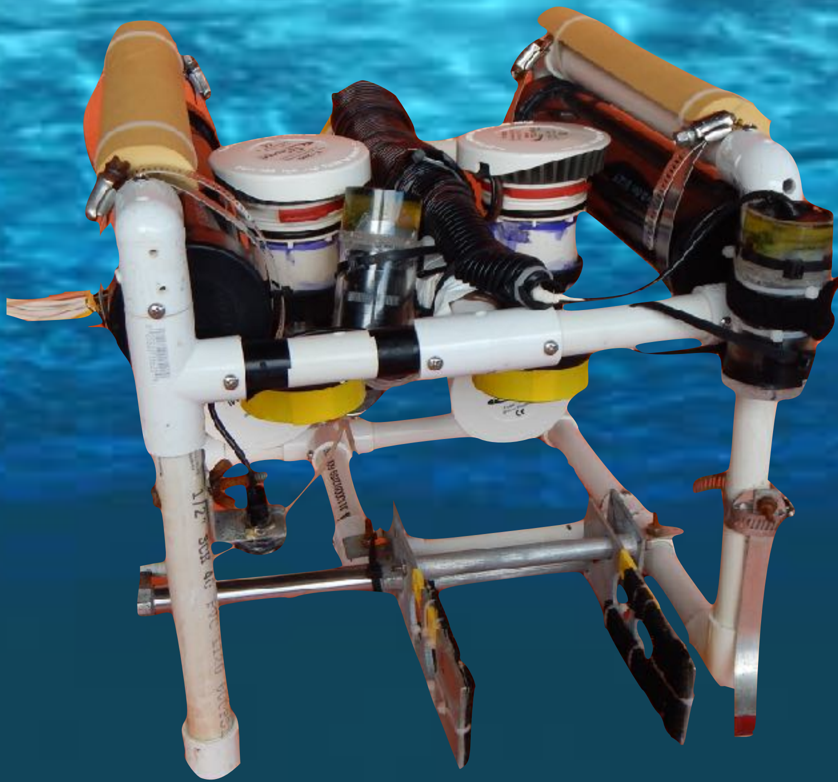
Kaimana Enterprises

Highlands Intermediate School/Pearl City High School
Pearl City, Hawaii, USA



Top Row (left to right):
Eric Schlitzkus - CFO, CADD (Class of 2018)
Kody Kawasaki - Mechanical Engineer (Class of 2019)
Riley Sodetani - Lead Electrical Engineer (Class of 2017)
Second Row (left to right):
Alex Yamada - CEO (Class of 2017)
Lily Adcock - Lead Technical Writer (Class of 2019)
Andrew Hayashi - Lead Mechanical Engineer (Class of 2019)
Third Row (left to right):
*Jacquelyn Reilly - Public Relations Officer (Class of 2022)
*Alyssa Kainuma - Mechanical Engineer (Class of 2022)
*Kana Suzuki - Electrical Engineer (Class of 2022)
Bottom Row (left to right):
Reyan Lee - Electrical Engineer (Class of 2021)
*Janelle Liang - Mechanical Engineer (Class of 2022)
Remy Kubota - Quality & Safety Inspector (Class of 2021)
(New members denoted by *)

Mrs. Kathy Lin - Teacher
Mr. Lance Hayashi - Mentor
Mr. Robin Schlitzkus - Mentor
Mr. Joe Adcock - Mentor

I. Introduction

Abstract

Kaimana Enterprises, determined to produce quality ROV systems capable of efficiently completing arduous tasks, fittingly took up the challenge of constructing a vehicle requested by officials at the Port of Long Beach. Kaimana Enterprises' many years of experience and dedication towards the advancement of ocean exploration has led to the creation of a high performance, yet inexpensive vehicle: Kumu. Kumu is extremely capable of providing every service requested for accomplishing the four tasks required: hyperloop construction, light and water show maintenance, environmental cleanups, and risk mitigation.

Kaimana Enterprises brainstormed, prototyped, and troubleshot to ensure performance and restrictions were satisfied while constructing Kumu at a cost of under $500. The company met frequently exchanging inputs and updates to ensure everyone knew the exact status of each ROV component. Progress and safety were compared every workday against a detailed checklist, created and agreed upon by all company members.

Specialized mission tools, including a pneumatic gripper, aluminum hook, simulated Raman spectrometer, valve spinner, and sediment collector, were specifically designed by Kaimana Enterprises to keep the ROV lightweight and cost effective. PVC was the main building material for Kumu's frame. The company's detailed technical report illustrates the design rationale for each of Kumu's components, and the strict design and selection processes utilized to choose the ideal components while remaining within budget and size/weight restrictions.

Company Mission

Kaimana Enterprises' mission is to develop young engineers focused on producing remotely operated vehicle (ROV) to meet mission requirements as presented by MATE each year. Senior members of the company analyzed this year's tasks and concluded that an economical and efficient ROV could be built to fulfill their mission; as a result, Kumu was born. Kumu -- teacher in Hawaiian -- is an inexpensive, compact and lightweight ROV constructed entirely by Kaimana Enterprises company members. Kumu can complete various tasks such as retrieving positioning beacons, installing a new fountain, collecting sediments, and inserting sensors. Kumu is a simple, yet effective ROV.

Kaimana Enterprises originally formed as a middle school company, but over time, nearly all company members became high school students. Two members graduate this year, including one who has had six years of experience. To continue the mission of Kaimana Enterprises, several middle school students were recruited to join the company. Four seventh graders joined the company this year, and two eighth graders returned for their second year. As a building year, providing opportunities for junior company members to participate in all aspects of building the ROV helped fulfill Kaimana Enterprises' mission to develop young engineers.

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II. Design Rationale

Overall Design

Kumu is designed with the following considerations in mind:

1. Mission requirements: Kaimana's top priority was to build an ROV able to complete the four tasks put forth in the Port of Long Beach's request for proposals in a timely and effective manner. Decisions on how to complete the tasks within the confined space of the busy waterfront were made by the company before the initial design process for Kumu.
2. Simplicity: A priority throughout the season was to find the easiest, smallest, and most cost efficient solution. This allowed the ROV to stay within the budget estimated by the company while still effectively completing each task. When designing the ROV, parts from previous year should be reused if they were not degraded or damaged through long-term use.
3. Size and weight constraints: The company's third priority was to meet the most stringent size (smaller than 48 cm) and weight (less than 11 kg) requirements to increase the likelihood of Kaimana's ROV being selected as the winning design. Weight and size reductions were considered in every design decision and implemented whenever they were possible without sacrificing performance.

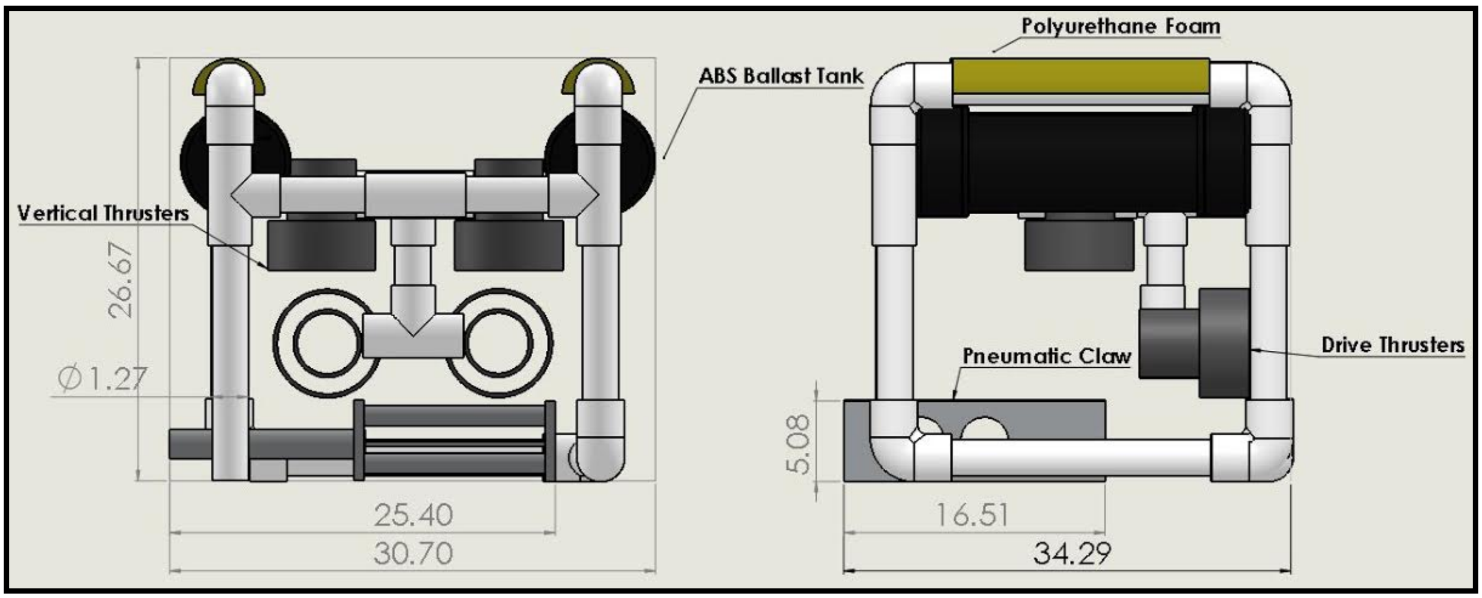


Figure 1: Mechanical Drawing of Kumu with the measurements of the key components of the ROV, all dimensions in centimeters. (Credit: E. Schlitzkus)

Frame

When designing Kumu's frame, various materials were identified and discussed, such as aluminum extrusions and different types of plastic. The company identified that the ROV needed a lightweight frame to satisfy weight constraints for this year's competition. As a result, ½ inch PVC was used to construct the frame to keep costs low. PVC is much cheaper than the initial materials that were considered: aluminum extrusions, high density polyethylene, and carbon fiber, while still remaining lightweight, resistant to rust, and easily modified for design changes. The only drawback of using PVC was the loss of a professional vehicle

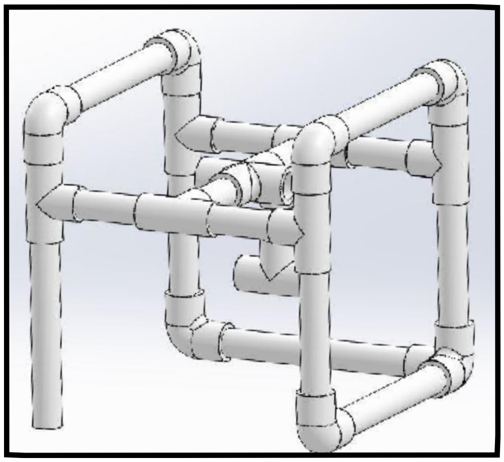


Figure 2: CAD of Kumu's frame using Solidworks. (Credit: E. Schlitzkus)

appearance; however, company members felt that prioritizing funds for other vehicle components was more prudent.

The size of the vehicle was determined by the size and weight requirement bonuses. At the beginning of the season, the company decided to pursue the maximum points from the bonuses, which provided the motivation for the ROV design to remain compact and simple. With the decision to build the frame using PVC, a rectangular prism frame proved to be the best choice because one dimension on the vehicle needed to be larger than the others in order to house the vehicle's components and mission tools safely and securely. Kumu's frame measures 35 cm (L) x 30 cm (W) x 30 cm (H). With these dimensions, all components of the ROV were able to fit within the frame and the ROV also met the size bonus requirement. The horizontal pipes in one corner of the frame were removed to enable the vehicle to activate its Raman Spectrometer and retrieve clams without the frame getting in the way. A small brace was built into the bottom of the frame so the gripper could be attached to Kumu. The frame is as simple as possible, minimizing overall cost and weight.

Buoyancy

Kumu's low center of gravity relative to the center of buoyancy is extremely important and allows for the vehicle to be controlled and driven with precision. In order to achieve near-neutral buoyancy, two 29 cm long Acrylonitrile Butadiene Styrene (ABS) ballast tanks were constructed and attached to the top of Kumu's frame using hose clamps.

The selection of ABS was made based on the light weight and the rigidity of ABS. The ABS tanks will not compress significantly at the depths encountered in the port. Polyurethane foam was chosen to fine-tune the buoyancy as needed. Polyurethane foam is readily available, easy to work with, and not compressible at the needed depths, but is heavier and more expensive than ABS tubes, therefore wasn't used as the primary source of buoyancy. A small quantity of polyurethane foam scrap was available in the shop, which was reused for Kumu.

Figure 3: Washers used to easily adjust buoyancy. (Credit: R. Lee)

The amount of additional buoyancy required was determined by obtaining the wet weight (weight minus displacement) of the ROV by suspending the submerged ROV from a spring scale, then calculating the necessary size of the ballast tanks needed for neutral buoyancy. The 29 cm length of the ballast tanks were determined by the length of the frame. Calculations were made to determine the required diameter and the nearest smaller size of commercial ABS pipe selected. Each tank displaces ~876 cm3 while weighing ~0.3 kg. Thus, the net buoyant force produced by the two ballast tanks was 1.15 kg. Any additional buoyancy required was then provided by polyurethane foam to make the ROV slightly positively buoyant. By performing these calculations instead of estimating through trial and error, the company saved time and money.

To achieve zero list and trim, stainless steel washers are attached to the corners near the bottom of the frame. This helps to improve stability by slightly lowering the ROV's center of gravity. The metal washers also proved to be useful as an easy method to compensate for small weight and moment changes due to modifications during the design process.

Propulsion System

Kumu's four thrusters are T-1200 Tsunami Series bilge pump motors: two drive thrusters and two vertical thrusters. The two drive thrusters are secured towards the back half of Kumu's frame, the location and spacing providing maneuverability and stability. The two vertical thrusters were placed near the top center of the ROV, so that the upward thrust would be as balanced as possible, maintaining the ROV's near zero trim.

Thruster selection was made by evaluating different types of thrusters. Thrusters that were researched during the planning and designing phase were BlueRobotics T200s, SeaBotix BTD150s, and bilge pump motors. The T200 thrusters have ample power and weight, but are cost prohibitive and would have required on-board electronics, significantly raising costs. The BTD150 thrusters have very good power, but are too heavy and too expensive for this project. Therefore, the bilge pump motors were the most cost effective choice. The 1250 gallons per hour (GPH) (4732 L/h) rating was chosen as the minimum that could readily handle the required tasks for the customer.

Figure 4: One of Kumu's four thrusters attached to the frame. (Credit: R. Lee)

Kumu's thrusters use plastic triple-bladed propellers. An experiment was conducted to analyze the amount of thrust generated by easy to procure propellers of various materials, number of blades, and diameters. As shown in Table 1, the propellers selected are able to generate the greatest amount of thrust, producing 0.23 kg more thrust than the second best propeller, which was a plastic two-bladed propeller. Kaimana Enterprises aimed to maximize the amount of thrust that the motors could produce, so Kumu could maneuver and perform missions quickly.

The propeller shrouds were constructed from ABS reducer couplings because even after modification, they remain strong, which was our main goal. The shrouds were used in order to increase safety for our personnel and to prevent wires, cords, and other material that Kumu may encounter from touching the ROV's rotating propeller. The shroud shape focuses and directs the water flow that the motors produce, maximizing thrust.

Table 1: Thrust (kilograms) Produced by Various Propellers

Propeller Type	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average	SD
2-bladed Plastic (6 cm dia)	3.40	3.41	3.37	3.42	3.37	3.39	0.02
3-bladed Plastic (6 cm dia)	3.58	3.63	3.6	3.67	3.62	**3.62**	0.03
2-bladed Copper (7 cm dia)	2.52	2.57	2.56	2.5	2.55	2.54	0.03
3-bladed Copper (7 cm dia)	2.78	2.79	2.77	2.68	2.69	2.74	0.05

Amount of force that each propeller produced at 12 volts when attached to a 1250 GPH (4732 L/h) bilge pump motor.

Tether

Figure 5: Kumu's tether neatly bundled. (Credit: L. Adcock)

Kumu's 20 m tether is comprised of five 14 AWG (2.08 mm2) stranded audio cables, two air tubes, and two CAT-5e cables. The stranded audio cables power the four bilge pump motors. The air tubes transfer air from an on-land air compressor into the pneumatic cylinder to operate the gripper. The CAT-5e cables power the cameras while also sending visual communications to the monitor on-deck. These materials were chosen for the tether because they provided sufficient power to vehicle components, were inexpensive, and compatible with Kumu's mechanical and electrical systems. The large stranded audio cables can carry more power to the four bilge pump motors, while the higher gauge cables, which transmit less power, were chosen to power the three cameras. These lighter wires also reduce the diameter and weight of the tether.

Control System

Control system evaluation considered cost, reliability, and functionality. A software based system is most functional, and analog controls are superior to switches. However, the requirements for this project are easily satisfied with the functionality of a hardwired, switch based system. The hardwired, switch based system is also the lowest cost and most reliable, resulting in its selection for Kumu's control system. This choice results in a thicker, heavier tether, but for the shallower depths involved in this project, this is not a significant restriction.

Kaimana Enterprises uses a control box that has four double throw toggle switches, enabling each thruster to be controlled independently for optimal vertical and rotational movement. These switches are secured to a waterproof, plastic container which houses all of the wiring.

Figure 6: Control box with labels for thrusters and a fuse. (Credit: L. Adcock)

Pneumatic Gripper

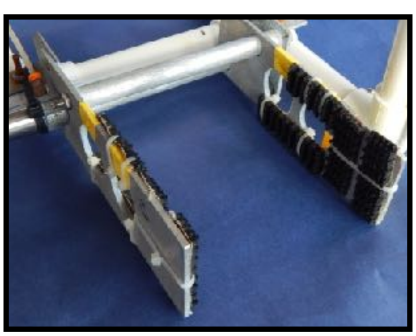


Figure 7: Kumu's main mission tool - the pneumatic gripper. (Credit: L. Adcock)

Kumu's main tool is the pneumatic gripper located at the front of the frame, which was designed specifically to retrieve the simulated clams, rebar pieces, and attach the buoy marker. The shape and size of the gripper were determined by the available space within the vehicle's frame and by the dimensions of the objects that needed to be transported, such as the clams.

Aluminum bar stock was chosen as the material for the gripper because it is lightweight and will not corrode. There are many other materials that have lightweight and non-corrosive qualities, such as polyethylene plastic or stainless steel, but they are either more expensive or difficult to work with. Kaimana Enterprises' initial gripper design utilized a 1250 GPH (4732 L/h) bilge pump motor and lead-screw which opened and closed the gripper like a vice. After constructing the prototype, the design was determined to be effective, but unreliable. Rather than attempt a solution with a new motor, the company decided to replace the motor and lead-screw with a pneumatic cylinder because it was cheaper, lighter, and smaller. A pneumatic cylinder in excellent condition was available from a prior year's ROV and reused for Kumu. Pieces of textured rubber were added to the ends of the gripper to improve its grasp of the various objects.

Hook

Figure 8: Hook attached to Kumu's frame. (Credit: L. Adcock)

Kumu has a hook attached to its frame that assists the pneumatic gripper in picking up and moving objects on the seafloor. This hook was designed to aid the gripper in retrieving clams that are simulated by 1½ in PVC rings. A hook was chosen to be used rather than another gripper because it is inexpensive. Having a hook allows the ROV to pick up multiple objects at once, which reduces the time that the vehicle must take to resurface or go back and forth. This hook is constructed from ½ in (1.27 cm) by ⅛ in (0.32 cm) aluminum bar because this material is lightweight, non-corrosive, and can be easily shaped to securely pick up specific objects. A thin, wide bar was used because it provides a secure grip when picking up objects. The hook is secured at the front of the vehicle, so the tool is visible from multiple camera angles that are positioned at the front of the frame. The angle of the bent hook was optimized during pool practices in order to ensure consistent success. The hook's current design is able to pick up a clam consistently in less than 10 seconds. The hook also serves a backup in the case the gripper fails.

Raman Spectrometer

Kumu has a simulated Raman spectrometer, made from a light emitting diode (LED). The company had numerous designs for this mission tool ranging from a flashlight to an LED strip. The factors that influenced which design was chosen were cost, durability, size, weight, and brightness. The light source also had to be able to be controlled remotely with the on-deck control panel, in addition to being completely waterproof. As a result, the company chose to purchase an inexpensive 12 volt underwater LED boat plug light that is typically used on small marine vessels like speed boats. The LED is made out of brass for corrosion resistance in water and is waterproofed with epoxy to prevent leaks. The Raman spectrometer is secured alongside the sediment collector enabling each sediment location to be tested, and then immediately collected if found to be contaminated.

Figure 9: Kumu's Raman spectrometer (Credit: R. Lee)

Sediment Collector

A sediment collector was designed specifically for collecting sediment, as represented by agar. It is constructed from a PVC pipe, silicone rubber flap, and two metal plates attached to the sides of the PVC pipe. The end of the PVC pipe has been ground to a sharp, jagged edge to more easily penetrate the agar. This tool is held in the claw between the two plates providing a solid grip to minimize unwanted rotation and stopping the tools from slipping up or down within the claw when pushing down into the agar and being pulled back out. A hole in the sheet metal at the top of the sediment collector lets water out when it is being pushed into the agar.

The silicone rubber flap closes over the hole when the sediment collector is being pulled back out, providing suction to prevent the agar from falling out.

Inspiration for this design came from a core sampler that uses a sharpened edge to cut into the surface. The collector was designed to be carried down by Kumu's gripper, rather than permanently attached to the vehicle, in order to allow company personnel to remove the sample while Kumu continues to complete other tasks.

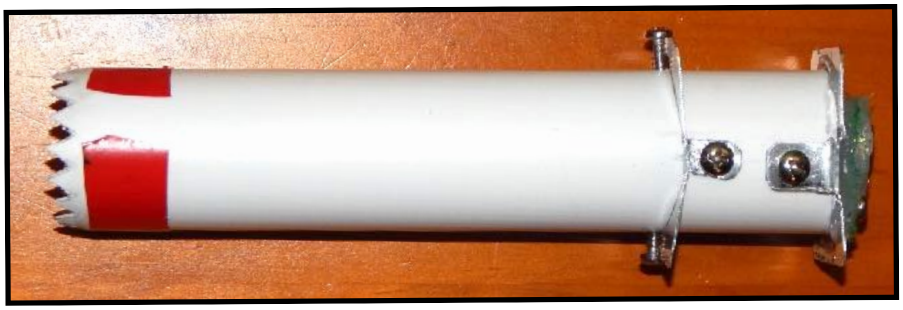


Figure 10: The sediment collector with the metal plates and sharpened and jagged edge. (Credit: L. Adcock)

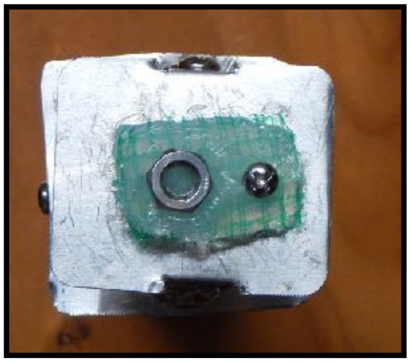


Figure 11: The silicone rubber flap that allows air and water to escape. (Credit: L. Adcock)

Spinner

The valve spinner is constructed out of VEX parts and a reused 500 GPH (1893 L/h) bilge pump motor. VEX parts were chosen because they are compact and can be used to quickly construct mechanisms. The initial design did not work correctly, since the motor did not have enough torque to consistently start the valve turning, and had high RPM without any load which made it difficult to control. This problem was corrected by creating a gearbox with a gear ratio of 1 to 5 which decreased the speed and increased the torque. Two aluminum hexagonal rods are used to turn the valve, a very simple design, which allows the pilot to easily line up the spinner with the valve. The valve spinner was constructed to be held in the gripper, so that space on the frame is not needed to mount it, and it can be removed once the mission task is finished.

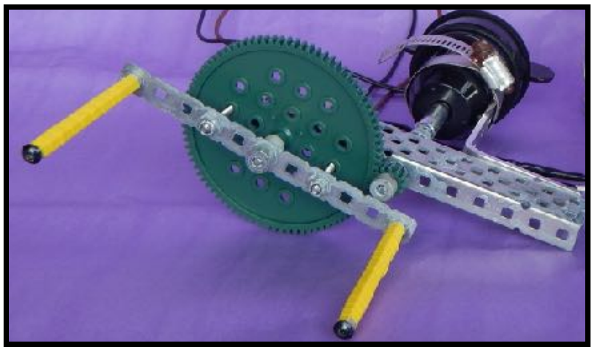


Figure 12: The valve spinner, for opening and closing valves. (Credit: L. Adcock)

Cameras

The imaging system consists of three Pyle Charge Modulation Device (CMD) cameras. These front-rear view car cameras allow Kumu to be effectively piloted, and to complete missions underwater. Two cameras are specifically positioned to monitor the mission tools, which include the gripper, hook, LED, spinner, and sediment collector. This enables the pilot to easily view and use the mission tools, thus enabling missions like retrieving clams and rebars to be quickly completed. One of the cameras is positioned to look not only at the pneumatic gripper, but also directly ahead of the ROV for a constant forward navigational view. Another camera looks down to monitor the Raman spectrometer and also provides a good view below Kumu to aid in locating the destination. The camera outputs are fed into a video switch which has been reused from prior years.

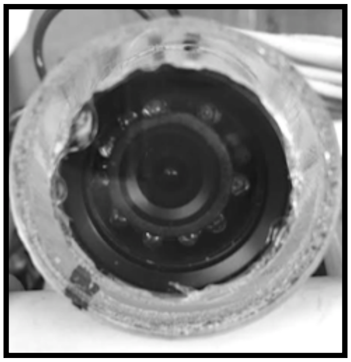


Figure 13: Camera in the waterproof acrylic housing. (Credit: R. Lee)

Commercially available waterproofed cameras were desired, but the cost of these cameras was prohibitive, costing hundreds of dollars. The company members having experience with the car cameras suggested those as alternatives, and the decision was made to purchase the cheaper cameras and modify them for underwater use. Each camera was waterproofed using a combination of five different waterproofing materials: liquid tape, RTV silicone, hot glue, epoxy resin, and marine epoxy. Then, the cameras were sealed in an acrylic housing to further reduce the possibility of water entering the camera. This waterproofing method proved to be effective, enabling the automobile cameras to be used underwater, while retaining their high quality and night vision capability.

Design Decision Analysis

With the exception of the thrusters, simulated Raman spectrometer, and cameras, every component on Kumu was designed and constructed solely by the members of our company. Even then, the thrusters, simulated Raman spectrometer, and cameras were significantly modified by Kaimana Enterprises. The thrusters were supplemented with custom-made ABS shrouds, additional waterproofing, and company tested propellers. The simulated Raman spectrometer was secured to the vehicle with a handmade aluminum mount. The cameras were waterproofed by company members. Months of research were conducted for the generation of Kumu's design and mission tools. For new members, extensive research on basic engineering and fluid mechanic principles, such as active/neutral buoyancy, types of drag, thrust vectors, and water pressure, substantially improved the company's overall knowledge and understanding. The new members were taught to solder, use power tools, and waterproof connections. Professional and competition ROVs were also analyzed by the entire company in order to remain mindful of the wide spectrum of designs and mission tools ROVs can utilize. This invaluable research proved that there are inexpensive high-performance solutions that contributed to the Kumu's final design. In order to optimize the effectiveness and cost-efficiency of Kumu's design, all vehicle and mission tool designs went through a strict selection process before becoming a part of the ROV.

In order to keep costs down, parts that did not degrade were reused such as the video switch box, pneumatic cylinder, and polyurethane foam. By reusing these parts, the company was able to save money.

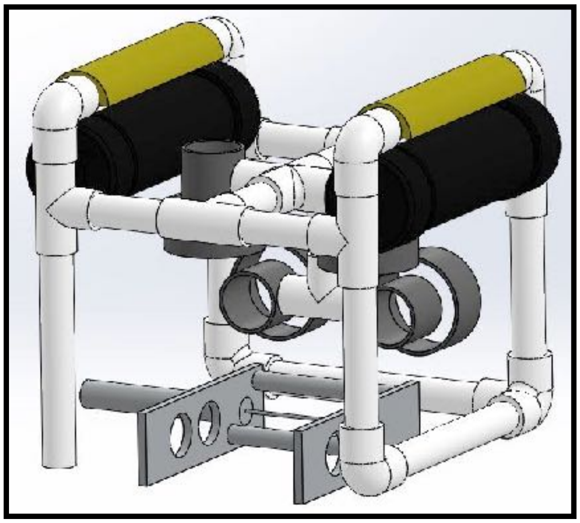


Figure 14: CAD drawing of Kumu using Solidworks' CAD software. (Credit: E. Schlitzkus)

III. Safety

Company Safety Philosophy

Kaimana Enterprises' goals for every member participating in the MATE underwater robotics program is to have an enjoyable learning experience, while ensuring proper safety precautions are always taken. Kaimana Enterprises takes safety very seriously under all circumstances when working. Due to this strict safety philosophy, no accidents occurred during the months our company worked on Kumu. Kaimana Enterprises' "Safety and Function Checklist," located on page 12, was created at the beginning of the season and given to each company member to ensure that everyone followed the correct procedures when working. All company members were taught the necessary safety precautions and had proper training on how to use the machinery safely. To further ensure that no one got injured during building and ROV operation, all company members were supervised by our company's mentors. While using any power tools, an adult was always present, and everyone was required to wear personal protective equipment (PPE), such as eye and ear protection, safety glasses, or face masks when working or observing someone working with power tools. The proper attire while working on Kumu included long pants, covered or close-toed shoes, and tied back long hair. Protective gloves were worn when necessary (such as when sanding) to prevent abrasions, cuts, burns, and other injuries.

Vehicle Safety Features

Kaimana Enterprises' safety philosophy can be seen through the myriad of safety features incorporated into the design of Kumu. For instance, colored electrical tape made sharp edges and moving parts of the ROV highly visible, so anyone handling Kumu would remain safe and aware of any possible hazards. A bright yellow rope was attached and intertwined within the tether to prevent anyone from tripping on the tether in the work area and during water operations. The tether is also neatly wound around a large spool when the vehicle is not in use. Propellor shrouds, manufactured by our company, were placed around each propeller to ensure no one could be injured by the motor's propeller. After attaching the main components of the ROV, the frame was screwed together to ensure that Kumu would not fall apart during transportation or testing. The control system's wiring is sealed in a plastic box to prevent water from getting in and shorting the system as well as preventing electrocutions. The vehicle's electronics system has a 25 amp fuse installed less than 30 cm from the power source attachment, ensuring that the circuit will be broken in the event of excessive current flow, preventing fire or other damage to Kumu's systems. These designs assured both company personnel and Kumu would remain safe at all times.

Figure 15: Red electrical tape on the sediment collector to indicate a sharp edge. (Credit: L. Adcock)

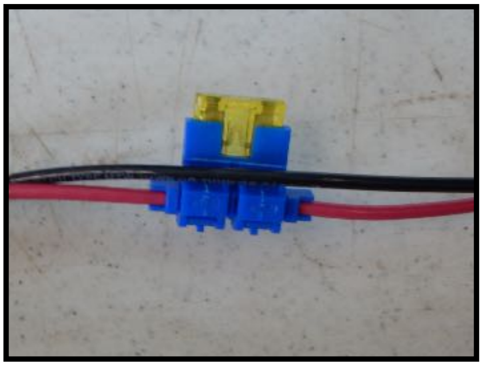


Figure 16: 25 Amp fuse on the main power cable for the ROV. (Credit: L. Adcock)

Safety and Function Checklist

Company

Before Work

- ☐ Tie up long hair
- ☐ Wear appropriate safety apparel: long pants, covered shoes (closed-toed), and safety goggles
- ☐ No loose clothing

During Work

- ☐ If power tools are being used, remember to protect ears and eyes
- ☐ Adult supervision when using potentially dangerous tools/equipment

After Work

- ☐ Clean up work area
- ☐ Put away supplies and tools in an organized fashion

Physical

Before Work

- ☐ ROV has no sharp edges or harmful parts that are exposed
- ☐ All mission tools and components secured tightly (will not fall off)
- ☐ Tether is secured on surface and ROV
- ☐ Strain relief on all connections
- ☐ All potential hazards (motors, hook, etc.) are marked with brightly colored caution tape
- ☐ Each thruster has a shroud to protect anyone and/or anything in the vicinity
- ☐ Buoyancy tanks attached to frame with hose clamps; hose clamps tightened as much as possible

During Work

- ☐ Tether is secured on surface and ROV
- ☐ Strain relief on all connections
- ☐ All potential hazards (motors, hook, etc.) are marked with brightly colored caution tape

After Work

- ☐ ROV carried by two or more people during transportation
- ☐ All potential hazards (motors, hook, etc.) are marked with brightly colored caution tape
- ☐ Each thruster has a shroud to protect anyone and/or anything in the vicinity
- ☐ Wind up tether
- ☐ Clean up any debris

Electrical

Before Work

- ☐ 25 Amp fuse on the positive side of the main power source
- ☐ All wires and electrical parts kept away from water
- ☐ All connections are checked before the power is turned on
- ☐ Wiring and electrical components are all properly sealed and waterproofed
- ☐ Electrical components enclosed in a box at the surface
- ☐ Waterproofing of cameras is checked

During Work

- ☐ All wires and electrical parts kept away from water
- ☐ Electrical components enclosed in a box at the surface
- ☐ Check camera image and angle
- ☐ After checking image and angle, cameras are secure

After Work

- ☐ All wires and electrical parts kept away from water

IV. Logistics

Budget

Through meticulous planning and designing, Kaimana Enterprises ensured that every aspect of Kumu was designed to be effective and cost efficient. The company began brainstorming the overall vehicle design as soon as mission details were released in order to visualize a vehicle capable of accomplishing every mission while meeting all quality and safety standards. Each member individually submitted a potential vehicle design and listed the components necessary to construct it. The entire company met to evaluate each design and identified the strengths and weaknesses of each.

After the overall vehicle design was selected, the company researched possible materials and designs for individual components. For example, each company member spent an entire week researching cost-effective materials that would be optimal for the vehicle's specific mission tools such as the gripper and sediment collector. After the lists of materials and design alternatives were compiled, the company held additional meetings to evaluate the selected materials. This resulted in the "Projected Product Costing Chart" (Appendix A), used to determine if the vehicle would remain under the budget of $500. As shown on the chart, $50 was set aside for design alterations and replacement parts. The company utilized the Projected Product Costing Chart when purchasing all materials. If the actual cost of materials for a component exceeded its expected cost (i.e., the mission tool designs), then a company meeting was organized to discuss whether alternative materials or designs should be investigated.

Schedule

To effectively schedule meetings**,** Kaimana Enterprises implemented two systems: a community weekly schedule and a monthly calendar. All company members keep this schedule updated by inputting their upcoming events. This allows the CEO to avoid conflicts when scheduling mandatory meetings. The schedule also helps to set up a timeline to best keep track of and meet deadlines.

Having updated weekly and monthly calendars assists the company to coordinate with their mentors and teacher. This was especially important because the mentors and teacher are all volunteers that are giving up their free time to come and help the company throughout the season. If company members didn't show up to sessions that the mentors were coming to, this would be extremely disrespectful and a waste of their time. This system proved to be very important to organize all company members and meetings.

Project Management

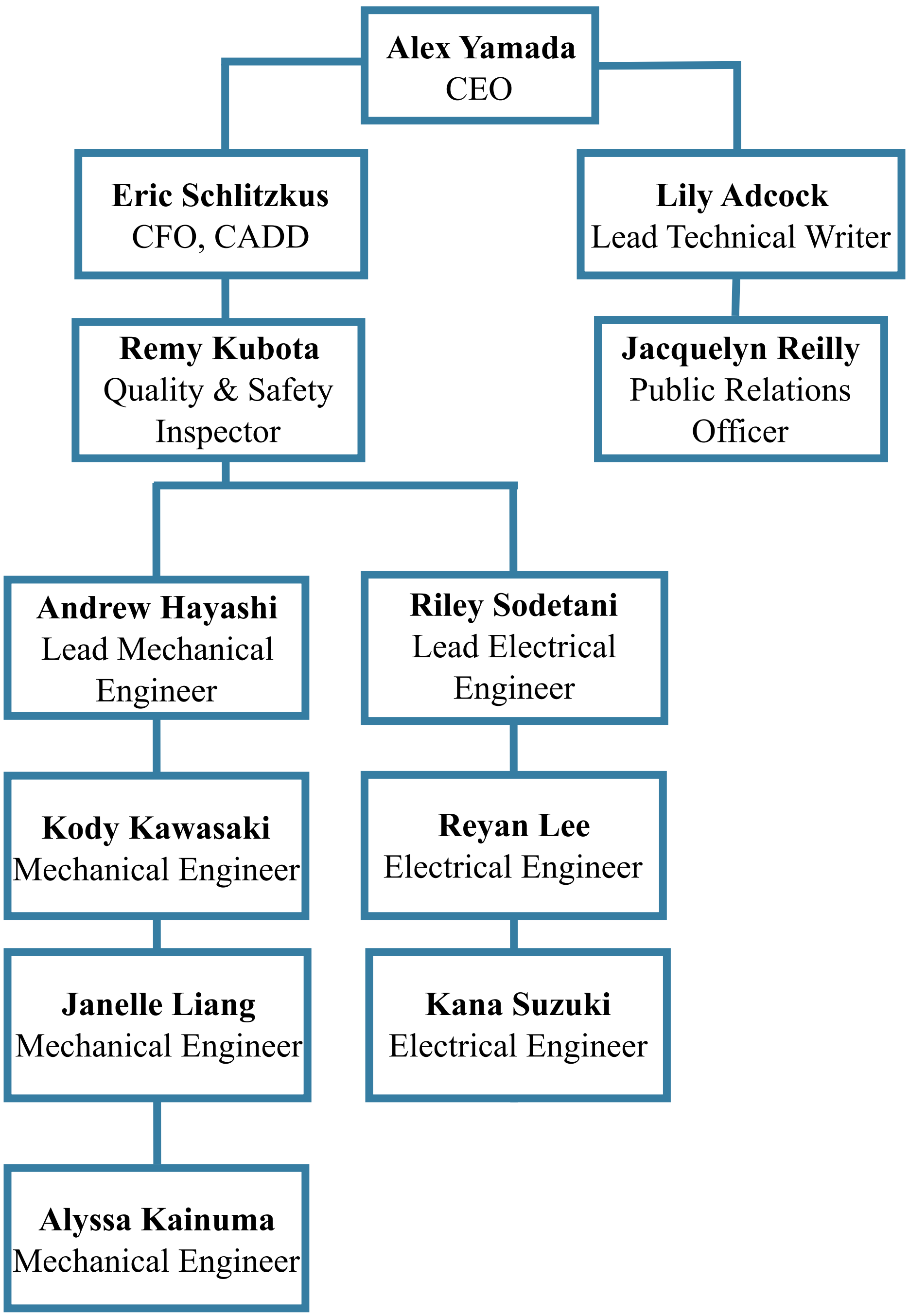
Constant communication was vital to the overall success of the company. In order to maintain constant communication, mandatory meetings were held three times a week where members were able to plan and design each component of Kumu. Each design was evaluated and assessed at meetings to ensure that the company would remain under budget while continuing to meet the target goals. Budget and finances were a major discussion at every meeting as controlling resources was vital for Kaimana Enterprises' success. Company members were assigned roles to work on based on their interests and the parts that needed to be finished. The meetings also kept the company organized and on-task as each member updated everyone about their respective components.

At the beginning of the season, the company created a Gantt chart (shown below), which listed each individual's assignments and was posted at the front of the classroom for all members to track their progress. This protocol of constantly checking the chart ensured that every member was aware of what needed to be done on a daily basis. The use of safety checklists, job safety analyses, and troubleshooting techniques ensured work was effective and safe.

Task	**Company Member(s)**	**March**				**April**				**May**				**June**	
		1	2	3	4	1	2	3	4	1	2	3	4	1	2
R & D	Whole Team														
Establishing Roles	Whole Team														
Planning Frame	Alex, Andrew														
Buying Supplies	Whole Team														
Building Frame	Andrew, Reyan														
Building Props	Whole Team														
Hook	Andrew														
Claw	Eric														
Electronics	Riley, Reyan, Kana, Lily														
Tether	Alyssa, Jacque														
Buoyancy	Lily														
Finalize ROV	Whole Team														
CAD	Eric														
Tech Report	Whole Team														
Pool Practices	Whole Team														
Marketing Display	Whole Team														
Sales Presentation	Whole Team														
Safety Inspection	Whole Team														

Company Assignments

At the beginning of the season, company members individually conducted their own research and design drafts. Then, the entire company held a series of design meetings where everyone selected and contributed to the overall vehicle design. The CEO was in charge of making final decisions and oversaw the construction of Kumu. Alongside the CEO the lead engineers assigned each engineer to the construction of different aspects of the vehicle. The distribution of the vehicle components were as follow: frame, buoyancy, propulsion, visibility, and mission tools. One engineer was assigned the tether and control system. The CEO also delegated an individual to handle the business side of the company including quality and safety and public relations. This individual was more interested in logistics, rather than the manufacturing process. The chart below depicts the company's assignments and order of operations.



V. Conclusion

Testing and Troubleshooting

After construction was completed, a test procedure was developed which was also used after significant changes or repairs. First Kumu's components were tested individually on land, then the entire vehicle was tested in water. The initial test was in the school's aquaponics garden tank. Following this, Kumu was tested in a large swimming pool where the company practiced piloting and completing all of the product demonstration tasks. Whenever problems were encountered during design, construction, or at pool practices, Kaimana Enterprises used the plan-do-check-act (PDCA) method to efficiently find a solution.

Using the PDCA method, the company first planned an approach to identify the problem, took action, checked the results, and finally acted to fix the problem. The PDCA steps are repeated until the problem is corrected. The repair (and the ROV) is then checked using our test procedure. This allows the company to discover what the problem is, create a plan to solve it, and look at the results to ensure that it is a proper solution. Based on whether or not a solution worked, changes were made. This is a simple method of problem solving that allows the company to quickly and effectively address each problem that is faced throughout the season. This method provides the basic structure necessary to solve a wide variety of problem even though they vary in nature.

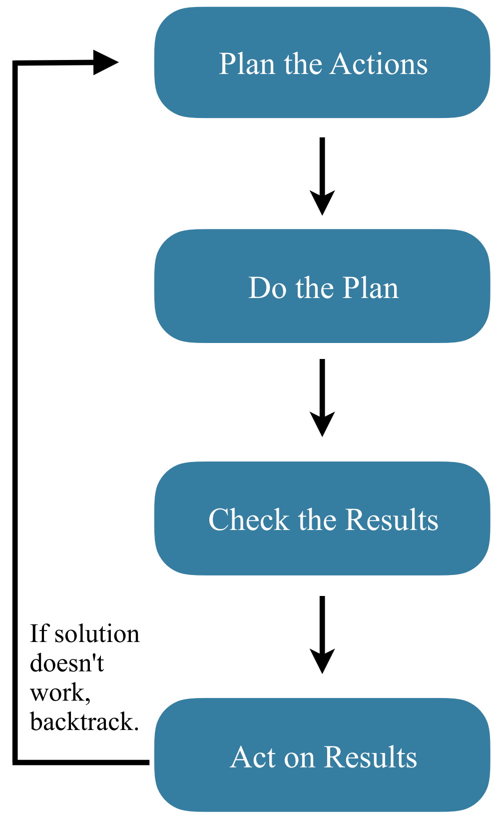


Figure 17: The PDCA chart that shows the flow of Kaimana Enterprises' troubleshooting method. (Credit: L. Adcock)

An example of when the troubleshooting process was implemented was during the construction of the sediment collector. Initially, a system from an earlier company ROV was to be used. This solution was to lift the sediment with an Archimedes' screw. The solution was attempted, but before the tool was complete it was noticed that the additional weight was too great, and a new solution needed to be developed. This led to us going back from the act stage to the planning stage. From here, research was done to look for a new system that was significantly lighter in weight. This research gave us a core sampler that uses a sharpened edge to cut into the surface. This design was chosen because it provided a lightweight and efficient method for removing the sediment sample (agar). The initial version of the tool did not work well, but an additional round of discussion and planning produced a tool which could consistently collect at least 100 mL of sediment.

Challenges Faced: Technical

The company faced numerous challenges while creating the optimal solution for two missions, one of which was retrieving the two clams. The ability to collect two clams at once, rather than one after the other, increased mission efficiency by reducing the number of times Kumu needed to resurface. The company decided to use a hook to complete this mission due to its low construction cost. However, the hook was ineffective during the first few pool practices. Utilizing its troubleshooting procedures, the company initially attributed the ineffectiveness to piloting technique. After additional practices and re-evaluating the results, further troubleshooting pointed to the design of the hook itself. The hook was then redesigned numerous times by modifying the angle of the hook, and the grip materials covering the hook were altered until the mission could be completed efficiently. The other challenge the company faced was collecting the sediment sample, which is described above in the testing and troubleshooting section of this report.

An additional problem faced throughout the season was the design of the gripper. Kumu's pneumatic gripper went through many modifications. When operating the vehicle, the gripper would have a tendency to get jammed, so the gripper would get stuck in either the open or closed position. To fix this problem the company had to fix the rails so that they were perfectly aligned to reduce the amount of friction between the plate and rails. In the gripper's original stages it had no grip on the claw resulting in objects falling out. Through testing different materials for grip, the company ended up using textured rubber that ensured a strong grip when completing different missions.

Challenges Faced: Non-Technical

Being in constant communication with all company members was challenging for Kaimana Enterprises because the members attend two different schools and have completely different schedules, making full attendance at company meetings very difficult. As a result, there were a few miscommunications at the beginning of the season, which included delays on designs and prototypes. An example of this was when one of the engineers began constructing initial parts for a second gripper because he was unaware that Kumu's new design had a hook instead of another gripper. In order to overcome this communication obstacle, the CEO decided to communicate through various media, such as text messages, emails, teachers, and other students. For example, when one of the company's engineers requested an additional 5 cm on the frame to secure the gripper to the frame, the CEO had to contact every other company member to ensure that this adjustment would not interfere with any of the other components on the compact frame. This ensured that everyone was always on the same page and no one was ever unaware of what was going on at a given time. The increased flow of information reduced misunderstanding, duplication of work, and wasting time doing unnecessary work on the ROV.

Lessons Learned

Technical

The foremost technical skill gained by members of the company was waterproofing techniques. Since the junior members entered the season with little to no experience in underwater robotics, the purposes of all the materials and components were taught to them by the senior members. Many waterproofing techniques were taught as the ROV could be rendered useless without that knowledge. This made waterproofing a primary skill to gain. Members learned about waterproofing through research and the teachings of more experienced colleagues. Even the members with prior underwater robotics experience gained new knowledge about this topic, such as new waterproofing materials like crimped wire connectors, sealed acrylic housings, and butyl rubber tape. Other lessons learned by company members include learning where certain materials are applied, like adhesive heat shrink tubing for soldered connections and marine-grade epoxy for large vehicle components.

Interpersonal

In addition to technical knowledge, company members also developed skills in cooperation, determination, and teamwork. Company members were required to learn how to not only communicate to the public through professional engineering presentations and public relation interviews, but also how to communicate clearly and efficiently with other individuals within the company. Every member had to learn how to truly cooperate and work together as a team by embracing the unique perspectives and essential qualities that each member provided. All members demonstrated an incredible amount of dedication, putting in countless hours towards the project despite the many obstacles that occurred.

As a result of these challenges, the members of Kaimana Enterprises learned how to work as a team, with respect and responsibility. Each member learned to be mindful and considerate of others' opinions and responsible for his or her assigned tasks. The goals and standards of the company must be communicated constantly, in order for the individuals to feel and act as part of the company. When everyone knows the plan of action, the entire company moves forward together towards overall success.

Future Improvements

The main improvement that the company would like to have is the incorporation of an on-board electronics system. This system was not implemented this year because it was unnecessary to complete the missions and the components would have caused the vehicle to have a significantly higher cost. Also, a less complex robot provided a better training experience for junior engineers to really learn the basics. Most of the planning and design process this year was spent on mission tool research and prototyping. The company was also able to meet both weight and size requirements with the hardwired system. Starting the MATE season earlier would allow more time and research to be spent on the implementation of an on-board system. This would significantly reduce the size and weight of the tether, and enable the company to gain more technical knowledge regarding programming, waterproofing, and electronics.

Company Reflection

After witnessing the struggle of a complex system in previous years, the senior members made the conscious decision to construct a simplified ROV this year. New company members previously struggled with a more complex ROV. Thus, by opting for a simplified system this season, veteran members were able to teach new company members, and in this process, they learned the importance of patience and mentoring.

This year has been a successful building year for Kaimana Enterprises. After feedback from last season, the senior company members realized that more time had to be spent on teaching basic engineering concepts to new and junior members, not just building skills, or the company would risk losing the knowledge necessary to design and construct successful products. All members were expected to take time to propose designs and research potential materials to use for building. Full company discussions about the pros and cons of designs and materials helped further science and engineering understanding by all members. New and junior members were also given an opportunity to gain experience in all aspects of building such as using power tools, soldering, and waterproofing.

The MATE competition has been a demanding and rewarding experience, due to the difficulties that the company encountered and overcame throughout the season. Obstacles encountered throughout the season allowed company members to achieve personal and professional accomplishments. The most important personal accomplishment was the improvement of leadership and teamwork skills. Due to company members being from both the high and middle schools and all being involved in different extracurricular activities, scheduling was difficult. The company scheduled meetings and arranged deadlines through text and email to allow for constant communication. Due to the goals set by the company at the beginning of the season, all company members were willing to give up their already limited personal time to benefit the company. This MATE season was a great learning experience for each member of Kaimana Enterprises as they learned more about teamwork skills as well as expanded their knowledge about engineering while collaborating to accomplish different goals and objectives. Whether it was a new company member or an experienced veteran, every member of the company contributed to the production of this season's innovative ROV - Kumu.

As mentioned in the Company Mission, our ROV's name, Kumu, means teacher in Hawaiian. Throughout this season, the veteran members have embodied this spirit by teaching the junior members their experience gained over the years and sharing their passion for learning more about this ever expanding field of underwater ROVs. It has been truly been a season of reflection and teaching, of passing on the torch to the next generation of young engineers. It is this hope and dream that drove our desire to built a simple, but effective ROV that served as a teacher, a "Kumu," to those who will continue the legacy of Kaimana Enterprises in the future.

References

Marine Tech. Winter 2016-2017. Accessed Spring 2017. "Ranger Prop Building Instructions & Photos." Marine Tech.December 16, 2016. Accessed January 13, 2017.

Moore, S. Underwater robotics: science, design, and fabrication. Monterey, CA: Marine Advanced Technology Education, 2010

Matt, S. Electricity and basic electronics. South Holland, IL: Goodheart-Wilcox, 1989.

"Plan-Do-Check-Act (PDCA) Cycle." ASQ. Accessed February 10, 2017. asq.org/project-planning-tools/overview/pdca-cycle.html.

Acknowledgements

Individual/Company	Support/Service
MATE Center	Sponsoring the competition every year (Countless hours)
Highlands Intermediate School	Financial Support ($13,000), Workroom (~60 hours)
The Haramura Family	Access to a pool (~90 hours)
Robin’s Painting	Access to a workshop (~20 hours)
Parent Volunteers	Moral and Technical Support (~150 hours)
Solidworks	CAD Software

VI. Appendices

A. Projected Project Costing

Component	Estimated Cost (US Dollars)
Research and Development	50
Frame	25
Buoyancy	25
Propulsion	100
Tether	50
Visibility	50
Electronics	25
Waterproofing	25
Emergency Funds	50
Mission Tools	100
Total	**500**

B. Actual Project Costing

Category	Item	Type	Value $	Cost $
Frame	½” PVC (pipes, connectors, joints)	Purchased	9.13	9.13
	1 ¼” PVC (1.5 m)	Purchased	2.37	2.37
	Stainless steel ½” screws	Purchased	2.54	2.54
	Primer and solvent glue	Purchased	5.52	5.52
	1.27 cm Hose clamps (6)	Reused	9.00	0.00
	Subtotal		28.56	19.56
Buoyancy/Ballast	2” ABS pipe (60 cm)	Purchased	2.31	2.31
	2” x 2” ABS end caps (4)	Purchased	12.80	12.80
	1” Stainless steel washers (12 pack)	Purchased	4.99	4.99
	Polyurethane foam (2.5 cm x 60 cm x 212 cm)	Reused	16.95	0.00
	Subtotal		37.05	20.10

Category	Item	Type	Value $	Cost $
Propulsion	Tsunami Series bilge pump motors 1200 GPH (4)	Purchased	81.16	81.16
	1 ½” x 2” ABS reducer couplings (4)	Purchased	7.92	7.92
	Triple-bladed plastic propellers (3)	Purchased	17.97	17.97
	Subtotal		107.05	107.05
Tether	NYCOIL tubing (20 m)	Purchased	9.72	9.72
	14 AWG Speaker wire (20 m)	Purchased	15.22	15.22
	Cat-5e cable (20 m)	Purchased	9.91	9.91
	Pool noodle (1 m)	Purchased	1.99	1.99
	Split loom tubing	Purchased	2.81	2.81
	Hollow braid polypropylene rope	Purchased	7.99	7.99
	Subtotal		47.64	47.64
Visibility	CMD camera (3)	Purchased	37.96	37.96
	Subtotal		39.96	37.96
Electronics	Toggle switches (4)	Purchased	14.96	14.96
	Plastic electronics box (7.5” x 4.5” x 2.5”)	Purchased	3.72	3.72
	Video switch box	Reused	9.92	0.00
	Subtotal		28.60	18.68
Waterproofing/ Adhesives	Adhesive heat shrink	Purchased	6.99	6.99
	60 mL RTV silicone	Purchased	6.99	6.99
	½” ID x ⅛” wall Plexiglass tube (30 cm)	Purchased	4.43	4.43
	Liquid tape	Purchased	3.99	3.99
	Electrical tape	Purchased	3.99	3.99
	25 mL Marine epoxy (3)	Purchased	9.35	9.35
	Subtotal		35.74	35.74
Mission Tools	2” x ⅛” Aluminum flat bar (60 cm)	Purchased	8.85	8.85
	½” dia Aluminum rod (30 cm)	Purchased	5.56	5.56

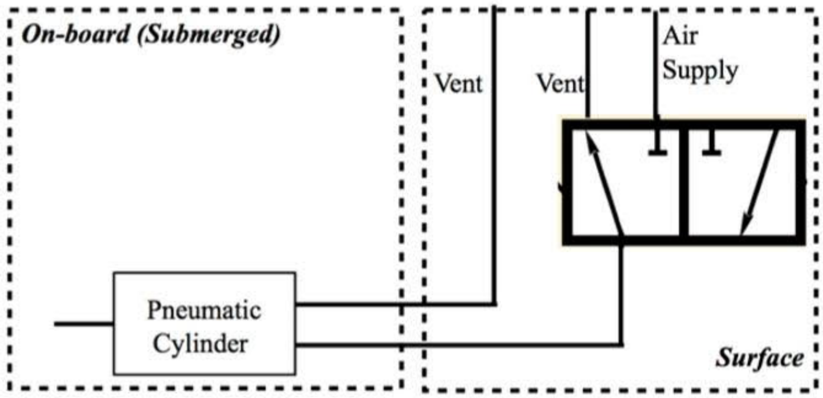
Category	Item	Type	Value $	Cost $
Mission Tools	Blue LED boat light	Purchased	7.99	7.99
	Johnson pump 500 GPH bilge pump 8800 motor	Reused	17.82	0.00
	VEX C-channel 1” x 2” x 1” x 35” (2-pack)	Purchased	8.99	8.99
	VEX gear kit	Purchased	10.99	10.99
	VEX drive shaft 2” & 3” pack	Purchased	5.49	5.49
	VEX bearing flat (10-pack)	Purchased	4.99	4.99
	VEX bearing attachment rivet (50-pack)	Purchased	7.99	7.99
	Industrial textured rubber	Purchased	6.85	6.85
	2 cm bore dia x 10.16 cm stroke pneumatic cylinder	Reused	10.39	0.00
	1” thin wall PVC pipe	Purchased	2.23	2.23
	Aluminum sheet metal	Purchased	7.32	7.32
	Subtotal		105.46	77.25
R&D	Two-blade plastic propeller	Purchased	4.99	4.99
	Two-blade copper propeller	Purchased	6.99	6.99
	Three-blade plastic propeller	Purchased	9.95	9.95
	Subtotal		21.93	21.93
Total for ROV			**451.99**	**385.91**
Props	Mission Props	Purchased	196.45	196.45
	Mission Props	Reused	200.00	200.00
Total for Props			**396.45**	**396.45**
Travel	Airfare: Honolulu to Long Beach (12 students)	Purchased	9,600	9,600
	Ground Transportation	Purchased	3,000	3,000
	Lodging	Purchased	2,500	2,500
Total for Travel			**15,100**	**15,100**

C. System Integrated Design (SID)

Fuse Calculations

Tsunami T1200 Bilge Pump Motors: 3.5 amps*5 = 14 amps
Universal through Hole Rear View Camera: 0.25 amps*3 = 0.75 amps
LED: 0.002 amps*1 = 0.002 amps
Total current draw = 14.752 amps
Safety Factor (SF): 1.5 (150%)
Fuse: 14.752 amps * 150% = 22.128 amps
25A blade fuse

Pneumatic System SID



Electrical SID