WATSONVILLE FIREFIGHTERS

SEAL TEAM 1272

Because fortune favors the brave.

Watsonville, CA 95076

Mentors: Victor Da Costa and Mary Seamount

Our Team:

Chief Executive Officer (CEO)	Chris Whaley, 3rd Year
Chief Financial Officer (CFO)	Sun Woo Da Costa, 3rd Year
Chief Technical Officer (CTO)	Jamie Walton, 3rd Year
VP of Electrical Engineering	Keegan Martin, 3rd Year
VP of Marketing	Pratham Rathi, 3rd Year
VP of Mechanical Engineering	Katherine Walton, 3rd Year
VP of Research and Development	Amelia Lovell, 2nd Year
VP of Software	Jacob Sandler, 3rd Year
VP of Safety Engineering	Jordan Chin, 2nd Year
General Council	Cameron Barrett, 2nd Year

ABSTRACT

Here at Watsonville Fire Department Seal Team 1272, our group of engineers have collaborated to construct a top-notch ROV, the Argo IV, that assists architects in turning their port city plans into a reality: A reality that will eventually lead to the overall development of civilization. Its combination of fully custom ultra lightweight 3D printed parts and economical commercial parts caters to four major aspects of welfare: commerce, entertainment, health, and safety. It's a small, light rectangular prism packed with high-end technology, such as two cameras, a fully programmed, rotating claw, and a bright Raman laser. These qualities are complemented by maneuverability and speed, originating from two high-strength up/down motors and two high strength forward/backward motors. This makes for easy transport of Hyperloop parts and efficient maintenance of the entertainment system at the port. Apart from the standard features, the Argo IV also exhibits a distance measuring tether that is able to attaches to metal using due to strong magnets. It also has a manual syringe that can take samples from the ocean floor to be used in for testing for malicious substances. This helps our team keep our top priority--the health of the environment. With this in mind, our ROVs rounded corners and smoothed out protrusions guarantee no harm to marine life. All of the features on the Argo IV allow for maximum efficiency, and minimal safety risks. Watsonville Fire Department Seal Team 1272 believes that the future is now, as we will demonstrate.

A diagram of the predicted Hyperloop System, to be built with the assistance of ROVs. (Photo Credit Hyperloop One)

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BUDGET

Our team is the combined force of two companies, Logic Cube^3 and Seal Team 7, from last year's competition. This merger allowed us to craft parts using our combined ingenuity and salvage parts using our two previous ROVs. The cost to build our prototype, including research and development, totaled $1,111. To reproduce the ROV, the cost of each would be $1,013.57, which includes the market value of the reused parts, but not costs for props, failed experiments, and the MATE event. Our costs were offset through the wonderful generosity of our sponsor, the Watsonville Firefighters Local 1272 who invested $1000 in our company.

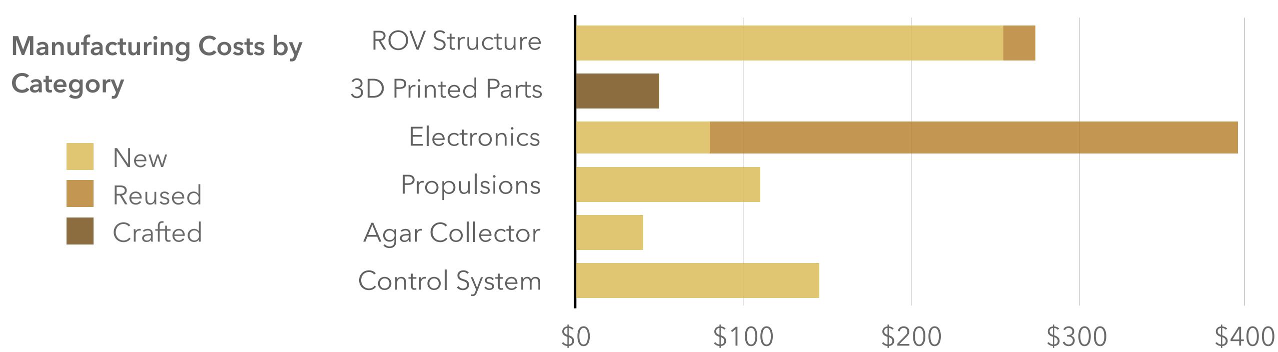
PROJECT COSTING

Category	Description	Cost	Value of Reused Parts	New , Reused, or Crafted?
ROV Structure	Aluminum Tent Poles	$91.92		New
	Misc Hardware	$152		New
	Claw		$18	Reused
	Lead Shot	$12.06		New
Parts Designed and Fabricated 3D Printer and Filaments	Frame Connectors	$50 for Two ABS Filament Reels.		Team Crafted
	Motor Propellers			Team Crafted
	Propellor Guards			Team Crafted
	Claw			Team Crafted
	Wire Clips			Team Crafted
	Claw Attachment			Team Crafted
	Holder for Ballast Tanks			Team Crafted
	Tether Strain Relief			Team Crafted
	Adjustable Corner Weights			Team Crafted
	Rotation DC Housing			Team Crafted
	Camera Holder			Team Crafted
	Cable Harness			Team Crafted
Electronics	DC Motors for Rotating Claw	$30		New
	Endoscope (for LED light)	$34.47		New
	2 Cameras		$40	Reused
	2 LCD Displays		$32	Reused
	Claw Servo Motor		$65	Reused

Electronics (Continued)	2 Sabertooth Controllers Arduino Uno Teather	$14.75	$130 $19 Additional $30	Reused Reused Reused
Propulsions	4 Pulge Pump Motors		$110.00	Reused
Agar Collector	Hand Pump ½ Inch Tubing (50 ft.)	$14.43 $25		New New
Control System	On/Off Switches Wiring Supplies	$22.15 $122.79		New New

The below costs ($391.45) are specific to non-reoccuring research and development and won't be needed to manufacture another ROV.

Competition Costs	Poster Board Supplies MATE Registration	$75 $150	New Misc.
Failed Experiments (Not Using)	Baster Ball Bearings 12V DC Diaphragm Pump USB Wall Mount	$4 $14.01 $19.95 $6.15	New New New New
Mission Props	PVC Parts J-Bolts, rope Agar	$200.34 $22 $41	New New New
Travel Expenses	Gas to and from the competition 16.2 mi X .52/ mi. (irs.gov)	$9.00	Misc.
Total Cost (Prototype + R&D)		$1,111.00	
Cost to Manufacture ROV		$1,013.57	(Including market value for re-used parts, but excluding costs R&D)
Sponsors	Watsonville Fire Dept.	+ $1,000	

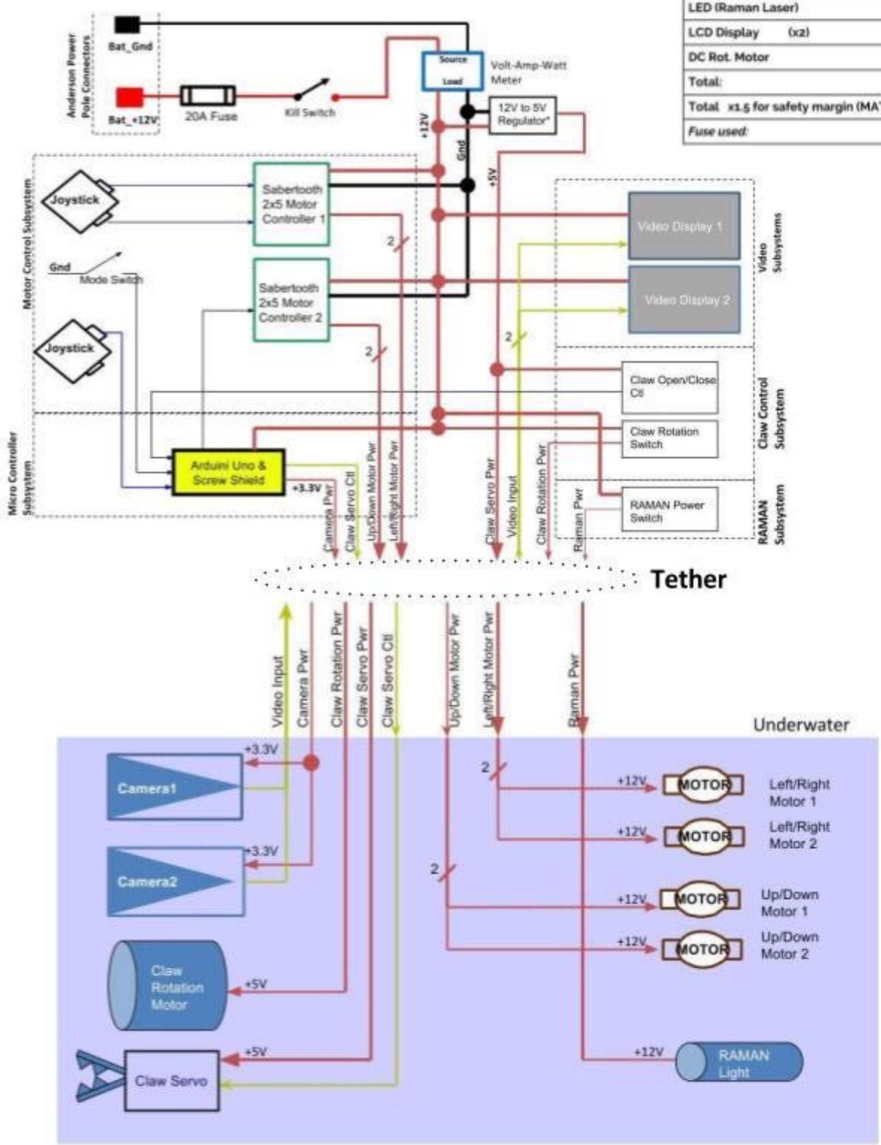


SYSTEMS INTEGRATION DIAGRAMS

ARGO IV TOPSIDE

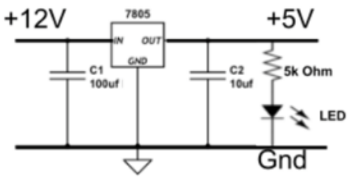
Fuse Calculation

750 GPH Motor	3.0A
500 GPH Motor (x3)	7.5A
Backup Camera (x2)	0.6A
Servo Motor	2.1A
LED (Raman Laser)	0.12A
LCD Display (x2)	1.6A
DC Rot. Motor	0.6A
Total:	15.5A
Total x1.5 for safety margin (MATE):	23.3A
Fuse used:	*20A*



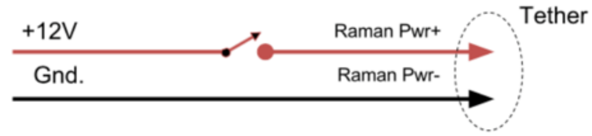
Note:
All tether power connections (marked **Pwr**) contain the supply voltage value shown and ground.

12V to 5V Regulator Circuit

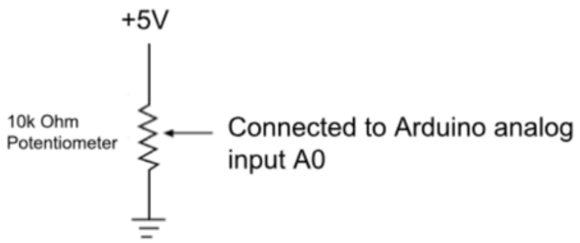


Source: Application circuit from LM7805 chip datasheet

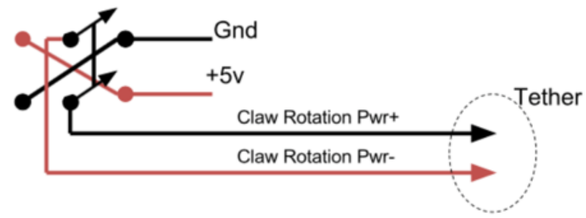
Raman Power Switch Circuit



Claw Open/Close Control Circuit

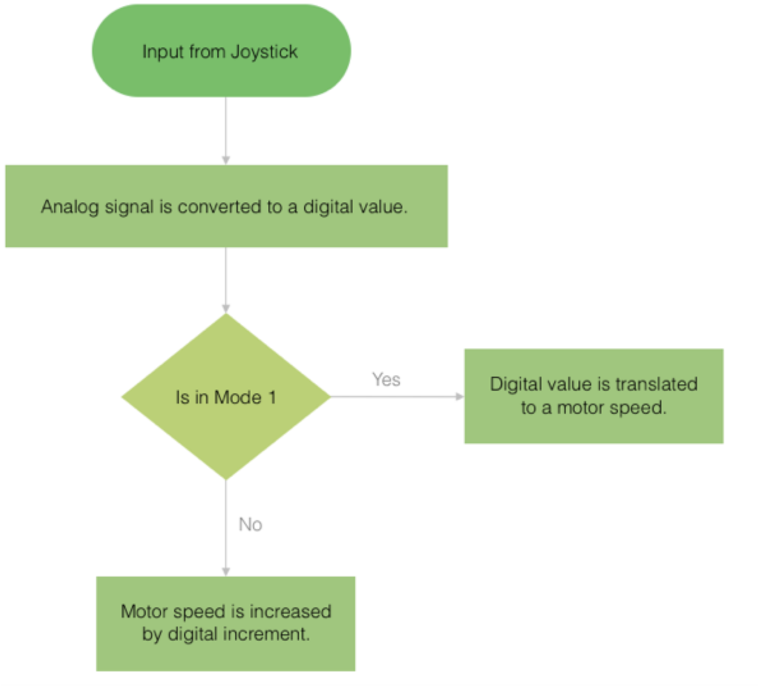


Claw Rotation Switch Circuit

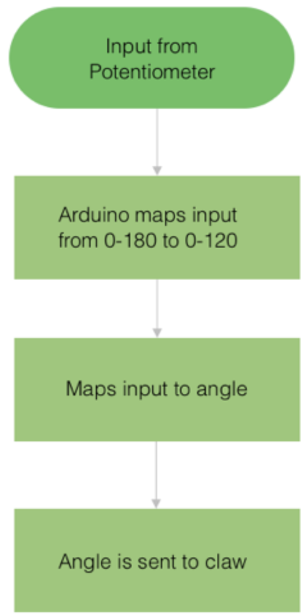


SOFTWARE FLOWCHARTS

MOTOR SYSTEM

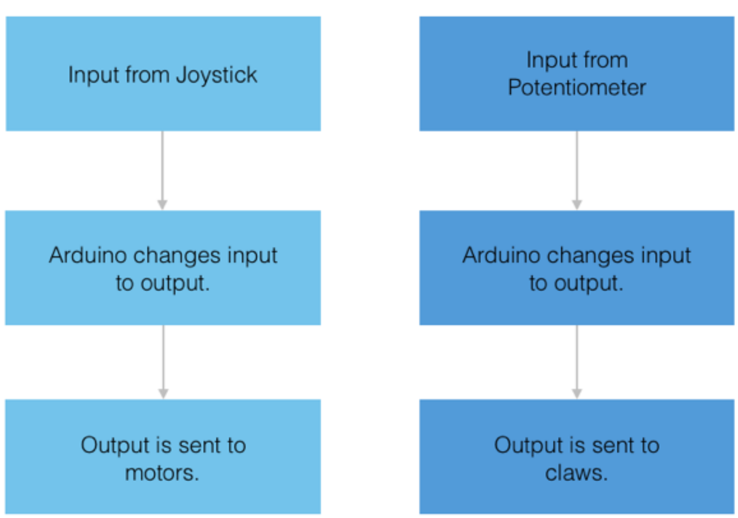


CLAW SYSTEM



SOFTWARE BLOCK DIAGRAMS

MOTORS (LEFT), CLAW (RIGHT)



DESIGN RATIONALE

Argo IV was designed for maximum speed and control, minimal size and weight, and to be as safe as possible for users and other organisms it may encounter. Our teams of engineers worked for months to create the best ROV we could.

PROJECT MANAGEMENT

At Watsonville Fire Department 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 managed consistent schedules to maximize productivity and workflow. In addition, we developed specific procedures to address day to day operational issues and trajectories.

Our team discussing the agenda for our meeting. (Photo Credit Seamount)

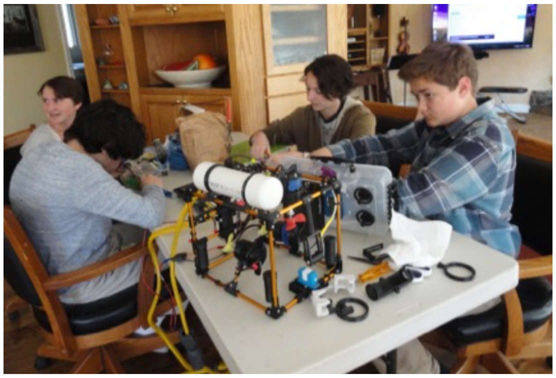
Almost all of our project management revolves around documenting tasks -- the ones we have finished, are working on, and have yet to start. At the beginning of each of our meetings, we discuss the objectives for that day and a long term schedule. Typically, this agenda is divided into electrical, mechanical, 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 and to determine if we need to increase productivity or add meetings

We wanted to take good documentation one step further. 3D technology has played a major role in building the Argo IV, so we decided to use it to document our progress as well. Using a program called TinkerCad, our VP of Mechanical Engineering created a scale replica of the Argo IV. After any changes were made to the physical design of the ROV, we would update the digital model to reflect them. This procedure guaranteed that any design was double checked, thus ensuring efficient and thoughtful 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 building process, we designated team members to head our major departments. For example, we appointed a VP of Software Engineering, VP of Research and Development, etc. Everyone was involved in each area of the engineering process, but each member specialized in a specific role. This system ensured the following:

1. Maximized organization and communication.
2. Expanded department management and accountability.
3. Increased efficiency in the building process.

This system also contributed to our protocol for productivity and issue management. During the meeting, teams would check in with their department head about their trajectory in their task so that it was completed properly and in the best way possible. This also made sure that everyone was on the same page on the work being done.

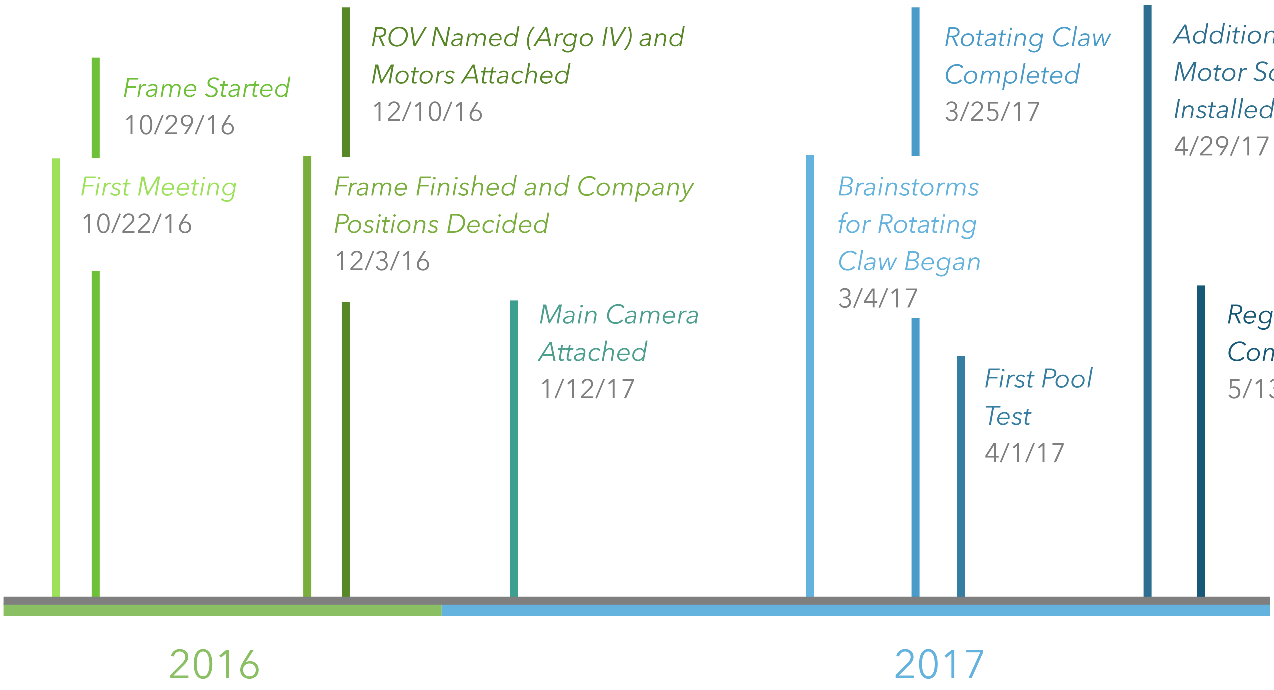


A team wiring and soldering. Left to Right, Top: Jamie Walton, Katherine Walton. Bottom: Jacob Sandler, Chris Whaley. (Photo Credit Seamount)

Exploring and learning more about robotics is also 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.

When developing the Argo IV, we began with discussing the best options for specific parts of our ROV. We would discuss the advantages, and disadvantages of each attachment before we decided on a further course of action. After we decided on one or more of the best designs we would create a prototype. These prototypes would usually be 3D printed and would be put to use a soon as they possibly could. We would try to modify each prototype as often as possible to maximize the efficiency of the attachment. We would make sure that the attachment worked as well as possible before we implemented it into the Argo IV. This was accomplished through multiple tests outside of the water. We used our hands to simulate the ROV and guided the new attachment through multiple tasks. This maximized efficiency because if we couldn't use the attachment during these tests, then it would never work on the actual ROV. Because of this, we never wasted time testing undeveloped components on the ROV itself. When we would implement a new attachment we would immediately go into the pool for testing. Most of the time the attachments would work because of the previous tests we conducted. When an feature did work, then we would move onto the next one, and start the process over again.

PROJECT MILESTONES



The Argo IV's First Pool Test.
(Photo Credit Seamount)

The Monterey Bay Regional ROV competition.
(Photo Credit Lee Martin)

NAVIGATION

Our team of designers built Argo IV to be efficient and to complete its tasks effortlessly. Argo IV can navigate the water with speed and effectiveness, so our customers can complete important jobs as quickly as possible.

Motors. Onto the frame, we incorporated three 500 GPH 12V bilge pump motors and one is a 750 GPH 12V bilge pump motor. These four high-quality motors allow for 360° navigational technology. The stronger motor was chosen for the front up/down motor to handle the additional task of retrieving the agar. The back up/down motor helps drive the Argo IV to and from the surface. The two other motors face backward and can be powered in both directions for forward and backward movement, All motors are directly within the frame for a compact design and protection from potential safety hazards.

Lateral motor with a 3D printed motor shroud.
(Photo Credit Walton)

All movement motors have been recycled from previous designs to be financially and environmentally friendly. We purchased motors commercially to ensure a high-quality product for our customers.

Vision. Our latest model has two waterproof cameras that are designed for automobile drivers to use while backing up. Each requires 3.3V power source and has a 120° viewing angle; one of them faces forward with the claw in partial view, and the other has a full view of the claw and its movements. Each camera is wired to its own display screen, which the driver can position for optimal view.

Our camera.
(Photo Credit Walton)

Our design also features multiple all-new LEDs embedded in an endoscope obtained from Amazon. Since it is meant to view the inside of a body, it is waterproof. A clip is attached to the front left pole on the frame for when the light is not in use, and our claw has two clips to hold the light in place for sample collection.

Weight Distribution. Weight and buoyancy in the water is one of the most crucial elements of navigation. At Watsonville Fire Department Seal Team 1272, we recognize the importance of weight distribution and included it as a fundamental component when creating our latest model. Every feature on Argo IV, from the frame to the attachments, has been perfected to suit a weight density equal to water and to glide through the water lightly and effortlessly.

An ROV frame that is smaller is easier to maneuver and experiences less drag in the water. PVC materials that are used conventionally for ROV products are large, bulky, and thick, making for a frame that is large, yet with little interior space for motors and attachments. Our ROV is 25 by 30 by 25.5 cm. and because of the compact design, it only weighs 3.1 kg. The Argo IV doesn't contain any PVC on its frame or on its attachments, unlike any previous models; we replaced the material with newly obtained aluminum, a lighter alternative with an orange sheen that is easy to spot with its bright coloring when navigating deeper waters.
Since aluminum is thinner in circumference than PVC, we designed custom connectors, clips, and built-on attachments using 3D technology. All of the frame's connecting elbows and joints have been designed and printed by our team of engineers to fit our new model perfectly, and any attachment that clips to the frame has been modified or built from scratch.

The thinner frame of our newest design allows for significantly more interior space for attachments. Our ballast tanks rest on the top of Argo IV to save room for motors and other attachments through custom-made clips, which have been calculated to the decimal by our engineers to ensure it is the exact size needed to keep Argo IV neutrally buoyant.

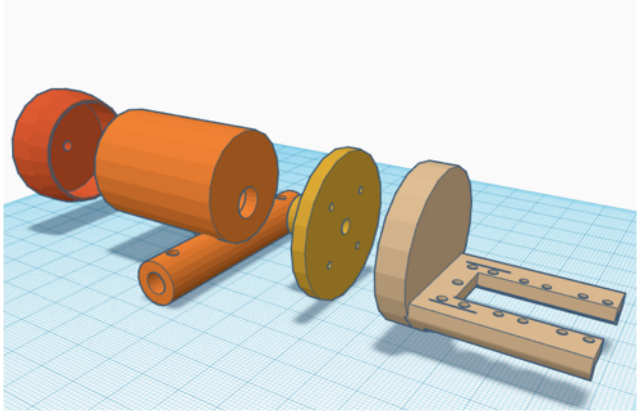
3D Printed capsule for shotgun pellets. (Photo Credit Walton)

Argo IV also has custom-made containers that can attach to the frame and can be filled with shot to accommodate any added weight. These containers were designed on 3D printed technology and modified by our designers to fit the frame. They have never been used on any previous models.

TASK COMPLETION

Claw. Our latest model includes a claw device created entirely by our team of engineers through 3D printing technology. The claw contains a clip to hold the LED light during use, and its design has never been used in any previous missions. When closed, the claw's opening is a hexagonal shape; the top and bottom ends of the claw touch in a closed position, but a gap is left in the middle to allow sample collection, and we designed the hexagon to suit PVC pipes and their size and shape for specific missions. 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. A servo attached to the claw allows the user to control it using a knob on the control box. Users can control exactly when and where the claw starts and stops expanding or contracting so that larger samples can be collected with the claw partially closed.

The Argo IV's Rotating Claw (Photo Credit Walton)



A mechanical drawing of the DC motor mount. (Created by Da Costa using TinkerCad)

Argo IV 's claw is revolutionary in its movement: unlike our previous model, the claw on our newest design has the ability to rotate 360 x 3 in both directions. A DC motor is behind the claw to allow for rotation; Argo IV's claw can rotate full-circle numerous times, both clockwise and counterclockwise, so that Argo IV can efficiently turn valves, collect samples, and complete difficult tasks effortlessly.

Sample Collection. Our team of engineers designed a simple and quick method to gather samples of materials underwater. Using an off-the-shelf hand pump with a long tube attached brings the agar samples to the surface. We 3D-printed a large hypodermic-like plunger that our ROV inserts into the agar. It remains in the agar while the Argo IV completes other tasks. The surface team then pumps the agar to the surface and a sieve is used to separate the agar from the water.[1]
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Agar collecting hypodermic needle. (Photo Credit Walton)

[1] For more details on our agar collection system, see page 16.

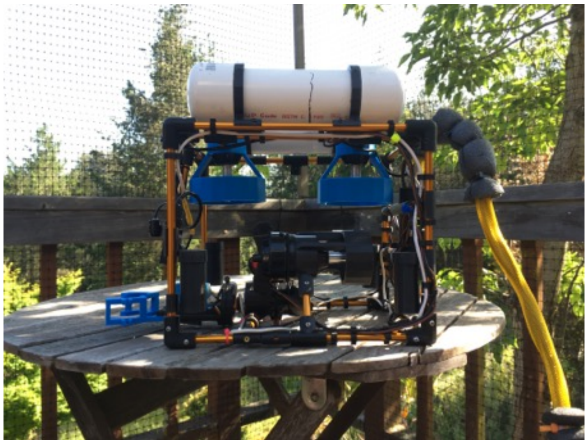
CONTROLS

Argo IV's control box was modified from Argo III's and reprogrammed by our software team, to suit the Ranger class. A TriggerFish programming kit provided some of the fundamental components for this year's model, but our programmers modified the Argo IV's Arduino to include actions that will be required for 2017's mission. The kill-switch on the control box is protected with a hinged plastic covering to prevent accidents, and is located on the side of the box. Both control methods related to the claw are also located on the side. The opening and closing controls for the claw are a rotating knob to allow for a spectrum of placements, and the rotation is controlled by a white switch, allowing the user to press the switch until the claw is rotated enough to complete the task.

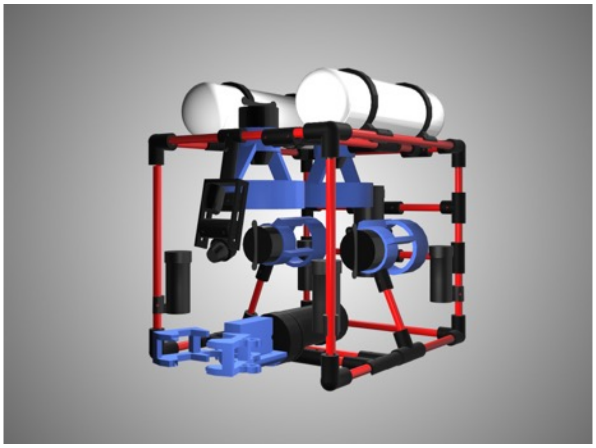
The top of the control box houses the screen that displays the view of the water ahead of Argo IV, as well as both joysticks that control motor action and direction. The display screen for the camera facing down over the claw is separate from the control box, which can be placed anywhere in a work space to allow a driver to get a 120° view of Argo IV's surroundings beneath it.

CONCLUSION

Over the past months, the members of Watsonville Fire Department Seal Team 1272 have worked to design and build Argo IV. We have equipped our newest model with many custom 3D-printed parts to ensure high quality, safety, and efficiency.



Side view of the Argo IV.
(Photo Credit Walton)

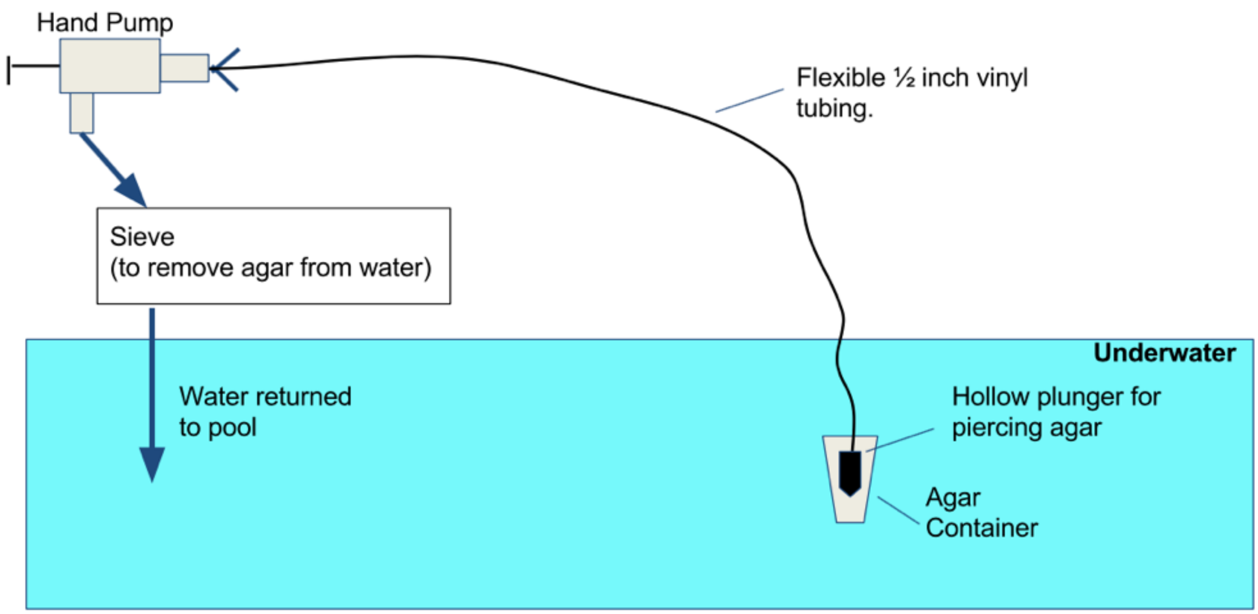


An mechanical drawing of the Argo IV made with TinkerCad, E3D, and Adobe After Effects.
(Created By Barrett, Walton, and Walton)

AGAR COLLECTION SYSTEM

Our ROV does not use pneumatic or hydraulic systems. We do, however, use a hand pump operated on the surface to pump agar up from the pool bottom for one of the mission tasks. The diagram below is to conform to the Ranger requirement for hand pump operated fluid systems.

- Only uses a hand operated pump (FLUID-001N)
- Only pumps water (FLUID-002N)
- There are no points of pressure accumulation (FLUID-003N)



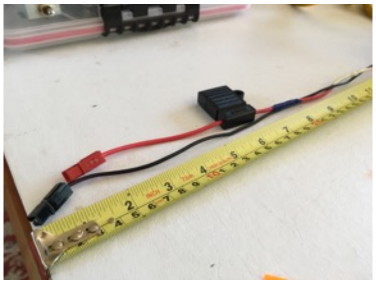
SAFETY

At the Watsonville Firefighters Seal Team 1272 Robotics, safety is taken very seriously. 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 that we follow are, always grabbing the ROV from the top with both hands, putting the ROV down without smashing the claw, gently putting the ROV in the water, always keeping the battery and control box away from any water and having everyone aware of where the tether is. We also call out so everyone is aware before power is applied to the ROV by closing the master switch. We have also installed several safety instruments on our ROV. The safety instruments include, 3D printed guards around all 4 of the propellers, tightly tied zip-ties for the wires, and smooth edges. The propeller guards reduce the risk of having wires caught in them and also prevents cuts. Also, we used waterproof heat shrink on our underwater splices where possible. This heat shrink combines internal glue that flows when when heated sealing each end of the splice as the material shrinks. The tether has strain relief on both ends, on the ROV side the strain relief was accomplished with a 3D printed clip that attaches the tether to the frame.

Fuse Calculations	
750 GPH Motor	3.0A
500 GPH Motor (x3)	7.5A
Backup Camera (x2)	0.6A
Servo Motor	2.1A
LED (Raman Laser)	0.12A
LCD Display (x2)	1.6A
DC Rot. Motor	0.6A
Total:	15.5A
Total x1.5 for safety margin (MATE):	23.3A
Fuse Used:	20A

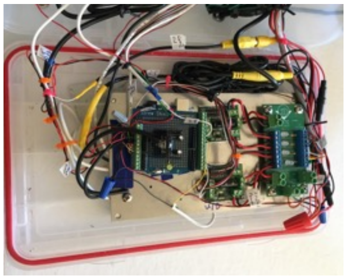
SAFETY CHECKLIST

- ✓ Our Anderson Powerpole connectors are the only point of connection for power.
- ✓ AC power is NOT used in the control box.
- ✓ Our fuse about 14 cm away from the main point of connection (see below).
- ✓ The inside of our control box doesn't have any exposed wires and is laid out neatly.
- ✓ We do not use any hydraulic or pneumatic systems to control the ROV.
- ✓ All of our four propellers are shrouded (see below).
- ✓ The ROV edges are rounded 3d printed parts (see below).
- ✓ Strain relief is on both the ROV and control box for all cables (see below).

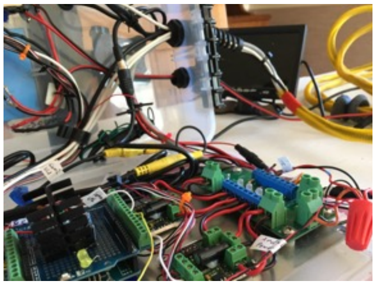


Bottom inside of our control box.

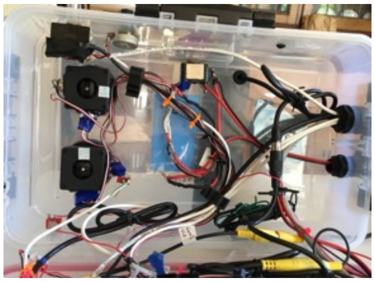
Strain relief on tether on ROV side.



Anderson Powerpole connectors with fuse 14 cm away.

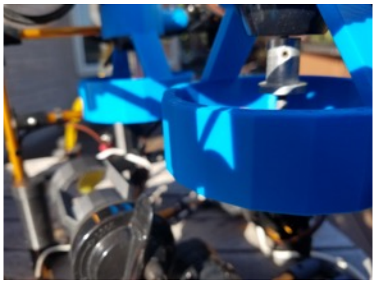


Inside of control box showing tether attachment with strain relief.



The top underside of our control box.

Shrouded forward and back motors.



Shrouded up and down motors.

Rounded Corners.

CRITICAL ANALYSIS

In addressing the challenges and pitfalls along the way, the Argo IV has gone through many changes. Through each challenge, we were driven to learn and create the ROV that stands before you.

The rotating claw was a crucial aspect of our design, mostly for turning the valve in the entertainment mission, but it also introduced a new set of challenges. The claw runs on a standard DC motor, which runs at 2 rpm. This small rate of rotation allows us to stop the claw at the right time, but also allows for it to turn quickly enough to complete the missions efficiently. While the 2 rpm looked good on paper, in practice, it was a different story. The motor moved too quickly, so we couldn't stop the claw at the right time. We couldn't fix it with programming, so we decided to just put less power to the motor by running the claw at a lower voltage (5V instead of 12V). At this slow speed, the pilot is able to stop the claw at the exact position they want. We learned a valuable lesson about using the simplest and easiest solution to solve this problem. There were many things we could've done to fix this problem, but by taking the easiest solution possible, we were able to move on quickly, and the solution has been very effective.

One of our hardest challenges this year, though, was extracting the agar from the container at the bottom of the pool. We tried a number of attempts to find a simple way to collect the agar from turkey basters to specially designed 3D printed cutting tools. All these attempts failed, foiled either by the viscosity of the agar or because the agar fell out of our cutter on retrieval. The agar problem really taught us to think outside the box, and we are proud of our final solution.

Next, we found that it was difficult for the ROV to breach the surface of the agar with an instrument large enough to hold the agar as well – but then we realized that we didn't have to. We noticed that if we could get a tube long enough, we can just pump the agar from the bottom to the surface. After a careful examination of the rules, we saw that we could not only do this legally, but even move the ROV away from the agar storage and do other tasks as we pumped the agar to the surface. We bought a small hand pump and a large tube, but ended up running into the same roadblock we had before: the ROV couldn't puncture the surface of the agar with the tube itself. But we didn't give up. That is one of the greatest qualities of our team we will try everything we can to make a possible solution into a valid one. We first decided to cut the tube at an angle to form a spike. We thought that this would allow for us to breach the surface more easily. But it was still difficult. Because the tube was made out of rubber, it wasn't sturdy enough to break the surface of the agar. So we went back to our 3D printer and came up with another custom-made solution. We made a thin cylinder that could fit snugly inside of the rubber tube, then recreated the long thin spike we had cut in the rubber and replaced it with a plastic one. This was sturdier, which allowed for us to breach the surface much more easily. The sample retrieval mission was a big challenge, but it taught us to look closely at the rules. By carefully evaluating what was legal, we found that our ROV could do other tasks while pumping the agar, which allowed us to reach maximum efficiency for the task.

Keegan working on the wiring. (Photo Credit Barrett)

Even though we were able to overcome these challenges, there were challenges that we had to face beyond the scope of the ROV. These came mostly in the form of time. Engineering isn't the only talent that the members our team possess, and many are deeply invested in other activities. These include participation in debates in other counties, the school play, and sports, which ate up time each and every week. Instead of cancelling meetings and changing around the schedule, we instituted a policy where the meetings were the same time every week, and anyone who could make it would show up, which in most cases was all but one or two people. There was never a meeting that was cancelled, and at all of them we worked efficiently. Even though the challenge of time was a stumbling block, we never let it trip up our team. Through this experience we were able to learn how to function effectively even when not all of our team members were present. We learned to cover for each other when one of us couldn't come to a meeting. This willingness to help each other gave each of us an understanding of all aspects of the ROV and the ability to give a new input into all of the aspects of the ROV.

Throughout all of the challenges we faced this year, we never let one of them bog us down. We used our ingenuity and perseverance to solve any problem that came our way. We never gave up and always came up with a new idea after one didn't work. Our dependability and drive truly helped us this year, and got us through all of the challenges that we faced. We collaborated as a team to overcome our challenges, and bring you the ROV that stands before you.

DISCUSSION OF FUTURE IMPROVEMENTS

Argo IV is an exceptional ROV; it is efficient, maneuverable, and capable of accomplishing the variety of tasks it may encounter, all the while being lightweight and compact. However, there is always something that can be improved. Argo V will have a greater range of vision: we would like to give the future model a camera on the rear of the robot to enable it to travel in both directions with a view of objects ahead. Our next model will also be able to move laterally, so that moving to a specific place or object is quick and controlled. Next ROV season, we will modify some of the features on Argo IV to be better adapted to a new set of tasks that will be required of Argo V. Argo V will have significant improvements to measure up to our growing standards of efficiency and safety.

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