KAIMANA ENTERPRISES

Highlands Intermediate School ● Pearl City High School
Pearl City, Hawaii 96782

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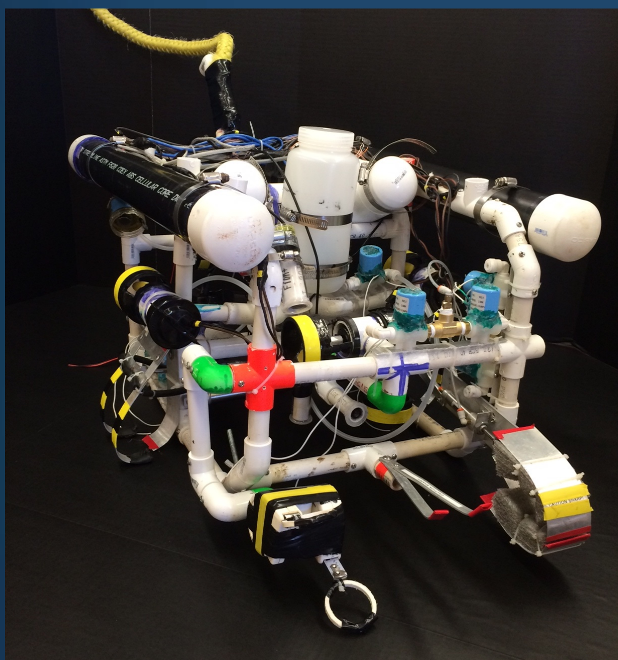

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9th Grade, Second Year

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Table of Contents

Abstract

Michigan's Thunder Bay National Marine Sanctuary contains more than fifty shipwrecks that have been claimed by the bay's destructive waters. Because of these corroded vessels, important data and research opportunities are being lost. ROVs collect data samples that can be brought back to scientists. This data can help preserve shipwrecks everywhere, not only those in the sanctuary.

Our ROV, PC-XII Strong uses a collection of mission tools and electrical systems to complete this year's three given tasks. Three pneumatic claws were positioned at different angles in order to collect items such as the water bottles, dinner plate, and sensor string. Tape measures are used to determine the dimensions of the shipwreck. A hand-twisted metal rod is mounted within a PVC pipe and connected to a bilge pulp motor, allowing us to collect the agar in a drill-like fashion. A screw attached to a voltmeter allows us to measure the conductivity of the groundwater vent. Our ROV also utilized seven cameras, six bilge pulp motors, and many other vehicle and electrical systems. Dedicated and focused, Kaimana Enterprises is ready to take these innovative solutions and memorable experiences to the real world in order to benefit the society that we live and thrive in.

Mission Theme

Figure 1: The propeller of a wooden bulk freighter in Thunder Bay.

Heimerl, Phil. "Webinar Today on Thunder Bay Sanctuary Research." True North Radio Network, 12 Feb. 2013. Web. 14 May 2014.

Dozens of shipwrecks have been uncovered in the large expanse of Michigan's Thunder Bay. This area is also known as "Shipwreck Alley" due to its treacherous weather, dense fog banks, and rocky landscape. Located in Lake Huron, this 1169 square kilometer sanctuary is infamous for its collection of wooden sailing schooners, propeller-driven bulk freighters (Figure 1), and steam-driven paddlewheel ships that have been engulfed beneath the waters. Maritime heritage research of this region is being threatened by man and nature.

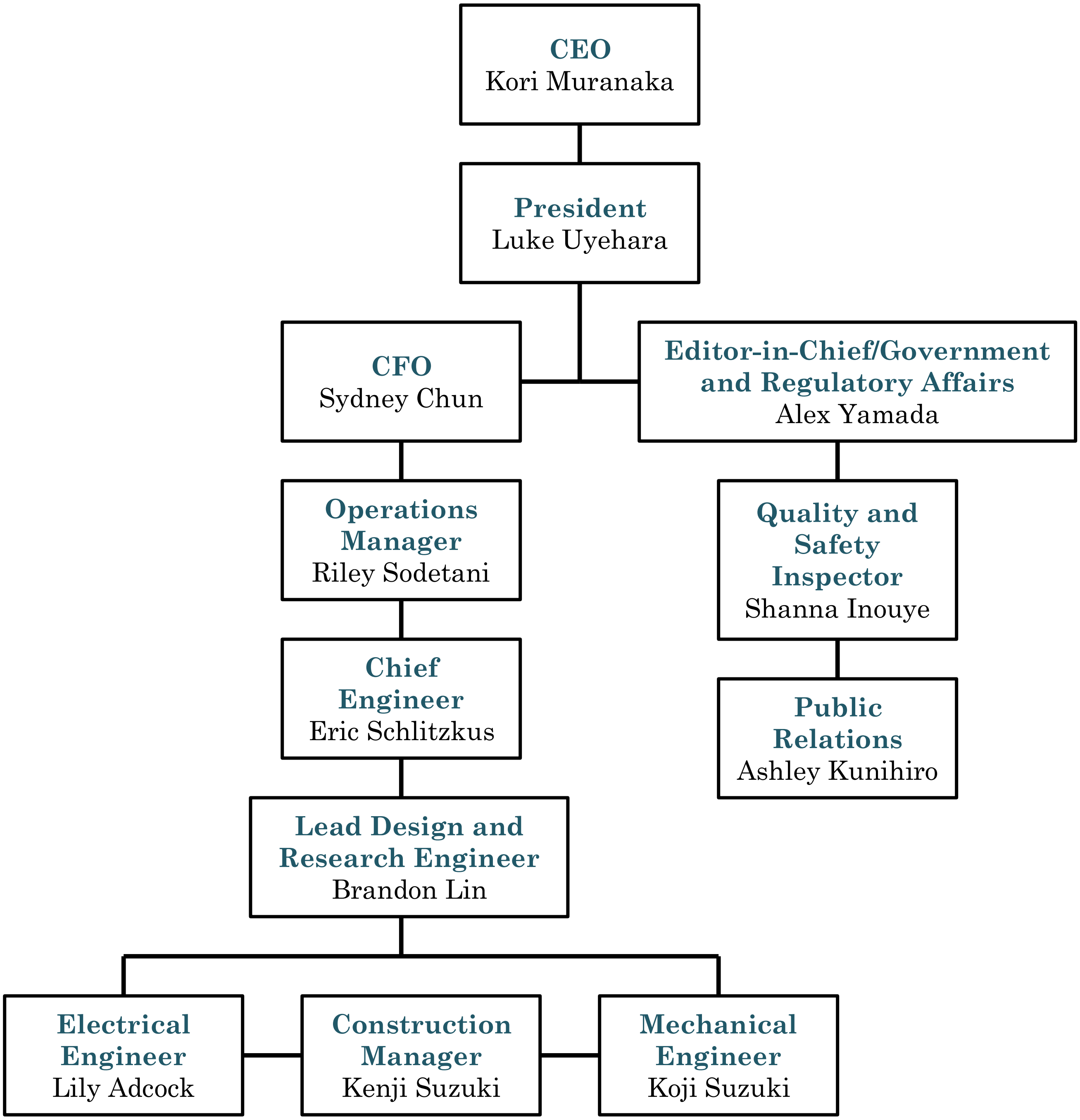
The Thunder Bay National Marine Sanctuary (TBNMS) is an area where researchers are attempting to understand how its unique conditions are affecting the corrosion and deterioration of shipwrecks. Among the conservation effort to prevent shipwreck deterioration, scientists are continuing to research innovative solutions to preserve these unique environments. Using Remotely Operated Vehicles (ROVs) will allow researchers to explore, document, and identify unknown shipwrecks. The collection of microbial mat samples, the measuring of conductivity near sinkholes, and the removal of trash and debris from the environment will provide data that can be used to develop strategies to protect these underwater time capsules.

We designed and built an ROV that can pinpoint an unsurveyed shipwreck, amass microbial samples, remove debris, and collect data from surrounding areas. Our ROV uses cameras and mission tools to assess the construction date, homeport, and cargo relating to the shipwreck. We use a custom made drill to sample the agar from the microbial mat and pneumatic driven claws to gather objects from the sea floor. A mounted tape measure will also be used to determine the exact measurements of the wreck. A third pneumatic claw is used to deliver the quadrat and grab the ceramic plate.

Company Information

Tagline: Fighting for ocean conservation

Mission: Our mission is to conserve and protect maritime history by analyzing aquatic environments and developing innovative solutions.



Budget

Expense	Description	Notes	Value	Actual Cost
ROV	ABS Pipes		$15.19	$15.19
	PVC Tubing/Joints		$58.32	$58.32
	Screws/Washers		$21.50	$21.50
	Nalgene Bottle	Donated	$4.42	N/A
	Aluminum (Flat & Angle Stock, Sheet)		$115.37	$115.37
	Pneumatic Actuators/Valves (3)		$203.81	$203.81
	Surgical Tubing	Donated	$2.33	N/A
	Plugs (Banana, Power, DB9)		$75.65	$75.65
	Cameras (3 Bullet, 1 Through-Hole)		$200.00	$200.00
	Cameras (3 Anacondas)	Recycled	$87.00	N/A
	Tubing (1/8" & 1/4")		$41.68	$41.68
	Cat 5e Wires (200')		$27.36	$27.36
	Speaker Wire (300')		$74.91	$74.91
	Pipe Insulation Foam		$1.49	$1.49
	D-Sub Connector-Video (2 pair)		$12.00	$12.00
	Heat Shrink Tube		$30.88	$30.88
	Bulk Fasteners		$2.52	$2.52
	Pins/Sockets		$48.43	$48.43
	Power Connectors		$7.50	$7.50
	Cabinet Hinges (Side Claws)		$2.97	$2.97
	PVC Glue		$13.34	$13.34
	1000 Bilge Pump Motors (7)	Recycled	$245.00	N/A
	Propellers (6)	Recycled	$7.32	N/A
	RTV Silicone		$14.48	$14.48
	Stretch and Seal Silicone Tape		$14.56	$14.56
	Liquid Tape		$6.58	$6.58
	Joysticks (2)	Donated	$15.90	N/A
	Hollow Yellow Polypropylene Rope 55' (5/8")		$43.45	$43.45
	Solenoids (9)	Donated	$137.61	N/A
	Misc. Brass Parts		$65.14	$65.14
		Subtotal:	**$1,596.71**	**$1,097.13**
***Research/Development**	Bicycle Inner Tube		$5.61	$5.61
	Carabiners		$6.84	$6.84
	O-Ring		$4.35	$4.35
	Hollow Yellow Poly Braided Ropes (3/8")		$84.93	$84.93
	Cameras (1 Bullet, 2 CMD)		$150.00	$150.00
	Servelet Camera Mount		$7.60	$7.60
	Misc. Brass Parts		$9.32	$9.32

	Clear Nylon Tubing		$39.86	$39.86
	Pneumatic Actuators/Valves (2)		$132.00	$132.00
	Speed Controllers		$124.99	$124.99
		Subtotal:	**$565.50**	**$565.50**
Props	PVC Tubing/Joints		$53.19	$53.19
	Plastic (Corrugated Plastic, etc.)		$17.05	$17.05
	Plastic Plate		$2.49	$2.49
	Shade Cloth		$37.66	$37.66
	Screws		$2.42	$2.42
	ABS Pipes	Recycled	$0.89	N/A
	Brass Hinges		$1.52	$1.52
	Nuts/Bolts		$30.84	$30.84
	Fender Washers		$2.88	$2.88
	Milk Crate	Donated	$5.10	N/A
	Diamond Braid Polypropylene Rope		$0.57	$0.57
	Knockout Caps		$0.76	$0.76
	Dive Weights	Borrowed	$2.00	N/A
	Rebar		$2.43	$2.43
	Reducer Bushing		$0.18	$0.18
	Bricks	Donated	$10.89	N/A
	Agar	Donated	$12.00	N/A
		Subtotal:	**$182.87**	**$151.99**
Time and Services	Robin's Painting	Donated	$1,000.00	N/A
	Min's Plastics	Donated	$50.00	N/A
		Subtotal:	**$1,050.00**	**N/A**
		Total:	**$3,395.08**	**$1,814.62**

***Research and Development includes parts for failed design ideas and items damaged due to inadequate waterproofing.**

Travel Expenses	Description	Notes	Per Person	Team Total
Regional Competition	Airfare		$250.00	$3,000.00
	Hotel		$50.00	$600.00
	Ground Transportation		$50.00	$600.00
	Meals		$100.00	$1,200.00
		Subtotal:	**$450.00**	**$5,400.00**
International Competition	Airfare		$1,500.00	$18,000.00
	Hotel		$100.00	$1,200.00
	Ground Transportation		$90.00	$1,080.00
	Meals		$270.00	$3,240.00
		Subtotal:	**$1,960.00**	**$23,520.00**
		Total:	**$2,410.00**	**$28,920.00**

Design Rationale: ROV Components

Frame and Buoyancy

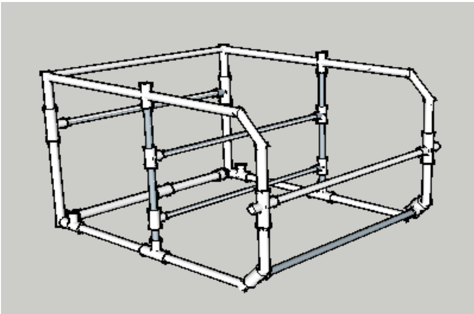


Figure 2: CAD drawing of ROV frame.

Design Description

Our ROV's irregular hexagonal prism frame includes hexagonal shaped sides and a cube-like rear and is constructed using ½-inch PVC pipes and various connectors. Several horizontal beams run across the frame. The ROV measures 58.5 cm long, 38.5 cm tall, and 34 cm wide.

Two 63 cm ballast tanks made of 2-inch ABS pipes and 2-inch end caps were used for our ROV's buoyancy. They are mounted at the top of the ROV, along the length of the frame. Holes have been strategically drilled into the PVC frame to allow the air to escape as the ROV submerges. An accumulator made of PVC was placed on the top center of our ROV. A Nalgene bottle was also mounted in the middle of the ROV. We also decided to hold washers between screws and wing nuts in the lower four corners of the ROV. This washer ballast system provides a quick method to adjust ballast in small increments, longitudinally and vertically, to achieve near-neutral buoyancy.

Design Rationale

Several models were constructed for our ROV; however, we realized the designs were either too small to hold all of the components or too big to easily fit into the 60x60 cm square opening of the shipwreck. This specific configuration was chosen because it allows us to accommodate many mission tools, as well as remain lightweight. We chose PVC as our building material because it does not rust and easily accommodates quick modifications. The beams within the frame reinforce the structure transversely and are used as mounts for the motors and tools without interfering with the performance.

ABS pipes are used for the buoyancy tanks because they are lighter than PVC and do not compress at depths of 6-7 meters. They have been placed high on the ROV to raise the ROV's center of buoyancy. We used an accumulator made of PVC because it provided extra buoyancy and it also stores air to power the pneumatics. An on deck compressor (or SCUBA tank) is connected via an air hose to the solenoids and is used to displace water in the Nalgene bottle with air for additional buoyancy when lifting heavy objects and for surfacing quickly. The Nalgene bottle is placed towards the front of the ROV because that is where additional buoyancy is needed since most of our heavy payloads are picked up there. Washers are pinned in the lower four corners of the ROV for ballast to lower the vehicle's center of gravity. The high center of buoyancy and low center of gravity increases the ROV's stability.

Propulsion System

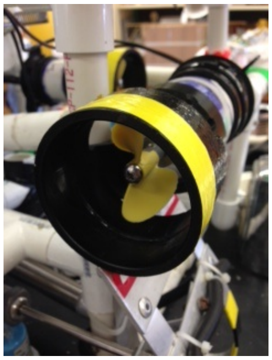


Figure 3: Shroud, used for safety, on a motor.

Design Description

Six 1,000 gallons/hour (3,785 liters/hour) bilge pump motors are used to control our ROV. We have two lateral thrusters, two drive thrusters, and two vertical thrusters. Lateral thrusters are positioned on horizontal beams on the front and back of the frame. They allow our ROV to maneuver left and right. The vertical thrusters move the ROV up and down and are positioned in the center area of the frame, diagonal from each other. The drive thrusters are positioned along the sides of the frame, above the two side claws. Each motor is powered through speaker wire (zip cord) and is held by homemade mounts created with ½-inch and 1½-inch PVC pipes.

Design Rationale

Our original design used six 500 gallons/hour (1,893 liters/hour) bilge pump motors that were powered through Cat-5e wires all positioned near the center of the ROV. We replaced these motors and wires with 1,000 gallon/hour motors and speaker wires. The speaker wire has a larger diameter than the Cat-5, allowing more power to reach these bigger motors. While reworking the positioning of motors, we took into account maneuverability, stability, and weight distribution. We realized the original motors were placed too close together, inhibiting maneuverability. This was because by having the motors further apart the ROV can turn faster and has more speed. All motors were positioned so that they did not interfere with any mission tools or camera views.

Control System

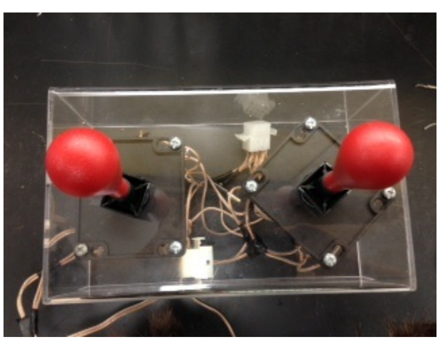


Figure 4: Control Box with joysticks.

Design Description

Our control system uses two joysticks that direct our ROV's movements and a Task Control Panel that manipulates our attachments. One joystick handles the ROV's forward, backward, and turning capabilities, while the other manipulates vertical and lateral movements. The Task Control Panel uses three double throw switches to control the claws and two momentary double throw switches to manage the air ballast and agar motor. We have two control boxes, one for piloting and the other for operating attachments. Our ROV also houses nine solenoids, which control an air ballast and three pneumatic claws. We used four solenoids to enable the dual action cylinder in the front claw. To save space and reduce the number of solenoids, we used surgical tubing to close the two side claws, which resulted in us using only two solenoids for each claw. A twenty-five-amp fuse was also installed within the wires, running from the battery to our power distributor.

Design Rationale

We used two joysticks because it is easier to control the ROV motion than the first switch box that our company had. Tests revealed that Cat-5e wire causes a significant voltage drop and is unable to apply a sufficient amount of volts that is provided to our motors. Based on the results, we chose speaker wires to cable the joysticks. We have two control boxes because the pilot requires both of his/her hands to effectively control the ROV and is unable to manage ROV tools simultaneously. We used solenoids to control our pneumatic systems instead of an on-shore manual switch because we wanted to minimize the delay between the activation of the switch and the reaction of the ROV. Solenoids were also implemented because pneumatic tubes made the tether very stiff, which restricted the ROV's movements. Using solenoids allowed us to run only one pneumatic tube in the tether, which decreased our tether's size and improved our ROV's maneuverability.

Pneumatics

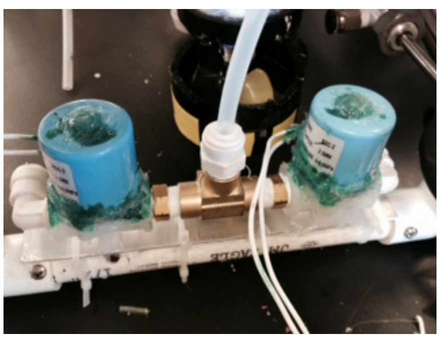


Figure 5: Solenoids mounted on our frame.

Design Description

Our pneumatics system includes an accumulator, solenoids and actuators. The H-shaped accumulator was made using 2-inch PVC Tees, caps, and pipes. The Tees and end pieces were attached using PVC glue and primer, applied according to manufacturer's instructions. We used RSC-2 solenoids. We used two solenoids for each of the side claws, four solenoids for the front claw, and one solenoid for the Nalgene bottle. The solenoids were waterproofed by spreading liquid tape and RTV silicone on all possible openings. Four pairs of solenoids were constructed by attaching each pair using elbows and brass T fittings then screwed down onto a length of aluminum sheet metal. Then a single solenoid was attached to the ROV in the same way. A total of 9 solenoids were used. These solenoids controlled the tools by allowing the pressurized air to pass through and move into our pneumatic actuators (pneumatic cylinders). Three of our tools use pneumatic cylinders: the front claw and the two side claws.

Design Rationale

Before we used the accumulator, one problem we had was that when we picked up items with our front claw and then activated the ballast, the front claw would not have enough power and would open back up. The air pressure coming down from the compressor lessened because of the small diameter of the air tube. To fix this problem we decided to use the accumulator, which was used to make sure that the air pressure could be at maximum. The accumulator is filled with air, which keeps the pressure going through the solenoids high. This allows our tools to work at maximum power. We used the solenoids because they allow us to control our tools with only one air tube going down the tether instead of seven, which we would have needed without the solenoids. We used a second smaller air tube to increase performance by venting to the surface. Too many air tubes would have caused the tether to be more stiff and thick. The solenoids have metal coils inside of them. In the center of the metal coils is a metal piston, used to bring the gate blocking the air tube, up. This allows the air to pass through. To control when the gate is opened and closed, the solenoids are connected to wires. These wires send electricity through the coil, causing a magnetic field to be made. The piston is pulled up magnetically by the magnetic field and pushed back down by a spring when there is no magnetic field pulling it up. This allows the air to pass through or to stop flowing, thus controlling our tools. This air pressure controls our tools by pressing air into the ROV's pneumatic cylinders. These pneumatic cylinders have pistons inside of them. These pistons move when air pressure is pressed against them. There are two openings for air tubes on the cylinder. When air is pressed through one hole, the air pushes the piston out. When air is pressed through the other, the air pushes the piston back in. By attaching the front claw to the cylinder, we were able to open and close it. The side claws were opened by the pneumatic cylinders but closed by surgical tubing, to help us save solenoids.

Tether

Figure 6: Tether

Design Description

The tether consists of eleven different wires, cables, and air tubes inserted within a polypropylene hollow-braided rope. The 16.75m tether contains seven speaker wires used for the motors and agar auger, one air tube that brings air from the on-deck air compressor to the solenoid system and accumulator, and two Cat-5e wires that power our seven cameras. A second air tube is used as a vent to the surface to release excess air.

Design Rationale

After several group discussions, we decided to use a hollow-braided polypropylene rope because it was the most ideal material to use. The polypropylene rope provided a tight fit for the wires so that the tether wouldn't get caught on any props in the pool. This material also allowed us not to put flotation on the tether since the hollow-braided rope was already close to neutral buoyancy. The air tubes that are inside the hollow-braided polypropylene rope also provided extra buoyancy for the tether because the tubes are filled with air. To power up the cameras we used Cat 5e wires instead of the wires the camera came with so that we could save space in the tether.

Visibility

Figure 7: Bullet Camera

Design Description

Our ROV has seven cameras: three Anaconda Indoor/Outdoor Color Video Cameras, three Universal Small Bullet Cameras, and one Through-Hole Camera. The three Anaconda cameras are located on the back of the frame and monitor the two side claws and the agar auger. One Small Bullet camera serves as our drive camera and monitors the front claw and V-hook. The second Bullet camera views the two tape measures, and the final camera gives a downward view that gives us a visual of the pool floor. The Through-Hole camera functions as our rear view camera and is positioned at the back of the frame.

Design Rationale

The Anaconda cameras on our ROV were recycled from previous years. It was used because we wanted a direct, accurate view of the payload tools the cameras monitor. The Small Bullet cameras are used for the most important views because of their wide view. If we used cameras with a narrower angle of view for these tasks, such as the Anaconda Cameras, we would not be able to monitor our tools effectively. The wide angle of the camera is also significant because it gives us a better drive view. The third Small Bullet camera was added later in the design process because during practices, we did not know our location because we did not know what the ROV was driving over. It also makes it much easier to count the zebra mussels on the shipwreck. Our company had attempted to use Anaconda cameras as our drive camera, but angle of view was too narrow for driving purposes. The Through-Hole Camera is our rear view camera because we needed a moderate angle view to maneuver out of the shipwreck and determine our location in the pool.

Design Rationale: Mission Tools

Tape Measures

Figure 8: Tape measures

Mission Task

Task 1.1: Determining the length, width, and height of the shipwreck.

Design Description

Two tape measures are mounted on the front starboard side of our ROV. Both 3.65m tape measures are attached to a PVC tee. Tape Measure 1 is mounted horizontally and is used to determine the length and width of the shipwreck. Tape Measure 2 is mounted vertically allowing the ROV to go straight down to measure the height of the shipwreck. A 2-inch PVC ring is cable-tied onto the end of each tape measure. There are also holes drilled into both of their casings. The springs within each casing that allowed the tape measure to extend and retract were loosened.

Design Rationale

Our company decided to use tape measures instead of lasers because it is a very simple method to get accurate measurements of the shipwreck's dimensions. The horizontally mounted tape measure allows the length and width, and the vertically mounted one measures the height. The PVC rings serve as a mechanism that easily hooks onto the screws of the shipwreck. We prevented the tape measures from rusting by drilling holes into the bottom of their casings to let water out. After several practices, we found that the tape measures were hard to pull out, so the springs were loosened for easier sliding.

Front Claw

Mission Task

Task 1.7: Recovering the ceramic dinner plate from inside the ship.
Task 2.1: Measuring the conductivity to determine which area is venting groundwater.

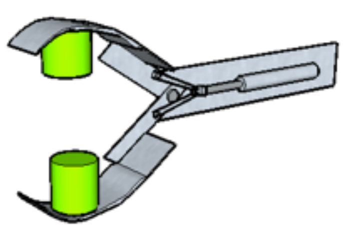


Figure 9: CAD drawing of front claw.

Design Description

Our ROV uses a claw powered by a pneumatic cylinder to collect the dinner plate, deploy the quadrat, and insert a probe that measures groundwater conductivity. This claw was built using aluminum sheet metal, pool noodles, nuts, and bolts. The claw is placed on the front beam of the frame. Four solenoids are used to control this claw. Air tubes deliver compressed air from the on-deck air compressor through our solenoid system, which is connected to the claw.

Design Rationale

This design was inspired by an aircraft's doors that open and close to deploy landing gear. This claw was initially powered by manual switches that were managed by the on-deck crew. After extensive research and discussions, we decided to switch to solenoids. Aluminum sheet metal was used because it is durable yet lightweight. Pool noodles acted as our gripping material, ensuring that nothing could fall out of our claw. Each port of the pneumatic cylinder requires an input solenoid and an output solenoid. Four solenoids are needed because there are two ports within each cylinder.

Side Claws

Mission Tasks
Task 2.4: Placing the quadrat into position on the top of the shipwreck.
Task 3.1 Removing the glass and plastic bottles

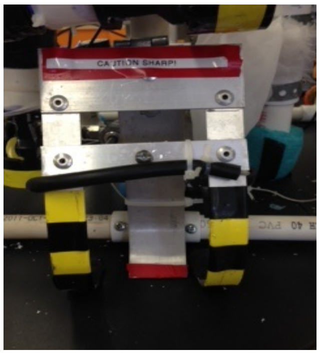


Figure 10: Side claw

Design Description

The two side claws are composed of aluminum sheet metal and a pneumatic cylinder. On both claws there is yellow and black electric tape to indicate that it is a moving part. Red electric tape is used to indicate the claw's sharp edges. One side of the claw is attached to the ROV and the other is attached to the pneumatic cylinder. Surgical tubing was used to close the claws, to avoid using additional solenoids and reduce the amount of air tubes within the tether. All three claws were designed and made by company members from scratch.

Design Rationale

We decided to construct the claw with aluminum sheet metal because it is lightweight, it does not corrode, and it can be molded into any shape. Surgical tubing was used because it provides a stronger force to hold the weighted bottles in the claws when the ROV is moving. We used solenoids to remove air tubes from the thick tether.

Agar Auger

Mission Task
Task 2.2: Retrieving a sample of a microbial mat.

Figure 11: Agar auger

Design Description

We used an "Archimedes Screw Pump" device, which is connected to a 1,893 liters/hour bilge pump motor (1,000 gallons/hour), to collect a sample of agar from the microbial mat. This mission tool was constructed from a hand-twisted aluminum metal bar mounted within a 1" PVC pipe. Aluminum pieces on the side of the PVC pipe connect to a metal mounting device within our frame. When the drill is in use, the agar is transferred to a mesh pouch, formed from a sports bag, where it is stored until the ROV surfaces.

Design Rationale

This device was innovated and not commercially bought because the sizes of other augers did not suit its unique design. Our drill was hand twisted and mounted within PVC. It was then connected to a metal mounting piece, which makes it easy to position. When in use, the drill extends from the PVC allowing it to penetrate the plastic wrap. The revolving auger acts like an inclined plane as it lifts the agar out of the cup. The agar moves up this incline plane with ease because there is a minimal amount of friction. The spiraling drill draws the agar out towards the mesh bag, where there is less pressure.

V-Hook

Figure 12: V-hook

Mission Task

Task 2.3- Recovering the sensor string, then replacing it with a new one.

Design Description

The V-Hook was built using aluminum sheet metal that was cut and screwed together at one end to simulate a "V" shape. The two ends of the "V" are bent upward so the sensor string cannot escape as the ROV surfaces.

Design Rationale

We used aluminum sheet metal because it was light and easy to cut. The V-hook is held down by two screws to prevent the hook from shifting.

Conductivity Probe

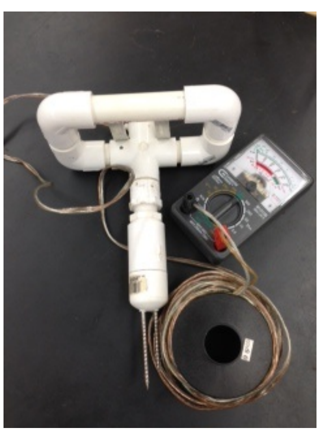


Figure 13: The conductivity probe connected to a voltmeter.

Mission Task

Task 2.1- Measuring the conductivity to determine which area is venting groundwater.

Design Description

Our conductivity probes were constructed by connecting one end of an eighteen-gauge wire to a screw and the other end to an ohmmeter. The measuring probe was built by sanding the top of each screw, then painting a thick coat of flux onto this area. We then painted another thick coat of flux onto the wire, after wrapping the wire around the top of the screw. Since the screws are stainless steel, we used special solder containing silver and an acid core. We then drilled the screws into a ¾-inch PVC cap. We connected the eighteen-gauge wires to 15.25m of speaker wire. The pipe cap was then filled with epoxy to keep the wires and screws in place and keep water out.

Design Rationale

Screws can easily puncture the plastic wrap above the groundwater vent. We decided to connect the eighteen-gauge wire to speaker wire instead of starting with speaker wire because it would have been harder to solder on. We chose this system because it is reliable and we can get a reading quickly and easily.

Vehicle Systems

Vehicle systems are explained in detail in the design rationale section above. Our ROV's design has been completely designed for this year's mission tasks. The majority of our ROV has been designed and built by our company, which includes all of the critical attachments. Attachments that were completely built are the side claws, front claw, V-hook, agar auger and conductivity probe. These were researched and built completely from scratch using original design ideas. However, to control our side and front claws, we purchased pneumatic cylinders. We purchased pneumatic cylinders instead of building them because we had no prior experience in building them. They would also be time consuming because the cylinders would need to be sent to lab techs to determine whether they would be safe enough to use. Motors, cameras, and solenoids were also commercially purchased, but they were also significantly modified. The bilge pumps were available locally and already slightly water resistant. However, we modified the motors by applying our own waterproofing techniques and adding shrouds and propellers. We reused the motors to save money. We re-waterproofed the motors and placed them in new mounts. We also reused the propellers because they were cheap and a perfect fit for the motors that we had. One new system we added is pneumatics. Pneumatics is used to control complex mission tools, such as the claws.

We also purchased cameras because we did not have the ability to make them ourselves. However, we modified them by encasing them in epoxy resin and covered any openings using RTV silicone. The cameras were also spliced off the original camera wires and re-soldered Cat-5e to minimize tether bulkiness. We used three different types of cameras (see Visibility Design Rationale) to suit the needs of the specific tasks.

Safety Procedures

At Kaimana Enterprises safety is our number one priority both in the workplace and at the pool. We ensured that no injury or impairment was done to our company members, as well as the ROV and pool. We incorporated a safety checklist to maximize safety and efficiency while working on the ROV. During the construction phases, preventative measures were taken to ensure the well being of our company. One precaution that was taken was consistently wearing safety goggles when we worked with power tools (drilling, sawing, soldering, etc.). We made sure that every person wore eye protection and we also had an advisor that reminded us when we were working with tools. While working on the electrical systems, we monitored it for cracks and leaks and constantly double-checked that no water had entered the systems prior to placing the

ROV into the water. All sharp objects on the ROV, such as the aluminum sheet metal corners, were colored red with electric tape or markers. This made the sharp objects easy to see and kept team members safe. Yellow tape was used to identify moving parts, such as our motors and claws. Many precautions were taken, for example, shrouds were used to protect the motor and all wires were taped down. Labels were printed and put onto objects that could cause harm when handling the ROV.

We reviewed the buoyancy tanks before and after our practices to ensure that there were no problems with the ROV. Another safety precaution taken by our company was confirming that the ballast tanks were firmly attached.

Cameras were very crucial in the performance of our ROV. Before plugging in the cameras, we checked that they were mounted onto the robot with stability. We also examined the cameras for cracks, checked the waterproofing connections, and inspected them for any water or moisture leaks. After plugging the cameras into the ROV, we guaranteed that we had a clear image of its surroundings and that the camera's cables were not crushed. After performing our missions, we checked the vision and clarity to ensure that no water had permeated it.

Many safety precautions were also taken for our control box. When testing the controls, connections to the box had to be double-checked, and the plugs connected to the controls were also reviewed. After everything was surveyed, the motors and attachments were tested to confirm excellent connection between the ROV and control box. A 25 amp fuse was used as a safety measure.

Precautions were taken with the conductivity probe by coloring the tip of the screw red. While coloring the screw, we had to take into account the possibility that if there was too much marker put on, it could interfere with the measurements.

While the safety procedures prevented many accidents, minors cuts on fingers that required the use of bandage was unavoidable. Another incident that occurred was when one of our company members grabbed the tip of the solder iron holder when another member was soldering. To prevent this from happening again, we created a solder workstation sectioned off with tape where only the person soldering would be able to enter.

Troubleshooting Techniques

One issue we had was the positioning of cameras. Prior to the first pool practice, a single monitor was used to test the visibility and range of every camera mounted on the ROV. Although the positions may have been fine in the days leading to the practice, during transportation the camera angles became slightly altered. When each camera moved, we had to plug the cameras into the monitors to reposition them. To prevent problems during competition, we check all of our cameras during the set-up time prior to entering the pool.

Another problem that we faced was to choose between using solenoids or manual air tubes. One reason why solenoids where considered is because they make it easier to give air to the different parts of the ROV without needing many different air tubes. The decision to use solenoids was a big problem because we noticed that the solenoids were rusting after only a few times underwater. This made us very concerned because many mission tasks relied on the use of solenoids. One of the claws did not grab the dinner plate consistently inside the shipwreck. This was because the solenoids were not providing enough air to the claws because the Nalgene bottle was receiving all of the air. An air accumulator was designed to control the airflow to the different payload tools to solve the problem of the insufficient grabber strength.

Our ROV was constantly changing, which caused the buoyancy to change along with it. The technique that we used to resolve this was to place the ROV in the water with slack in the tether. We would then identify which area was the most negatively buoyant and remove weights from that side of the frame. The opposite procedure would be taken if the ROV were too positively buoyant, as we added more weights to that side. When we added the Nalgene bottles to the ROV, we had to constantly modify the amount of water within each of them in order to remain neutrally buoyant.

Challenges and Solutions

While creating, designing, constructing, and wiring the ROV, we experienced many challenges. The majority of our problems were due to the conflicting schedules of our company members. Our team consisted of both intermediate and high school students, so there were many issues with creating a work schedule. Because the high school students attended a different school, they had to make time to go to Highlands Intermediate School. Several commitments made transporting difficult, which caused miscommunication problems. Mandatory team meetings once a week solved many of the schedule conflicts and communication difficulties. We even had pool practices on days with no school, such as holidays and weekends, to accommodate everyone's schedule.

Another major issue was the construction of constantly changing tool designs. We first designed three tools: a multi-purpose pneumatic claw, a sharpened syringe-like ABS device to collect agar, and tape measures to determine the dimensions of the wreck. However, due to time restraints and limited resources, the multi-purpose claw was deemed not feasible. We had to redesign the agar auger because the first few designs failed. These initial designs were modified because they were inefficient and took very long to complete the mission. Our mission tools changed to a pneumatic claw, bomb bay doors to collect the water bottles, tape measures, and an agar collection tube. Once again, due to time restraints, the idea of using bomb bay doors was eliminated. Instead, two side claws used to collect the bottles were constructed. The agar auger was completely redesigned to a hand-twisted metal rod as a drill, powered by a bilge pump motor. The designs of all mission tools were finalized, constructed, and implemented once they were reliable.

The control system was a challenging process that required countless hours, effort, accuracy, and patience to complete. Since we had never worked with joysticks, individual wires had to be manually tested, one by one, in order to learn their function. This was very time consuming, but absolutely necessary for the success of our system.

Lessons Learned

Over the course of this MATE season, our company has learned many lessons. The short time frame made it difficult for each of us to do the many required tasks. We also learned leadership skills. Whenever any experienced members worked on a specific task, they had to have a new member next to them, so they learn from them. Another lesson that we received was efficiently managing our time. Many of our team members are active in other extra-curricular activities. We learned many lessons including the importance of completing tasks, communicating with the team, and having patience when working under extreme pressure. We also learned about the importance of plugs to connect our tether to the control box. We previously dealt with many ripped wire connections. The plugs allowed us to easily detach the tether from the wiring without having to worry about broken wires. Finally, careful waterproofing techniques reduced equipment failure, compared to previous years. Every team has gained technical skills from the use of power tools to wiring a complex control system.

Future Improvements

The main improvement we would have liked to make is starting to prepare earlier. This would have given us the time to create the efficient mission tools that we were unable to construct due to a lack of time. We would also be able to practice with our ROV for a longer amount of time, resulting in a better mission score.

Another improvement that we wanted was the addition of a multi-purpose claw. A mission tool that could rotate about a central horizontal axis, bend up and down at a ninety-degree angle, and grasp objects was initially designed as our primary attachment. However, as our company had only eight weeks to prepare for the regional competition, we did not have a sufficient amount of time to design, construct, and test a claw that would include three motors. Instead, we decided to use two different types of claws that would be mounted at different locations and angles. If we had a multi-purpose claw, only one camera could be used to monitor the claw.

Another feature that we wanted to incorporate was the use of micro controllers and speed controllers. This requires only one power line, which would make the tether smaller and easier to manipulate. We did not use these because we did not have enough time to complete them. It takes an extensive amount of time to remove the interference from speed controllers, and waterproofing micro controllers is another very difficult task due to them being underwater with the ROV.

We would also like a more controlled buoyancy to fill and release air. Adding small amounts of air as we drop off and pick up heavy objects could help us achieve more missions in one underwater run.

If we had an unlimited budget, we would like to investigate a better tether system. Another component that may be tried is purchasing more powerful motors to create more thrust. This may help us reduce our mission time.

Team Reflection

MATE was a challenging, but rewarding experience for all of Kaimana Enterprises, from new to returning members. Our company faced countless difficulties while preparing for this competition. However, these obstacles allowed everyone to learn various lessons, such as teamwork, communication, and dedication. These lessons were acquired from the problems that we encountered while working. Creating a schedule was difficult, but this task could have been easier if the team communicated efficiently. Although there was a wide range of underwater robotics knowledge throughout the team, every member was able to give their ideas during team discussions and develop by acquiring skills that will benefit them in the future. Our company was able to learn engineering skills using solenoids, pneumatics, and many other systems. Solenoids were a new idea that was applied after doing extensive research and practice. We had a lot of fun participating in MATE this year and we look forward to learning even more during our next MATE experience.

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Appendix

A: Safety and Function Checklist (Safety Items in bold)

Buoyancy System

- ☐ **Two buoyancy tanks and accumulator attached firmly to the ROV.**
- ☐ **Check for cracks (especially around the ABS pipes and Nalgene bottle)**
- ☐ **Ensure that hose clamps for buoyancy tanks and accumulator are filed down.**
- ☐ **Double check**

Cameras

Prior to System Plug-in:

- ☐ Check mount for defects
- ☐ Examine if there are any cracks
- ☐ Double check the waterproofing connections
- ☐ See if there is water/moisture in the camera case
- ☐ Make sure camera wires are not punctured

After System Plug-in:

- ☐ Check camera image/angle – Upside down? Sideways?
- ☐ Cameras are tightly secure after fixing the image
- ☐ Make sure camera wires are not tangled in the casing

After Missions

- ☐ Check cameras for leaks
- ☐ Spray the cameras down with fresh water to get pool water off
- ☐ Wipe cameras down to prevent corrosion

Control System/Motors

- ☐ **Make sure control box is secured to the tether.**
- ☐ **Ensure there are no visible shorts or disconnections in the system**
- ☐ **Ensure that the correct plugs are plugged in and they are not flipped**
- ☐ **Check if fuse is working**
- ☐ **Have extra fuses ready in case one burns out**
- ☐ **Check that all motors are working and propellers are clear**
- ☐ **Ensure there is proper communication occurring**

Tether

- ☐ Ensure that all wires are tucked into the hollow braided polyester rope
- ☐ Make sure any wires in the polyester rope are not kinked
- ☐ **Check that tether is not in any danger of tripping anyone**
- ☐ Check to see if air tubes have any holes or leakage

Claw/Pneumatic Cylinders

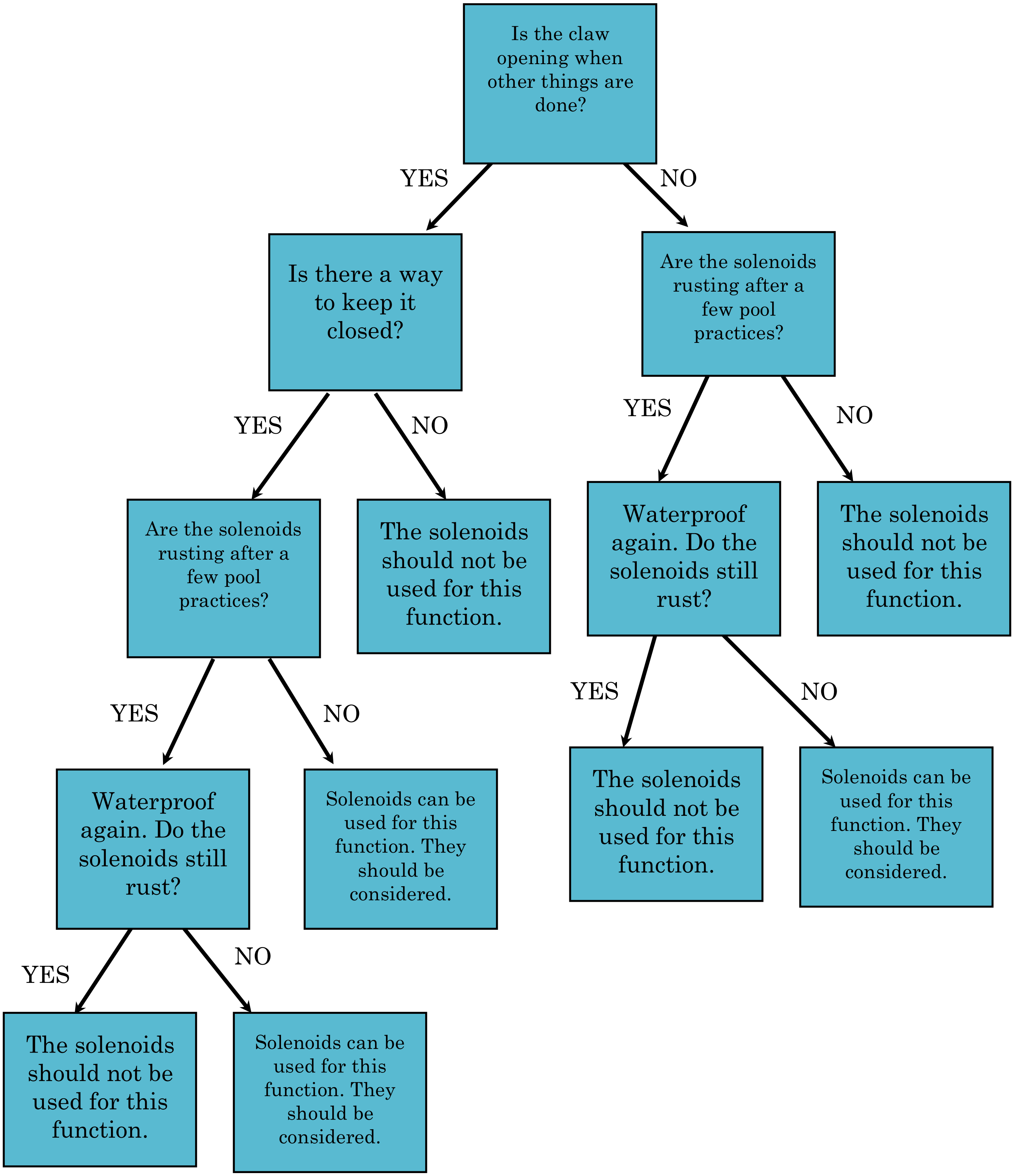
- ☐ **Check that air tubes are secured to the pneumatic cylinders**
- ☐ **Ensure that sharp edges and pinch hazards are taped**

Appendix B: Teamwork

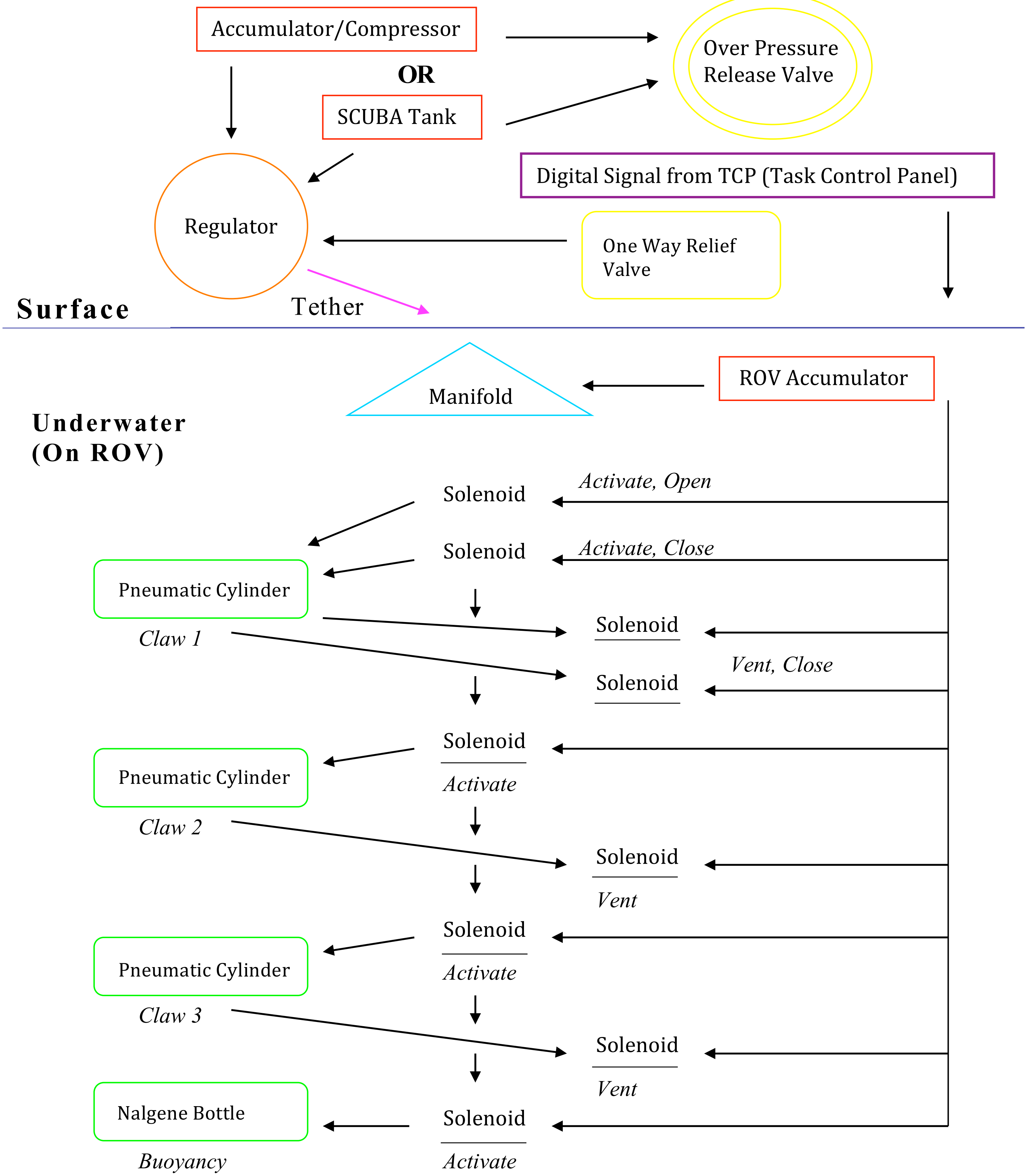
Task	Name	Week													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Established Roles	Whole Team														
Plan Frame Design	Brandon, Luke														
Built Frame	Brandon, Luke, Kenji														
Props	Whole Team														
Waterproofing Motors	Luke, Kenji, Lily, Sydney														
Tether 1	Brandon, Luke														
Claw 1	Kenji, Eric														
CAD Design	Lily														
Control Box	Luke, Brandon, Lily, Ashley														
Electrical Schematic	Luke														
Tape Measures	Brandon, Luke														
Pool Practices	Whole Team														
Buoyancy	Brandon														
Probe Assembly	Lily, Ashley														
Probe Waterproofing	Lily, Ashley														
Tether 2	Kenji, Luke, Lily, Ashley														
Pneumatics	Brandon, Luke, Sydney, Lily														
Claw 2	Eric														
Claw 3	Eric														
Agar Attachment	Kenji														
V Hook	Brandon, Kenji														
Tech Report	Whole Team														
Motor Switches	Lily, Ashley														
Camera Construction	Brandon, Lily, Luke,														
Financial Report	Sydney, Ashley, Lily														
Poster Board	Whole Team														
Engineering Presentation	Whole Team														
Packing for Regionals	Whole Team														
Regional Debriefing	Whole Team														
Re-design Meetings	Whole Team														
Design Improvements	Whole Team														
Resize Frame	Riley, Luke, Brandon, Eric														
Update Technical Report	Whole Team														
Payload Tools	Eric, Brandon														
Motors and Cameras	Alex, Luke, Brandon														
Financial Report	Sydney														
Ballast Tanks/Nalgene Bottle	Brandon, Eric, Riley														
Re-wiring	Luke, Riley														
Solenoid Wiring	Lily														
Tether	Luke, Riley, Brandon, Alex, Eric, Sydney, Koji, Kenji														
Poster Board	Kori, Lily, Ashley, Sydney														
Pool Practices	Whole Team														
Packing for Michigan	Whole Team														

* We kept to this schedule by creating specific deadlines in order to insure that each component was completed and explained in detail for the technical report. Each person was assigned a task to achieve by a certain date. However, if it was not completed by the date, we put additional members on that task to help. We did not stray from the schedule because once it was noticed that a task was not progressing, we gave them extra members to complete that task faster.

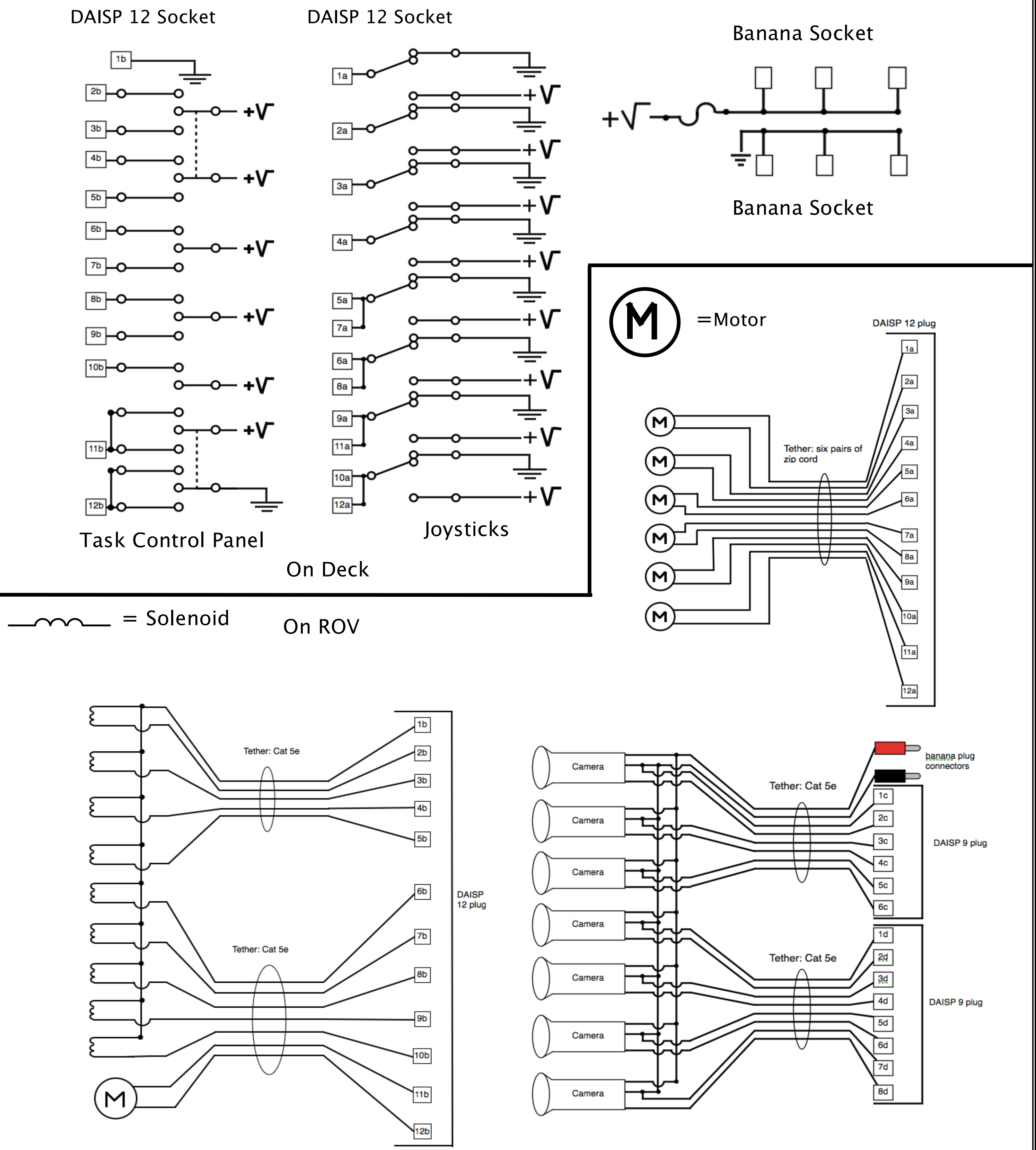
Appendix C: Solenoids Troubleshooting Map



Appendix D: Pneumatic Diagram



Appendix E: Electrical Schematic



Appendix F: Wiring Diagram