WATSONVILLE FIREFIGHTERS

SEAL TEAM 1272

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Cameron Barrett	Head of Control Box
Caleb Broxton	Chief Financial Officer
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Keegan Martin	Head of Electrical Engineering
Pratham Rathi	Head of Video
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Katherine Walton	Head of 3D Design
Chris Whaley	Head of Propulsion

Mentors: Victor Da Costa, Mary Seamount

Aptos High • Aptos, California

ABSTRACT

Our engineers at the Watsonville Fire Department Seal Team 1272 have released the newest model for underwater navigation: the Argo V, designed to complete three essential tasks for the Applied Physics Laboratory (APL) at the University of Washington. The Argo V can locate and recover sunken aircraft wreckage, install a seismometer, and install a tidal turbine to generate electricity[1]. The Argo V is lightweight, compact, and filled with modern features, including four cameras, a fully rotational claw, and an OBS system. The rectangular frame is constructed from light, hollow tent poles, and is propelled by four 1250 GPM bilge pump motors, two vertical and two lateral. These high-power thrusters allow the Argo V to drag an aircraft engine to the shoreline; the claw, now able to rotate infinitely in both directions, can orient the Argo V to move objects from any angle, such as the seismometer and tidal turbine. Our company also uses custom designed lift bags to recover the aircraft's engine from the seafloor. The Argo V was created to preserve marine life by removing human-made wreckage from Puget Sound, installing a tidal turbine to power electricity through marine currents, and placing sensors to monitor eelgrass activity. To uphold this goal even further, the ROV's frame has rounded edges to protect eelgrass. Safety is also a top priority in our company; members adhere to in-depth safety guidelines. The Argo V, the latest model from an award-winning company, is perfectly suited to assist the APL in conserving Puget Sound's ecosystem.

Mechanical drawing of the Argo V.
(Made in TinkerCad by K. Walton)

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BUDGET

We were well aware of the fact that reconstructing the Argo V to successfully complete the Ranger tasks this year was going to require a lot of resources. Thankfully, due to the generous donations of our sponsors as well as our reuse of materials, we were able to stay within our budget of $2,750. We purchased everything new– except for two cameras and the aluminum tent poles used to create the Argo V's frame– to have the most functional materials possible.

Catgeory	Example	Projected Cost	Budgeted Value
ROV Structure	Aluminum poles	$200.00	$202.17
3D Printer Materials	Filament	$100.00	$73.01
Electronics	Servos	$1,750.00	$1,635.42
Propulsion	1250 GPH bilge pump motors	$200.00	$213.79
Additional Tools	Force meters	$0.00	$48.85
Control Board	Carrying case	$150.00	$151.78
Props	PVC	$200.00	$195.47
Miscellaneous	Screws, bolts, spacers	$150.00	$146.00
Total		**$2750.00**	**$2666.49**

PROJECT COSTING

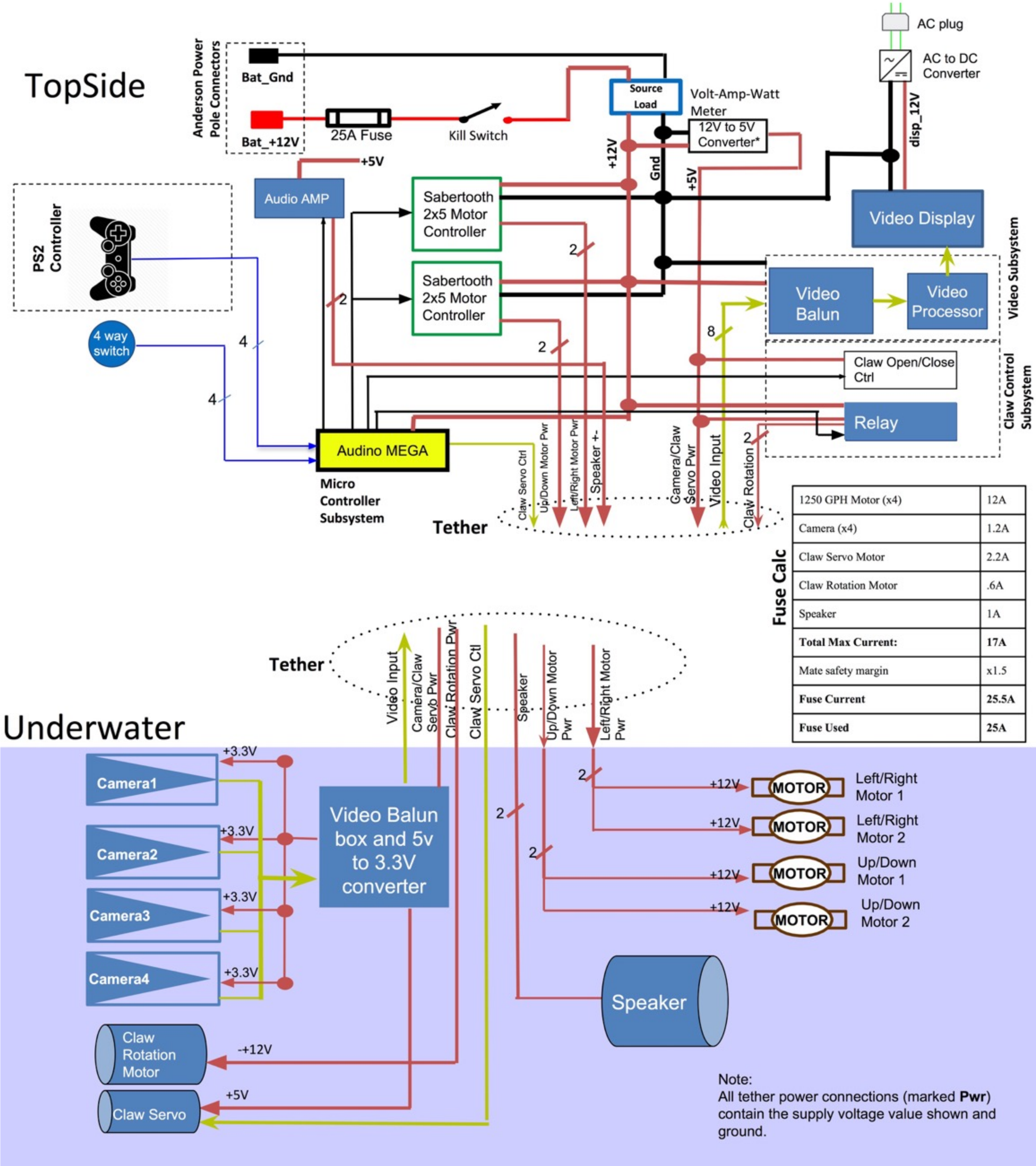
Category	Type	Name	Amount	Value of Reused Parts	Running Cost
ROV Structure	Re-Used	Aluminum tent poles		$35.00	
	Purchased	Velcro wire sleeve sample/cable sheath	$97.98		$97.98
	Purchased	Cable clips	$21.97		$119.95
	Purchased	100' vinyl tubing and air check valve	$33.93		$153.88
3D Printer Materials	Purchased	3D Filament	$73.01		$226.89
Electronics	Purchased	PS2 Controller Materials	$34.17		$261.06
	Purchased	Arduino	$89.97		$351.03
	Purchased	Bar30 Depth Sensor	$79.78		$430.81
	Purchased	Basic ESC	$33.13		$463.94
	Purchased	Jumper wire	$6.98		$470.92
	Purchased	Battery clip	$19.97		$490.89
	Purchased	LM2596 Buck Regulators	$11.59		$502.48
	Purchased	SunFounder 20 x 4 LCD w/ i2c	$12.99		$515.47

	Purchased	i2c Level Shifters (4 pack)	$7.88		$523.35
	Purchased	Quad video passive balun	$32.18		$555.53
	Purchased	RCA to HDMI Converter	$13.95		$569.48
	Purchased	4 Channel quad CCTV Multiplexor	$35.99		$605.47
	Purchased	Banana to alligator test leads (2 set)	$6.88		$612.35
	Purchased	Mega screw shield and proto area	$24.99		$637.34
	Purchased	Hookup wire, spade lungs, terminals	$73.65		$710.99
	Purchased	1' Cat 6 cable	$1.95		$712.94
	Purchased	cat 6 keystone F-F coupler	$5.95		$718.89
	Purchased	PCB Breadboard	$11.85		$730.74
	Purchased	12A dual sabertooth motor control	$79.99		$810.73
	Purchased	Ethernet cable/coupler/patch cable	$60.84		$871.57
	Purchased	Additional tether materials	$544.96		$1416.53
	Purchased	RJ45 Materials	$17.98		$1434.51
	Purchased	Transducers	$81.48		$1515.99
	Purchased	Amplifiers	$17.90		$1533.89
	Purchased	Underwater speaker	$57.00		$1590.89
	Purchased/Re-Used	Servos	$39.98	$60	$1630.87
	Purchased	Connector crimp pins	$41.12		$1671.99
	Purchased	opa amps and sockets	$7.49		$1679.48
	Purchased	2 micrphone and right angle	$25.39		$1704.87
	Purchased	16GA bik wire	$8.15		$1713.02
	Purchased	Insignia 20" display	$74.30		$1787.32
Propulsion	Purchased	Motors/Propellers	$213.79		$2001.11
Additional Tools	Purchased	Meters	$48.85		$2049.96
	Purchased	12V to 4V Converter	$14.99		$2064.95
Control Board	Purchased	Seahorse SE920 hard case	$115.22		$2180.17
	Purchased	Control Board shelf material	$16.64		$2196.81
	Purchased	Angle Brackets	$6.43		$2203.24
	Purchased	3/8" board	$13.49		$2216.73
Props	Purchased	PVC/ABS	$187.48		$2404.21
	Purchased	Collapsible Bucket	$7.99		$2412.20
Miscellaneous	Purchased	1/2 Drawer storage	$47.00		$2459.20
	Purchased	USBest dual wall heat shrink kit	$9.99		$2469.19
	Purchased	Misc Hardware	$10.18		$2479.37
	Purchased	Screws, spacers, nuts, bolts	$57.80		$2537.17
	Purchased	Silicone oil	$11.39		$2548.56
	Purchased	O-ring set	$8.99		$2557.55
	Purchased	Rescue tape	$13.95		$2571.50
Competition Costs	Purchased	Mate Regional Registration Fee	$215.00		$2786.50

Donations	Donation	Watsonville Fire Dept. 1272	$1,000.00		+ $1,000.00
	Donation	GoFundMe	$750.00		+ $3,465.00

TOTAL (spent)	$2786.50
TOTAL (raised)	$3465.00
GRAND TOTAL	+ $678.50

ARGO V SID

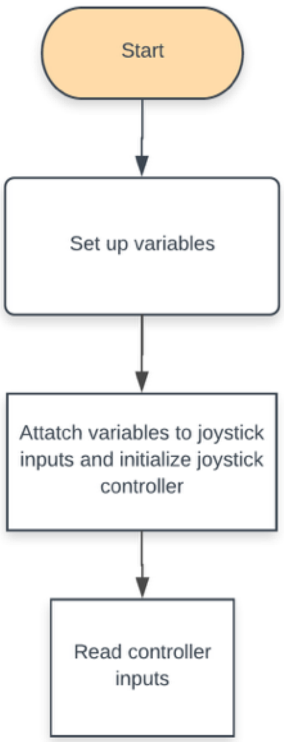


Fuse Calc

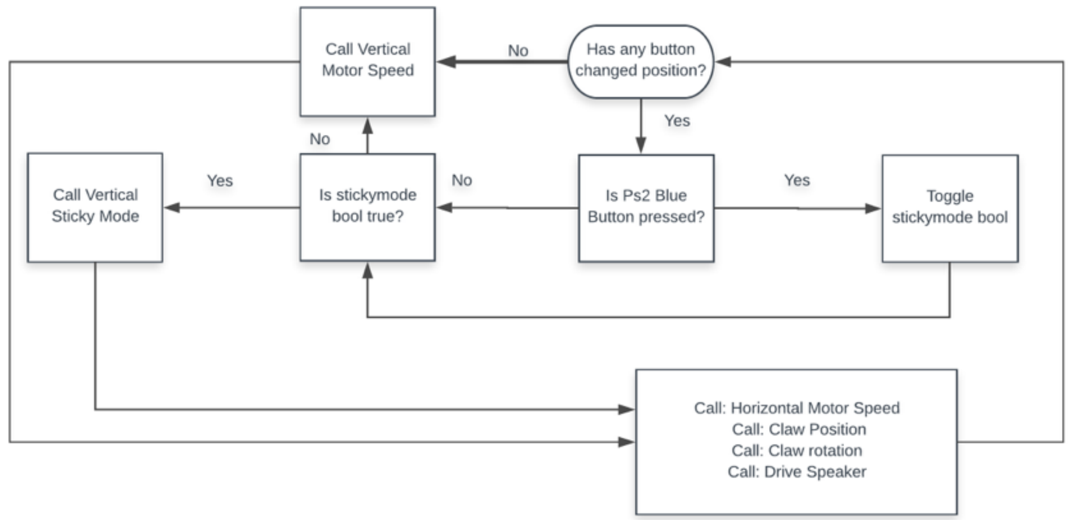
1250 GPH Motor (x4)	12A
Camera (x4)	1.2A
Claw Servo Motor	2.2A
Claw Rotation Motor	.6A
Speaker	1A
Total Max Current:	**17A**
Mate safety margin	x1.5
Fuse Current	**25.5A**
Fuse Used	**25A**

ARGO V SOFTWARE FLOWCHARTS

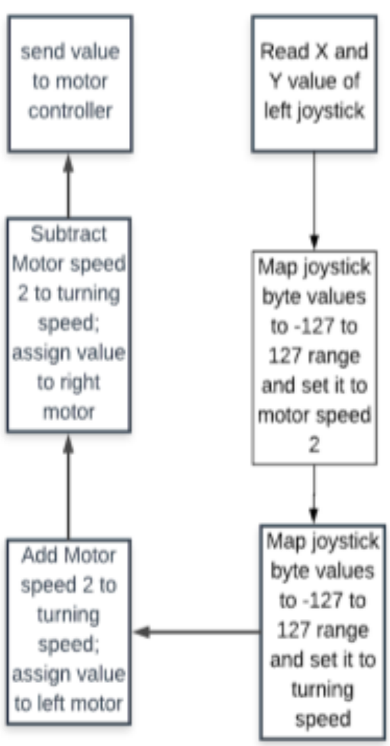
Arduino Setup



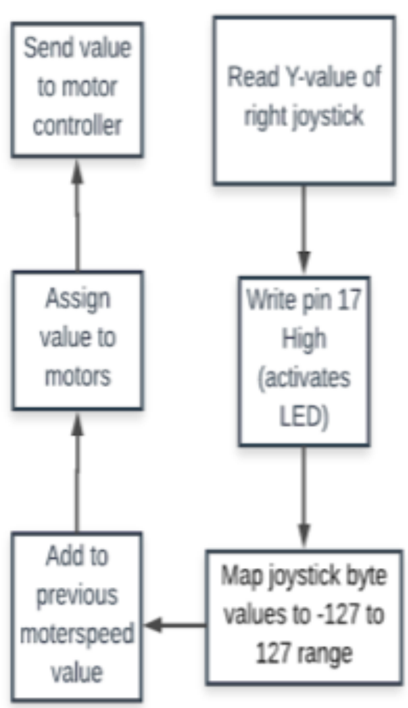
Arduino Main Loop



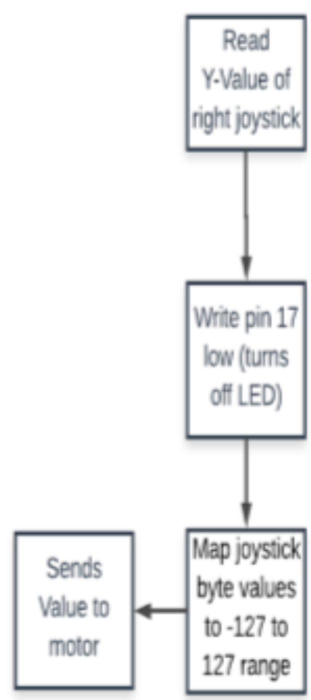
Horizontal Motor Speed



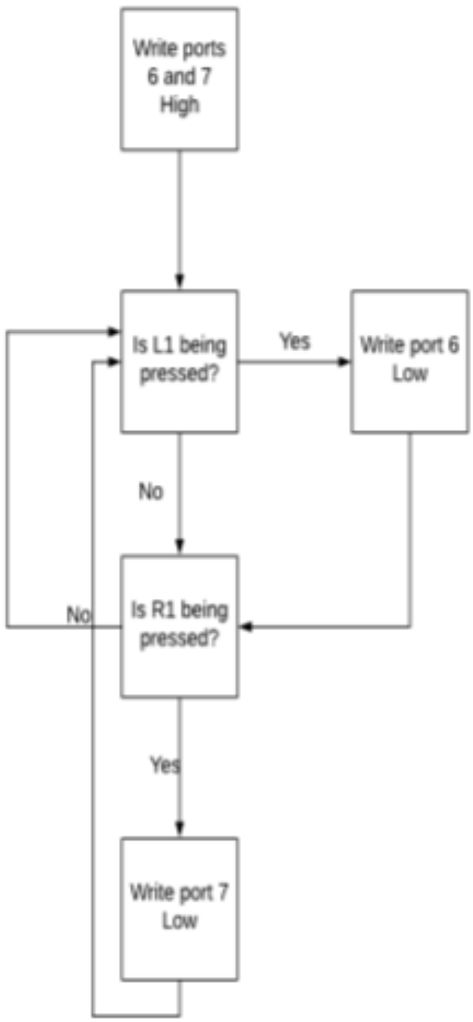
Vertical Sticky Mode



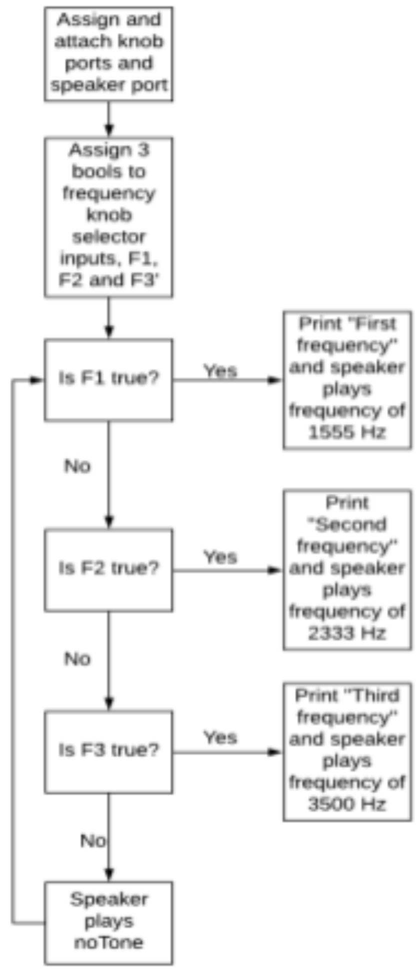
Vertical Motor Speed



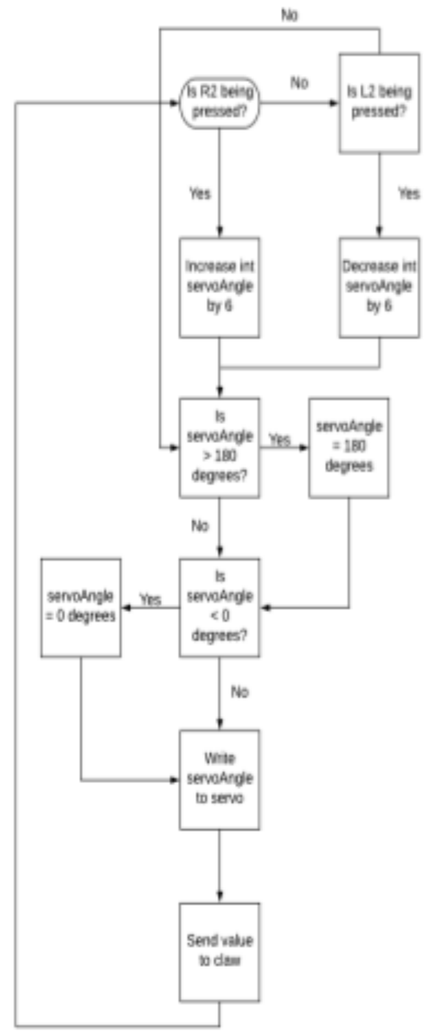
Claw Rotation



Drive Speaker

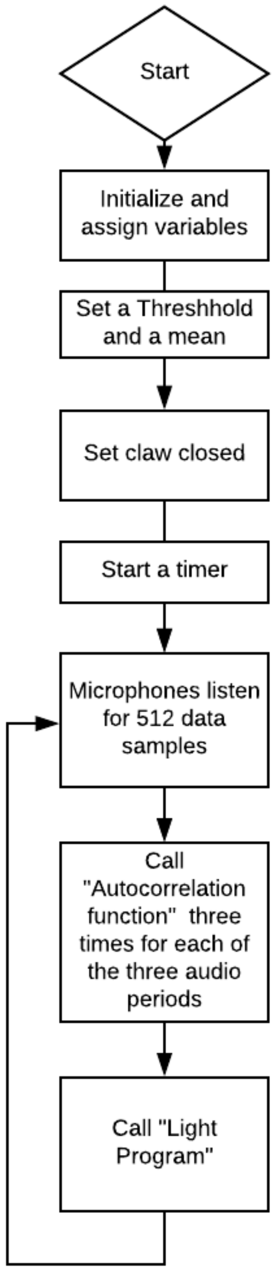


Claw Position

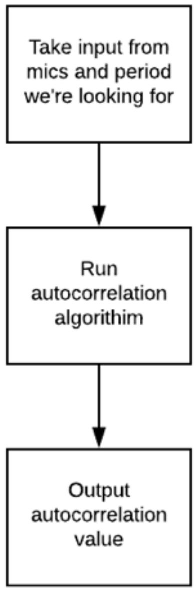


OBS SOFTWARE FLOWCHART

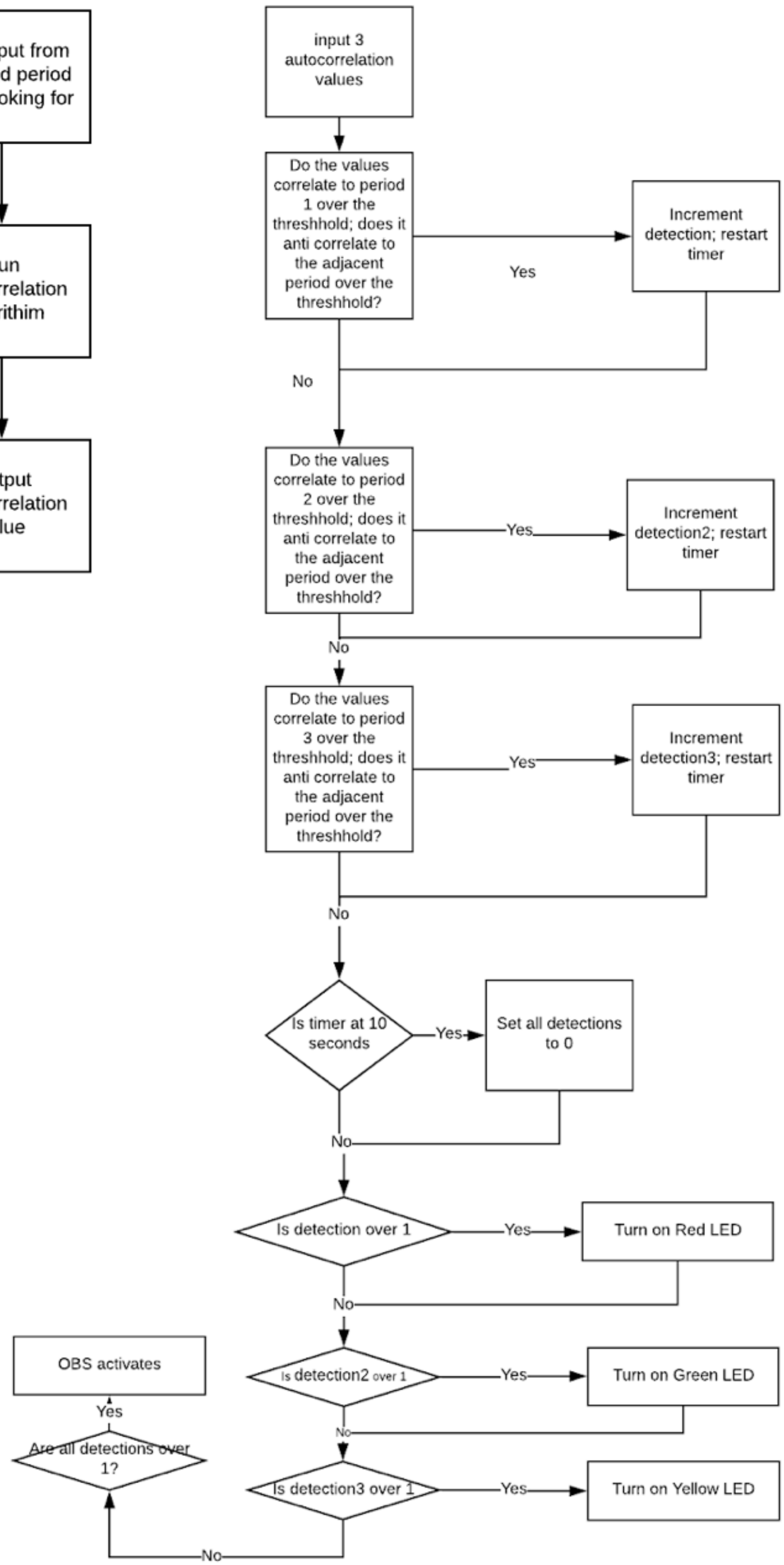
Setup and Main Loop



Anticorrelation Function



Light Program

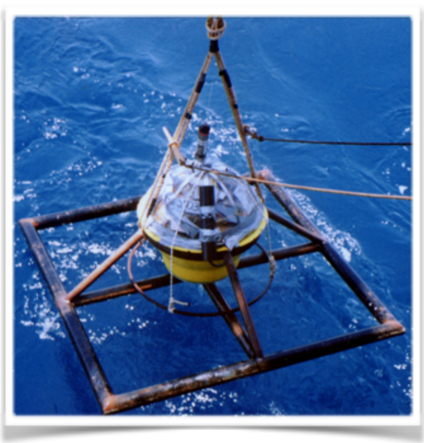


DESIGN RATIONALE

THEME SIGNIFICANCE

Our engineers designed the Argo V to solve ecological and scientific problems in Puget Sound, Washington. Throughout the process, we delved into how the scientific community recovers sunken aircrafts, addresses earthquakes, and harnesses energy. The Argo V employs strategies based on technologies and procedures in the real world (as well as our own creativity), to be the best product possible.

Our first mission is to locate and recover the engine of a sunken aircraft on the ocean floor. The Argo V uses a lift bag to retrieve the simulated engine. Some lift bags are closed, meaning they have no gaps in material and are filled with air, but these designs are used primarily for missions close to the water's surface; open air bags, which have a hole in the bottom, are more effective in deeper waters to adapt to changes in water pressure[2]. The Argo V uses an open air bag to accommodate the pressure levels of the ocean floor. In addition, this ability to release pressure is especially useful on assent, when trapped pressure can cause the bag to expand and rip, thereby dropping the engine before reaching the shoreline.



An ocean-bottom seismometer. (Photo Credit University of Texas Institute for Geophysics)

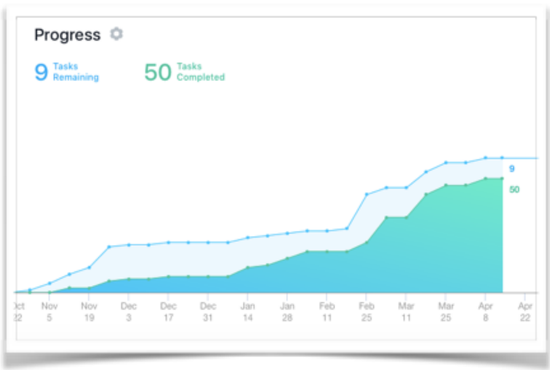
After recovering the engine, the Argo V installs a seismometer. A seismometer is the internal part of a seismograph, a device that measures and records ground motion during earthquakes[3]. Since Puget Sound is particularly susceptible to earthquakes, this device provides scientists with crucial information about the frequency and severity of these occurrences so they can formulate solutions. Our seismometer is equipped with an acoustic sensor; when it detects a specific sound, a hook holding the seismometer to the ocean floor will release, causing the buoyant device to float to the surface without requiring a salvage mission. Our program ensures that scientists have access to this data without expensive and time-consuming expeditions to the ocean floor.

The Argo V's final mission is to install a tidal turbine. A tidal turbine is designed to draw energy from water current and develop electricity. It functions similarly to a wind turbine, with propellor blades that turn with marine current. These turbines interfere with normal current patterns, potentially impacting wildlife; however, they capture even more energy than wind turbines and can reduce the use of fossil fuels for electricity[4]. During the mission, engineers stationed at the shoreline will use obtained tidal current data to determine the most effective location for a tidal turbine, install an array of turbines, and place a monitoring device to observe its impact on marine life.

The MATE simulation for the mission at Puget Sound reflects the importance of technology in monitoring environmental changes so that scientists can preserve ecosystems.

PROJECT MANAGEMENT

At Watsonville Firefighters Seal Team 1272, we work to create the best possible product for our customers. In order to accomplish this, our meetings and collaborations are designed to enhance communication and success. We manage consistent schedules to maximize productivity and workflow. In addition, we developed specific procedures to address day to day operational issues and trajectories.



Graph of our progress on our tasks throughout the year. (Photo Credit Asana)

Almost all of our project management revolves around documenting tasks -- the ones we have finished, are working on, and are planning. At the beginning of each of our meetings, we discuss the objectives for that day and a long term schedule. Typically, this agenda is divided into electrical, mechanical, software, and documentation. We then divide the tasks according to each team member's area of expertise and interest. Larger tasks are assigned to small groups and smaller tasks to individuals. This agenda serves as weekly meeting notes for absent members to reference online through Google Drive and to determine if we need to increase productivity or add meetings. Additionally, we use a program called Asana to assign ourselves specific or general tasks and check off finished ones. At the end of each meeting, we all enter in Asana what we accomplished that day so that we can keep track of exactly what and when tasks got done and make notes for later meetings.

We wanted to take good documentation one step further. In addition to using Asana, Katherine, our head of 3D Design, found that Tinkercad, the program we use to design our 3D components, can be used to document our progress as well. Using Tinkercad, Katherine created a scale replica of the Argo V. After any changes were made to the physical design of the ROV, we updated the digital model to reflect them. This procedure guaranteed that any design was double checked, thus ensuring efficient features. It also made the design accessible outside of our designated workspace, so that everyone could be completely up to date and always thinking about the latest design and how to improve upon it.

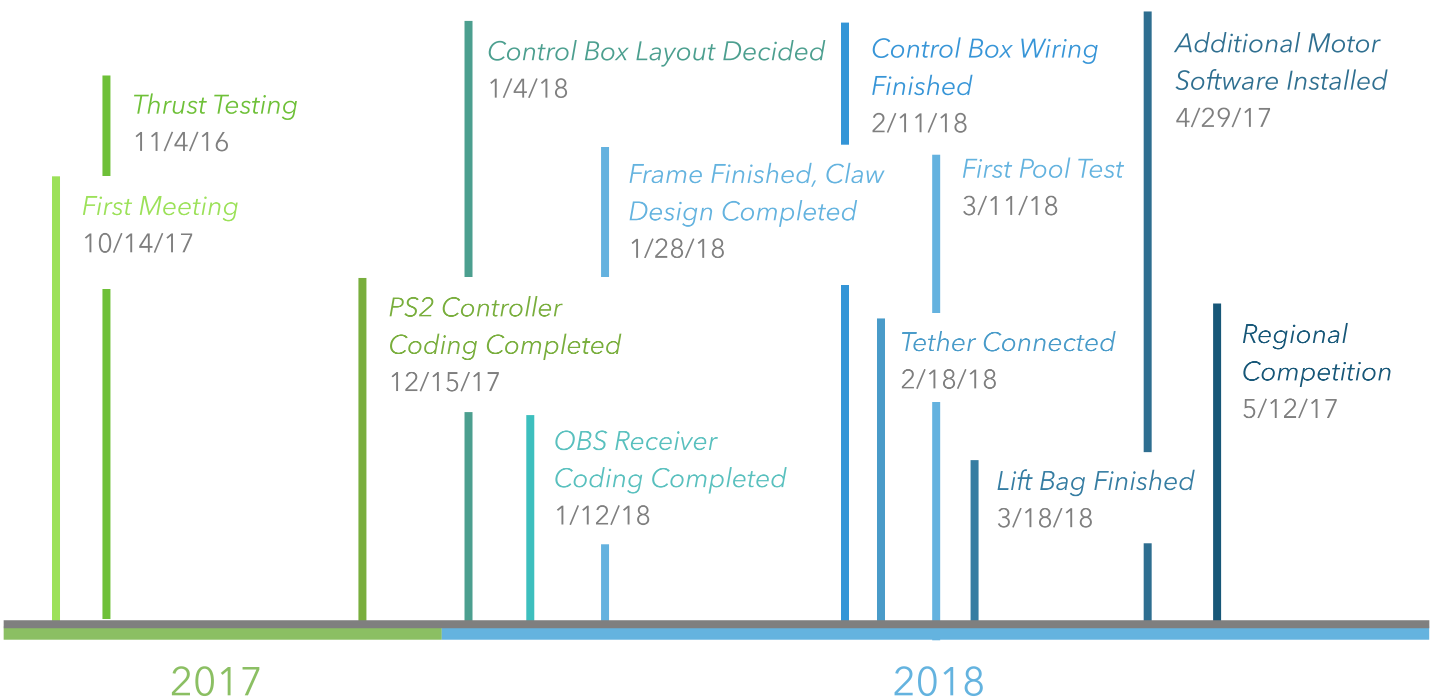
Furthermore, each team member's role contributed to managing the project. At the very start of the design process, we designated team members to head our major components of the Argo V. For example, we appointed a Head of Software Engineering, Head of Claw, etc. Everyone was involved in each area of the engineering process, but each member specialized in a specific role. This system also contributed to our protocol for productivity and issue management. During the meeting, teams checked in with their department head about their trajectory in their task so that all tasks were completed properly and in a timely manner.

Exploring and learning more about robotics is a significant part of our mission. The roles act as a way to increase organization, but we also strongly encourage our members to work on every aspect of the building and designing process. We work hard to balance everyone's time so that we not only create an amazing product, but also develop amazing young engineers.

Our Head of Software teaches the basic of coding to our other engineers. (Photo Credit J. Walton)

When developing an attachment for the the Argo V, we began by discussing the best options. We discussed the advantages and disadvantages of each idea before deciding on further action. After we decided on one or more of the best designs, we created a prototype. These prototypes were usually 3D printed and put to use a soon as possible. We modified each prototype until we maximized the efficiency of the attachment and it worked flawlessly. Before adding an attachment to the ROV, we manually tested each component to check that it would work before attaching it to the Argo V. Because of this, we never wasted time testing maldeveloped components on the ROV itself. When we implemented a new attachment, we immediately went to the pool for testing. Most of the time the attachments worked because of the previous tests we conducted. When a feature did work, then we moved onto the next one, and started the process over again.

PROJECT MILESTONES



3D PRINTED PARTS

Our engineers 3D printed more of a third of the Argo V, including frame joints, feature mounts, and weight capsules. *(Photo Credit C. Barrett)*

Our engineers created original designs for the Argo V using customized 3D printing technology. We used an online design system called Tinkercad to create specialized features suited for specific tasks. Many of the Argo V's most central parts, such as the claw and propellor shrouds, were designed by members of the team. 3D printing the Argo V's features allows our company to customize the new model to complete this year's tasks. This method is also economically efficient; these original designs account for over a third of this year's model, but our company only spent about 1.5% of this year's expenses on 3D products and technology. When developing a 3D feature for the frame, our engineers built a prototype online before printing a final product. The member who built the design would upload a link to the model to the team's online database of designs so that other members could view and edit the prototype before printing. Then we printed a low-density plastic prototype and tested it on the Argo V's frame. If this prototype was successful, we would print out the final design and attach it to the frame. If the Argo V encountered any difficulties with the final product during testing, we would revisit the design and start the process again.

Our process for designing and printing original features ensured that all 3D-printed products were effective and peer-approved by numerous members of the team. Even designs reused from previous models were printed newly before use to maximize product quality and durability. Original 3D designs were a crucial element in designing the Argo V to create a highly original and effective model that was specialized to complete all of the tasks required for the Pacific Northwest area at Washington State.

ARGO V SOFTWARE

Last year, the Argo IV used minimal software for its systems; however, our completely revamped control systems in the Argo V are all software based for even more efficiency. We used the potentiometers on the PS2 controller's joysticks to control basic motor movements, but this just scratches the surface. This year, we noticed that many tasks require us to drag objects through the water, such as engine debris. Because of this, we wanted to make both ends of our ROV act as the front through software. To accomplish this, we used one of buttons on the PS2 controller to switch the direction of all the motors. At the push of a button, users can switch the direction the motors turn when using the forward joystick. Thus, both sides of the ROV can act as the "front." We also added a "sticky mode" for the vertical motors. This allows for our ROV's upward movement to be controlled in increments which slowly increase the amount of thrust the motors give. This allows for users to have more control over upward mobility. We use this for tasks that require focus on a specific object, such as identifying the airplane wreckage.

NAVIGATION

Propeller	Thrust	Current Draw
Yellow	7 Newtons	6.2 amps
Black	7 Newtons	7.1 amps
Red	5 Newtons	6.7 amps

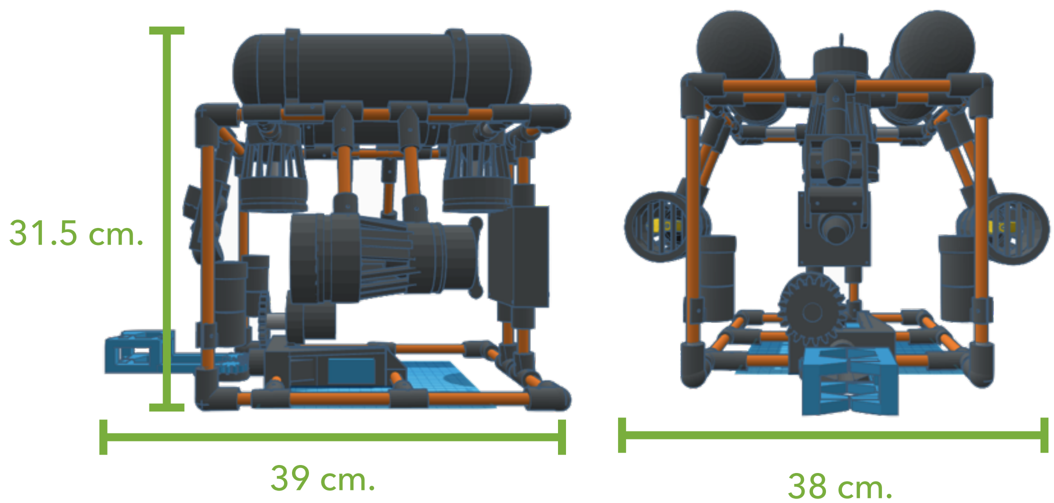
Above: Thrust calculations to find the best propellers. Left: Propellers tested. (Photo Credit J. Walton)

Propulsion. The Argo V has been designed to effectively propel through the water allowing the vehicle to complete tasks with efficiency and ease.The Argo V features four motors--two used for horizontal propulsion, and another two that are oriented to provide vertical thrust. All four of the Argo V's motors are 1250 gallons per minute (GPH) bilge pump motors that are 2x more powerful than last year's motors. These thrusters allow the ArgoV to quickly and efficiently maneuver across all three axes. The Argo V's two horizontal motors are also placed on the outside of the frame to provide quicker turning by placing them further away from the ROV's center of mass. This change was made because last year our team found the ROV turned too slowly. With this turning taken into account, the motors now had been placed on the outside of the frame, making our users more susceptible to injury while removing or placing the vehicle into the water. To counteract this, we designed and 3D printed shrouds and coverings for each of the motors, making it impossible for stray fingers to be caught and inured.

The Argo V has the capability to make either end of the frame behave as the front relative to the pilot controls. So technically, our ROV has two front ends. A button on our controller selects which end will be selected as the front. As soon as the front is selected, the software controlled horizontal thrusters respond correctly to the new front end. The pilot then steers using the camera that points to the new front. With this feature, our customers never have to blindly and awkwardly backup the ROV; they just switch front ends to efficiently maneuver in the opposite direction. This year, because it is easier to pull, rather than push large objects, we also changed the direction of our maximum horizontal thrust to be opposite the claw end. This innovation allows the ArgoV to tow large and heavy objects better than any other earlier iteration. Since the missions this year involve moving heavy and large wreckage from an airplane, this thruster change enables us to tow with maximum thrust. With this mentality of providing maximum thrust with the motors we had, we also tested the thrust of different propellor designs.We ended up testing the default yellow propellers that MATE provides in the Navigator kit that we purchased in 2015. Along with testing the default propellers, we found two other designs on the 3D design software Thingiverse. All three had vastly different designs, so we were curious on which would be the best to use in terms of power. To conduct these test, a group of members designed a small testing rig that would pull on a spring, giving us the measurement of force in newtons. Using this method, we concluded that one of the 3D printed designs produced only five newtons of force, while drawing 6.7 amps; however, the default propellor design and the other 3D printed model both yielded seven newtons of force. In the end, the decision on which propellor to use came down to the current draw. The 3D printed variant drew 7.1 amps, while the mate provided yellow propellor design only drew a small 6.2 amps. With these findings, the team concluded that the most powerful and efficient propellor design was simply the default.

Weight Distribution. Weight and buoyancy in the water is one of the most crucial elements of navigation. Every feature on Argo V, from the frame to the attachments, has been tested and positioned with the goal of making the Argo V perfectly balanced and able to glide through the water smoothly.

We made the Argo V's frame as light and compact as possible so that it experiences less drag and is easier to maneuver in the water. We made our frame out of thin, lightweight aluminum tubing to achieve maximum strength for minimum weight and size. We chose to use the aluminum tubing instead of another material such as PVC because it only has a diameter of 8mm while half inch PVC has a diameter of 21.4mm. Our ROV is 31 by 28 by 27 cm and, because of its compact design, it only weighs 9.97 kg in air.



(Left) Side view mechanical drawing. (Right) Claw front view mechanical drawing. (Made by K. Walton in TinkerCad)

The thin frame of our newest design allows for a lot of interior space for attachments. Our buoyancy tanks rest on the top of Argo V to save room for motors and other attachments. Our engineers calculated the volume of the buoyancy tanks to ensure they would keep Argo V slightly positively buoyant. This slight buoyancy means that carrying props to the surface takes less time, and if the Argo V malfunctions, it can float to the surface where our team can safely remove it from the water. Also, improving on last year's model, custom clips allow for easy removal of our buoyancy tanks, ensuring easy access to the top of the ROV for modifications and repairs.

To counterbalance the buoyancy tanks, the Argo V also has custom-made containers that attach to the bottom corners of the frame and can be filled with lead shot to accommodate any changes in weight. These containers were designed with 3D printed technology and can be clipped and unclipped from the frame easily so that the Argo V can remain perfectly balanced.

The weighted containers aren't the only removable components -- almost every part of the Argo V is attached to the frame using connector clips. This allows us to make micro adjustments on the weight distribution and easily exchange parts.

Vision. The current iteration of our robot is designed with four waterproofed cameras, positioned strategically to make piloting the ROV an easy task. We have one camera facing forward on the claw side of the ROV and another camera facing backward on the backside of the ROV. Both of these cameras are used for navigation since the software control system of the ROV allows either end of the ROV to be controlled by the pilot as the ROV 'front' end. Our third camera looks down on the claw. This is used for orienting the claw and for making distance and depth measurements. The fourth camera points at a depth gauge, which we use to measure the height of the ADV attachment.

Front facing camera. (Photo Credit C. Barrett)

Our team opted to use analog backup cameras -- the same ones found on the back of automotive vehicles. Analog technology minimizes the lag that comes with digital cameras. Additionally, this model is financially efficient, with each camera costing around $16 and easily available online. Although each camera is marketed as pre-waterproofed, we place heavy emphasis on our product's safety and reliability by encasing all cameras in a 3D printed frame, which is then filled with epoxy, ensuring that no water enters the internal camera. Each camera is then fitted with a 3D printed attachment that allows for snapping securely onto the main frame. Each 3D printed attachment also has a swiveling joint, reducing the work needed to reangle and reorient the camera.

In last year's design, we had noise artifacts on the screen due to interference between the thruster control wires and the camera wires in the tether. To combat that this year, we have converted the analog signal from each of the four cameras to a differential signal using a commercially available passive quad video balun. This conversion takes place in the ROV. Each of the four differential signals is then sent over a twisted pair of an ethernet cable running the length of the tether. The use of differential signaling makes the camera output much cleaner noise-wise than last year's design. The ROV camera system also contains a single voltage converter that takes a 5V supply from the surface and converts it to the 3.3V supply that each of the cameras require. To waterproof, we designed a 3D printed box that contains the quad video balun circuit board and the voltage converter. The box was then filled with clear epoxy to seal in the electronics.

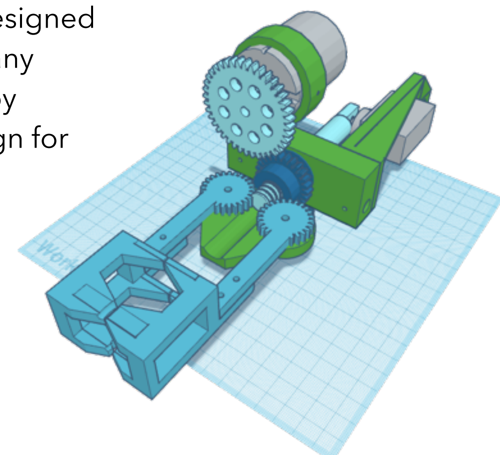
Multi-channel viewer in our control box. (Photo Credit C. Barrett)

In the control box, the differential signals from the ROV have been converted back to analog signals using a matching quad video balun. Each of these analog signals are then sent to a multi-channel video viewer device purchased on Amazon. This device takes the four analog video inputs and combines them into a signal video output. A small remote for the multi-channel viewer device controls how the video streams are combined. It allows the pool side team to view the output of a single camera on the screen, or all four cameras simultaneously, along with many other layout options. The single output of this device goes to a new 19'' LCD TV screen mounted in the lid of our control box. Both the multi-channel viewer and the TV run on 12V. Every ROV needs vision, and the Argo V has the complete package.

TASK COMPLETION

Claw. The Argo V is equipped with a state of the art claw device designed entirely by our engineers using 3D technology. While there are many commercial grippers available for purchase, our team found that by designing our own claw, we had the opportunity to tailor our design for the missions with every detail.

Before we started designing our claw in TinkerCad (the 3D technology we use for all of our printed components), we brainstormed as a team which parts of last year's model worked, which did not, and what new ideas we wanted to incorporate.



A mechanical drawing of the Argo V claw system. (Made by J. Walton in TinkerCad)

After hours of practice and competition last year, we decided that the shape of our claw worked very well. Thus, we reprinted the arms of our claw from the Argo IV model. When closed, the claw's opening is a hexagonal shape. We specially tested the shape to grip PVC pipes, so the design would be ideal for carrying our lift bag, connecting power cables, installing turbines, and other tasks. It has a strong grip on plastic materials, but to ensure the safety of our customers, the claw is designed to be smooth and safely interacted with.

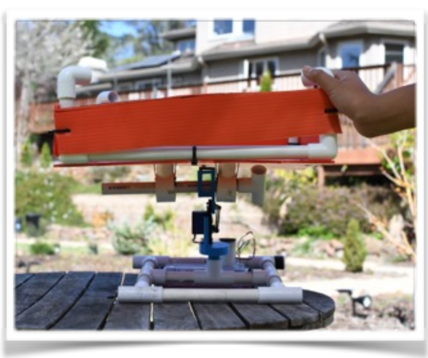
Last year, our team designed a rotating claw in order to turn a valve to restore a fountain. Through much experimentation, we found that the rotating claw was an asset in every task; it allowed users to position the claw at the perfect orientation for the task at hand. However, the claw could not freely rotate last year because of placement of the servo motor used to open and close the claw. As it rotated, the wires of the servo motor wound around the rotation spindle, causing it to stop after only two rotations due to a lack of wire. Users were obligated to track the number of rotations and unwind the claw if they exceeded the maximum. We decided this year that a rotating claw would still be highly beneficial in using our lift bag, installing the tidal turbines, and all other tasks which require precise maneuvering, though we wanted to improve the design. We set out to create a claw which rotated independently of the servo motor to allow free movement. After discussing and sketching numerous ideas, we decided to take a mechanical approach using a system of gears inspired by the claw of our new members' previous robot, Mr. Whiskers. Using this idea, Argo V's claw features pinion gears on its arms. These arms open and close using a cylindrical rack gear which a software-controlled servo motor moves back and forth. A waterproofed DC motor, which is electrically controlled using surface side relays also under software control, rotates the claw and gear assembly around the rack gear. Because of the claw's ability to rotate freely, users can position it perfectly for every task and never have to worry about unwinding.

Lift Bag featuring custom 3D printed hooks. (Photo Credit S. Da Costa)

Lift Bag. Our lift bag is a lightweight plastic bucket. When filled with air, it has enough volume to lift the heavy plane wreckage off the ocean floor. Conversely, the ROV lowers the bag by pulling on a spring loaded release valve that releases the trapped air. To make sure all the air is released, we made the 3D printed valve the highest point by deforming the flat bottom of the thermoplastic bucket with a heat gun. Hanging from the bottom of the bag is a 3D printed cylinder that has multiple hooks for attaching to the airplane wreckage.

OBS. The OBS is constructed from three main parts: the lift cradle, the anchor, and the electronics box. The OBS uses an acoustic release mechanism to trigger a servo opening, which then releases the lift cradle with the power connector inside.

Our team of engineers chose to challenge our skills and design our OBS release mechanism using audio signals. The Argo V emits three loud sound frequencies picked up by internal microphones in the OBS. After hearing these three frequencies one after the other, the Arduino in the OBS box sends a signal to the servo, which opens the claw and releases the lift cradle. To make our OBS release only respond to signals from our ROV and not other sounds, we implemented two main techniques.


The OBS. (Photo Credit C. Barrett)

First, we use two separate microphones at different ends of the OBS housing. The output of each mic is input to a single differential amplifier in the OBS that will only output the difference between its two sound inputs. This enables the OBS to ignore distant sounds, since both microphones pick up the same sound from such a source and cancel each other out. However, when our ROV outputs the trigger sound frequencies, it will be close to the OBS, ensuring that one microphone will detect a stronger sound amplitude than the other. By only looking at the difference we detect only the sound coming from the vicinity of the Argo V.

The second technique uses unique digital processing inside of an Arduino Nano, also installed in the OBS. The Arduino inputs the output signal from the differential amplifier. The Nano is programmed to quickly take 512 sound samples from this input. Once it has 512 samples, it implements an autocorrelation algorithm to determine the fundamental sound frequency of the input. It is pre-programmed to look for the three trigger frequencies from our ROV. During our original tests, we found that the autocorrelation technique worked, but was extremely sensitive to noise; as soon as it encountered a loud sound (like the sound of thrusters), every frequency would be detected and the OBS would trigger when we didn't want it to. To fix this, we not only look for a correlation with the frequencies we want, but we also look for an anticorrelation with the adjacent frequencies. In other words, when the program evaluates a wave to see if it correlates, it also checks to see if it anti-correlates on the next frequency. If the Arduino doesn't see this anti-correlation along with the detected frequency correlation, then the OBS won't trigger. This works because the frequencies we picked have a period 1.5 times the period of the adjacent frequency. This means that as one wave approaches a peak in its sine wave, the other approaches a valley. That extra corroborating step completely got rid of the false activation.

***Depth Gauge*.** In order to find the height that the Argo V needs to suspend the Acoustic Doppler Velocimeter, we decided to create a depth gauge. When submerged, the gauge begins to fill with water. The volume of air decreases as the pressure increases, so our deck team can determine the depth of the gauge by reading the water level in the plastic tube. Our engineers used Boyle's Gas Law to calculate the volume of the depth gauge needed to get the most precise reading possible.

CONTROLS

We engineered the control box for the Argo V from the ground up. We scrapped our previous design in order to accomodate effective organization and layout of the control box. All connections are easily traceable and understandable throughout their runs. We designed the control box with expansion in mind; we designed it for flexibility and effective use of space, something we encountered as a problem last year. We found that an open-ended approach to control box design would allow for evolving ideas and new components.

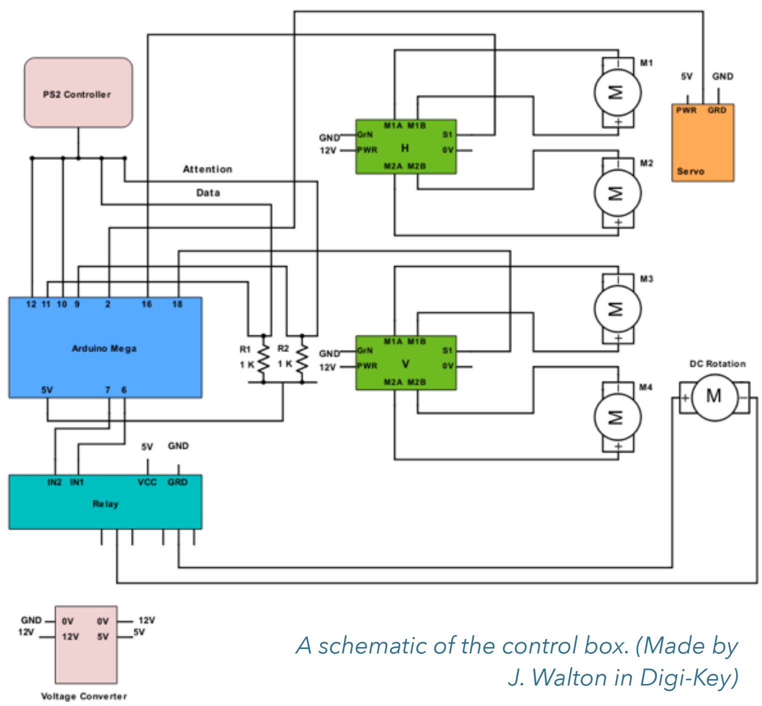
Our electrical engineers work on the skeleton of the control box. (Photo Credit J. Walton)

We chose a waterproof industrial travel case for the Argo V's control box. This 62cm x 38cm x 26cm wheeled housing provides immense structural integrity and copious amount of space to accommodate all components. We built our control box from scratch, using no precompiled kits; instead we purchased individual components for maximum flexibility and customizability. We use two sabertooth motor controllers to drive the Argo V's onboard thrusters and a relay to control the claw's DC rotation motor. We knew from experience these were functional parts that would be reliable to include. We accomplished vision underwater through the use of four analog cameras. This is similar to our former design, but scaled up immensely for greater visibility. We run the cameras signals to the surface through the tether and display them on a 19" TV mounted in the lid of the control box. We have multiple camera views and many options for their layout on the screen; this facilitates maximum visibility and ease of operation for the surface team.

The PS2 Controller used for navigation. (Photo Credit J. Walton)

The brains of the control box is an Arduino Mega. The Mega interfaces a PS2 game controller to the mechanical systems of the ROV: thrusters, claw angle, and claw rotation. The use of a game controller is a big difference from last year's control system. This old control system was too large to be held in the pilot's hands, making it cumbersome to use all the control systems simultaneously. This year's PS2 controller interface allows users to manipulate the Argo V through a compact and intuitive controller. This allows all-digital control through software running on the Arduino Mega that our software team, working closely with the electrical and mechanical engineers and pilot, developed to make the Argo easy and fun to drive.

We put the brains of the control box at the surface in order to keep the Argo V simple and light, and most importantly: reliable. This means that our tether needs to convey all the control and sensor data between the Argo V and the control box, making our tether an important sub-system. This year, we adopted a velcro tether sheath to keep the twenty-four conductors and airline of the tether bundled together and protected from the environment. The velcro seam running along the length of our tether allows our team to easily make changes to the tether by giving us easy access to its internal wiring. The velcro seam also allows us to add internal buoyancy to the tether instead of relying on the external buoyancy of last year's design. We found that external buoyancy floats with zip ties would frequency get snagged in the environment underwater. Keeping the buoyancy internal means we have no snaggable edges on the tether making our ROV able to work in tight locations.



A schematic of the control box. (Made by J. Walton in Digi-Key)

One of our most important innovations that truly sets us apart from our competitors is our use of a disconnectable tether. his was a large undertaking that yielded an equally large reward. By disconnecting the tether from the control box, transporting the Argo V becomes safer, easier, and quicker. This feature allows for construction and repair of the Argo V to be far simpler and safer, as you can separate the control box and tether to work on each separately. It also allows the ROV to be shipped to new locations in two separate pieces making it easy to deploy at a job site.

SAFETY

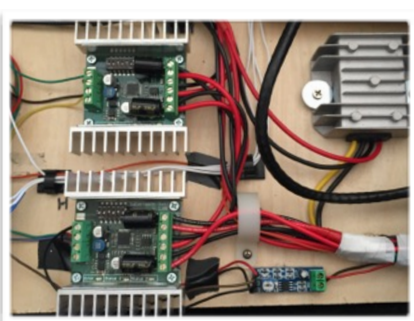
At the Watsonville Firefighters Seal Team 1272, safety is our number one priority. We follow a set of rules that guide us away from danger and make our tasks and practices run as smoothly as possible. The guidelines are as follows: always grabbing the ROV from the top with both hands, protecting the claw when carrying or setting down the ROV, gently putting the ROV in the water, and staying aware of where the tether is. We have also installed safety instruments on our ROV. The instruments include: 3D printed shrouds around all 4 of the thrusters, 3D printed clips that keep wires away from propellers, and smoothed edges. We used waterproof heat shrink on our electrical splices where needed. This heat shrink combines internal glue that flows when heated, sealing each end of the splice as it shrinks.

Pre-Run CheckList

- ✓ Make sure deck crew is in place
- ✓ Uncoil and organize tether
- ✓ Connect tether
- ✓ Inspect control box and make sure there are no exposed wires or debris
- ✓ Make sure no liquid is close to control box or battery
- ✓ Ground is always connected first to the external power supply
- ✓ Tuck airline into proper position for mission
- ✓ Pilot calls out when power is turned on to alert deck crew
- ✓ Test all motors and attachments before putting the ROV in the water

Construction CheckList

- ✓ Professional behavior during meetings
- ✓ Handle tools properly and safely
- ✓ Have supervision from another teammate while using power tools
- ✓ Wear safety glasses while soldering and sawing
- ✓ Wear rubber gloves when handling epoxy/chemicals
- ✓ Unplug power tools when they are not in use
- ✓ Clean and organize workstations after a construction task has been completed



(Left to Right) *Neat wiring in the control box (Photo Credit J. Walton), Covered and shrouded motor (Photo Credit C. Barrett), Sun Woo following safety guidelines when using a power drill (Photo Credit J. Walton).*

CRITICAL ANALYSIS

After months of designing and perfecting cutting-edge features, our company is prepared to release our latest model, the Argo V. New ideas and discoveries throughout the design process lead to the creation of an advanced ROV that is suited to complete the missions in the Pacific Northwest areas with speed and efficiency.

Our team began testing the complete product in the water on March 11, 2018. After evaluating the buoyancy and navigation, the Argo V was ready to tackle the missions with increasing speed. We kept track of our progress, using a timer, clipboard, and the MATE rubric. Between each run, we addressed any problems experienced.

Our team from left to right: (Top) Sandler, Govaars, Rathi, Whaley, Broxton, Barrett. (Bottom) Lovell, Chin, K. Walton, Da Costa, J. Walton, Martin. (Photo Credit C. Barrett)

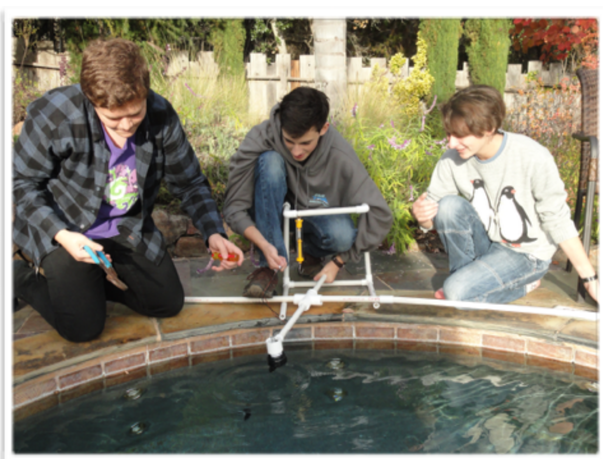
Each time the Argo V encountered a problem, the team collaborated to brainstorm various solutions as a group. For example, when the Argo V encountered buoyancy issues during its first run, the whole team initiated a discussion afterwards to discuss what could have gone wrong and how the problem could be averted in the future. The team concluded that the Argo V was in fact topheavy, and decided to add clip-on, 3D printed containers filled with lead shot to the backside of the frame. After adding these containers, the Argo V was tested underwater once again and found to be successful.

Our team also developed a method of designing each feature for the Argo V. When creating an original 3D design, our engineers built a prototype online using a 3D design program called Tinkercad, then uploaded the design to the team's online database to receive feedback from other members. Once the design was perfected, engineers printed out a low-density ABS plastic version, and proceeded to test this version on land. If the said test was successful, the engineers printed a final copy. If the Argo V encountered any difficulties with the final product during testing, we would revisit the design and start the process again.

When adding commercially obtained features to the Argo V, one individual member or small group researched the most high-quality options online before purchasing an item. Department heads then tested this product on the Argo V, evaluated the product's success, and then added it to the frame if it was successful. If the product didn't function the way engineers expected, the group came together to discuss what could have gone wrong and started researching again for a solution. The team this year implemented many technologies that were unfamiliar and complicated to our vehicle. These new technologies include a new acoustic speaker, using a PS2 controller as the main control system, and learning how to code for excel. All of these new methods are extremely important to the teams success. Using a PS2 controller allows our ROV have a more simplistic and more maneuverable control system. This year, an acoustic speaker was also added to complete the OBS task, along with gaining the maximum amount of points available in the task. In addition to adding an acoustic speaker and a foreign control system, we created an excel spreadsheet to calculate and graph the vectors for the airplane section of the product demonstration. With all of our success with new technologies, there were bound to be some failures, such as our attempt to use ultrasound for the OBS release. Instead of using an acoustic sensor, originally, the team brainstormed using ultrasound waves to release the OBS. Our engineers tried to adopt ultrasonic transducers for use underwater but we could not make them work in that environment.

The purchased acoustic sensor. (Photo Credit C. Barrett)

The team also faced many issues with waterproofing specific components of the ROV, especially with the DC motor that is used to turn our claw in a 360° range of motion. We also used a DC motor on the Agro IV to rotate the claw for specific tasks such as turning the valve on the entertainment complex. We found this way of rotating extremely efficient; however, the DC motors were not waterproofed out of box, so we used mariner grease, a hydrophobic material, to keep water out of the electrical motor. This year, we wanted a more sophisticated– and more importantly, reliable– way to waterproof so we turned to epoxy. This choice brought a multitude of its own problems, however, as two DC motors froze once the encasing epoxy hardened. On our third motor, we were successful in encasing them in epoxy once we left the motors running during the entire hardening of the epoxy.



Chris, Johan, and Katherine collaborate on thrust testing. (Photo Credit M. Seamount)

Beyond just technological difficulties, our team also experienced collaboration and management issues. On the biggest hurdles our team faced was using the online organization program Asana. Originally, we had planned for every member to add to Asana what they had completed during the meeting, so it would be simple to see what was completed and what still needed work; however, this method failed almost immediately. Close to nobody would input their activities, leading to general confusion at the start and end of every meeting. However, the team decided to not abandon Asana, and instead, we dedicated the last few minutes of every meeting to inputting what people had completed to Asana. With this new practice, people could decide what they would like to do quickly without any confusion or conflict, as well as giving us an efficient way to track our team's progress.

FUTURE IMPROVEMENTS

The Argo V is an extremely capable ROV that has been specially built to accomplish a variety of tasks, but here at Seal Team 1272, we're always looking for future improvements and innovations to make the Argo VI even better. The first of these improvements is going to be sticking to a more comprehensive budget plan. After securing a sponsorship from the Watsonville Firefighters again, we became a little lax with our budgeting and our financial cushion disappeared more quickly than we hoped. We knew the budget would be more of a challenge this year since our goal was to completely redesign our control box from scratch. Even so, the budget still grew faster than we expected due to the cost of developing the new technology needed for this year's tasks. Part of the problem is that we had a budget that still made purchases in our individual departments without running them past the entire team and actually discussing if what we're buying is worth it. Next year we will have a comprehensive budget plan that puts purchases under more scrutiny. For every major purchase, we will require a team meeting in order to decide if what we're buying is worth it or not. Along with this, we will also have a budget debrief at the end of each meeting so we can see how much of the budget we've used and at what point we should start budgeting or fundraising. This way, we can avoid making expensive purchases that drain our budget and not have to scramble at the last minute to start budgeting.

In terms of improvements to the ROV itself, we are going to improve our distance measurement system to be more accurate. To do this, we are going to switch from a physical measurement system where we use a measuring tape to measure distances, to instead implement a measuring system using lasers or sonar. We will accomplish this by sending out a signal with light from the laser or sound from a speaker much like our OBS, and timing how long it takes for the signal to come back to the ROV. This way we can more accurately calculate distance. The would be a major improvement; although the physical measuring tape serves all of our purposes, it can sometimes be difficult to read using just the ROV cameras. This can lead to some discrepancy in the measurements. By using lasers or sonar, we can fix all of these problems and make the Argo VI even better than the Argo V.

ACKNOWLEDGEMENTS

This year, many individuals and groups supported our team, donating their money, time, and experience. We first give our sincere thanks to Victor Da Costa and Mary Seamount for their invaluable mentorship. Without them, the team wouldn't be here today. We also appreciate all the parents for bringing members to practice, doing supply runs, and loaning us tools. Next, we thank the Watsonville Firefighters Local 1272 for investing one thousand dollars in our vision of building an award-winning robot. Their contribution was the foundation we needed to begin reconstructing and improving the Argo V. We are also grateful to the Aptos High Booster Club, who, year after year, generously donates to all the ROV clubs at Aptos High, as well as our club sponsor, Joe Manildi. We sincerely thank the many family and friends who contributed to our GoFundMe Page and encouraged us along the way. Finally, we would like to thank MATE for hosting and organizing this competition; without them, the entire ROV competition experience would be non-existent and we would miss out on this amazing experience.

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