OCEANUS

Titan Robotics Club

AT

Guilford Technical

Community College

Greensboro, North Carolina

Team Roster

Kyle Gibbons	President	Mechatronics/Electronics
Roderick Fletcher	Treasurer	Mechatronics
Sean Whitley	Secretary/Time Keeper	Mechanical Engineering
Richard Chia	Operations Manager	Mechatronics/Pre-Engineering
Jason Herrera	Programming	Mechatronics
Holden Price	Acquisitions Manager	Mechatronics
Morgan Dahlin	Technical Writer & Graphics	Mechanical Engineering
Jared Lindsay	Drafting & Design	Mechanical Engineering
Terrell Warner	Intern	Middle-College
Israel Suarez	Intern	Middle-College
Andy Baughman	Faculty Advisor	Mechatronics Instructor

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Introduction

Founded spring of 2013, as a student-run club at Guilford Technical Community College's campus in Greensboro, North Carolina, the Titan Robotics Club is dedicated to the idea that automation should be accessible to interested parties from all walks of life. After a fourth place finish at last year's ATMAE Battle Hoops competition in New Orleans, Louisiana, the team was eager to push the limits of their skills and face a greater challenge. That is when we found out about the MATE competition. It was soon decided that we would create an ROV named for Oceanus, the titan who ruled over all fresh water in Greek mythology.

Oceanus is the Titan Robotics Club's entry into the 2014 MATE competition, and is our first attempt at constructing a submersible ROV. In order to get up to speed on the vagaries of aquatic robotics, we entered into a 'crash course' on underwater engineering, and have done extensive tests in preparation for the contest. The team is eager to establish a positive reputation among the robotics community, and is happy for the opportunity to display their skills publicly. The Oceanus project has been an undertaking with a great deal of trial and error involved. The entire team has had to really step up their game in order to complete all experimentation and work within the deadlines.

The Oceanus ROV

Design Philosophy

Although a variety of hull types were discussed in the early conceptual phase of the project, it was eventually decided that an essentially open frame built from light but sturdy PVC was the most practical approach from a perspective of both time and money. Closed hull designs would require too much time to construct and test, and a metal frame would be too heavy and expensive. PVC allows for a great deal of experimentation with different dimensions for Oceanus, with minimal time and expense.

The only part of the ROV that absolutely has to remain water-tight is the command module, a thick PVC tube containing all of the robot's processors; a veritable electronic brain. Many lessons were learned concerning this vital area.

From the beginning, the need to keep systems aboard the ROV as simple as possible was well understood. This serves to eliminate potentially costly delays in implementation and execution of tasks. Also simple techniques and devices tend to prove more reliable in the field than their more complex counter-parts.

Definition by Limitation

The rules and specifications of the competition help to define the nature of the Oceanus ROV more than any other factor. The use of an umbilical to deliver power and exchange control data precluded the use of a 360 degree design, and meant that there would be no need to devote precious space to heavy and potentially dangerous onboard batteries. The size of the opening the robot will have to navigate through and the interior of the mock ship dictate the maximum dimensions of the unit quite clearly.

The list of tasks which the Oceanus ROV must perform also has great impact on the design process. The need to identify so many different features within a limited time-frame made it clear that multiple cameras employed at different angles would be an invaluable asset. The need to manipulate the environment at a number of junctures in the mission also required some members of the team to acquire new skills in the construction and use of a remote operated claw.

Frame

The ½" PVC used to construct the frame of the ROV is commercially available at hardware retailers across North America. A variety of different connectors are employed, and the entire framework is fast, easy and inexpensive to construct. In order to avoid unwanted buoyancy from air pockets within the pipes, holes are drilled through them at intervals along the frame to allow the air to escape when the robot is placed in the water, and the water which then fills the frame adds weight. The reduction in air pockets and the additional weight of water increases stability for the ROV. From the start of the construction process the basic cube shape has been used for the frame, because it provides the best blend of stability and maneuverability for the effort expended.

Lighting

Illumination for Oceanus operation at depth and inside closed spaces is supplied by a pair of custom modified LED lights mounted on the frame on the front corners. These lights each operate independently on 5 volts. This allows the ROV to operate in low light.

Cameras

Four Waterproof Rear Backup View Cameras are mounted on the frame of the ROV at intervals to allow for a wide field of vision, and increase the chance of finding obscure features with fewer passes through a given area. Each camera has a 170 degree field of vision, and a resolution of 656x492 pixels, which are uploaded to an onboard DVR which is linked to the Ubuntu laptop for display on the monitor for nearly instantaneous review. Each camera runs on12 volts and operates independently of the other three cameras.

Thrusters

For power, Oceanus relies on five SeaBotics thrusters, rated for up to a 500 foot depth, which are mounted strategically upon the frame to allow a full range of movement within three dimensional space. Each thruster can produce a force up to 2.9 kilograms per foot (28.4N). Each thruster runs on 18 volts.

Manipulator

A modified Vex articulated claw is the robot’s tool for lifting and manipulating the environment around it. This item has been painstakingly waterproofed for operation in Oceanus intended element and runs on 12 volts.

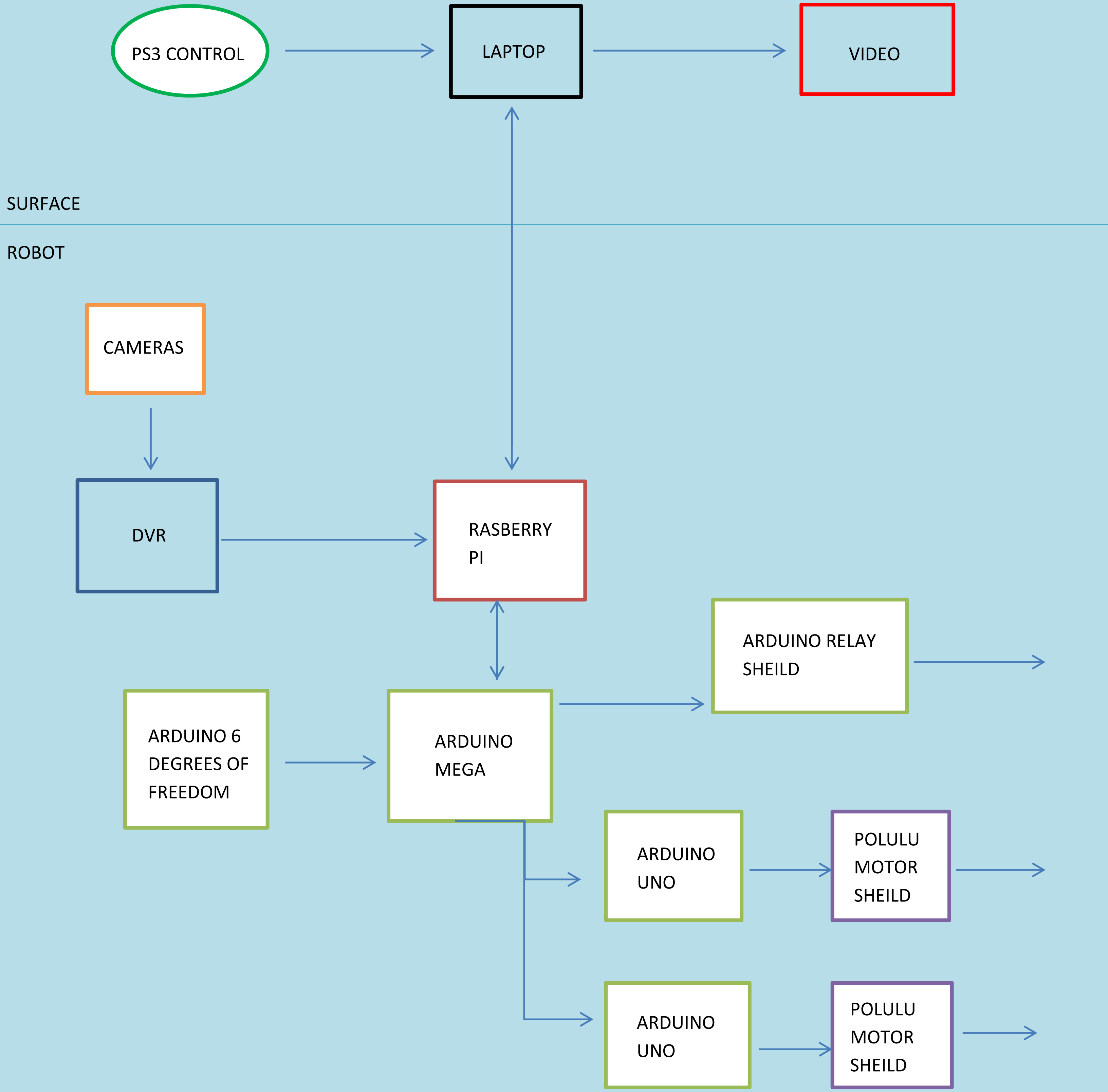
Safety Features

The robot is equipped with a series of dense foam flotation devices at varying points along the frame, so that in the event of a catastrophic, system wide failure, the ROV will float to the surface, and can be easily retrieved. It was decided during the design phase of the project that no pneumatic or hydraulic features would be included in Oceanus, in order to reduce the risk of injury and environmental contamination. To protect against electrical accidents, all wiring has been carefully inspected by at least two team members during each step in the unit’s construction. In case of a signal failure the robot has failsafe programmed into the code which shuts off all thrusters. Finally, as per the standards of the contest, a 40 amp fuse protects the robot from an electrical surge.

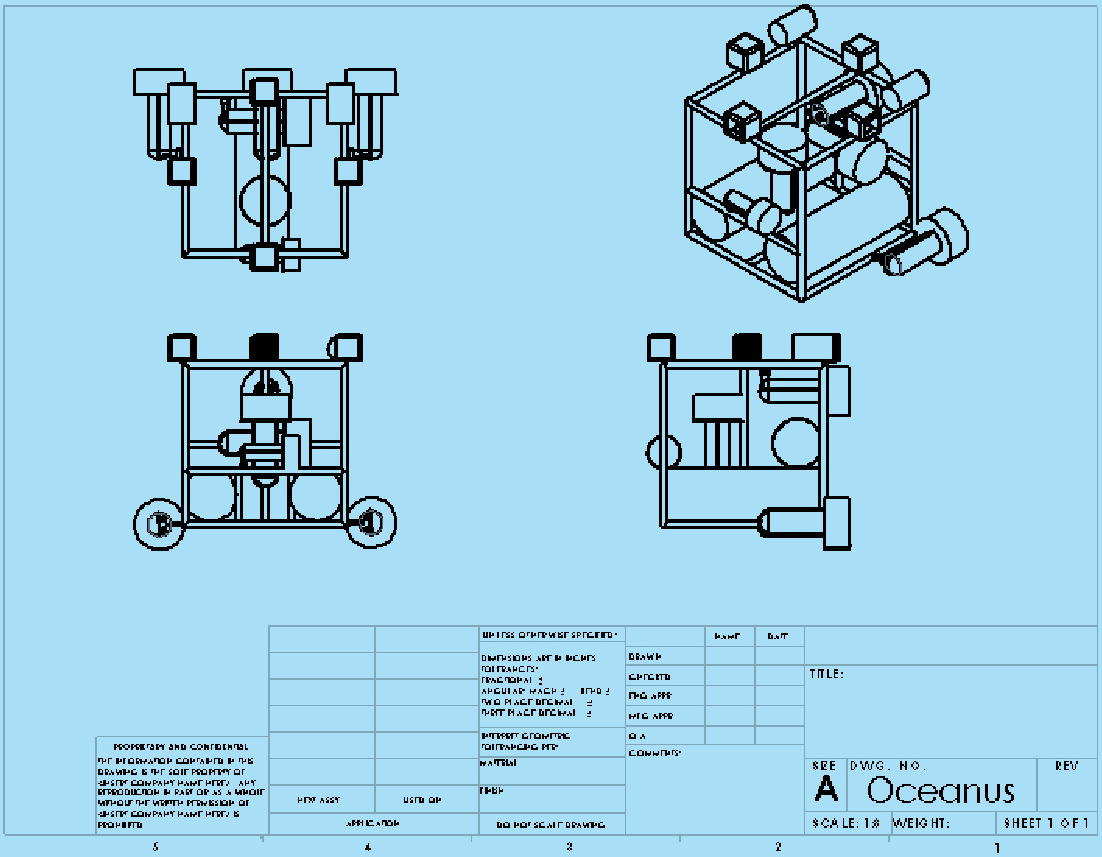
Processing

The heart of the control system is a Raspberry Pi model B, with 24 GFLOPs, and has a default operating frequency of 700 MHz. Linked to the Raspberry Pi is an Arduino Mega, equipped with a Polulu Motor Shield, which is connected to an Arduino Six Degrees of Freedom. A pair of Arduino Uno each with Polulu Motor Shields is enthralled to the Mega, as is an Arduino Motor Relay Shield to control the lights and manipulator arm. Each Arduino controls two of the SeaBotics thrusters.

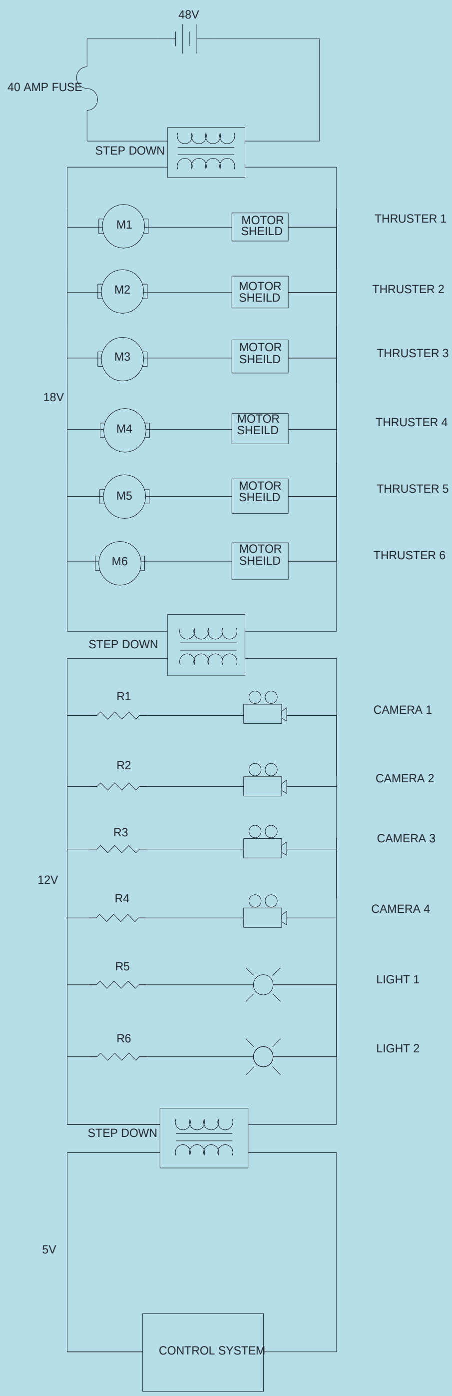
Control Architecture



3-D Model of Design



Ladder Diagram for Electrical Systems



Learning Process

A number of things were learned from our experimentation and construction of Oceanus. One of the chief lessons was with regards to the effects of current and drift, even in a seemingly unmoving pool. It was noted that within the small test pool set up in our lab the wash of the thrusters themselves would often create unexpected water movements which in such a confined space could easily affect the steerage of the robot.

A similar lesson was also learned regarding the distortions caused by viewing objects through several feet of water, as opposed to the relative clarity of open air. The distances to various target features, and the relative positions of things can often be difficult to judge, especially when the water is stirred up by the thruster on the ROV. Relying on the view on the monitor as supplied by the camera, instead of the view from the naked eye at poolside was not easy to instil in Oceanus' operators.

Challenges

The creation of the air tight command module for the delicate electronics systems for Oceanus presented the greatest chain of challenges to the Titan Robotics Team. Making the container for the processors out of a length of PVC pipe seemed like an obvious choice, however during testing it became clear that keeping water out of this tube was going to be far more difficult than originally thought.

Holes obviously had to be drilled in the cap which seals the end of the tube, so that the umbilicus could be run from the surface to the fragile electronics, and then from the processors to the various systems they control which are spread across the frame. Originally it was believed that a simple application of silicone would be sufficient to seal these openings around the wiring, but as repeated tests showed, it would require epoxy in place of silicone due to its versatility and ability to dry without exposure to air. This resulted in a veritable sculpture of adhesive to keep the water out when pressure was applied, especially at depths greater than one or two feet.

The second lesson learned from this process was in the area of maximizing space. The interior of the command module being quite small, it was eventually clear that there was simply too much vital equipment to comfortably fit within the confines of the prototype tube. The result of this was that some team members developed a great aptitude for carefully packing the vital components into a very small space. Eventually the dimensions of the tube for the final version of Oceanus were increased considerably.

Reflections

Working on the Oceanus ROV project has been a very rich and rewarding experience for everyone involved. Participating in the MATE competition has taught the entire team a plethora of basic lessons with regards to communication and teamwork. This competition has held an interesting array of otherwise uncommon experiences. There is something unnatural about throwing expensive electronics into a pool, let me just say that. However the competition exposed the team to real world lessons that most would have not otherwise experienced.

Future Improvements

The possible applications that Oceanus could see use in are many and varied, even though the focus of the MATE competition is on underwater study and conservation. The robots design is versatile enough that repair and maintenance crews on ships or oil rigs might use a modified version to do inspections below the waterline. Marine biologists could use the ROV to observe aquatic habitats, and possibly even deliver or retrieve tracking devices from migratory sea animals.

The future of marine robotics is bright, and the experiences gained from the Mate competition will enable the Titan Robotics Club to enjoy further developments in this exciting genre of mechanization. The simplicity of their basic design, and low over-all cost could make the Oceanus robot, or a design evolved from it, available to the budgets of even small organizations.

Bill of Materials

Item	*Unit Price*	*Quantity*	*Total Price*
Frame and testing			
½” PVC Pipe	$ 2.00	15	$ 30.00
PVC Connectors	$ 0.36	20	$ 7.20
PVC Elbow Connectors	$ 0.51	20	$ 10.20
PVC T Connectors	$ 0.46	20	$ 9.20
PVC 45° Connectors	$ 0.67	20	$ 13.40
Shade Cloth	$ 39.98	1	$ 39.98
4” PVC Pipe	$ 12.17	2	$ 24.34
2” PVC Plug	$ 0.35	2	$ 0.70
3” PVC Pipe	$ 9.31	2	$ 18.62
2” PVC Pipe	$ 7.91	3	$ 23.73
2’x4’ Sheet Lexan	$ 9.61	1	$ 9.61
J-B Weld Adhesive	$ 5.67	4	$ 22.68
2" PVC Cap	$ 1.56	3	$ 4.68
3” PVC Cap	$ 4.12	1	$ 4.12
4” PVC Cap	$ 8.05	1	$ 8.05
Assorted Zip Ties	$ 5.99	1	$ 5.99
Foam Pool Floats	$ 1.00	2	$ 2.00
Intex 15’ x 4’ Pool	$ 312.00	1	$ 312.00
½” PVC Cap	$ 0.36	20	$ 7.20
Electronics			
UBEC DC/DC Converter	$ 9.95	1	$ 9.95
Camera (Waterproof)	$ 13.01	4	$ 52.04
Raspberry Pi Kit	$ 79.99	2	$ 159.98
48V to 12V Converter	$ 25.98	1	$ 25.98
Adjustable Converter	$ 11.50	1	$ 11.50
Silicone Oil	$ 18.94	3	$ 56.82
DVR w/t remote viewing	$ 130.00	1	$ 130.00
SeaMate Puffer Fish KIT	$ 130.00	2	$ 260.00
RF Adapters	$ 1.24	4	$ 4.96
Arduino Mega ADK	$ 69.95	1	$ 69.95
Arduino UNO R3	$ 24.51	2	$ 49.02
Arduimu 9DOF	$ 39.98	1	$ 39.98
Pololu Motor Shield	$ 49.95	4	$ 199.80
Relay Board for Arduino	$ 7.12	2	$ 14.24
Conductivity Kit	$ 149.95	1	$ 149.95
LED Flashlights	$ 10.00	3	$ 30.00

Travel			
Hotel	$ 600.00	6	$3,600.00
Gas	$ 3.78	120	$ 453.60
			$5,871.47

Work Breakdown Structure

What	Who	When
Planning Meeting	Entire Team	January
Initial Paperwork	Michael Whitley	February
Initial Parts Order/Procurement	Kyle Gibbons	February
Construction of Test Course	Kyle Gibbons, Michael Whitley, Jared Lindsay	January-February
Test Pool Set-Up	Kyle Gibbons	February
Second Parts Order	Kyle Gibbons	March
Programming Review and Discussion	Kyle Gibbons, Jason Herrera	March 6-March 20
Rough Draft of Spec Sheets Written	Michael Whitley	March 13
Raspberry Pi and Arduino begin communicating with one another for the first time	Kyle Gibbons, Jason Herrera	March 20
Power Management discussed, and preliminary Electrical Diagram sketched	Michael Whitley, Kyle Gibbons	March 27
Motor Control Refined	Kyle Gibbons, Jason Herrera	March 27
Frame Constructed	Kyle Gibbons, Richard Chia	April 3
Thrusters and Processors Attached and Wired	Kyle Gibbons, Roderick Fletcher, Richard Chia	April 10
Initial Testing of ROV in Water	Kyle Gibbons, Jason Herrera	April 15
Repairs Made to Waterproof Seal	Kyle Gibbons, Roderick Fletcher, Jared Lindsay	April 17
Waterproofing Tested	Kyle Gibbons, Holden Price, Roderick Fletcher	April 17
Assembly of Lights Begun	Kyle Gibbons, Richard Chia	April 22
Initial Work Done with Claw	Kyle Gibbons	April 24
First Camera Mounted and Wired In	Kyle Gibbons, Jason Herrera, Richard Chia	April 29
Camera Resolution and Performance Tested	Kyle Gibbons	May 1
Circuitry Repair	Kyle Gibbons, Roderick Fletcher	May 8
Rough Draft of SIDs Created	Kyle Gibbons, Michael Whitley	May 8
Pilot Testing	Kyle Gibbons	May 8

Additional Waterproofing Applied to Command Module	Kyle Gibbons, Jared Lindsay, Michael Whitley	May 13
Command Module Reloaded	Kyle Gibbons, Jarod Lindsay	May 15
Final Hand Drawings of SID Diagrams Finished	Michael Whitley	May 16
Final Spec Sheet Composed, and Pictures Added	Michael Whitley	May 16
Demonstration Video Filmed	Kyle Gibbons, Jared Lindsay, Roderick Fletcher, Michael Whitley, Jason Herrera, Holden Price	May 17
PVC for Larger Command Module Ordered	Kyle Gibbons	May 19
Piloting Tests	Kyle Gibbons, Holden Price, Jared Lindsay	May 19
Seal of Command Module Reapplied and Tested	Kyle Gibbons, Jason Herrera, Jared Lindsay, Roderick Fletcher	May 19
Budget Report Revised	Michael Whitley, Morgan Dahlin	May 20
Computer Version of SIDs Made	Morgan Dahlin	May 20
Morning News Interview with Faculty Advisor	Kyle Gibbons, Morgan Dahlin, Jared Lindsay, Michael Whitley	May 21
Revised Demonstration Video Filmed	Kyle Gibbons, Jared Lindsay, Roderick Fletcher, Jason Herrera, Michael Whitley, Richard Chia	May 21
Revised Video and SIDs Re-submitted	Kyle Gibbons, Michael Whitley, Richard Chia	May 21
Final Edit of Technical Report	Michael Whitley	May 21
Solidworks Model Completed	Jared Lindsay	May 21
Submit Technical Report	Morgan Dahlin, Michael Whitley	May 22

References

www.openROV.com

www.raspberrypi.org

www.hardwaresecrets.com

www.darkpirises.com

http://www.marinetech.org/

Raspberry Pi Cookbook, Simon Monk

Arduino Cookbook, Simon Monk

Acknowledgements

Guilford Technical Community College

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