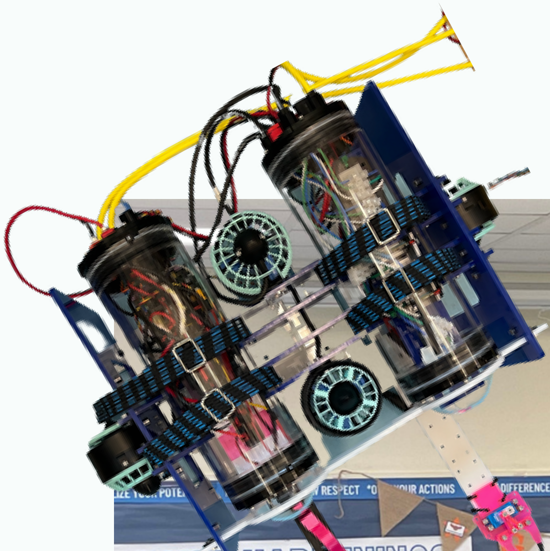
2023 MATE ROV Competition
Technical Documentation

H2Operations

The Francis W. Parker School of Chicago, IL



Team member	Role	Grade
Diana Llamas	CEO	12
Gabby Druger	CFO	11
Brian Campoverde	Lead of Mechanical Engineering	11
Savanna Maness	Lead of Software Engineering	12
Krystal Xu	Lead of Electrical Engineering	12
Matthew Borden	Co-lead of Mechanical Engineering	11
Frances Gomez-Barrientos	Co-lead of Software Engineering	10
Beckett Nikitas	Co-lead of Electrical Engineering	10
Ava Farhat	Marketing	9
Solena Ornelas Pagnucci	Programmer	9
Felix Farkas	Engineer	9
Simone Shonuga	Props	10
Emma Webster	Marketing	10
Delilah Davis	Engineer	10
Paige Randell	Programmer	9
Charlotte Paul	Engineer	9
Caitlyn Howe	Props	10
Suhani Aggarwal	Programmer	11
Naia Trukenbrod	Engineer	9
Daniel Chang	Programmer	9

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Project Management

ROV Tasks			
Check in		*12/12 completed*	
✓	**Date Task was entered**	**Task**	
			Build Team Month something to celebrate
	10/17	First Meeting	Build Team Month Task
	11/16	Build Task 1	(completed)
	11/23	Build Task 2	
	10/14	Long term Task (2 month task) on month 1	Build Team Long Term Task (completed)
			Programming Team Month something to celebrate
	11/16	Programming Task 1	Programming Team Month Task (completed)
	11/23	Programming Task 2	
	12/14	Programming Task 2	
	12/28	Long term Task (2 month task) on month 1	Programming Team Long Term Task (completed)

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Design Rationale

Engineering Design Rationale

The ultimate goal that our company is working to achieve is to use our functional ROV system to help remove plastic waste and restore both freshwater and marine ecosystems. Our ROV system vehicle consisted of a frame with four thrusters, two enclosures, two cameras, a gripper, and a hook. We used OBS studio to see the video coming through the cameras as well as PS3 controllers to control the thrusters and the gripper/claw. This year we started to brainstorm different designs for our new robot, Dory. In previous years we used one enclosure to hold all the wiring controlling thrusters, grippers, etc. This year, after looking through past designs, we decided to use two dry-boxes for various purposes. It designs for the most beneficial use, and helps us to navigate wiring problems faster and more effectively. One enclosure is used for electrical and communication purposes, while the other is used for camera and thruster control. Our frame made out of acrylic, was laser cut in house and used 3D printed aspects to improve stability and use as our hook. In past years we used two claws, and this year we opted for one as well as a hook. We believe this optimizes the opportunity to pick up waste and other debris off of the sea floor using the hook, while we can use the claw/gripper to collect floating waste and litter from in front of the robot. We only did a few pool tests, and we adjusted each component we needed to after these tests, tweaking the design and sanding down the acrylic and 3D print as needed. All of these meticulous details added to our ROV system helped ensure that it would be able to complete tasks at peak performance, and would be able to serve as a model of ways that we can mitigate the amount of plastic in our water and clean our coral and waterways for future generations.

Innovation

This year Subaquatic Solutions has strived to make our robot; Dory, as innovative as possible. We have worked to lessen the cost of building our robot, while ensuring that it is as functional and as effective as it can be. A major way we have done this is by recycling parts from old robots like the screws, nuts, and bolts. We also reused the thrusters, grippers, and buoyancy weights from our previous robot. This was beneficial because the thrusters were extremely expensive and now as we continue to reuse them we can remain cost-efficient.The majority of our robot's frame is built from laser cut acrylic. Most of our frames this year were made from the nis material which has been extremely eco friendly, as well as extremely cost efficient. By using the cut acrylic our costs have gone down and we have been able to make prototypes easily using a laser cut machine, although only the final product was cut acrylic. Overall, throughout this build we strive to remain cost efficient as well as eco friendly, and our design reflects that.

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Problem Solving

Throughout this school year, we have faced many challenges, the most significant to us was waterproofing. To preface this, Francis Parker does not have a pool, so throughout the year it has been difficult to do pool tests and generally practice in the pool. We have only been to the pool three times, and that included water testing, learning and practicing driving our ROV, and practicing tasks. Since we only had three instances with a pool at our access, we did not have a lot of practice. On our first pool test, we noticed that one of our dry enclosures was allowing water to leak in. Due to it only being a slight amount of water, our team's solution was to put absorbent pads within the cylinder. We also put some inside the second dry enclosure, for thrusters and claws, for safe measure. Our reasoning was that the pads would soak up any water leaking in as we did not have enough time to explore the issue with the water sealant. The pads worked well and continued to work into the regional competition. Immediately after our first pool demonstration during the regional competition, we noticed an excess amount of water within the robot. We became increasingly concerned and decided to change the pads from both dry enclosures. Fortunately, we did not have any large issue with water damaging the electrical and we completed the second pool demonstration. As we prepare for world competition, the team plans on exploring other more permanent water proofing solutions.

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Systems Approach

Every component of our ROV system is interconnected and has a purpose that contributes to the functionality of the ROV as a whole. Currently in the system we have four thrusters : upward, downward, right, and left. We have placed the upward and downward thrusters in the middle of our system in order to ensure balance and buoyancy is maintained within our robot. Our robot won't tilt because of this and more problems are avoided. Additionally we have placed ballast weights around the robot in order to maintain this neutral buoyancy. In the system we have one horizontal gripper which collaborates with the ROV in order to pick up and drop items. The gripper uses a waterproof servo and custom made acrylic components that we used on last year's ROV. This year we also added a hook with a magnet in case there were props that we could not pick up with the gripper. This hook helps to pick up smaller magnet components under water as the ROV is able to get close to that object and attract it very easily. These all work together in order to help us do as many tasks as possible. Although looking under water is another problem we have experienced. We currently have two cameras in the dry enclosure, one front facing camera, and one downward facing. The front facing camera gives us a great view of the hook and gripper. When it comes to the downward facing camera it helps us look into our surroundings and see the ocean floor. Another significant feature of our design was the idea of two dry enclosures. Two dry enclosures means that if one enclosure gets water into it we still have the other dry enclosure that is still working. Two enclosures also helps us with buoyancy! As you can see all parts of our system design ensure that the ROV is staying buoyant and completing all the tasks it needs to. We have all these parts working together to ensure that the ROV is performing well!

Vehicle Systems

Our team has worked to design our robot Dory in order to create a robot with the most effective and adaptable design possible. We firstly looked at past ROV's in order to gain inspiration on what works and what doesn't and sought to incorporate what works into our design. Our rectangular shaped frame is made up of three main components, the sides, the base, and the supports. The U-shaped supports are designed to hold and keep in place the two enclosures and areas to screw in the vertical thrusters. The fifth support is made of white acrylic and shaped similar to a pair of glasses, which are designed to keep the enclosures in line with each other. The sides are blue acrylic with two openings in them in order to ensure waterflow is able to reach the thrusters on the inside. One horizontal thruster is attached in the middle of the top of each side for stable movement. The base of the frame is white acrylic with four openings in order to have continuous waterflow to all thrusters, there is a section in the middle of the base with holes cut into it as a place for weights in order to keep the robot neutrally buoyant. Attached to the base are two arms, one holds the hook which is 3D printed and meant to dislodge items as well as a magnet for picking up trash. The other arm has a gripper to attach to and pull things. Another key part is that this design features two enclosures which allows for a more neatly organized wiring system as well as in case of water leakage, not all of the electrical-ware is lost. This design allows for practical use in this competition as well as being capable of adapting to future challenges.

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Control Electrical Systems

Our electrical team spent most of the year working on the signal transportation between the pool box and the dry enclosures. Like said earlier, we had to troubleshoot numerous times to get any signal inside out thrusters and grippers, let alone the right ones. Though we get most of our electrical material from PowerWerx, Dory's electrical process included adding ends to wires, soldering, heat-gunning, and more. Our ROV system consists of a mate ROV issued power box, a West Mountain Radio RIGrunner 4006U power hub, one rocker switch, two servo connecter to cat6 breakouts, three Daygreen 12V to 5V converters, five Chunzehui F-1011 power hubs, multicolored jumper cables, and one arduino MEGA. These, along with two USB power hubs, two CAT6 to servo breakouts, four bluerobotics basic escs, and two USB cameras, make up the foundational electrical system of Dory. The power system powers both the camera system and sends power down the tether. This power box is connected to the two boxes inside of the robot. In the pool box, there is a supply of 12V that connects to a 20A power distribution fuse. This connects to the two PS3 controllers that control the robot (one joystick powers the up and down movement of the robot, while the other controls the forward, backward, left and right movements). The other joystick controls the movements of the gripper. Cables run from these two joysticks that connect to the four thrusters. Meanwhile, the computer has a video cable that runs to the camera, which helps us see out of the ROV. Cables run from the servo through a CAT-6 booster which powers the two grippers. Though we ended up with a system that we are very proud of, there were problems with the jumper cables detaching, which we solved by attaching them with electrical tape, thruster malfunctions that were solved by restarting the code, and countless more issues.

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Software Controlled System

This year we were trying to add analog programs into our system. This means that based on the degree you pushed the joystick, the thruster would run at that corresponding speed. If you move the joystick to the highest position the speed will be the greatest then. We hope to have this next year, but this year most of our code models a power switch. We have our code stored onto two different software's : Arduino and Mu Editor. Mu Editor stores our python code which communicates through the serial monitor to our Arduino IDE code stored into the Arduino. Two parts of the system that were coded for were the thrusters and the grippers.In order to combat the positive buoyancy of the robot we always have the downwards thrusters running even while the ROV is moving forward. Currently when it comes to the grippers we have the servo attached to the gripper operating like an on and off switch with the commands being 0 degrees and 180 degrees. We have the gripper and the thrusters on two separate PS3 controllers so communication needs to happen between both the driver and the backup driver who controls the gripper.

Propulsion

Coming into the competition, H2O Operations decided to overhaul the entirety of how our ROV works; this meant creating a whole new ROV. Newly named and made, Dory is built to maximize the use of our dry enclosures and how much space it takes up. Dory is square-shaped and 9.5 inches tall, with two dry enclosures fitted next to each other. One for the camera system, and one for the thruster and gripper system. Dory uses four thrusters; two for up and down movement placed near the center of the dry enclosures in the ROV, and two for left and right movement placed on their respective sides of the ROV. A trade off that was made this year was to have one servo-operated gripper instead of two. The basis for this rationale was the idea of relying on our thrusters for precision rather than having to spend more runtime using the grippers to close around objects which is a difficult maneuver due to the view of the gripper being difficult to see at times on the camera system. Most tasks in the competition need the ROV to be able to move precisely and fit through slim areas. To achieve that requirement, the layout of Dory's thrusters are meant to minimize its size, while maximizing the area of movement the ROV is able to achieve.

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Camera Systems

In Dory, there are two cameras in the dry enclosure on the left side of the ROV. Originally, we had more than two cameras, but we felt that because we had many issues with our cameras last year, it was finally time to simplify our camera operating system. Our front facing camera gives a clear view of not only the pool, but our gripper on Dory. The bottom facing camera aids the drivers in seeing how close they are to the ground, and what tasks might be near. Both cameras are inside of the dry enclosure so we can have better visibility at all times without having to worry about water damaging the cameras. Outside of the left-side dry box, an additional camera is positioned to see the right side of the ROV. This camera is able to aid drivers in seeing the secondary hook on the ROV and to be able see their distance from tasks and any obstacles. All three of the cameras (two inside and one outside of the enclosure) are viewed on the computer via OBS Studio with four different settings. Three of the four settings are for single viewing of each camera, and the fourth is for viewing all of the cameras on one screen.

Buoyancy and Ballast

When it came to buoyancy during the build of our ROV the biggest struggle we faced was regarding the Mate Float Challenge. Throughout the time we spent on the challenge we developed two different prototypes and two different final designs. We spent the year building them separately using one as a failsafe if the first one didn't work. As we developed both floats the main problem we faced was dealing with buoyancy. To address the buoyancy requirements, we opted for a method of adjusting buoyancy by pumping water into the floats. Initially, both prototypes were positively buoyant when placed in the water. However, as they sank further, they transitioned into a negatively buoyant state. It's important to note that there exists a third type of buoyancy, where the ROV remains suspended at a fixed depth, neither sinking or floating. Unfortunately, neither of our floats achieved neutral buoyancy during testing. Testing our actual ROV 's buoyancy was very difficult especially with our limited pool tests. This year we distributed our buoyancy by using two separate dry enclosures evenly spaced on the frame. Once we figured out how to place these dry enclosures, everything fell into place. Our ROV starts with a positive buoyancy, because of this in order to make it neutrally buoyant we placed weights onto the frame. This causes it to be negatively buoyant once placed in the water. As we pilot the ROV throughout pool challenges it remains negatively buoyant. It is never positively buoyant. Resolving this issue requires further exploration of alternative buoyancy control methods such as adjusting the dry boxes placements or incorporating additional flotation devices.

Payload and Tools

The ultimate goal that our company is working to achieve is to use our functional ROV system to help remove plastic waste and restore both freshwater and marine ecosystems. This year our ROV system vehicle consists of a wide, square frame with four thrusters, two cameras on the interior, one facing forward and one facing downwards, two dry enclosures, one gripper, one hook with a magnet, and a blue acrylic frame to blend in with its surroundings, as well as a waterproof servo to control the gripper of the ROV system.

We designed the frame so that the ROV could move through the water better and placed the thrusters in the places we did in order to help the robot move up, down, forward and backwards with ease. Each position of our equipment is symmetrical, aligned, and set in accurate positions after many adjustments to ensure balance. We verified that the camera was in a stable and clear viewing area, the thrusters are secured at the front, middle and sides of the ROV, and that the weights are tightly secured in a well balanced place. Our team decided to add a hook to our ROV system to remove the biofuel and a magnet to pick up trash. Lastly, we decided to use two enclosures to separate the camera and thrusters from the electrical and communications. We did that so there would be less tangled electrical work when removing the cameras and thruster wires from the enclosures and to better understand any electrical problems that arose within the robot.

All of these meticulous details added to our ROV system helped ensure that it would be able to complete tasks at peak performance, and would be able to serve as a model of ways that we can mitigate the amount of plastic in our water and clean our coral and waterways for future generations.

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Build vs Buy, New vs. Reused

Our main purchases while building our robot Dory were the spacers that we put in between the supports and the straps to secure the enclosures. With a limited amount of time, these purchases provided our team more time to build upon what we originally had. We built many items such as the 3D printed electrical trays that were put into the dry enclosures. The entire frame, and the gripper were laser cut from acrylic. We reused many tools as well such as our thrusters, our hook, gripper, and one of our dry enclosures. In addition, many electronic pieces such as power hubs and the Arduino Mega were reused. We made a significant effort to laser cut and 3D-print as many components of our robot as possible. This is not only cost effective because the material is less expensive, but also more environmentally friendly because we only print the material that we need with minimal environmental impact.

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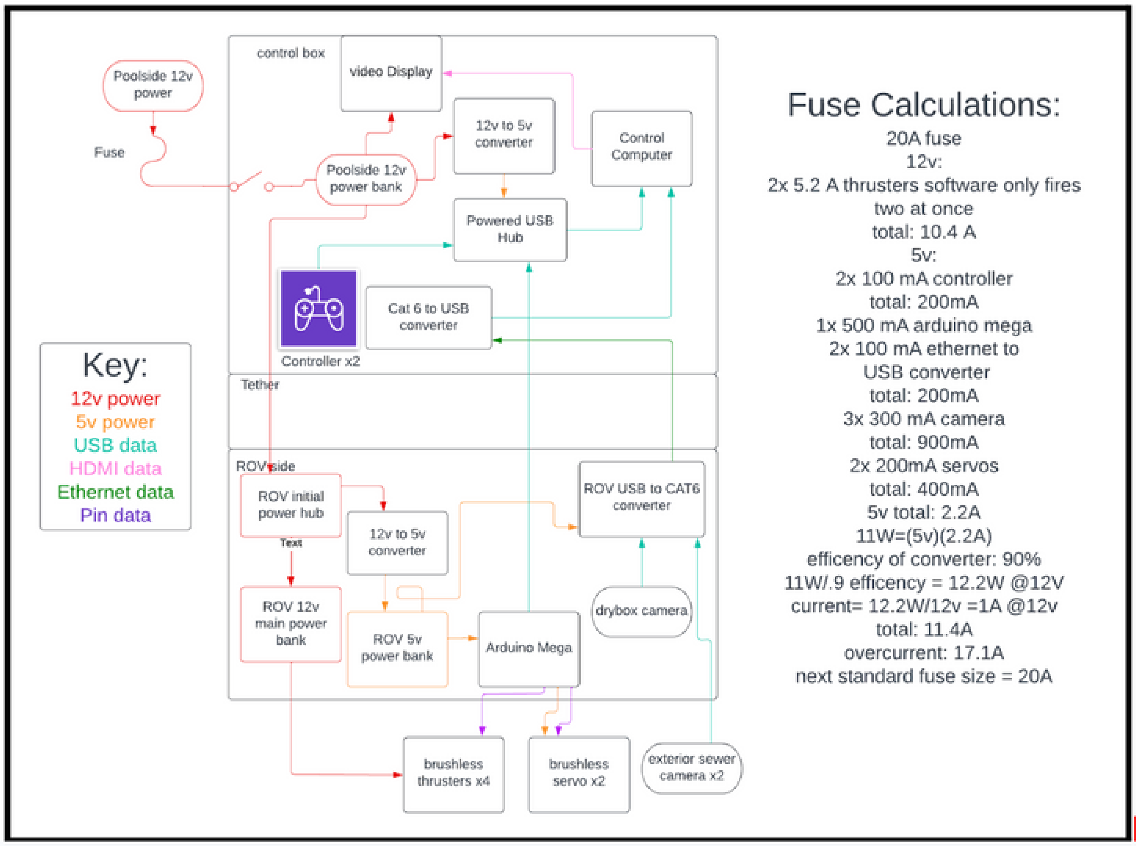
SID

ROV SID:



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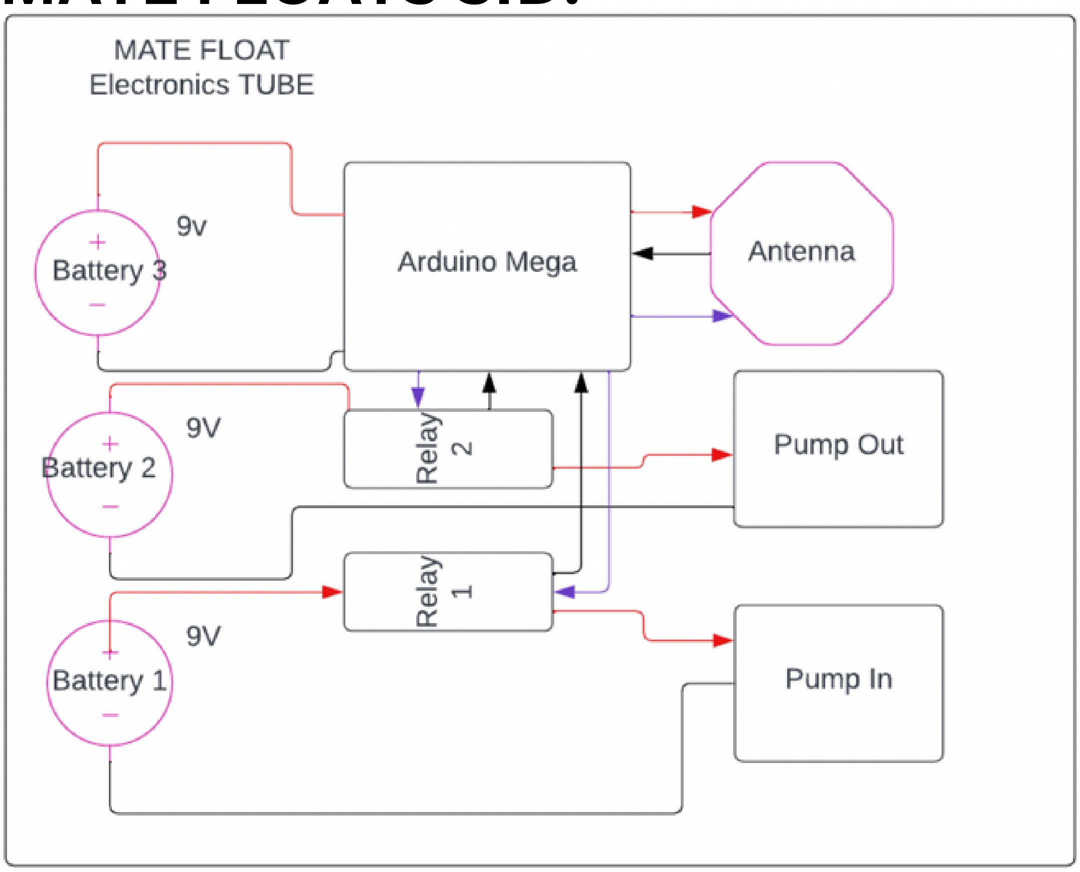

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Safety Precautions

Testing and Troubleshooting

Throughout this year, H2O Operations produced Dory, and while we built the ROV system, precautions were taken and significant planning was completed. The planning consisted of how to successfully complete tasks, but also how to solve any issues that could arise. When an issue did appear during our ROV pool practice sessions (we had just 3!), our group was quick with responding and coming up with solutions. As such, H2O Operations tried to make every step and detail of our system functional. Therefore, every part of our ROV system, Dory, was premeditated or had a design reason behind it.

A part of Dory which was heavily thought upon was the gripper. At first, the gripper was positioned vertically. An issue that we thought of was that the gripper could malfunction or lose power, therefore we moved the gripper horizontally and added a hook. If the gripper did lose power or function, it could still be used as a hook. The frame of our ROV system was also very thought about. We tried to include the camera in the middle of a system, but the exterior sewer cameras often malfunctioned and lost power. We had to remove this camera and keep just two cameras in the dry enclosure. Adding on to the camera, we intended to have the gripper in sight of the camera. As you can see, the purpose of such a frame is to have all of the components relatively in the middle, the thrusters and their shrouds are closer to the center of the system, as well as the buoyancy centered. To be very effective, a smaller frame would allow for slightly quicker speed, as least weight is being pushed. The smaller frame also allows for the electrical components to be inside two enclosures making it easier for repairs. Opening just one enclosure, with just half of the components, allowed us to safeguard potential water sealing issues.

Accounting

Budget

The purchases for the ROV Team came out of the robotics budget. We've spent our budget on buying essential things to build Dory, this year's ROV. We've purchased video cameras so we can see where Dory is, servo controllers, cables, and other essential things. Without being wasteful, we reused parts from our old ROV that was made in 2019. PVC pipes, PVC cutters, pool noodles, buoyancy foam, soldering tools, etc., were just some of the tools we reused while building Dory.

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Cost Accounting

We've spent $1849.50 on our supplies to build Dory.

Appendix A: Cost Accounting

Item name	Costs
4 Blue Robotics Thrusters	725.00
10 Pieces T-handle Hex Key Set T-key Allen Wrench Kit	16.99
Actobotics® Servo Controller (x2)	159.98
6" Male to Male Extension (x2)	7.98
D646WP Servo-Clockwise	54.99
Standard Gripper Kit A (x3)	29.97
1080p Hd Industrial Usb2.0 Camera USB Camera Module	50.99
25.0' CAT6 Cable	9.99
Actobotics® Hardware Pack A	39.99
ATC Blade Type Fuses (Amps: 15) Pack of 3 (x10)	9.90
ATC Style Fuse Holders with Powerpole Connectors (x3)	47.97
2.1mm x 5.5mm DC Male Power Plug to Anderson Powerpole Adapter 6 Feet (x4)	31.96
Four Thruster Kit	132.00
Pufferfish Video System Kit - TWO Cameras	180.00
Tie-Dye Team T-shirt	351.79
Total Cost	**1849.5**

New vs. Reused

Item name	Re-used/ Purchased
PVC pipes	Re-Used
PVC Cutter	Re-Used
Pool Noodles	Re-Used
Buoyancy Foam	Re-Used
Digital Multimeter	Re-Used
Cable Zip Ties	Re-Used
Tape Measure	Re-Used
KOTTO Third Hand Soldering Tool	Re-Used
Soldering iron	Re-Used
Wire Stripper	Re-Used
Rotary Tool	Re-Used
Silicone waterproof glue	Re-Used
m10 cable penetrator	Had extra