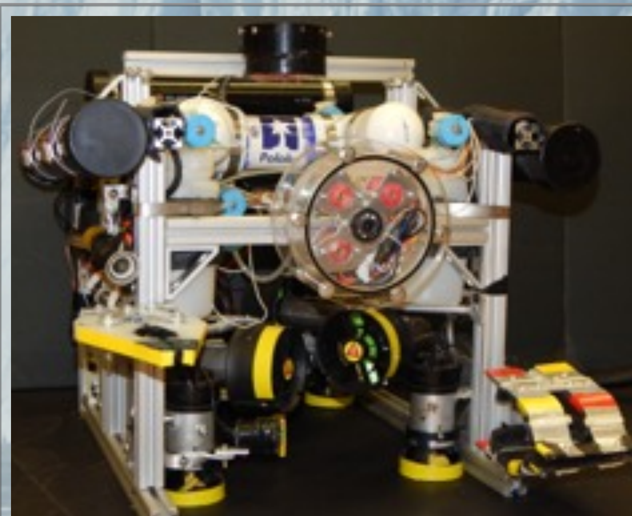
Kaimana Enterprises

Highlands Intermediate School/Pearl City High School
Science Club
Pearl City, HI 96782

Alex Yamada- CEO, Class of 2017
Lily Adcock- President, Electronics Manager, Class of 2019
Eric Schlitzkus- Chief Engineer, Class of 2018
Riley Sodetani- Operations Manager, Software Engineer, Class of 2017
Brandon Lin- Chief Design Engineer, Class of 2017
Luke Uyehara- Head Researcher, Class of 2017
Andrew Hayashi- Mechanical Engineer, Class of 2019
Everett Suzuki- Construction Manager, Class of 2019
Shane Suzuki- CADD, Class of 2019
***Dylan Sodetani- CFO, Class of 2020**
***Kody Kawasaki- Public Relations, Class of 2019**
***Sky Swarup-Barruga- Quality and Safety Inspector, Class of 2020**

(new members denoted by *)

Mrs. Kathy Lin- Teacher
Mr. Joe Adcock- Mentor



Kaikoa- ROV

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Abstract

At Kaimana Enterprises, safety, innovation, and environmental protection are our first priorities. Six years of experience in the Marine Advanced Technology Education (MATE) competition has given our company the skills needed to construct a versatile Remotely Operated Vehicle (ROV) that can effectively complete multiple tasks. Our ROV, Kaikoa, has an aluminum frame allowing easy configuration modifications and efficient performance in near-freezing underwater environments. Kaikoa's seven mission tools and eleven motors are wired through a 20 meter tether to our control system, which utilizes programmable Arduino boards, Cytron and Pololu motor controllers, joysticks, and task control panel. Kaikoa also has many specialized components including the Tri-Laser, Algae Collector, Valve Rotator, Valve Pump, Voltage Tester, Lift Line, grippers, and additional cameras. Our unique Tri-Laser system is used to determine the dimensions of an iceberg, wellhead, and corroded pipeline. The Algae Collector is an acrylonitrile butadiene styrene (ABS) tool that collects algae samples. Bilge pump motors are used to power the Valve Rotator that is used to operate the valves and the Valve Pump is used to pump water through the underwater pipeline. The Voltage Tester detects voltage from anodes. Kaikoa's main tools are the custom built front grippers, capable of retrieving and deploying numerous objects. ROVs, like Kaikoa, are needed to effectively conduct scientific research and repair pipelines in the harsh environment of the Arctic Ocean by St. John's, Canada. Kaimana Enterprises is ready to utilize our innovative solutions to benefit the society in which we live and thrive.

Company Mission

Kaimana Enterprises has taken advantage of our many years of engineering experience to construct a high performance ROV. Our newest model, Kaikoa, was created and perfected by our determined and skilled team of engineers. Our vehicle is aptly named Kaikoa, which means "ocean guardian" in Hawaiian. The implementation of numerous innovative solutions enable Kaikoa to live up to its name as guardian of the marine world.

Budget

After analyzing this year's missions, a budget of $8,000.00 was allotted to construct our ROV. Technical reports from previous years were reviewed and examined, which gave us a starting point to brainstorm ideas that we wanted to incorporate into the new vehicle. Most of the season was spent on designing and creating prototypes before constructing the final design. The prototype assisted in staying within the budget by eliminating unworkable ideas before proceeding too far in the building process. This budget did not include travel expenses to the international competition, which amounted to $23,220.00.

Financial Report

Category	Description	Type	Value	Actual Cost
ROV	ABS Tubing/Joints	Purchased	$83.33	$83.33
	Aluminum (Flat & Angle Stock, Sheet)	Purchased	$85	$85
	Aluminum Extrusions	Purchased	$108	$108
	Arduino Mega 2560 Microcontroller	Purchased	$23.60	$23.60
	Arduino Uno Microcontroller	Purchased	$6.39	$6.39
	Battery	Purchased	$79.88	$79.88
	Bilge Pump Motors (7)	Recycled	$210	N/A
	BTD-150 SeaBotix motors (4) **(SPAWAR)**	Donated	$3,800	N/A
	Bulk Fasteners	Purchased	$38.85	$38.85
	Cat-5e Wire (210')	Purchased	$29.56	$29.56
	Cytron Enhanced DC Motor Drivers (4)	Purchased	$185.88	$185.88
	Driver Shields (4)	Purchased	$399.92	$399.92
	D-Sub Connector-Video (4 pairs)	Purchased	$24	$24
	Electrical Wire/Connectors	Purchased	$56.58	$56.58
	Gusset Corner Brackets	Purchased	$113	$113
	Heat Shrink Tube	Purchased	$42.35	$42.35
	Hose Clamps	Purchased	$25.12	$25.12
	Lasers (3)	Purchased	$43.47	$43.47
	Linear Bearings	Purchased	$128.80	$128.80
	Liquid Tape	Purchased	$27.96	$27.96
	Logitech Joystick	Recycled	$29.99	N/A
	Miscellaneous Brass Parts	Purchased	$118.29	$118.29
	Nalgene Bottle **(Highlands Intermediate)**	Donated	$4.42	N/A
	Plastic Sheet	Purchased	$15	$15
	Plexiglass Sheet **(Robin's Painting)**	Donated	$20	N/A
	Pololu Dual Motor Controllers (2)	Purchased	$121.90	$121.90
	Poly Tubing	Purchased	$96.90	$96.90
	PVC Tubing/Joints	Purchased	$10.24	$10.24
	Quick Connect Adapters	Purchased	$34.28	$34.28
	RTV Silicone	Purchased	$39.54	$39.54
	Screws/Washers	Purchased	$45	$45
	Solenoids (11)	Purchased	$183.48	$183.48
	Soriau Standard Circular Connectors	Purchased	$875.64	$875.64
	Speaker Wire (630')	Purchased	$207.89	$207.89
	Spray Paint	Purchased	$4.44	$4.44
	Stainless Steel Scrubbers	Purchased	$2.33	$2.33
	Stretch and Seal Silicone Tape	Purchased	$8.93	$8.93

	Through-Hole Cameras (8)	Purchased	$400	$400
	Treaded Rods	Purchased	$16.72	$16.72
	Wooden Buoy **(Robin's Painting)**	Donated	$15	N/A
	Thompson's Water Sealer **(Robin's Painting)**	Donated	$13	N/A
		Subtotal:	**$7,774.68**	**$3,682.27**
Props	Adhesive Letters and Numbers	Purchased	$5.98	$5.98
	Bricks	Recycled	$10.89	N/A
	Electrical Wire/Connectors	Purchased	$5.24	$5.24
	Galvanized Hanger Strap	Purchased	$4.99	$4.99
	Gate Valves (7)	Purchased	$69.23	$69.23
	PVC Tubing/Joints	Purchased	$150.91	$150.91
	SPST Switches **(Highlands Intermediate)**	Donated	$9	N/A
		Subtotal:	**$256.24**	**$236.35**
R & D	Two 1-1/4" PVC Tee	Purchased	$3.98	$3.98
	3" Plug-on Cap	Purchased	$0.99	$0.99
	Acrylic Sheets/Tubing **(Robin's Painting)**	Donated	$88.99	N/A
	Cytron Enhanced DC Motor Drivers (8)	Purchased	$107.20	$107.20
	Driver Shields (4)	Recycled	$209.50	N/A
	Go Between Shields	Recycled	$27.90	N/A
	Logitech Webcam	Purchased	$124.99	$124.99
	USB Hubs	Purchased	$105.98	$105.98
	Vehicle Camera	Purchased	$59.55	$59.55
	Waterproofed Cables/Connectors	Purchased	$500	$500
		Subtotal:	**$1,229.08**	**$902.69**
Time/Service	Robin's Painting	Donated	$1,000	$1,000
		Subtotal:	**$1,000**	**$1,000**
Regional	Meals **(Parent Volunteers)**	Donated	$100	N/A
Competition		**Subtotal:**	**$100**	**$0**
International	Airfare	Purchased	$16,200	$16,200
Competition	Ground Transportation	Purchased	$720	$720
	Lodging	Purchased	$3,600	$3,600
	Meals	Purchased	$2,400	$2,400
	Uniforms	Purchased	$300	$300
		Subtotal:	**$23,220.00**	**$23,220.00**
		Total:	**$33,580.00**	**$29,041.31**
Cash	Pearl City Merchants Association		$500	$500
Donations	Monsanto Hawaii		$500	$500
		Total:	**$1000**	**$1000**

Design Rationale: ROV Components

Frame

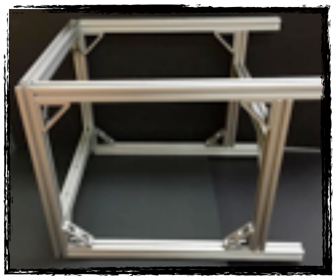


Fig. 1- Kaikoa's aluminum extrusion frame.

Design Description

Kaikoa is constructed as a rectangular prism measuring 48 cm long, 38 cm wide, and 44 cm tall. This configuration houses eleven motors, eight cameras, and seven mission tools, while remaining compact. The vehicle's frame is constructed out of aluminum extrusions, rather than polyvinyl chloride (PVC), which had been used for the prototype.

Design Rationale

The rectangular design allows components to be attached easily to the frame. Last year, PVC was used to construct the frame; however, it made attaching and detaching components inefficient and time consuming. Therefore, this year, aluminum extrusions were chosen because they have grooves to allow the motors, mission tools, and cameras to be effortlessly mounted to the frame. The grooves also allow the position of components to be altered quickly. PVC, a cheaper alternative, was used to construct a prototype frame, which provided a way to accurately size the minimum volume required to contain all the components desired before the final product was built with aluminum extrusions.

Fig. 2- CAD Mechanical drawing of Kaikoa's frame.

Buoyancy/Ballast

Fig. 3- One of the four Nalgene bottles with solenoid attached to the top.

Design Description

Kaikoa's main source of buoyancy are the two 35 cm and two 45 cm ballast tanks that were constructed using 2-inch ABS pipes, 2-inch end caps, and a PVC accumulator placed at the top-center of the ROV. The tanks are mounted along the top of the frame. Our most innovative method for controlling the ROV's buoyancy is the use of Nalgene bottles, which act as variable ballast tanks, mounted vertically on the top four corners of Kaikoa. Each Nalgene bottle has a solenoid valve on the top of the cap. There is another solenoid valve in the center of Kaikoa that fills the four Nalgene bottles. Metal washers were added at the lower four corners of Kaikoa and secured between screws and wing nuts for small adjustments.

Design Rationale

Our company chose to use ABS pipes and end caps for our main source of buoyancy because they will not compress at the depths we will be operating at. The accumulator at the top of Kaikoa stores air for our pneumatics, as well as provides additional buoyancy, which makes this design ideal. Four Nalgene bottles are mounted at the top corners of the frame and act similar to a submarine's main ballast tanks. These bottles will remain at ambient pressure and will not compress in deep water because there is a hole at the bottom of the bottle where water can escape. A similar idea was used last year, but it had only a single bottle that had to be filled with water manually. The Nalgene bottle tanks allow us to alter our ballast to compensate for the different temperatures and water types in the three demonstration tanks and in our warm water testing pool.

The Nalgene bottles operate using five solenoids. When the bottom solenoid is activated it displaces water by filling all four bottles with air making the ROV more buoyant. When the solenoid on the top of each bottle is activated, it allows air to flow out replacing it with water and making Kaikoa less buoyant. Washers are pinned in the lower four corners of the ROV, lowering the center of gravity. The lower center of gravity increases Kaikoa's overall stability. This efficient washer ballast system also provides a quick method to adjust ballast in small increments, longitudinally and transversely, to achieve near-neutral buoyancy with good trim and no list.

Propulsion System

Fig. 4- The aluminum mount and ABS shroud attached to a bilge pump motor.

Design Description

Four BTD-150 SeaBotix motors supply vectored thrust, and four 1,000 gallons/hour (3,785 liters/hour) bilge pump motors are used as vertical thrusters to operate Kaikoa. The SeaBotix motors are placed inside the four corners of the base of the frame at a vector angle of 45º parallel to the bottom of the ROV. Handcrafted ABS shrouds are secured to the bilge pump motors. Motor mounts are constructed from welded aluminum bars and attached to the aluminum extrusions with screws and metal plates. The SeaBotix motors are able to produce 2.2 kg of thrust at only 4.25 amps (SeaBotix, 2012).

Design Rationale

SeaBotix motors are used as the vector thrusters because it allows Kaikoa to move faster in water by producing more thrust than the bilge pump motors. Vectored thrusting was implemented this year because it enables Kaikoa to maneuver in every direction. We were concerned about the currents and waves, and felt that vectored thrust would allow us to compensate so that Kaikoa could perform the needed tasks. Last year only two bilge pump motors were used as vertical thrusters, which could barely surface the ROV; therefore, four bilge pump motors are being used this year. The ABS shrouds were implemented to keep personnel safe from the propellers and to focus the water flow created by the motors. Aluminum is an ideal material for mounting the motors, as it is rust-proof and firmly secures the eight drive thrusters.

Fig. 5- The SeaBotix thruster attached to the handcrafted motor mounts.

Control System

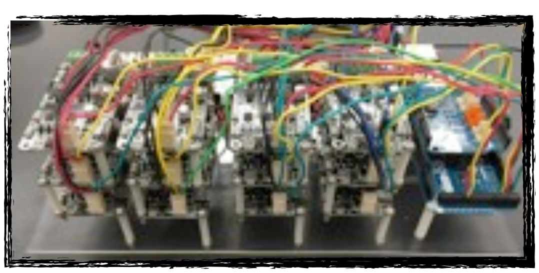


Fig. 6- Completed electronics system, before it was attached to the acrylic sheet within an acrylic box.

Design Description

The control system consists of an Arduino Mega Board, USB Shield, two terminal strips, four Cytron motor controllers and two Pololu dual motor controllers. The six motor controllers operate eight motors: four for the vertical thrusters and four for the vector thrusters. The electronics system is secured to a plexiglass sheet within an acrylic box which is placed on deck.

14 gauge (2.08 mm^2) solid copper wire is used to supply the motor controllers with power. Each controller is connected to terminal strips with 14 gauge (2.08 mm^2) stranded copper wire, which transfers power down the tether and to the motors. We also use a Task Control Panel (TCP) to control four mission tools (two grippers, adjustable ballast, and Tri-Laser). The TCP consists of five double throw momentary toggle switches and two double throw toggle switches. This second control panel allows our driver to focus on positioning the ROV while another team member operates the mission tools.

Design Rationale

During the previous MATE season, tension from surgical rubber tubing was used to keep the ROV's grippers closed, and a pneumatic system opened the gripper. This limited the functions of the gripper, as the position could not be altered and the gripper's clench was too weak. This year, double action pneumatic cylinders allow our two grippers to open and close without the use of surgical rubber. We attempted to use Seamate boards to control the motors; however, they could not be correctly programed and wired. The team decided to replace the Seamate boards with 4x4 driver shields or Cytron motor controllers. After further research, it was found that the 4x4 driver shields couldn't reverse the motors. Therefore, the Cytron motor controllers, controlled by the Arduino Mega board were chosen because of their ability to handle high currents and their reputation for high quality. We faced some difficulties with giving more power to our SeaBotix thrusters, but after discussing this difficulty with experts at another STEM competition, they recommended the implementation of Pololu dual motor controllers because they would be able to provide more power to our drive thrusters.

Programming (for software flowchart refer to Appendix G: Software Flowchart)

Design Description

Arduino v. 1.6.3 software is used to send Pulse Width Modulation (PWM) power signals to the motor controllers. The Logitech joystick and the Arduino are programmed to specifically operate our ROV. Using the C language, the Arduino software constantly checks the status of the Logitech joystick and alters the power intensity to each motor using our algorithm to implement vectored thrust and vertical position. This program also contains unique features, such as the ability to tilt the ROV and an autopilot function.

Fig. 7- Joystick that was programmed to operate Kaikoa.

Design Rationale

The Arduino software was chosen to program the electronics system because it is operable for amateur programmers and is free. This is the first year that programming was used, so there were many problems that needed to be troubleshooted. In one instance, the proper method to code a certain function could not be determined, so online tutorials and examples were utilized and applied to the system. Before the season started, our team members learned basic C language to ensure that we were capable of programming our desired functions.

After conducting research, we discovered that two of the three tanks at competition would have currents, making it harder to perform tasks. To prevent this problem, an autopilot feature was added to the program. This feature compensates for the current while still giving the driver the ability to move the ROV when needed.

Visibility

Fig. 8- The Through Hole cameras were waterproofed with green liquid tape and clear RTV silicone.

Design Description

Kaikoa utilizes eight strategically placed cameras: seven Through-Hole cameras and one Universal Small Bullet camera. One camera is located in the acrylic Tri-Laser housing, which allows a wide field of vision in front of Kaikoa, while also monitoring the lasers. Two Through-Hole cameras are used for back and side views, so that we can easily identify our location underwater. The remaining five cameras monitor our mission tools. One Small Bullet camera and one Through-Hole are mounted on the front side of the ROV's frame and focus on the two pneumatic grippers. Two Through-Hole cameras are located at the top of the frame towards the center, which observe our Water Pump and Algae Collector. The final camera is mounted toward the back of the frame and monitors our Valve Rotator.

Design Rationale

Initially, the use of 1080p Logitech cameras was attempted because they could produce higher quality images. The USB video signals that were required for this camera could not travel over the tether because the extenders that were available to us could not handle the video signal. Therefore, the Logitech cameras were replaced with the current cameras, which are the same type of cameras that were utilized in last year's ROV. Both cameras have a slightly lower quality, but the video signal is able to travel through twisted pairs of Cat-5e wires, instead of USB cables. The Through-Hole cameras have an O-ring and require less waterproofing, which make them ideal for underwater usage.

Tether

Fig. 9- The cables within the PET covering with handmade wooden buoys.

Design Description

The tether consists of eleven pairs of 14 gauge (2.08 mm^2) speaker wires, three Cat-5e cables, two air tubes, and one pair of wires within the Cat-5e cable held within a Non-Fray Clean Cut Expandable Braided Sleeving made out of Polyethylene Terephthalate (PET) monofilament yarn. We used a Non-Fray Clean Cut Expandable Braided Sleeving for our tether because it holds all the wires in one bundle. The tether has a length of 20 meters. Each pair of wires are used to power thrusters, mission tools and the ROV's power bus. Two Cat-5e cables transfer video signals from the eight cameras to the surface and are all powered using 14 gauge speaker wire. A third Cat-5e cable runs from the task control panel to three bilge pump motors and eleven solenoids.

The separate Cat-5e wire connects the Tri-Laser to the surface switch, providing power to its onboard 3 volt supply. Our team also made handcrafted wooden buoys that kept our tether positively buoyant, thus, improving our mobility.

Design Rationale

Our team chose the PET tubing because it can stretch and become longer with a smaller diameter or bunch up and become shorter but have a bigger diameter. We also used Cat-5e wires to carry signals to our ROV because Cat-5e wires contain four pairs of thin wires inside, thus allowing us to minimize the amount of space we used up in the tether. Finally, we used a pair of wires from a Cat-5e cable to return the laser's ground to a surface switch instead of using the minimum one wire requirement because the other wire helps add support to the first wire. The single piece of wire inside the Cat-5e cable bends easily and is very fragile so the extra wire supporting it helps to make it more durable. The wooden buoys are made by turning them on a lathe and applying Thompson's Water Sealant. These buoys are incompressible at the expected operating depth.

Pneumatics

Fig. 10- The solenoid system that were used for the grippers.

Design Description

The pneumatics system consists of 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, and tested as required. We used nine RSC-2 solenoids and two dual action solenoids: two single and one dual action for each of the two front grippers, and five for the Nalgene bottles. The solenoids were sealed and waterproofed by spreading RTV silicone all over the inside of the solenoids and on all possible openings. These solenoids control the tools by allowing the pressurized air to pass through and move into our pneumatic actuators (pneumatic cylinders). The two front grippers are operated using pneumatic cylinders.

Design Rationale

Last year, before using an accumulator, we encountered a problem: when we picked up items with our front gripper and then activated the ballast air valve, the front gripper would lose power and would open back up. The air pressure coming down from the compressor lessened because of the length and small diameter of the air tube. To fix this problem we decided to use an accumulator, which maintains the air pressure on the ROV. The accumulator is filled with pressurized air, which keeps the pressure going through the solenoid valves high, allowing our tools to work at maximum power. We use solenoid valves because they allow us to control our tools with only one air tube going down to the tether instead of seven, which we would have needed without the solenoid valves. Additional air tubes would have caused the tether to be more stiff and thick. We added a second air tube to increase performance and keep the system dry by venting to the surface. It is important to keep the system dry since any water in the system may freeze, disabling the solenoid valves, as happened when we tested our ROV in a tub of ice water before adding the vent line.

Design Rationale: Mission Tools

Grippers

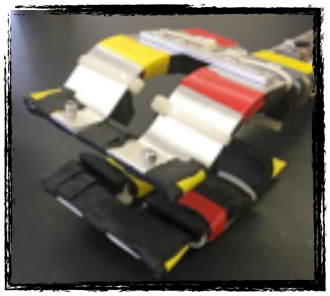


Fig.11- Aluminum gripper with safety tape indicating it is sharp and moves.

Design Description

Our ROV uses two grippers that are powered by pneumatic cylinders. The first gripper opens vertically and is constructed from aluminum bars, aluminum sheet metal, pipe insulators, and pop rivets. The second gripper opens horizontally and is made from a plastic cutting board, aluminum, and aluminum sheet metal. Air tubes deliver compressed air from the on-deck air compressor through our solenoid system. Rubber tape is attached to the gripper to improve its grip and to keep objects from slipping out from the gripper. Red and yellow tape on the grippers highlight moving parts and sharp edges.

Fig. 12- Plastic gripper with liquid and rubber tape for grip.

Design Rationale

The grippers are designed to perform numerous tasks which involve deploying, retrieving, and lifting various objects, such as grabbing the O-ball, deploying a passive acoustic sensor in a designated area, attaching a Lift Line to the corroded section, removing the corroded pipeline segment, and installing a hot stab into a wellhead. After analyzing the tasks that had to be completed, we decided to construct two grippers, which differ in size, shape, and orientation, because this would allow the robot to complete the various types of missions. Aluminum sheet metal was chosen for the vertical gripper because it could be easily formed to our desired shape. Plastic was used for the horizontal gripper because it is strong, durable, lightweight, and was already at the desired thickness. This gripper needed to be thicker and stronger, in order to lift heavier objects. The hole in the horizontal gripper was incorporated to allow the robot to easily hold the hot stab and insert it into the wellhead. There are pipe insulators attached inside the vertical gripper that are able to mold around the object it is grabbing and prevent it from escaping. Velcro was attached to the second gripper to securely hold the hot stab. The two different gripper orientations allow for the execution of various tasks.

Valve Rotator

Fig. 13- Valve Rotator with orange paint on the motor, indicating that it is a moving part.

Design Description

The Valve Rotator is designed to rotate the valves on the oil pipelines quickly and easily. Due to limited space on the ROV's frame, the Valve Rotator was constructed to be compact and simple. It is powered by a 1,000 gallon/hour (3,785 liters/hour) bilge pump motor that is mounted to an axle with a 3.5 cm metal gear. The smaller gear turns a larger 9.7 cm gear that is attached to an aluminum flat bar with two parallel prongs which turn the valves.

A Tetrix bar, which extends below the frame, is used to mount the motor and the Valve Rotator's components. This bar is secured to a linear bearing which is part of the aluminum extrusion. Another 1,000 gallons/hour (3,785 liters/hour) bilge pump motor is attached to a threaded rod with nuts, allowing the assembly to slide up and down.

Design Rationale

The original design for the Valve Rotator created a significant amount of friction between the motors and small gear, which prevented smooth operation. In order to solve this problem, two bearings were added through the Tetrix bar, between the motor and gear. The Valve Rotator required a gearing system strong enough to turn valves, so many different gear ratios were tested. After testing, it was determined that the 3.5 cm gear to 9.7 cm gear is the best system to turn the valve. In order for the ROV to remain compact, and easy to attach, waterproofed mechanism was designed to extend the Valve Rotator outside of the frame.

Algae Collector

Fig. 14- Algae Collector with rubber bands on the screws to capture the ball.

Design Description

The Algae Collector is a simple, yet innovative tool that was created using a 3 inch ABS pipe that was 5 cm tall. Eleven screws were drilled into the outer rim of the ABS pipe. These screws allow multiple rubber bands to be easily attached to the pipe. The tension from the rubber bands assists in the retrieval and collection of the algae samples. The screws also provide a quick way for rubber bands to be removed and replaced.

Design Rationale

The collector was designed to have the smallest possible profile, since it is mounted outside of the frame. The depth of the collector was chosen to be 5 cm deep to have adequate room to accommodate the 4 cm diameter ping pong ball that is used to simulate algae. We decided on this design because it did not require a motor and was very simple in comparison to other design alternatives. An ABS pipe was used because it is cheap, lightweight, and simple. Eleven screws are drilled into the rim of the pipe, evenly spaced, so the placements of the rubber bands can be easily altered and positioned. Rubber bands are ideal because the algae will go into the collector and remain inside, without the use of a motor or complex tool.

Voltage Tester

Design Description

The Voltage Tester is a C-shaped tool made from ½-inch PVC. The ends are closed by stainless steel fender washers covered with stainless steel scrubbing pads, and held in place with stainless steel bolts. Inside, ring terminals connect each of the bolts to a 14 gauge (2.08 mm^2) speaker wire. An assembly of aluminum bars with electrical tape is attached to the PVC, so the tester can be held in Kaikoa's horizontal gripper.

Fig. 15- Voltage Tester that uses stainless steel wool to measure voltage.

Design Rationale

The tester is designed so that one scrubbing pad makes contact with a test point in Task 3 while the other connects to the common ground to test for the voltage. The 14-gauge speaker wires that are connected to the two bolts are connected to a voltmeter which is used to tell whether or not there is voltage when the probe makes contact with a test point and common ground. The PVC holder was made so that it can touch each test point and common ground. The scrubbing pad was used because it can be compressed and can push up against the test points, so exact positioning of the tester is not required. The aluminum bar is used for the gripper to easily grab onto and hold the probe without twisting.

Lift Line

Fig. 16- The Lift Line attached to the black 550-paracord cable.

Design Description

The Lift Line is comprised of a double gated S-biner, parachute cord (550-paracord), a Tetrix aluminum flat connector, and Tetrix hub. The S-biner is used to securely lock onto a pipeline and retrieve it. The Lift Line is held in the gripper with the Tetrix flat connector and hub, and the 550-paracord is used to pull the pipeline back to the surface.

Design Rationale

After thoroughly analyzing the functions that the Lift Line would have to complete, the S-biner was chosen because it is simple, lightweight, and inexpensive. The S-biner has a lever attached to a spring to open, so when the lever is pushed, it moves inward and traps the U-bolt. It is orange, ensuring that it is highly visible while it is underwater. Originally, yarn was attached to the S-biner to pull the pipeline back the the surface. However, during test runs the yarn tangled easily and was replaced by 550-paracord. The Tetrix components allowed the Lift Line to be securely held within the gripper.

Tri-Laser

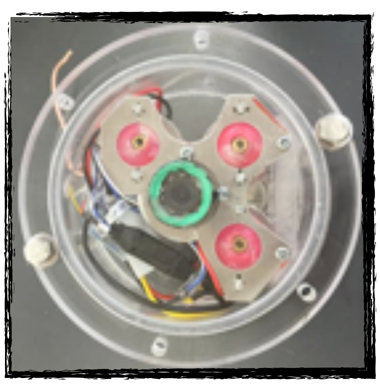


Fig. 17- The completed Tri-Laser placed into the acrylic housing.

Design Description

The Tri-Laser system uses three Quartet Mini Laser Pointers spaced a distance of 5 cm apart horizontally and vertically. This tool was designed to measure the length of corroded pipeline, measure the height and length of the wellhead from the seafloor, and provide measurements to calculate the volume of the iceberg. Each laser was inserted into a rubber ball before being mounted between two aluminum plates. The rubber balls hold the laser firmly in place, as well as make adjusting their position quick and simple. The lasers must be placed exactly parallel to each other to ensure that 5 cm distance between the laser beams remains constant over all distances away from the lasers.

The entire assembly is held within a watertight, cylindrical acrylic casing. The housing protects the laser while still keeping the beams visible.

Design Rationale

The mini laser pointers were used because they were easy to disassemble and mount. Our initial design consisted of two lasers that could rotate around a camera. However, prototyping resulted in a simpler design using three lasers because it could measure height and width without the use of a motor to change the orientation. The system works by having the laser dots 5 cm apart. We freeze the video feed from our cameras and we measure how far apart the dots are. We then measure the size of the object that was being measured and calculate the dimensions.

Water Pump

Fig. 18- The Water Pump was painted yellow to be highly visible.

Design Description

Our company's Water Pump is a simple way to pump water through the pipeline very quickly. It was created using 1 inch PVC pipes and a 800 gallons/hour (3,028 liters/hour) bilge pump motor. The PVC pipe was then secured to the opening of the bilge pump motor with RTV silicone.

Design Rationale

Kaimana Enterprises tried multiple methods to achieve this mission task. As a company, we decided that this idea would be consistent and effective, as well as simple and inexpensive. The bilge pump motor provides a sufficient amount of strength to quickly push water up the pipeline. The PVC pipe is inserted into the pipeline to focus the thrust and rubber tape is attached to the end of the pipe, to stop water that is being pushed from escaping.

Vehicle Systems

Kaikoa and each of its specially tailored mission tools were designed and constructed by the members of Kaimana Enterprises, with the exception of a few basic commercially purchased parts. For example, the motors were commercially purchased, but were modified by our company with original components, which included custom-built ABS shrouds, additional waterproofing, and propellers selected by our company. Arduino boards were also purchased, but our company programmed and wired them specifically for Kaikoa's missions. The decision to construct, rather than commercially purchase, advanced everyone's engineering and problem solving skills through hands-on experience and kept Kaikoa within the company's budget.

In order to improve the performance of our ROV, the majority of Kaikoa's components are brand new, including the control system, electronics system, and frame. Previously, Kaimana Enterprises had used PVC as our main building material, but it was easily distorted and was difficult make adjustments to the frame.

Therefore, this year aluminum extrusions were chosen in place of PVC for its stable and effective characteristics. In addition, Arduino boards, Cytron and Pololu motor controllers, and Arduino v. 1.6.3 programming software were utilized to create a completely new control and electronics system.

Our company underwent a long decision making process to decide whether or not to reuse components from our previous ROV. This process consisted of analyzing the requirements of each mission, brainstorming the design of the ROV, and holding a company meeting to discuss the reuse of certain components. After going through this extensive process, we decided to reuse two bilge pump motors, nine solenoids, and the PVC accumulator. The motors were used as thrusters last year, but were recycled this year to operate Kaikoa's Valve Rotator. The motors were reused because they were extensively waterproofed and provided sufficient strength to rotate the valves. The accumulator and solenoids for our pneumatics system were fully functional, so our company decided to reuse these components as there was no reason to purchase new solenoids or construct a new accumulator. However, the solenoids were disassembled, cleaned, and further waterproofed. This decision also allowed us to remain within our budget.

Our company's mission is to produce a quality ROV that can effectively perform specific tasks. This year's theme incorporated missions that simulated the performance of tasks in arctic environments. Kaikoa's design has evolved this year, in order to become fully functional in near-freezing water temperatures. Kaikoa has a variable ballast system to compensate for varying water density as well as components that will not freeze in cold temperatures. The design of Kaikoa was also greatly influenced by issues and challenges that our company faced throughout previous MATE seasons. Every year, waterproofing difficulties required constant troubleshooting. This year, RTV silicone and butyl rubber tape were implemented to protect the electronics system. Previously, a PVC frame was used; however, difficulties emerged when mounting components onto the ROV. The team discussed different frame materials and the decision was made to use aluminum extrusions. It made attaching and adjusting components on the frame much easier and quicker. Throughout this year, our company held many meetings to discuss obstacles and brainstorm possible solutions. All members of Kaimana Enterprises were able to provide their insight and solutions to the multiple challenges that arose.

Troubleshooting Techniques

With the implementation of new, complex components this MATE season, the members of our company had to improve troubleshooting processes and procedures. The troubleshooting technique which we employed had three main steps: locating the source of the problem, finding the reason behind the problem, then creating and implementing a solution to the problem. If our initial solution did not completely solve the issue, a new solution was tested. We used this technique during the building and testing period. Numerous issues with waterproofing, electronics, and pneumatics taught us to quickly brainstorm possible solutions.

We were able to test the ROV as a whole, rather than as individual components through the use of a large aquaponics tub in the school's garden. After successful testing in the tub, final testing was completed at a neighborhood pool. This allowed us to test the control system and observe the accuracy of our programming and practice operating the vehicle underwater. After testing the ROV during a pool practice, one of our motors stopped working. Rather than immediately attaching a new motor, we first checked the status of the control system, tether, and motor itself. Eventually, we discovered that the motor had taken in water during testing and had to be replaced. We then added additional waterproofing to all of our motors, ensuring that this problem would not occur again. This situation demonstrates the troubleshooting technique that was applied throughout the entire season.

Challenges and Solutions

Our company experienced many technical difficulties during the course of this season. Efficiently programming and wiring the control system proved to be an ongoing technical challenge. Since this was the first year that Arduino programming was implemented, the members were required to learn how to program the control system. By watching numerous tutorials and reading online manuals that explained wiring and programming procedures, everyone was able to learn and implement these new skills. Lectures which explained the basics of programming were delivered to the team members by engineers, who were introduced by our mentor. We were also aware that our robot had to perform tasks in currents, therefore, we implemented a new method of orientating our drive thrusters, which allowed the robot to easily readjust underwater when faced with strong currents.

Since the members of Kaimana Enterprises attend different schools, many nontechnical challenges arose, such as scheduling meeting times and practice days. Detailed schedules had to be made to accommodate the two different school schedules and various after-school activities. For example, many members are highly active in sports and other extracurricular programs, so meetings were mandatory all day on the weekends. Many methods were implemented to overcome this problem, such as creating a detailed schedule, which accommodated every member's hectic schedules, along with constant communication throughout the company via texting, emailing, and social media. Another challenge that we faced was purchasing certain materials because we live in Hawaii, so many companies did not ship to our island. Therefore, we had to overcome this problem by planning ahead and researching numerous sources for components that we needed to purchase.

Lessons Learned: Technical

This season, Kaimana Enterprises gained many valuable skills while working on the electronics system. Due to the addition of new electronics (Arduino boards, Cytron motor controllers, USB shield, and lasers) our company's software and electrical engineers had to quickly learn how to effectively utilize these new technologies. This system required programming, which gave everyone the opportunity to establish and enhance their programming and wiring skills. We also learned the importance of carefully waterproofing every component on the ROV to reduce the incidence of equipment failure that was experienced throughout the season. Every company member was able to gain and improve their technical skills, including the use of power tools and learning how to troubleshoot various challenging problems.

Lessons Learned: Interpersonal

Company members learned to work together and gained many life skills, including communication and time management. For example, planning daily objectives for each work day helped all members stay aware of their vital roles in successfully meeting deadlines. The importance of respect, patience, and leadership continued to be emphasized throughout the season. As three new members joined the company, the experienced members needed to mentor, support, and assist them in learning and developing crucial engineering skills, which allowed the experienced members to enhance their leadership ability.

Future Improvements

Kaimana Enterprises continuously seeks ways to improve our company and the efficiency of our products. Next year, our company plans to start earlier, in order to provide additional time to design and test various components, increase practice time underwater, and improve our overall performance. Our company also plans to expand the use of technology on next year's model. Instead of using an on-deck control system, we plan on incorporating an on-board system to reduce the size of the tether. We also plan on improving our technology by implementing a multi-purpose gripper that has an arm which rotates along its central axis, and has the capability of swinging 180º from top to bottom. This would improve the versatility of the gripper and improve our overall efficiency of completing missions.

Project Management

In order to achieve our company's goal of producing a quality ROV that can efficiently perform the given tasks, we had to plan and organize the company well. One of the engineering problems that we faced while building the ROV was designing the mission tools. There were numerous factors that we had to keep in mind, which included our limited time frame, budget, and role in the company. The process that our company took to overcome this problem began with a group meeting where everyone could brainstorm and provide ideas. After a design was chosen, the team was split into smaller groups, each of which focused on a specific mission tool component, allowing every team member to remain highly involved in the company. However, before the actual mission tool could be built, a list of materials and estimated costs had to be sent and approved by the Chief Engineer and CFO, in order for the design to pass. This procedure allowed our company to plan ahead and control our limited resources well. A schedule was made to ensure that the whole team was aware of which components would be worked on each day and helped us to effectively manage our time. However, we encountered many problems that we did not anticipate, causing us to occasionally fall behind the initial schedule. In order to get back on schedule, we had to spend many hours of overtime working on the robot. In the beginning, CADs and pencil drawings were used to accurately visualize every aspect of the ROV, because the design constantly changed before finalization. PVC frame prototypes were also constructed before building the final frame out of aluminum, allowing our company to manage our limited resources well and remain cost effective. After each mission tool was prototyped, the finalized components were then constructed and attached to Kaikoa's aluminum frame. Upholding and further improving the company's reputation were the key motivational factors in striving towards executing our company's goal. These methods of organization and planning allowed Kaimana Enterprises to operate as a successful company.

Safety

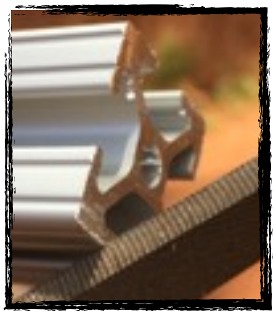


Fig. 19- All edges of the frame's aluminum extrusion were filed down.

Our philosophy at Kaimana Enterprises is that safety is our number one priority. We upheld this philosophy by constantly referring back to the MATE safety specifications while building the ROV and creating a safety checklist (refer to page 18) to maximize safety and efficiency while working on the ROV. This ensured that no injuries or impairment occurred to any company members.

During the construction phases, measures were taken to ensure the well-being of our company members. For example, when working with power tools (sanding, drilling, soldering, etc.) there were specific safety measures, such as wearing safety goggles, designating work areas, and having an advisor present for supervision. When welding, only team members involved with the welding were in the same room, and they had to wear welding helmets to prevent burns or other injuries.

Fig. 20- The Algae Collector's screws were filed to remove any sharp edges.

Kaikoa was constantly checked to ensure that no water could enter the electronics or pneumatics systems, prior to being placed into water. As a visual precaution, all sharp objects on the ROV, like the corners of the aluminum sheet metal, were colored red with electric tape. Yellow tape was used to identify moving parts, such as the motors and grippers.

Many other structural precautions were taken, including the addition of shrouds to protect motors and having all wires, cables, and air tubes secured to Kaikoa's frame. The edges of the aluminum frame were filed down to a curve to remove sharp edges and prevent injuries.

Fig. 21- The 25 amp fuse was protected with a plastic covering.

Multiple safety precautions were also taken for the control boxes. Every connection in the control system was constantly checked to ensure that every plug was secured and attached correctly. After everything was surveyed, the motors and mission tools were tested to confirm excellent connection between Kaikoa and the control system. A 25 amp fuse was installed into the wiring, which would open the circuit in the event that too much current passes through the main power wire.

At the end of every work session, the subject of safety was always included during the evaluation of the day's progress in order to highlight safe practices and cautions.

Appendix A: Safety and Function Checklist

Safety Specifications
☐ There are no exposed motors and all propellers are completely shrouded.
☐ No exposed copper wire/all splices are soldered and sealed.
☐ There are no sharp edges on the ROV that can cause harm.
☐ A 25 amp inline fuse is attached within 30 cm from the power supply attachment point.

Buoyancy System
☐ Ensure that the Nalgene bottles are completely filled.
☐ Ensure that the buoyancy tanks are securely attached to the ROV's frame.

Cameras
Prior to System Plug-in:
☐ Double check the waterproofing.
☐ Ensure camera wires are not punctured or tangled.

After System Plug-in:
☐ Check camera image/angle.
☐ Cameras are securely attached after fixing the image.

After Missions:
☐ Check cameras for damage or flooding.
☐ Spray the cameras with fresh water, to get chlorine water off, which prevents corrosion.
☐ Wipe cameras down to prevent rusting.

Control System/Motors
☐ Ensure that the control box is securely attached to the tether.
☐ Ensure that there are no visible shorts or broken connections in the system.
☐ Ensure that the plugs are inserted correctly and not flipped.
☐ Check that all motors are working and propellers are free of obstruction.
☐ Ensure all components are responding to control system.
☐ Double check the system.

Tether
☐ Ensure that all wires are tucked into the polyethylene tubing.
☐ Make sure all wires in the tether are not kinked.

Laser
☐ Laser shield is on when the ROV is not underwater.
☐ Laser safety glasses are worn when the laser is activated.

Company Members
☐ All members are wearing safety goggles when using power tools.
☐ Long hair is tied up and accessories are removed.
☐ Adult supervision while working with hazardous tools.
☐ No horseplay in the work place or at the pool.

Appendix B: Teamwork/Schedule

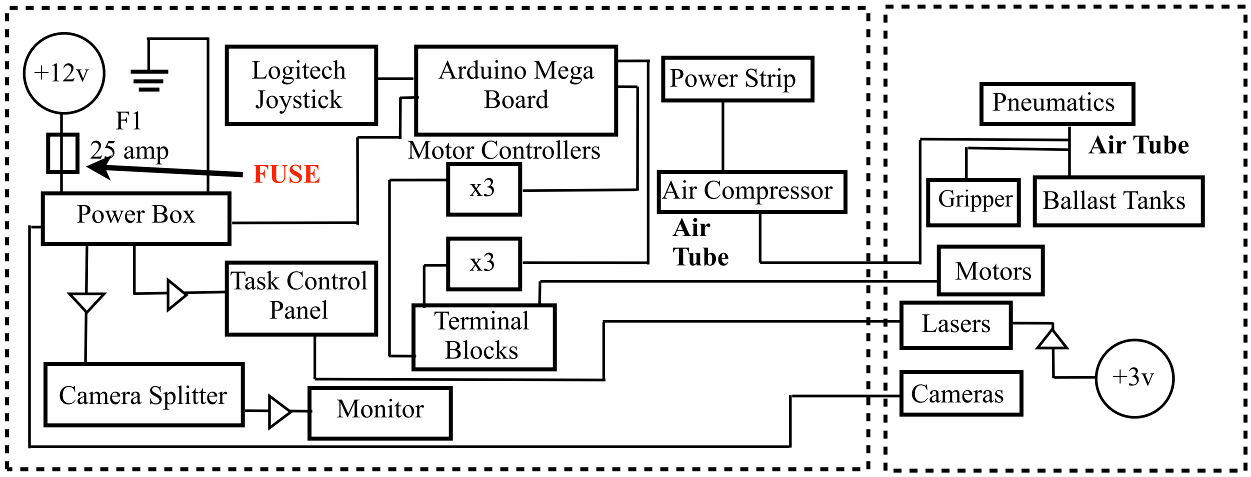
Task	Name	Month	Feb.	March				April				May				June		
		Week	N/A	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3
R & D	Alex, Brandon, Eric, Riley																	
Establishing Roles	Whole Team																	
Plan Frame Design	Alex, Brandon, Eric, Riley																	
Buying Supplies	Whole Team																	
Frame Prototype	Brandon, Eric, Riley, Luke																	
Build Final Frame	Luke, Brandon, Eric																	
Build Props	Whole Team																	
Algae Collector	Alex, Brandon, Eric																	
Valve Rotator	Alex, Brandon, Eric																	
CADD	Shane																	
Tri-Laser	Riley, Luke, Lily, Eric																	
Voltage Tester	Dylan																	
Electronics	Luke, Lily																	
Tether	Riley, Luke, Lily, Eric																	
Programming	Riley																	
Gripper/Lift Line	Andrew, Kody, Everett																	
Buoyancy	Eric																	
Finalize ROV	Whole Team																	
Tech Report	Whole Team																	
Pool Practices	Alex, Lily																	
Marketing Display	Whole Team																	
Sales Presentation	Whole Team																	
Safety Inspection	Whole Team																	

Company Effort:
The diagram above clearly demonstrates that every aspect of the ROV (designing and building vehicle and mission tools), technical report, and marketing display were done solely by the members of Kaimana Enterprises. All non-commercial components of the ROV were designed and constructed solely by members of Kaimana Enterprises. Our mentors and teacher assisted us only by providing power tools and supervision.

Appendix C: Teamwork: Team Assignments

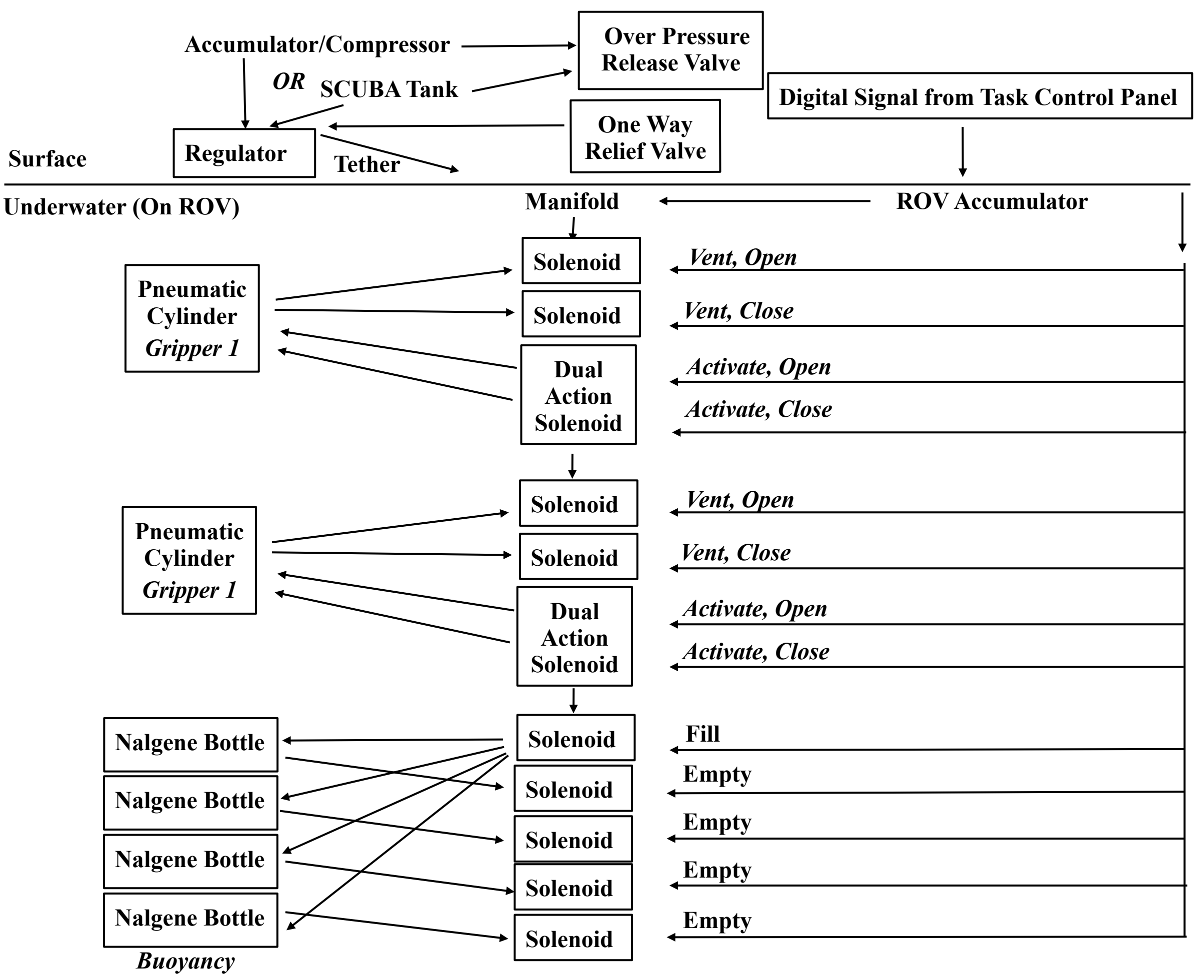
- **CEO** — Alex Yamada
  - **President/Electronics Manager** — Lily Adcock
    - **Chief Engineer** — Eric Schlitzkus
      - **Operations Manager/ Software Engineer** — Riley Sodetani
        - **Chief Designer** — Brandon Lin
          - **Head Researcher** — Luke Uyehara
            - **Mechanical Engineer** — Andrew Hayashi
              - **Construction Manager** — Everett Suzuki
    - **CFO** — Dylan Sodetani
      - **CADD** — Shane Suzuki
        - **Public Relations** — Kody Kawasaki
          - **Quality & Safety Inspector** — Sky Swarup-Barruga

Appendix D: System Integration Diagram (SID)

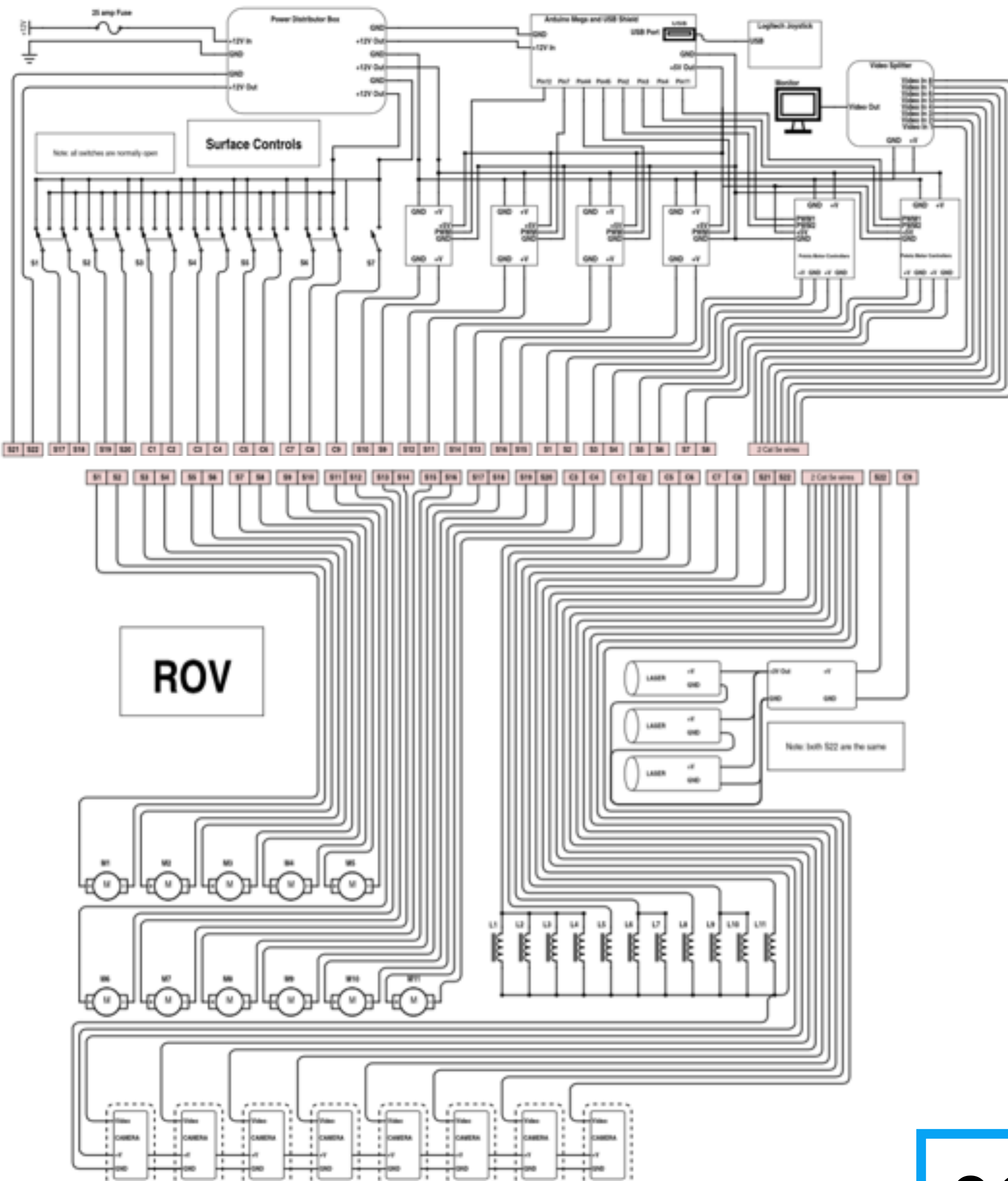


(refer to Appendix E: Pneumatics Diagram for the pneumatics diagram/information)
(refer to Appendix F: Electrical Schematics for the system level/connection diagrams)
(refer to Appendix G: Software Flowchart for the flowchart of the programming software)

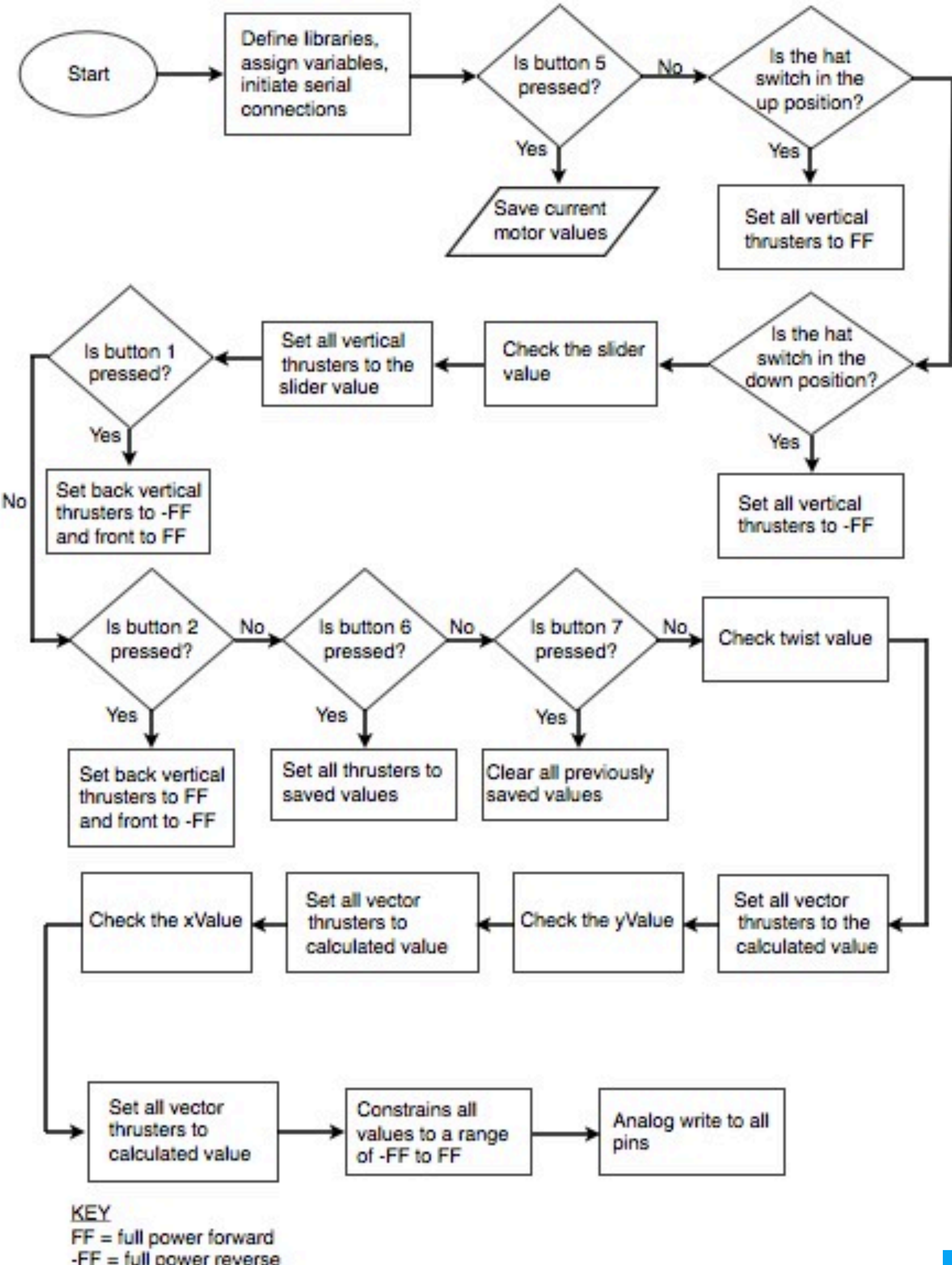
Appendix E: SID- Pneumatics Diagram



Appendix F: SID- Electrical Schematics



Appendix G: Design Rationale- Software Flowchart



Team Reflection

MATE was a demanding experience, due to the astounding number of difficulties that were encountered and had to be overcome. Each of these obstacles allowed us to achieve both personal and professional accomplishments. One of our most important personal accomplishments was improving our communication and teamwork skills. Constant communication between company members through texts, emails, and social media was key to successfully working as a team and improving our teamwork. We worked under a very short time frame this season, and had to work diligently every day, in order to complete our ROV and produce quality mission tools. Whether it was a new team member or an experienced veteran, every member of the team contributed to the production of the ROV and completion of mission tools, which allowed everyone to enhance their engineering skills. Our team also had no prior experience with Arduino programming, but was able to successfully work with Arduino software to program the ROV. This demonstrated the vast amount of professional growth that we have undergone this year. This MATE season was a great learning and growing experience, that allowed each member of Kaimana Enterprises to achieve growth in engineering skills, while learning to collaborate with others to accomplish goals and objectives.

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