2012

Cytrobyte ROV Technical Report

Cytrobyte Group, Houston TX

Team Members

Reidar Eliassen – Mentor

Julian Yao – Mentor

Tian Yao – CEO; Waterproofing and Main Electronics Engineer

Tim Flichy – Public Relations; Gripper and Metal Detector Engineer

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Cytrobyte I

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ABSTRACT

Our company specializes in marine technology and is composed of ethnically diverse students. Our latest project is a working underwater ROV. Together with our ingenuity we designed, planned, programmed and constructed a working ROV. Our small staff made it easy to get organized and ensured everyone was on task. We split the different subsystems among us and made a weekly timeline of tasks that must be done. We worked by ourselves during the week and got together on the weekends to share and get feedback on our work. During the planning stages, we agreed on the basic structure of the ROV and its different sub systems. We decided to house all of our electronics in a 15.24cm aluminum cylinder with an acrylic dome and mount the subsystems on a PVC pipe frame. We agreed on using an Arduino Mega as our microcontroller and Sabertooth motor controllers to control the 6 bilge pumps. When the basic enclosure of the ROV was completed, we tested the ROV without the electronics to ensure a waterproofed enclosure. After making several adjustments and fixing all leaks, we mounted the electronics and tested the ROV for movement. We had to make the ROV slightly negative buoyant by using screws and washers attached to each corner. These exercises challenged us to prepare for tomorrow's aquatic related endeavors. We worked and collaborated together to brainstorm creative ideas and solve problems to successfully complete this project.

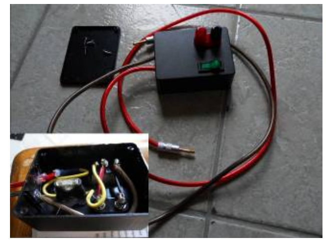
Cytrobyte during the planning and design stage

SAFETY

Tian Yao carefully and safely drilling a hole

Here at Cytrobyte safety is our main priority. During all stages of planning and construction we followed a strict code to ensure the safety of everyone in the building. Safety glasses and closed toe shoes were required at all times. First aid kits and fire extinguishers were always at hand but fortunately we never had to use them. We also implemented security features within our control system in case we begin to lose control of the ROV.

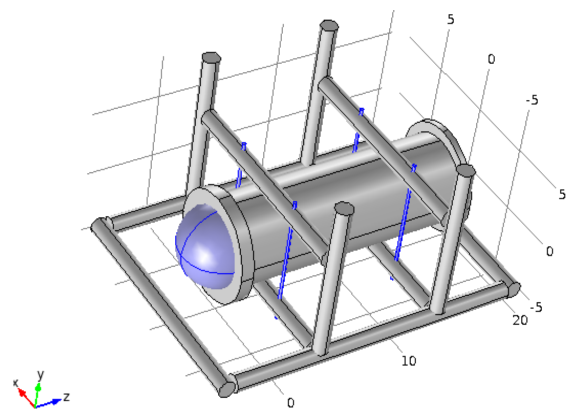
Additionally, we implemented a wire holder in the ROV to prevent the tether to being pulled and also created propeller protectors to avoid human contact with the swift bilge pumps. Another aspect of the safety is protection for the facility and ROV itself. An inline detachable fuse box was made, with easy banana plugs and a switch. The maximum current is limited to 25A by this fuse box to avoid any damage to either power supply or ROV circuit.



Fuse and switch box

DESIGN RATIONALE – MISSION TASKS AND SYSTEMS

ROV FRAME & HOUSING – 1" (2.54cm) PVC pipes and various fittings are selected to build the frame of our ROV due to the wide availability, cheap cost, and ease to cut, drill, and joint. At the center, a 15.24cm (6") diameter 45.72cm (18") long aluminum pipe served as the main housing for the electronics and the camera. A clear acrylic dome at the front provides a wide view angle for the camera. All electric connections go through the aluminum back plate with four feedthroughs. Two of them are commercial Bulgin connectors for main power line and Ethernet cable from the tether. The other two are waterproof feedthroughs made by ourselves for all wirings to the in water devices. Rubber gaskets are placed between main housing and back plate to provide effective waterproofing and easy re-opening for maintenance and further development of the ROV.



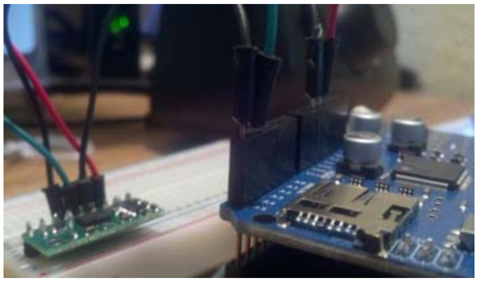
3D design of ROV for physics simulations

WATERPROOF – Two feedthroughs were made for the connections between in-housing electronics and in-water devices. First one is made based on a Swagelok fitting, in which we routed 10 pairs of 16 gage speaker wires for devices that need a large current, such as the thrusters and the suction pump. The second one is simply based on PVC fitting in which we routed 11 conductor wires for small current devices like metal detector and servo control signals and another Ethernet cable for potential secondary camera installed outside the housing. Fabrication of both feedthroughs involves extensive use of different types of epoxy and silicon rubber. Beside the reusable feedthroughs and gaskets, we mainly used commercial liquid tape and silicone grease to make "permanent" waterproofing on in water servos and many connections between feedthrough wires and devices leads.

THRUSTERS- For our propulsion system, we opted to use six waterproof bilge pumps. Four pumps are strategically position in each internal corner of the ROV at 45 degree angles. The remaining two thrusters were placed in the top to allow for up and down movement. We wired these to 3 motor controllers inside the ROV and controlled them through the joystick. This kind of configuration, along with a software algorithm based on vector force concept, enable us to have a fully 3D movement control on the ROV by a single joystick.

CONTROL SYSTEM – Due to the complexity of the tasks, we agreed that easy control and smooth movement had to be a priority. We agreed to use a USB joystick because of its myriad of button combinations and ease of use. We interfaced this USB joystick with our Control System. We created the on land control Station using C#; it sends and receives packets from the Arduino through UDP and displays information such as thruster power and compass heading. Only a USB Joystick is needed to control the 6 Bilge pumps and the other sub systems inside the ROV.

ORIENTATION - For this task we must measure the orientation of the ship in degrees in order to accurately survey the shipwreck. During the planning stages, we decided to use a small tilt-compensated 3D digital compass. The compass is located in front of the ROV parallel to the main housing so that when we position the ROV parallel to the shipwreck, we will get an accurate reading. We programmed the compass to connect to our Arduino Mega and send the tilt-compensated coordinates. The Arduino is programmed to send these headings through UDP to our control station program. To ensure the accuracy of the device we programmed a calibration method in case we need to calibrate the compass from our control station.



Digital compass connected to the arduino

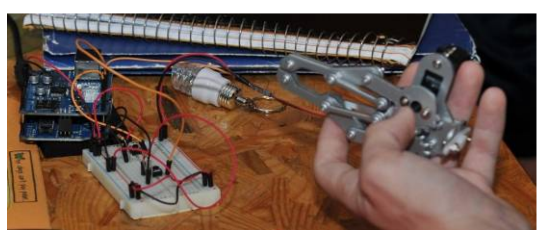
LENGTH MEASUREMENT – This task requires the ROV to measure the length of the shipwreck. We spent a considerable amount of time brainstorming ideas to accomplish this task. We first thought about using an HD camera and video analysis software to obtain the distance of the shipwreck. This idea was rejected when a member commented that the actual surface area of the tracking points would be too small to accurately create such a measurement. We also thought about using a laser measurement device but ultimately concluded that refraction underwater would skew the results. Finally, we settled on using a tape measure with a hook at the end. A tape measure provided the most versatility because of its accurate readings and cheapness. The hook will be maneuvered and hooked on to one end of the shipwreck as the ROV travels to the other end. We will be able to see the measurements with our HD camera.

SURVEYING – This task requires creating an accurate map of the shipwreck including the orientation and length of the ship as well as the places where debris is found. The above systems will be used to complete this task but our HD camera will be especially important for this task.

METAL DETECTOR – A part of the Surveying tasks requires us to detect whether debris on the grid is metallic or not. We used a metal detector which we took apart and created a separate PVC pipe enclosure for in front of the ROV. We extended the wires of the LED that lights up when metal is detected and connected them to the Arduino. When the Arduino detects that 1.7V are going through the wires, it sends a message to the control station which displays whether metal was detected or not. While working on the metal detector, we discovered that it would only work on metal that moved, this concept confused all of us. After some research we learned about Faraday's law of induction and how the metal detector reads the change in the number of magnetic field lines passing through a loop.

EXTRACTION – This task requires our ROV to drill through a layer of petroleum jelly and extract a sample of water. We initially thought of using a car windshield pump, but due to its gravity fed system we discarded the idea. We then thought of using a fish tank pump, but it would take too much voltage. Finally, we decided to use a computer liquid cooling pump. This pump was perfect because of its small size and power consumption. We connected the pump to an IV bag with vinyl tubing and attached a metal rod in the sucking end of the pump. This rod will be used to drill through the petroleum jelly. Experience and research with different pumps allowed us to observe the way they work. We learned that the spinning impeller compresses the water against it and the centrifugal (outward seeking) force pushes the water out.

CLAW- The claw is a vital part of the ROV as it is used to accomplish several tasks such as transporting the endangered coral, resealing the hole and inflating the lift bag. We implemented a claw powered by a servo attached to the Arduino. This setup allows for easy communication between our control system and claw. Additionally, it makes for a cheap and reliable grasping mechanism.



Servo-Powered Claw connected to Arduino

CHALLENGES

NON-TECHNICAL

Dealing with a team of three means everyone must be determined and able to devote a lot of time. This proved to be a challenge because we also have to manage our schoolwork, SAT, and extracurricular activities. Homework from our AP classes is already plentiful but we managed to get it done and set time aside for the ROV. Our different extracurricular also made it difficult to find a time where we can all meet. We solved this challenge by dividing the sub systems among each other and working on them independently on our own free time. Our weekly meetings were extremely productive because we had a list of points to discuss and a timeline to follow. After school levied off and we were done with SAT, we met 3 hours daily and 9 hours on the weekends to finalize the ROV and report.

TECHNICAL

During our building stage, movement seemed to work fine outside of the water. The thrusters were responsive and powerful. However, upon testing the ROV underwater for the first time, we discovered a significant unbalance that made it tilt to the side and almost flip. As highschoolers, we had never truly exposed to the concept of buoyancy so we didn't really think about it during the planning process. The challenge revealed itself after we had built most of the ROV and it seemed to be too late to fix. Using our ingenuity and creativity we experimented with different methods for balancing the ROV such as attaching pool noodles, bricks and water bottles. We ultimately decided to attach one bolt in each corner of the ROV and add the necessary washers to each until the desired balance was reached. Once we had achieved slight negative buoyancy, movement was smooth and our problem was solved.

ROV's natural tilted position before balancing

TROUBLESHOOTING TECHNIQUES

Here at Cytrobyte, we all share a passion for computers and technology and have learned various troubleshooting techniques. We were able to apply similar techniques to troubleshoot our ROV. In case of a hardware issue, we began by testing each system independently, and then we tested the whole vehicle on land. In the case that the entire

Troubleshooting and Testing the ROV

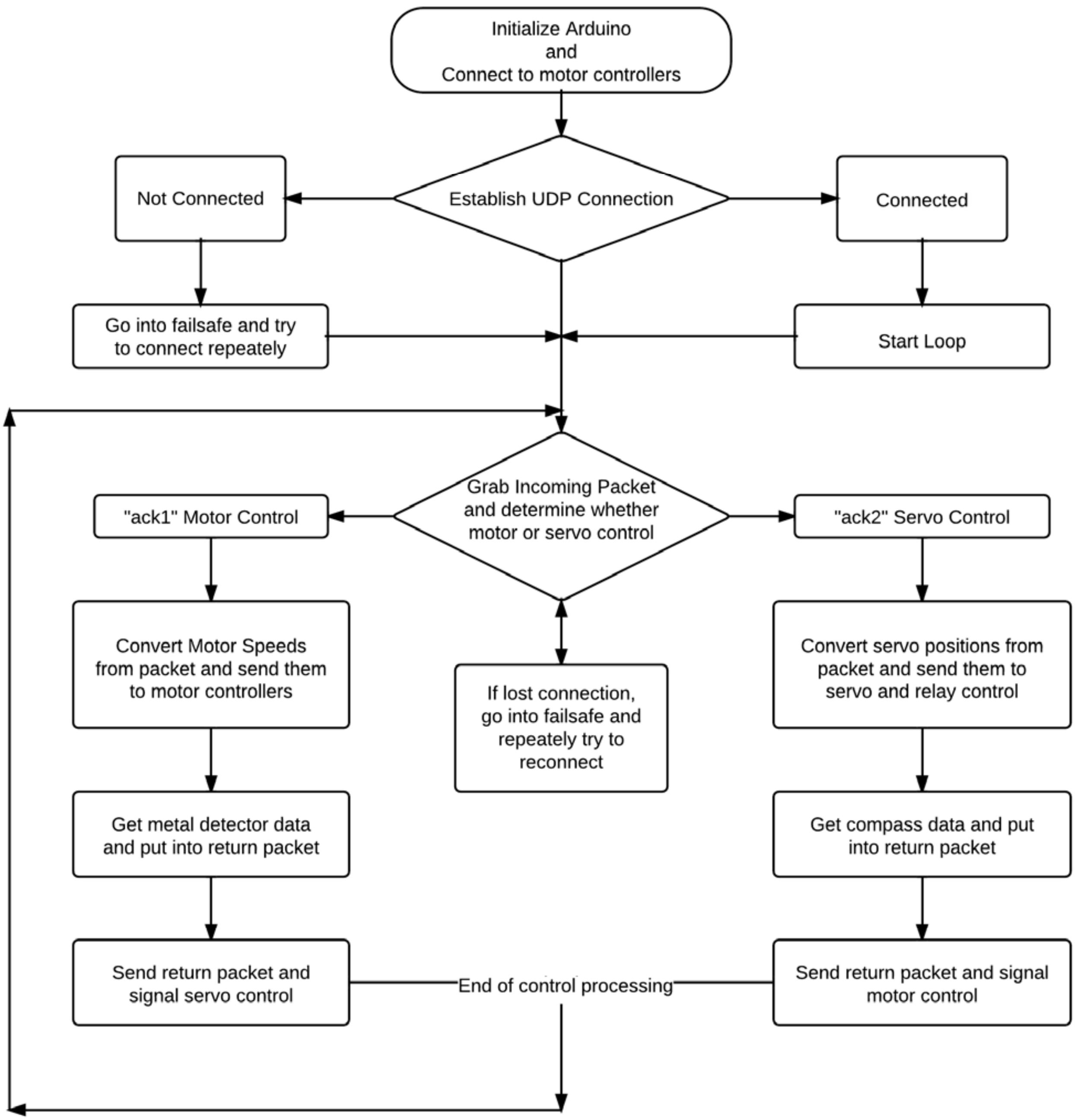
system did not function correctly, we took apart the ROV and tested each system independently in order to isolate the malfunction and make any adjustments. Before throwing the ROV In the water for testing, we conducted a failure mode and effects analysis which allows for early detection of potential failure. We designed the ROV so it would be easy to take apart while still retaining a tight waterproof seal. This allowed for easy troubleshooting of internal components. Usually, we were able to solve a problem by simply looking for error lights in the internal components. For example, our microcontroller kept crashing when the propellers were run at full power but after a close examination of the internal components, we noticed the motor controllers were giving an error light which indicated that not enough voltage was being received. We then quickly realized that our faulty power supply was the issue. In some cases, where opening of the main hosing is not necessary, we use the built in functions of our control system to determine the frequency of packets sent and received by the ROV, this can detect faulty or loose connections. In case of a software issue, we used similar techniques that we knew from previous programming experiences. These include isolating an individual function to ensure that it is doing what it is supposed to. Overall, we managed to solve problems quickly by utilizing our team's combined ingenuity.

FUTURE IMPROVEMENT

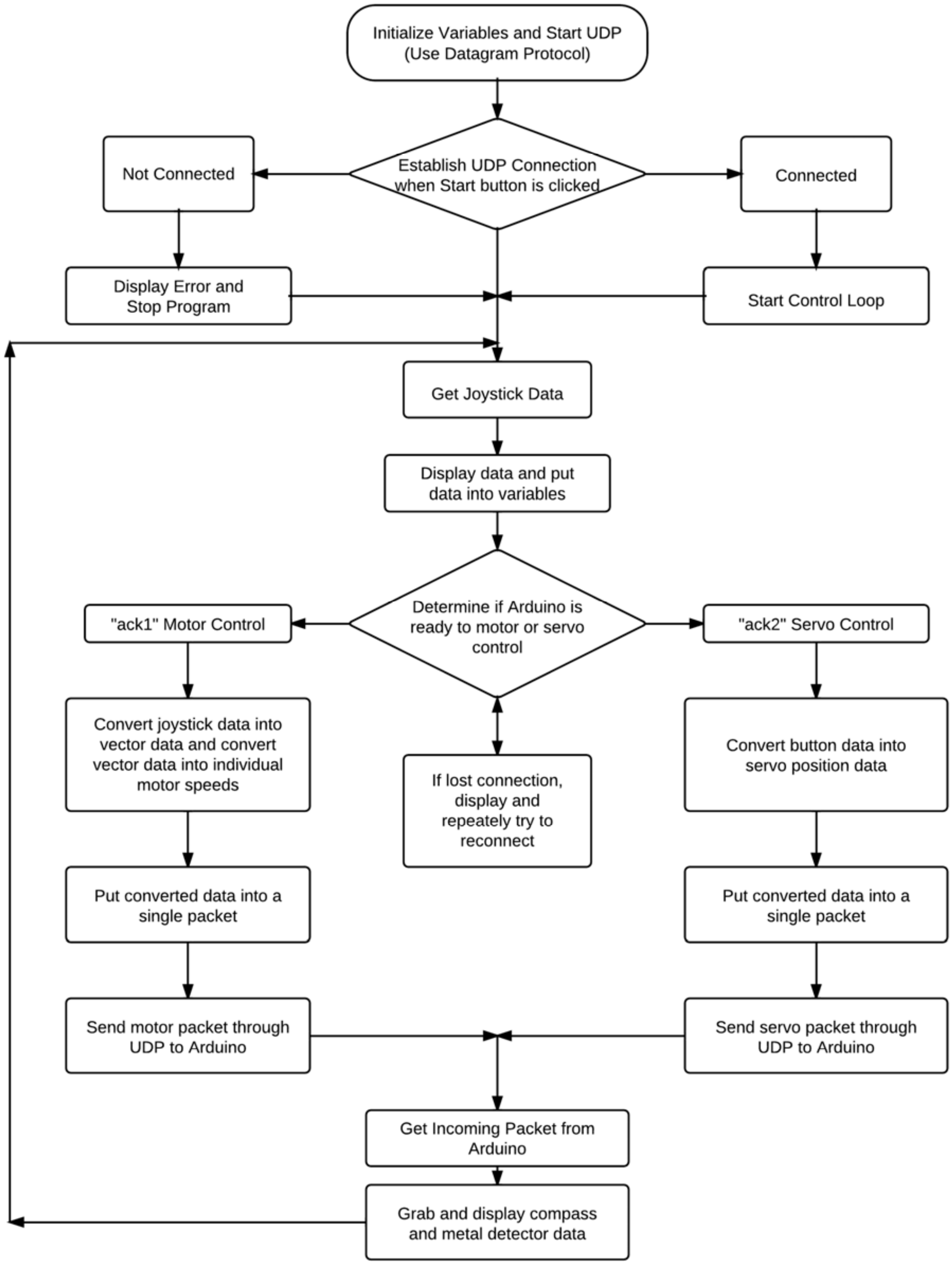
Although our company is quite satisfied with the way the ROV has turned out, there are, as there always are, areas for improvement that have become apparent only in hindsight. Chief among these are the claw and measurement device. We went through a lot of trouble while testing the arm, which was not powerful enough. This could be resolved by installing a pneumatic arm which would have a better grip of the objects and higher torque. Our measurement device is also lacking; it proved to be difficult to accurately maneuver the ROV to hook onto the shipwreck. During the planning stages, we thought about using easier methods such as video analysis and digital readers, but these devices seemed too inaccurate or expensive. This issue might be addressed by dropping the extra money on a sophisticated water measurement device. This device would accurately and easily measure the distance between two points. Additionally, after several underwater tests, we noticed that most of our nuts and bolts began to rust. This problem could be easily fixed by using stainless steel materials.

SOFTWARE FLOWCHARTS

ARDUINO MEGA MICROCONTROLLER



C# CONTROL STATION



LESSONS LEARNED

INTERPERSONAL - Since we had to manage our schoolwork, extracurricular and ROV building we learned organization skills and how to manage our time efficiently. We built a detailed timeline and had points to discuss for each meeting; we will be able to apply these organization techniques in our future endeavors. We also organized our expenses efficiently by making a collaborative spreadsheet.

TECHNICAL– All of us had experience with programming in C and C++, but this competition opened our eyes to a variety of different languages such as C#. We also had to get used to a new Integrated Development Environment (IDE) for the Arduino. The knowledge that we have acquired by programming this ROV will greatly ameliorate out programming future.

Additionally, during the first building stages, we discovered we made some small mistakes while creating the PVC frame. We were going too fast and missed out on important details of the construction. This event taught us to spend more time planning, drawing and measuring each part before doing any irreversible work on it.

Furthermore, this competition has taught us that, even though each system works independently, that does not guarantee that they will all work together. For example, our digital compass worked perfectly by itself, but other components inside the ROV created electromagnetic interference and rendered it unreliable.

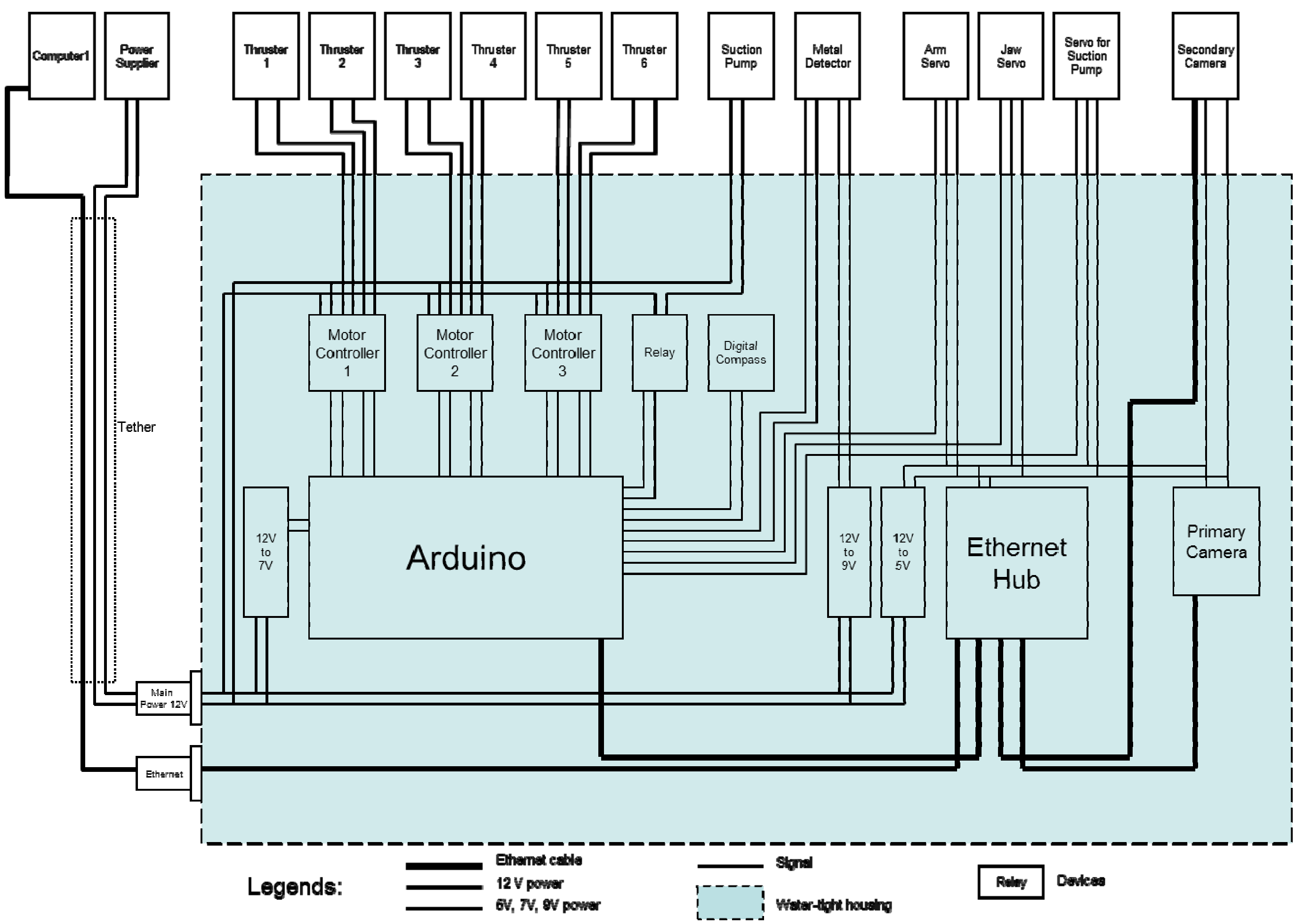
REFLECTIONS

“This life-changing experience opened my eyes to a new field of possibilities that I didn’t even know existed. Robotics meetings marked the apex of my day as I greatly improved my programming skills and learned much more about technology and electronics. The last few months have shown that a determined team can accomplish a task that would be impossible for an individual to complete. “– Fernando Trujano

“Before this year I had never participated in any sort of robotic competition. Being able to build a robot, and a team, has opened my eyes to what a real world engineering environment would be like. Even though we remain a small team, we have accomplished as much as any of the larger teams. This shows that with dedication and perseverance anyone can succeed. And such qualities are exactly what are necessary to overcome devastation from the abundance of shipwrecks in the world.”- Tim Flichy

"To be a good engineer, one needs to maintain the three balances. The first balance is between ambitious imagination and realistic solution. In many cases, projects are constrained by limited fund, manpower, knowledge, and skill set, therefore only the plans based on the available resources can be carried out successfully. The second balance is between the overall big picture and the small details. When a project becomes complicated with multiple sub-systems, integration is essential for success. Ignoring the details will cause the final product to be never achievable, and ignoring the whole picture will make any perfect sub-system useless. The third balance is between the technical endeavor and non-technical management. Putting too much emphasis on only one of these will cause the other to become a persistent problem that may greatly delay the project. These three balances need to be perfectly mixed like a compound epoxy to cure a near perfect end product." – Tian Yao

ELECTRICAL SCHEMATIC



TIMELINE

- **January 16** — Introduction to project
- **January 21** — Item list completed. Start design
- **January 31** — Get most raw parts and build fuse box
- **February 4** — Detail CAD design drawing
- **February 11** — Complete main housing + tether + feedthrough
- **February 13** — Main housting Waterproof test
- **February 18** — Complete Basic Programming. Build arm and suction device
- **February 25** — Build ROV Frame and metal detector
- **February 26** — Waterproof individual components
- **March 3** — Assamble ROV and test for leaks
- **March 4th** — Test for buoyancy and make proper ajustments
- **March 10** — Finish Programming and Begin Testing
- **April 1** — Isolate Problems and Troubleshoot
- **April 5** — Finish Report and Posteboard
- **April 14** — Competition

EXPENDITURES

Material	Amount	Quantity	Supplier	Order Sum
Registration	$50.00	1	MATE Rover	$50.00
Housing Aluminum and assembly parts	$249.78	1	Speedy Metals and McMaster	$249.78
Sabertooth Motor Controllers	$79.99	3	Dimension Engineering	$239.97
Trednet Ethernet Hub	$29.99	2	Newegg	$29.99
Arduino + Ethernet Shield	$106.60	3	Adafruit	$319.79
Bilge Pump	$33.00	4	Amazon	$132.00
Ethernet couplers and wire	$102.09	1	Digikey, Mouser and Newegg	$102.09
PVC Frame fitting and assembly parts	$153.94	1	Amazon and Mcmaster	$153.94
Wire and tubing	$133.11	1	Electronic Parts Outlet and Home Depot	$110.12
Servos	$191.72	1	Towerhobbies and Sparkfun	$191.72
Arm and parts	$86.33	1	SparkFun	$86.63
Pumps and suction device	$94.55	1	Amazon	$94.55
Tether and sleeving	$119.38	1	Electronic Parts Outlet	$119.38
Digital Compass	$50.90	1	Pololu	$50.90
HD Camera P3304	$787.99	1	Donation: Axis	$787.99
Secondary Camera	$269.00	1	Donation: Axis	$269.00
Machining on main housing	$180.00	1	Sivco Inc	$180.00
Fuse box and parts	$34.56	1	Amazon and RadioShack	$34.56
Electric Circuit	$30.38	1	Mouser	$30.38
Waterproofing materials	$36.79	1	Amazon and Home depot	$36.79
7V and 5VDC Regulator	$52.05	1	Dimension Engineering	$52.05
Propeller	$5.85	2	Tower Hobbies	$11.7
Anti-Fog Spray	$8.86	1	Amazon	$8.86
Pan-Tilt for camera	$13.29	1	Sparkfun	$13.29
Total				**$3,355.48**

ACKNOLEDGEMENTS

INTECSEA
WorleyParsons Group

AXIS®
COMMUNICATIONS

Sivco Inc.
The source of High Metal Fabrication

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MATE