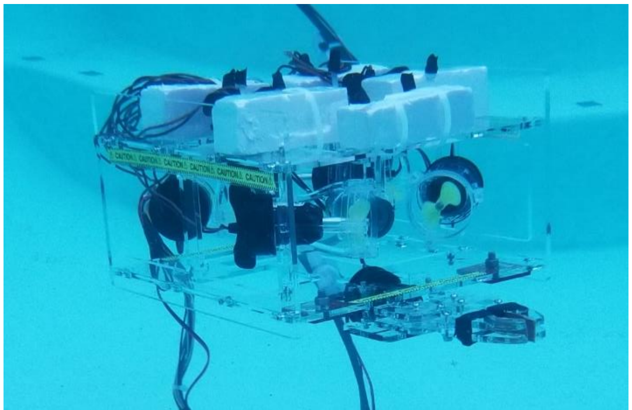

The Atlas in Avi's pool.

SEAWOLF ATLAS TECHNICAL DOCUMENTATION

Seawolf Incorporated, 2016 – 2017

Hunter Banks
CEO & Pilot

Avi Mittal
Programmer & Marketer

Cedric Nagata
CAD Designer & Electrician

Craig Lemke
Mentor

Abstract

Here at Seawolf Incorporated, we dedicate ourselves to producing quality equipment for the marine community.

Shipping is a vital piece of the US economy, with over $3.5 trillion traded each year in imports and exports. The **Port of Long Beach** is the second-busiest in the country, producing $100 billion in trade annually (OEC). Recognizing that it will have to keep up with further trade, it has issued an RFP for an ROV to assist with promoting **commerce**, servicing **entertainment**, protecting **health**, and ensuring **safety**.

What is an ROV? A Remotely Operated Vehicle is a submarine craft that is controlled from a distance by a human pilot. ROVs are used to accomplish tasks that are too dangerous or too expensive for humans. The Port of Long Beach requires one for maintenance, construction, and cleanup tasks to increase efficiency and protect divers in the busy port. To fulfill this, Seawolf Inc. has developed the **Seawolf Atlas**, a versatile and maneuverable ROV that has the capabilities to perform these critical tasks in a 21st-century port.

Woodinville High School, Woodinville, WA, USA

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1 / COMPANY INFORMATION

HUNTER BANKS, CEO

Hunter Banks is the CEO and CFO of Seawolf Inc. On deck, he is the pilot of the Atlas. This is his 3rd year competing in MATE, and he would like to major in business. He is currently attending Woodinville as a 10th grader. His interests include remote controlled planes and video games.

CEDRIC NAGATA, DESIGNER

Cedric Nagata is the designer of the Atlas ROV. On deck, he is the operator, handling the tether and ROV. He has a passion for math and basketball and is interested in drone technology. He is currently attending Cedarcrest as a 9th grader, and this is his 2nd year in MATE. Cedric has a great interest in flight, and wants to be an aerospace engineer.

AVI MITTAL, PROGRAMMER

Avi Mittal is the programmer of the Atlas and marketer for Seawolf Inc. On deck, he is the analyst, serving several odds and ends. He loves space and everything STEM, and wants to major in aerospace engineering and computer science. This is his 4th year with MATE and he is currently attending Woodinville as a 10th grader. He plays and makes video games in his spare time.

2 / SAFETY

We take safety seriously at Seawolf Inc., and we have taken precautions to ensure our employees' safety when building the Atlas, such as:

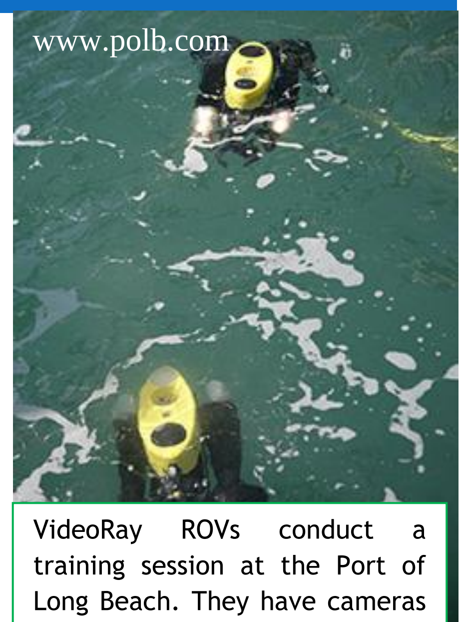
- Always having a 25A fuse installed when systems are on. This prevents overcurrent from overheating parts, which could cause fires or smoke.
- Always wearing closed toe shoes. This prevents falling objects from causing injuries.
- Using safety glasses while soldering, or machining, or working with power tools.
- Having our tether strain relief in place when in the water, preventing the tether from breaking loose and spilling current into the water.
- Staying within reach of the power switch at all times, to ensure that we can turn off the system if anything untoward happens.

- Ensuring the system is turned off when not in use, both to reduce undue wear and to prevent mishaps from happening with no one to stop them.
- Keeping non-employees at least 5 feet away from systems when they are on, to protect them, the employees, and the system.
- Verbally warning personnel when the robot is going live, and waiting for a response to ensure everyone is prepared.
- Keeping a fire extinguisher nearby when working on electronics in case of a wood or electrical fire.

Safety features on the Atlas itself will be discussed more in Section 5.8.

3 / COMPETITION THEME

WELL INTO THE 21ST CENTURY, more and more fields rely on the technology of the Information Age. With container shipping growing faster than previous trends, seaports are no exception. These ports must modernize their operations and facilities to keep up with ever-increasing traffic, and ROVs are becoming essential assets. ROVs can operate in the confined, hazardous, and heavily trafficked environments of busy ports without risking injury to human divers.



VideoRay ROVs conduct a training session at the Port of Long Beach. They have cameras and sonar for submarine imaging.

THE PORT OF LONG BEACH is the 2nd busiest in the country, and it has already recognized the importance of modernization. In 2007, the port deployed small VideoRay ROVs for port security. The fleet of 4 is equipped with surveillance gear and searches for underwater obstructions and hazards. The port has now asked for an all-purpose ROV as outlined in the Request for Proposals (RFP), which they plan to use as a step towards further modernization: constructing a hyperloop and a fountain show, using Raman spectroscopy to identify contaminants, and using RFID tracking of cargo containers.

3.1 / MODERNIZATION

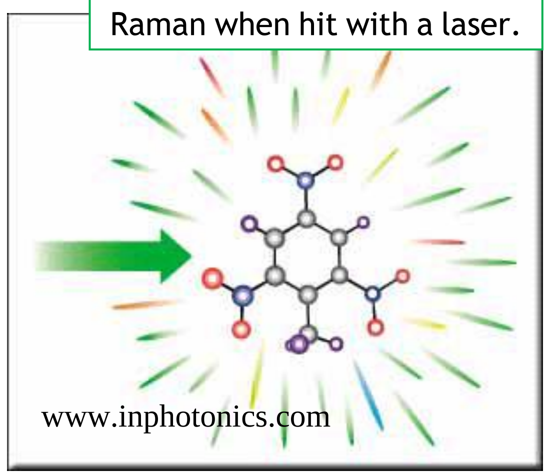
A test rig built by Hyperloop One.

COMMERCE - HYPERLOOP

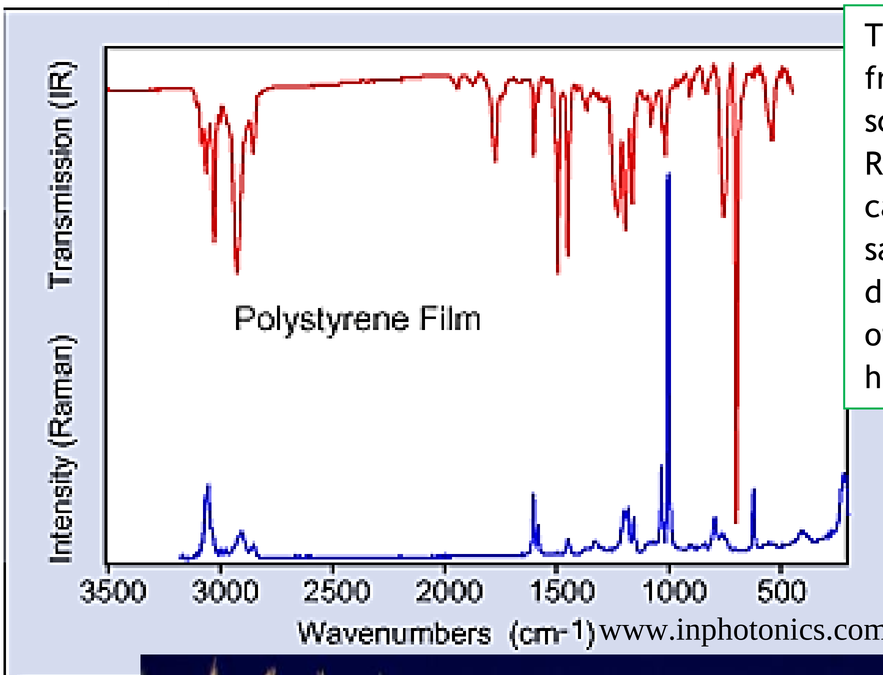
The Hyperloop concept, devised by entrepreneur Elon Musk, is a transport that involves a levitating pod shooting down a tube at high speeds. Most proposed Hyperloops are for passengers, but the ROV will help the port construct one for cargo. Hyperloops are a very attractive idea due to their high speed and capacity – millions a year at well over 1000 km/h (620 mph) – as well as relatively low cost. There are, however, many technical challenges before one can be realized, such as how to levitate and propel the pod and how to vacate the tube so the atmosphere doesn't slow the pod. Despite doubt regarding the practicality of such a system, the company Hyperloop One has already conducted tests, its model accelerating a pod to 177 km/h (110 mph) in just one second. SpaceX is also sponsoring a design competition for such models. A passenger transport Hyperloop will be some years coming, if ever, but a cargo transport could take containers from ships in open ocean to the port, freeing up coastlines and congestion and saving money.

HEALTH – RAMAN SPECTROSCOPY

Chemicals scatter specific frequencies of light called Raman when hit with a laser.



Port waters are often polluted, but through decades of effort, Long Beach's waters are fairly clean. The Port would like to maintain this health, and one way to identify contaminants is through Raman spectroscopy. This method of chemical analysis involves shining a laser onto a sample and analyzing the frequency of the scattered light. Each chemical has a unique signature of frequencies of this radiation, called Raman scattering. Raman spectroscopy, unlike other analysis methods like IR spectroscopy, can identify substances without any preparation - useful for field work. Water is also a poor scatterer, making it ideal in a marine environment. Both advantages make Raman spectroscopy a perfect technique for chemical analysis of toxins in the port.



The blue peaks show the frequencies of light scattered – the chemical's Raman "signature". One can match the peaks of a sample to a known one to determine what it's made of. The signature shown here is polystyrene.

The 100-foot Fanfare Fountains at the nearby Port of Los Angeles bring in enough income from tourism to make up for their $14 million cost.

3.2 / REQUEST FOR PROPOSALS (RFP)

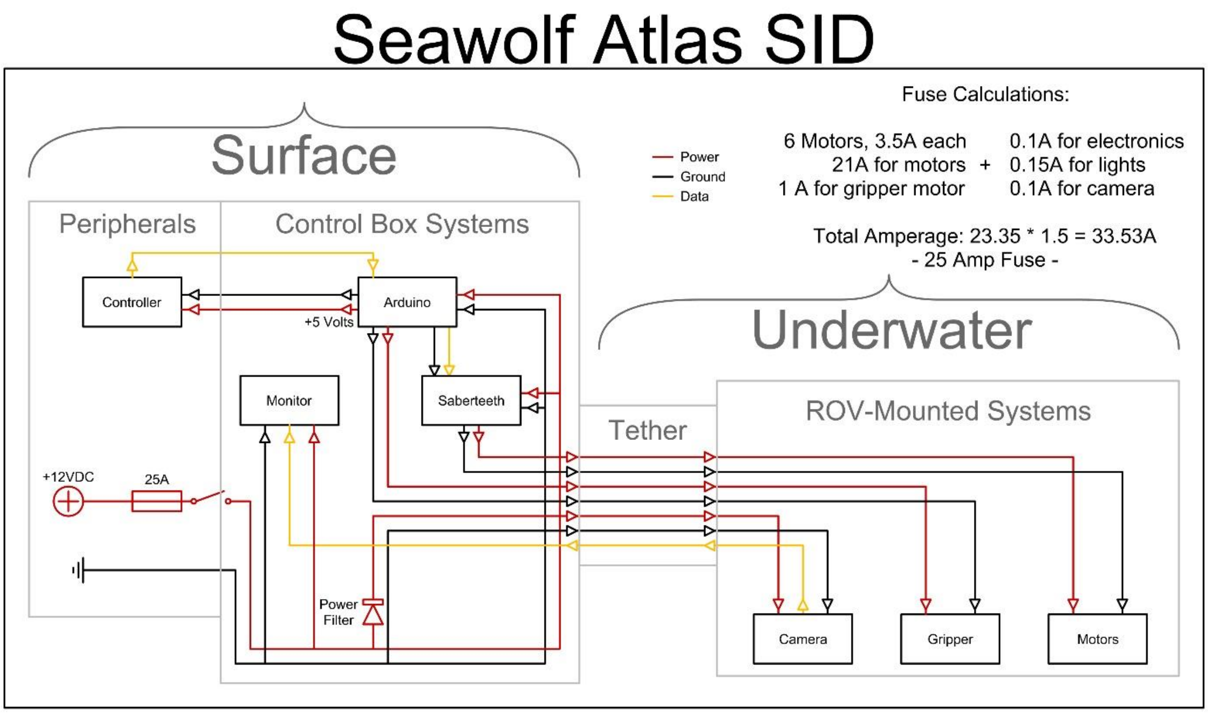
With all of this in mind, the Port of Long Beach has issued a Request for Proposals through MATE to design a construction ROV to promote commerce, entertainment, health, and safety. It would recover objects and samples and work on hardware at the seafloor. It would be as small and light as possible to operate well in the port waters, and adhere to stringent safety requirements. The competing companies will be demonstrating their robots at Long Beach City College, and the contract will be awarded to the company whose robot performs greatest, as well as communicating most effectively. SeaWolf Inc. is confident that with the Atlas, it can secure the contract.

The Port of Long Beach handles 2000 ships, 6.8 million containers, and $180 billion in cargo annually.

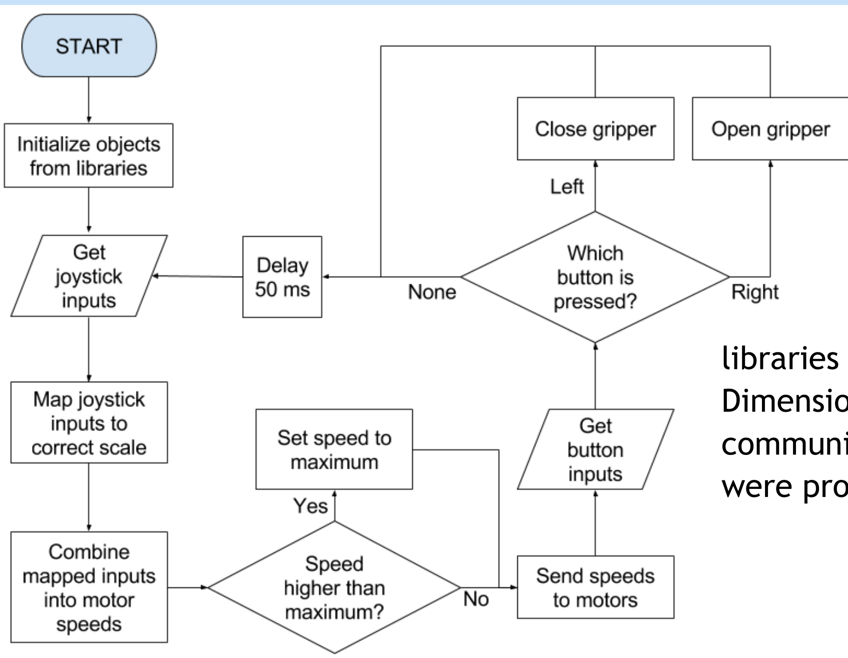
Incoming cargo ships, like the pictured *Benjamin Franklin*, can reach thousands of feet long. A Hyperloop would remove the need for such a beast to go into port, and would carry these 18,000 containers into port from the open sea.

4 / SYSTEM DIAGRAMS

4.1 / SYSTEM INTEGRATION DIAGRAM



4.2 / SOFTWARE FLOWCHART

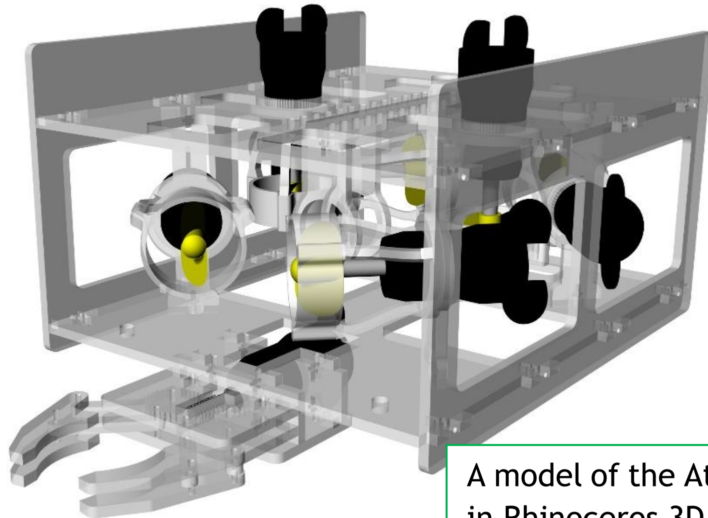


For more information on the electronics and wiring behind the Atlas's software, see 5.3.1 Electronics. The Sabertooth control libraries were provided by Dimension Engineering. The serial communication and servo libraries were provided by Arduino.

5 / DESIGN RATIONALE

The Seawolf Atlas needed many special design considerations for it to be inexpensive and simple, yet effective. 3D modeling in the program Rhinoceros 5 and rapid prototyping out of wood were used extensively for designing the ROV.

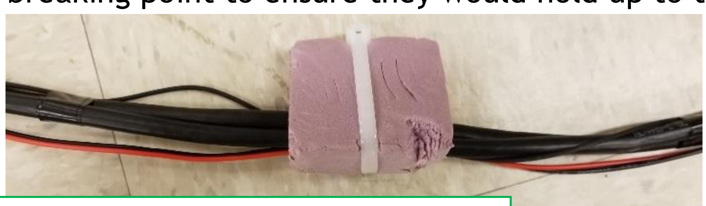
5.1 / FRAME



A model of the Atlas in Rhinoceros 3D.

The Atlas has a cuboid frame, measuring 36 cm long by 31 cm wide by 31 cm tall (14 x 12 x 12 in). Its length increases to 46 cm with the claw attached. The frame is composed of cast acrylic and weighs about 1.8 kg. Cast acrylic was chosen for three main reasons: it is readily available, it can endure extended contact with water, and it produces a clean finish when laser-cut – no burnt or jagged edges, improving safety and keeping the water clean. Every corner on the frame is rounded to prevent injuries.

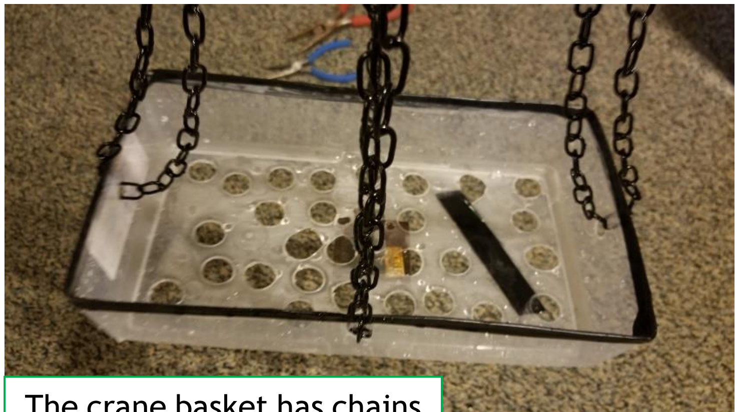
The frame was designed in the CAD software Rhinoceros 3D. The slot-and-tab joins ensure the robot is sturdy without needing very many screws; only 8 are used for the frame. The holes cut in the frame reduce weight and hydrodynamic drag, as well as letting the propeller thrust flow freely. The mounting plates were tested to the breaking point to ensure they would hold up to the repeated stresses of motor thrust.



A section of tether with its foam float. The thick cables are for motors, the red-and-black for the gripper, and the thin black cable is for the camera.

5.1.1 TETHER

The 16.5 m (54 ft) tether has 19 conductors in 4 cables. The 2 cables that power the motors are each 6-conductor 18-guage stranded, leading to a voltage drop of 2.1V at the motors. The camera cable has 5 conductors for power, lights, and video. The gripper cable is composed of 18-guage speaker wire. High-density foam floats, the same type used on the ROV, make the tether nearly neutrally buoyant. The tether weighs 4.6 kg, requiring three 5 x 5 x 2.5 cm (2 x 2 x 1 in) slices of foam every 2 meters. Strain relief at both ends protects the wire joints at either end, and the tether is clipped to the control box to prevent it from falling in.



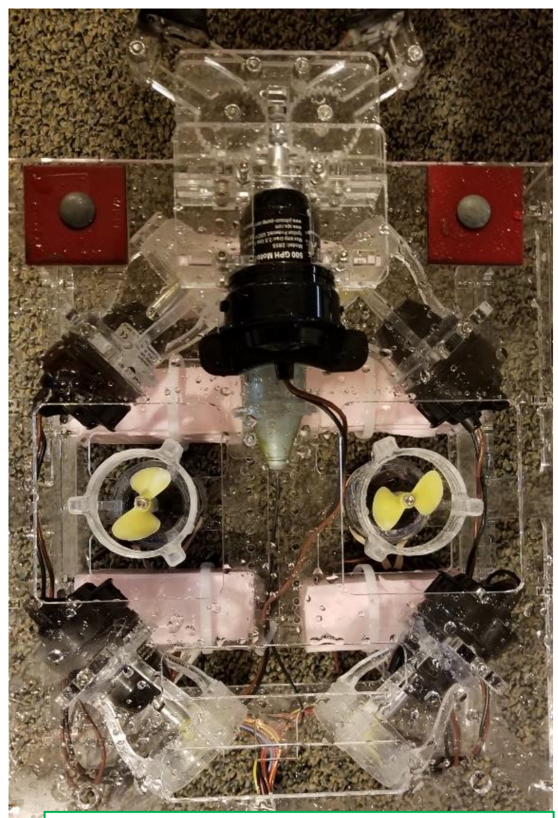
The crane basket has chains on all sides for stability, so nothing is dropped when it is raised/lowered.

5.1.2 CRANE

The included hand-operated crane is used to speed missions by limiting trips to the surface. A round trip to the surface and back to drop off a sample could last 30-40 seconds per task, but with a crane, the ROV can simply drop it and any other cargo in the basket and have everything raised at once. The basket is simply a cut-down plastic box with holes to reduce drag, with cut edges sanded down to prevent injury. It is attached to an 8 m (26 ft) nylon cable with #100 chain to form the crane, attached on all 4 sides of the basket for stability.

5.2 / PROPULSION

The Atlas uses 6 Johnson 500 GPH bilge pump motors for propulsion – 4 500 GPH for horizontal and 2 750 GPH for vertical. Each 500 GPH motor produces 1 kg (2.2 lbs) of thrust, accelerating the Atlas to 1 m/s (2.2 mph / 3.6 km/h), while the 750 GPH motors produce about 1.5 kg (3.3 lbs). The 750 GPH motors are used for vertical movement because their added power is useful when carrying heavy loads to the surface. The 500 GPH motors consume about 36 W of power (3A @ 12V) and the 750 GPH motors draw about 42 W (3.5A @ 12V).



From the underside, all 6 propulsion motors along with the gripper motor (top) are visible.

The motors are arranged in a vectored layout, with a horizontal motor at each corner pointing 45° inward and a vertical motor on both sides. This allows for 4 axes of motion: longitudinal (forward/backward), lateral (left/right or "strafing"), rotary (turning left/right), and vertical (up/down). The angle of the horizontal motors represents a tradeoff between speed and maneuverability. Angling them less means speed is higher going forwards and lower when strafing or rotating. The 45° angle is optimal for maneuverability, since thrust is the same for all axes of motion. Bilge pump motors were chosen because we could reuse them from last year's ROV, and they have proved themselves reliable.

5.3 / CONTROL STATION

The control station, affectionately called "The Box" at Seawolf Inc., is a Pelican 1600 case. This Pelican case was chosen because it is highly durable and waterproof, and because it was easy to source. Inside the case is a laser-cut wood frame that holds all the electronics.

The control box. On the top is the monitor. On the left is the I/O, and on the right is storage.

At the front left of the bottom half of the case is an Arduino microcontroller that translates controller inputs. Just to the right of that are the 4 Sabertooth ESC (Electronic Speed Controllers) that control the motors and gripper. More detail is in 5.3.1 Electronics. The rest of the control station is left empty for storage of the controller and power cords, but includes space for a camera splitter box at the back left if one uses multiple cameras. The top half of the case houses the 19-inch 12V monitor. All of this draws about 300 mA.

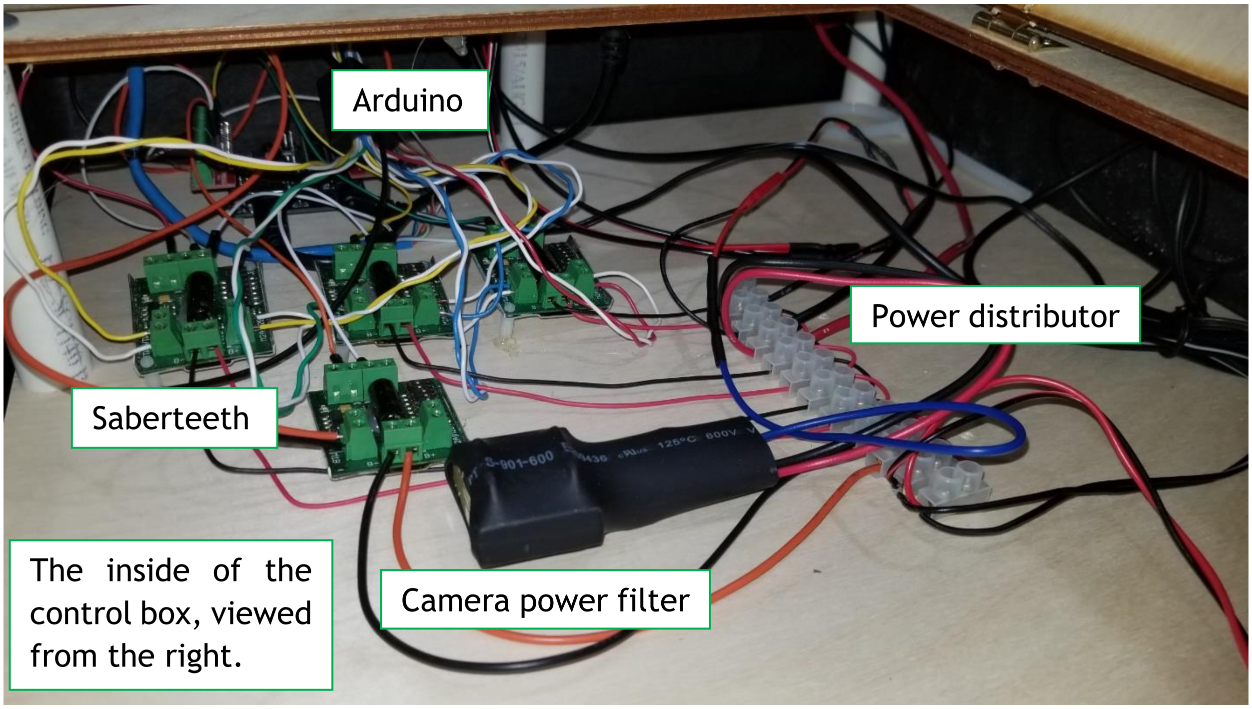
The bottom panel has 8 ports: power in, motor power, controller input, arm power, camera power, video, lights power, and the USB for the Arduino. It also has a rocker switch that controls power to the entire system.

5.3.1 ELECTRONICS, WIRING, & SOFTWARE

To translate the signals from the controller into motor speeds, an Arduino Uno is used. This microcontroller was chosen because the Arduino platform is used ubiquitously in robotics, the Uno especially.

The software takes joystick/button inputs, maps them onto an exponential scale, and sends these speeds over a serial bus to the Saberteeth. An exponential scale, where inputs are mapped onto a steepening curve, is used to improve precision at low speeds without sacrificing the Atlas's top speed. The exponent found to have the best low-speed control is 1.5. The gripper control, however, is digital, with a set speed for opening and closing.

The Sabertooth ESCs take the serial inputs and use it to change voltage to the motors, controlling their speeds. Saberteeth were chosen for a few reasons: they could be reused from last year, they have proven reliable and durable, and they have safety features like overcurrent protection to keep both the system and personnel from harm.

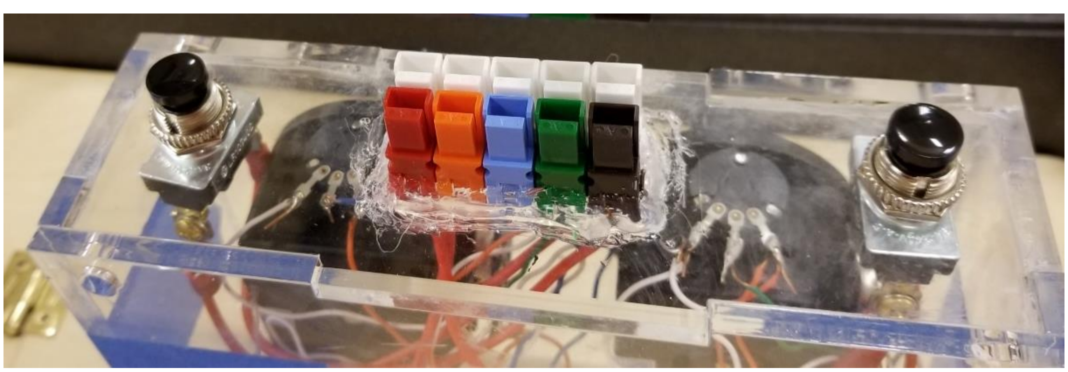


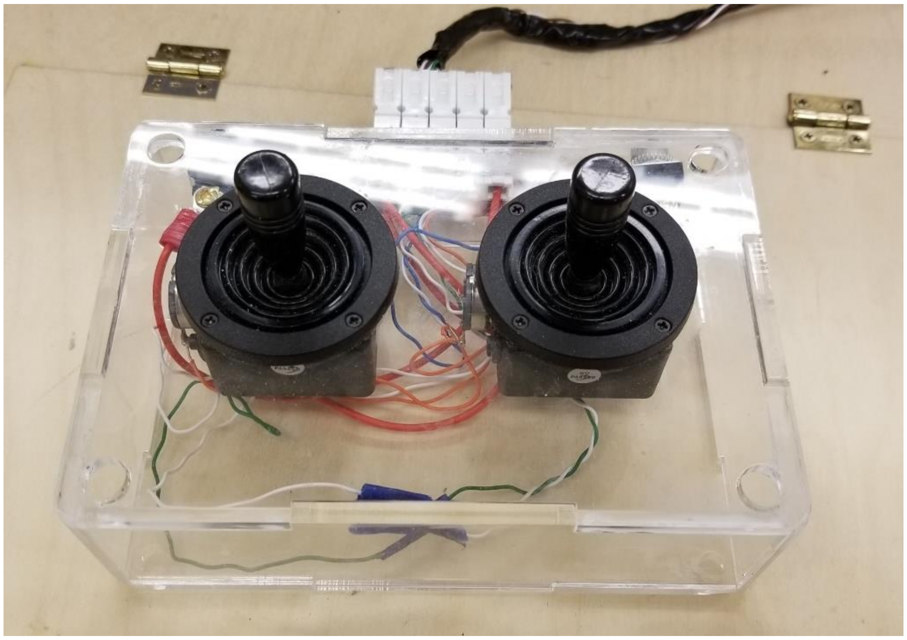
The inside of the control box, viewed from the right.

Power to all the components in the box is provided through the power distributor, which uses screw terminals for easy assembly and disassembly. The camera power filter helps clean up noise that occurs when the motors are in use.

5.3.2 HANDHELD CONTROLLER

The controller is an acrylic box attached to a 2.4 m (7.8 ft) Cat5e cable; this length allows the operator to sit comfortably. The corners of the controller are rounded to prevent injury, and long bolts serve as feet to avoid scratching the bottom. The left joystick controls rotation on the X-axis and longitudinal on the Y-axis, while the right joystick controls lateral on the X-axis and vertical on the Y-axis. The left shoulder button closes the gripper; the right button opens it. A 10-conductor cable connects the controller to the control box.

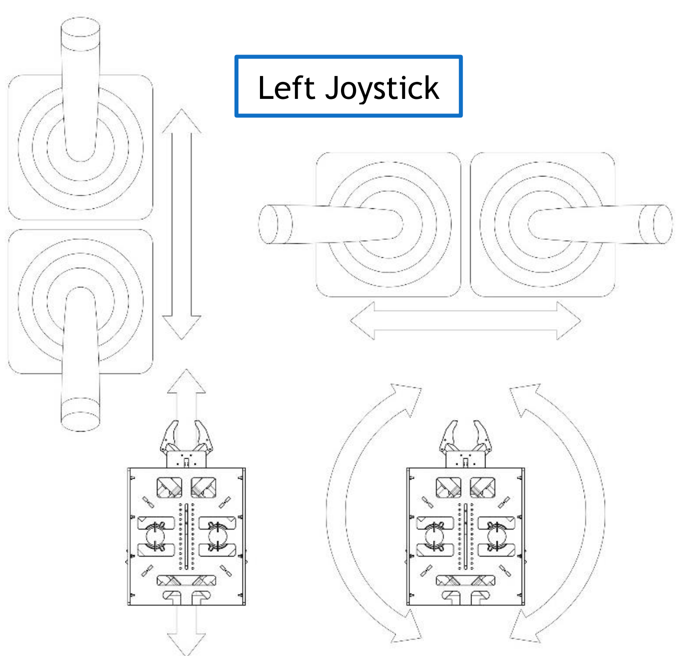

The shoulder buttons and port on the controller.



Glue is used to hold the controller together. It is made of acrylic because it was on hand, and it allows us to see the wiring and notice faults more easily.

The dual joysticks on the controller allow for movement on all four axes at once.

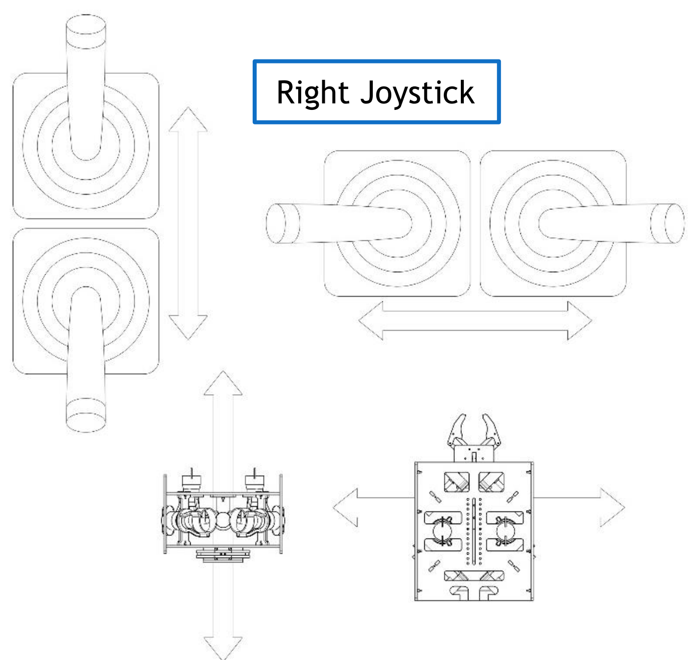
Left Joystick



When the left joystick is pushed up or down, the ROV goes forwards or backwards.

When the left joystick is pushed left or right, the ROV turns left or right.

Right Joystick

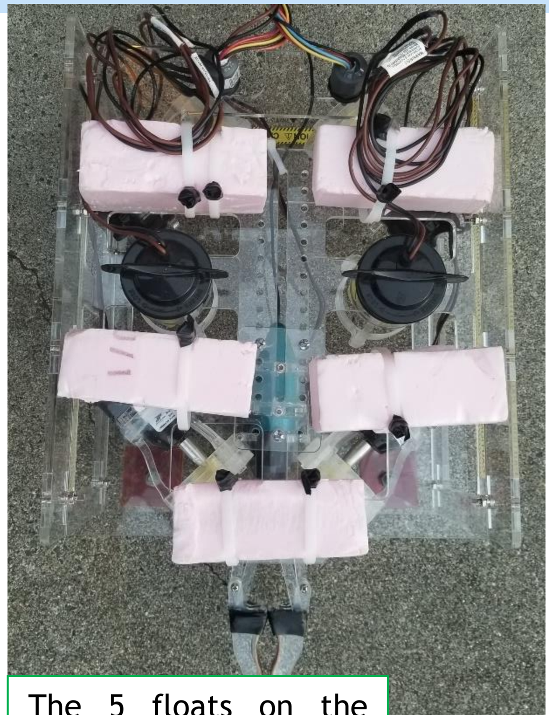


When the right joystick is pushed up or down, the ROV goes up or down.

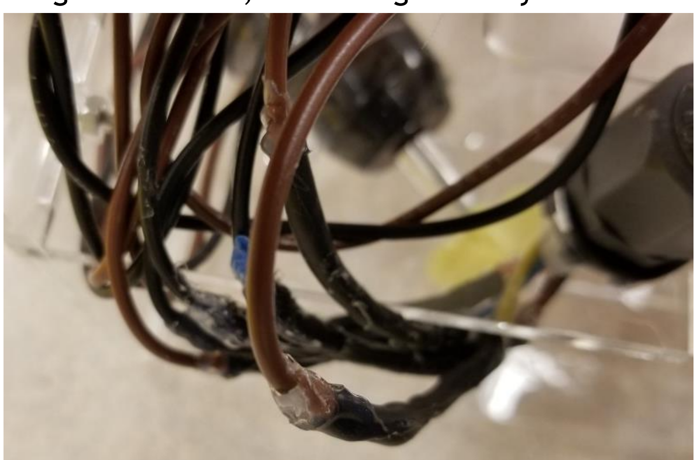
When the right joystick is pushed left or right, the ROV slides left or right.

5.4 / FLOTATION & WATERPROOFING

High-density foam is used for the floats of the Atlas. It was depth-tested at 20 ft for 2 hours and at 40 ft for 30 minutes to ensure it would not crush from the water pressure. Since the Atlas ROV weighs 4.2 kg in water, it was calculated that .00675 m^3 (6.75 L, 0.24 ft^3) of foam would be needed for it to be neutrally buoyant. Pink foam was chosen for its high visibility in water. The foam is placed so that the center of buoyancy matches the center of mass, so the ROV will not tilt. 100 g weights, painted to prevent rust, can be placed at the corners of the Atlas as ballast to weight it exactly right. The floats are attached at the top so the ROV hangs from them, increasing stability.



The 5 floats on the Atlas, seen from above.



The motor wires on the Atlas. The clear hot glue and black heat-shrink tubing are visible around the joints.

Waterproof connections are of the utmost importance in an ROV. Any exposed conductors could shock anything that comes near. To ensure that underwater connections are sealed, Seawolf follows a 3-step process: coat the exposed area in hot glue, cover it with heat-shrink tubing and shrink it around the area, and finally seal the ends of the heat-shrink tubing with more hot glue. This method of double-waterproofing has proven highly effective for 3 years now.

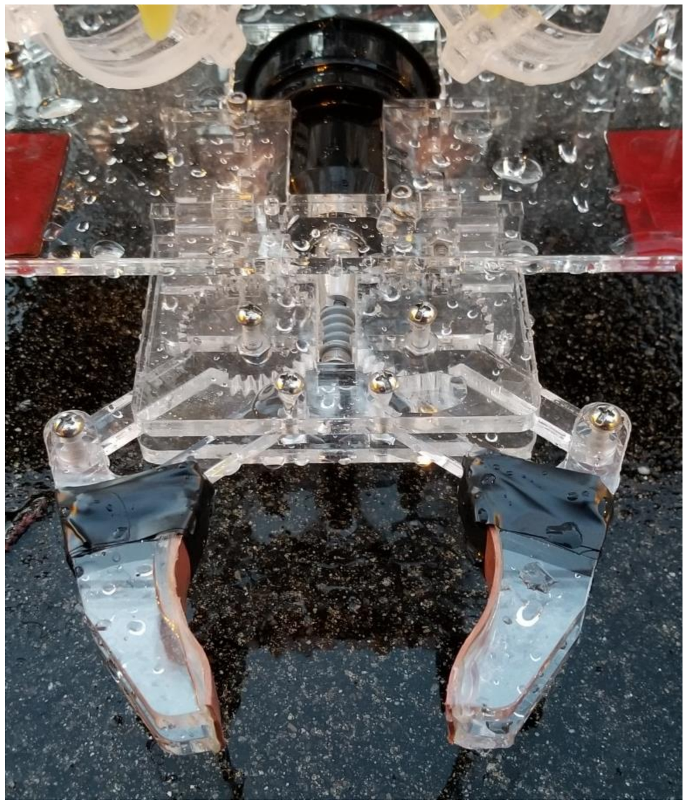
5.5 / MANIPULATOR

The Atlas carries a gripper manipulator on its front. One was deemed necessary for the mission tasks outlined in the RFP, many of which involve moving hardware underwater. The gripper has simply open-and-close functionality – more degrees of freedom would be more weight and more failure points, and this risk was too much to justify the added flexibility.

The gripper is powered by a 500 GPH bilge pump motor, which is cheaper and simpler than a servomotor or stepper motor. The precise control gained with these motors in unnecessary, since the manipulator will always be in view and the pilot can adjust as needed. A worm drive, or screw drive, is used to transfer the motor rotation into claw movement. In the Atlas's worm drive, the motor rotates a worm gear (a LEGO screw) that has gears meshed with its thread. A worm drive is ideal for several reasons:

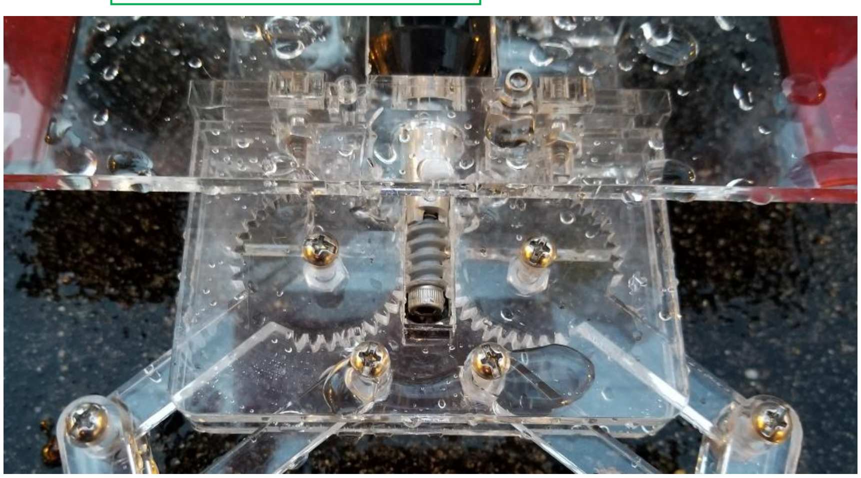
- It allows the motor to be oriented forwards, keeping it out of view of the camera
- It is a compact way to gear down the motor speed, increasing the gripper's torque
- It is one-way – rotation of the worm gear makes the gripper gears move, but pushing back on the claws of the gripper does not make the worm gear rotate, so the gripper's position is locked.

The manipulator is made of acrylic because the material was on hand, and its claws manipulator have rubber grips to increase friction and thus grip. The bolts are held on with nyloc nuts so that the rotation of the arms does not loosen them. The claws apply about 0.4 kg (0.9 lbs) of grip force, and are split into 2 plates with a gap in the middle to increase gripping area.



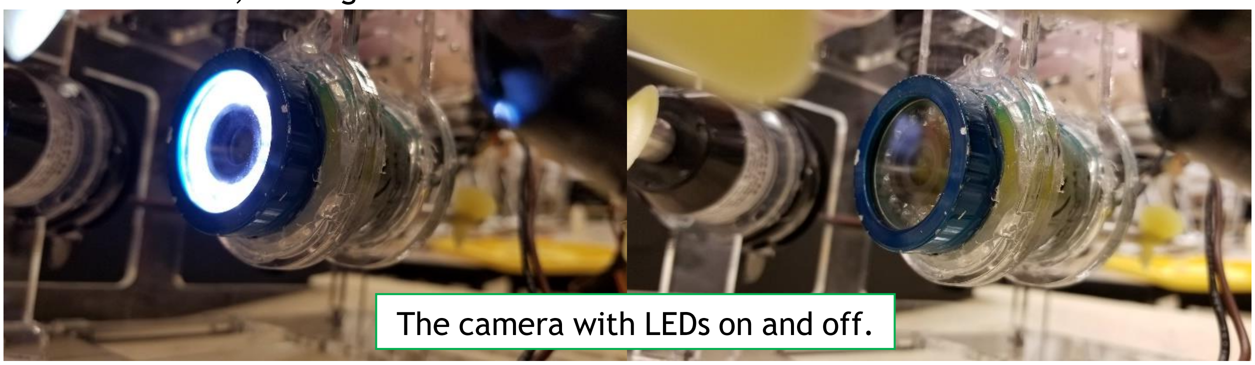
Above: The gripper manipulator, with the claws at the bottom, worm drive in the middle, and bilge pump motor at the top.

Below: The claw gears intermeshing with the LEGO worm gear.



5.6 / CAMERA

The Atlas has a single HD camera mounted at the top, forwards of center. It is a commercial fish-finder camera rated to over 50 m. After last year's camera difficulties, Seawolf has invested in commercial cameras to ensure waterproofness at depth. The camera also has built-in LEDs, so it is being used as the Atlas's Raman spectrometer as well. The camera uses RCA connectors, making internal wiring more convenient since there are less wires per signal. The foil shielding around the spool acts as a large electrical choke, cutting down on camera interference.



The camera with LEDs on and off.

5.7 / SAFETY FEATURES

Safety is paramount in the operation of ROVs. Here is a list of some of the features the Atlas has to protect both hardware and personnel from harm:

- There are no soldered connections in the entire control box – any damaged parts can be replaced immediately.
- The master power switch can shut off power to the entire Atlas system in under one second.
- Anderson connectors are used for many of the ports, and other types of plugs for the rest. Systems can be quickly unplugged if they malfunction.
- The crimps in the Anderson connectors are sealed with hot glue so they don't pull out; this also makes them water-resistant.
- Every propeller is shrouded 3 mm in front and behind to protect divers' fingers.
- A multimeter is built into the system to easily check for overcurrent or overvoltage.
- The motor software has an option to limit motor speed if overcurrent becomes an issue. This is disabled by default, as the Atlas draws only 20A at 12V.

The built-in multimeter.

All Atlas photos by Avi Mittal. 3D models by Cedric Nagata.

6 / FINANCES

6.1 / PROJECT COSTING

NOTE: This is a valuation of the Atlas system. It **excludes** the costs of tools and other hardware we have paid for that are not included in the Atlas system itself. For the costing of these items, see 6.2 / Budget. The value of an Atlas unit is $1361.34.

Quantity	Part	Source	Cost per Unit	Total Cost
1	Fuse Holder	Reused	$4.97	$4.97
1	Pelican Case	Reused	$159.99	$159.99
1	19-Inch 12 Volt Monitor	Reused	$144.00	$144.00
1	18-2 Wire 100'	Bought	$11.98	$11.98
1	18-6 Wire 120'	Donated	$116.50	$116.50
4	Sabertooth Speed Control	3 Reused, 1 Bought	$59.99	$239.96
2	Joystick Potentiometer	Reused	$33.60	$67.20
1	Arduino Uno	Reused	$10.50	$10.50
5	500 GPH Bilge Pump Motor	4 Reused, 1 Bought	$17.27	$86.35
2	750 GPH Bilge Pump Motor	Reused	$22.84	$45.68
3	Propeller Set	Reused	$22.99	$68.97
1	Fish Finder Camera	Bought	$134.00	$134.00
1	Tool Box	Reused	$39.99	$39.99
1	Portable Cart	Reused	$66.00	$66.00
2	Button	Bought	$5.00	$10.00
1.15	Acrylic Sheet (m^2)	Bought	$135.00	$155.25
	Key: Over $100		**Total Value:**	$1,361.34

6.2 / BUDGET

NOTE: This is the total cost of the Atlas development project, **including** the cost of tools and other things not associated with the sale of an Atlas unit and **excluding** reused and donated parts. Since many things were reused from last year, this costing is significantly lower than in 6.1 / Project Costing. Total expenses were $474.30.

Key: Below estimate Within 10% of estimate Above estimate

Category	Description	Projected Cost	Amount Spent
Electronics (Components)	Microcontrollers, joysticks, servos, etc.	**$60**	**$79.44**
Electronics (Hardware)	Monitors, cameras, motors, etc.	**$50**	**$30.97**
Structure	PVC piping, structural components, case	**$120**	**$162.95**
Connections	Wiring, connectors, jumpers	**$20**	**$14.98**
Tools	Multimeters, soldering irons, etc.	**$200**	**$185.95**
	TOTAL	**$450**	**$474.30**

7 / CHALLENGES

There were many challenges that we as a company had to overcome during the process of developing the Atlas. These problems had to be faced, thought logically through, and solved before they caused too much of a strain on our deadlines. We at Seawolf believe that these challenges made us a better team, honing our troubleshooting and problem-solving skills.

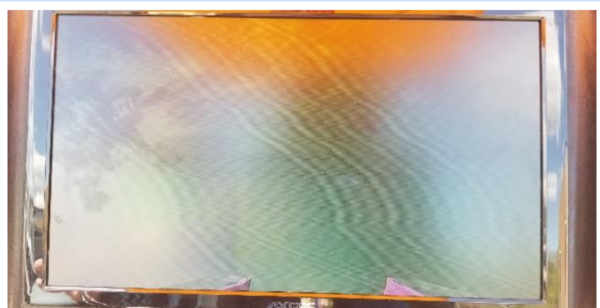
7.1 / TEAM CHALLENGES

Our biggest challenge we had to face was time. This is the first year of high school for all the members of Seawolf, and our schedules have been busy; however, with a team size of just 3 people, often everyone must be present at meetings to plan our course of action. We have struggled to make time for developing the Atlas, but by reprioritizing our schedules we have finished it on time. We feel that this reflects our newfound dedication to the MATE Challenge.

Another challenge we faced was that we undervalued business practices like outreach in favor of building an impressive system, but, nearing the end of the development program, we have realized that business and marketing are just as important as the ROV itself. In the MATE competition, we are not only to be engineers: we must “think of [our]selves as entrepreneurs”.

7.2 / TECHNICAL CHALLENGES

By far, the most difficult technical challenge was the cameras. Interference from the motors was a major problem, sometimes becoming intense enough to render the video feed useless. We tried many types of filters, but none seemed to work. Finally, through research and advice from both our mentor, Craig Lemke, and veteran ROV team AMNO & CO, we found a power filter that cleaned the signal noise, enabling the Atlas to be fully effective underwater. One other challenge was the gripper manipulator, which tended to jam or even come apart. We solved this by using nyloc nuts to prevent the gripper’s motion from loosening the screws, and experimented with varying screw tightnesses to find one that worked fluidly.



An example of camera signal noise that used to be a major issue in the Atlas. The power filter shown in 5.3.1 Electronics prevents this.

8 / LESSONS

Over the course of developing the Atlas, we have learned quite a bit about how to run a team and how to act more independently of advisors. We have exposed ourselves more to administration and public relations and have gained new understanding of how to run a business. An example that comes to mind is our public demonstration at Kirkland Marina Park – we set that up ourselves. One of the most important lessons we have learned is that time management is paramount. Building a successful ROV takes a huge amount of time and effort, and we have learned we must be willing to sacrifice our free time for the Atlas. We have also found that proper delegation is key to getting all the required work done; over the course of developing the Atlas we took on responsibilities according more to our roles, instead everyone doing everything. This allowed us to accomplish much more in a given amount of time than last year.

In terms of technical learning, we have all broadened our scope of knowledge, each team member learning some of the skills that others use for their roles. This will allow us to be more technically well-rounded in the workforce later. We have learned how to properly use cameras underwater to minimize interference. We also have a better knowledge of programming and 3D modeling. Finally, and most importantly, we have a better understanding of the troubleshooting process and solving problems.

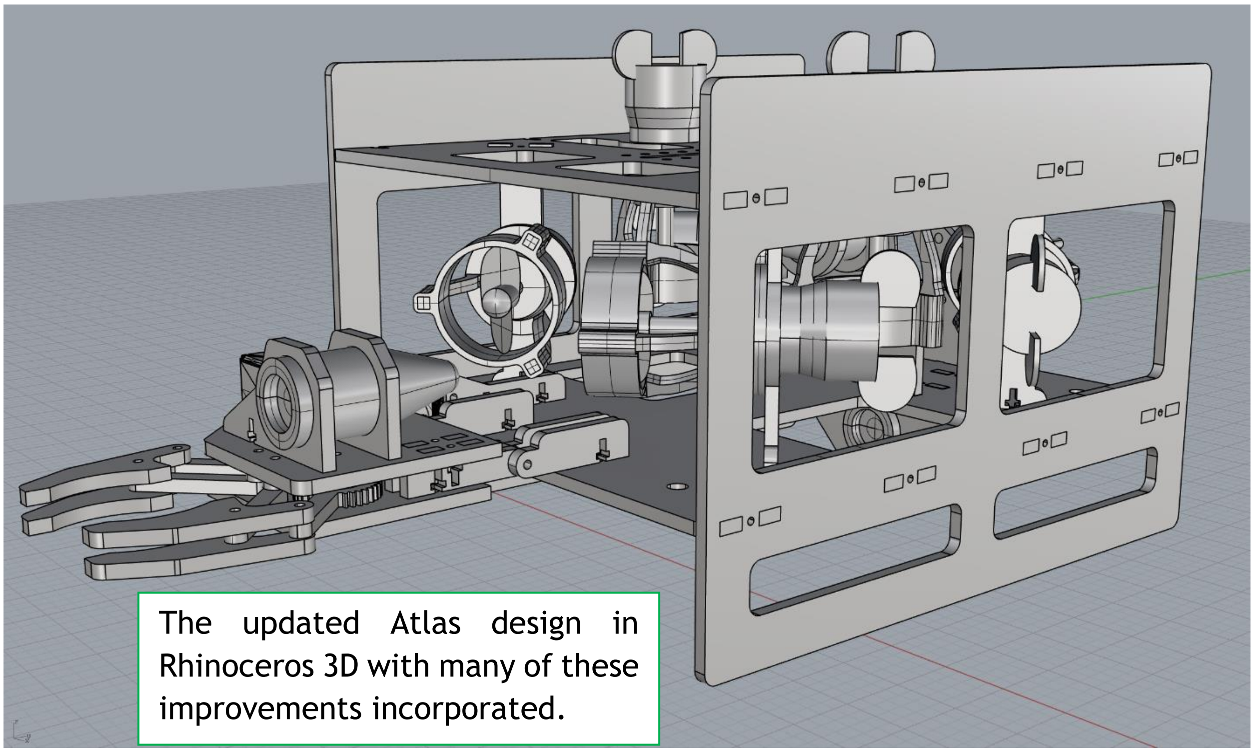
9 / FUTURE IMPROVEMENTS

As effective as the Atlas might be, improvements can always be made. The frame was a bit heavy and quite brittle, and the clear acrylic was difficult to see underwater. The solution would be to use Starboard, which is stronger and less dense than acrylic. The flotation should be cut more neatly, and it and the wiring should be attached using a more elegant method than zipties. The frame should be taller to avoid resting on the gripper manipulator, and should have more holes to reduce drag.

The Atlas's toolset was not quite advanced enough to complete all tasks. The gripper manipulator struggled to pick up clams that laid flat in the bed, and the solution would be to add pitch to it. Using servos instead of a bilge pump motor to power it would produce more torque at low speeds and thus higher grip force. In addition, a spinner manipulator could be added to the back to turn the fountain valve.

To make room for all these extra controls, the controller could be swapped for a PlayStation DualShock 4 controller, which has 2 joysticks, 2 triggers, and a full 14 buttons, among other things. The code could be better written, more streamlined. The tether should be more flexible, more buoyant, and less bulky.

The camera layout needs work as well. We were unable to see the bottom of items we picked up, so we were unable to place a sampler in the agar or install the rebar. We would also need more cameras to effectively see the manipulators. The solution would be three cameras: one on the gripper manipulator itself so it can be pitched; one slung under the frame at the back, to see the below the Atlas; and one at the back, facing backwards, to see the spinner manipulator. The cameras should also use shielded cables to cut down on interference.



The updated Atlas design in Rhinoceros 3D with many of these improvements incorporated.

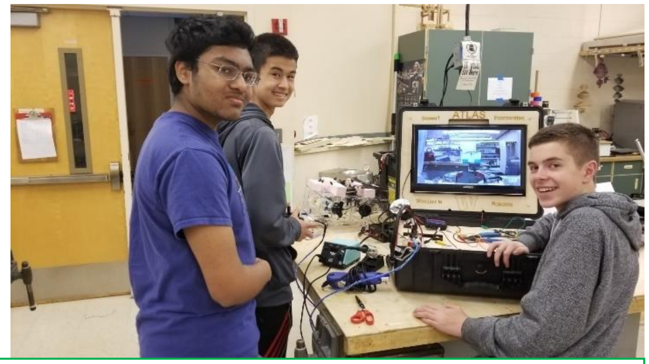
All the above are changes that Seawolf Inc. is planning to add before the international competition, but there are many other things that could be better. The motors could be brushless, allowing the Atlas to be quicker, more maneuverable, and more efficient. A Raspberry Pi computer could be added to the control box to allow interfacing with the Atlas system. A second monitor could be added to complement the new cameras.

10 / REFLECTIONS

THE EXPERIENCE

As participants in the MATE Challenge, we must take on two roles. We should be competitors as students and as entrepreneurs, educationally and commercially. We must work as a team of friends and as one of colleagues. We have to be teenagers and we have to be Seawolf Incorporated. That is the point of the MATE competition: to introduce students to both technology and business and to have fun in the process, so that years from now we can be readier than ever to enter the field.

The Seawolf team at the Woodmoor pool.
From left to right: Avi, Hunter, Cedric



The Seawolf team at the Timbercrest shop.
From left to right: Avi, Hunter, Cedric

HUNTER BANKS

I feel that this project has been incredible, and I'm very fortunate for this opportunity. I am proud of what our team has accomplished with all the hours we spent coding, wiring, and troubleshooting. As the CEO, I have learned leadership skills, as well as how to build a successful team and company. With the creation of the Atlas, I tried to push myself to learn new things so I would come out of it as a better person.

AVI MITTAL

This project has been an incredible experience. The Atlas represents the culmination of so much time and effort, but to see it move so fluidly is worth it. By far the most rewarding and prideful experience was demonstrating the Atlas in Lake Washington before a crowd. I want to pursue a career in the aerospace or computer science field; I have not quite decided. However, what I do know is surety is that the skills I have built will come in handy in each field. The lessons I have learned about teamwork and entrepreneurship will serve well when I become part of the workforce. MATE has provided an irreplaceable opportunity to create something great.

CEDRIC NAGATA

I have realized many things during my experience this year, including the idea that there is more reward from planning every step of a process in detail, rather than making the easiest and quickest solution. To me, it is not just about getting the task done as quick as possible, but more about learning different ways to approach the problem. This is more valuable because it provides a better experience, and more knowledge for the next time a similar task occurs. The way I like to work is best represented by the proverb, "Give someone a fish, they have food for a day; teach someone to fish, they have food for a lifetime." If I just speed through a task and I don't learn anything from it, I don't benefit from the experience. If I take the time to understand what I am doing, I will not only be able to come up with a better solution to the task, but I will also learn valuable skills that could help me later on. This mentality will continue to aid me in my future career, and my life.

11 / ACKNOWLEDGEMENTS

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