D-B EXCEL HIGH SCHOOL

R-MATEYS

RANGER CLASS **2019 MATE ROV COMPETITION**

TECHNICAL REPORT

MEMBERS

Gavin Bentley- CEO

Quintin Folkner- Pilot

Ashlee Wall- Chief Documentation Analyst

Brady DeBruin- CFO

Quinn Bentley- Chief Project Manager

McKinley Sexton- Project Manager

Carter Grim- Safety Engineer

Bre Rill- Documentation. Analyst

Jasmine Monroe- PR Manager

Landon Taylor- Co- Pilot

Kerrigan Bentley- Chief Electrical Engineer

Trinity Dutro- Electrical Engineer

Pearson Mills- Chief Mechanical Engineer

Katie Pangle- Mechanical Engineer

Asheton Shepherd - Mech. Engineer

Kaden Hutson- IT Support

MENTORS

Zachary Gardner - Eastman Chemical Company

Wes Matson - Bell Helicopter

Phil Bentley - BAE Systems

Erica Gardner - Coach

Sara Leimkuhler - Coach

DB EXCEL R MATEYS

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Abstract

The R-Matey's second year ROV, Próklisi, is this year's creation from the D-B EXCEL MATE program. The latest iteration has been designed based on an Eastman Chemical Company proposal, which outlines the crew and ROV operations within freshwater environments of local waterways. The R-Mateys, as a company and through the ROV initiative, will be capable of ensuring public safety, maintaining healthy waterways, and preserving history. The company devoted countless hours into the fabrication of the ROV product. With a total of $1,448.74, Próklisi encompasses a manipulator, aluminum frame, and four motors. Stability, efficiency, and accuracy are key attributes to the ROV's design. This document covers all technical aspects and the creation of the ROV. These aspects include information of the company, the design of Próklisi, tasks the ROV is capable of completing, testing and safety.

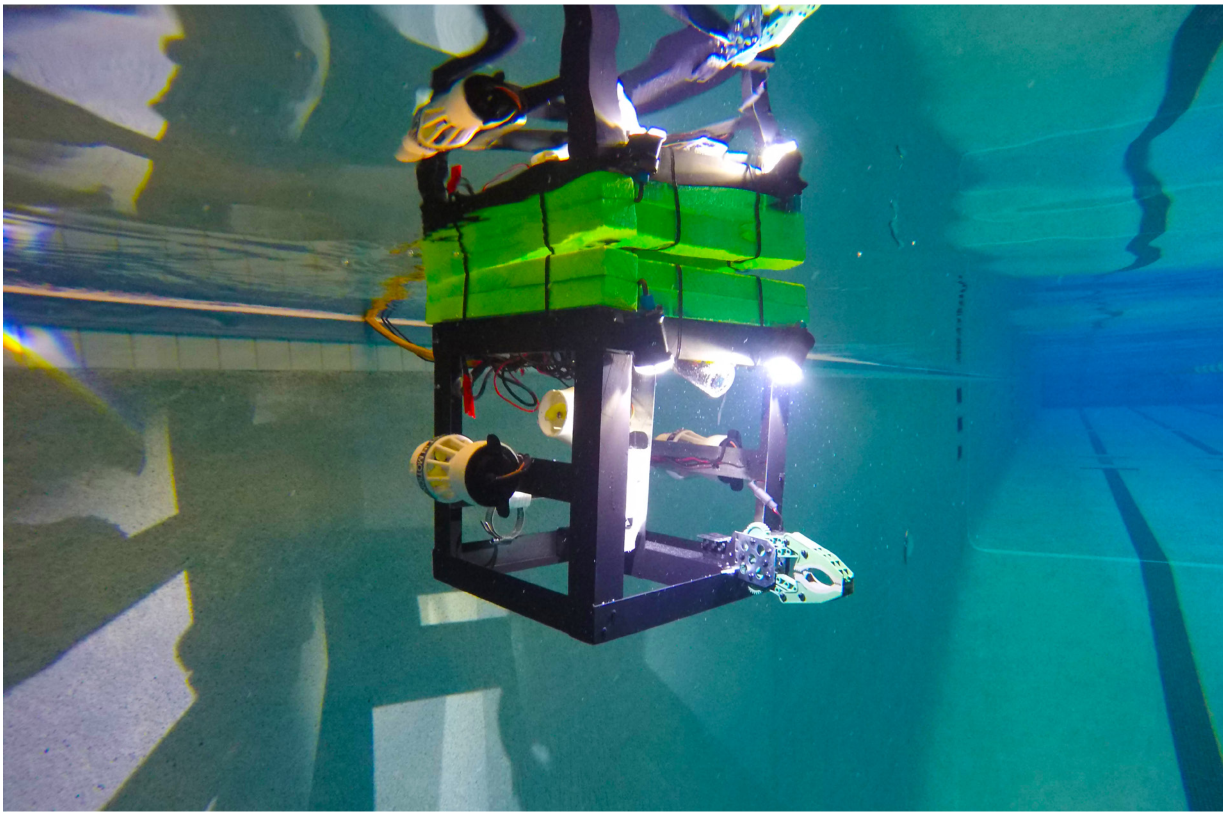


Figure 1: Finished ROV, Proklisi. Photo Credit: Gavin Bentley

Team Work

COMPANY EFFORT

The entire company worked together to help complete the task of designing, documenting, and building Proklisi. Each company member literally had a hand in the construction of the ROV. The CEO made it a point to have company members take turns placing rivets in the ROV's main frame. This was meant to be a physical representation of the R-Mateys and this process. MATE brought the company together and collaborating on the process rivets the team together. In addition, the entire company contributed to the completion of all the documentation in some capacity depending on the team placement in which they served.

Figure 2A: Team working on ROV
Photo Credit: Jasmine Monroe

Figure 2B: Team working on documentation
Photo Credit: Jasmine Monroe

The R-Mateys were divided into three teams: documentation, project management, and build. Company members were placed on these teams depending on their individual strengths; these strength were determined by a strengthsfinder assessment given upon application to the R-Mateys. The purpose of the teams were to divide the work into manageable amounts. When the regional competition was on the horizon, all three teams came together to collaborate. Build team shared their design process and provided technical information. Documentation team lead the discussions and provided the outlines for the necessary documentation for the competition. Project management team created the schedules and took notes from both teams and acted as the relay between the teams. See Figure 3 in Appendix for the R-Matey's Company Structure that was created using Adobe Photoshop by Jasmine Monroe.

PROJECT MANAGEMENT

The CEO was in charge of guiding all the teams in the R-Mateys company, but had a special role in the project management team. The project management team created a schedule for the entire 2018-2019 season. This team was responsible for tracking the completion of the objectives on the schedule and making comments upon completion. This helped the team constantly move forward and progress towards to goal of a fully functioning ROV.

In order to complete the task of building the ROV, the R-Mateys had to repeatedly follow the Engineering Design process. The company as a whole would research and design the ROV or systems used with the ROV. Then the build team would create a prototype and bring it to the entire company for testing. Then the company as a whole would test and redesign. Then the build team would create a finalized product. Throughout this process the project management and documentation teams would be documenting and recording this process.

Whenever conflict would arise, the R-Mateys had a set process for resolution that would occur. The issues would be brought to the team leader. The the team leaders from each team and the CEO would sit down together to find a solution to bring back to the company. This system was found to be productive at finding solution and resolving interpersonal conflicts.

Design Rationale

FRAME

The ROV, Próklisi, has an orthogonal, or cube, frame. This configuration provides a stable and secure ROV. The center of gravity is not directly in the center, due to the claw being offset, but it is not too far away from the exact center to cause any issues. Aluminum was chosen as preferred material for construction of frame. Aluminum tensile strength is 310 MPa compared to PVCs tensile strength of 46 MPa (Moore, Bohm, & Jensen 2010). The structure is constructed of Aluminum L Channel, creating a lightweight vehicle. The L channel is 4.2 millimeters thick and 38.1 millimeters wide. This thickness aids in the process of installing pop rivets. The L channel aluminum allows the wires to be thoroughly hidden and attached to the ROV. Last year, the R-Mateys chose a PVC frame, which is weaker and less durable. In contrast to a PVC structure, the Aluminum frame of this year's model is the most cost-efficient considering weight and longevity.

Figure 4: Image shows 38mm by 304.8mm by 4.2 mm aluminium constructed into a cube as the frame of Proklisi. Photo Credit: Ashlee Wall

ELECTRONICS

SID & FUSE CALCUALTIONS

Proklisi is outfitted with many different electrical components. The R-Mateys produced a SID with fuse calculations, and has outlined the temperature sensor, cameras, wire management plan, and both the main and secondary control box.

The electronics department constructed a systems integration diagram (SID) using AutoDesk. The SID is a system-level, connection diagram that displays and labels electrical power wiring information. See Figure 5 in appendix for SID and Fuse calculation.

TEMPERATURE SENSOR

Proklisi is equipped with a resistance temperature sensor or RTD. This will allow the pilot to instantly know that temperature of the water in which the ROV is operating to a high degree of accuracy. The sensor is mounted to the side of the ROV but not in contact with any part of the ROV; this will ensure that the temperature read out is only for the water. The RTD is connect via USB cable to a laptop on the surface.

CAMERAS

The ROV is equipped with two backup cameras that are included in the Baracuda kit. Each camera is waterproofed according to MATE specifications with a two-part pour in epoxy. Connections are placed inside of an acrylic casing in order to create a water safe housing. Mounting in two locations on the ROV provides multiple views at different angles aiding in the operation of the Vex claw. Both of the cameras' fields of view are overlapping, providing different perspectives of the same object, which assist in the pilot's decision-making. The lights are placed strategically to prevent any shadows from distorting the pilot's sight. The cameras are mounted using hose clamps attached to a custom made mount. Thus, allowing our cameras for an angled perspective.

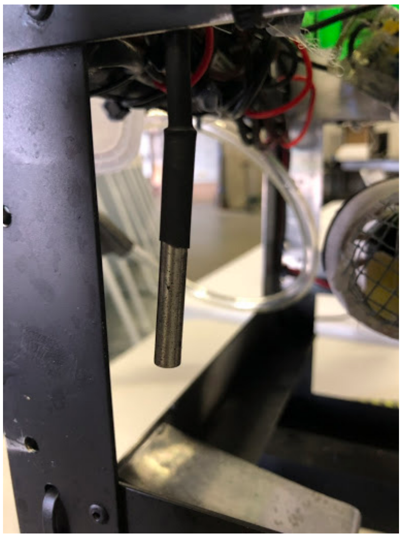


Figure 6: Temperature Sensor. Photo Credit: Quintin Folkner

Figure 7: Pictured Left to Right: Front mounted backup camera and back mounted backup camera. Photo Credit: Quintin Folkner

IMAGE RECOGNITION

In this year's competition, teams were tasked with observing the type and quantity of benthic species underneath rocks in the local waterways. Proklisi is equipped with an image recognition system that will seek out and count the type and amount of four select species. The R-Mateys use the PyCharm Integrated Development Environment in partnership with the OpenCV Processing Library to process the image and output the requested values. The image processes from the Blue Robotics Low-Light HD USB Camera into a Lenovo ideapad to be outputted into a results window for the judges to read clearly. While the program is being run, it converts the raw input image into a Hue-Saturation-Value (HSV) image that eliminates objects of any color other than black. It then uses the predetermined areas of the species to resolve the type being witnessed. To make a wider angle of operation, the program uses the area ratio of the species to consistently regulate correct outputs.

WIRE MANAGEMENT

The Aluminum L-channel provides simple and easy management of all wires connected to the tether point. Wires run throughout the frame and are securely attached with zip ties in order to allow for uninhibited water flow.

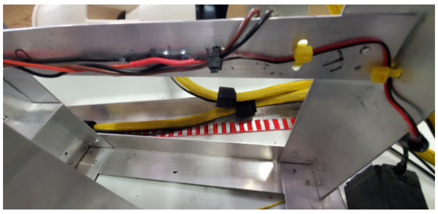


Figure 8: Images show how L-channel was used to hide wires. Photo Credit: Ashlee Wall

MAIN CONTROL BOX

The control box is the interface that controls the ROV. A single monitor connected to both cameras is located on the inside of the control box lid and displays live video footage to the pilot. The pilot will switch between both cameras using the V1 and V2 button. The control box includes two joysticks and one double pole, double throw switch. The left joystick operates the forward and aft motors and the right joystick controls the strafe motor, lateral movement. The double pole double throw switch is located between both joysticks and controls the vertical motor. We added the double pole, double throw switch due to the joystick that controls the vertical motor malfunctioning. The watt meter monitors voltage and amps being used throughout the system. The main internal components are two Sabertooth motor controllers, a camera signal processor, and an Arduino. The Sabertooth motor controllers allow Próklisi to control multiple motors at various voltages. It also allows for quick stops and reserve of direction by quickly changing polarity. The camera signal processor converts the electrical signal from the cameras into a viewable image. The Arduino will allow Próklisi to measure the temperature of the water through a series of programs.

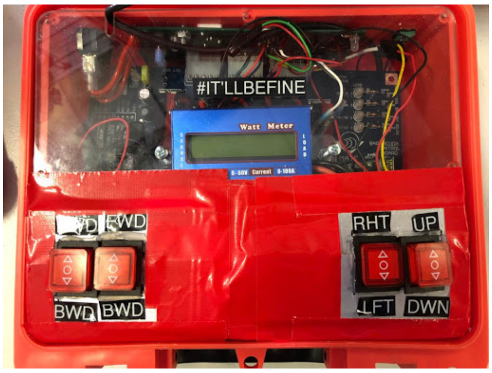


Figure 9: Proklisi main control box with labeled switches and watt meter.
Photo credit: Quintin Folkner

SECONDARY CONTROL BOX

The secondary control box holds all components responsible for the operation of the electric claw and lights. The box has two double pole double throw switches and three on/off switches. The double pole double throw switch is used to control the claw. Lights on the ROV are run by the leftmost on/off switch and the rightmost on/off switch is used as the main power switch for the control box.

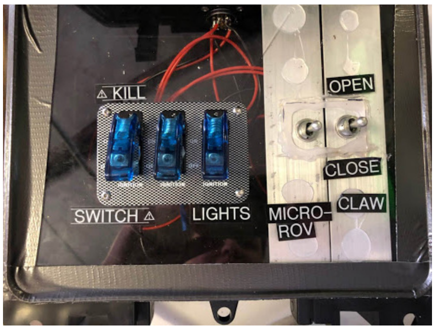


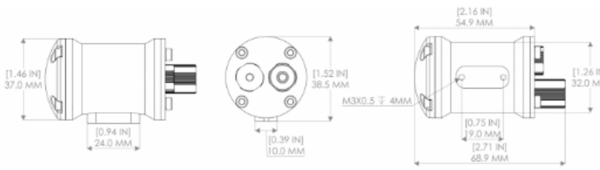
Figure 10: Proklisi secondary control box with labeled switches.
Photo credit: Quintin Folkner

LIGHTING

Próklisi uses two 1500 Lumen Subsea Lights purchased from BlueRobotics. For a total of $99.00 per unit, these LED lights have a 135 degree beam angle and omit 1500 lumen at 15 watts making Proklisi capable of exploring great depths amidst low visibility (“Lumen Subsea Light for ROV/AUV”). The product does not require any additional waterproofing, which ensures efficiency. Each light is mounted diagonally in the front of the ROV directed downward. Equipping the ROV with two lights minimizes the shadow effects caused by water, augmenting visibility. After deliberate discussions between the electrical and engineering departments, Blue Robotics’ 1500 Lumen Subsea Lights were deemed a more beneficial component to the ROV, Próklisi, compared to Teledyne Marine’s 1000 Lumen lights.

Blue Robotics	Teledyne Marine
1,500 Lumens	1,000 Lumens
135 degrees beam angle	85 degrees beam angle
950 m	300 m depth

Figure 11: Schematic diagram of LED lights.
Photo Credit: Blue Robotics (“Lumen Subsea Light for ROV/AUV”).



MANIPULATORS

Próklisi has been designed to include two different style manipulators The first claw is an electric claw that has been wired into the secondary control box. This acts as the pilots hands underwater. The second is an hydraulic dispenser that is connected to the recycled hydraulics system from last year; this will serve primarily for transportation from topside to the mission field.

ELECTRONIC CLAW

The claw is a Vex EDR electric claw mounted on the front of the vehicle for mission tasks. Its vertical placement maximizes the space in front of the ROV. The claw is offset from the center to provide an open space in the bottom right-hand side of the vehicle. This allows for more opportunities regarding mission-specific modifications. In order to waterproof the servo motor, petroleum jelly is applied to the shaft which allows the gears to rotate. The liquid tape covers the servo motor in order to create a waterproof seal. It is important that back up gears and parts are always on hand while using the claw. Compared to other claws, the VEX Robotics Claw is strong enough to hold a soft drink can and operates with a high degree of precision ("Claw Kit" 2019).

Figure 12: Vex EDR mounted on the ROV. Photo Credit: Ashlee Wall

HYDRAULIC DISPENSER

The hydraulic dispenser system is a custom built device that allows Proklisi to safely transport small objects from the surface to any location under the water. It is a combination of new and reused parts. The hydraulics board was designed last year and proved to be a successful system that was a benefit to the team to reuse. Attached to the hydraulics board is 15.24 meters of 4.5 mm diameter plastic tubing to transport the hydraulic fluid between the surface board and the dispenser itself. The dispenser consists of a 60 ml syringe. When it is closed the hydraulic fluid is putting pressure on the dispenser. Topside, the master cylinder will be mark so that the operator can incrementally release the hydraulic fluid. This causes the dispenser to retract and thus, dropping the desired objects one at a time. This system allows Proklisi to carry multiple objects under the water and then release them at different times in different locations without failure. See Figure 14 in appendix for hydraulics SID.

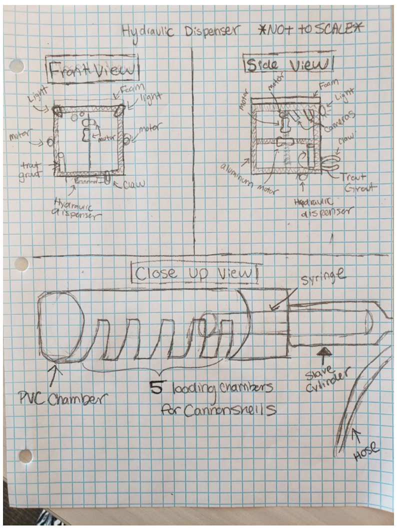


Figure 13: Custom build hydraulic dispenser. Photo Credit: Ashlee Wall

MOTOR SCHEME

The ROV has four motors attached to its aluminum L-channel frame. Two of the motors are 750 gallons per hour bilge pump motors; these two motors move the ROV forward and aft. The motors were strategically placed on the outside of the ROV to keep from restricting water flow. Placing these motors on the outside would keep them from obstructing the strafe motor's water flow. The vertical motor is a 1000 gallon per hour bilge pump motor. It was placed in the middle of the ROV near its center of gravity to ensure a level lift and descent. Equipping the ROV with a motor larger than the 1000 gallon per hour will pull too many amps. Since this motor controls the Y-axis by itself, it is needed to be a motor of higher capabilities to ensure proper lift. The fourth and final motor is used to strafe the ROV from starboard and port directions. The motor is offset so that it ensures that it does not interfere with the ROV's other motors.

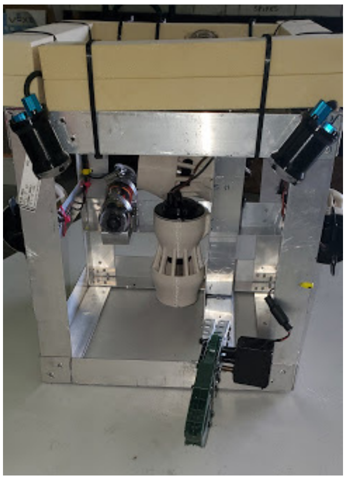


Figure 15: Proklisi with attached motors in the described scheme.
Photo Credit: Ashlee Wall

The vertical and strafe motors have been placed on L-channel as the motors will vibrate. And the forward and backward motors are on a flat bar. The design allows for more stability than just a regular flat piece of aluminum. By choosing the L-channel and flat bar, we get the benefits of the design being more sturdy and having two different points to rivet.

BUOYANCY

Archimedes principle is a major concept crucial in determining an object's buoyant force. The principle states that the buoyant force on a submerged object is equivalent to the weight of fluid being displaced by the object (Halliday & Halliday 1970). If the displaced water weighs less than the ROV, the ROV will sink, which is known as negative buoyancy. The ROV motors would need to continually push the ROV upward in order to keep the same depth. Positive buoyancy occurs when an object is lighter than the weight of displaced water. Próklisi is neutrally buoyant, meaning the ROV's weight is equal to the weight of water being displaced. This allows the ROV to stay at depths without using the motors.

To calculate the buoyancy of the ROV, all components were individually weighed and the force due to gravity was calculated. In order to achieve the goal of neutral buoyancy, the Solver function of Excel was used to calculate the ROV required 2007.11 cubic centimeters of buoyancy foam. The foam is mounted on top of the ROV for stability when deployed in the water.

Items	Weight (Grams)	Quantity	Total	Volume(in^3)	Volume(cm^3)
Shroud	57	4	228	16.68921875	273.4862277
750 Motor	253	2	506	21.205125	347.4883834
Claw	270	1	270	8	131.096
Light	108	2	216	6.806	111.529922
Temp sensor	22	1	22	0.003926990817	0.06435159852
Piece of flat 12"	47	3	141	3.375	55.306125
L Channel	92	16	1472	35.25	577.64175
Piece of Flat 15"	61	1	61	1.40625	23.04421875
1000 Motor	249	2	498	21.205125	347.4883834
Camera	185	2	370	17.6625	289.4353875
Clamp	23	3	69	6.72	110.12064
Strain Relief	30	1	30	0.0914	1.4977718
TOTAL		g	3883	138.4145457	2268.199161
		Kg	3.883		
		Fg	38.0534	Newtons	

Figure 16: R-Mateys parts list with masses and volume.

Buoyant Force No Foam	22228.35178	g*m/s^2
	22.22835178	Newtons
Apparent Weight No Foam	15.82504822	Newtons
Foam Density	12	lbs/ft^3
	192.216	kg/m^3
	192216	g/m^3
Mass of Foam	385.8	g
	0.3858	kg
Volume of Foam	0.002007116993	m^3
	2007.116993	cm^3
	122.4341366	in^3
Grav. Force Foam	3.78084	Newtons
Buoy Force Foam	19.6107373	Newtons
App Weight Foam	-15.8298973	Newtons
Total App Weight	-0.00484907387	Newtons

Figure 17: R-Mateys buoyancy calculation Excel notebook with comments.

Figure 18: R-33 Subsea Buoyancy Foam mounted on the ROV according to the calculations.

BUY VS BUILD

As a second year company, the R-Mateys were given the opportunity to reuse systems as well as build parts of their product, Próklisi. Items that were bought for this season include: 1) lights, 2) camera kits, 3) control box kit, and 4) electronic claw. Lights from Blue Robotics were purchased for their superior quality for a reasonable price. Camera kits were purchased because the cameras from last year were not very clear. This made it difficult for the pilot, so as a company the R-Mateys decided to purchase and build new cameras. The Barracuda Control Box Kit was purchased new from Seamate because this has all the necessary components for the controls box. The R-Mateys purchased a claw kit from Vex Robotics because it was very cost effective and came completed. This served as a huge time saver.

Many things on the ROV were built by the company. These items include 1) frame, 2) lift bag , 3) Motor Shrouds, and 4) hydraulic dispenser. The R-Mateys decided to build the frame out of aluminum l-channel because of its higher tensile strength over PVC. The ROV need additional buoyancy. Therefore, the company decided to construct a lift bag out of a 4 liter water bladder and clear plastic hosing attached to the repurposed pneumatics board. The R-Mateys also decided to 3D print their motor shrouds at DB EXCEL in order to save money. Building all of these items gave the R-Mateys a chance to build everything according to their specific scale and what they needed at the time. The hydraulic dispenser was built because of the need for easy and accurate transportation of the cannon shells. It was decided to be a built item because the team could repurpose the hydraulics board from the previous season and repurposed materials already purchased such as PVC pipe and 60 ml syringes.

The pneumatics and hydraulics boards are both reused systems from the 2017-2018 season. The R-Mateys won the innovation award at the 2018 International Competition for the pressure relief valve on the pneumatics board. Thus, the company decided to reuse this board. The hydraulics board was also reused due to its simplistic yet reliable design that proved to be functional at last year's competition.

Missions

CRACK MEASUREMENTS

A computer will be poolside and operated by our CEO. The computer serves two purposes: allows the team access to the endoscope and to perform the necessary calculations for the missions. During the design phase of the build, a team brainstorming session was held to attempt to find a way to make dam crack measurements. It was remembered that the length of any line can be calculated using a horizontal and vertical measurement. This application of the Pythagorean Theorem was determined to be an easy, cheap, and low tech solution to the problem.

A square measurement device was constructed having measurement scales along all four edges. The measurement device's interior edge length of 13 inches was decided upon so that the maximum crack length defined in the mission briefing could be measured in the horizontal or vertical position. To make the measurement, the pilot will move the ROV with measuring apparatus so that the bottom or top, depending on the orientation, of the crack is positioned at zero inches on a horizontal and vertical ruler. The pilot will read the crack's horizontal length in quarter inches and then the vertical length in quarter inches to the computer operator. The CEO will input the numbers in an Excel document that will convert quarter inches to inches and then to centimeters by multiplying by the conversion factor of 2.54 (1 inch = 2.54 centimeters). Upon inputting this data, the Excel sheet will be set to perform the Pythagorean Theorem to find the crack length.

R-MATEY's Calculation Notebook
Crack Measurement

Horizontal Length in Quarter Inches	Horizontal Length in Inches = A Cell / 4	Horizontal Length in cm = B Cell * 2.54 (in to cm factor)	
12	3	7.62	Crack Length by Pythagorean Theorem (cm) A^2 + B^2 = C^2
Vertical Length in Quarter Inches	Vertical Length in Inches = A Cell / 4	Vertical Length in cm = B Cell *2.54	12.7
16	4	10.16	

Key:
Input Cell
Output Cell

CANNON CALCULATIONS

A separate task in the mission brief describes the need to determine if a submerged cannon can be recovered and brought to the surface. First, the volume of the cannon is to be calculated assuming that there was no bore through the cannon. After researching, the volume of a truncated cylinder was found to be $V=(⅓)\pi(r_1{}^2+r_1r_2+r_2{}^2)h$, where r_1 is the smaller outer radius, r_2 is the larger outer radius, and h is the overall length (Marin 2016). Then the volume of the inner bore will be calculated using the formula$V= \pi r^2h$, where v is the volume, r is the inner bore radius of the cannon, and h is the overall length of the cannon. To calculate the actual volume of the cannon, the bore volume will be subtracted from the truncated cone volume. The specific gravity or density of the canon material will then be determined from the production markings on the cannon and the provided field guide. Using the volume and density, the mass of the cannon can be calculated along with the force due to gravity. Then using Archimedes Principle, along with the density and volume, the upward buoyant force is to be calculated. To get the apparent weight of the cannon in the water, the buoyant force is subtracted from the force due to gravity. This number is then compared to the maximum lift capacity of Proklisi. All equations described above were programmed into the Excel spreadsheet to be used poolside.

To physically make the measurements, the pilot will take the measuring apparatus to the cannon, line up with the cannon barrel, and read the diameter in quarter inches. This process will be repeated for the other two required diameter measurements. The CEO will enter this into the Excel sheet and it will convert this to centimeters and divide by 2 (radius = ½ diameter). The pilot will then measure the lengths of each section in quarter inches. The CEO will enter these values for unit conversion and calculation. Excel is programmed to take the various inputs for each cell and calculate the volume as described above.

R-MATEY's Calculation Notebook

Cannon Volume

	Quarter Inch Segments	Length in Inches = B Cell / 4	Length in Centimeters = C Cell * 2.54 (in to cm factor)	Specific Gravity of Cannon Material Given value based on material	
Segment 1 Length	18	4.5	11.43	6.9	
Segment 2 Length	15	3.75	9.525	Density of Cannon Material (g/cm3)	
Segment 3 Length	12	3	7.62	6.9	
Overall Length		11.25	28.575	Mass of Cannon (grams) = Volume * Density	
				1769.173122	
Segment 1 Diameter (Smallest outside Diameter)	8	1	2.54	Mass of Cannon (Kilograms) = Grams / 1000	
Segment 2 Diameter (Larger Outside Diameter)	16	2	5.08	1.769173122	
Segment 3 Diameter (Small End Inside Diameter)	11	1.375	3.4925	Gravitational Force on Cannon (Newtons). = Mass in kg * 9.8 m/s^2	
				17.33789659	
Key:		Outer Volume Research Formula		Bouyant Force on Cannon (Newtons) = Volume * Density of Water * Gravity / 1000	
Input Cell		1351.388347		2.512738637	
		Hollow Interior Volume in Cubic Centimeters = pi * r^2 * h		Cannon Apparent Weight (Newtons) = Gravitational Force - Buoyant Force	
Output Cell		1094.986945		14.82515796	
		Total Cannon Volume in Cubic Centimeters = Outer - Interior Volumes		Lift Capacity of ROV (Newtons)	Lift capacity of lift bag (Newtons)
		256.4015017		50	50
				Will the ROV be able to lift the cannon?	Will the lift bag be able to lift cannon?
				YES	YES

Figure 20: R-Matey's cannon calculations EXCEL notebook with comments.

TROUT GROUT TRANSPORTATION

The newly designed trout-grout transportation device was a second generation design. During the regional competition, the R-Mateys had designed a separate device that could be placed in the claw and transported to the bottom of the pool to deliver both the trout and the grout. This was found to be problematic for two main reasons: 1) it took too much time to bring the device back to the surface to eliminate leaving debris, 2) it was difficult for the pilot to accurately place the device in the correct places for dispensal. The solution to this was to create a new trout-grout dispenser that was attached to the ROV itself. The new device is positioned on the front right corner of Proklisi. The PVC tube from our previous device was reused as the loading chamber. The pilot needs to line up the funnel shaped device with the target region for delivery. The claw itself will be attached to the door of the device via a small tether. When the claw is closed, the door to the device is being held closed. When it opens, door at the base of the chamber will open. This will release either the grout, trout, or any small object depending on the need of the pilot.

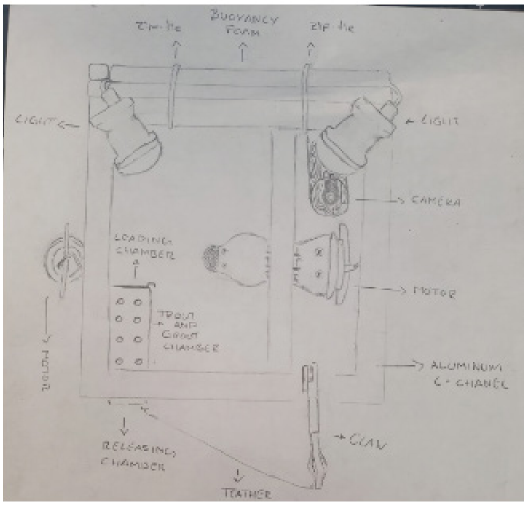


Figure 20: R-Matey's cannon calculations EXCEL notebook with comments.

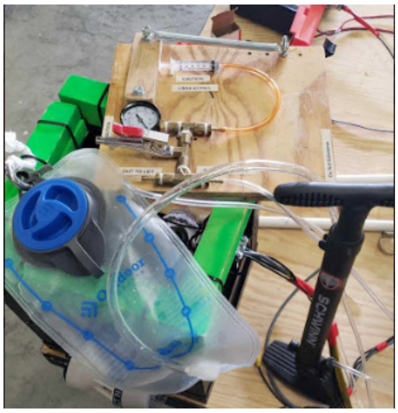


Figure 22: Pneumatics system: including lift bag and pneumatics board.

Photo Credit: Ashlee Wall

LIFT & LIFT BAG

As a part of the development of Próklisi, we tested with a practice cannon to see how much Próklisi could lift. After multiple tests we decided that Próklisi was not capable of lifting the practice cannon. As a solution to our problem, we built a lift bag consisting of a backpack water bladder and an S-hook. Air will be supplied by a pneumatic operator using a standard bicycle pump. The air will travel through the airline tubing into a pneumatic safety board we used in last year's competition. Our pneumatic safety board consists of a manual pressure release valve, pressure gauge, and an automatic pressure relief device triggered by a pressure of 40 psi. The maximum lift capacity of the bag was calculated to be 40.7 Newtons, using Archimedes Principle, as described above. For the lift of the cannon, the deflated bag will be carried down to the cannon by Próklisi. Once the lift handle is inside of the S-hook, the poolside tech will begin inflating the lift bag. Once at the surface, Próklisi will guide the lift bag and the cannon to the side of the pool so another poolside technician can retrieve the cannon. See Figure 23 in appendix for pneumatics SID.

Safety

R-Mateys' main focus is creating a safe and efficient ROV by containing various safety features. The ROV's Aluminum corners are filed to prevent any injury when transporting and operating Próklisi. After cutting each zip tie, the ends are covered to avoid scratching. Próklisi is also equipped with several fuses which break an electrical circuit after reaching an unsafe amperage level. The vehicle is operated off of a Powerwerx 30 Amp Desktop DC Power Supply with Powerpole Connectors. In order to protect the circuits from a power surge, a GFCI surge protector is used. The shrouds mounted on the ROV were 3D printed at the R-Matey's high school, DB-EXCEL, using the MakerBot. The ROV is also equipped with two Lumen Subsea Lights which provides a higher level of visibility in dark areas. In addition, the R-Mateys routinely complete the a safety checklist developed by the project management team during each work session.

SAFETY CHECKLIST

ELECTRICAL SAFETY: ☐ Proper outlet use ☐ Proper power strip use ☐ Avoiding tripping hazards	**ON DECK SAFETY:** ☐ Hair pulled back ☐ Tether management ☐ No loose clothing ☐ Closed toe shoes
SOLDERING SAFETY: ☐ Safety glasses ☐ Hair tied back ☐ Iron to proper holder ☐ No Horseplay	**POWER ON SAFETY:** ☐ Notify members of power up ☐ "Power On" ☐ System Check
SAFETY EQUIPMENT: ☐ Safety glasses ☐ Gloves worn when needed ☐ Closed toe around heavy machinery	**SHOP SAFETY:** ☐ Safety glasses ☐ Proper use of all equipment ☐ Proper attire ☐ No horseplay

Figure 24: R-Mateys Safety Checklist.

As an added layer of safety for the ROV and for the company, several different systems have been outfitted with a lockout-tagout (LOTO) system per OSHA standard 1910.147 (OSHA 1910.147). An LOTO system is used to prevents any unintended change in a system. The R-Mateys used one for the electrical system, pneumatics system, and the hydraulic system. The LOTO for the electrical system will prevent the power cords from the 12V power supply from connecting to the control box until the company is ready for testing. The LOTO for the pneumatics will lock the pressure relief valve in open position; that way even if the pump is moved, the system will come under no pressure until this LOTO is deactivated. The LOTO for the hydraulics will lock the master cylinder in place; this will prevent any accidental pressure being applied to the slave cylinder so that the system is static.

Critical Analysis

TESTING & TROUBLESHOOTING

The R-Matey's spent the year testing and troubleshooting in order to provide a ROV that would be fully functional and efficient. Each electrical component had a series of tests before being immersed in water. After testing each part's wiring, they were placed in water to test its waterproof capabilities. The completed vehicle was placed in a 13ft (3.96 meter) chlorinated pool. After each test, the parts and ROV were carefully examined to detect any leaks or damage caused by water. The company developed troubleshooting strategies and techniques that positively impacted the lengthy process. A major strategy is adjusting one variable at a time. Adjusting multiple variables at once makes it difficult to identify the main cause of issue. To eliminate the variable of the source of problems the team took each component and hard wired them into a power source and then to the main source it self. This allowed them to bypass most electrical components like the circuit board.

CHALLENGES

Throughout the processes of creating Próklisi, the team came across various technical challenges. Troubleshooting, changing the tether connector, rewiring, switching out unusable cameras and recalibrating joysticks. The cameras unexpectedly stopped working, after checking the wiring, fuses, LEDs, resistors, and capacitors, and still left with no possible cause, the team believed the circuit board was fried. To determine if the board was fried, the cameras were connected to the circuit board used from the previous year. Both cameras were nonfunctional after the test with the operational board. Before having all motors wired, the tether connector was ineffective. While rewiring, the team implemented the Pufferfish switch in order to correct a separate problem relating to the motors. Adjusting one variable at a time provided an efficient solution in eliminating which area was faulty. The Strafe motor continuously ran without the pilot's control. After calibrating the left joystick,

With every technical challenge there is always a personal challenge to go along. One such challenge the R-Mateys resolved was the matter of attendance and reliability. Certain members had more absences than attendances, resulting in tension between members. When there was problem, the member went to the team leader. The team leader would have a meeting with CEO, Gavin Bentley, and the other two team leaders to reach a decision. If needed, coaches would supervise said meetings to aid in reaching a conclusion. until it was "zeroed in", the pins were taped in. Securing the pins corrected the motors from running without movement of a joystick.

LESSONS LEARNED

After going through technical and personal challenges, the company learned many lessons. While working with circuit boards, it can be difficult to pinpoint where the problem stems from. The company learned it was easier to hardwire and create their own components in the future. An interpersonal lesson revolves around attendance. Next year, the team plans on creating a strict attendance policy which will place more responsibilities on each member. Veteran members with engineering and documentation backgrounds will participate in mentoring new members in order to improve the companies performance.

Finances

After the electrical and mechanical design drafts were completed, an estimated cost of the ROV was written so the company could begin the fundraising process for the fabrication process. From various sponsors, donors, and the remaining balance from the previous year, there was a total income of $8,752.90. Over the course of the build season, the R-Mateys budgeted for Proklisi to cost $1,770.81. This budget includes hardware, electronics, travel, and the main ROV kit purchased from Seamate. This will leave the company in excellent financial standing going into the 2019-2020 season with a balance of $6,982.09. See Figure 25 in the appendix for a complete breakdown of the R-Matey's budget for the 2018-2019 season.

FUNDRAISING

One of the fundamental keys used to get sponsored was to create winning partnership proposals. The team researched and found similarities shared with several businesses such as GRC construction, Zion Marine, STREAMWORKS, and Eastman Foundation. Before proposing a potential sponsor, the team figured out what services they could offer. The proposal offered companies three main sponsoring packages labeled Gold, Platinum, and Silver. The benefits depend on the amount of money donated. A total of $2,665 was raised through this initiative.

Other fundraising activities targeted different aspects of the community. The team leaders organized a Putt-Putt night. Money was raised through ticket purchases, concessions, and hole sponsorships through local businesses. This event took place May the 23rd at a local putt putt center. Currently, the event has raised $2,700 on hole sponsors alone. Additionally funds will be raised through concession sales and a raffle of items donated from local businesses for advertising purposes.

EXPENSES

The actual purchasing and spending for the Proklisi was calculated to be $1,448.74; this is $322.07 under the budgeted amount. The expenses are made up of structure (6.67%), propulsion (9.18%), tether (6.48%), visual (26.09%), electronics (50.13%) and payload (1.30%).

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Appendix

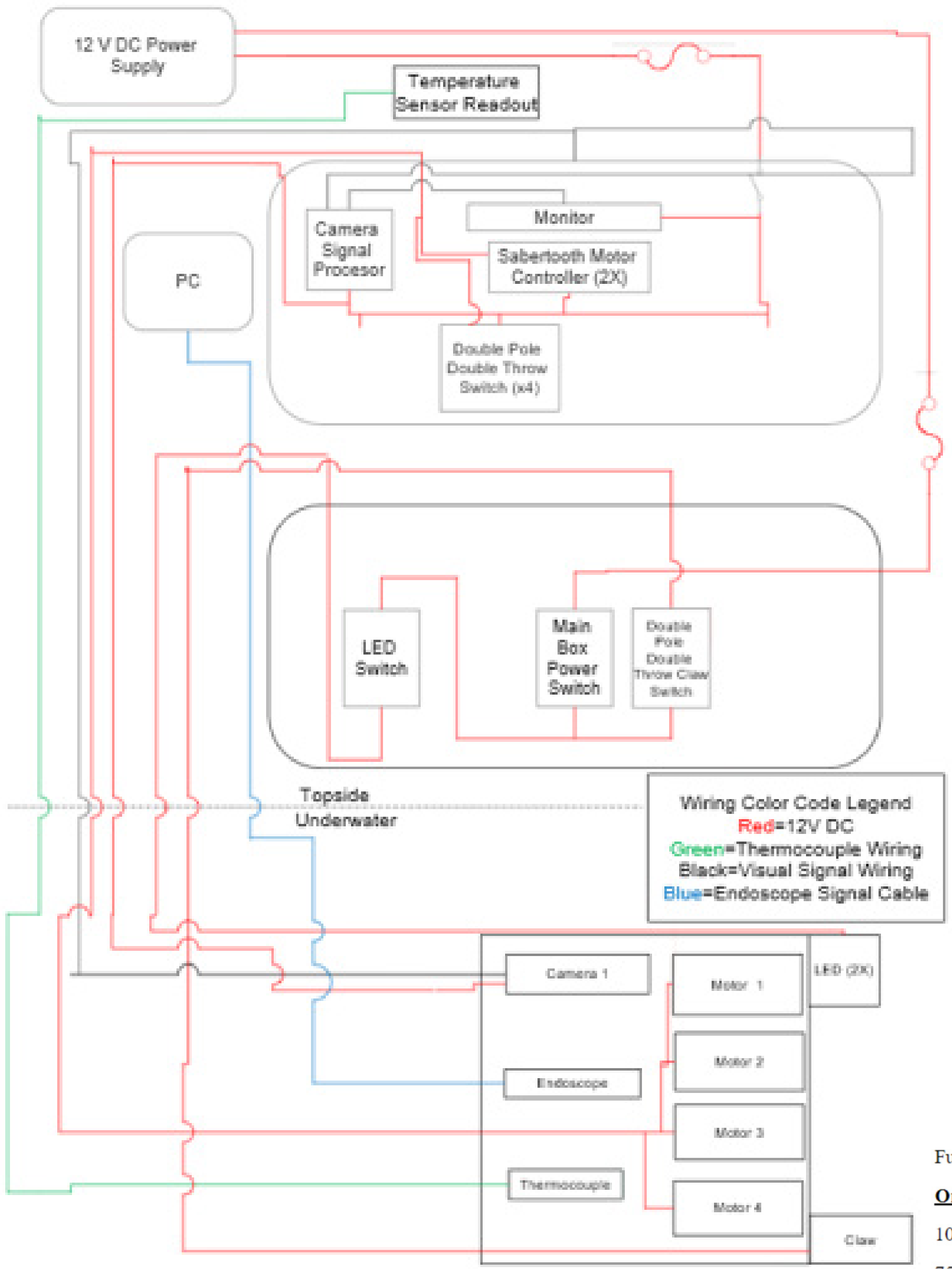

Figure 5: System Integration Diagram (SID) for electronic components of Proklisi.

Fuse Calculations

Orange Box 25 A Fuse

1000 GPH Motors	3.2 A
750 GPH Motors	3 A
Backup Cameras	1 A
	7.5 x 150% = 11.25 A

Black Box 25 A Fuse

2 1500 Lumen LED	2 A
Servo Motor	4.8 A
Micro-ROV Motor	2.5 A
	9.3 x 150% = 13.95 A

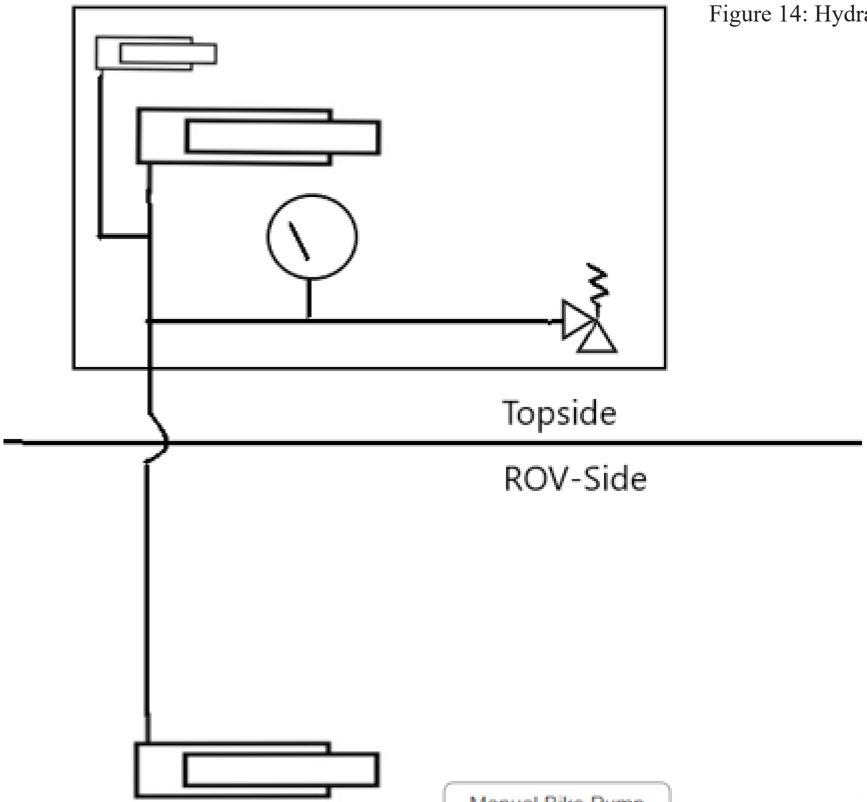

Figure 14: Hydraulic system SID. Created with Autodesk.

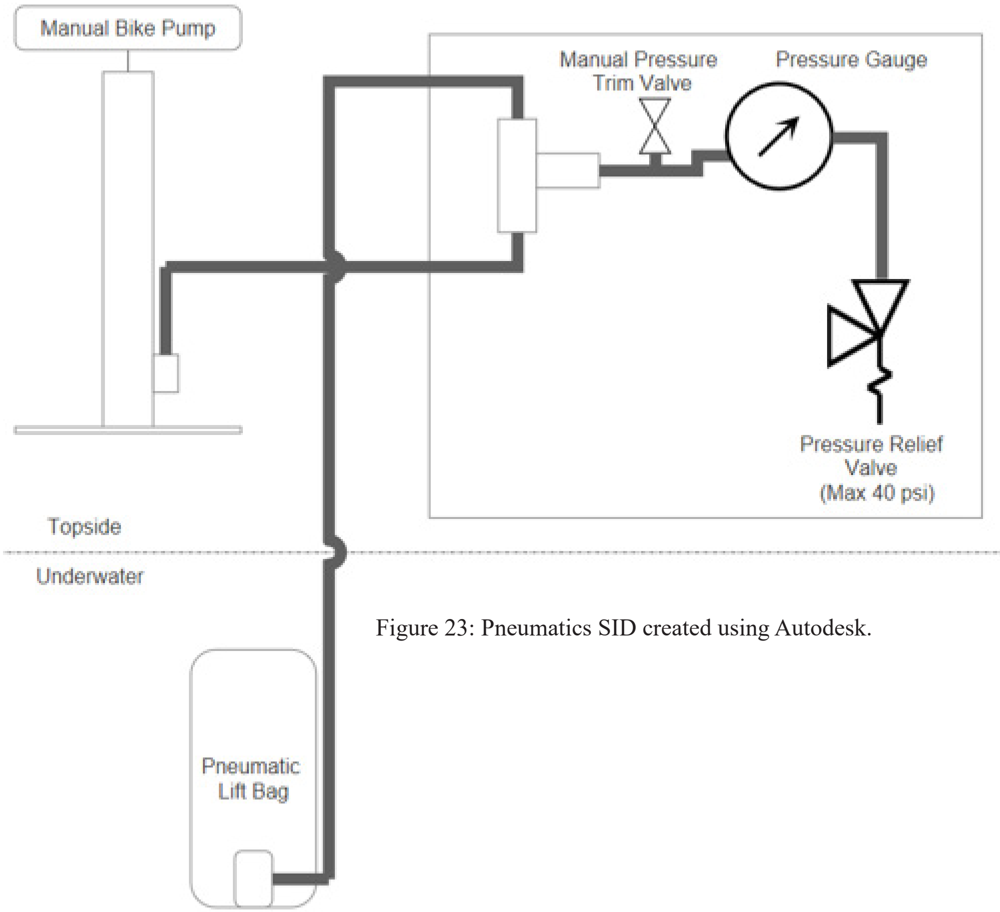

Figure 23: Pneumatics SID created using Autodesk.

Budget 2019

			Reporting period	
School Name:	*DB-EXCEL*		From:	1/1/2019
Instructor/Sponsor:	*Sara Leimkuhler and Erica Gardner*		To:	4/27/2019

Income

Source				Amount
DB-EXCEL				$ 2,952.90
Eastman Foundation				$ 1,500.00
Johnston				$ 50.00
Various				$ 180.00
Physicians Plasma Found				$ 500.00
Goins Rash Cain Construction				$ 200.00
Sponsorship/various				$ 3,370.00
			Total Income:	**$ 8,752.90**

Expenses

Category	Type*	Description/Examples	Projected Cost	Budgeted Value
Hardware	Purchased/New	L channel aluminum, tether managment, tools, etc.	$ 425.50	$ 425.50
Hardware	Re-used/Built	Pnuematics System	$ -	$ -
Hardware	Re-used/Built	Hydraulic System	$ 20.00	$ 50.00
Electronics	Purchased/New	Bilge pump motors, Claw kit, Servo motor, waterproof temp. sensor, Camera system kit, tether management, electrical tape, batteries	$ 375.31	$ 375.31
Travel	Purchased/New	Fuel costs for transportation between R-Mateys headquarters, Kingsport Aquatic Center, and the Marriott.	$ 50.00	$ 50.00
ROV kit	Purchased/New	Baracuda ROV Kit	$ 900.00	$ 900.00

Total Income:	$ 8,752.90
Total Expenses:	$ 1,770.81
Balance:	$ 6,982.09

Figure 25: R-Matey's 2019 Budget Spreadsheet

R-Mateys
400 Clinchfield
Kingsport, TN 37660

ROV Cost

Próklisi
Remotely-Operated Vehicle

Category	Description	Qty	Unit price	Total price		
Structure	1-1/2" x 1/16" Aluminum Angle/ L-Channel	487.68cm Linear	$18.54/243.84cm	$37.08		New
Structure	1-1/2" x 1/16" Flat Bar Aluminum	99.06cm Linear	$13.48/2.44m	$5.48		New
Structure	Rivets 1/8" x 1/8"	66	$0.13/Rivet	$8.58		New
Structure	Subsea Buoyancy Foam R-3312	122.35 Cub. In	$0.29 cubic inch	$35.48	6.67%	New
Structure	Hose Clamps 33-57 mm	3	$3.37	$10.11	$96.73	New
Propulsion	Johnson Compact Bilge Pump 750 GPH	2	$30.76	$61.52		New
Propulsion	3-D Printed Motor Shrouds (PLA Baige)	4	$2.85	$11.40	9.18%	Built
Propulsion	Johnson Compact Bilge Pump 1000 GPH	2	$30.10	$60.20	$133.12	New
Tether	SeaMATE Triggerfish Tether Kit	1	$93.00	$93.00	6.48%	New
Tether	Clamp-on Connector Conduit Fitting	1	$0.96	$0.96	$93.96	New
Visual	Reverse Back-Up Camera Kit (2 cameras)	1	$180.00	$180.00	26.09%	New
Visual	Subsea Lumen LED Light	2	$99.00	$198.00	$378.00	New
Electronics	Barracuda Control Box Kit	1	$700.00	$700.00		New
Electronics	Underwater Arduino Temperature Sensor	1	$11.95	$11.95	50.13%	New
Electronics	2-Wire Motor 393 Servo (VEX)	1	$14.99	$14.99	$726.28	New
Payload	Vex Claw Kit	1	$19.99	$19.99	1.38%	New
					$19.99	
			Subtotal	$1,448.74		

Figure 26: R-Matey's Expense Report Spreadsheet