

CPRC Otter Bots

- COMPANY SPECIFICATION -

Company Name: CPRC Otter Bots
 Origin: San Luis Obispo, California, U.S.
 Distance to International Competition: 4,600 mi.
 Participation History: This is our first year!
 Mentor: Dr. John Seng
 Team Education: California Polytechnic State University; 1st - 5th years.



Company Members

Name	Education & Role
Jesse Tambornini	Mechanical Engineering, (CEO) Lead Safety Officer
Lisa Dischinger	Mechanical Engineering, (COO) Chief Financial Officer
Kyle Gonsalves	Electrical Engineering, Electrical Systems Engineer
Andrew Hostler	Electrical Engineering, Visual Systems Engineer
Connor Sullivan	Mechanical Engineering, Chief Science Officer
Gaby Dinata	Mechanical Engineering, Navigation Systems Engineer
Matthew Ferretti	Mechanical Engineering, Lead Manufacturing
Carson Busch	Mechanical Engineering, Chief Control Officer
Shelby Boyd	Materials Engineering, Chief Systems Engineer
Josh Warner	Mechanical Engineering, Lead Manufacturing Engineer
Jamie Forslin	Mechanical Engineering, Chief Marketing Officer, Human Relations
Caleb Barber	Mechanical Engineering, Fluid Flow Engineer
Andrew Corvin	Mechanical Engineering, Lead Design Engineer
Nick Loey	Mechanical Engineering, Oilfield Maintenance Engineer
Jakob Graf	Mechanical Engineering, Manufacturing Engineer
Skylar Tusting	Mechanical Engineering, Lead Valve system Engineer
Aaron Parisi	Electrical Engineering, Chief Digital Officer
Sam Romano	Electrical Engineering, Chief Data Officer
Justin Satnick	Mechanical Engineering, Structural Engineer
Andrew Pirondini	Computer Science, Chief Logic Officer
Tim Jung	Mechanical Engineering, Chief External Advisor
Kyle Kruse	Mechanical Engineering, Lead External Advisor

- ROBOT SPECIFICATIONS –

ROV Name: Santiago De La Mancha
 Total Project Cost: \$12,281.69 Total Robot Cost: \$4,451
 Primary Materials: 6061 Aluminum, Acrylic, and Polycarbonate
 Robot Dimensions: 0.61m x 0.61m x 0.30m
 Weight: 42 lb
 Safety features:
 Safety Signs Propeller Shroud Rounded edges E- Stop Button
 Special features:
 Custom Ethernet Connection Quick Connection System
 Adjustable Buoyancy Easily Removable Electronics

I. Abstract

The Underwater ROV team from Cal Poly Robotics consists of 22 students, studying Computer Science, and Computer, Electrical, Mechanical, and Materials Engineering. This year we developed our frame into a functional UROV, and qualified to attend the 2015 international Marine Advanced Technology Education (MATE) competition in St. John's, Newfoundland. MATE asks competitors to act as companies and to produce and market their UROV as a proposed solution to a marine science problem. This year's request for proposals came from polar scientists and the offshore oil and gas industry, looking for an ROV that can observe marine biology underneath ice sheets, remove corroded pipelines, test for corrosion on oil platforms, and measure underwater objects. Starting with our ROV frame from last year, we added a secondary connector box to provide extra surface area for connectors, with both off-the-shelf and team-designed waterproof connectors. We also reorganized the electronics, designed a neutral buoyancy system for both the tether and the ROV, coded an on-shore Python server to interface with our game controller and the Arduino boards, and compiled testing procedures to ensure the ROV is watertight before each practice run. As the year wraps up, we are designing final mission tools and collecting technical documentation.

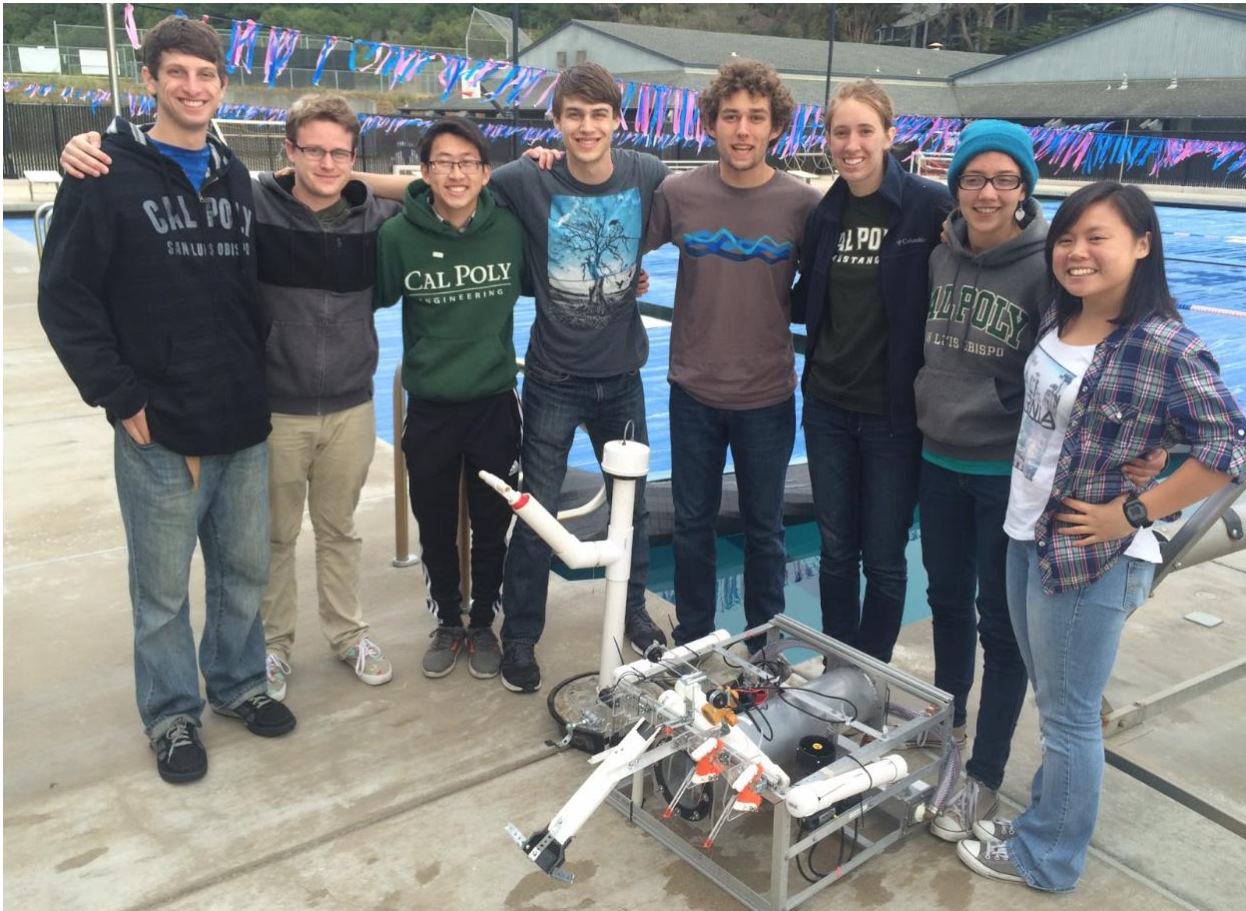


Figure 1. The wellhead prop, the ROV, and part of the team at qualifiers in Aptos, CA.

Table of Contents

I. Abstract	1
A. Structure Design	3
1. Frame.....	3
2. Electronics Housings	4
3. Connectors.....	5
B. Thrusters	6
C. Electronics	6
D. Mission Tools.....	10
III. Safety.....	12
IV. Challenges Overcome	13
V. Reflections and Lessons Learned	14
VI. Future Improvements.....	15
Acknowledgments	16
Appendix.....	17

II. Design Rationale

A. Structure Design

1. Frame

In order to achieve the most customizable set of configurations for our robot and its tooling, we incorporated a modular frame into the design. It is a rectangular prism space frame, constructed from 90° angle bars of 6061-T6 aluminum. This material was chosen for our frame because it has a strong strength-to-weight ratio, it is easily manufacturable, and it is more corrosion resistant than many other metals. Holes were indexed along the edges of the frame so that we could easily add and remove parts and features in the future. The frame is large (0.61x0.61x0.3 m) so that the motors and other fragile components can be mounted inside the frame without risking damage incurred by contact with surroundings and competition props. The length of the frame corresponds with the length of the canister that we designed, which acts as a structural member and adds longitudinal and transverse rigidity to the space frame. Figure 3 shows the basic design, with the frame, central electronics canister, and thrusters. Our team chose stainless steel 8-32 machine screws because they are thin enough to fit into the inner web of the angle aluminum struts without the heads hitting the edge of the struts or compromising structural integrity from bearing stress, while they are thick enough to resist shear failure from independent movement of the struts that comprise the frame, and will not strip when pre-loaded to apply pressure around the end cap. Paired with each screw is a zinc-plated lock washer in order to apply axial force to the screw and engage the frictional force of the screw threads, even when the robot is jostled and nuts are slightly loosened. These prevent the robot from coming apart unintentionally.

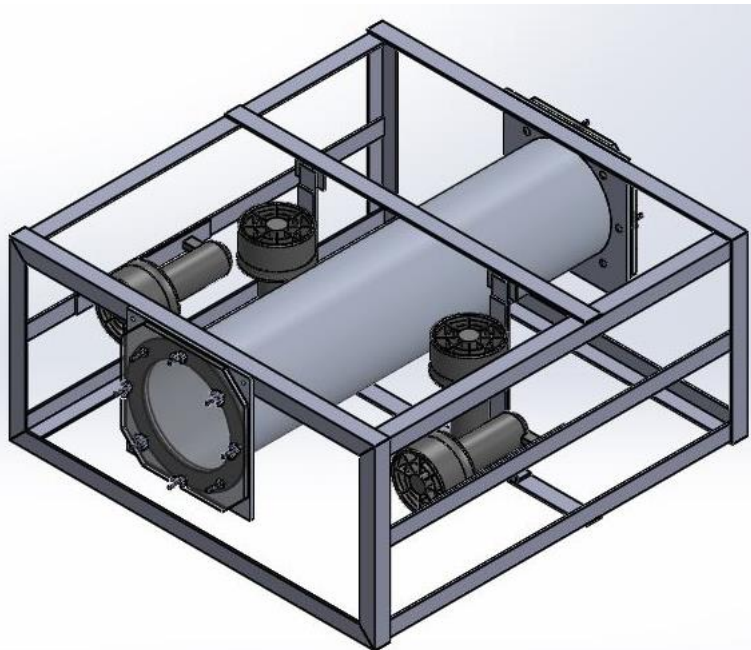


Figure 3. The basic modular frame has space to attach mission tools both inside and out, and a central electronics canister with removable end caps. The thrusters are positioned so their fluid streams do not impinge on each other, making the ROV more controllable.

Finally, to keep the ROV level and neutrally buoyant underwater, we added aluminum extrusions, buoyancy, and sand ballast along the frame. Because of the mission tools, the ROV's front

was initially heavier in the water than the back. Figure 4 shows the PVC capsules and extra extrusions we attached to even the ROV out.



Figure 4. The ROV during a night test, before we balanced it with the right buoyancy and ballast. At this point, it was neutrally buoyant and stayed at this off-kilter position for almost 45 minutes. However, driving the ROV is difficult when it constantly leans.

2. Electronics Housings

The canister is a 0.61 m tube with an 0.15 m diameter. This size was chosen for easy access to the electronic components and wires inside the canister. We chose a cylinder because it is the strongest shape (aside from a sphere) under pressure, and it works well with off-the-shelf O-rings and gaskets. The canister was also made out of 6061 Aluminum, and convects heat from the air inside the canister to the surrounding water, reducing the chances of the electronics overheating. It needed to be weldable so we could incorporate gaskets and end caps on either end. The square flanges we welded on each end allowed us to attach the canister to the frame, and seal it with rubber gaskets and polycarbonate end caps. This is the best design that we found to tightly secure a watertight container, because pressure can be distributed evenly around the perimeter of the canister by bolting the end caps and gaskets to the flanges. For the end caps, we chose clear polycarbonate because it is tough enough to prevent brittle failure upon impact or when securing the end caps to the gaskets. Its transparency lets us verify that the electronics and wires are functioning properly inside of the canister and to ensure that the gaskets are thoroughly sealed. Similarly, since polycarbonate is easy to machine, it is convenient for adding more connectors as our electronic system necessitates more wires over time. Wing nuts simplify attaching and removing the end caps, allowing two team members may work together to tighten multiple wing nuts at one time, which is useful in time-sensitive situations relating to the electronics within the canister. Additionally, flat washers are used under the wing nuts on the end caps to apply a more even pressure to the end cap, improving the seal with the gasket.

After finishing the basic frame we decided to add a secondary canister, providing additional surface area for control and mission task connectors (Figure 5). This design fit across the ROV, under

and perpendicular to the main canister, minimizing the distance from each end of the secondary tube to the back of the main canister. Each connection in the secondary box sends wires through a brass bolt into the box. These bolts have small o-rings at their interface with the box, and we thread the wires through the bolt used to tighten each connector down. This 0.61 m box has two flanges in the middle, making it actually two sections of tube, allowing the team to reach into it to tighten the nuts down and handle wires. The central and end cap flanges use o-rings, which fit into a groove cut on a CNC mill. While the main canister is a circular tube, this canister is rectangular because the o-rings seal best to a flat surface.

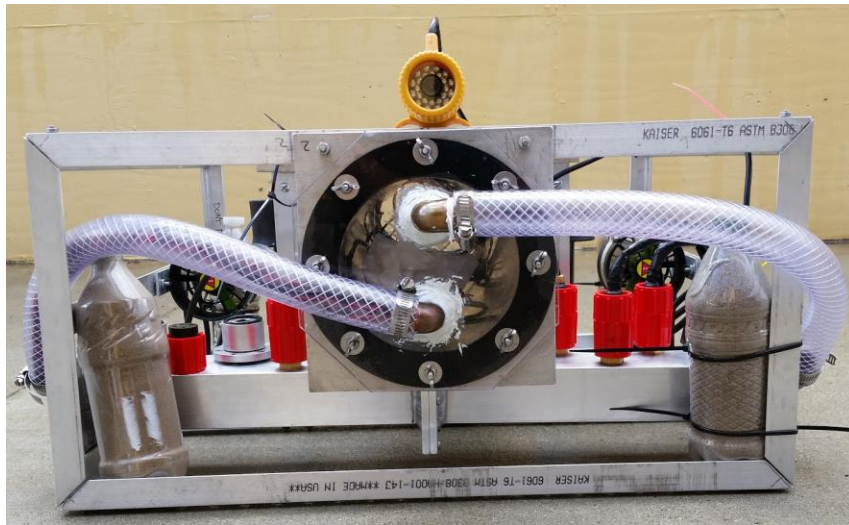


Figure 5. The back of the ROV shows the central flanges on the connector box, and the cut-resistant tubes routing wires from the connector box to the main canister. The water bottles full of sand are an intermediary ballast system.

3. Connectors

Our company showcased their manufacturing capabilities with the ethernet connectors. These custom-designed 6061-T6 aluminum and 5-minute epoxy connectors use plates and o-rings to clamp the camera and control signal wires (Figure 6). The plates ensure easy plug removal with their central slit, and distribute the load by closing the connection with four hex bolts. In addition to these Ethernet connectors, we used SubConn connectors for each thruster and the main power line, because we knew they would be reliable. The wires internal to the secondary connector box were routed to the main canister through nylon-reinforced flexible tubing and sealed with hose clamps around copper 90° pipe segments connected to the secondary box endcaps with PC-11 epoxy.



Figure 6. The custom aluminum ethernet connectors, and red SubConn connectors on the secondary connector box. The end of the box shows the tube routing wires from this half through to the main canister, where they connect to the electronics.

B. Thrusters

Our ROV uses four Seabotix BTD150 thrusters, two controlling forward-backwards movement, and two controlling up-down. They are rated to draw a maximum of 4.25 amps continuously, on 19.1 V CD +/- 10%, for a maximum power of 110 W. They exert 2.2 kgf normally, going up to an instantaneous maximum of 2.9 kgf. These thrusters have a shroud around the propellers, preventing any objects larger than 0.05x0.05x0.05 m from interacting with the propellers.

Each thruster is mounted to the frame with a 0.0032x0.0254 bar of 6061-T6 aluminum, which we chose because it is machinable and acts well in tension. The vertical motor mounts are slightly shorter than the nominal distance from their corresponding mounting brackets at the top and bottom of the frame. This makes the horizontal bars connecting to the mounting brackets act as leaf springs, keeping the vertical motor mounts rigid. The same is true for the horizontal mounts. This rigidity is important when the rotors are spinning to keep the columns of water that the thrusters push in their intended vertical directions, assisting with the ROV's stability and control. Each motor mount was positioned so that the columns of water produced by the thrusters exerted no moment about the ROV's center of mass. Additionally, the thrusters were positioned so they do not interfere with other thrust vectors. This prevents the ROV from unexpectedly rotating due to thrust interference, making it more controllable.

C. Electronics

Because game controllers provide a familiar control interface, we chose one to drive our ROV. A topside Python TCP server communicates with a client program ran on an Arduino Mega and sends commands from the controller to the ROV over an Ethernet cable. Figure 7 shows the systems interconnect diagram (SID), which shows how the boards are connected and controlled, and Figure 8 shows the software flow sheet for the ROV.

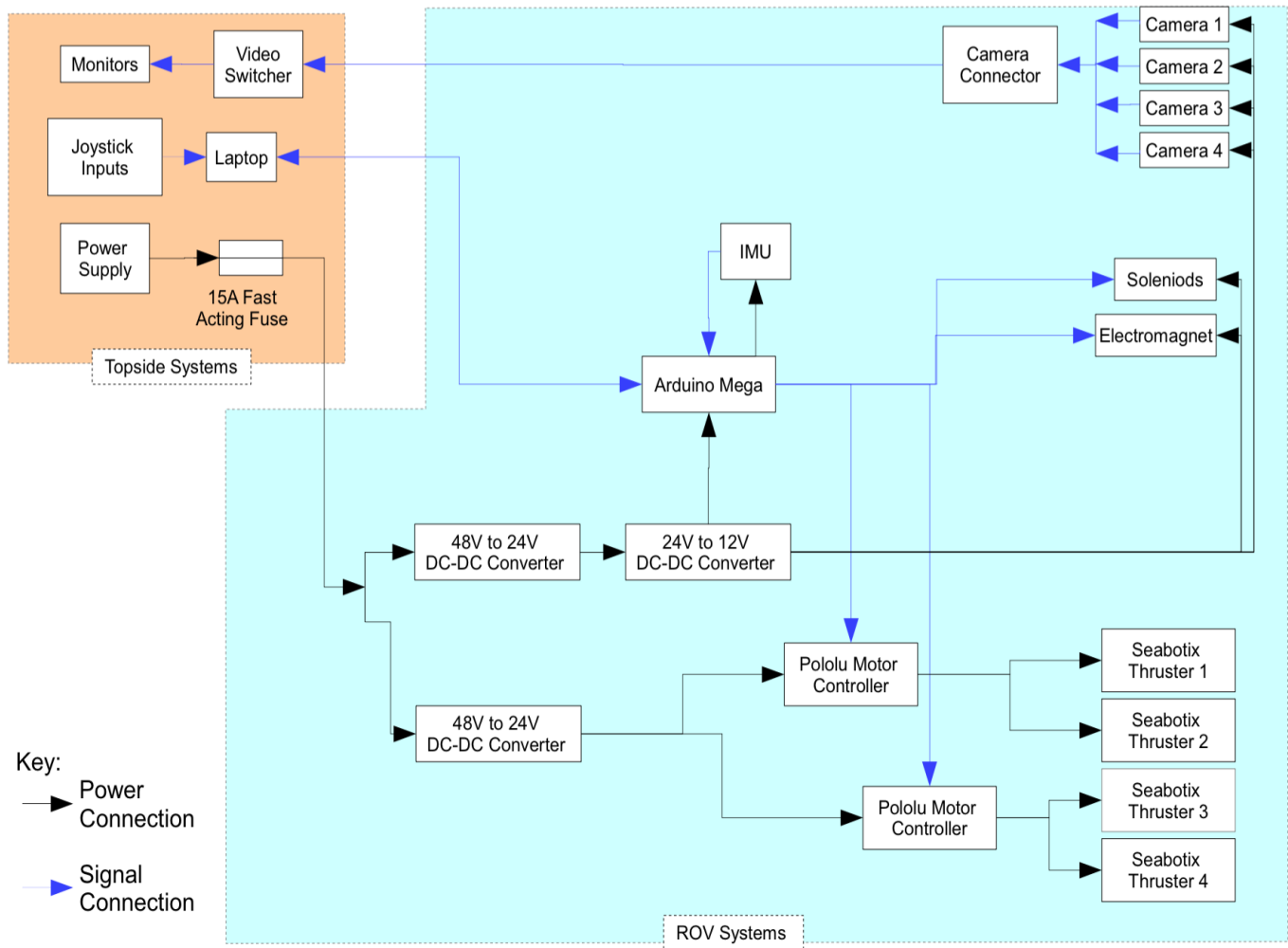


Figure 7. Systems Interconnect Diagram showing the power and signal connections on the ROV.

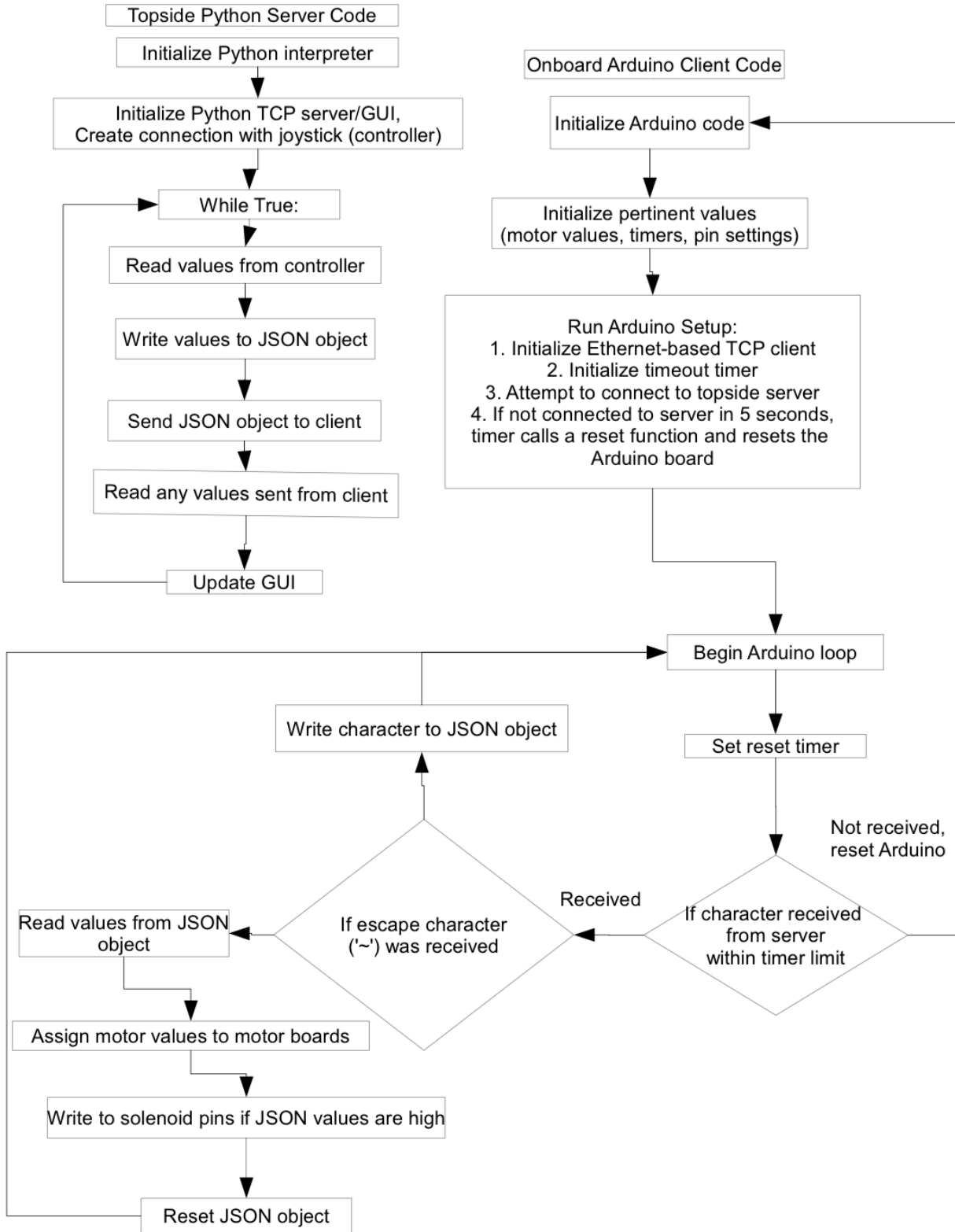


Figure 8. Code flow chart explaining how the computer and ROV communicate.

We ordered two custom printed circuit boards (PCBs) to convert the 48 volts received from topside down to 24V (Figure 9). The voltage converters on these boards generate a significant amount of heat, but are conveniently located to facilitate installing a heat sink. We used a Pyle PSWNV480 24V to 12V converter to further step down the voltage for the Arduino Mega, which cannot handle a 24V input. Since the 24-to-12 volt converter produces significantly less heat than the 48-to-24 volt converters, no heat sink was necessary. The Arduino Mega handles signals from topside via an Ethernet shield, and sends the signals to the thrusters over the two Polulu VN5019 motor controller boards via pulse width modulation (PWM) signals. In addition to motor control the Arduino also contains the means of signaling the solenoids to trigger, making it the sole controller of the entire ROV. The boards are laid out on an acrylic laser-cut board, which keeps the wiring organized and accessible (Figure 10). It has components attached to both sides, clarifying how circuits are connected and simplifying additions.

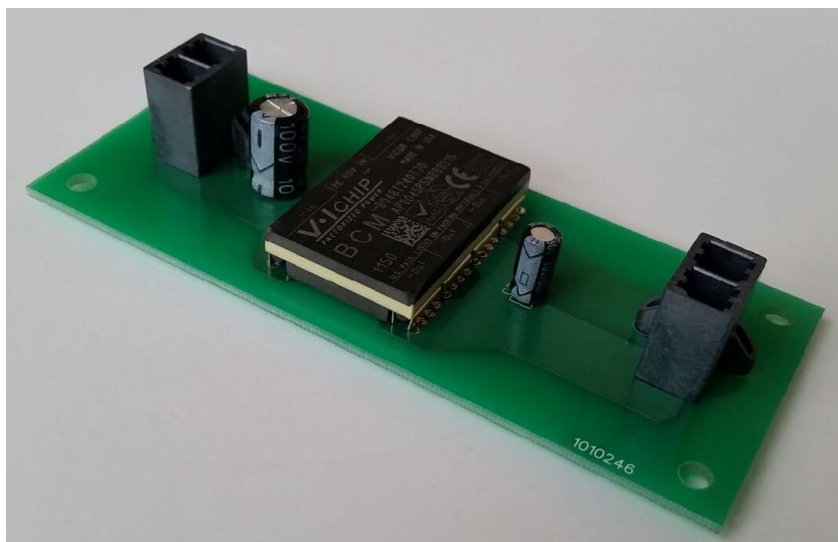


Figure 9. These custom PCBs convert the 48 V coming from topside to 24 V.

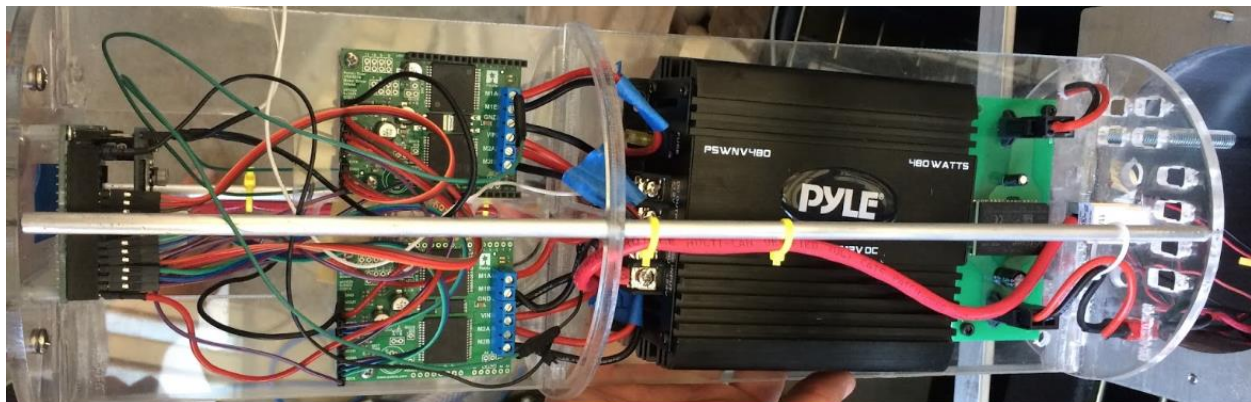


Figure 10. The organized electronics board before we installed the heat sink on the 48-to-24 V converters. This, like many aspects of our design, was inspired by the Sacramento Jesuit High School's *Leviathan*.

The entire system is composed with few possible sources of failure, and the on-board 24-12 V converters also acts as a surge protector for the Arduino Mega, which is by far the most sensitive piece of equipment in the ROV. Additionally, the topside 120 V AC - 48 V DC power supply has a 15 A fast-acting fuse to protect the rest of the electronics.

Our camera is self-illuminating, negating the need for additional lights on the ROV. It sends visual signals topside via Ethernet, which connects to an RCA output monitor. This monitor is how our pilot sees where to guide the ROV.

D. Mission Tools

Priorities drove our process for designing mission tools, and we first focused on completing qualifiers. That means we placed our highest priorities on removing the wellhead, inserting the gasket, and manipulating the hot stab. Once we had our tasks selected, it was a matter of brainstorming possible options that could both perform the tasks and function under our ROV's limited mobility and visibility. To account for this, we added alignment aids to counteract any sway in the ROV's movement. Simplicity was paramount as we took on the challenge of completing the tasks with as few electronics as possible.

For the wellhead we had three main concerns: aligning the tool with the 0.0508 m-wide U bolt in the cap, holding the cap while the ROV drove around, and being able easily reset and release the wellhead back on the pipe. For alignment we chose a small, flat hook 0.005 m wide, which gave us a fairly large area in which we could place it and still catch the bolt. To keep the wellhead on the hook under driving conditions we added small magnets that also held it steady when we placed it back on the pipe, and easily released it under downward pressure.

After removing the wellhead, we had to insert the gasket. For this, our main concern was lining up on the pipe properly and easily releasing the gasket. To simplify deployment we held it with a sprinkler solenoid, which we chose for its low cost and waterproof construction. The solenoid we used was in the normally open position, which held the gasket in place. By applying power, the solenoid retracted, releasing the gasket. To operate, the solenoid assembly is mounted on an acrylic frame behind the wellhead hook (Figure 11). The frame has a guide to help align the gasket in the wellhead. With the wellhead hook in front of the gasket alignment tool, the ROV only has to move forward after removing the wellhead, rather than approaching the prop from a different angle.

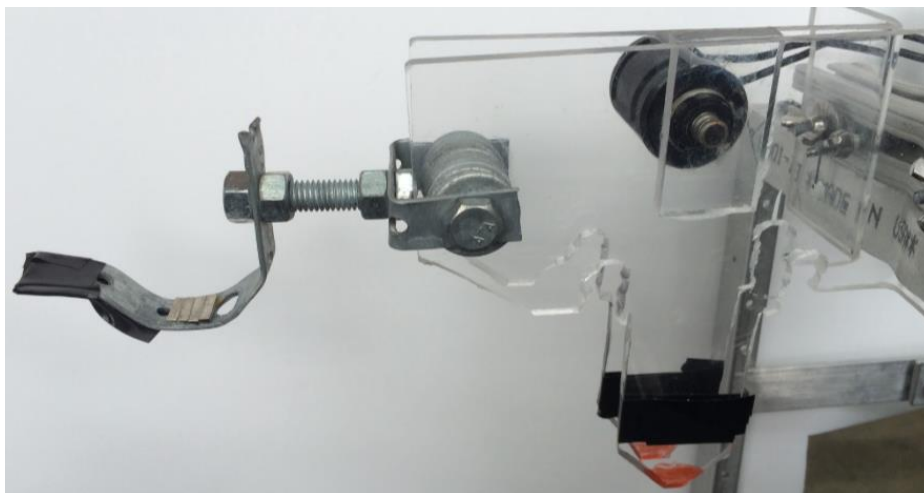


Figure 11. The hook used to remove the wellhead cap sits in front of the gasket alignment rods and installation solenoid. The entire tool sits on the front right corner of the ROV.

Lastly, we had to manipulate the hot stab. This was the most challenging task for our engineers and pilot, as we had to insert it into a clearance fit pipe, completely release control, and then re-acquire it. We designed separate tools to release and recover the hot stab. The release mechanism uses two sprinkler solenoids, one on either side of the stab, and a guide rail to align the tool with the pipe. Because the hot stab's was 1.5" inner diameter PVC, going into 2" inner diameter PVC, precision was key. We machined an adjustable rail (Figure 12) that allowed us to roughly line up with the pipe, and self-aligned as the ROV drove forward slowly. Once the hot stab was inserted, powering the solenoids released it.

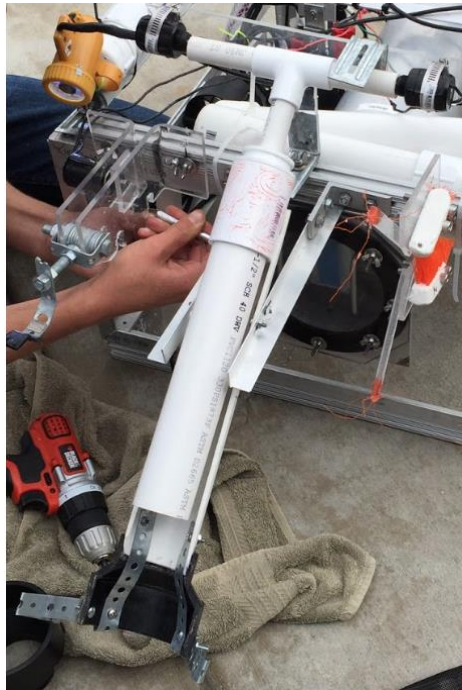


Figure 12. The hot stab in the alignment and insertion apparatus. The hangar strip at the end of the tool provided rough alignment, while the PVC chute helped guide the hot stab in.

The recovery tool was purely mechanical, requiring little precision in lining up the ROV. We used cleaning brushes oriented into two V shapes about 0.15 m apart (Figure 13). As long as the pilot aligned both V's near the hot stab's handles, as we drove forward they automatically oriented the stab horizontal to the ROV. Once aligned, we simply drove forward. Because we installed the brushes with bristles angled toward the ROV's frame, the hot stab easily went into the tool, but caught on the bristles if it tried to fall out. This system presents a pleasingly simple solution to the task.

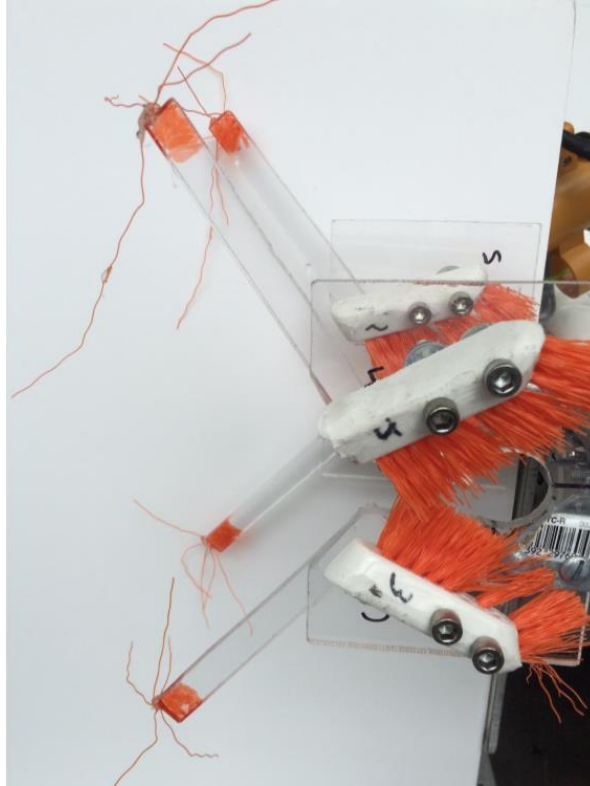


Figure 13. The bristle whiskers provide some depth perception for the pilot during the approach, and the brush's orientation and spacing easily catch the hot stab so it cannot fall out.

III. Safety

Our ROV has several features designed to protect the user and environment around it.

- Fuse on power supply to prevent power surges into the ROV
- Smooth sheathing on tether protects the handler
- Redundant power cut-offs and emergency stops, between the provided power and the power supply, and on the power supply itself.
- The onboard 24-12 V converter protects the system from short circuits, overload, high voltage, and low voltage
- Filed and taped over sharp edges on the ROV
- All cut sections were filed to make the ROV safe to work on without gloves
- Organized electronics keeps connections together when we pull the central board out. This protects the user and boards by preventing shorts.

IV. Challenges Overcome

One of the biggest challenges faced by our team was a failure within our camera system the night before qualifiers. Our team spent the week of qualifiers testing the robot and its subsystems every night, ensuring that everything was in correctly working. At this stage of our design, the robot used a single light-equipped underwater camera that we repositioned as necessary for each separate task.

Throughout the week the camera worked perfectly with no problems, until the night before competition. We used the night before the qualifier as a final test run, in which we ran through all of the qualifier tasks and timed ourselves, providing extra practice for our pilot and ensuring that all mechanisms on the robot worked correctly. We successfully completed all qualifier tasks with our test props on several runs, but during the final test of our hot stab insertion system, our camera system developed a problem. The camera feed became inconsistent during the test, to a point where our pilot was unable to complete any of the tasks.

We removed the robot from the water and checked the camera for water to see if it had developed any leaks. We found the camera to still be intact, so we ran through the entire system from the camera to the tether to the feed and outlet, making sure there were no loose or corroded connections. The entire system, including the Arduino, was reset, but the problem was not resolved.

It became apparent that the entire camera system within the robot needed to be taken apart to find the source of the problem. This was a significant issue, since qualifiers were just a few hours away.

We began by disconnecting the tether for the camera system and checking the connector box and main housing for water. There was evidence of slight moisture within the system so we sent a few students to go find desiccants that would keep the overall system dry. Though there was moisture in the tube, we were sure that there was still a very prevalent issue with our camera. In reviewing the history of our camera system we remembered that the camera and its accompanying cable were spare parts from a previous robot built by a different team. The previous users had frayed the camera wire in some places and crudely repaired it. It was proposed that water could be leaking directly into the wire itself. The old repair joint was cut open and this was found to be the case. But even when we redid the solder joint, we were still receiving little to no camera feed. Through conductivity analysis, in which we used a multi-meter to test specific segments of wire for conductivity, we were able to narrow our search down to the length of the cable that contained the wire between the bottom connector and the Ethernet bullet connection within the canister. We had narrowed the possible problem locations from seven feet to an eight inch piece of wire. Upon closer inspection, we finally found that the cable, which was directly beneath our connector in the box, was completely unattached.

The exact problem had occurred when the crude solder joint allowed water within the cable and through capillary action the water made its way into the connector box. The wires beneath the connectors were subject to twisting and tight bends that weakened the wire. When the water finally reached that point it corroded the already weak wire and made it completely break. We had only been able to receive some feed due to the jostling motion of the ROV that randomly allowed the wires to touch or get close enough that the water could help to complete the connection.

To fix the problem, the wire was stripped back and the connection was re-soldered, restoring the full connection. With the ROV and all its systems working, we were finally able to leave for qualifiers.

V. Reflections and Lessons Learned

Cal Poly Robotics gleaned many important lessons from our experience building Santiago. These lessons ranged from new skills learned as individuals to important lessons in the management of processes and organizations. The vast majority of the UROV team had no experience with underwater robotics; only three of us had worked with underwater systems before. As such, we learned much about how to optimize a robot for aquatic use. For example, we learned early on that the best way to avoid water ingress was to minimize the number of seals required. To accomplish this our design emphasizes passive interaction with the environment. By cutting down on the number of external moving parts we greatly reduced the number and complexity of seals that needed to be incorporated into the bot.

In making the ROV waterproof, we learned the materials of what sealants could cure underwater, and how to relieve strain on joints to keep them from breaking. Our ROV uses few off-the-shelf components, so most team members spent time in the machine shops learning to manufacture our parts. During design, the ME students taught the others necessary basics of fluids, and all students learn about soldering in the constant electronics repair and improvements. MATE students assisted in materials selection for manufacturing processes, including weldability and ability to be cut with a laser. The most interdisciplinary collaboration during the project was connecting the mechanical systems to the electronics. Without these collaborations, the ROV would not work.

We learned that effective teamwork requires lots of communication and dedication. It's important to remind the team of our ultimate goals, both to stay motivated and to keep designs relevant. Early on in the year, the management style was very centralized, with almost every decision needing the approval of one person. As a consequence, we fell behind, with many team members effectively rudderless. Eventually, we found this was ineffective, and delegated individual projects to small autonomous teams. These teams kept members engaged and spread the workload. Under this decentralized system, we made much more rapid progress. In three months, the ROV was developed from a frame assembly to fully functional. While most team members increased their knowledge of design and manufacturing, the most valuable lesson from this endeavor is that learning to delegate responsibility is a powerful and effective tool.

VI. Future Improvements

With every design iteration, the ROV improves. Some of the more major improvements we intend to make next year include:

Maneuverability

- Vector drive would enable us more intuitive motion in all directions
- More uniform power

Better Waterproofing

- Problems with waterproofing - brittle failure of epoxy
- Try to remove epoxy seals in favor of removable ones

Camera

- More cameras - better visibility
- More robust video system - data processing

Connector input system

- Hard to access interior (build a scale model)
- Easier system to access

Acknowledgments

<i>MATE Center</i>	For providing advice, support, and for hosting such a great competition
<i>SubConn / MacArtney Group</i>	For a generous discount on connectors
<i>Seabotix</i>	For technical and financial assistance in repairing a damaged thruster
<i>CP Connect</i>	For providing much-needed financial support
<i>Cal Poly ME Department</i>	For monetary support
<i>Cal Poly CSC Department</i>	For financially supporting the travel costs of our mentor, Dr. John Seng, as well as for all the assistance with travel paperwork
<i>Cal Poly Robotics Club</i>	Allowing us to use the lab space and monetary support
<i>Friends & Family</i>	Thank you all for supporting us, both emotionally and financially as we took this often crazy and ambitious journey.



MATE
MARINE
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Appendix Project Costing

	Object		Qty	Cost EA	Net Cost
Hardware	Arduino Mega	Purchased	3	\$37.71	\$113.13
	Power Cable	Purchased	250ft	\$0.66	\$165.55
	Hose organizer	Purchased	1	\$49.97	\$49.97
	Nylon sheathing	Purchased	250ft	\$0.50	\$153.75
	Connectors	Purchased	14	\$30.00	\$392.19
	Misc. PVC fittings	Purchased	Unknown	\$10.00	\$10.00
	Aluminum Stock	Purchased	Unknown	\$40.00	\$60.00
	Plastic Stock	Purchased	Unknown	\$40.00	\$45.00
	Circular Aluminum tube	Purchased	1	\$40.00	\$40.00
	Rectangle Aluminum Tube	Purchased	1	\$30.00	\$30.00
	O-rings and Gaskets	Purchased	Unknown	\$15.00	\$15.00
	Nylon Tubing	Purchased	3ft	\$2.00	\$6.00
	Acrylic	Purchased	4 ft	\$20.00	\$20.00
	Asstd. Hardware	Purchased	Unknown	\$20.00	\$20.00
	PVC piping	Purchased	170	\$0.40	\$68.00
Electronics	Solenoids	Purchased	4	\$7.98	\
	Thrusters	Reused	4	given	\$2,800.00
	Transistors	Purchased	2	\$0.50	\$5.00
	Sensors	Purchased	1	\$53.99	\$53.99
	Capacitors	Purchased	6	\$0.15	\$0.90
	Cameras	Purchased	3	\$15.99	\$47.97
	Batteries	Purchased	2	\$37.85	\$75.70
	Power source	Purchased	1	84.95	84.95
	Fuse	Purchased	1	18	18
	Pololu Motor driver	Purchased	1	53.9	53.9
	Power converter	Purchased	1	35.06	35.06
	Printed Circuit Boards	Purchased	1	42.63	42.63
	General	Air Fare to St. Johns*		minimum of 6	\$850.00
2 Rooms			4nights	125/day	\$875.00
Shipping bot to St. Johns			2	\$450.00	\$900.00
Monterey Regional Various Expenses					\$150.00
MATE Registration Fee					\$100.00
CP Connect					(\$5,000.00)
Funds	MESFAC				(\$840.00)
	Cal Poly Robotics Club				(\$350.00)
	GoFundMe Fundraiser				(\$1,650.00)
	Student Travel Fees		4	300	(\$1,200.00)
				Final Cost:	

Budget

Object	Qty	Cost EA	Net Cost
Arduino Mega	1	\$45.95	\$45.95
Power Cable	250ft	\$0.66	\$165.55
Batteries	4	\$37.85	\$151.40
Nylon sheathing	250ft	\$0.50	\$140.00
Solenoids	2	\$8.69	\$17.38
Motors	2	\$24.95	\$49.90
Servos	2	\$13.95	\$27.90
Transistors	10	\$0.50	\$5.00
Potentiometer	10	\$0.79	\$7.93
Relays	5	\$1.55	\$7.73
Accelerometer	1	\$9.95	\$9.95
Gyroscope	1	\$9.95	\$9.95
Cameras	2	\$29.99	\$59.98
Asstd. Hardware	Unknown	\$20.00	\$20.00
PVC piping	~170 ft	\$0.19	\$32.30
Misc. PVC fittings	Unknown	\$20.00	\$25.00
Aluminum Stock	Unknown	\$40.00	\$45.00
Plastic Stock	Unknown	\$40.00	\$45.00
Connectors	14	\$30.00	\$420.00
Unexpected Costs**			\$1,000.00
Air Fare to St. Johns*	minimum of 6	\$745.00	\$4,470.00
Rooms	7 nights, 2 rooms	\$160/day	\$2,240.00
Shipping bot to St. Johns	2	\$450.00	\$900.00
St. Johns Varius Expenses			\$500.00
Monterey Regional Varius Expenses			\$200.00
Rental car (mini van)	1	45/day	\$225.00
Gas for Rental Car			\$100.00
MATE Registration Fee			\$100.00
		Overall Cost:	\$11,020.92
Funding			
CP Connect			-\$5,000.00
MESFAC			-\$845.00
Cal Poly Robotics Club			-\$250.00
		Final Cost:	\$4,925.92