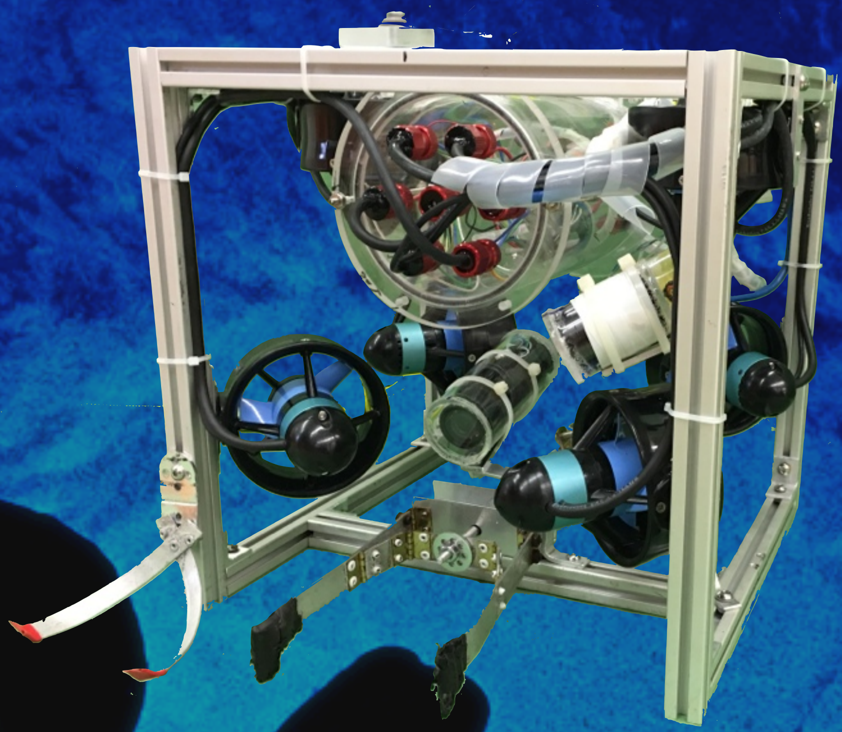
Kaimana Enterprises

Highlands Intermediate School/Pearl City High School
MATE Underwater Robotics Club
Pearl City, Hawaii 96782

Kaimana Enterprises' Staff



Honu- ROV

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I. Introduction

Abstract

The National Aeronautics and Space Administration (NASA) and Oceaneering Space Systems (OSS) have requested a dual-purpose remotely operated vehicle (ROV) that can operate in the harsh environments of both the deep ocean and outer space. Kaimana Enterprises' latest vehicle, Honu, has the ability to complete the specified tasks in both of these harsh environments. *Honu*, Hawaiian for *Turtle*, represents months of planning, designing, manufacturing, and successful testing under rigorous safety protocols.

Throughout this journey, many obstacles were overcome, including vehicle size and weight restrictions, new technology (on-board electronics), cost effectiveness, and communication (problem solving, teamwork, and commitment).

The size and weight constraints influenced every decision about Honu. The design of the frame, the components (including mission tools), and their effectiveness to complete missions, were brainstormed and discussed during the countless meetings held throughout this year. For example, a V-shaped hook replaced a planned second gripper due to its cost effectiveness and decreased weight. An on-board electronics system was introduced and implemented in response to the downsizing, and resulted in a significantly thinner and lighter tether. Honu's cost effectiveness is evident through the modification and waterproofing of the automobile cameras, depth sensor, and temperature sensor.

Dealing with all of these technical issues required numerous company meetings to maintain the coordination and communication necessary to efficiently identify and troubleshoot problems.

This technical report documents Kaimana Enterprises' process of designing, manufacturing, and testing Honu, along with a detailed design rationale of the vehicle and its specialized mission tools.

Company Mission

Kaimana Enterprises, a company determined to produce quality ROV systems capable of efficiently completing arduous tasks, fittingly took up the challenge proposed by NASA and OSS to create the dual-purpose vehicle. The company's hard work and dedication towards the advancement of ocean exploration, has led to the creation of its latest vehicle, Honu. Each year that Kaimana Enterprises participates in the MATE program, a myriad of valuable knowledge is gained, allowing its vehicles and mission tools to improve significantly. The wealth of experience and knowledge that the company has gained over the past seven years of involvement in the ROV industry, can be clearly seen in Honu. As a result, the company believes that Honu is extremely capable of accomplishing every task in both harsh environments.

II. Design Rationale

Frame

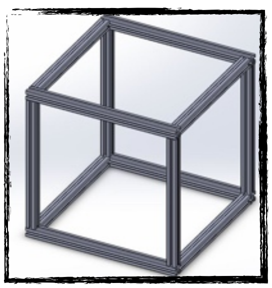


Figure 1: CAD of Honu's frame.

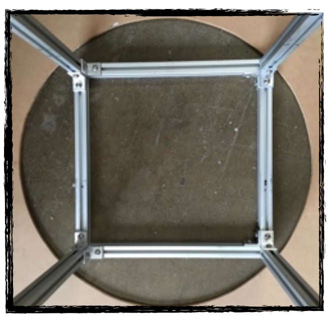


Figure 2: Frame is under 48cm size restriction.

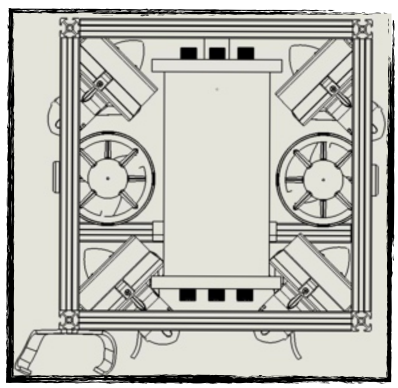


Figure 3: CAD mechanical drawing of Honu's top view.

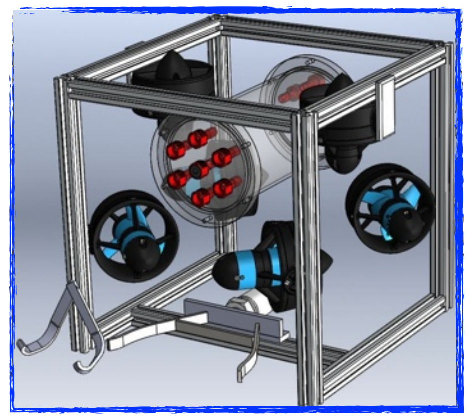


Figure 4: CAD mechanical drawing of Honu.

Honu's frame is a rectangular prism measuring 30cm (L) x 30cm (W) x 24cm (H). It is constructed out of 20mm sqaure aluminum extrusion bars, which are fastened together with corner brackets. The frame houses all of Honu's components safely and securely, while meeting the 48cm NASA and OSS specified optimal size.

When the vehicle request was released, the members of Kaimana Enterprises evaluated various materials ranging from inexpensive polyvinyl chloride (PVC) to high density polyethylene (HDPE). After careful analysis, aluminum extrusions, similar to those used on last year's vehicle, were chosen due to its lightweight, rust-proof, and inexpensive qualities, as well as its groove tracks, which allow components to be easily attached and repositioned. The company decided to use narrower extrusions than those used last year, making it easier to keep the total vehicle under the specified 12kg weight set by NASA and OSS.

Solidworks, a 3D CAD software program, was one of the tools used to brainstorm the initial frame design because it allowed the company to accurately view and evaluate designs. The company concluded that a frame with many corners (i.e. hexagonal) would add additional weight and unnecessary complexity. As a result, a cubic frame was initially chosen because it is simple, lightweight, compact, and would be able to house all components. During the design process, the company encountered the challenge of planning a way to meet or exceed the given size and weight restrictions. Numerous hand-drawings and CADs were created, which included all brainstormed components, to evaluate the efficiency of each design.

An inexpensive prototype frame was then constructed using PVC to check spacings and practice securing components together before constructing the final aluminum frame. This allowed the company to analyze and conclude that there was excess space at the bottom of the frame; therefore, the height was reduced by 6cm, resulting in a highly compact rectangular prism frame. The entire frame was designed and manufactured entirely in-house by the members of Kaimana Enterprises.

Buoyancy/Ballast

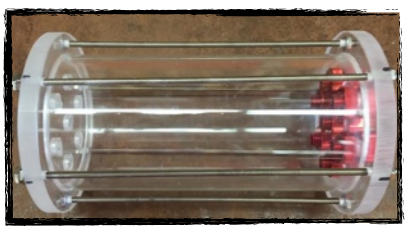


Figure 5: Honu's on-board electronics housing.

The main sources of buoyancy on Honu are polyurethane foam and an on-board electronics housing. Initially, the company incorporated an active ballast system comprised of 1L Nalgene bottles connected to solenoids and air tubes, which allowed Honu to ascend and descend rapidly. However, after testing, it was found that the use of an active ballast system was unnecessary because the vertical thrusters provided a sufficient amount of power to quickly surface the vehicle. An active system requires numerous components, such as solenoids and air tubes, that significantly increase the weight of the vehicle. It was also unnecessary for the vehicle to transport or retrieve heavy objects. As a result, the company determined to remove the active system and implement a passive buoyancy system.

The electronics housing was secured above the central axis at the center of the frame in order to keep the vehicle close to an even trim and list while also increasing stability by raising the vehicle's center of buoyancy. Polyurethane foam was chosen over other materials, such as ballast tanks and other foams, in order to supply the remaining amount of buoyancy because it can be easily manipulated into any shape, has a high buoyancy to weight ratio, and does not compress at the specified maximum depth of 4.8m. The foam barely extends above the frame, remaining under the size constraint, and prevents Honu from getting stuck on objects while completing missions.

The company deliberately calculated the foam to make Honu positively buoyant to allow for modifications to the vehicle and water densities. Bolts and wing nuts are secured to the four bottom corners of the vehicle, allowing metal washers to be added onto the frame. This provides an effective and simple way to quickly adjust Honu's weight in small increments, allowing the operator to easily adjust trim and list and achieve near neutral buoyancy. The washers also keep Honu's center of gravity low, thus improving the overall stability.

Propulsion System

Figure 6: T200 thrusters secured to the frame.

Honu's propulsion system consists of six Blue Robotics T200 thrusters: four supply vectored thrust (at 45º angles) and two enable vertical movement. The four drive thrusters are located at the four corners of the frame. The two vertical thrusters are secured to aluminum bars at the top of the frame.

The T200 thrusters were chosen because they are compact, lightweight, inexpensive, and waterproof. In order to conserve money, the company initially planned to reuse the Seabotix BTD150 thrusters from last year's ROV, but they were too bulky and heavy for this year's vehicle at almost double the length and weight of the T200. In addition, at 12V, a BTD150 produces 23.1N (2.4kg) of force, while a T200 produces 34.7N (3.5kg). In other words, even though the T200 thrusters are almost half the weight and size of the BTD150, they are significantly more powerful. The vectored thrust design enables Honu to move more quickly and precisely in all directions compared to direct drive.

Control System

Figure 7: Wooden draft of housing cover (left). Final acrylic cover (right). Waterproofed connectors attached to the cover (bottom).

Honu's control system consists of two components: a Logitech 3D Pro joystick and the custom built Task Control Hub. The Logitech joystick is read through an Arduino Mega 2560 that allows the pilot to indicate the direction and speed of the ROV. The Arduino then calculates each thrusters' rotation. This method of control was chosen over other joysticks or hardwired switches because it allows far greater control of the ROV. The Logitech joystick is also one of the few models that allows for a twist function, making it popular among ROV teams and drone pilots. The programmable Arduino allowed us to add speed control, which allows the pilot to alter Honu's speed with the joystick's position, to match the ideal speed and power required for certain tasks. Besides lateral and vertical movement, the joystick is also used to engage the autopilot and hover mode. These features use an accelerometer and depth sensor to keep Honu suspended in one location without pilot interference. This hovering ability improves Honu's overall efficiency while taking measurements and retrieving stationary objects.

The Task Control Hub was constructed within a 1460 Pelican protector case to house two toggle switches and two LCD displays. It also serves as a power distribution box, a case for the joystick, and the single connection point to the tether. This allows the on-deck controls to remain compact and simple to set up. The Pelican case ensures that all internal components are protected from inadvertent exposure to water.

During previous years, Kaimana Enterprises attempted to move a portion of the electronic control system onto the ROV, but time constraints and waterproofing issues prevented its completion. This year, the company invested additional time and resources into finally integrating an on-board control system due to the new size and weight constraints. In order to do this successfully, a compact, watertight housing needed to be constructed that could withstand water pressure at a 4.8m depth. Previous failures with rectangular-prism shaped housings and ineffective waterproofed connectors led to the construction of an effective cylindrical, acrylic housing fitted with Blue Robotics' waterproofed connectors. After successfully testing the housing several times at a local swimming pool, the company deemed it safe and ready to implement. With the addition of an on-board electronics system comprised of an Arduino Mega 2560 and an Arduino Micro, the size and weight of the tether and on-deck system were substantially reduced. The reduction in weight of the tether was significantly greater than the amount of weight added from the housing itself.

Software

Figure 8: Logitech 3D-Pro joystick used to pilot Honu.

Honu's control system implements an application programed in C language through the Arduino compiler. This code allows responsive and fluid control of the ROV by the pilot. The joystick sets values for the motors based on the shaft's position on the x-axis and y-axis along with its rotation. An algorithm within the program allows these values to be scaled up, resulting in very precise movements. Similar functions also enable the use of the mission tools and the transmission of subsea sensor data. All of these elements are stored within the application's serial buffer and are processed at a controlled rate over the serial communication lines.

All software components are programmed using the compiler provided by Arduino. The company selected this specific program because of the implementation of Arduino computer boards in the control system. These microcontrollers provide the pilot with the ability to control the speed of each thruster, enabling increased maneuverability during tasks that require precise movements or hovering in place. The on-deck crew is able to communicate with Honu through a form of data transmission known as full-duplex serial communication. This allows sensor data to be sent to the surface over one twisted pair and motor values to be sent to the ROV over another twisted pair. As a result, Honu, with an even thinner tether, is able to tackle challenges such as measuring the temperature of the venting fluid and calculating the depth of the ocean. Serial communication proved to be a great advantage when designing the ROV to meet the size and weight constraints.

Visibility

Figure 9: Camera housed in waterproofed acrylic tube.

Honu has three rear-view car cameras that allow the pilot to effectively complete missions. Each camera views a mission tool (gripper, hook, or temperature sensor) that is used to retrieve various objects from the seafloor or take measurements. One of the cameras is also positioned to look directly below the vehicle, allowing the entire seafloor to be visible and mapped out, while a second provides a forward drive view. The optimal position for each camera was determined during pool practices. Underwater cameras were the company's first choice, but the cost of commercial underwater cameras was prohibitive. Alternatives were researched and discussed at company meetings, and the decision was made to purchase cheaper cameras that are only water resistant. Automobile rear-view cameras were selected because they can be waterproofed, wired easily, and are inexpensive. This type of camera was used in previous years' vehicles, but the previous method of waterproofing occasionally failed. As a result, a new method was implemented this year, which was a combination of three different materials: hot glue, epoxy resin, and marine epoxy. Each adhesive material was used to seal different parts of the camera. For example, the epoxy resin and hot glue were used to seal the camera into the acrylic housing, while the marine epoxy was used to prevent water from entering the housing through the video cables. The tether contains one twisted pair for video, so the outputs of the three cameras are sent to a video multiplexer (MUX) controlled by the Arduino Mega, allowing the pilot to select which camera signal is sent up the tether.

Tether

Figure 10: Honu's tether is safely bundled when not in use.

The 20m tether consists of a pre-made VideoRay tether, along with two air tubes, held within an expandable polyethylene terephthalate (PET) monofilament tube. Using a pre-made tether saved time and provided a compact tether with enough twisted pairs needed for all control features.

This year, the team focused on reducing the diameter of the tether in order to meet the size and weight restrictions. In order to achieve this, serial communication is used to transmit all data. The three twisted pairs within the VideoRay tether are sufficient to send and receive all control and camera signals. The two air tubes carry pressurized air from the on-land compressor and vents any water that could compromise the system. The air tubes and wires are secured within a yellow sleeving because it is sturdy and highly visible underwater. In previous years, wooden buoys were used to help the tether achieve neutral buoyancy. However, this component was eliminated due to the fact that the new tether is neutrally buoyant and the wooden buoys could get snagged on mission props.

Pneumatic Gripper

Figure 11: Honu's completed gripper.

The gripper was designed specifically to retrieve an ESP cable connector and use a bolt to secure a flange to a wellhead. This gripper opens horizontally to grab the hook on the ESP cable connector and to pick up the bolt that secures the flange to the wellhead. The shape and size of the claw 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 flange.

Aluminum sheet metal was chosen 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 more expensive or difficult to work with. Kaimana Enterprises' initial gripper design utilized a pneumatic arm that allowed Honu to pick up objects in front and below the frame. However, a smaller, lighter gripper design was tested and performed the missions just as efficiently. The design of the smaller, lighter gripper was powered by a 4732lph (1250gph) bilge pump motor and opened and closed like a vice. After constructing the prototype, the design was determined to be effective, but unreliable as the gripper would occasionally get stuck in the closed position. This problem was caused by an insufficient amount of torque from the motor. Rather than purchasing a brand new motor, the company decided to use a pneumatic piston because it was cheaper, lighter, and smaller. The gripper itself was able to successfully complete its designated missions, so only the motor had to be replaced for a pneumatic piston. Rubber tape was added to the ends of the gripper to enhance its grasp of the various objects.

PVC Hook

Figure 12: The hook's tips are red for visibility and safety.

Honu has a V-shaped hook secured to its frame, which is used to supplement the main gripper in retrieving and moving objects on the seafloor. A hook was selected instead of adding another gripper because it is efficient, inexpensive, and lightweight. This mission tool allows Honu to pick up multiple objects at once, which reduces the number of times that the vehicle has to resurface to bring them back. The hook is made out of 1.27cm by 0.16cm, and 2.54cm by 0.16cm aluminum sheet metal because it will not corrode and can be easily shaped to securely pick up specific objects. Aluminum sheet metal was selected instead of an aluminum rod because it is easier to see underwater on camera and has more surface area, thus providing more stability for picking up objects.

The hook is designed to be easily attached and detached to avoid a potential safety hazard while out of the water. It is secured at the front of the frame next to the gripper and temperature sensor. Therefore, an additional camera is not necessary to view the hook. The angle of the hook was constantly altered at pool practices. If the pilot was not able to retrieve an object, such as the PVC oil sample, quickly and easily, then the hook was bent slightly in order to make it more effective.

Temperature Sensor

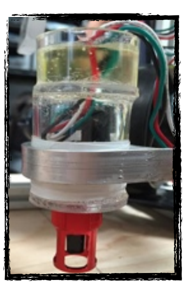


Figure 13: Temp. sensor secured to the frame.

Honu utilizes a Blue Robotics' temperature sensor in order to measure the temperature from a simulated hydrothermal vent. This specific sensor was chosen because it is built to function in marine environments and is compatible with the Arduino I2C bus that Honu utilizes. The sensor is also very compact and lightweight. Kaimana Enterprises encased it in a small acrylic housing in order to prevent water from entering the wiring and damaging the sensor. It is positioned near the middle bottom of the vehicle and makes use of the downward facing camera. As a result, an additional camera is not needed to monitor the sensor. This position also allows the sensor to be piloted directly over the venting fluid.

Depth Sensor

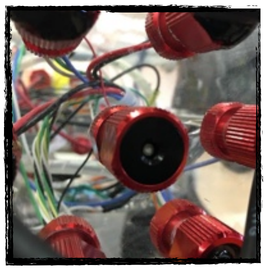


Figure 14: Depth sensor secured to the acrylic on-board housing.

A 30bar Blue Robotics' pressure sensor is used to measure the the depth of the ocean and the thickness of the ice sheet. The measurements from the sensor are sent through the on-board electronics system to the on-land system's LCD screens, which can be quickly read by company personnel. Originally, the company planned to use 100psi automotive pressure transmitters, but these were too large and lacked good documentation. The Blue Robotics' sensor was chosen because it is highly compatible with Honu's electronics, and since it also uses the I2C bus, it is easy to program, as the company has experience programming other Blue Robotics' components. The sensor is secured onto one of the two covers of the on-board electronics system. The pilot lines up the forward looking camera with the bottom of the ice sheet and with the simulated ocean floor to generate precise measurements, adding the distance from the pressure sensor to the camera.

Vehicle Systems

Honu and its specialized mission tools were designed, manufactured, and tested by the members of Kaimana Enterprises. The vehicle utilizes commercial electronic components, such as cameras, thrusters, and sensors, but most of the commercial components were modified by the company in order to efficiently perform the required missions. The decision-making process to either construct or purchase a component began with a company meeting to discuss five main factors: efficiency, quality, safety, cost, and time. For example, after learning that the missions required depth and temperature measurements, a meeting was held to discuss possible solutions using either original or commercial products. Commercial sensors were chosen over self-constructed sensors because they are more accurate, reliable, and less time-consuming. The sensors were then waterproofed and programmed by company members. Another example of a product that was purchased, but significantly altered, are the cameras. Although high-quality cameras are vital to piloting and completing missions, they can cost upwards of hundreds of dollars. A more cost-effective option was brainstormed, and the innovative solution to this required an inexpensive camera that could be easily altered. The rear-view cameras used in cars were ideal due to their low cost and wide angle lens. Kaimana has used this type of camera in the past, but the waterproofing was inadequate. A brainstorming session during a company meeting resulted in an acrylic housing design that is able to withstand the pressure at 4.8m. Every component on Honu, excluding the electronic components (thrusters, cameras, and sensors), is not only designed, but also constructed by company members.

The only reused components on the ROV are the Arduino boards and Logitech joystick. The process to determine which components would be reused began with thoroughly analyzing the missions. After the general design of Honu and its mission tools was finalized, the company looked towards components from last year that would be needed for this year's vehicle. At a company meeting, the decision was made to reuse these two components because they were still in perfect condition, were necessary for the vehicle's control and electrical systems, and would have been purchased anyway.

Construction of the vehicle began after analyzing the missions thoroughly and brainstorming multiple designs. Drafts created by individual members were presented and discussed with the entire team. Every member evaluated each design and shared their own insight on whether a better solution could be manufactured at a lower cost with at least the same level of performance. For example, aluminum flat bars were chosen to construct the gripper due to their lightweight and inexpensive qualities, maintaining the ROV weight restriction, and are easily bent according to its specific design to enhance the collection of coral and oil samples.

Kaimana Enterprises strives to improve itself and its ROV each year in accordance with the various new tasks and requirements dictated by the MATE program. This year, due to the weight and size restriction bonuses, the company implemented an on-board electronics system, which significantly reduced the size and weight of the tether. Implementing this new technology was extremely time-consuming because the team members have never constructed large acrylic pressure housings or used serial communication programming in the past. The new missions also resulted in the change of Honu's ballast system. Honu initially had an active ballast system, but the company decided to remove it because of the new weight restrictions and lack of missions requiring heavy lifting. The new restrictions also required every team member to conduct specific research in order to keep the ROV compact and efficient. Each team member was assigned a vehicle component, such as frame or buoyancy, to find the optimal methods and materials that the company would use to manufacture the vehicle.

III. Safety

Company Safety Philosophy

Figure 15: Power tool safety guide read by all company members.

At Kaimana Enterprises, safety is the number one priority. The company upheld this philosophy by constantly referring back to the MATE safety specifications while building the ROV and utilizing the safety checklist before, during, and after working on the ROV to maximize safety and efficiency. This ensured that no injuries or impairment occurred to any company members.

All products were designed to be safe to manufacture and use. A myriad of safety precautions and safety protocols were implemented every day in order to prevent accidents. When a company member got a minor cut from a sharp edge on Honu's frame, every sharp edge on Honu was filed down to prevent another injury from occurring. Each company member was trained and certified to use power tools and pneumatics before allowed to operate machinery, and an adult or mentor was always present. Company members were required to wear personal protective equipment (PPE), such as eye and ear protection, dusk masks, or safety glasses, for protection when working with power tools. Protective gloves had to be worn when sanding to prevent burns and injuries. Face masks were worn when welding.

Vehicle Safety Features

Figure 16: 25A fuse in the control system wiring.

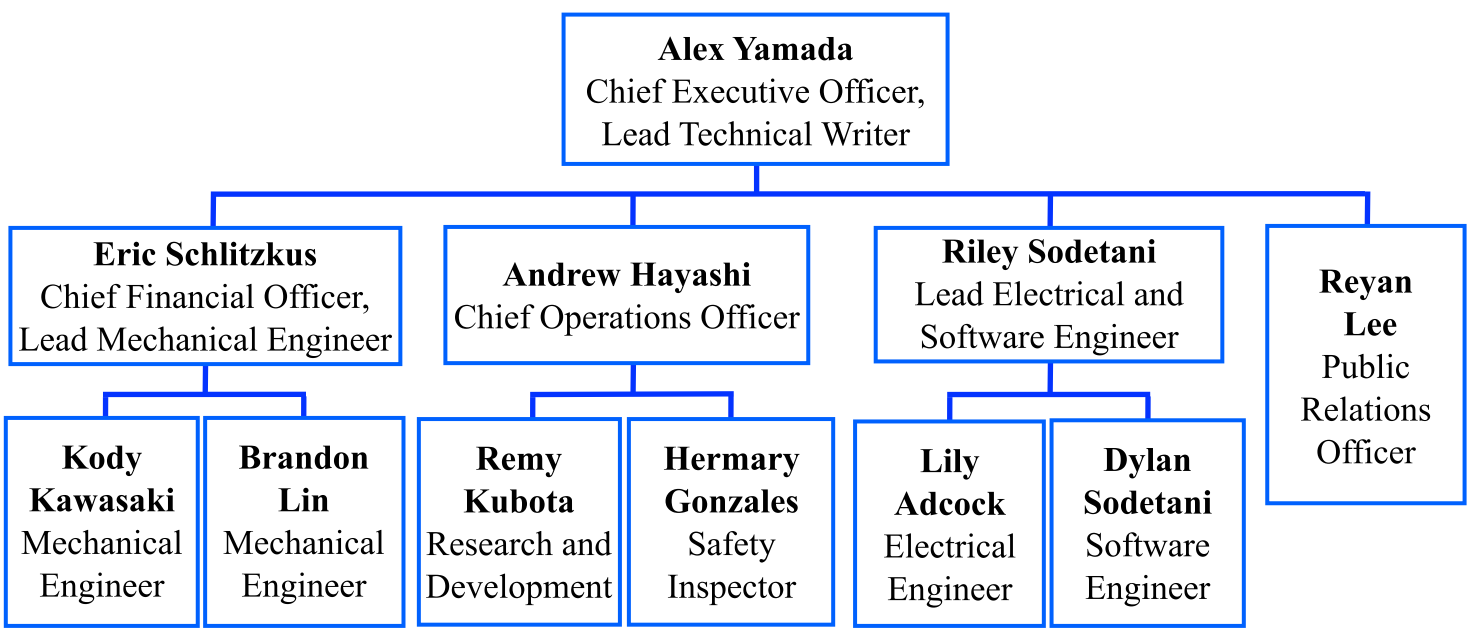
Kaimana Enterprises' strict safety philosophy is evident through the numerous safety features on Honu. The edges of all aluminum parts were filed down to a curve to eliminate sharp edges and prevent injuries. Honu's tether is bright neon yellow to ensure high visibility and prevent company members from tripping and falling. Many other structural precautions include shrouds around each thruster to protect both the motors and company personnel, and all wires, cables, and air tubes are tightly secured to Honu's frame.

Multiple safety precautions were also taken for the electronics system. On the surface controls, there is strain relief on the tether to ensure cables do not get bent or kinked. There are no exposed copper wire on the on-deck and on-board controls, which could otherwise damage electrical components and short the system. A 25A fuse is installed into the wiring less than 30cm from the power source attachment point that immediately opens the circuit in the event that too much current passes through the main power wire. The control system is housed within a waterproofed plastic case to prevent water from entering the control panel and damaging the system.

IV. Logistics

Team Assignments

At the beginning of the season, company members conducted their own individual research and design drafts. Then, the entire company held a series of design meetings where everyone contributed to the overall vehicle design. The CEO was in charge of making final decisions and ensuring that the correct designs were being constructed. The CEO was also the lead technical writer because this individual was aware of each of the decisions and its rationale. The CFO was in charge of the financial reports and worked closely with the lead engineer to fabricate efficient, cost-effective designs. Alongside the CFO and lead engineers, the COO assigned each mechanical engineer to construct certain aspects of the vehicle. The distribution of the vehicle components are as follows: frame, buoyancy, propulsion, visibility, gripper and hooks, and sensors. The electrical and software engineers were assigned the tether and control system. The company also had individuals that handled specific parts of the company, such as research and development, quality and safety, and public relations. These were the individuals more interested in logistics, rather than the manufacturing process. The chart below depicts the company's team assignments and order of operations.



Budget/Project Costing Description

At the beginning of the year, the company applied for numerous grants and entered various other competitions in order to attain a budget. The company was able to secure $2,931.00 for vehicle construction, research and development, and prop building. The completed budget chart can be found on Appendix A. Estimated travel expenses to the international competition is not listed in the budget because Highlands Intermediate School had previously agreed to cover the students' airfare if the company advanced. These funds would only be given under that circumstance and could not be spent on vehicle construction, thus not included in the budget. The budget was strictly adhered to throughout the planning and construction of Honu. After every purchase, the receipts were entered into a final product costing sheet and tracked against the budget, which can be found on Appendix G.

After the product demonstration descriptions were uploaded onto the MATE website, a company meeting was held to discuss a projected product costing for the upcoming year. The projected costing was determined after thoroughly analyzing each required mission and brainstorming which tools would be necessary to accomplish the mission. Other discussion topics included reusing components, implementing new technology, and conducting research and development. It was decided to reuse components from the prior year's electronics system because they would be necessary for this year's missions, thus reducing the total expenses. The projected product costing chart can be found on Appendix B.

Project Management

At the beginning of the year, all the members of Kaimana Enterprises assembled and discussed scheduling, budget, and brainstormed for the different mission tasks. Mandatory meetings were held every Friday and Saturday to work on the vehicle, which kept the company organized and aware of its progress. There were only two mandatory meeting days per week because all team members were involved in other extracurricular activities, but anyone who was not busy on the other weekdays would go to Highlands Intermediate School to work on Honu. A long research and development phase followed, where each member researched and presented possible technology that could enhance Honu's efficiency in accomplishing the missions. Towards the middle of the season, the company held a movie night, where the entire team gathered to watch Spare Parts, a movie about a team's success at the MATE competition. The movie not only kept company members relaxed and happy, but also provided determination and motivation to create Kaimana Enterprises' own success story.

When a team member needed materials, he or she was required to alert the CEO and CFO, and explain why the purchase was necessary. After approval, cost comparisons and other alternatives were researched before the purchase was made by the CFO or team mentor. The company created a Gantt chart (shown below), which listed 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.

Table 1: Project Management Schedule/Team Assignments

Task	Name	Dec.	January				February				March				April				May				June	
		N/A	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2
Research & Development	Whole Team	■	■	■	■																			
Establishing Roles	Whole Team	■	■	■																				
Design ROV	Whole Team	■	■	■	■	■	■	■	■	■	■													
CAD	Eric, Kody		■	■	■	■	■																	
Prototype ROV	Brandon, Eric			■	■	■	■	■	■	■	■	■	■	■										
Order Materials	Eric, Alex			■	■	■	■	■	■	■	■													
Build Props	Reyan, Remy, Hermary, Lily						■	■	■	■														
Prototype Attachments	Whole Team						■	■	■	■	■	■												
Propulsion	Hermary, Remy						■	■	■	■														
Pressure Housing	Whole Team								■	■	■	■	■	■										
Frame	Eric, Brandon								■	■	■	■												
Ballast	Lily, Reyan								■	■	■	■	■	■	■									
Tether	Dylan, Riley									■	■	■	■	■	■									
Visibility	Alex, Andrew									■	■	■	■	■										
Task Control Hub	Lily, Riley											■	■	■	■	■								

Finalize Attachments	Alex, Andrew, Eric																							
Programming	Riley, Dylan																							
Technical Doc.	Whole Team																							
Finalize ROV	Whole Team																							
Pool Practices	Whole Team																							
Marketing Display	Whole Team																							
Safety Inspection	Whole Team																							

Company Effort

The Gantt chart above clearly demonstrates that every aspect of Honu (missions tools, vehicle components, technical report, and marketing display, etc.) were designed and constructed solely by the eleven members of Kaimana Enterprises. Mentors assisted the company only by providing supervision, knowledge, and power tools.

V. Conclusion

Troubleshooting Techniques

The troubleshooting method used by the company is the Eight Disciplines of Problem Solving, which is commonly used in the automotive industry to identify and solve problems. The steps of this process are 0) plan, 1) form a team, 2) define the problem, 3) problem isolation, 4) root cause analysis, 5) verify solution's expected effectiveness, 6) implement solution, 7) prevent recurrence, and 8) congratulate your team. The factors that were kept in mind while troubleshooting were cost, time, simplicity, and effectiveness.

When one of Honu's thrusters worked well during the initial testing phases, but did not consistently respond to the joystick commands during later testing, a small team of one mechanical, one software, and one electrical engineers was assembled to solve the problem. After a thorough inspection of the thruster on land, the team concluded that the problem was either in the on-board system or software. The team discovered that one of the wires within the on-board housing was not fully inserted into the port. The housing was removed and the wire was reinserted into the port. The propulsion system was then tested and evaluated multiple times to ensure that this was the cause of the problem. After successfully addressing the problem, each wire in the housing was fixed in place with glue to ensure that this problem did not recur.

After testing Honu's components individually, the entire vehicle was tested on land before being tested in the school's aquaponics garden tank. Honu was then tested in a large swimming pool, where the company practiced piloting and completing all of the five product demonstration tasks.

Challenges and Solutions

Technical

One of the greatest challenges of this year's MATE competition was staying under the ROV size and weight restrictions while still being able to effectively accomplish the mission tasks. Kaimana Enterprises achieved this goal using several methods. First, Honu's frame was reduced within the specified parameters. All the components and mission tools needed to fit and perform within this smaller frame. Second, an on-board electronics system was implemented on Honu for the first time and encased within an acrylic housing unit which was designed and constructed to fit completely within Honu's frame. This system maintained Honu's performance while remaining the tether's weight and size. The active ballast system was replaced with a passive system to further reduce Honu's weight. Additionally, a lighter V-shaped hook replaced a planned second gripper. All these methods combined allowed the company to overcome the challenge.

The most challenging component for the company to complete was the on-board electronics system. If the acrylic housing unit which encapsulated the system failed, it could short-out and damage all the electronics. Honu's initial housing was unable to withstand the water pressure at a 3m depth. Water seeped in through the holes of the connectors that connected the electronic boards to the tether. In order to prevent this from happening again, waterproofing methods used on professional ROVs were researched. The problem was solved by purchasing better connectors that incorporated O-rings, which are able to compress and completely seal the gap between the connector and the acrylic housing. This solved the waterproofing problem and allowed this challenge to be overcome.

Non-technical

Constant communication was especially challenging because the company members attend two different schools and have completely different schedules, making full attendance at company meetings very difficult. As a result, there were many miscommunications at the beginning of the season, which included delays on designs, drafts, and team meetings. In fact, some team members actually constructed components, but the components were discarded because the parts were no longer compatible with Honu due to recent design changes that they were unaware of. An example of this was when one of the mechanical engineers began building parts for the second pneumatic gripper because he was unaware that Honu's new design had a hook instead of another gripper. In order to overcome this communication obstacle, Kaimana Enterprises decided to communicate through various media, such as social media, text messages, emails, teachers, and other students. For example, when one of the company's mechanical engineers requested an additional 4cm on the frame to secure the gripper to the frame, he 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.

Lessons Learned

Technical

Kaimana Enterprises overcame the challenge of waterproofing techniques for its automobile rear-view cameras and also for the acrylic housing for its onboard electronics system. Last year, the waterproofing of the automobile cameras occasionally failed, so this year, a new method was researched and implemented to eliminate the wasted time and effort spent when the waterproofing failed. Three different adhesive materials are used. Epoxy resin and hot glue are used to seal the camera into its acrylic housing, and the marine epoxy is used to prevent water from entering the housing through the video cables inlet. This lesson proved invaluable in preventing delays and wasting precious time at pool practices.

The other lesson learned involves the implementation of the on-board electronics system. As stated in the Challenges and Solutions section, solving the waterproofing problem of the acrylic housing is the single most important technical lesson learned this year. It enabled Honu to accomplish all its goals. Kaimana Enterprises learned first-hand about programming an Arduino board, wiring motor control boards, and creating and effectively waterproofing pressure housings. The knowledge gained through research opened the door to new materials such as O-rings, which are capable of sealing the housing effectively. The company also learned about the advantages of on-board electronics. It makes the use of sensors easier and streamlines the size and weight of the tether. All were valuable lessons leading to the success and accomplishments of Honu.

Interpersonal

Kaimana Enterprises learned the hard way, through experience, about the importance of communication, or more importantly, how lack of communication affects the team. These negative effects include inefficient use of time (delays, waiting for others, missed deadlines), frustration due to wasted time and effort, and disagreements among team members.

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 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. This increased awareness allows each member to realize the importance of discussion and consensus before implementation. When everyone knows the plan of action, the entire team moves forward together.

Future Improvement

As previously mentioned in the Challenges and Solutions and Lessons Learned portions of this report, communication was a problem throughout the year.

Although Kaimana Enterprises has encountered various challenging technical issues, such as reducing Honu's weight and size while remaining effective, the biggest obstacles were the non-technical, interpersonal issues of communication; specifically, the breakdown of communication.

During the process of constructing, testing, modifying, and completing Honu, Kaimana Enterprises was able to work out its breakdown of communication issues by utilizing all available media to keep its members fully informed of Honu's progress and hindrances. This also increased awareness of the interdependence amongst team members and showed how one person's decisions could affect the work of many others, which was the cause for numerous arguments regarding wasted time and efforts. In line with the problem solving and troubleshooting techniques utilized for the technical issues it faced, Kaimana Enterprises must first identify and solve its communication issues. This valuable tool will allow technical issues to be solved promptly and efficiently.

In the future, Kaimana Enterprises will address communication breakdowns and raise the awareness of how it affects the company and each individual member. This will begin at the very first meeting, so everyone will be informed and aware of the respect and responsibility each team member must show to others and the company. There will be meetings before work begins to ensure everyone is on the same page. Meetings will also be held after work is done to plan for the next workday and to learn from events that happened that day. These meetings also serve the purpose of reminding everyone of safety techniques and occurrences before, during, and after work. Improving communication and keeping everyone on the same page from the very beginning will increase efficiency by reducing stress, frustration, and wasted time.

Team Reflection

Participating in the MATE competition has enabled every member of Kaimana Enterprises to grow significantly due to the countless challenges and obstacles that arose. Although each company member was able to gain a myriad of technical skills, such as troubleshooting, welding, wiring, and programming, many of them are still unsure about their future career aspirations and have many years left before going to college. As a result, the personal, non-technical accomplishments that were gained this year were more valuable to the majority of the company. At the beginning of the MATE season, some members struggled with working together and communicating effectively, not only because of the various schedules of company members, but also due to some conflicting ideas and personalities. For example, a few members had some negative experiences working together on projects in the past, leading to numerous arguments during company meetings. As the competition approached, this issue slowly resolved itself as petty differences and arguments gave way to achieving company goals through compromise, cooperation, and teamwork. The whole team learned that a lack of effective communication and teamwork will hinder progress and possibly lead to failure.

References

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Table 2: Acknowledgements

Individual/Company	Support/Service
MATE Center	Planning and Running the Competition (Countless hours)
Highlands Intermediate School	Financial Support- Airfare/ROV ($13,400), Workroom (~600hrs)
Pearl Harbor Naval Shipyard	Financial Support- Thrusters ($1,165)
Space/Naval Warfare Systems Command	Financial Support- Tether ($66)
Parent Volunteers	Moral Support, Meals (~600hrs)
Solidworks	Access to Solidworks 3D CAD Software ($150)
Robin's Painting	Access to Workshop, Tools, and Machinery (~250hrs)
The Haramura Family	Access to Pool (~100hrs)
Oahu Regional MATE ROV Competition Staff and Volunteers	Planning and Running the State Competition at the Oahu Coast Guard Base

VI. Appendices

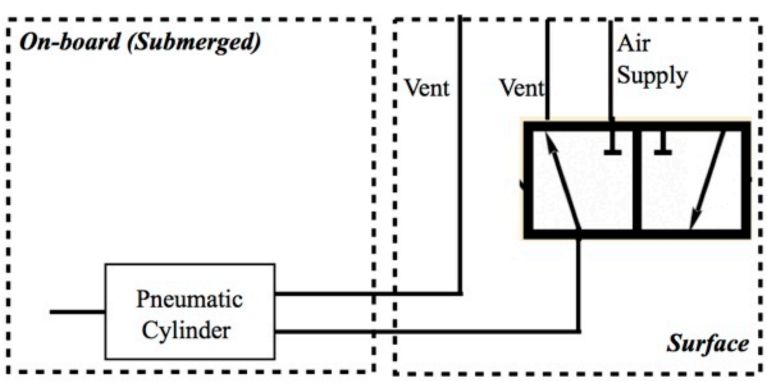
Appendix A: Budget

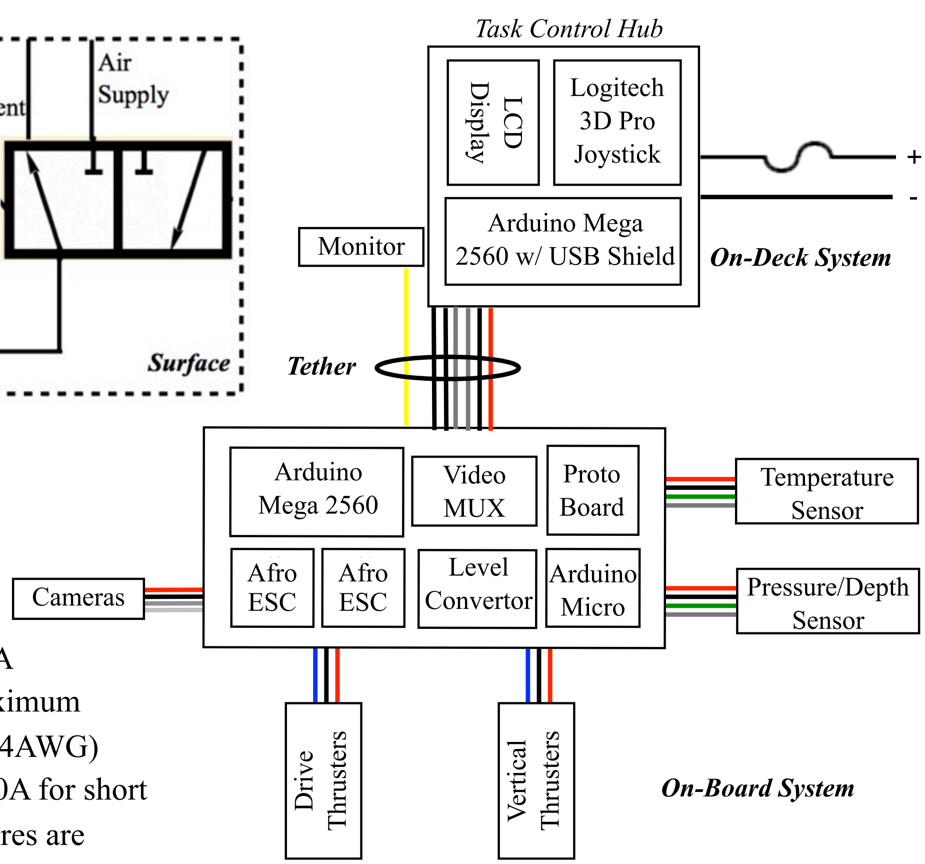
Source of Funding	Monetary Amount
Bank of Hawaii: Keiki Co. Contest	$1,500.00
Pearl Harbor Naval Shipyard	$1,165.00
Highlands Intermediate School Parent Teacher Student Association	$200.00
Space and Naval Warfare Systems Command (SPAWAR)	$66.00
Total:	**$2,931.00**

Appendix B: Projected Product Costing

Process/Component	Estimated Cost
Research and Development	$200.00
Frame	$50.00
Buoyancy/Ballast	$50.00
Propulsion System	$750.00
Control System	$750.00
Visibility	$75.00
Tether	$75.00
Mission Tools	$150.00
Remaining Emergency Funds	$831.00
Total:	**$2,931.00**

Appendix C: SID- Electrical Schematic & Appendix D: SID- Pneumatics Diagram

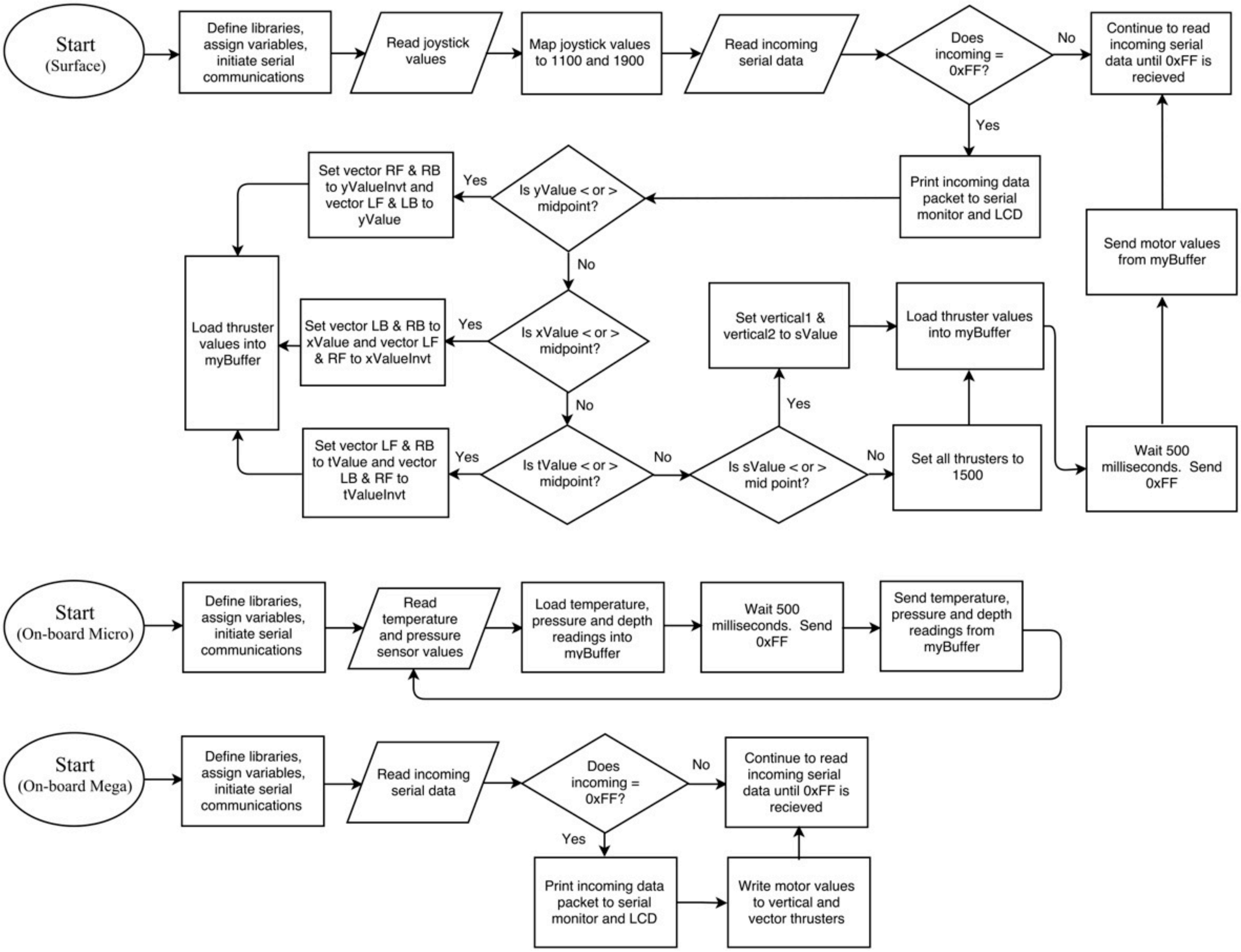




<u>Fuse Calculations:</u>

F: 25A blade fuse
Safety Factor (SF): 1.5 (150%)
Maximum permitted fuse: 25A
Typical working load: 15A, with SF: 25A
MATE Voltage: 12V nominal 14.8V maximum
Smallest power wire used: 2.08mm^2 (14AWG)
Wire is rated to carry 35A continuous, 40A for short periods. The 25A fuse will fail before wires are damaged. The 25A fuse will be used.

Appendix E: Design Rationale- Software Flowchart



Appendix F: Safety and Function Checklist

Occasion	Category	Safety Precaution
Before Work	Company	Wear proper safety apparel (covered shoes, tied-back hair, safety goggles when on-deck)
	Physical: (MATE Standard Safety Specs)	All sharp edges are filed down
		All components are connected securely to the ROV
		Tether is properly secured at the surface and on the ROV
		All electrical connections implement the use of strain relief
		Any possible hazards (thrusters, grippers, etc.) are marked with caution stickers/tape
		Every propeller is shrouded to protect both Honu, company personnel, and divers
		Buoyancy is securely attached to the frame
	Electrical	25A fuse on the positive side of the main power source
		All open connections are kept away from water
		Secure and check all connections before turning on power
		Make sure the compressor's air pressure is at 40psi prior to tether connection
During Work	Company	When using power tools and testing Honu wear protection for both ears and eyes
		Adult supervision when using hazardous tools
		Designated work areas for each job
	Physical	Tether is properly secured at surface and on the ROV
		Any possible hazards (thrusters, grippers, etc.) are marked with caution stickers/tape
	Electrical	All electrical wires and parts are kept away from water
		All electrical components are enclosed in a case at the surface
		All wiring and electrical components are properly sealed
		Cameras are secure on ROV
After Work	Company	Clean up the work area
	Physical	Follow the Kaimana Enterprises' Tether Management Protocol
		Clean up any debris created during testing
	Electrical	All electrical wires and parts are kept away from water
		All wiring and electrical parts are properly put away
		Wipe cameras down

Appendix G: Actual Product Costing

Category	Item	Type	Amount Paid	Actual Value
Frame	Aluminum Extrusions	Purchased	$34.64	$34.64
	M5 Slide-In Economy T-Nut	Purchased	$5.25	$5.25
	M5 Button Head Hex Socket Cap Bolts	Purchased	$7.46	$7.46
	1.9cm (3/4in) Aluminum Angle Iron	Purchased	$11.45	$11.45
		Subtotal:	**$58.80**	**$58.80**
Tether	20m VideoRay Tether **(from SPAWAR)**	Donated	$0.00	$66.00
	0.3175cm (1/8in) Natural Nylon Tubing	Purchased	$21.14	$21.14
	0.635cm (1/4in) Poly Tubing	Purchased	$96.90	$96.90
	300m Cat-5e Cable	Purchased	$41.66	$41.66
		Subtotal:	**$159.70**	**$225.70**
Electronics	Arduino Mega 2560 Microcontroller	Reused	$0.00	$23.60
	Arduino Uno Microcontroller	Reused	$0.00	$6.39
	Logitech Joystick	Reused	$0.00	$29.99
	1.27cm (1/2in) Thick Acrylic Plastic Sheet	Purchased	$60.48	$60.48
	Electrical Wire/Connectors	Purchased	$56.58	$56.58
	7.62cm Diameter (3in) Acrylic Plastic Tubing	Purchased	$65.20	$65.20
		Subtotal:	**$182.26**	**$242.24**
Propulsion	BlueRobotics T200 Thrusters with BlueESC (6) **(from Pearl Harbor Naval Shipyard)**	Donated	$0.00	$1,165.00
		Subtotal:	**$0.00**	**$1,165.00**
Mission Tools	BlueRobotics Pressure Sensor	Purchased	$68.00	$68.00
	BlueRobotics Temperature Sensor	Purchased	$56.00	$56.00
	Pneumatic Cylinder	Purchased	$50.15	$50.15
		Subtotal:	**$174.15**	**$174.15**
Other	Mission Props	Purchased	$219.26	$219.26
	Waterproofing (Epoxy, Adhesive Heat Shrink, etc.)	Purchased	$78.90	$78.90
		Subtotal:	**$298.16**	**$298.16**
		Total:	**$873.07**	**$2,164.05**
Travel Expenses	Airfare: Honolulu to Houston (11 members) **(from Highlands Intermediate School)**	Donated	$0.00	$13,200.00
		Total:	**$0.00**	**$13,200.00**
Time/Services	The Haramura Family Pool ***(Approx. 100hrs)***	Donated	$0.00	$0.00
	Robin's Painting Workshop ***(Approx. 250hrs)***	Donated	$0.00	$0.00
		Total:	**$0.00**	**$0.00**