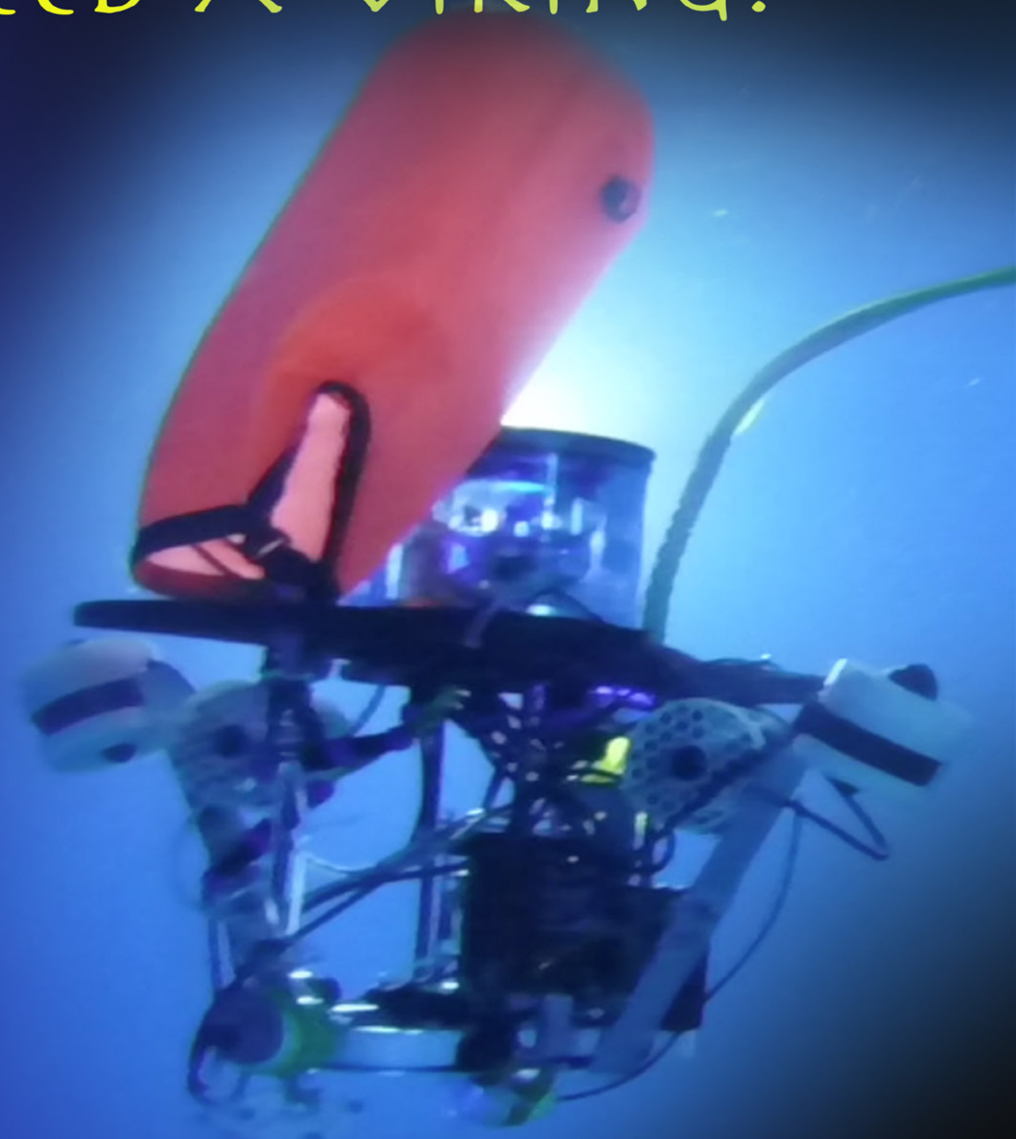
When you need to explore waterways...

YOU NEED A VIKING!



Request For Proposal:
Eastman Company via MATE
Kingsport, TN
June 20-22, 2019

MATE
ROV COMPETITION
2019

LONG BEACH CITY COLLEGE
VIKINGS

MATE ROV
COMPETITION

INTERACTIVE TABLE OF CONTENTS

COMPANY: VIKING EXPLORERS

Long Beach City College, Long Beach, CA

Photo: A. Hill

Alan Hill
CEO
“Canute”

Triton Seibert
Micro ROV Designer/Software Design
“Øystein”

Vaclav Sareja
Image Recognition Software
“Sven”

Raul Felix
Electrical Engineer
“Beserker”

Peter Donovan
Image Recognition Software
“Sven”

Mentor: Scott Fraser

Johnathan Hernandez
Software Design
“Scon”

Krista Zaloudek
Archivist/CFO
“Odin”

Oscar Basurto
Surface Controls
“OB1”

Gerardo A Barrera
Lead Software Developer
“Zapitor”

Matthew Hall
Surface Controls
“Magnus the Tec”

Timothy Recker
Micro ROV Designer/Software Design
“Goðjaðarr”

Omar Quezada
Mechanical Engineer
“Wiiabo”

David Prieto Pineda
Mechanical Design
“David the Claw”

Brandon Ormeno
Software Design
“Torsten”

America Castaneda
Mechanical Engineer

Angela Montes
Mechanical Engineer
“Valdis”

Michael Lyon
Hardware Design
“Olaf”

ABSTRACT

The Vikings Explorers heard the call of a Request for Proposal (RFP) issued by MATE and the Eastman Company for a remotely operated vehicle (ROV) and crew to navigate fresh water regions of Boone Lake, Boone Dam and The South Fork of the Holston River. The Viking Explorer's ROV will help ensure public safety through dam inspection and repair, as well as helping to maintain healthy waterways. And lastly the Viking Explorer's ROV will assist in preserving the history of the region.

In compliance with the specification put forth, the Viking Explorer's ROV is capable of autonomously surveying the dam, creating a survey map and mark the locations of cracks found. For smaller, more difficult to find potential mud flows which can leak to catastrophic sinkholes, the ROV is able to deploy a self-propelled microROV featuring lighting and video capabilities. In addition, ROV will measure and recover to the surface, civil war era cannons. Other measurement capabilities include: temperature and pH sampling of water, and determining the ferrous nature of cannon shells.

The Vikings answered this challenge with a lightweight, maneuverable, fast, strong and modular ROV fitting into a spherical space of 23.5cm in diameter and weighing approximately 160N. The design allows for task specific packages to be quickly changed as well as future proofed for future customization. Deep learning trained algorithms were used to enable computer vision to optimize work flow and automate dam crack detection. When you need to explore waterways… You need a Viking!

PROJECT MANAGEMENT

The LBCC Viking Explorers have an all-inclusive and open door policy; all are welcome. In addition to the host program of Electrical Technology, outreach included students in the Computer Programming, Mechanical Design and Engineering Programs. We also reached out to schools nearby that may not have been able to get funding to build their own robot. Recruiting was also done at ROV demonstration days, as well as local meetups. The Viking Explorers faced a significant challenge in that the Long Beach City Electrical Technology Department, site of the lab space used to create the robot, was uprooted and shifted to a different campus—a multi-stage move which negatively impacted the ability of the team to gather as well as cut the build period short.

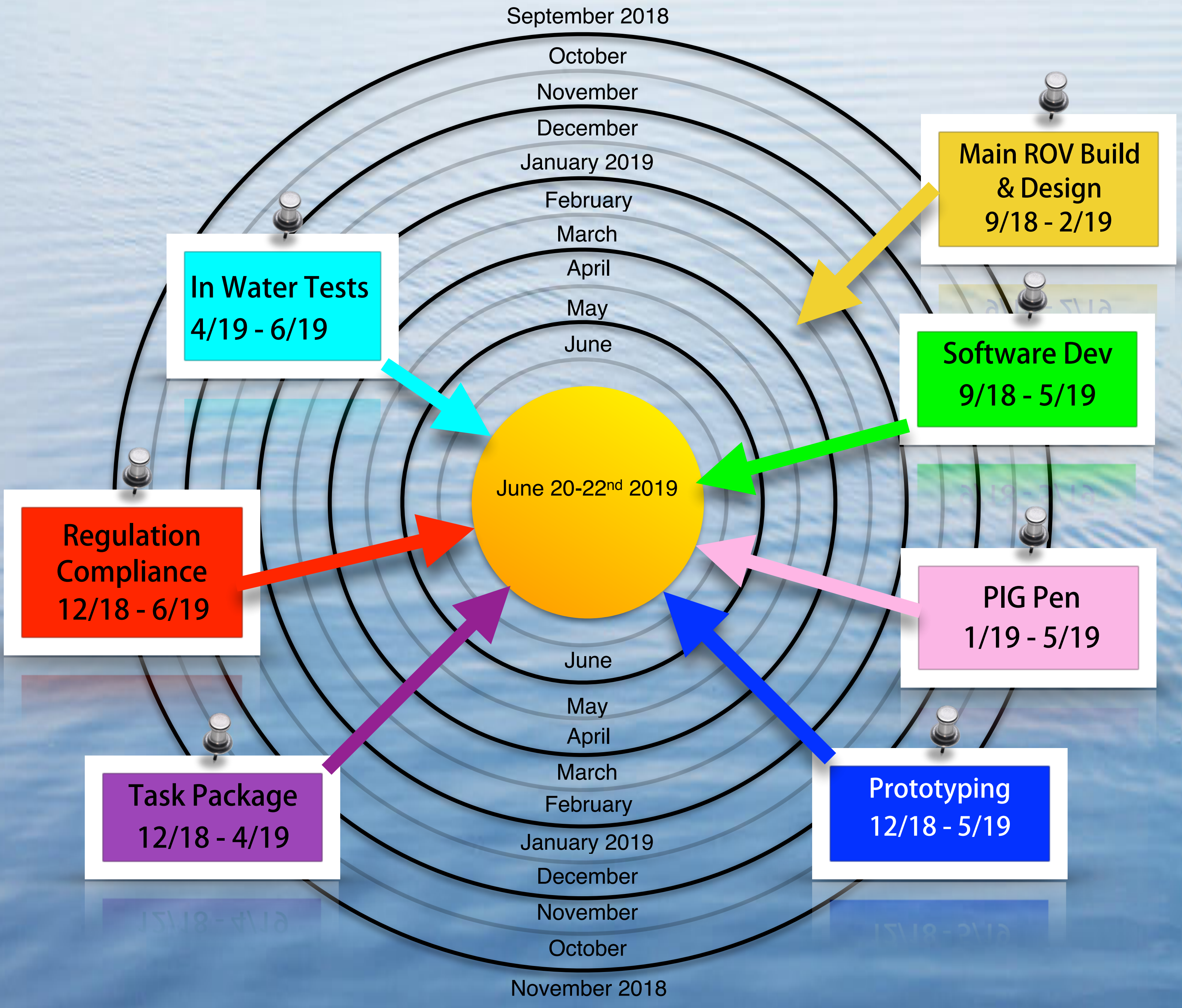
The team met a minimum of once a week for at least four hour sessions and spent many hours outside of the meeting time to continue working through the project. As the ROV project progressed, the team did experience attrition as it became evident that the amount of time, creativity, and the pace at which those objectives would need to be accomplished, would be too much for some to contribute. If teammates did not demonstrate initiative to dive into the project, they were asked by our CEO and Faculty Advisor to reflect upon their other commitments. They either self-selected out or stepped up their contributions.

BUDGET

	Viking Explorers Budget Items		
Donated Items			
Source	**Description**	Projected	**Actual**
Pepsi	ASB Pepsi Grant		$ 10,000.00
LBCC Robotics Grant	Robotics Grant		$ 15,000.00
Solidworks	40 Student Licenses		$0.00
AutoDesk	Free EagleCad Licenses		$0.00
AutoDesk	Free Fusion 360 Licenses		$0.00
Total			$ 25,000.00
Income			
EIR Club Balance	Past Balance		$ 8,148.31
Fundraising	Ebay Sales		$ 3,298.57
Pepsi Grant			$ 10,000.00
Robotics Grant			$ 15,000.00
Electrical Dept Support	Supply Budget		$ 2,500.00
Team Members	Travel Contributions		$ 4,800.00
	Total Income		$ 43,746.88
Expenditures			
uPrint Material	Support and ABS (Pepsi Grant)	$ 600.00	$ 675.53
McMaster.com	Material and Hardware Supplies	$ 2,000.00	$ 1,725.90
DigiKey.com	Electronic Components	$ 1,600.00	$ 1,495.64
Amazon.com	Supplies & Components	$ 2,000.00	$ 2,364.89
JLCPCB.com	Circuit Board Printing	$ 150.00	$ 216.78
Commercial Systems			
Amazon.com	Monitor & DVR	$ 600.00	$ 187.29
BlueRobotics.com	Thrusters, ESCs & Sensor	$ 2,000.00	$ 1,144.40
Equipment			
uPrint SE	Purchase of Machine (Pepsi Grant)	$ 9,000.00	$ 8,957.99
Expense Breakdown			
ROV Supplies		$ 6,000.00	$ 6,478.74
Commercial Systems		$ 1,000.00	$ 1,331.69
Equipment		$ 4,000.00	$ 8,957.99
Travel	8 Round Trip Tickets	$ 3,000.00	$ 4,096.00
Lodging & Car	Rooms	$ 3,000.00	$ 2,535.00
	Total Expenses	$ 17,000.00	$ 23,399.42
Balance Available	*Balance Available for Contingencies*		$ 20,347.46
Commercially Sourced Systems			
Blue Robotics Items	5 Thrusters	$ 1,000.00	$ 845.00
	5 ESCs	$ 100.00	$ 125.00
	Depth Sensor	$ 100.00	$ 68.00
	BR Total + Tax	$ 1,323.00	$ 1,144.40
Amazon	Monitor	$ 200.00	$ 99.99
	DVR	$ 100.00	$ 69.89
	Amazon Total + Tax	$ 330.75	$ 187.29

Contingency Fund $20,347.46 • No items were reused from previous ROVs

BUILD SCHEDULE



September 2018
October
November
December
January 2019
February
March
April
May
June

June 20-22nd 2019

June
May
April
March
February
January 2019
December
November
October
November 2018

Main ROV Build & Design
9/18 - 2/19

In Water Tests
4/19 - 6/19

Software Dev
9/18 - 5/19

Regulation Compliance
12/18 - 6/19

PIG Pen
1/19 - 5/19

Task Package
12/18 - 4/19

Prototyping
12/18 - 5/19

> “There’s no time left for excuses!”
>
> Heard at the 2019 SoCal MATE regional competition

SAFETY

LBCC recognizes the need for safety for all of its crew, its users, and the public at large. We have utilized industry safety standards throughout our design and build process as well as created a safe operating procedures checklist that will be provided with our ROV to any consumer group utilizing it. Throughout our process, our team did use personal protective gear: safety goggles, gloves, hearing protection, and worked in a well ventilated brightly lit area. Further, our ROV team employed teamwork to partner to lift heavier objects using OSHA safe movement.

Poolside personnel also wore proper personal protection equipment as well. Safety glasses, long pants, sleeved shirts and closed toed shoes are required of all personnel, and personal flotation devices are required of those who launch and recover the ROV.

The ROV itself has been carefully planned to incorporate many safety features. The surface control system has been grounded to NEC standards, it has a 5 Amp fuse. Voltage drop calculations were made and 16 AWG wiring was chosen for the 48Volt main ROV power supply. A clearly labeled, red power kill switch is located in the middle of the surface control panel, so power can be cut to the ROV with one quick flip of a switch.

Emergency Shutoff Photo: A. Hill

Electrical component housings were sealed with O-rings as well as pressure testing at 138kPa for 2 hours which far exceeds the competition typical operations. In addition, the air solenoids were tested in identical conditions to verify waterproofing of these components, so the electrical testing was verified with a 500 Volt Fluke Megohm meter.

Thrusters were covered with custom honeycomb shrouds with openings of less than .5 inch protecting personnel, aquatic life, and the equipment itself.

Due to lead's negative effect on human health, the lead ballast has been replaced by an alloy of Bismuth (88%) / Tin (12%). While the use of this alloy requires a slightly larger space, the over all difference is negligible, and the risk from lead has been completely removed from the workplace.

DESIGN RATIONALE

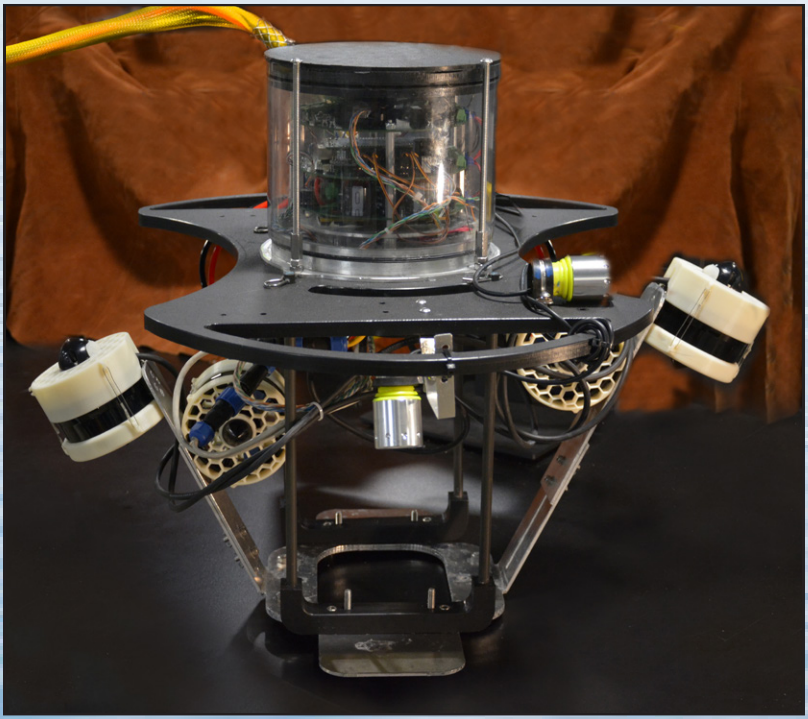
The design of the 2019 LBCC ROV for the MATE competition began as a question: What is good design? Our school has been participating in MATE competitions for the past 15 years, so we reflected on our championship year as well as the years that we approached victory for inspiration. As we first defined each task and started discussing ideas, there were complicated parts and motors galore, sensors, and endless gizmos that would be "perfect" for that one task. It was unclear if each of the complex schemes would fall into place properly. The breakthrough that happened came while discussing the grate replacement, as a student went to pick it up, sliding their finger under the u-bolt and simply lifting. There it was. Simplicity. Why not build an ROV with a finger? "Well, we have to lift a cannon, so it had better be a really strong finger." So was born the proboscis, which is a similar concept to an elephant's trunk. No circuits, no stepper motors. **Simplicity**.

Complex systems to deploy marker flags gave way to a simpler design inspired by a Pez dispenser. Intricate grout and trout deployment systems that would have made Rube Goldberg proud, gave way to simple trap door designs tripped by highly reliable pneumatic cylinders. A micro ROV became as simple as a PIG in a pen. How does a typical Viking design session go? First, a group forms to attack a task. Our faculty advisor, Scott Fraser asks how it can be done and a bunch of ideas are thrown against the proverbial wall. Some ideas work and, some don't. Scott usually guides the discussion down to one design. Mentioning "We've tried that in the past and it didn't go so well." It's always great to avoid dead ends. Once a final design concept is chosen, SolidWorks is launched and the model building would begin. Often these questions lead to different designs and would ex- pose the strengths and weaknesses in each design. The overwhelming theme in choosing a design was to make it simpler. At first, we were coming up with very complex solutions to the tasks, many which were difficult to build and had lots of moving parts. Each design revision was, especially in later iteration, enacted to simplify the design. An example of this is the stepper motors' replacement with pneumatic cylinders, streamlined implementation, and fewer controls.

Our ultimate goal in super simplification was to remove the barriers to technology that limit the user experience. The Pilot should not be focusing on the technology, rather the focus should be on accomplishing the tasks at hand. Simply, quickly, and hopefully first.

Reviewing software design Photo: A. Hill

MAIN ROV BUILD


The ROV Photo: A. Hill

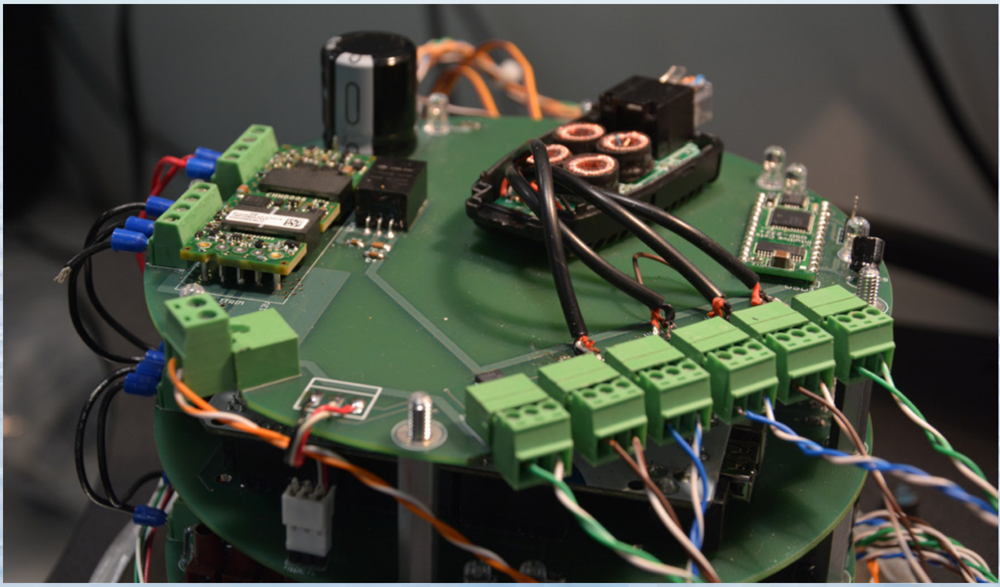
The heart of the ROV is a modular design core. The frame is made from HDPE, High-density polyethylene. HDPE was chosen for its strength, waterproof and neutral buoyant nature. Atop the frame sits the board stack, the brains of the ROV. This innovative circular design features unparalleled strength and easy expansion, should future needs arise. Below the main deck are four thrusters: two thrusters face forward/aft, two others face up and out. Why angle our lifting thrusters out and not straight up? Well, these clever Vikings have a trick or two up their sleeves. After extensive testing, we found the optimal angle to allow for solid lifting capabilities while also allowing the thrusters to be operated in crabbing mode. By alternating the thrust of the outboard thrusters, one up and one down, it is possible to move the vehicle sideways. Which is highly advantageous when needing to make fine adjustments to the vehicle during critical testing. Gone are the days of backing up and trying a second time to hit your mark. Simply shift the ROV into crabbing mode and fine tune you position. Simpler, quicker, better.

PURCHASED VS. ORIGINAL

We have a healthy budget, why not go out and purchase a full-feature ROV off the shelf? Why go to the trouble of designing almost everything on the vehicle from scratch? Each and every part of the ROV was analyzed to see if custom built part made sense. In some items like the display monitor or the digital video recorder, it made not sense to build our own equipment and we chose to purchase these items.

Some items we decided we didn't entirely need to reinvent the wheel. Store bought diving flashlights were converted into camera housings and a system of quick-connect and disconnects were designed for the cameras. This provided an accessible watertight housing for the cameras and the ability to quickly replace a faulty camera.

PRINTED CIRCUIT BOARDS



The Board Stack Photo: A. Hill

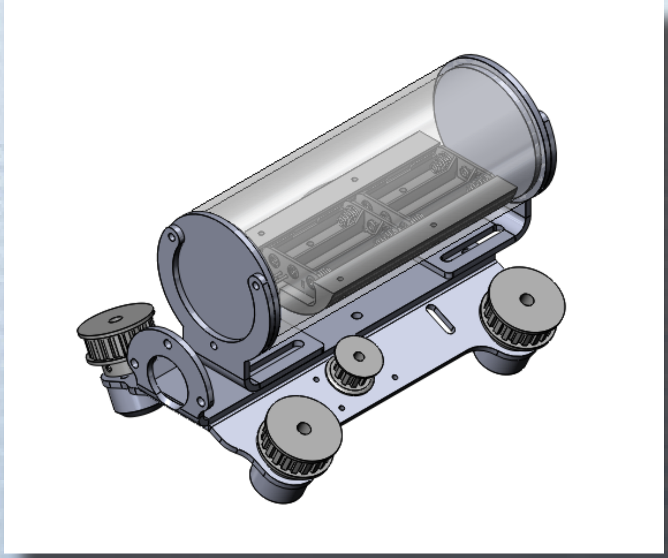
The LBCC Viking Explorer's circuit design team created a system of custom designed, stacked printed circuit boards for the ROV. The stacked approach allows for an acrylic cylinder to be used for the waterproof housing. Input and output connectors attach to the circumference of the circular board, allowing for easy access. Viking Explorer clients may expand the scope of the ROV at any time by simply adding additional boards vertically and installing a taller acrylic cylinder, thereby avoiding costly delays when integrating additional functionality.

The four boards that make up the main stack were designed using EagleCAD and then outsourced for production, then soldered and assembled by the team.

The power distribution board is designed to accept source voltages ranging from 12 – 48 Volts, that enter the board through a center port. The voltage is regulated down to 12 Volts and then distributed vertically to the other three boards by jumper wires. Three separate power rails with voltage regulators allow for power output of 9 Volts, 5 Volts, and 3 Volts. The power distribution board feeds 12 volts to the task package board. The task package board operates on 9 volts and has separate temperature and pH probes, ferrous metal sensor, as well as an Arduino Nano to monitor the sensors and operate the five mosfet switches that control the pneumatic actuators.

Assembling a circuit board Photo: S. Fraser

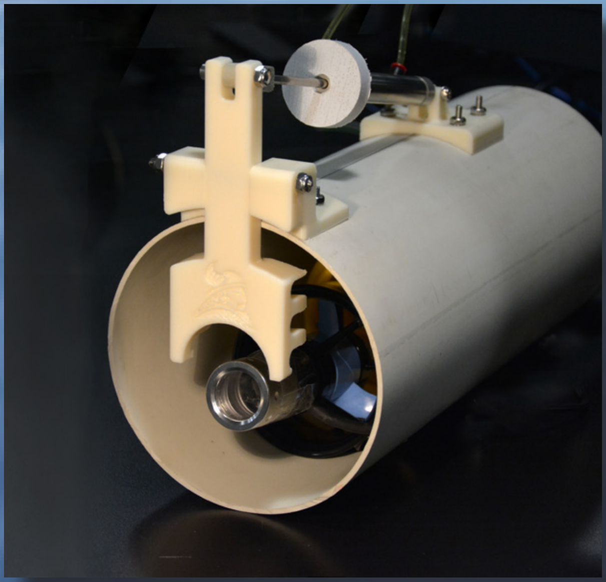
MICRO ROV (PIG)



The Second PIG prototype

Pigging is the process of sending a device down a pipeline for cleaning or inspection. Our PIG (Pipeline Inspection Gadget), started off as a single wheeled vehicle driven by a stepper motor. Initial testing proved the design to be both unstable and lacking in torque. To simultaneously increase the PIG's inherent stability and torque, we designed a sideways facing tank-tread design, which would give us better traction and allow the torque to be varied by changing the size of pulley. This solved some of our problems and created others. Due to time constraints and the looming deadlines, it became painfully obvious to the team that we needed to go even simpler. At yet another redesign meeting, the idea came, "Why don't we just strap a camera onto a thruster and send it down the pipe?" It sounded too simple to be true. It would mean giving up the extra 10 points for utilizing copper instead of a fiber optic cable, but in the trade-off we gained speed, simplicity and a plan that could go from design to prototype in just a few days. And so the PIG 3.0 was hatched: leaner, meaner, and easy to build. It's in production now.

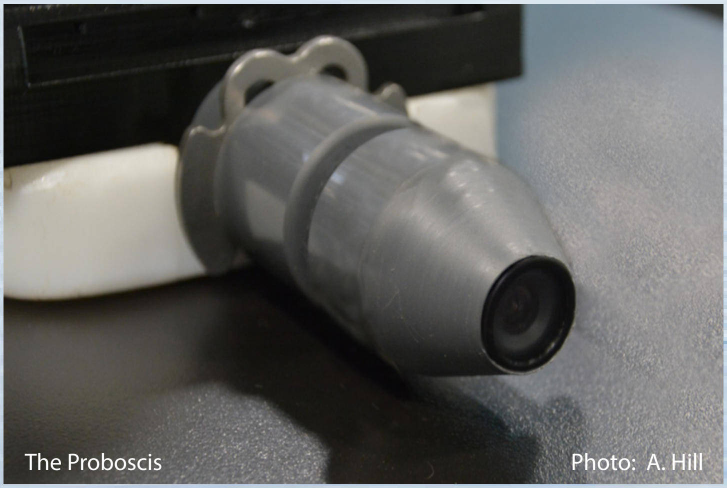
The PIG's home (pen) aboard the ROV is a 6" ABS tube that matches the diameter of the corrugated pipe. The gate is opened and closed by a dual acting pneumatic cylinder. The gate features grooves that grab onto the corrugated pipe, docking the ROV at the entrance. As the PIG deploys, its "tail" trails out behind it in the form of control wires in a coiled pneumatic airline. The airline protections for the wires and acts as a spring, returning them to the housing as the PIG returns to the pen. This tail serves as the PIG's sole connection to the ROV and, ultimately, the topside controls. The speed and direction is controlled using a joystick on the surface controller. The micro ROV is propelled by a single Blue Robotics T200 thruster mounted in the center of the frame. At full power, the thruster's maximum current is 14.86 amps. The thruster is limited to 33% power through PWM selection and a 7.5 amp fuse is used. The nose of the PIG consists of a camera surrounded by LEDs controlled using the Adafruit NeoPixel library.



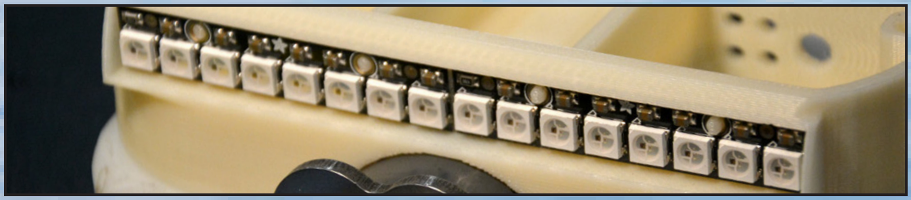
The Board Stack

Photo: A. Hill

TASK PACKAGE BUILD

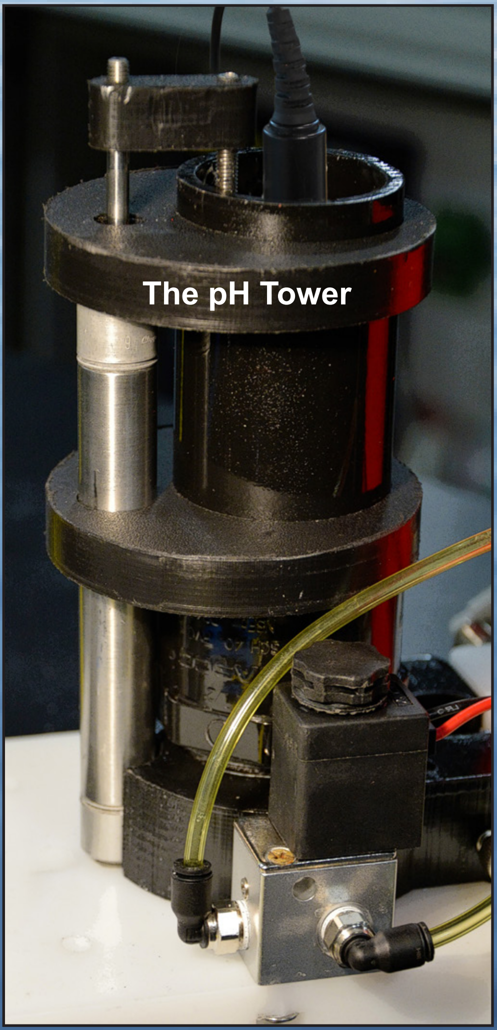

The Proboscis Photo: A. Hill

Does your ROV have a nose? Ours does. It's called a proboscis, an appendage to grab the various objects in the competition. With a camera up front, we can see exactly where our proboscis is going. With no moving parts, neither electrical nor pneumatic, there are few points of failure. The proboscis is also very strong; for the cannon lift, a collar with the lift bag and claw is slid over the proboscis. A retaining clip holds it all in place and you're ready to lift some heavy metal. The ROV with the 150 kilogram lift bag will lift 222 Newtons of payload. This exceeds the maximum weight of the cannon in water which is 120 Newtons.

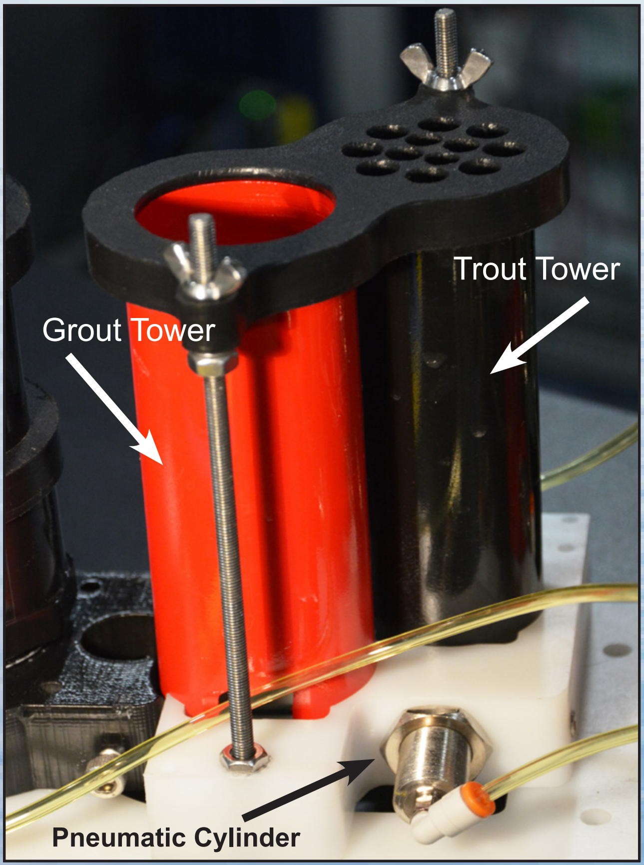

The LED Strip Photo: A. Hill

Just aft of the proboscis is the lighting panel and wiring bulkhead. The dual Adafruit NeoPixel Stick eight LED strip lighting features a fully addressable array of sixteen LEDs that can be used for forward illumination of the ROV's path, or displaying system status information.

Continuing aft is the pH injection tower. This tower consists of our American Marine PINPOINT pH probe in a protective copper tube, which is mounted on a sliding arm housed in the outer PVC tube. The probe is connected to a pneumatic cylinder that is pressurized to quickly move the pH probe downward. The pH probe travels downward through a coupling port on the bottom of the ROV. When sampling the ROV will sit atop the 3/4" coupler that holds the bottle with the water sample. The pH probe is designed to penetrate the water sample by 40mm, in order to obtain a pure pH sample without influence from the surrounding pool water. The pH probe can be manually reset by landing the vehicle on the pool bottom.



The pH Tower Photo: A. Hill

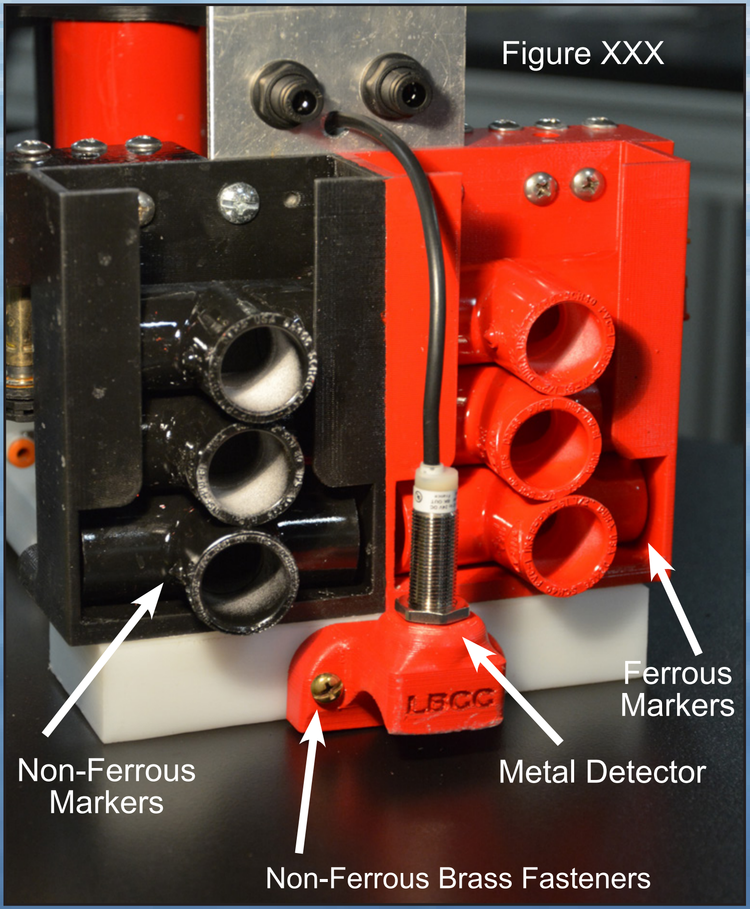


Task Package Photo: A. Hill

Continuing aft on the task package, one comes to the grout and trout dropping mechanisms. These two separate dropping mechanisms are based on a trap door principle. The door is closed, pneumatic cylinder is energized and the payload is loaded. The operator simply moves over the target, guided by a convenient downward-facing camera between the two drop points and flips a switch to release the grout or trout. The resultant payload drop can be very accurate and swift, leaving the team more time to complete other work.

A ferrous sensor is fastened to the stern of the task package by non-ferrous brass screws. The detector sensor is placed on the simulated cannon shell and either a red (ferrous) or black (non-ferrous) marker can be deployed at the touch of a switch.

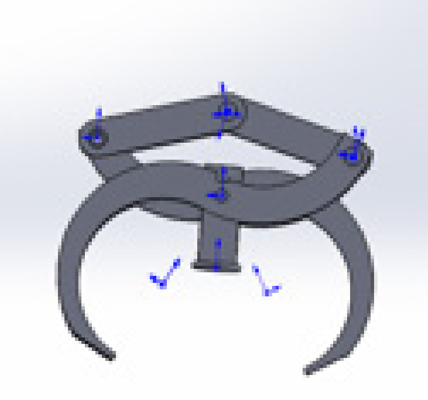
We decided to build original holders for our cannon shell marker flags. They are deployed from their holders by pneumatic cylinders activated by solenoids. Their design was inspired by the PEZ candy dispenser.



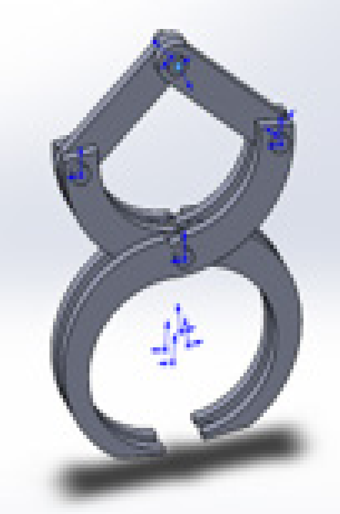
Task Package Photo: A. Hill

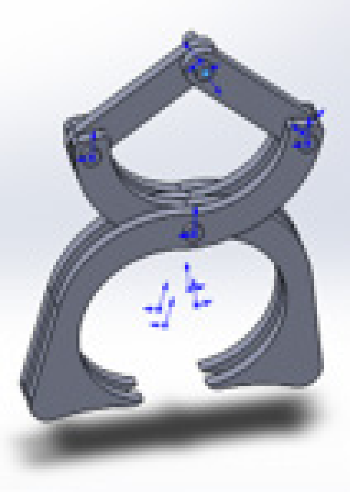
PROTOTYPING AND REVISIONS

Rather than following the footsteps of several other teams who are most likely implementing some sort of pneumatic or electronic arm, we have decided to go for a completely mechanical approach. Our initial design got its inspiration after a pipe claw used by the company in a previous year. The model looked as though it would come parallel to the ocean bottom and scoop up the object where a gravity operated latch would hold it in place. While attempting to replicate this design in SolidWorks we first started by making sure the cavity was at least three inches in diameter. However, after making this adjustment we immediately discovered the latch would have to end up being ridiculously large.



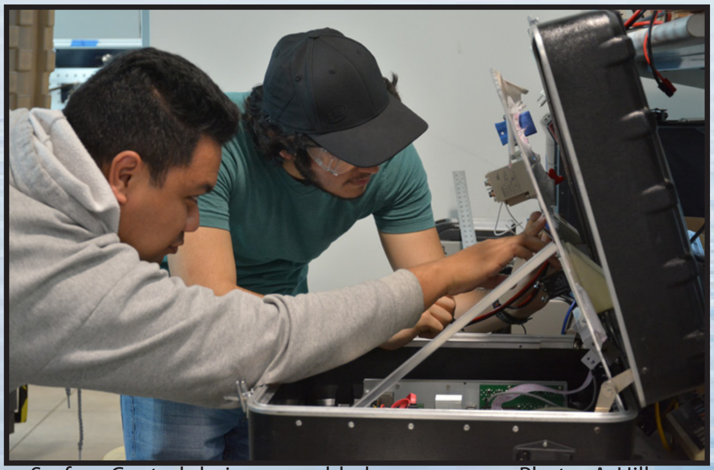
Our first prototype, the claw as we soon named it, was based off a pipe lifting clamp which would tighten its grip as the mechanism pulled the object upward. Now, instead of having to come at the objects parallel to the pool floor, all we must do is position the ROV directly above the tire or cannon and drop down on them. However, with this iteration of the claw we realized it would sometimes close prematurely. Though this could be undone by lowering the ROV to the pool floor to pry it open; it would cause too much loss of time during the competition. We went through numerous iterations, building and testing each. Finally, we made some final design changes that resulted in a very easy to use and repeatable claw.





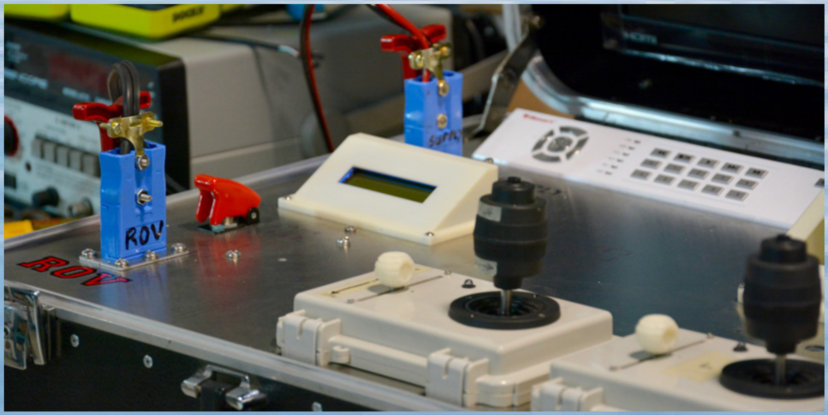
These changes included, protruding the tips of the claws downward and outward with a downward curve to guide the object into the center of the claws. The next change was to install a light spring connecting two claws, and finally, we installed Bismuth/Tin ballast at the bottom of the claws to help weigh the neutrally buoyant claw material down. We had finally reached our final product. This last iteration of the claw had drastically reduced time and practically made it effortless to retrieve the cannon.

SURFACE CONTROLS



Surface Controls being assembled Photo: A. Hill

The electrical control team had created a custom case in which to house the surface removable joystick controls, LED monitor, switches, as well as the internal power conversion and wiring. This case did use a salvaged plastic suitcase as a base and monitors, but all other components were created or enhanced. The sleek aluminum metal covering was custom cut to allow for dual removable joysticks for separate ROV and microROV operation, the wiring and components underneath the water resistant base were wrapped in a shock protective cushion. The internal AC to DC power converter was positioned away from the hard drives, Watt meters, screen controllers, LCD display, and other electrical components used in any of the data collection to minimize any electrical interference. The ROV systems are protected by a 30 Amp master fuse to NEC and MATE standards and wiring was tested to insure proper strain relief. The monitor mounting design was internally housed within the case to not only create a single unit for ease of transport but additionally to protect the monitors as well as to minimize set up to operation time.



Surface Controls Photo: A. Hill

Surface Controls in action Photo: A. Hill

SOFTWARE ALGORITHM

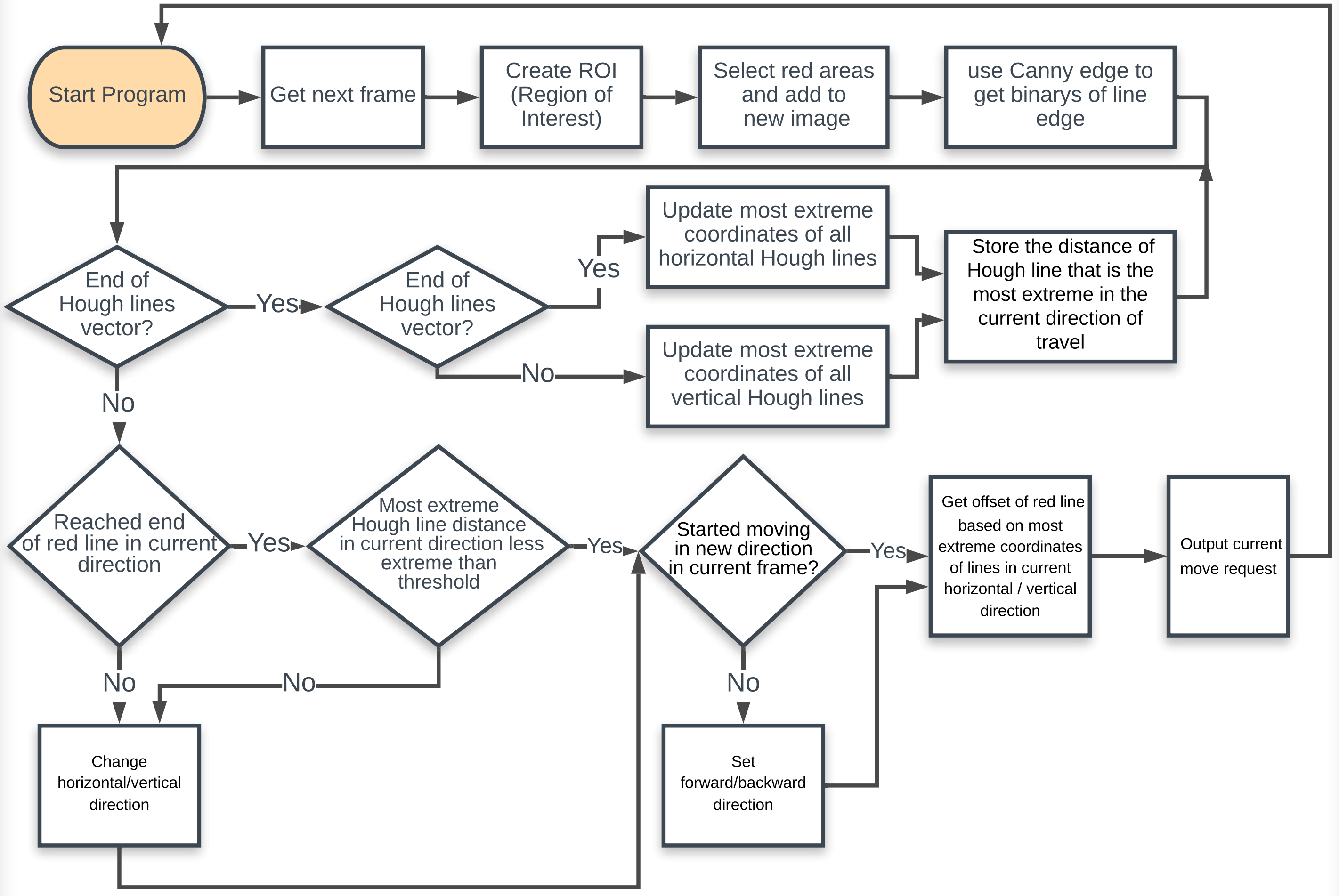
The image recognition division of the LBCC Viking Explorer ROV had conceptualized usage of open source libraries and tools to create their own image recognition algorithm. The basis for the algorithm design was first to receive data from a video feed of the sample that was iterated through on a frame by frame basis using a waitKey function. The algorithm then cleans (preprocesses) the data using a Gaussian blur and Canny edge detector and then a findContours and approxPolyDP functions were used to get and simplify the contours of the shapes. From this point, the data was analyzed and categorized by number of vertices to determine the shape. Should the object have three vertices, it is a triangle, if there were four, the shape could be either a line or rectangle and the algorithm compared the ratios of side lengths to determine the object, and, lastly, if the object had eight vertices, it was classed as a circle. The algorithm then displays the total number detected of each shape with an icon and a count.

The algorithm was tested against a video of a laminated set of the Benthic species placed underwater to fine tune and overcome any distortion of the water, as well as correct against small visual noise. Aspect ratios were tested between .6 and 1.4 to maximize correct image detection.

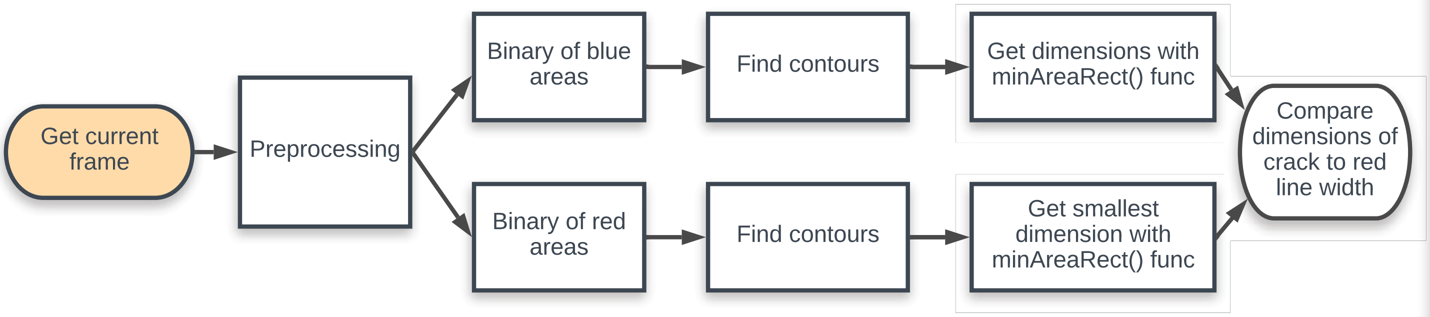
With regards to the crack detection, the algorithm used the OpenCV library as a basis and the team adjusted the HSV (Hue, Saturation, and Value) ratios to identify lines based upon color. The algorithm was then adjusted to accept data of lines and to compare the measurement of the potential crack to the known width of 1.85 centimeters to find the length and width of the crack through the getMinBoundingRect function.

As for the autonomous operating portion of the algorithm, the algorithm design was conceptualized to measure and determine the thin black boundary lines of the grid squares through a sampling of random pixels taken from the image and creating an adjustment for light based upon comparing the average values of the background to both the white of the pool, as well as the blue and red lines, to determine the desired color. Pixels identified as darker than the average value of the background and not red nor blue are identified as the lines through which to navigate. A mask was then created from the current binary image, which could be eroded and dilated to remove the black lines and, additionally, remove noise. The function houghLinesP() was then applied to the resulting binary to find the dark lines of the image to create a minimum of four line segments where the red line crosses the black to be used as markers. These markers are combined to form a transverse axis and angles will be the weighted mean of the arctangent function, to create a gridline of similar lines for the ROV to follow. Accommodations were made to the algorithm, so should the dark grid line leave the ROV view for a threshold number of consecutive frames, the history will be analyzed and based upon an exit from the side, the algorithm will identify this as a new square and map accordingly.

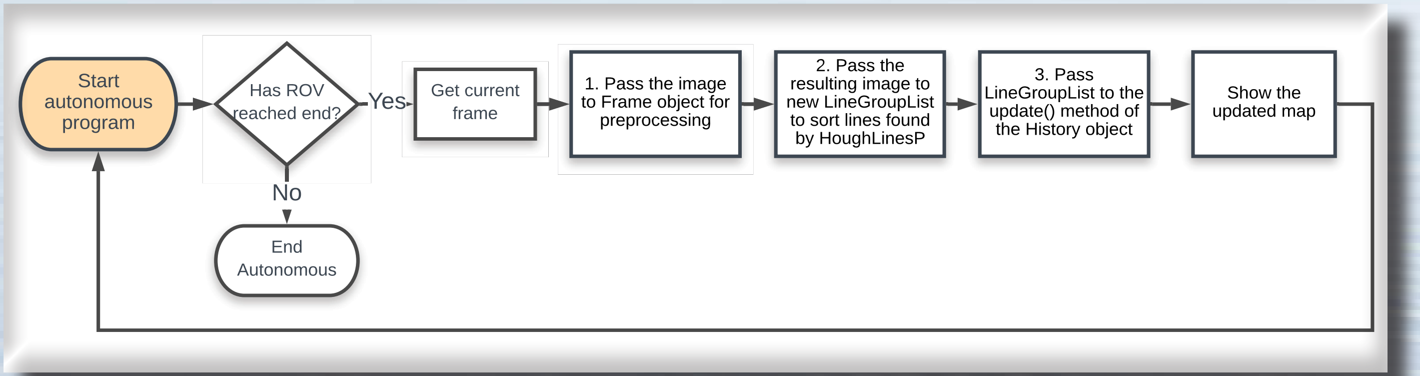
SOFTWARE LINE FOLLOWING FLOWCHART

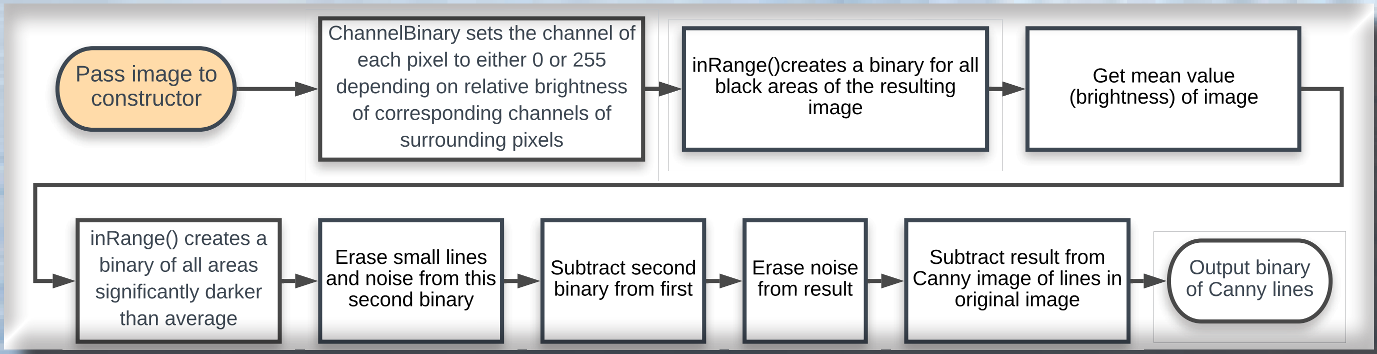


SOFTWARE CRACK MEASUREMENT FLOWCHART

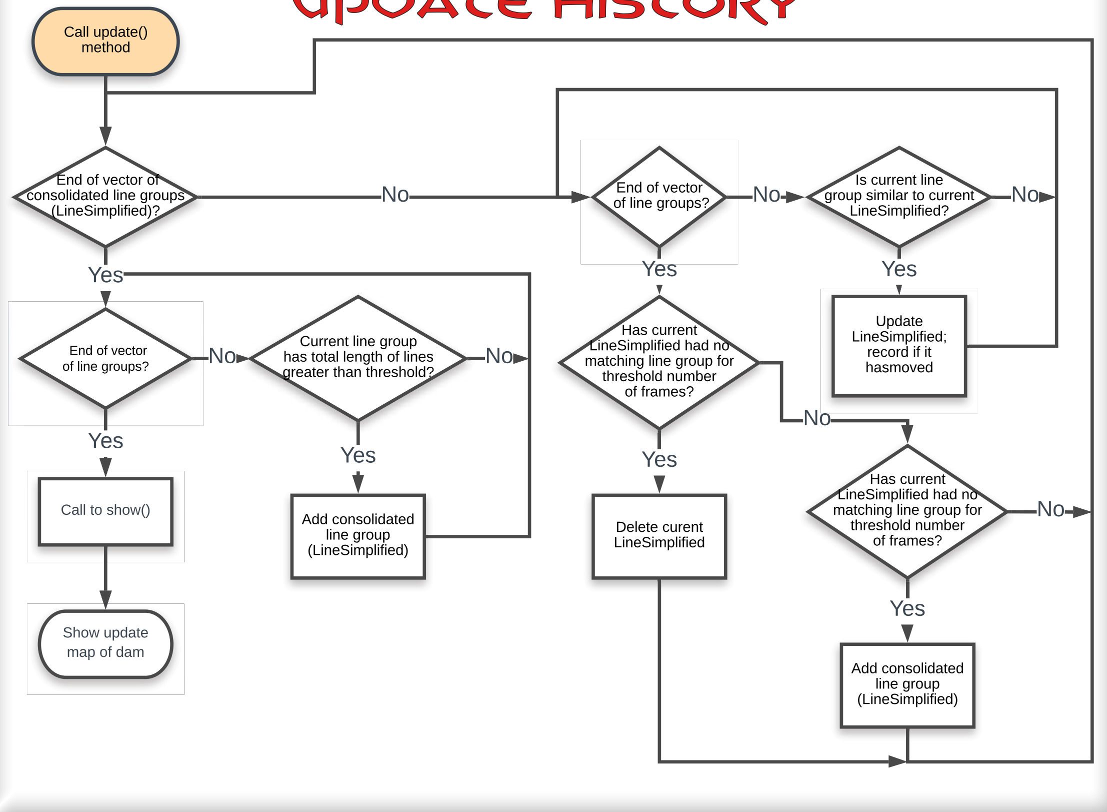


DAM MAPPING CONT.

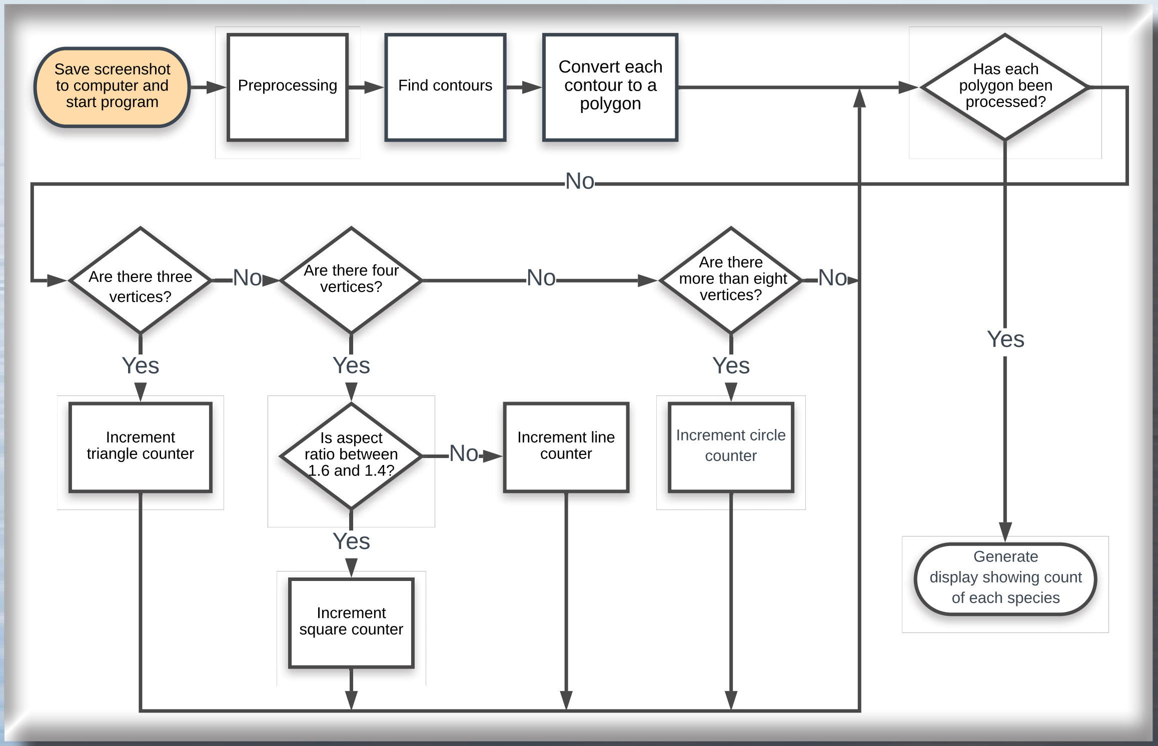




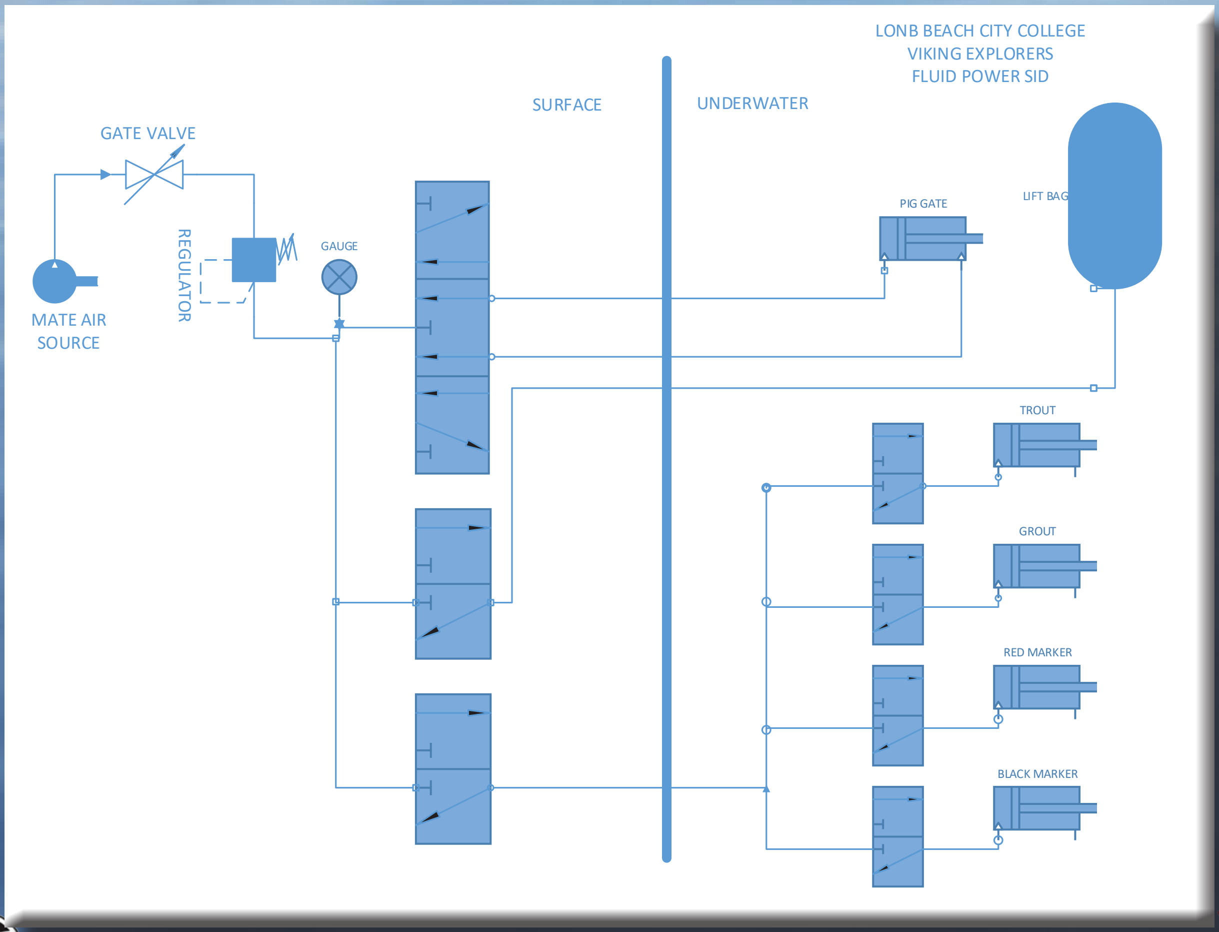
UPDATE HISTORY



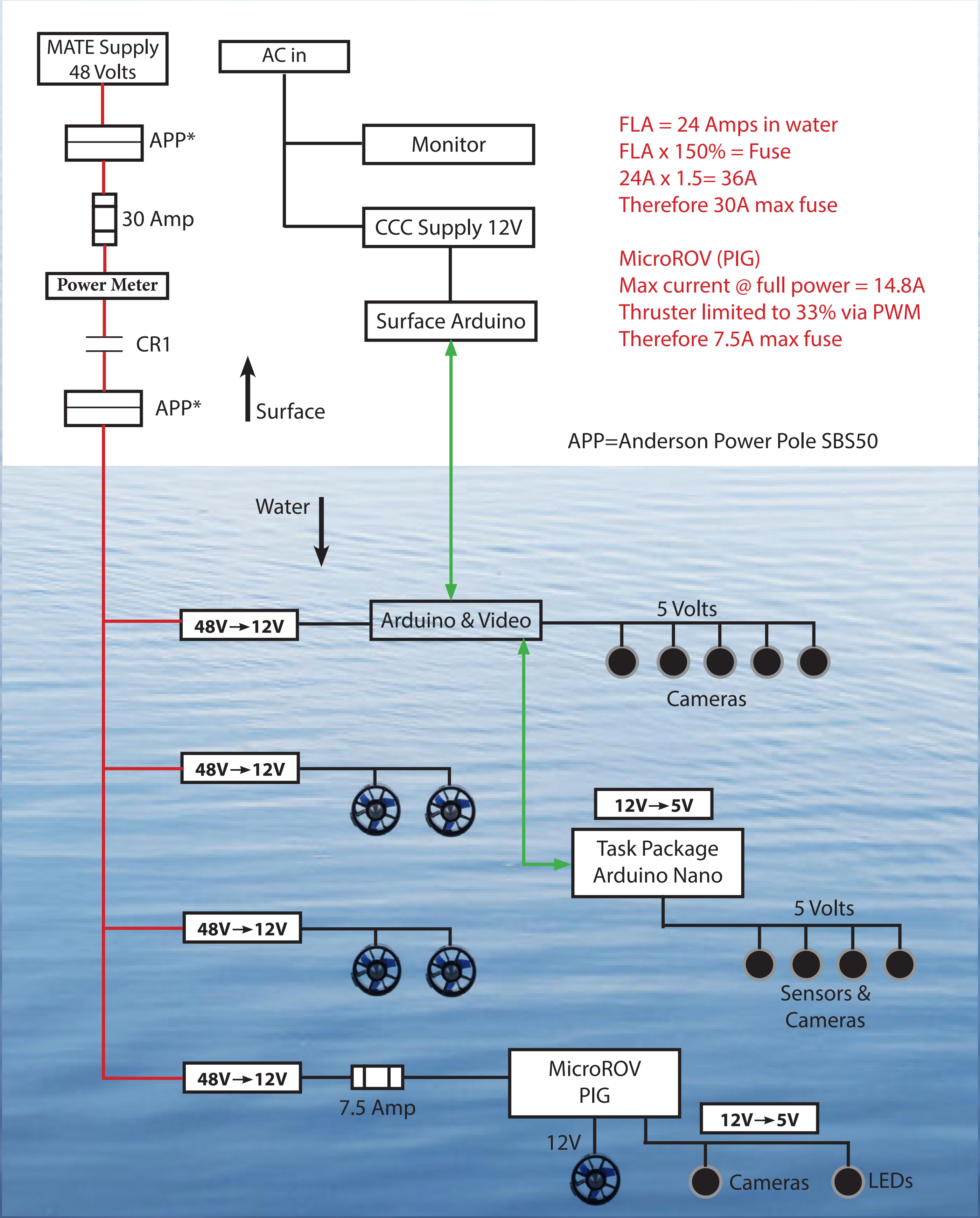
SPECIES IDENTIFICATION



FLUID POWER SID



SYSTEM INTEGRATION DIAGRAM



FLA = 24 Amps in water
FLA x 150% = Fuse
24A x 1.5= 36A
Therefore 30A max fuse

MicroROV (PIG)
Max current @ full power = 14.8A
Thruster limited to 33% via PWM
Therefore 7.5A max fuse

APP=Anderson Power Pole SBS50

TECHNICAL CHALLENGES

There were technical challenges that our team faced throughout the design and build process. It was discovered that the initially chosen motors did not have enough torque to move the ROV through the water fast enough, during paper testing, after the housing had already been designed. After completion of Excel modeling, different motors of different sizings were chosen and the housing redesigned.

The computer vision tasks were challenging in that LBCC currently educates its students in Computer Science in C++ but many algorithms and libraries used in industry today are written in Python. Student team members had to test functionality of potential programs and libraries in Python and then rewrite into C++ for testing. Additionally, computer vision has been commonly optimized for vision in open air space rather than water. The water itself posed a challenge in that it caused distortion and false positives for circles.

Time itself was a challenge in that the flow of work was difficult to manage. An optimized design flow would be to have electrical circuit boards built and programs completed to then have the mechanics tested. Due to an evolving design and the iterative process as well as outsourcing of circuit board manufacturing, the finalized components were not ready prior to build out, so designers of different departments were working from concepts rather than actual parts.

PERSONAL CHALLENGES

There were many skills gained in building the 2019 LBCC Viking Explorer ROV. Our teammates were able to really delve deeply into SolidWorks for 3D mechanical design and EagleCAD for printed circuit board design. They were additionally able to explore 3D printing, the OpenCV library for computer vision, and to explore the concept of deep learning for algorithms. Teammates became fluid with soldering, Ethernet wiring, pneumatics, as well as basic networking and electrical principles. Some of the many tools that our team were able to use were metal lathes, mills, drill presses, and CNC routing. Our programmers improved their Python and C++ abilities as well and were able to navigate the divides between the Raspberry PI and Arduino in very practical applications.

The lessons learned throughout the project were not limited to only technical hard skills. Our teammates needed to form a cohesive group and gained soft skills, including project and time management, job readiness skills, and improved their communication skills both written and oral. Some of our teammates also improved their marketing and sales abilities as they were able to effectively communicate their ideas as well as to guide the group towards a win win design outcome. Our teammates gained skills, took risks, and grew as people and friends.

Lessons Learned

There were many skills gained in building the 2019 LBCC Viking Explorer ROV. In addition to industry standard programs used, including SolidWorks for mechanical design, EagleCAD for printed circuit boards, 3D printing for custom parts, the OpenCV library for computer vision, teammates worked to solder components, wire for Ethernet, plumb for pneumatics, as well as improve their Python and C++ abilities and navigate the divides between the Raspberry Pi and Arduino in very practical applications.

As classroom theory came to life throughout the build. Archimedes Principal influenced in-depth materials discussions and seemingly easy decisions became balancing acts of weight vs. strength vs. water displacement. Through careful selection of our building materials and placement, we managed to create an ROV that was just slightly positively buoyant, by less than a 1/2 kilogram—a critical detail as the LBCC Viking ROV came in under the weight class threshold.

Lenz's Law of magnetic inductance was considered when solenoid power wires were initially placed next to the magnetic sensor wires. Guided by our Faculty Advisor, the wiring was separated so the magnetic field generated around the power wires didn't induce a current into the highly sensitive magnetic sensor wire and, ultimately, read a false positive.

Voltage drops from Ohm's Law were seen when the initial 48.21 Volts that entered the ROV tether at the surface dropped to 43.07 Volts at the other end under load. This confirmed our calculations and decision to go with only a single set of 16 AWG conductors for the power to the ROV from the surface Would our tether float or sink—and did we want it to float or sink? These and hundreds of other small, yet important decisions went into the building of this system that is the Viking Explorer's ROV. Dozens of different systems and parts were interlinked and produced a vessel that is operating better than expected. While the idea of lessons learned can often be thought of as missed opportunities, maybe it's better to look at the other side of the coin. What did we get right? For all the near misses, whoops, and oh ohs, there was that smile on the face of a student who powered up the ROV to test their contribution and that split second when the anticipation builds as to whether it will work or not. Then it comes, the smile from ear to ear when their creation works, exactly as designed. A very high percentage of the designs worked well upon launch.

If the story ended there it would be enough, but virtually everything on the LBCC Viking Explorer ROV was reviewed a second and third time. Students went back and made good, featuring even better--parts got smaller and more hydrodynamic. The complex was made simpler, the smiles only got bigger. And that's the Viking way.

FUTURE IMPROVEMENTS

While there was great success of our LBCC Viking Explorers ROV, there were areas for growth and improvement of both design and process. For video, due to a smaller robot footprint, standard video was used. In the future, the team would like to use high definition video to improve computer vision and ease of pilot operation.

While we tried to maintain our mantra of smaller, simpler, and more hydrodynamic, there is one item that came out in the testing phase that would have improved our design. At one point in time, we had discussed adding a fifth thruster to this ROV. Unlike our other thrusters which were purposely placed near the center of gravity for the craft, the fifth thruster would have been positioned near the front with a vertical orientation to provide pitch control. The ability to tilt the nose up or down would be an enhancement for easier diving. But for now, our pilot is operating the ROV beyond expectations, which makes for happy designers.

Group communication could have been improved as well. It would be best to start the design process with one consistent communication channel being used across the team for both chat as well as coordination and archival documentation purposes. Our team had three social media platforms which made communications confusing.

Acknowledgments

We are grateful to the following companies and organizations for providing materials, licenses, and funds that we were able to utilize to build our robot:

- MATE -- For pushing the envelope in technology education excellence and all the countless hours spent to make the competition seamless.
- Pepsi Corporation -- For the amazingly generous grant used to purchase our 3d printer.
- Dassault Systems—creators of SolidWorks who generously provided licenses
- AutoDesk—creators of EagleCAD who also provided licenses
- The OpenCV developer team—a group of developers who gave their time to build this open source library
- The Long Beach City College Electrical Technology professors and professional lab staff, including Tedde Titus who helped us find ways to actually build the crazy designs we came up with. Stewart Hively, for his support, encouraging us to work safely.
- Mr. Damon Skinner and the Long Beach City College Metal Fabrication program who generously allowed us the use of his labs and tools.

The Long Beach City College Viking Explorer team wishes to thank our faculty advisor, Scott Fraser, Chair of the Electrical Technology department at Long Beach City College. We are grateful for his energy, enthusiasm, and expert knowledge of robotic design and Solid Works.

We would also like to thank another unsung hero of the LBCC Robotics program, Scott's wife, who we have yet to meet. She was the voice on the other end of the telephone line, calling late at night to ask her husband when he would be coming home. "We're wrapping things up..." would be the response. Scott would usually be home in a short hour or two. Thank you, Mrs. Fraser, for not filing a missing persons report on your husband.

Further, we are thankful for the unwavering support of our families and spouses for working to support us for our many hours in the lab, late nights by the pool, and time away so that we could follow our passions and build a robot for the competition.

APPENDIX

Safety Checklist Sheet

☐ 1. ROV on deck
☐ 2. No loose parts
☐ 3. Tether out and not in the walk way
☐ 4. Connect to MATE power
☐ 5. Switch 1 on. Confirm that it is OK.
☐ 6. Switch 2 on. Confirm 48 Volts is running to the system.
☐ 7. Switch 3 on. Confirm that the ROV is connected.
☐ 8. Turn pneumatic controls off.
☐ 9. Connect to house air. Verify that air pressure is at 40 PSI.
☐ 10. Enable all four actuators.
☐ 11. Remove before flight tags.
☐ 12. Launch ROV

REFERENCES

MATE 2019 EXPLORER COMPETITION MANUAL
EXPLORER Product demonstration prop building instructions
EXPLORER benthic species handbook
Benthic species template
EXPLORER cannon handbook
MATE 2019 safety inspection tutorial and checklists

Arduino Website: www.arduino.cc
Microsoft C++ Documentation and community
OpenCV.org