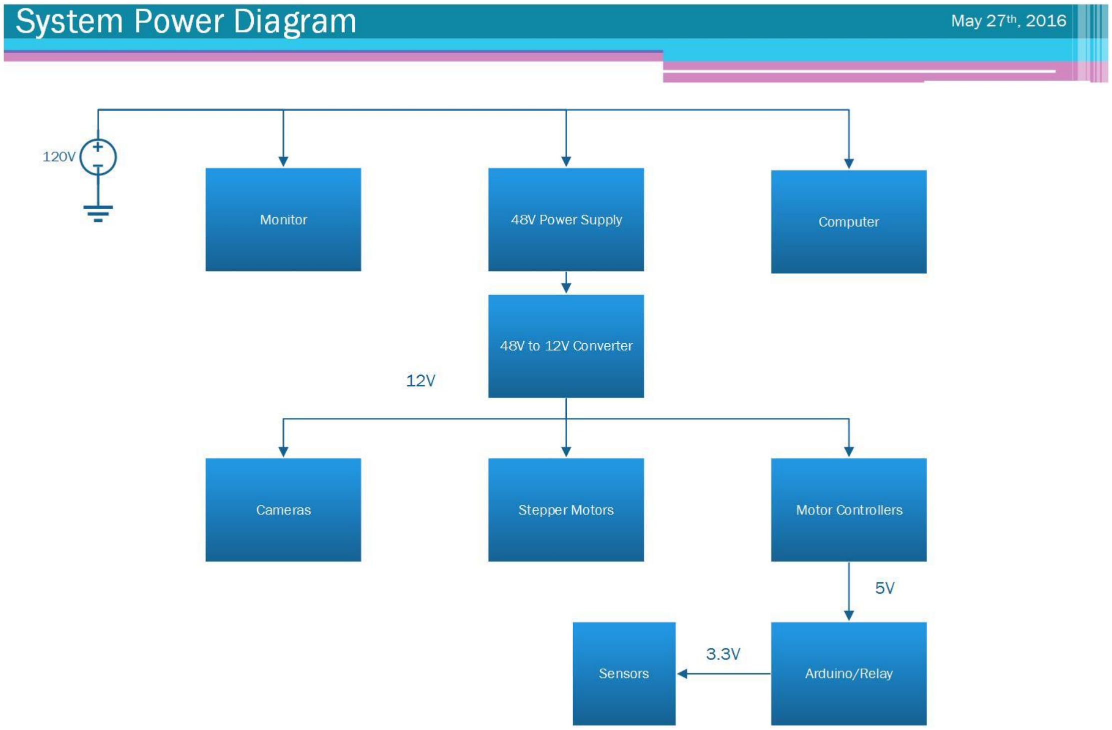

Figure 9: *Power Flow Diagram starting from wall outlet through entire UROV.*

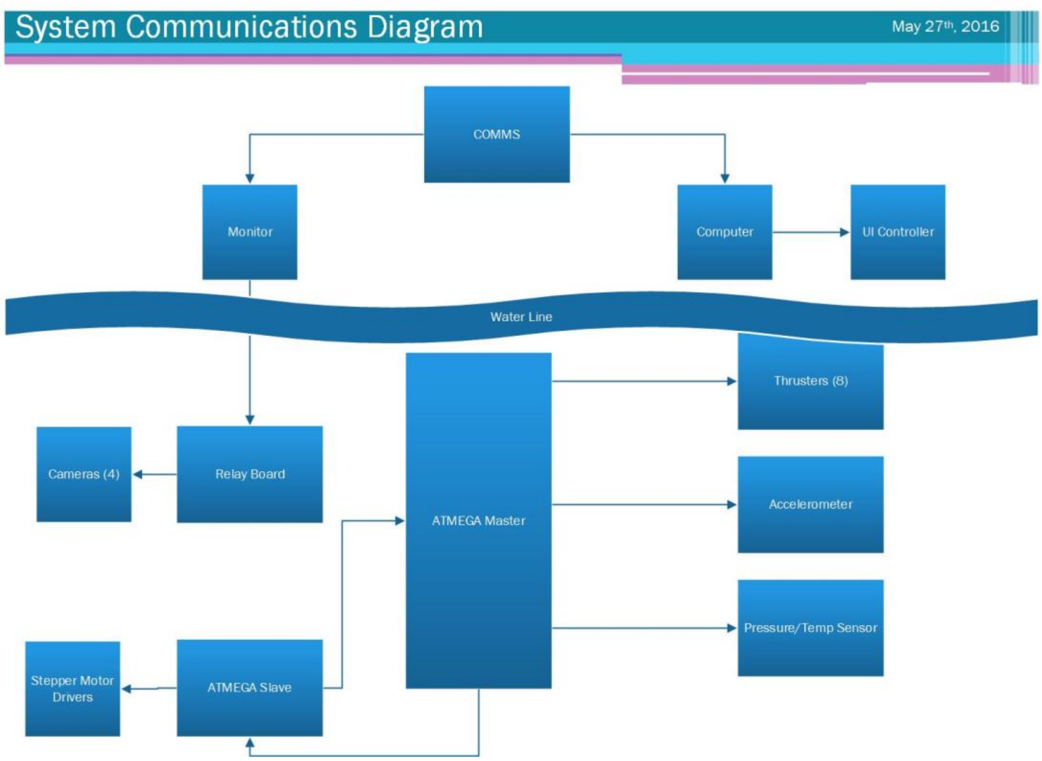

Figure 10: *Communications Flow Diagram of the UROV. The wave represents the water line between the COMMS station and UROV.*

Software

The UI is written in Python and uses a Pygame library, and the microcontroller code is written in C++/Arduino. The reason we chose to write the UI in Python is because of its ability to easily handle multiple types of data at once as well as its simplicity. We also chose the library PyGame due to its simplicity and ability to handle image translation. The UI receives input from an Xbox controller connected to the computer and the master Arduino through a serial line using the protocol RS485. We choose RS485 because it is designed to be transmitted over long distances.

When the UI initializes it looks for the controller and for a USB transmitter connected to the tether. When it finds it, it initializes the main window. On the user interface, all sensor information is displayed in a user-friendly fashion. All data received from the sensors is filtered to reduce noise and make it more accurate. The information appears in green for as long as data is received, displays the last data in red when there is a communication loss, and alerts the pilot when the controller is disconnected. There is also an artificial horizon which takes information from the accelerometer onboard and helps the pilot visualize the orientation of the submarine. It also has buttons for normalizing and resetting the artificial horizon. Furthermore, the UI also process the data from the controller before sending commands to the ROV's Arduinos. This includes a half power mode that be activated through a button on the controller.

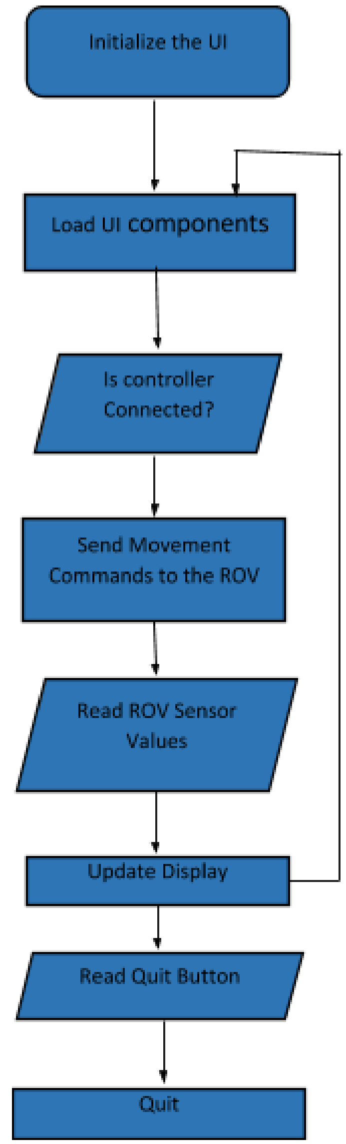

Figure 11: *Block diagram of software*

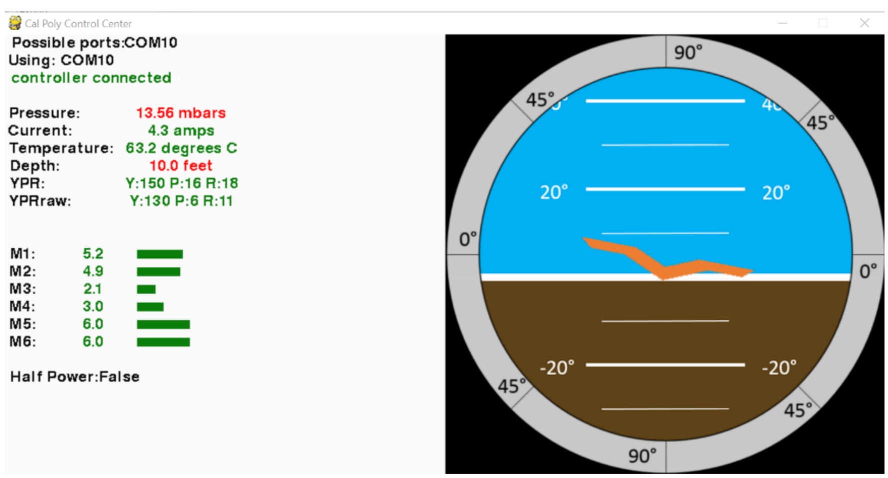

Figure 12: *A screenshot of the topside user interface.*

Mission Tools

In our design, we have opted to use mission specific tools for each stage of the competition, rather than use a universal manipulator for all tasks. Our reasoning behind this is that, since we have knowledge of our mission tasks ahead of time, we believe creating specialized tools for each task will aid in both ease of design and ease of use of the robot. We also have decided to use passive, unpowered tools. This reduces cost and complexity of the robot, while still maintaining excellent performance.

ESP Cable Connecter Recovery Device

To recover the ESP cable connector, we are using a powered mission tool instead of a passive one. This is due to the more complex shape of the connector and the delicate nature of the connector insertion process. We felt that the added precision gained by using a powered mission tool outweighed the added complexity. The basic operation of the device is powered by a single stepper motor that has been modified to be water resistant. The frame of the tool is made of laser cut ¼'' acrylic and aluminum bar stock, and is attached to the robot using modified rifle scope mounts.

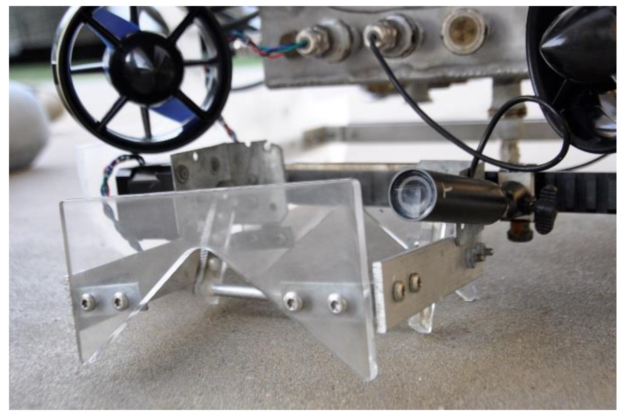

Figure 13: *A closeup of the connector recovery device. Note the adjacent camera to aid with precise maneuvers.*

The device functions by using the stepper motor to pivot an aluminum rod attached to the motor and a neutral pivot point via acrylic bars. The stepper motor gives the robot more space to maneuver into the correct position to take hold of the connector. Once the connector is clear, the robot can then pick it up by hooking the aluminum rod onto the I-bolt attached to the connector. By then actuating the stepper motor, the entire connector is pulled into the v shaped tool frame, locking it in place. Once locked in, the robot can freely maneuver without dropping the connector. Once the connector is inserted into the power hub, the stepper motor can be reversed to release the connector and allow the robot to disengage.

Communications and Power Hub Access Device

In order to open the door to the communications and power hub, a simple hook was all that we found was necessary. An aluminum rod was bent by hand into the appropriate hook shape, then welded to a small piece of L channel aluminum that was then screwed into a modified scope mount and attached to the side of the robot. Through the maneuverability gained through the vector drive, the driver can easily align the hook with the door handle and drive backwards to open the door. Once the door is opened, the position and shape of the hook allows the driver to easily disengage from the door.

Figure 14: *Shows the hook used for hub access.*

Oil Sample Recovery Device

For our oil sample recovery device, a passive system was deemed appropriate. To recover the oil samples, two sections of 1 ¼'' PVC pipe was cut and then thermally formed into an approximate "C" shape. This functions like a simple springed claw. These claws are also mounted via rifle scope mount near the base of the robot. By driving the tool directly downward onto an oil sample, the claws should snap into place around a sample, preventing it from being released from the robot until it is pulled out by an outside source. Since the samples do not need to be removed from the robot until it has returned to the surface, the inability to drop the sample without outside assistance was deemed acceptable.

Coral Sample Recovery Device

According to our research, the chenille brand pipe cleaners used in the coral sample prop is slightly magnetic, so we are utilizing again a passive approach of magnets. 3 high strength neodymium magnets are glued to each side of a section of L bracket that has been bolted onto mounting holes near the base of the robot. Each side of the magnetized L bracket can easily hold a coral sample by simply running into it. The high strength magnets output enough force to hold the coral samples even during the roughest of maneuvers with the robot (as seen by the tests done through the jolty elementary students driving at the San Mateo Maker Faire). The coral samples will be safely extracted to the surface where they can be removed from the robot for analysis.

Temperature Probe

A Spark Fun brand waterproof temperature sensor (DS18B20) is used as the base of our probe. A slightly modified ABS 2'' to 1'' PVC adapter is used to act as a guide for our probe. The temperature sensor is mounted in a 1'' PVC pipe via a modified endcap that is inserted into the end of the 2 to 1 adapter. Several holes have been drilled into the pipe to allow the hot water to vent while the temperature is being measured. The device is attached to the robot frame via an L bracket that attaches to a mounting point on the base of the robot.

Depth Probe

A Measurement Specialties brand depth sensor (MS5541C) is used for our depth probe. The depth sensor is housed within a sealed connector housing that we normally use for attaching electrical components to our robot. The connector is attached in the bottom center of the robot, and the dimensions from the top and bottom of the robot have been carefully measured. This allows us the estimate the depth of objects the robot is in contact with by subtracting or adding the dimensions of the robot to our measured depth.

Safety

Mustang Robotics is built off of its employees, and we take great measures to ensure that they work in a safe and healthy environment. This is done through rigorous hardware and software safety precautions, employee training and safety procedures. We maintain that all hazards can be avoided and we work hard to preemptively ensure that hazardous conditions do not occur. We live and act knowing that safety is everyone's responsibility and this can be seen in each of our employees' high standards for safety

Please review Appendix D "UROV Risk Assessment", for a list of the possible risks and the specific steps taken to eliminate those hazards.

Lab Safety Protocols

Our company is thankful that it has such great access to the machine shops and pools on campus and it takes great efforts to use those facilities correctly and safely. Whether machining is done specifically in the company's headquarters or in the official machine shops, tools are regularly checked that they are in a safe condition to handle, and that each person using, and those nearby, have the correct PPE (personal Protection Equipment). In addition to the basic training that our machinists go through to get access to the campus machine shops, further training is done to ensure that the users know the precautions needed for each specific task such as material handling, fixturing, and necessary settings. Employers are never allowed to work alone in the shops and are always accompanied by the team's shop technician, whose sole job is to ensure the safety of the employees. All employees are required to know the safety protocols for the headquarters. Mustang Robotics implements the 5S workplace standard (Standardize, Sort, Straighten, Shine and Sustain) to keep the tools in good condition ensuring that the work space is clean and safe. As we use campus labs for testing, we go through our checklist to minimize human error and to protect the crew, ROV and the facilities.

ROV Safety Features

Mustang Robotics ensures that the utmost is done in safety procedure as it pertains to the team and to the final product. There are fail safe connectors used to guarantee that the ROV cannot be plugged into the power supply incorrectly. Fuses and a GFCI (Ground Fault Circuit Interpreter) are used to protect the ROV against power spikes. More precisely, the GFCI is used both as our E-stop device and a regulator that trips once the current returning no longer matches the amount leaving. This makes sure that our ROV is not shorting to something outside of itself, thus protecting anyone or anything nearby. Fuses on board and power busses monitor the current being used for vital components such as the thrusters. To ensure that lose objects or people's fingers cannot be harmed by the propellers on the thruster, grating has been placed over each shield of the thrusters. Bright yellow tape also is wrapped around the body of the vertical thrusters, since they protrude out the furthest; while tape is wrapped around the nose cone of the horizontal thrusters to be a more visual sign of the thruster's location underneath the frame. Further safety precautions have been implemented and can be read in our design rationale.

Challenges

Technical Challenges Overcome

Our team learned from last year that having flat surfaces on the main canister is vital for connector access, thus this year we decided to go with a rectangular box for our canister. To do so we were either going to weld 5 different flat pieces into the box shape, or use an off the shelf 8x8 in square aluminum channel. We decided to go with the aluminum channel to mitigate manufacturing time and the possibility of our canister not coming out square. We still machined out top plates and flanges for our o-ring surface. But in machining the flanges we had machined the thickness of the plate down. When the can was welded the flanges were really warped to the extent that the o-ring was useless for sealing. Our first choice of action was to mill it flat, but in the process of doing so, we quickly found that the welding also warped our datums and where one corner of the flange would be barely machined, another would have a deep machining pass making the flange even thinner. We then decided to go with something with more control so that we could ensure that we would not cut entirely through the flange. The next choice action was to use a belt sander, but that is only about 6 in. wide and could not cover the whole flange. This in turn sanded down the middle parts more than the rest, even under our close watch and attempts to even out the sanding. Once the flange was down to be about reasonably even, we used a hand held grinder, then proceeded to tape sandpaper onto the micro-flat and repeatedly scrape the flange surface over it. It was a labor of love and has made us weary of welding. We understand now that for aluminum, the two pieces being welded together should have about the same thickness, jigs should always be used, and that intervals need to be taken to not overheat the material. After about a month and about 110 man hours, we had a sealing can with the aid of an 1/8 in. A40 gasket. This set us back in our Gantt chart and postponed the companies whole progress.

Team Challenges Overcome

A team challenge that we have faced this year is, as it is with many teams, communication and dedication. There are always three to four people who understand fully what the build day tasks are, but the rest of the team does not necessarily. This is not only pertaining to build day tasks but also in designing. New students are shy and are cautious to add input, especially when there are members who are very knowledgeable on the subject. We want to hear everyone's input and have everyone participate in the tasks. This makes us a more robust company and a united company when each person feels as if they have contributed to the final product. To help this occur in our company dynamics we split into sub teams and gave out responsibilities. We have increased in our dedicated team member numbers since the last year and that has really helped us make a quality ROV. We have also done many things outside of the build days, such as a BBQ, game nights, and outreach events such as Maker Fair and showcasing out on the Cal Poly Pier. This has helped bring the team together and build the comradery. We can still improve on this, but we do take pride in where we have improved.

Lessons Learned and Future Improvements

Lessons learned started when we went to last year's competition after our first year and seeing what other teams did, and how they organized themselves. We are worked hard this year to really slim up our design and be efficient with our systems.

In our structural design, the biggest lesson learned is to be very cautious when welding aluminum and to set up the company's schedule so that a setback such as the electronics canister not being ready will not be a bottleneck for all other branches of the project. Our Electronics team was waiting on our mechanical team so that they could start testing the code. Next year we will have mock systems that will allow the electronics and software to be tested even while the main chassis. is still being built.

During connector design, we did not fully plan out the mass manufacturing process to make all the connectors quickly. There were multiple times when we had to wait for a run while a connector was finishing up curing. We learned a lot this year how to use the miniature CNC on campus and how to set up an efficient casting procedure. We learned about maximizing flow paths, creating jigs, and mass production procedures. Next year we will be building off of this knowledge and will have greater access to the tools necessary to make the part all at once.

From last year we faced many issues of gaining quick access to our electronics and in adding tools. That was our main focus this year was in the design of the canister. Last year, Santiago, had a massive cylindrical canister that did not have enough flat surface area for connectors, thus we had to design and what was effectively an extension cord. This had plenty of surface area but was very narrow and crammed on the interior and was incredibly hard to reach inside and connect wires. This year, our robot Sebastian, has a large rectangular box canister, with different tiers inside to organize the connectors entrance and the main electronics plate. The top half of the canister is easily removed to reveal the whole electronics hub, which in turn can be easily unplugged from the DB25 that bridge the connectors and the plate. This has had some of its own lessons learned as wires are more likely to come undone or pinched as the top half of the canister is clamped on.

Next year, we will be aiming to have the chassis done in the first three months, so that the software and electronics aspects of our ROV can really be able to test and experiment with their systems. We have yet to really implement sensors, and it is the next big step for the quality of our ROV. This would also bring in more non- structural engineering students and would further boost our presence on campus.

For the team aspect, we will still be working on organization, communication and unifying the team across all branches. As our progress, enjoyment of working and goal to reach out to students, relies on the community of the company, we will always be striving to do better. Organization will improve as the younger students build off of their knowledge from this year and can help direct and spread the work. We aim to improve communication by the use of a Facebook communication board that will be regulated such that only important notices go on it and not used as a team chat board.

Reflection

I joined Mustang Robotics on a whim. After a two-year absence from Cal Poly (kicked out due to poor grades) I had managed to turn my grades around at the local community college and worm my way back in via contract. The transition was going smoother than I had expected. College at age 21 is a lot less daunting than at age 18. Academically, my life was going pretty well, but meeting people on campus was proving to be difficult. My social life as a freshman had been great (which might have played a role in my poor grades) but two years down the line almost all of my friends from freshman year and I had fallen out of touch, and I no longer lived on campus.

I met Jesse and Lisa – our design leads – at a club showcase. Jesse was standing next to the frame of last year's robot, Santiago. We struck up a conversation on waterproofing and how difficult it actually is. My internship the summer prior had been centered around waterproofing temperature sensors in harsh environments so we could talk shop about the merits of various potting compounds or types of seals. They invited me to check out the team, on a whim I obliged. Our first year was fun but frantic, I had joined midway through the build and was thrust into a team in a three-month last minute panic. There were a lot of skills I needed to learn on the fly with no formal instruction, flow modeling in Solidworks, the proper way to seal a gasket, and I even had to brush the dust off some of my middle school geometry skills in order to design mission tools. When I joined Santiago was a tube braced in aluminum stock, when summer arrived he could drive and see. When I got the text message that we had qualified I was thrilled, this was our first outing, we were using water bottles filled with sand for ballast!

When this season rolled around we had a road map. Santiago had been an exercise in frugality, a robot built as conservatively as possible by people who wanted to prove that it could be done. Now that we had built a robot that could qualify, we set out to build a robot to *compete*. The entire robot was designed from scratch applying lessons learned from Santiago. The number of thrusters went up from four to six, the electronics housing sealed using four latches instead of eight wingnuts, the connectors were now compact and proprietary, and the frame was polypropylene instead of plastic. Our new bot – christened Sebastian – is much more maneuverable in the water, much easier to work on, much safer, and much lighter than Santiago. As a team we have gotten larger, more dedicated and have managed to forge bonds. As a person, I have become a better teammate, a better leader, and I even managed to make some friends.

I think that as far as whims go, this one worked out for me pretty well.

~ Carson Bush

Appendix A: Budget

Mustang Robotics 2016 Approximate Budget		
Travel	*subtotal*	**$2,400**
Travel: Out-of-state		$2,400
Operating Expenses	*subtotal*	**$2,710.00**
Stock Components		$400.00
Electrical Components		$500
Hardware		$200
Propulsion		$810
Vision		$100
Mission Props		$200
Registration		$100
Postage/Shipping (Shipping the Robot to Houston, TX)		$400
Contractual Services	*subtotal*	**$0**
	TOTAL	**$5,110.00**

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Appendix B: Project Costing

Mustang Robotics 2016 Project Costing

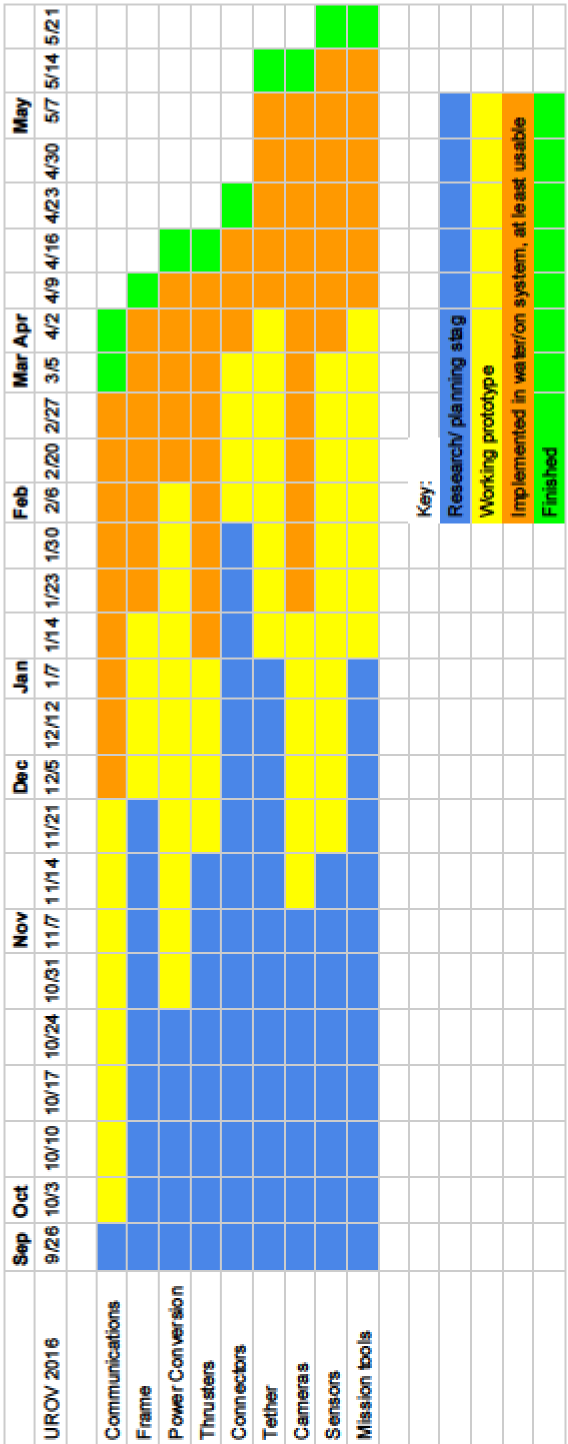
Material Expenses	Type	Category	Description	Quantity	Cost per Item	Total
Arduino Mega	Purchased	Electrical	Provides control center of the ROV, controlling all thrusters, sensors, and mission accessories	2	$45.95	$ 91.90
Solenoids	Purchased	Mission Tools	Actuators to help perform mission tasks	2	$8.69	$ 17.38
Power ICs	Purchased	Electrical	Convert 48 V from Mission Spec. topside to useful voltages below	4	$75.00	$ 300.00
Power system PCBs	Donated	Electrical	Student designed PCB for power conversion	5	$32.95	$ 164.75
Stepper Motors	Purchased	Mission Tools	Actuators to help perform mission tasks	3	$14.95	$ 44.85
Relay Shield	Purchased	Electrical	Multiplexes video channels to topside control	1	$8.99	$ 8.99
IMU	Purchased	Sensors	Obtains real time data about the robot's movement and orientation	1	$55.00	$ 55.00
Pressure Sensor	Purchased	Sensors	Measures depth and temperature to find out conditions of the mission environment	2	$25.00	$ 50.00
Cameras	Purchased	Electrical	Allows the pilot to navigate in the pool and complete mission tasks effectively	4	$21.99	$ 87.96
Aluminum Tube Stock	Purchased	Mechanical	Used to create the waterproof housing of the ROV	1	$48.81	$ 48.81
Aluminum Plate	Purchased	Mechanical	Used to create the endcaps and flanges for the waterproof housing	1	$71.89	$ 71.89
Polypropylene Sheet	Purchased	Mechanical	Used to create frame pieces for the body of the robot	2	$22.34	$ 44.68
Acrylic Sheets	Purchased	Mechanical	Used to make electronics sled and mission tooling	2	$20.97	$ 41.94
Toggle Latches	Purchased	Mechanical	Creates a fast, easy, and consistent system for sealing electronics canister	8	$12.48	$ 99.84
Weaver Rail	Purchased	Mechanical	Allows for easy indexable mounting of mission tools	3	$10.97	$ 32.91
Asstd. Hardware	Purchased	Hardware	Hardware to assemble our ROV	1	$257.75	$ 257.75
Mission Prop Parts	Purchased	Mission Props	Used to build task hardware the ROV will encounter at competition	1	$142.49	$ 142.49
Connectors	Purchased	Electrical	Allows for easy access to ROV components and tether	21	$16.42	$ 344.82
Nylon Sheathing	Re-used	Mechanical	Tether Protection, from last year's tether	100 ft	$0.50	$ 50.00
Tether Buoyancy	Re-used	Mechanical	Built from materials in the robotics room	100 ft	$0.50	$ 50.00
Data Cable	Re-used	Electrical	From last year's tether	200 ft	$0.20	$ 40.00
Power Cable	Re-used	Electrical	From last year's tether	100 ft	$0.80	$ 80.00
Controller	Re-used	Electrical	Used to drive the ROV	1	$30.00	$ 30.00
T100 Thrusters	Purchased	Electrical	Provides propulsion for the ROV	6	$135.00	$ 810.00
				Total Material Expendatures		$ 2,965.96

Competition Expenses	Quantity	Unit Cost	Team Cost
Travel to Houston	6	$250.00	$ 1,500.00
Hotel rooms for students	4 nights, 2 rooms	$100/day	$ 800.00
MATE Registration Fee			$ 100.00
	Total Competition Expenses		$ 2,400.00
	Total Expenditures		$ 5,365.96

Income	Amount
MESFAC grant	$ (660.00)
COAST grant	$ (377.00)
EE student project fund	$ (205.00)
Student travel contributions, $200 per student	$ (1,200.00)
CP Connect Grant	$ (3,288.15)
Donated Materials	$ (164.75)
Total Income	$ (5,894.90)

*All material expenditures shown are to date

Appendix C: Gantt Chart



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Appendix D: ROV Risk Assessment

April 16, 2016

UROV RISK ASSESSMENT

1. ELECTRICAL HAZARDS

A. Part of the electrical system runs at 48 volts, which can be hazardous to touch.

i. Consequently, the topside power supply has been placed in an enclosure and the tether cable is insulated to reduce such risks.

ii. Procedure is to power down and disconnect all electrical supplies before removing the ROV housing containing electrical components in order to avoid shock hazards.

B. Many parts on the ROV have high current going through them. This can be hazardous for many reasons, be it electromagnetic or the heating of wires.

i. Appropriate care has been taken to use proper gauge wire for our current draws so that the wire can operate reliably under stressful conditions.

ii. Fuses have been installed both topside and in the ROV to make sure the current in the ROV never exceeds 20 Amps through a given line.

C. With many high voltage lines, there can be a chance of electrical shorts if wires are not managed properly.

i. Every use of the ROV will involve a pre-mission Inspection of the wiring to make sure no lines have come loose. Proper insulation of wires has also been a priority for the electrical systems.

2. THERMAL HAZARDS

A. Power buses and components can reach high enough temperatures to burn skin if not monitored properly.

i. Heat sinks have been properly fitted on the system to dissipate heat to the chassis. Underwater, the operating temperatures are safe to touch but operation above water can heat the chassis to a hazardous degree if procedure is not followed.

ii. After operation sufficient time is given for the system to cool down before opening the electrical enclosure to perform work.

3. SHARP OBJECTS

A. Machining and shaping have been done on the ROV to reduce or eliminate cut hazards altogether. The separate issue of propeller hazards is dealt with in another section.

4. ROPE/CABLE HAZARDS

A. The tether cable and power cords for connected laptops and power supplies can be a trip or entanglement hazard. When setting up topside, care is taken to ensure the power cords for topside equipment are run in a safe manner. In order to reduce hazards from the tether cable only qualified personnel are permitted in the operating area, and care is taken to unroll and store the tether so that tangles and hazards are avoided.

5. WEIGHT

A. The ROV weighs approximately 35 lbs. This is of sufficiently small size and weight that one person can pick it up and handle it without causing muscle strains or back injuries. Crush injuries can happen if the ROV is dropped during handling, but this risk falls under the category of common-sense handling.

6. PROPELLER HAZARDS

A. The propellers on the ROV move at high speeds. Although there are shrouds on the propellers, it is possible to get fingers in between the protection.

i. Whenever maintenance is to be done for the ROV the unit will be disconnected from power to prevent unintended operation of the propellers.

ii. During testing and operation precautions are taken to ensure safe clearance from propellers before engaging the propeller motors.

iii. Care must be taken when handling the ROV to keep fingers and loose materials such as clothing away from propellers.

iv. When underwater swimmers should maintain a safe distance from the ROV.

7. PRESSURE HAZARDS

A. During bubble testing, the enclosure will be pressurized.

i. This is not a concern because the gasket is designed to fail safely before high pressures can cause an unsafe situation such as blasting off the enclosure lid.

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Appendix E: ROV Safety Checklist

May 25, 2016

UROV SAFETY CHECKLIST

Facilities Set-up

- ☐ Clear area of unnecessary objects and bystanders
- ☐ At least two personnel are always in the facilities; all with correct PPE
- ☐ Visually inspect the facilities being used for potential hazards

Pre-Test Check

Pre-Power:

- ☐ Set up operating control center
- ☐ Attach controls line to computer
- ☐ Verify the power is Off
- ☐ Attach tether and ensure solid contact with the connectors and computer
- ☐ Check that the gasket is clean and with new dive gel

Power Up:

- ☐ Driver boots up communication station
- ☐ Systems are nominal
- ☐ Ensure thrusters are clear of all appendages and obstructions.
- ☐ Driver Aid calls out when power is switched on by saying "Powering On"
- ☐ Communications are nominal
- ☐ Check basic motor functions and connectivity with protective can off to check system lights
- ☐ Check that cameras are correctly positioned
- ☐ Tooling is correctly and tightly attached
- ☐ Lock down can and ensure the gasket does not squeeze out unevenly
- ☐ For non-critical runs
  - ☐ Turn power to off
  - ☐ Place ROV in the water
  - ☐ Pull ROV out after 5 minutes of stand time in the water and check for water leaks.
  - ☐ Diagnose and fix if there are any leaks
- ☐ Deployment team (DT) put the ROV in water
- ☐ If large bubbles arise, pull out, diagnose and fix
- ☐ Driver does a quick thruster test in all directions

Drive Procedure

- ☐ Driver checks with the DT and calls for launch and the timer to start.
- ☐ DT verifies by calling out "ROV Launched"
- ☐ The mission starts

ROV Retrieval:

- ☐ Driver calls out for the retrieval of the ROV
- ☐ DT puts an arm into the pool, no deeper than the elbow
- ☐ DT informs when the ROV is in their control
- ☐ Thrusters are killed and the ROV is powered off and pulled out
- ☐ DT calls out "Land Secure"

Loss of Communication:

- ☐ Driver presses restart button and waits a couple of seconds
- ☐ If no communication persists
  - ☐ Power off ROV
  - ☐ Retrieve ROV by pulling lightly on tether
  - ☐ Pull out and dry off ROV
  - ☐ Open can; check for loose wires, leaks, or shorts
  - ☐ Fix any found problem
- ☐ Resume mission if possible

Leak is Detected:

- ☐ Turn off power to bot
- ☐ Retrieve bot by lightly pulling on tether
- ☐ Find leak and fix

Clean Up Procedure

- ☐ Driver surfaces the ROV and drives over to the DT
- ☐ DT calls out when the ROV is in their control
- ☐ Driver Aid turns the power off and informs the team while doing so
- ☐ Pull the ROV out of the water and dry off
- ☐ Safely collect sample specimens
- ☐ Clean work and test area
- ☐ Pack up drive station power control system
- ☐ Team vacate the area

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Afterword: Acknowledgements

MATE Center	For providing us support and teaching us to always go for higher goals
CP Connect	For providing the majority of our funding
Cal Poly MESFAC	For giving us the funding for our new thrusters
Cal Poly CSC Department	For supporting it's students
Cal Poly Robotics Club	For supporting us financially, and for being our headquarters full of great wisdom and knowledge
Cal Poly Fluids Lab	Letting us use the Weir tank as our initial practice tank
Cal Poly Pier	Allowing us to depth test our ROV in the ocean
Friends and Family	For being accessibly patient and supportive as we voyage on into the great depths of learning