Kailua High School
451 Ulumanu Drive
Kailua, HI96734

Surfrider Marine Recovery Systems

Technical Report

Austin Vegas
CEO - Class of 2013

Christopher Campos
COO/Pilot - Class of 2013

Samuel Rasay Jr.
Technical Writer - Class of 2013

Jacob Valencia
R&D - Class of 2013

Kristen Izmigawa
CFO - CLass of 2013

Jian Madiam
Tether Boss - Class of 2014

Ipo Silva
Machinist - Class of 2013

Michael Sabate
Electrical Engineer - Class of 2013

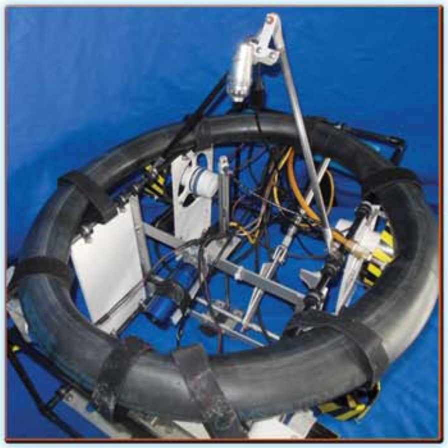
Leonid Poleshaj
Mentor

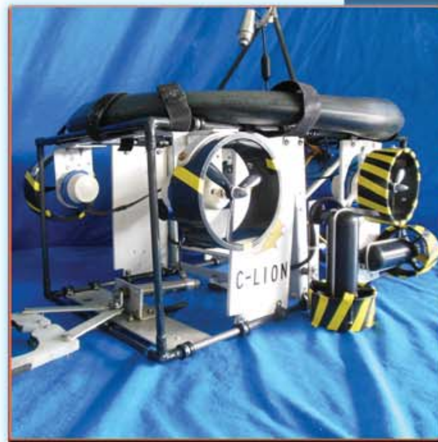
Nicholas Poleshaj
Mentor

C-LION MkIII

Surfrider Marine Recovery Systems

ABSTRACT





Images 1-3 - C-LION MkIII
Front, Top and Side views

Surfrider Marine Recovery Systems (SMRS) is a company with fresh ideas and a dedication to designing and developing quality, cost-effective ROVs. Driven by the four pillars of our corporate charter – Reliability, Efficiency, Ingenuity, and Adaptability – our company fulfills the needs and requests of our customers.

Our latest design, the **C-LION MkIII**, was built on those same four pillars.

- **Reliability** – Quality workmanship paired with top-standard engineering means a robot that is always ready for any challenge.
- **Efficiency** – Resources are limited, we use what we have to its maximum capability.
- **Ingenuity** – The best solutions are those that are simplest.
- **Adaptability** – We can meet challenges of a fast-moving global marketplace

C-LION MkIII is the result of a transformation from a robot specializing in shipwreck surveying to a machine capable of meeting the high demands of Science as we explore our ever-changing oceans.

We acknowledge the desire for a smart financial investment. We also know there must be no compromise to quality and we understand we have a responsibility to be good stewards of the sea. We meet these tough standards by designing and fabricating our own components with a dedication to repairing and using recycled parts and equipment. The C-LION MkIII is a machine born of its proud ancestors but improved upon with new innovation – maximizing the effectiveness of every single element.

C-LION MkIII

This Cat ain't afraid of the water...

Table of Contents

All photos, images, and tables contained in this report were generated by Kailua High School Surfrider Marine Recovery Services unless otherwise noted.

THEME

If the tides are the Earth's pulse, then the Oceans are most certainly her life's blood. Like a physician monitoring a gravely ill patient, we need to assess and understand the ocean as perhaps the most important part of our ecosystem.

Global Climate Change is a very real problem – one that 97% of scientists now agree is due to human activity (Consensus Project, 2013). It is our duty to repair the damage we have created and stem the destructive behaviors that have led us to the brink of catastrophe. Hawaii watches with bated breath knowing that the widespread coral damage around the world has been relatively gentle in our waters – but it's only a matter of time until these waters are affected.

Image 4 – Florida, Key West 1980
Photo courtesy of UPWELL

Image 5 – Florida, Key West 2010 photo courtesy of UPWELL. Same reef as pictured above showing 30 years of damage

With a warm climate, and a protective natural barrier, the coasts of the Hawaiian Islands are home to a diverse population of wildlife unique to our specific chain in the ocean. However, with rising ocean temperatures due to environmentally irresponsible policies, it is clear that Hawaii's current situation is tenuous at best. From the immediate threats of diminished fish supply and coral bleaching to the long-term concerns for rising sea-levels, the time is now to act aggressively towards making substantial improvements to how we treat our oceans.

Hawaiians have known the ocean as *Kai*, and have long lived in a symbiotic relationship with it. The Hawaiians knew the importance of the ocean's resources, and Surfrider Marine Recovery Systems hopes to continue this tradition through the use of our Remote Operated Vehicle (ROV), the C-LION^{MkIII}. By using our ROV, we aim to achieve a better understanding of our ocean. Gaining information and insight on the impact we have on the environment, and to foster a better understanding of how to reverse the damage we have already done and how to prevent future destruction.

Design Rationale

Due to the nature of the missions which C-LION^{MkIII} had to carry out there were numerous design elements to be considered including: Structure and Buoyancy; Propulsion; Controls System; Surveillance (Cameras) and Payload Handling Tools. The following subsections cover the details of these elements.

Structure & Buoyancy

The carbon fiber frame of C-LION^{MkIII} has been designed to be customizable, adaptable and maintainable.

Carbon fiber was selected as the main structural frame material due to its high strength to weight ratio, allowing greater payload carrying capacity than similar ROVs, as well as corrosion and conduction resistance. The 8mm carbon fiber rods making up the frame were connected using custom designed and fabricated stainless steel (S.S.) joints. To complete the frame structure, liquid tape was used to cover the exposed S.S., protecting the RSN equipment during the mission and protecting the employees of SMRS from any sharp edges during handling operations. Image 6 shows the completed C-LION^{MkIII} ROV with the carbon fiber frames and S.S. joints clearly visible.

To allow for a fully customizable ROV, four PVC panels were fastened to the frame. These panels serve as the foundation for mounting custom tools quickly and easily to the ROV. In addition to the ease of installing tools, the PVC panels themselves can also be relocated virtually anywhere on the frame structure further increasing the versatility of the ROV. These lightweight panels are very close to being neutrally buoyant (displace water equal to their weight) which is an added bonus to go with their utility.

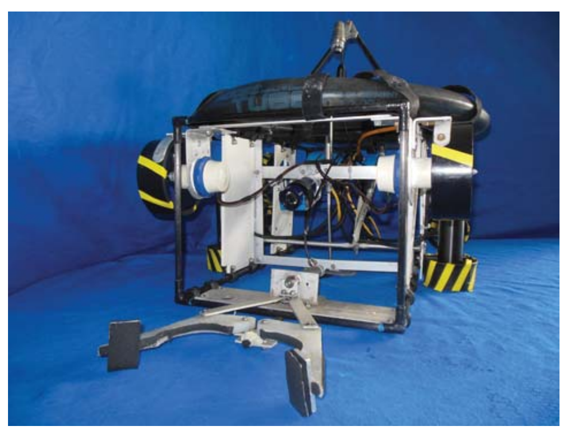


Image 6 – C-LION^{MKIII} Front View

Recognizing that buoyancy is a major concern and that the payload to be carried by the ROV is variable, SMRS chose to develop an adjustable buoyancy system. During the design phase SMRS constructed scale models to test two distinct approaches to tackling the problem: The first approach featured the use of a ballast tank which could be filled or emptied as needed. The second approach used an air tube system which could be filled to provide additional floatation or emptied to remove floatation.

An ROV which is negatively buoyant (tends to sink) will suffer from poor maneuvering, and other performance, issues as a certain percentage of the propulsion power must be used to hold it in place within the water column.

Both systems were tested using a scale model of the C-LION[MkIII] ROV (see images 7 and 8).

Image 7 – Ballast System Model

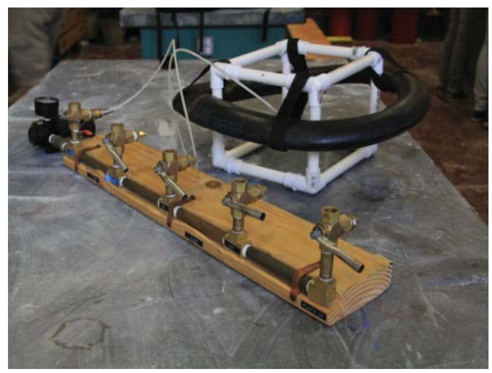


Image 8 – Air Tube System Model

Two tests were carried out, five times each, first to determine the time required to achieve neutral buoyancy at 1.21m depth, and second, to determine surface time from the bottom of the 1.21m depth. Each approach proved successful, with each system proving to be superior in one test. The following table shows the summary from the two tests:

	Neutral Buoyancy Test Time (sec)		Surfacing Test Time (sec)	
	Air Tube System	Ballast System	Air Tube System	Ballast System
Trial 1	21.23	15.35	6.12	8.39
Trial 2	21.46	18.71	6.18	8.37
Trial 3	21.34	16.94	6.09	8.57
Trial 4	21.51	16.81	6.24	8.46
Trial 5	21.30	17.53	6.16	8.32
Average	**21.34**	**17.06**	**6.15**	**8.42**

Table 1 – Buoyancy testing

Due to our testing and past experience, the air tube buoyancy system was chosen for use on C-LION[MkIII].

Propulsion

To propel the C-LION^{MkIII} through the water, we initially used six motors. Two SeaBotix BTD150 thrusters were used to propel the C-LION^{MkI} forward and back and another two were used to propel the C-LION^{MkI} vertically. Two bilge pumps, both equipped with a 4-bladed propeller, served to provide us with lateral propulsion. The C-LION^{MKIII} uses the same motor and thruster placement as the C-LION^{MkI}; the difference being the addition of the thruster rotation system, which gives the C-LION^{MkIII} an additional set of forward thrusters. The poor maneuverability of the C-LION^{MkIII}'s predecessor encouraged us to research ways to improve the maximum propulsion output of its motors.

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Increasing our thrust output from our lateral motor was an earnest research endeavor. Surprisingly, our research indicated that the propulsion deficiencies were not due to the power of our thrusters, but rather our propellers. A number of Bollard Tests were conducted using propellers of different pitches, blade configurations and sizes.

Image 9 – New three blade propeller

Testing showed a significant increase in thruster efficiency when we employed a three-blade propeller (see: Table 2 & Image 9) rather than the four-blade unit we had been using previously. With the output of a modified bilge-pump thruster, the power levels to the propeller are dramatically reduced by the extra drag caused by the fourth propeller.

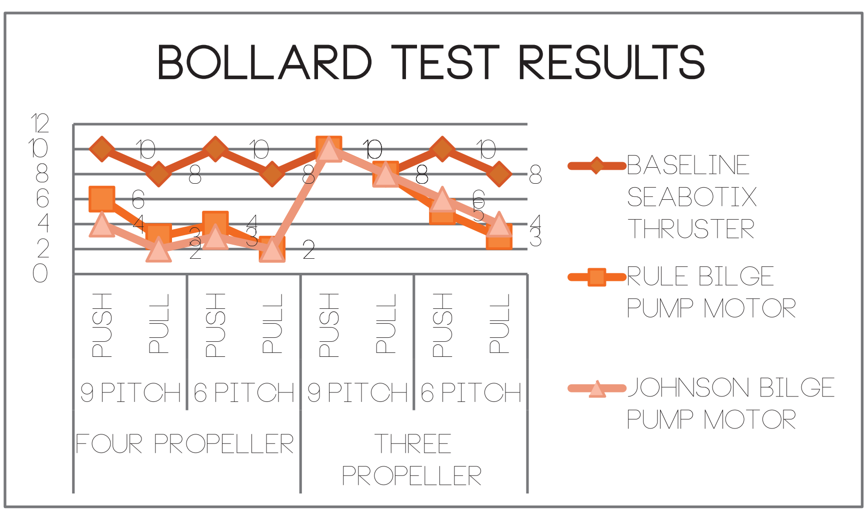


Table 2 – Bollard test results

Thruster Rotation System

Simplicity being the ultimate goal of Engineering, we knew we had hit upon a good solution when someone said "why didn't we think of this before?"

Our lateral thrust issue improved, we turned our attention towards improving our forward and reverse thrust. The solution was elegant in its simplicity. We designed and developed a thruster rotation system that allows our vertical thrusters to become a second set of forward thrusters.

The C-LION^{MkIII} Thruster Rotation System is run by a single-line spring-loaded pneumatic that keeps the thrusters vertical when not in use. When air from our pneumatic system is forced through, a rod extends and pushes a lever which rotates the thruster position axle moving the thrusters in a forward position. The thruster rotation system's versatility and outstanding performance has been an extremely beneficial addition to the C-LION^{MkIII}'s design.

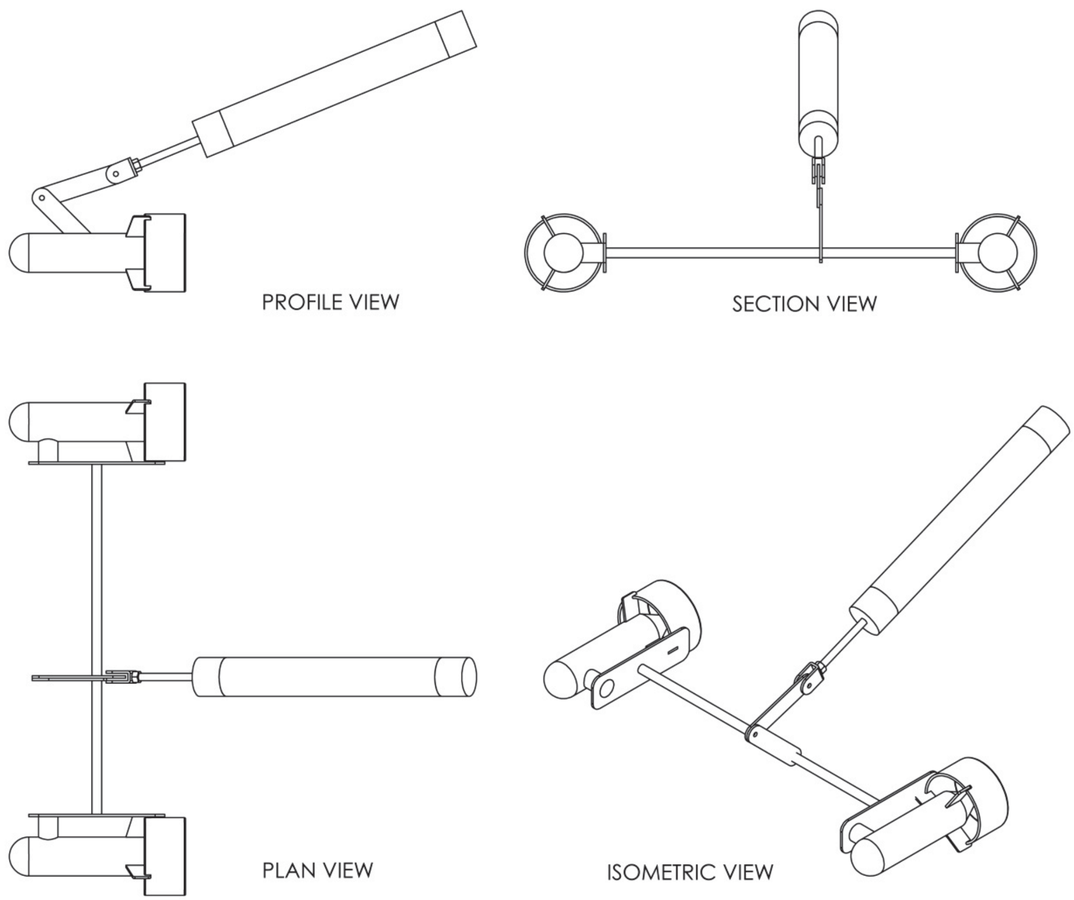


Figure 1 – Thruster Rotation System Drawing

Control System

If there is one component of the C-LION^{MkIII} that is most frequently adjusted and changed for improved performance, it would be our control box. Because of the adaptability of the MKIII, it is imperative that the control box be able to adjust and change along with the robot. Our control system is divided into two parts: the electrical system (see: Electrical Schematic p18) and the pneumatics manifold.

The electrical system is housed in our control box which keeps the entire system protected from water and contained for safety. The controller for C-LION^{MkIII} is a RealFlight Sim Controller. This is a flight simulator controller that has been customized to suit our needs. The flight simulator's joysticks are pressure-sensitive and adjust throttle accordingly. Variable controls allow us to adjust and finely-tune precision for maximum throttle, depending on the conditions of the water and the needs dictated by the mission.

Also controlling C-LION^{MkIII} are two double pull double throw switches which activate our lateral thrusters. Wired so as to quickly switch polarity, we are able to change direction with ease. Our four lateral thrusters are wired in pairs, increasing movement. Depending on current flow, propeller blades rotate to push the ROV either right or left with speed and precision.

Pneumatics Manifold

During the original design process for the C-LION^{MkI}, we faced the decision of running either an electrical system or a fluid system. Given the scope and design of our payload tools, we decided to stay with a pneumatics system. The least of which, being the ability to make minute adjustments quickly. By running a fluid system, the electrical power not being drawn by the pneumatic payload tools is available for other purposes such as additional cameras and thrusters. Substantial improvements were made to the design to improve aesthetics, reduce bulk and to improve the overall safety of the system.

The pneumatics manifold control box houses four valves that operate our buoyancy, manipulator, all-purpose pneumatic lift, and our Thruster Rotation System; the box also features a compartment which allows easy access to the manifold in the case of a repair or modification. Each of the four valves operates in a similar fashion to avoid complexity. When the entire system, or a single valve, is not in use, the "neutral" position is used to keep air from being forced into the system or vented. The "down" position (when the valve is turned towards the operator) allows air to flow to the tools for operation. The "up" position (when the valve is turned away from the operator) allows pressure to be vented from the pool to reset or undo the operation.

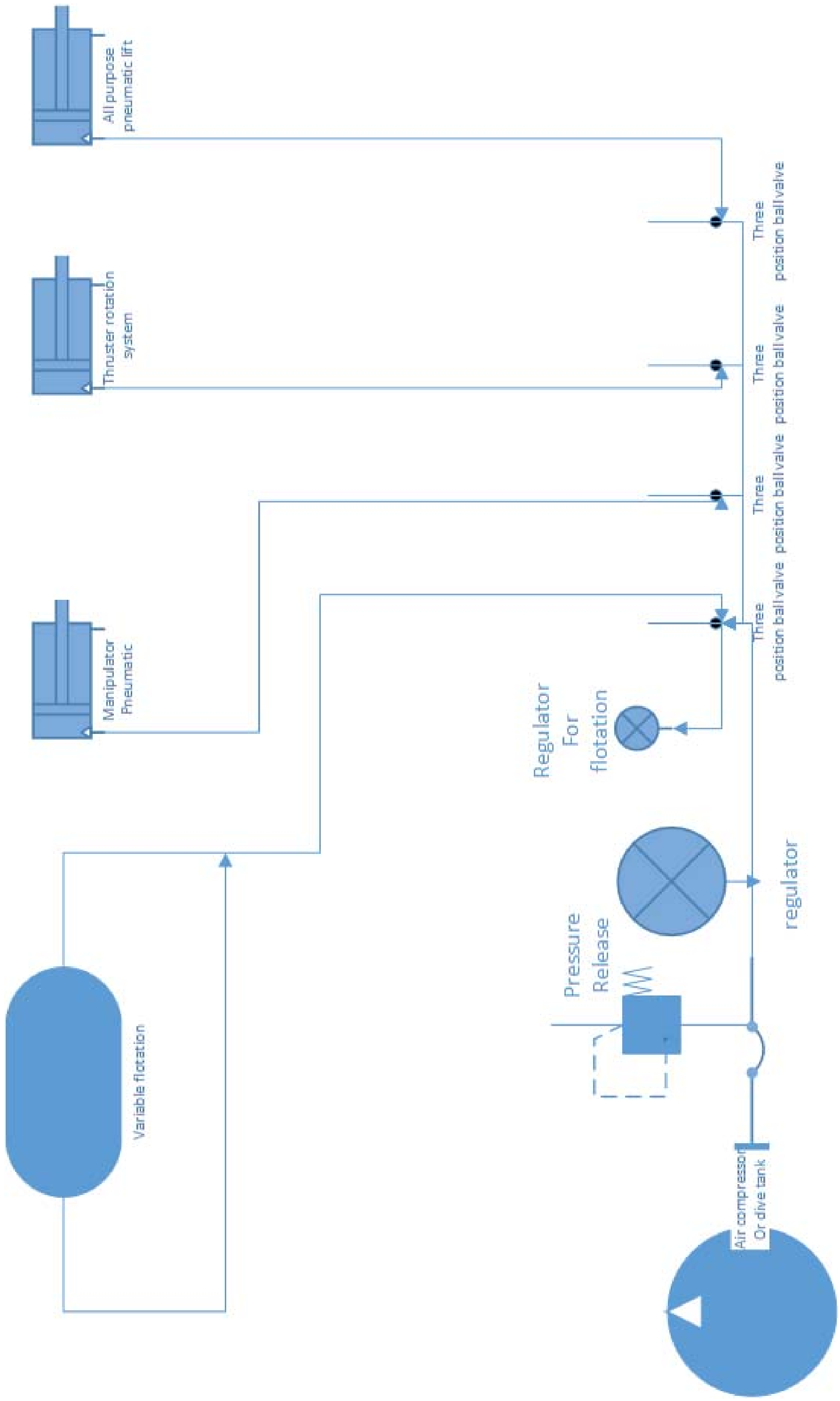


Figure 2 - Pneumatic System Schematic – C-LION^{MkIII}

Manipulator

The underwater missions involved in properly maintaining the scientific equipment necessary for ocean observing require, at the very least, a highly functional manipulator. After experimenting with a variety of different designs, we created a manipulator capable of landing accurate grabs on objects of all different shapes, sizes, and textures.

Keeping in mind our budget, we chose the materials for the manipulator with great care. Both sides of the manipulator were created out of plastic composite and were lined with rubber to increase friction while retrieving objects. They are joined by a carbon fiber rod and were attached to a single aluminum flat bar, which is attached to the pneumatic actuator.

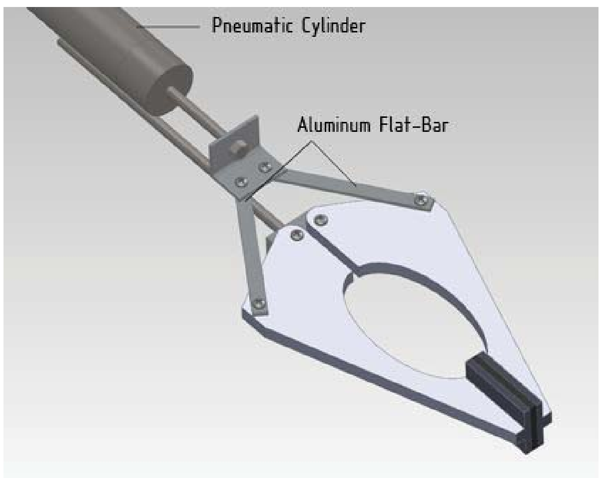


Figure 3 – Pneumatic manipulator, CLOSED position

Previously, our manipulator was operated by a double-line pneumatic actuator, but the additional bulk of the air lines in the tether slowed down the movement of the ROV significantly. An improvement on the C-LION^{MkIII}, we have replaced the double-line pneumatic actuator with a single-line spring-loaded pneumatic actuator. The swap allowed us to reduce the bulk of the tether, while still retaining the accuracy and power of the original design.

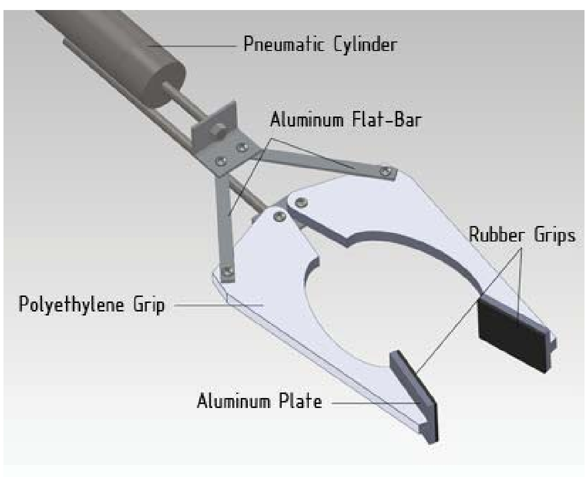


Figure 4 – Pneumatic manipulator, OPEN position

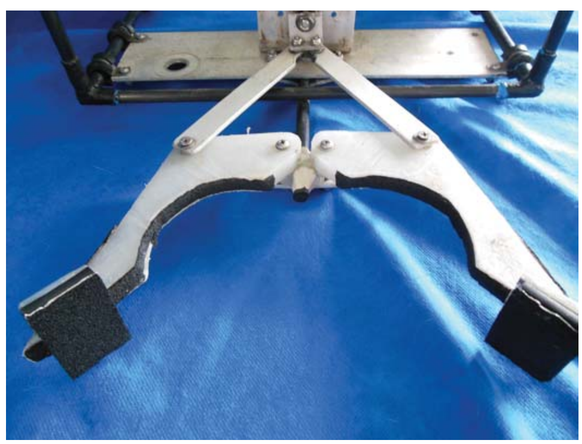


Image 10 – Actual Manipulator as manufactured

Payload Tools

All-Purpose Pneumatic Lift

The all-purpose pneumatic lift is a crucial tool for us to perform a majority of the tasks involving maintenance and installation of the RSN. Our mission tasks require us to lift and move objects that cannot be handled by the claw. The all-purpose pneumatic lift is constructed out of a stainless steel rod that is attached to a single-line spring-loaded pneumatic actuator. The spring keeps the hook in place against the guide plate to keep objects from escaping when the hook turns. We implemented a U-cut into the guide plate to compensate for the hook's rotation when retracting.

Temperature Sensor

To read temperatures accurately underwater, we chose to design a deployable temperature sensor. The temperature sensor is transported by the C-LION^{MkIII} to a desired location and sends temperature readings to our temperature read-out display. One of the major concerns that came with the purchase of the temperature sensor was the length of the cable. As a solution, we split the cable and added an extra 11.5 meters of length to it, allowing the temperature sensor to accurately read temperatures at a maximum depth of 12.2 meters.

Cameras

The C-LION^{MkIII} is equipped with three commercial waterproof video cameras. Each camera has its own cable within the tether that supplies power and signal. These cameras were chosen for their high quality and simplicity. The open interior design of the C-LION^{MkIII}'s frame has granted us the freedom of having multiple possible locations for our cameras. These cameras give our pilot excellent quality coverage of our surroundings and ROV.

The camera used for navigating is located inside of the C-LION^{MkIII}'s frame and is held in place by our own fabricated mount. The mount keeps it facing forward and aims the view of the camera slightly downward towards the claw. Our second camera is located on the lower backside of the C-LION^{MkIII}'s frame. It provides sight of the all-purpose pneumatic lift and any obstruction that might otherwise damage the robot. The final camera is placed on a bipod that allows us to view the ROV when using the all-purpose pneumatic lift; this is especially useful with precarious precision manipulations and placement on the seafloor.

Safety

Safety is a top priority at Surfrider Marine Recovery Systems. As such, we have enforced strict safety guidelines and regulations.

It is unbreakable company policy that every team member wears the appropriate safety gear when working with machine tools, or when using rotary tools like the band saw, grinder, or wire wheel.

Safety features are also implemented on the ROV. The C-LION^{MkIII}'s circuitry is protected by the main resettable 25 amp circuit breaker; a feature that protects our entire control system in the case of a catastrophic event. If the C-LION^{MkIII} encounters an electrical surge or problem anywhere in the electrical system, the circuit breaker will trip, killing the entire system and protecting everyone from injury. Our amperage draw is monitored by an amperage gauge to better analyze, predict, and prevent potentially hazardous instances.

As an added safety measure, we have installed an emergency kill switch which allows us to quickly cut off power to the ROV should the need arise.

All of our circuits are designed to run off of their own individual fuses. Should an individual system fuse blow, all other circuits remain intact. This allows us to safely troubleshoot and repair our control system.

Various modifications have been made to the C-LION^{MkIII} design to incorporate safety. The thrusters are shielded by improved shrouds which prevent foreign objects from entering and damaging the blades or the ROV. These shrouds also afford protection to anything in the water that the propeller blades might otherwise come in contact with – including divers. The visibility of these shrouds was improved with yellow caution tape to make people aware of a potential hazard.

Image 11 – Safety Cone Courtesy: PSDGraphics

Challenges Faced & Lessons Learned

One of the most difficult challenges we faced was developing and constructing payload tools for the C-LION^{MkIII}. Many of the mission tasks required us to be swift and accurate, something that the C-LION^{MkI} had difficulty with. Despite being able to survey a shipwreck, the C-LION^{MkI}'s design was too heavy and rendering it unable to do maintenance on an RSN. Much of our time and effort went into developing, testing, and evaluating many different ideas until we found something that we could compete with effectively.

Engineering and working through the construction of the Thruster Rotation System was another hurdle that proved difficult to clear. The natural progression of a new idea meant that we had to suffer the growing pains of innovation. Working from an idea, into a complex "maybe", into a simple and effective design was certainly worth the effort. A majority of our development went into testing the system until the angle of the pneumatic cylinder that operates it, turning the motors at a perfect 90 degree angle.

We faced many non-technical challenges as a company as well. Surfrider Marine Recovery Systems has two teams, Varsity and Jr. Varsity. The Varsity Team consists of the original nine members and sets the bar for Jr. Varsity, which is a team of new recruits. For several months, the company struggled with a lack of performance because of the required management for both teams. After dealing with the inevitable commitment issues with new team members, we decided to make changes to both team rosters. With this shakeup – adding experienced blood to a new and slight tweaking of our schedules, we were able to pull together two effective teams.

The biggest non-technical challenge that we faced overall as a company was the over-commitment as our team was primarily made up of very busy seniors. Ultimately, we resolved the problem through schedule changes and team discussions helping us avert problems that would have otherwise torn the company apart.

Image 12 – Kailua High School Team Surfrider Marine Recovery Systems
L-R: Austin Vegas, Romnick Valmoja, Michael Sebate, Kristen Izumigawa, Sam Rasay, Christopher Campos, Ipo Silva
Not pictured: Jian Madiam

Reflections

Image 13 – Austin Vegas

We have been through a lot the entire year and one reoccurring theme that we have observed as a company is relying on our quick thinking and problem solving. As a team, we bonded together on a whole new level because of the trust we built with one another. I learned just what we were capable of and how much room there was for improvement. Each and every member of the team was important to the success of the mission at hand. – **Austin Vegas, CEO**

Being in the robotics program for the past two years has taught me many things that will benefit me in life after high school. I have learned to manage and lead people to accomplish goals and in turn, have improved my problem-solving skills. I now think outside of the box in order to design and build the tools I need to accomplish my goals. I have enjoyed the experience because my friends and I were able to make our dreams a reality. – **Christopher Campos**

Image 14 – Christoper Campos

Image 15- Samual Rasay

My experience with the company over the past two years has been amazing. Designing and developing a solution in a real engineering environment has been enriching. I have learned new skills that I would have otherwise lacked, and greatly improved the ones I already have. The practical knowledge that comes along with this competition is something that will stay with me for the rest of my life, and will definitely be applied in my pursuit of becoming a software engineer. – **Samuel Rasay Jr.**

Joining robotics has been one of the best decisions in my life. As the machinist for last year's robotics program, my job was to create, build, and install the products to mount on the ROV. My friends helped me throughout the year when I was stuck on things and felt like failing. All the struggles and sacrifices we went through, made us a better team and further increased our level of friendship. I now feel more comfortable with hands-on activities like building and assembling products at the same time. – **Romnick Jude Valmoja**

Image 16 – Romnick Valmoja

Image 17 – Kristen Izumigawa

As the newest addition to the company, it was a great experience working with the team. I was able to exercise my skills as the CFO and explore new fields. – **Kristen Izumigawa**


Image18 – Michael Sabate

Robotics has been like a fountain of knowledge for me. There is so much to learn, not just from our mentor, but from each other as well. As the company's electrical engineer, my responsibilities were the construction and upkeep of our electrical systems located within the control box. Working on the control box and being a part of this team has given me a plethora of skills that will definitely benefit me in the long run. I will never forget my time with the company, and the experience it has brought me. – **Michael Sabate**

Being able to work on the ROV using tools and techniques I would not have been introduced to otherwise, was an interesting learning experience. I was able to work on so many different parts of the ROV that I developed skills I already had, and gained skills I thought I never had. I would love to do it all again. – **Jacob Valencia**


Image 19 – Jacob Valencia


Image 20 – Jian Madiam

I took away a lot of things from my experience with the company. I realize that sometimes it takes more than just you alone to get a task done. There is a lot of time, sacrifice, and brain power that goes into striving to become the best. I had a lot of fun, and I look forward to facing the challenges ahead.
– **Jian Madiam**

Working as a team is better than working alone. Through working with the company, I discovered skills that I never knew I had, and put it to use rather than wasting it. I believe working with robotics is able to change your life in a positive way by allowing you to discover yourself. – **Ipo Silva**


Image 21 – Ipo Silva

Acknowledgements

Surfrider Marine Recovery Systems would like to recognize the following people for their motivation, support, advice, donations, and compassion. Without these individuals, we as a company would not be where we are today:

Leonid "Uncle Lenny" Poleshaj (Mentor) – You have our utmost thanks and our eternal gratitude and respect. None of the things we accomplished could have been made possible without your help. Thank you for always being ready and willing to assist us whenever we needed it. Your continuous support over the past two years is something we cannot put a price on. You have helped us grow, and develop as a team, and as people.

Ms. Francine Honda (Principal) – Words cannot express how grateful we are to have you as our principal. Providing us with our own classroom to work with and showing interest and support in our program means the world to us. Thank You.

Mr. John Jay Feurer (Science Department Head) – Thank you for assisting us in our endeavors. You play such a big role in getting us where we need to go.

Mrs. Jill Laboy – For showing us a huge amount of support and helping all of us with our public speaking skills, we are indebted to you. Your efforts will definitely carry on with us throughout our pursuits.

Jill Zande (MATE Associate Director, Competition Coordinator) – Thank you for allowing us to pursue our dreams and for fanning the fire that fuels those dreams. This experience has been amazing!

Aunty Patti – You have taken such good care of us while we used your pool to practice in. Most of us would have died from starvation if you had not fed us during our test runs.

Mr. Rodney Tabiolo – Thank you for allowing us to use your tools and shop as well as giving us advice to better improve our robot.

Hydra-Air Pacific – For supplying us with parts at your cost.

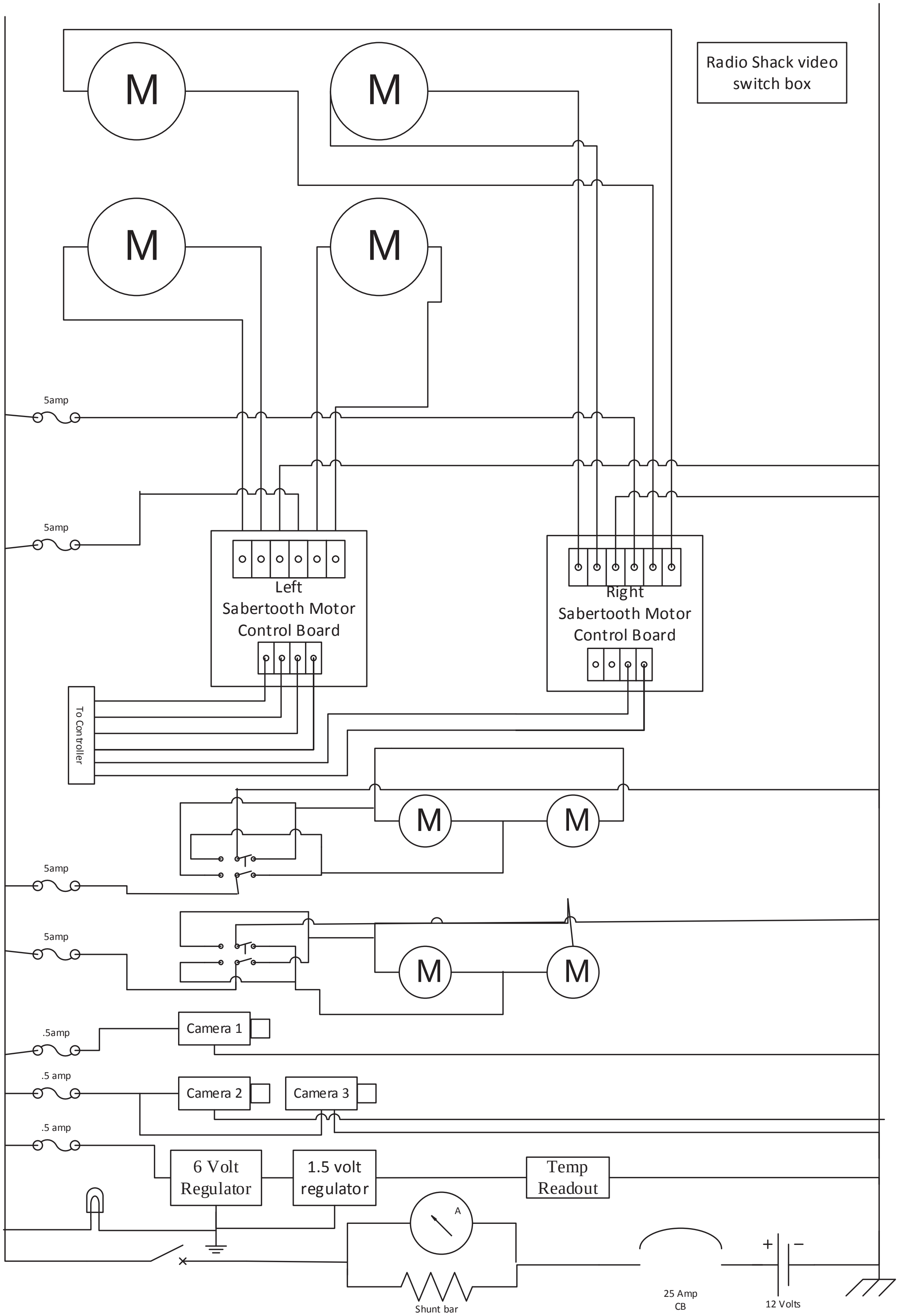
Hardware Hawaii – For the generous donation of miscellaneous wiring, it was very helpful.

Amaron CMD – For the scholarship and parts donation.

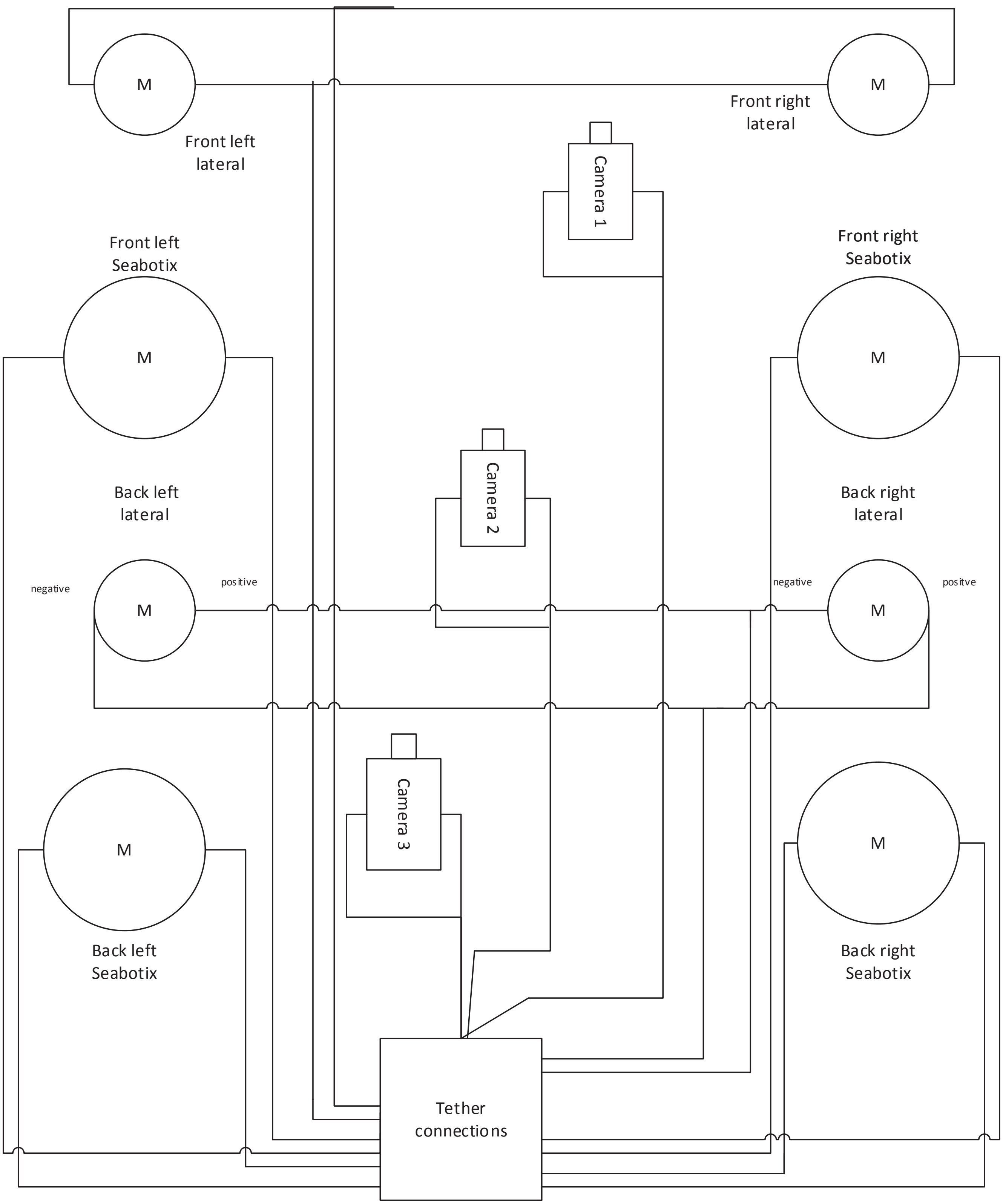
RK Industries Machine Shop – For helping us resolve our aluminum welding problems.

BUDGET

	Part	Total Cost	Value of Donation
	Friends of Hawaii Robotics Grant		$650.00
	Funds from last year		$2,700.00
MISSION PROPS	PVC pipes and fittings for props	$216.93	
	Air Cylinder	$27.35	
	Digital Panel Mount	$31.60	
	Brass Nipple (3)	$19.47	
	Speaker Wire (155m)	$17.50	
	Diamondback Sleeve (15.25m)	$80.33	
	Air Cylinder	$63.50	
RESEARCH & DEVELOPMENT	Bilge Pump (700 GPH)	$32.99	
	Bilge Pump (MTR 1000)	$37.49	
	20.32cm Propeller (6 Pitch)	$7.90	
	20.32cm Propeller (9 Pitch)	$4.72	
	Regulator w/ guage	$32.02	
	Nylon Tubing (30.5m)	$1.55	
	A/B Male Connectors (4)	$39.79	
	Bushings (2)	$4.31	
TEAM ITEMS	Term Ring (10 pack)	$2.69	
	Marine Sealant	$14.99	
	4" ABS Coupling (3)	$11.07	
	Speaker Wire (155m)	$26.00	
	A/B Male Connector (6)	$59.69	
	5/32" Black Nylon Tubing	$108.18	
	Cushion Clamp	$2.82	
	1/4" Brass Compression Elbow	$3.79	
	2.5cm Black Rescue Tape	$11.83	
	Electric Friction Tape	$7.58	
	Chalkline Cotton String	$5.49	
	Misc. Items	$25.00	
DESIGN IMPROVEMENTS	Pneumatic Actuator (17.78cm)	$31.75	
	Pneumatic Actuator (15.24cm)	$29.45	
	Pneumatic Actuator (10.16cm)	$29.45	
	Brakeline (45.75m)	$90.09	
	Propellers	$7.80	
	ABS Coupler (5")	$11.07	
	Thermometer	$31.60	
	Thermometer Circuit Boards (2)	$7.00	
	Aluminum Flat Bar (2.5cm)	$7.49	
	Tether Friction Guard	$70.09	
	Control Box Tether Connectors (2)	$9.90	
	Propeller Collets	$9.90	
	Speaker Wire (18 Gauge)	$9.90	
	Thermometer Speaker Wire (16 Gauge)	$12.35	
	Male Push-in Connectors (6)	$36.36	
	Poster Boards	$87.00	
	Tax & Shipping	$94.04	
	Cost of Improvements	$481.31	
	Total	$1,471.94	$3,350.00
	Estimated Value of ROV	$1,800.00	



Control Box Wiring Diagram – C-LION^{MkIII}



ROV Side Wiring Diagram – C-LION MkIII