Orange Mango

Presents, Alpha

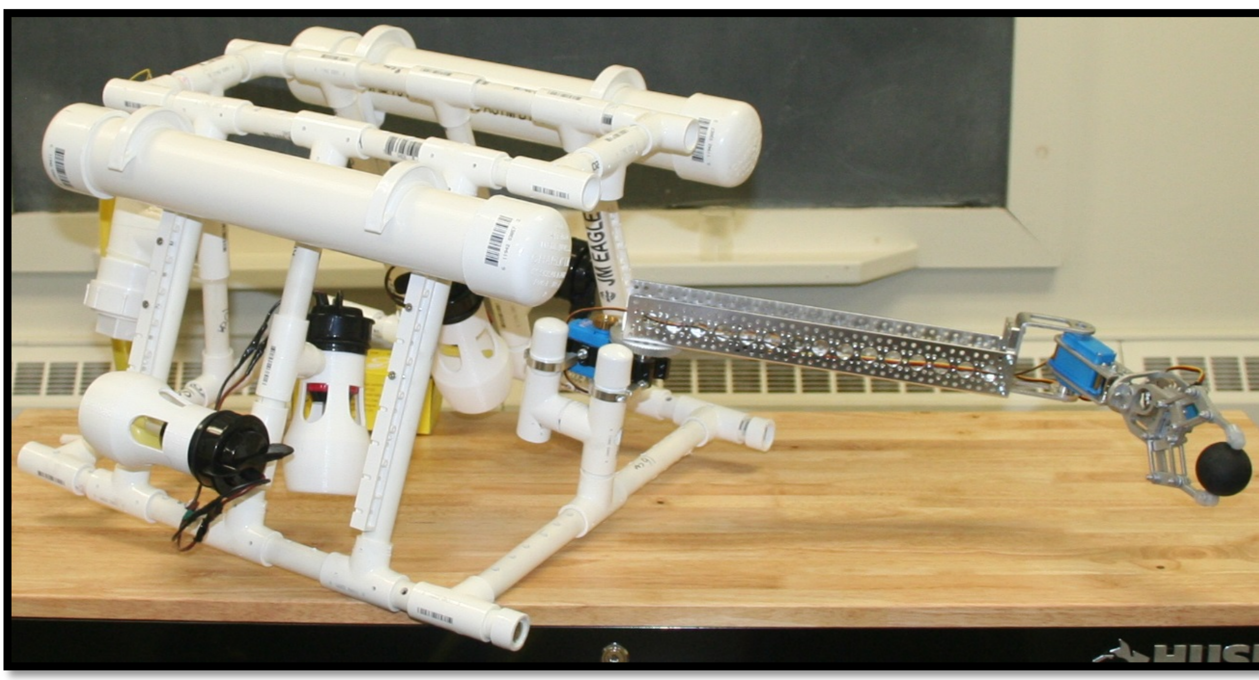

Photo 1: Alpha in the lab, photo by Damian Baraty

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The Orange Mango Team

Photo 1: Photo taken by Cathy Skitko of the Orange Mango Robotics Team

(From left to right)

Damian Baraty .... Corporate Advisor

Kevin Kim .... Design Engineer

Konstantine Golobokov .... Chief Security Officer

Nathan Rakos .... Chief Financial Officer

W David Null .... Chief Executive Officer

Adam Schiavone .... Chief Technology Officer

Dylan Spector .... Head Game Theorist

Owen Davies .... Chief Safety Officer / Video Technician

Max Opechowski (Not in picture) .... Communications Director

Executive Summary

Here at Orange Mango, we believe robotics truly is an art form. One of the cornerstones that we build into our projects is the pursuit of quality and style working in tandem. We seek to find elegant and lasting solutions to every problem we encounter. Since this was our first time entering the MATE ranger class robotics competition we wanted to start things off with a bang.

When we created Alpha, we started with the well-known vector design schematic from the Marine Advanced Technology Education Center, and have since made a series of technical modifications that we believe make our robot extremely versatile, easy to use, and playfully elegant. In short, Alpha brings together the best of traditional MATE designs with current cutting edge technology.

The Orange Mango brand name is quite unique to us. The fruit symbolizes creativity, productivity, and innovation. We take these three tenets to heart when we design. Our logo symbolizes the Big "O" Function, which any computer scientist will recognize as the fundamental complexity function of any algorithm. It reminds us to strive for grace and efficiency in everything we do.

Design Rationale

As first year entrants in the MATE competition, we sought a robot design that we knew would be easy to sink our teeth into. From the MATE website, we found the Triggerfish Vector design. We secured the PVC and tools required, and assembled our robot.

Next, our team met for comprehensive board meeting in which we systematically went through each task we would need to complete. From our observations and conclusions, we decided on a set of modifications to the vector design that we believed would allow us to accomplish the greatest number of tasks in the shortest amount of time. Our major modifications included designing and fabricating the robotic arm, implementing a four camera system for video, and adding the laser measuring system.

We began to order parts and assemble our adaptations. Probably the greatest asset to our design process was having a pool on campus that was available to us throughout our testing. From our real world pool tests, we gathered a full new set of revisions that needed to be made. Thus began our loop of designing, testing, analyzing results, and iterating this design loop.

While the design process continues, and we expect our design to evolve as we test and observe its performance, we are confident we have an effective design that can continue to adapt to new challenges and roles.

Special Features

3D Printed Motor Housing

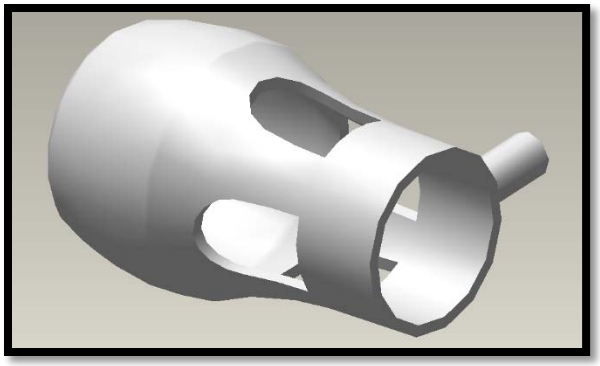
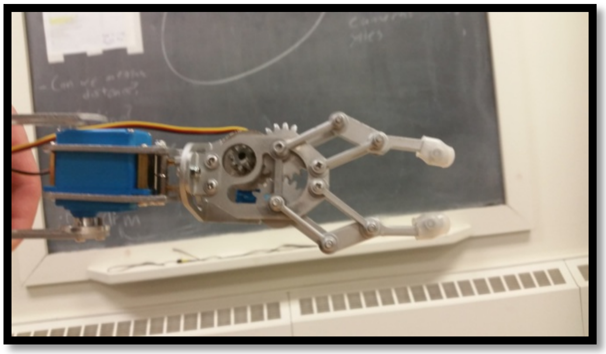


Photo 2: CAD file of motor housings captured by David Null (CEO)

To aid our propulsion system we have added 3D printed motor housings to streamline the thrust from our motors. The CAD design shown above was created using Pro Engineer™ from Creo™. We printed it on a Series-1™ 3D printer from Type A Machines™, one of three at The Hill School. Three revisions were made on the part in order to ensure the perfect shape for maximum thrust. The specific advantages to using this design are as follows.

- Safe encapsulation of propellers.
- Enhanced thrust capability.
- Custom fit exactly for our robot.
- Stylish design.

Robotic Arm



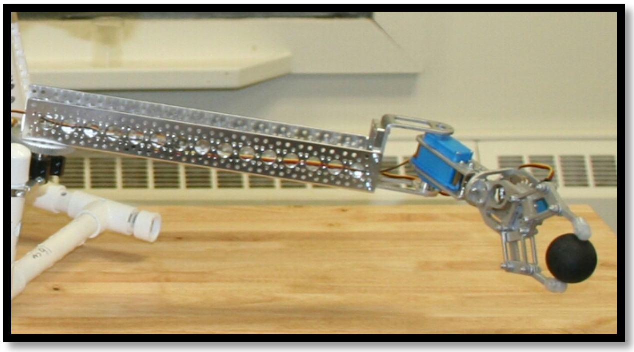


Photo 3: The robotic arm holding a squash ball. Photo by D. Baraty.

The Robotic arm was designed with simplicity in mind. The arm has two axes of freedom, along with a gripper. Each moveable component is powered by a HiTec Waterproof Servo motor. Each servo is supplied with six volts from the surface over a cat6 cable along with four servo signal lines. The only piece of exposed circuitry on the entire robot is here, the cat6 receiving board. It has a chip designed to boost the signal lines back up to full strength, while also breaking out the power lines for the servos. This small board is fully waterproofed and resides in the tether container.

We opted for servos over pneumatics for ease of use and precision. We are able to set each component of the arm to a specific angle, which is much more precise than we could get with pneumatics. Also, as the servos are digital they integrate very nicely with our existing setup of a computer controlled robot.

Cameras

We have four small color backup cameras.
All cameras operate on 12V. They all have three wires coming from them. They are: 12V GND Signal (using the middle wire of a RCA cable). All Signal RCA cables will be plugged into the video controller. The power cables will be connected as shown in the diagram, but with four cameras instead of three to a fifth RCA cable.

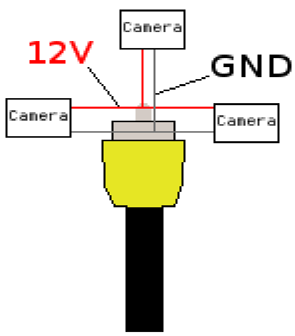


Photo 4: The basics of our cameras. Acquired from Google images.

This will be connected to the battery on the other end.
The camera arrangement on the craft will be as follows. One will be on the top front, one on the bottom front, and one on either side, as shown in the images below.

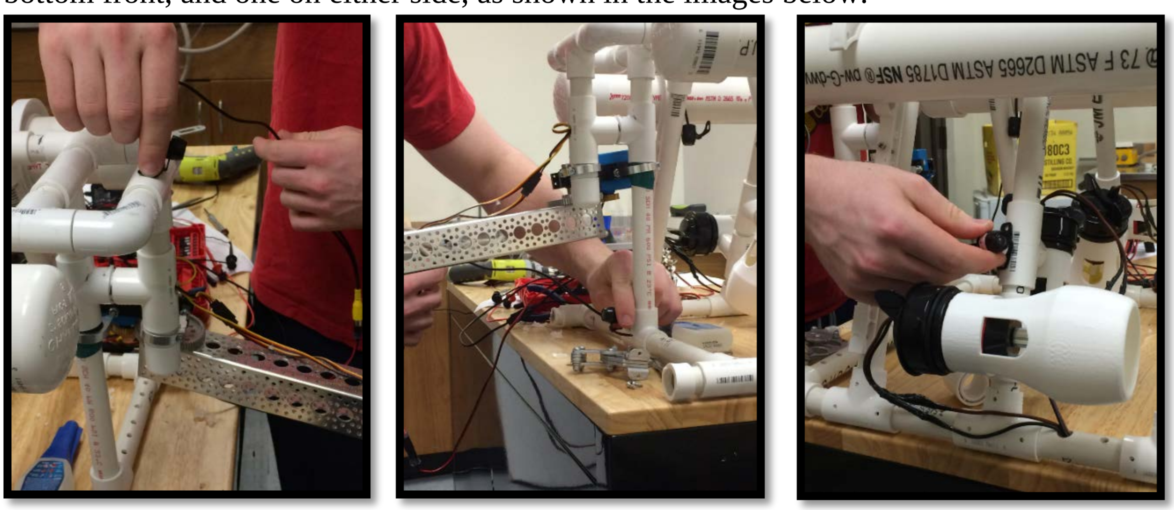


Photo 5: Camera Placement. Photo taken by Owen Davies.

Tether

Photo 6: picture of floating tether. Photo by Owen Davies.

Through our relationship with VideoRay and gPARSEC—the Greater Pottstown Area Robotics, Science, and Engineering Community—we were made aware of a supply of floating tether that VideoRay uses for their industrial strength line of tethered ROVs. We were allowed to select from scraps of former projects in lengths up to 150’. We were able to find four lengths under this limit and fashion four 75’ tethers to accommodate our two ROV’s, one following the Vector design and one the Ortho version of the Triggerfish. Our Ortho design was assembled for training purposes and is currently our backup ROV frame.

These tethers feature four thicker wires that we selected to power our four motors (requiring two tethers per ROV) and six thin wires (22AWG) to conduct video signals and control signals for our arm servos. Since these tethers are quite buoyant, we are able to bundle together CAT5 Ethernet cable to the floating umbilical and still have a tether floating on the surface, not getting in the way of ROV operation.

Lasers

SPECIFICATIONS

	SPECIFICATIONS	635-01	650-01
1	Dimensions	Φ10.4 x 18.4 mm (Φ0.409" x 0.724")	
2	Operating voltage (Vop)	2.6~5 VDC	
3	Operating current (Iop)	< 50mA	< 35mA
4	Continuous wave output power (Po)	LPT<1mW / LPA≦3mW	
5	Wavelength at peak emission (λp)	630~645nm	645~665nm
6	Collimating lens	Aspherical plastic lens(ø7)	
7	Spot size at 5M	5±1 mm	
8	Divergence (Half Angle)	0.5 mRad	
9	Operating temp. range	+10°C ~+40°C	
10	Storage temp. range	-20°C ~+65°C	
11	Housing	Brass	
12	Mean time to failure (MTTF) 25℃	5000hrs	10000hrs

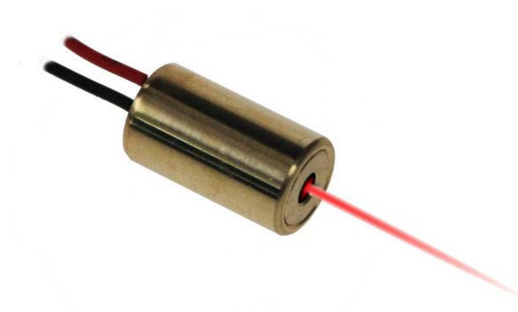


Photo 7: Photo and Specs of the lasers we used in our robot. Both were gathered from Google images.

We have three mounted 5mW red lasers pointed dead ahead, forming three parallel beams separated by sixteen inches in the horizontal and vertical directions. Our intent: to measure the size of objects by projecting a beam of a known separation upon a target. We did not have the opportunity to arm and test the laser system in our last competition, so we hope to employ the system in Newfoundland.

Control Board

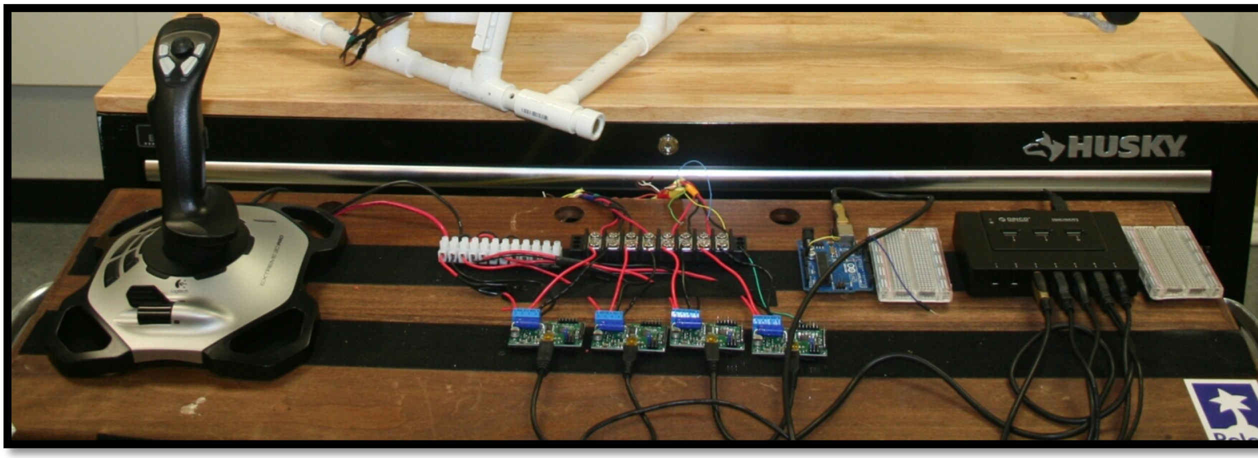


Photo 8: The main control board in all its glory. Photo credit: D. Baraty.

Logitech Joystick

Photo 9: The joystick we used to control our robot. Taken from the Logitech website.

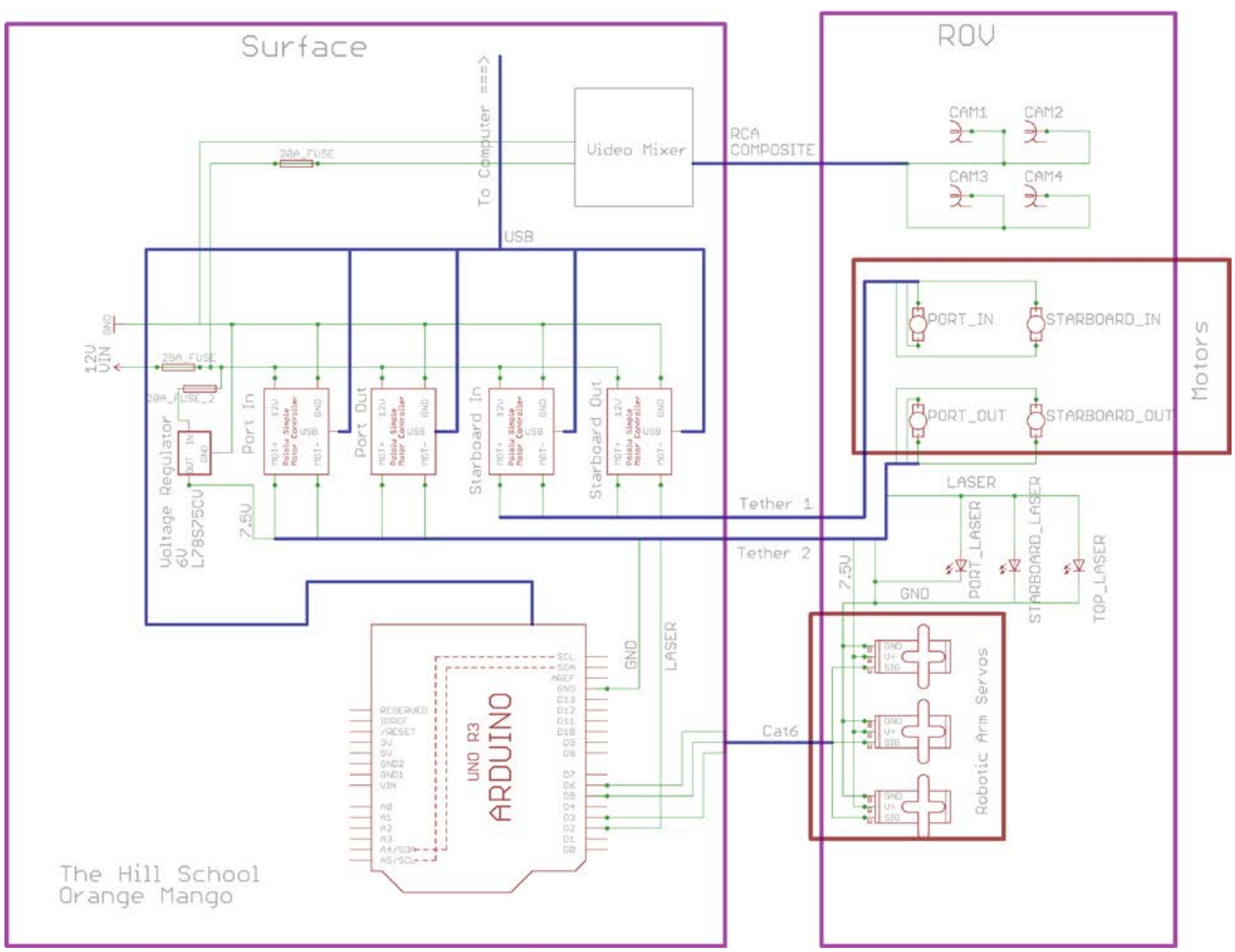
We chose to use a joystick as our main method of control input. The joystick has three axes that we can control: pitch, roll, and yaw. A simplified description of how the computer processes the joystick would be as follows: Pitch is used to directly control the outboard motors, thus controlling forward and reverse thrust. Roll is used to directly control the inboard motors. By firing the inboard motors in opposite directions we can cause to robot to slide left or right. Yaw is a rotation of the stick, so we mimic that action on the robot by increasing one outboard motor and decreasing the other motor. Up and down are read through two buttons on the top of the stick. Overall the joystick gives us the most natural way to interface a human with the underwater robot, all using one hand.

Pololu™ Motor Controllers

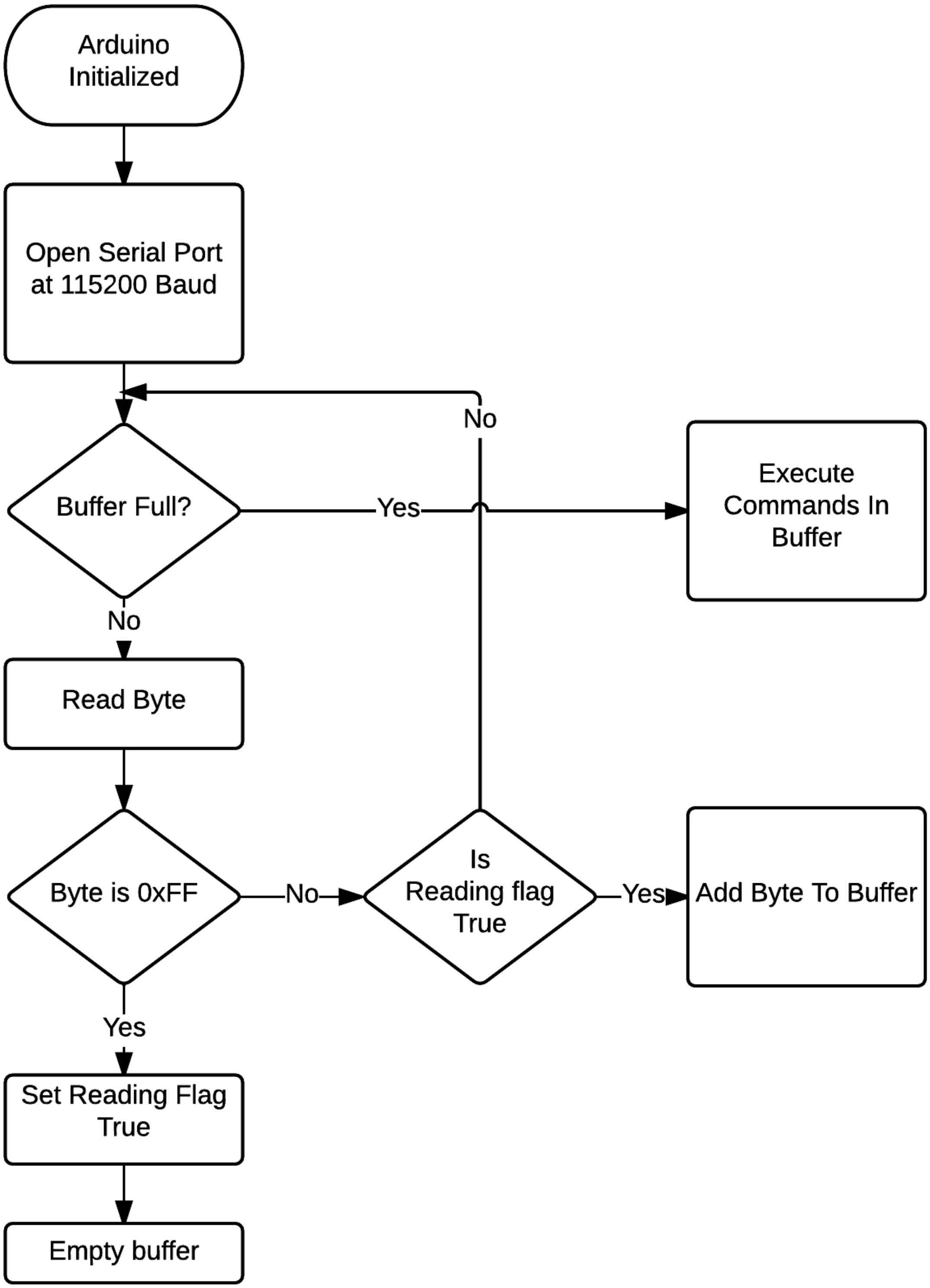
Photo 10: from Pololu website.

We chose to use Pololu™ Simple Motor Controllers (Rated 18V and 7A) for each motor. This is quite overkill as each only motor runs on 12V and about 4A max. But these motor controllers gave us great motor response, motor diagnostics, and USB support all at a reasonable price. One for each motor is powered directly from the 12V power source and given its data line from USB. All aspects of the motor's operation can be controlled over USB.

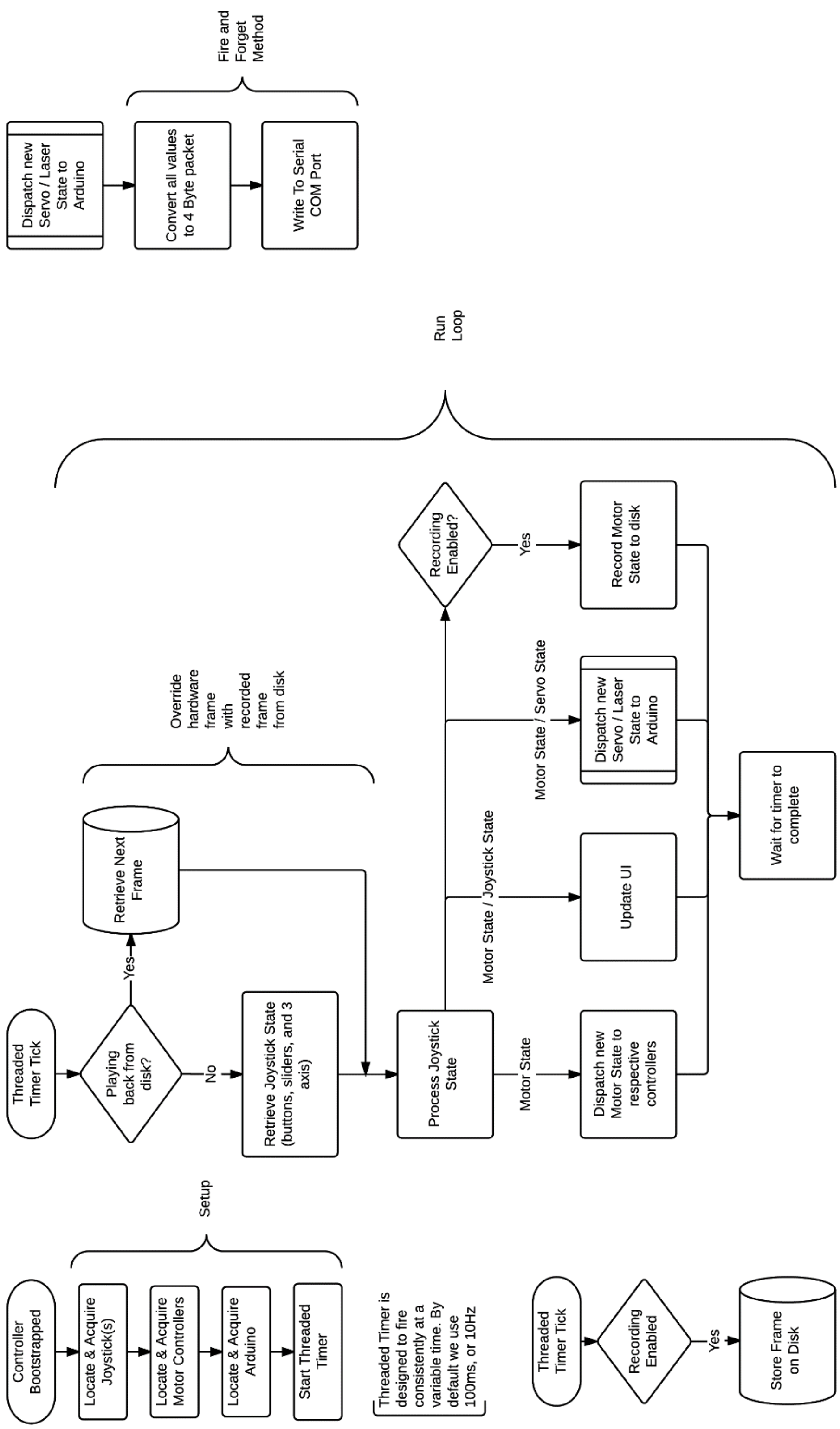
<u>Wiring Diagram</u>



Software Diagram – Arduino



Software Diagram – Computer



Buoyancy Calculations

In order to make Alpha neutrally buoyant, we needed the buoyant force to equal the force pf gravity $F_b = F_g$. This is logically equivalent to $(\rho_f)(V)(g) = (m)(g)$ where ρ_f is the density of water, V is the volume of our robot, g is the acceleration due to gravity, and m is the mass of the robot. After a few calculations...

Component	Number (dim)	Mass (g)	Volume (cm^3)	Density (g/cm^3)
Frame		718.327	933.8251	0.7692307692
Motors		196.55	99.25	1.980352645
Arm Assembly		1937	718	2.697771588
Steel Rod		259.05	33	7.85
Air Tanks		0.215513	175.93	0.001224992895
		3111.142513	1960.0051	

Photo 11: Calculations made by Max Opechowski.

Thus we have...

$$F_b = (999.97\ kg/m^3)(1960.0051x10^{-6}m^3)(9.8m/s^2) = 19.207N$$
$$F_g = (3111.142513x10^{-3}kg)(9.8m/s^2) = 30.489N$$

From this we figured out that we needed to add $30.489N - 19.207N = 11.282N$ of Buoyant force to our robot.

Financial Report

Item	Source	Cost	Number	Extended Cost
Johnson Pumps of America 28512 Marine Pump Cartridge for 1000 GPH Motor	Johnson Pumps of A	$36.11	4	$144.44
Quarton Laser Module-VLM-650-01 LPA (INDUSTRIAL USE DOT LASER)	Quarton USA	$19.60	4	$78.40
Arduino Uno R3 (Atmega328 - assembled)	Adafruit	$24.95	1	$24.95
Pololu 6V, 2.5A Step-Down Voltage Regulator D24V25F6	Pololu	$11.95	2	$23.90
Pololu Simple Motor Controller 18v7 (Fully Assembled)	Pololu	$33.95	6	$203.70
Logitech 963290-0403 Extreme 3D Pro USB Joystick	NewEgg	$39.99	1	$39.99
Esky EC170-06 World Smallest HD Color CCD Waterproof Vehicle Car Rear Viev	Esky	$19.99	4	$79.96
MATE Triggerfish Kit	MATE	$800.00	1	$800.00
Octura 1250 Plastic Prop	Octura	$2.89	4	$11.56
1" x 2' PVC pipe	The Home Depot	$1.98	1	$1.98
Velcro Industrial Strength 2in x 15ft Black	The Home Depot	$28.97	1	$28.97
1/2" x 20' Colored Electrical Tape 5pk	The Home Depot	$4.27	1	$4.27
HiTec HS-5086WP Waterpoof Micro Servo	ServoCity	$49.99	2	$99.98
HiTec HS-5646WP Waterpoof Standard Size Servo	ServoCity	$55.00	1	$55.00
Actobotics HS-5485HB 3-1 Servo Gear	ServoCity	$59.99	1	$59.99
Aluminum Channel 12"	SparkFun	$9.99	1	$9.99
Robotic Claw MkII	SparkFun	$11.99	1	$11.99
Robotic Claw Pan/Tilt Bracket - MKII	SparkFun	$29.99	1	$29.99
1/2" PVC SxSxS Tee	The Home Depot	$2.23	20	$44.60
Video Ray Tether 75'	Video Ray	$0.00	2	$0.00
4" Black Heat Shrink Tubing Assortment	The Home Depot	$14.97	1	$14.97
			Total:	$1,768,63

Photo 12: Financial records kept by Nathan Rakos, CFO.

We started with a Budget of $2,000.00.

Things We Can Do

This ROV was built with two things in mind: Ease of use, and Efficiency. It's minimalistic design allows it to easily propel itself through the water, stay perfectly buoyant, and "through its weight around" whenever it is required to produce a strong force.

The ROV is equipped with a robotic arm capable of easily retrieving, or otherwise manipulating most objects. The arm is equipped with two servo motors giving it both horizontal and vertical motion independent of the ROV.

This ROV is also capable of taking measurements with the aid of two lasers, built into its hull. It is also equipped with 4 cameras capable of giving the driver a nearly 360° view of the ROV's surroundings...

The ROV is programmed to respond to a Joystick's commands, allowing for simple control of all motors, the arm, and the lasers. The Joystick is also outfitted with a Throttle Adjuster. This allows the driver to quickly switch between speed and precision to accomplish their mission.

During the MATE competition, our ROV will be capable of completing nearly every task in the first 2 demonstration areas. The ROV is specifically designed to grab onto such objects as the Acoustic Sensor, O-Ball (Urchin), and Pipe Valve. Its nearly 360° view allows for full scanning of the pool. This will render such tasks as counting sea stars an easy. The ROV's triple-lasers allow for the measurement of most distances in the water.

Things We Cannot Do

In order to achieve the ease of use and simplicity we were looking for, we were forced to adopt certain design limitations when developing the ROV. For example, the ROV lacks the ability to measure voltage. This tool would not be as universally used as the ROV's other features. Implementing such a device into the ROV would have lead to a far less efficient machine.

The Robotic Arm is equipped with a medium size claw. While this claw is designed to grasp most objects it would encounter on a mission, it cannot grasp everything. Due to the claw's size, it is extremely difficult, if not impossible, to grasp objects that are either too small, or objects that have too large of a circumference for the hand to overcome.

Challenges We Overcame

Orange Mango has overcome many obstacles in the development of this ROV. The structural design of the ROV was our first challenge. Among these challenges were the need of motor protectors. We overcame this dilemma by designing and 3-D printing our own protectors. These protectors had multiple versions before their completion.

The testing of the ROV also resulted in errors. The first time we tested our lasers in the water, an undiscovered crack allowed water to seep into the compartment where the laser was stored. While the laser remained unharmed, this event did require some reassembly to fix.

At the regional competition at Villanova University, we experienced the failure of two motors due to broken mounts, and two cameras due to water penetrating the housing. We have redesigned our mounts, implemented a new method to secure motors to the frame, and are working on a more disaster-proof method of waterproofing our cameras for next time.

Future Improvements

Since this was the first year our team participated in the MATE ROV competition, we have a lot to look forward to and a lot of improvements and finer adjustments to make. However, the main and the most immediate focus of our team for the next year would include the incorporation of pneumatic and hydraulic technologies into our ROV. These advancements would allow us to use hydraulic power to perform our tasks. Instead of hoping that nothing goes wrong with our software and our servers, we would be able to rely on much simpler and more straightforward mechanical powers of hydraulic and/or pneumatic devices. That would make our ROV behave in a more predictable fashion. Another great application for a hydraulic/pneumatic device would be taking a lesson from nature and installing our own version of a swim bladder on our submersible.

Initially, the bladder would, connected to an empty compressed air tank, and would be filled with air, which would enhance the flotation properties of the ROV. During the submersion, however, the air can be pumped back into the tank, forcing the water to flow in through a one-way inside-facing valve. Thus, the weight of the ROV would increase, speeding up the submersion. When the surfacing takes place, we would be able to pump the air from the tank back into the bladder, forcing the water out through the one-way outside-facing valves. Thus, the weight of the ROV would decrease and the ascent will accelerate. In order to implement all that, we would have to construct a durable waterproof bladder with proper valves and to attach it at the center of mass of our ROV. We would also have to be able to control the air movement within the tank and its rate. We are looking forward to incorporating hydraulic and pneumatic technologies into our future ROVs.

Safety

Safety is Orange Mango's primary concern. All our machinery is designed to be safe to manufacture and use. This year we did our best to uphold our safety protocols on the worksite. We made sure to use proper eye protection at all times. Job-specific safety was also accounted for on each stage, e.g. gloves worn when cutting and sanding glass or cutting metal, protective fuses used when working with electricity, and fans used when soldering. As a result, we were able to finish the project without any major accidents. Although only a few minor injuries occurred in the making of our ROV, such as small scrapes and soldering iron burns, we were always ready to combat major injuries with a constant presence of a licensed CDL driver and/or our project mentor on the workplace for an emergency ride to the hospital. Before a group member was allowed to work with power tools, he had to receive a proper training from our mentor. All work with a power tool more complicated than a Dremel Tool or a drill, such as an electric saw, was performed in the presence of an outside expert within the woodshop workspace.

Some of our details were 3D-printed, which is a safer solution than cutting them out on a milling machine. A good example of such details is our 3D Motor Housing, which is designed to protect our tether wires from getting caught in the engine propellers. You can refer to the 3D Motor Housing section of this manual for more information.

As our ROV requires a large involvement with electronic circuitry, we had to incorporate special safety protocols to ensure the safe and durable functioning of our ROV underwater. Throughout the making and testing, we made sure to keep the naked wires as far from the water as possible. As for the wires that ran inside the frame, we waterproofed all the connections with epoxy and shrink tubing to ensure the prevention of any contact between naked wires and the water. When working with lasers, we made sure to wear glasses and cover the lasers with protector caps.

Safety Summary

Company:

- Eye protection worn at all times
- Job-specific protection accounted for (gloves, facemask, fans - depends on the job)
- Licensed driver/mentor present at all times
- Power tool training required prior to operating the tools
- Complicated power tools used under the supervision of an outside mentor, in the workshop setting

Physical:

- No sharp edges exposed on the ROV
- All connections are secured with PVC casing
- 3D Motor Casing protecting the engine propellers
- The transportation of the ROV must be carried out by 3 people: one carrying the ROV, one carrying the tether wire, and one carrying the control board

Electrical:

- All naked wires and non-waterproofed connections are located on the control board, away from the water
- All underwater wire connections sealed with shrink tubing and epoxy
- All lasers are covered with protector caps
- All controllers, servers, and circuit boards are securely attached to the control panel with Velcro

Sponsors / Acknowledgements

The Hill School –

We would like to first and foremost acknowledge the universal support and positive encouragement from The Hill School, “The Family Boarding School.”™ In addition to supporting this effort financially, we were able to devote class time and after school sporting block time, and several after quiet hours extended lights out privileges, exclusively to training and working on our robot. Without the School’s unwavering support, there is no doubt that we would not have been able to produce a highly functional robot in two month’s time with two weeks of Spring Break in the middle of that limited time. Thank you Hill School!

VideoRay –

Our Pottstown neighbors at VideoRay have provided substantial guidance and the donation of our tether. We would like to personally mention Scott Bentley, CEO, and Tom Glebas, for supporting our team and inspiring our team members to imagine and engineer our ROV.

gPARSEC –

The Greater Pottstown Area Robotics, Science, and Engineering Community provides local robotics teams with a top secret engineering facility to provide high school teams with tools and the training to develop quality ROVs. There, we specifically would like to thank the amazing Owen J. Roberts Sea Dog MATE Robotics Team for welcoming us and lending their expertise and substantial knowledge to our inaugural effort in this contest.