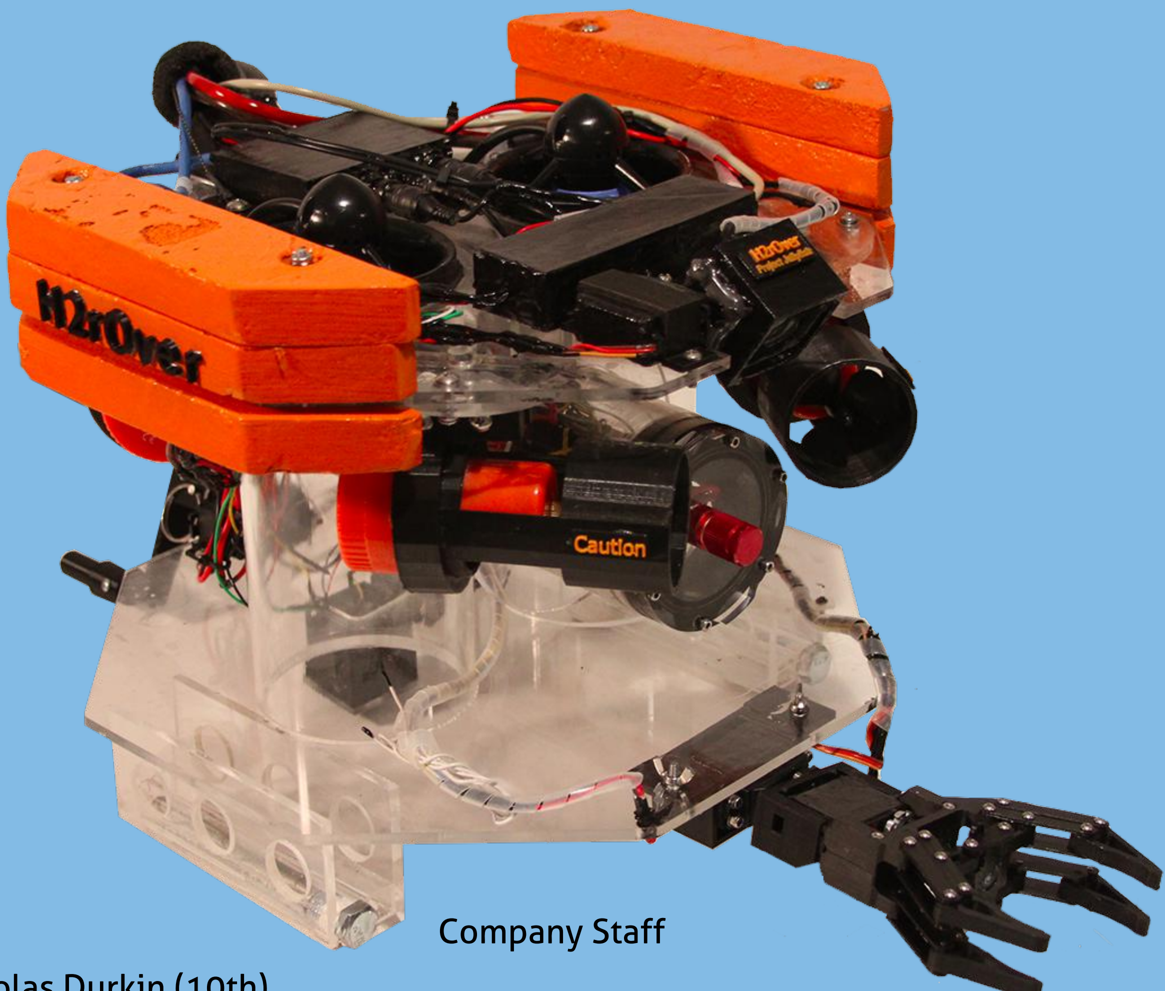
Curiodyssea

MATE ROV International Competition

Staples High School

Westport, Connecticut



Company Staff

Nicholas Durkin (10th)

Chief Executive Officer, Control/Electrical Engineer, Mission Strategist

John McNab (10th)

Chief Financial Officer, Design Engineer, Mechanical Engineer Co-Pilot

Nathan Wang (9th)

Chief Safety Officer, Visual Systems Engineer, Tether Manager

Daniel Westphal (10th)

Chief Compliance Officer, Propulsion Systems Engineer, Pilot

Mentors: Mike Durkin, Andy McNab, John Wang, Phillip Westphal

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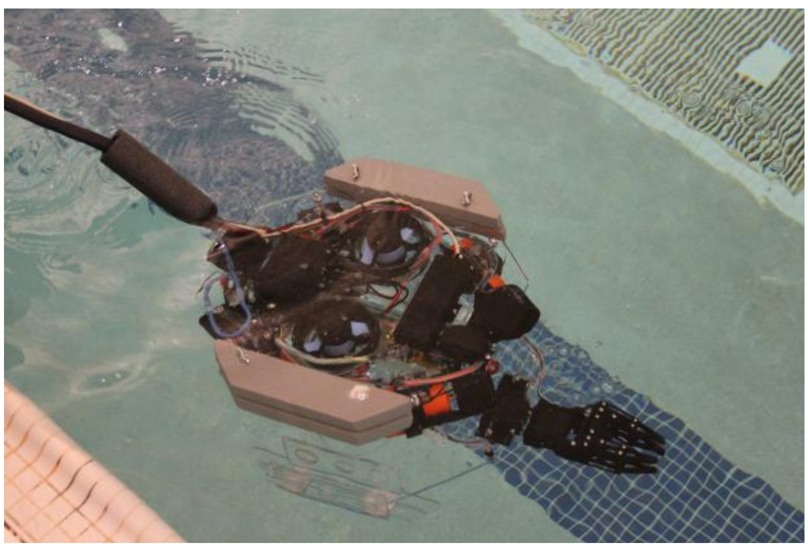
Abstract

Curiodyssea constructed the H2rOver - Project Jellyfish, its second generation remotely operated vehicle (ROV), to meet the requirements put forth in The Port of Long Beach's RFP. The H2rOver is designed to be a versatile vehicle which can maneuver the ports of Long Beach to meet all the service and maintenance needs of a 21st century port.

The H2rOver is able to install infrastructure to increase commerce, conduct maintenance on a diverse set of underwater systems, collect samples to ensure the health of the environment, and identify potentially dangerous objects in the harbor to protect the safety of the port. H2rOver accomplishes this through its onshore guidance and control system, integrated multi-camera video system, and custom designed mission tools.

The H2rOver is equipped with six motors, three cameras, a manipulator, and specialized mission attachments. The chassis of the ROV is built from acrylic board which is affordable, buoyant, and easy to customize and assemble. The control system of the H2rOver is comprised of an on-board Arduino, custom control software developed in Processing (Java language), and a Logitech F310 gamepad. Curiodyssea is committed to manufacturing cost effective, compact ROVs capable of operating in risky environments and performing mission critical tasks for years to come.



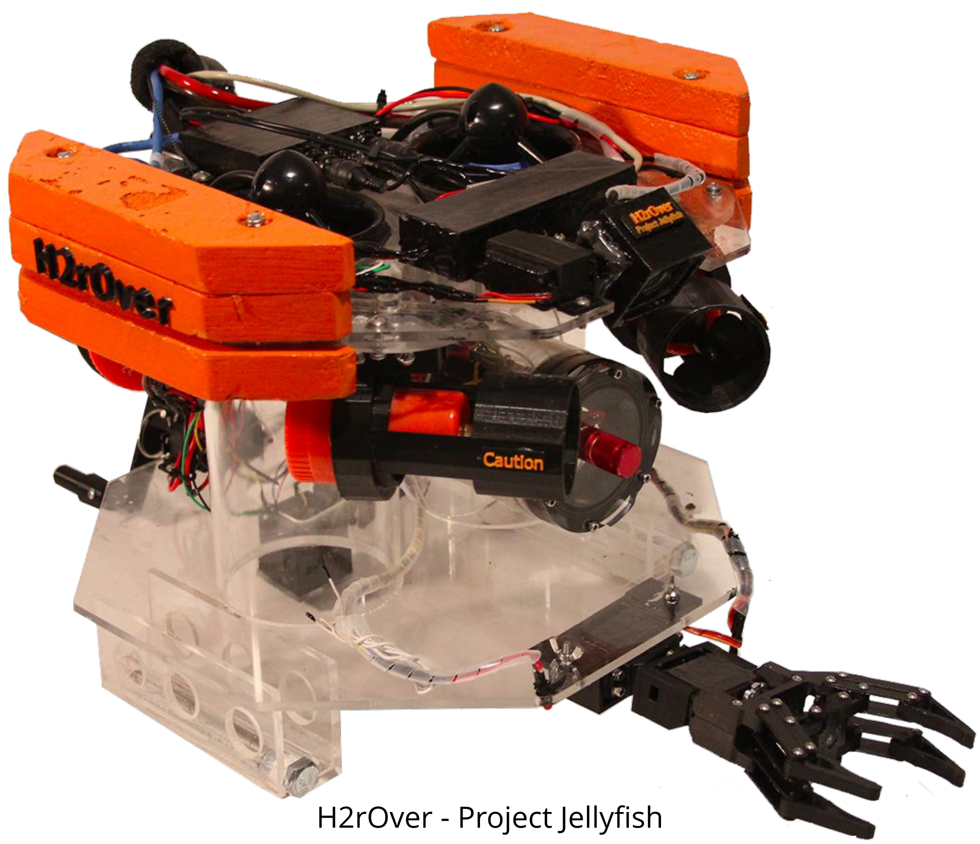
Underwater Test of H2rOver

Technical and Scientific Concepts Behind the ROV

After a thorough review of the *Underwater Robotics* textbook and the 2017 Ranger Manual, the Curiodyssea company evaluated the components and systems necessary to build an ROV that could complete the specified underwater missions in the RFP. Based on this evaluation, we established the following company objective for the ROV: Our goal is to build a remotely operated vehicle which uses multiple subsystems (cameras, manipulators, etc.) to effectively and affordably accomplish underwater missions while adhering to the size and weight restrictions for the requested ROV.

Each member of the Curiodyssea team was assigned lead responsibility for one of the ROV's core structural systems: Nicholas Durkin - electronics and control; John McNab - chassis design; Nathan Wang - camera systems; Daniel Westphal - propulsion.

The team next incorporated the functionality for the specific mission requirements into the ROV. All team members worked jointly to research and develop the mission specific systems (manipulator, spinner, agar collector, etc.). To comply with the size and weight restrictions, we prioritized finding the most compact structures to effectively accomplish each mission goal. After we created a complete list of the required parts/systems, we designed a model in Solidworks (3D design software) to see how all the parts would interconnect with each other. We tested prototypes of the ROV and attachments in Solidworks to identify possible issues and spatial requirements to simulate the systems as they would exist on the chassis. We were able to construct different virtual versions of the ROV on the computer, which saved time, money, and resources.



H2rOver - Project Jellyfish

Budget Planning

Based on competing in last years competition we had a basic understanding of how much it costs to build an ROV and travel to the competition. We budgeted spending $2,000 plus reusing equipment and components to cover our needs. For fundraising, we had each family commit to contribute $500 to cover the budget. This budget was for the regional competition.

Project Costing

By securing contributions, reusing old parts and carefully managing our expenditures, we managed to complete the project under budget. Our final ROV cost was $713 in new expenditures, which was about $250 under budget.

Budget		
Section	**Cost**	**Components**
Tether	Reused	Wire, ethernet, serial, cable, sheath
Claw	$200.00	Servos, 3D printed parts
Supplies/tools	$200.00	Glue, screws, nuts, sealers, tape, cable mounts, fuses, heat shrink, solder, etc.
Chassis	$375.00	Building material, watertight container
Electronics/control	$200.00	Arduino, speed controllers, joystick/controller, wiring, battery
Thrusters	Reused	T100, bilge pump motors, shrouds, Mounts
Camera system	Reused	Cameras, baluns, custom case, mixer
ROV Subtotal	**$975.00**	
Registration	$150.00	Entry fee
Travel to Competition	$6,000.00	mileage, lodging, food
Subtotal	**$6,150.00**	
Total	**$7,125.00**	

Reused		
Description	Year	Cost
T100s	2016	$300.00
Bilge Pump Motors	2016	$218.52
Water Tight Container	2016	$224.90
Cameras	2016	$70.95
Acrylic Tubing	2016	$61.09
Camera Mixer	2016	$115.00
T-Shirts	2016	$150.00
Arduino Mega	2016	$28.49
Game controller	2016	$27.29
Tether	2016	$300.00
Fuse holders	2016	$16.99
Tools and Supplies	2016	$231.13
Total		$1,744.36

New Expenditures	
Description	Cost
Gripper	$87.84
Foam	$15.00
Model Materials	$176.78
HSR Servos	$76.77
Worm Gears	$14.00
Cable Penetrator	$27.80
O-ring and vacuum plug	$15.00
O-ring flange	$48.00
Screws and Misc	$100.73
Mesh	$5.30
Registration	$125
PLA Plastic	$20.00
ROV Total	$712.22

Donated		
Description	Source	Aproximate Cost
Chassis Acrylic Plates	Select Plastics	$175.00
Computer Monitor	McNab Family	$100.00
$500 check	Oceanzeus	$500.00
3D Printer	Durkin Family	$320.00
Total		$1,095.00

Travel Expenditures	
Description	Cost
Ground Transportation	$400.00
Food	$1,000.00
Air Transportation	$1,600.00
Lodging	$3,000.00
Total	$6,000.00

Project Cost	$6,712.22

Design Rationale

Curiodyssea's design rationale was heavily influenced by what we learned from our first ROV, which was built for last year's missions. While we were satisfied with some of the systems and attachments we designed for the first generation H2rOver, we knew others did not work as well as we wanted so the first priority was to identify the systems and components that needed to be improved

The main improvements we focused on were the electrical system, the manipulator, and the buoyancy and stability of the ROV. Specifically, last year, the watertight case leaked intermittently and the positioning of the electronics in the case made it difficult to make software updates. Our previous manipulator drew too much power, was unreliable, and did not have enough range of motion. Our buoyancy system was ineffective under mission conditions, and the lack of sufficient stability made it difficult to complete precision tasks.

Our initial design process divided the ROV into systems (electronics, chassis, camera, propulsion, attachments), and then divided those systems into components. We designed each component, tested it, integrated it into the system, and then tested the entire system. This allowed us to take apart and put together our ROV with relative ease due to the systems design. This modular design made it easy to fix and modify parts of the ROV. A major difference between Curiodyssea's approach for design this year versus last year was to rigorously test each component and system before assembling the final ROV. This ensured the ROV would operate correctly during pool trials and helped us to significantly cut down testing time and troubleshooting.

Curiodyssea's design process for mission attachments prioritized simplicity, reliability, and efficiency. We limited the number of attachments by utilizing the manipulator whenever possible. Hence, we only needed three attachments: the manipulator, specialized spinner, and agar collector. Missions that required more specialization were accomplished with manipulator add-ons.

A good example of our design process is the creation of the agar collector. We first brainstormed solutions of how we could extract the agar and determined a specialized attachment was required for the mission. We simulated the task using commonly available parts. We tried soda cans with netting and a sharpened pvc tube as alternatives for gathering the agar. After learning from each of our failed prototypes, our design evolved to the final attachment, a funnel with a one way valve that consistently collects the agar.

Agar collector evolution

Design Rationale (cont.)

Another important design consideration we faced was the evaluation of commercial vs. in-house designed components. When assessing these decisions we considered cost, availability, necessary customization, reliability, effectiveness and required expertise. Both commercial and in-house designed components had their respective advantages and disadvantages:

Cost - Many non-electrical components cost less to create in-house. Electrical components are cheaper to purchase.

Availability - Specific or customized attachments are often unavailable for purchase. Depending upon the component, the product may only be available overseas, costing valuable time to ship.

Customization - Pieces that require specific dimensions are often unavailable for purchase. Using a 3D printer is a good way to create customized attachments and mounts.

Reliability - Commercial components are typically more durable and reliable. As such, electrical components and motors are purchased.

Effectiveness - Electrical components are difficult to create from scratch, and much more effective when purchased. Specific attachments such as the agar collector require custom parts to be effective so they were assembled in-house.

Required Expertise - Certain components such as the propellers, electronics and servos, required the knowledge and resources of an expert or manufacturer with knowledge or resources that we did not have in-house.

Buoyancy and Stability

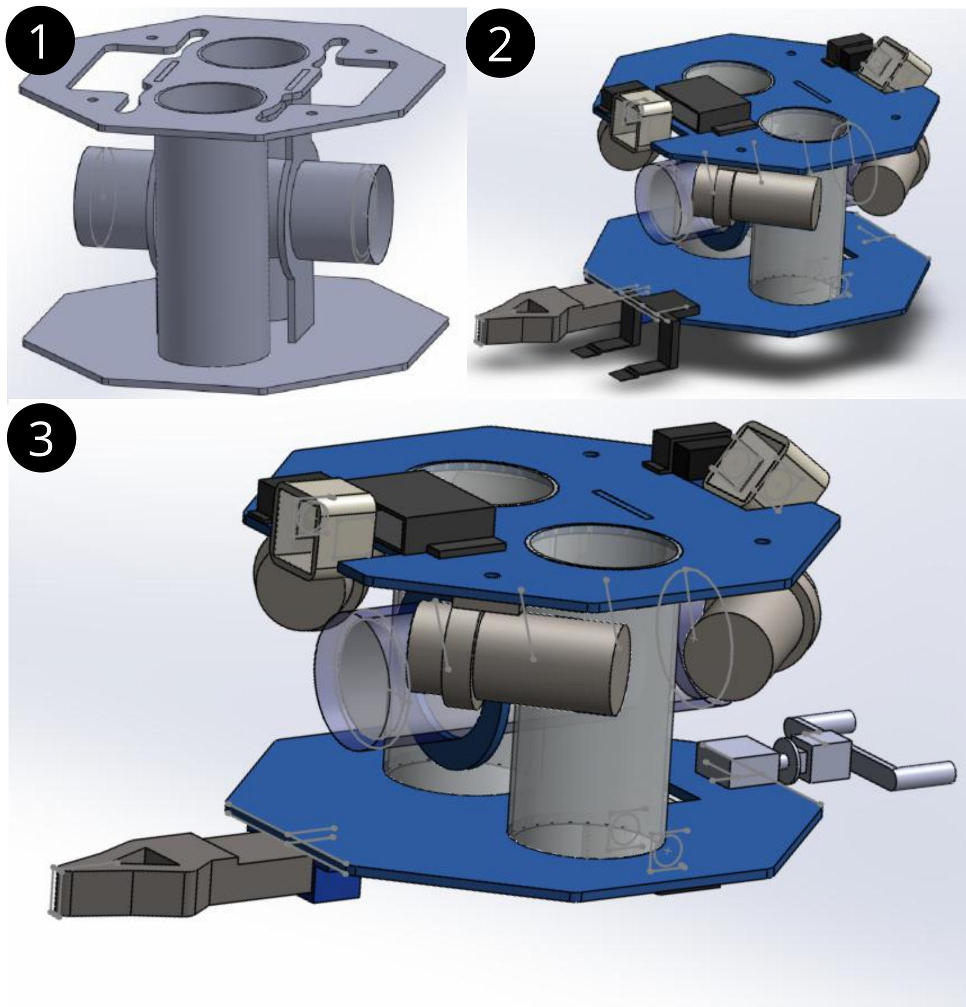
To obtain neutral buoyancy and stability for our ROV, we lowered the center of mass by putting weight on the bottom of the chassis and raised the center of buoyancy by adding flotation on the chassis's topside. There are many factors that influence the overall buoyancy, but the most significant ones are the buoyant foam, rebar weights, and watertight container which holds a significant amount of air. We installed high density foam along the upper sides of the ROV. This moves the center of buoyancy upwards, and keeps it towards the center, over the center of mass. Keeping these two points in line maximizes the overall stability. We were also able to lower the center of mass to further increase the stability with our adjustable ballast skids. The skids are hollow, and allow for rebar to be easily installed to increase ballast at the lowest points of the ROV. By combining all of these factors, the H2rOver is a very stable, neutrally buoyant ROV.

Foam for buoyancy

Chassis

Our chassis was designed completely in Solidworks, a powerful 3D design program used by engineers around the world. Solidworks enabled us to test many different ROV designs and components without having to build physical models. Once we were satisfied with the design, we exported it to a professional plastic cutting shop for laser cutting to create precision parts for assembly.

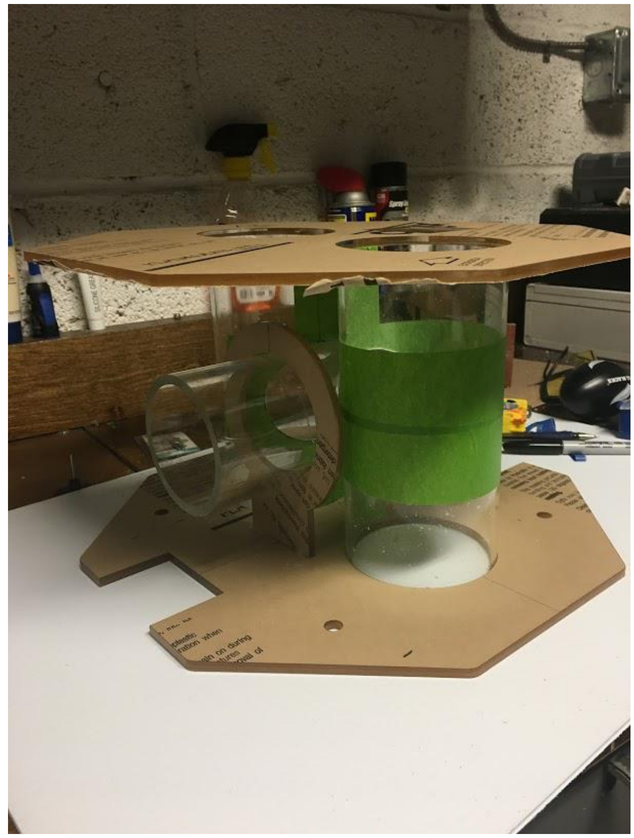
When designing H2rOver, we wanted to use space efficiently. We selected an octagonal design to give us an easy shape to work with that fit well within the RFP's 48 cm sizing circle. The shape allowed us to easily mount our systems in optimal positions, such as lining up cameras and attachments on the front and back, motors on the diagonals where they could be easily vectorized, and buoyancy on the outer edges of the ROV.



Evolution of the ROV chassis design:
1. Preliminary design concept
2. Design with attachment (later removed)
3. Final ROV design

Chassis (cont.)

We decided to use clear acrylic as our chassis material because it is strong, relatively light, can be precisely cut, and easily assembled using a plastic solvent. Our chassis consists of two laser cut acrylic octagonal sheets, two mounting rings for the watertight container, two acrylic vertical tubes, and skids. The vertical tubing had a large influence on space in our ROV. It allowed us to create structure, as well as direct the flow of water from the T100's through the core of the chassis without interfering with the ROV's systems. We also cut sections out of the vertical tubes to hold the watertight container, resulting in a very strong and compact chassis structure.



Chassis with watertight case during assembly

This compact structural design and octagonal shape gave us enough space to easily fit the necessary attachments, servo motors, and cameras onto the ROV. The selection of acrylic also made it relatively easy to adapt the chassis as we constructed our design. Examples of this include drilling holes wherever needed in order to mount the cameras and motors at the correct angles and securing the skids to exact positions with solvent.

We used two main methods for mounting components to the chassis. For permanent connections, such as the waterproof boxes and wires on top of the chassis, we use tapped holes and screws. These give strong, permanent connections that can be adjusted for troubleshooting. For quick mount connections such as the manipulator, we used screws with wing nuts to quickly and easily make secure connections.

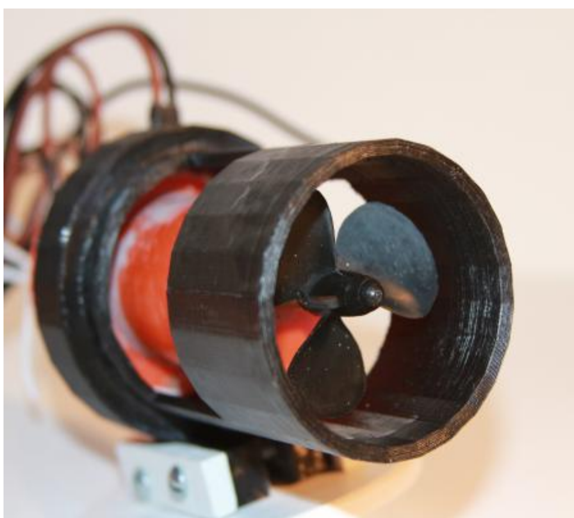
Propulsion

Our goal for the propulsion system was to effectively move with sufficient thrust throughout the mission field and complete various tasks. The thrusters on the H2rOver are reused from last year's ROV because we found that they generated sufficient and controllable thrust.

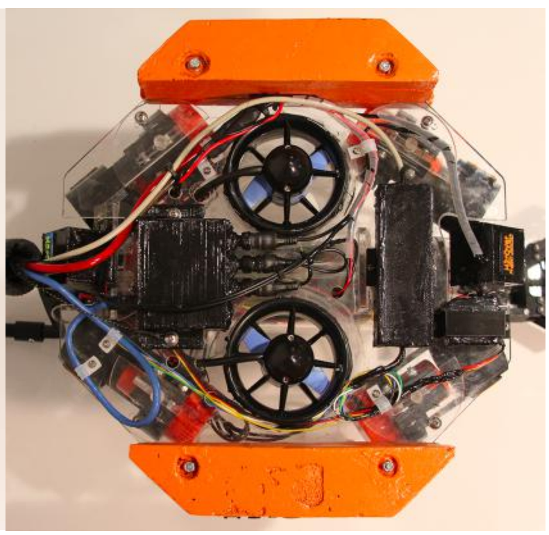
The propulsion system contains two T100 motors (which draw 13 amps at max power) and four 1100 GPH bilge pump motors (which draw 3 amps at max power). The T100s are used for vertical motion because of their effectiveness and strong thrust. One concept we kept from the original H2rOver is mounting the T100's on top of the ROV in acrylic tubes. These tubes direct the thrust through the chassis for greater efficiency and minimize disruption to any other systems.

For movement in the horizontal plane, H2rOver uses converted 1100 GPH bilge pumps. The bilge pumps were converted to thrusters by sawing off the casing and replacing the impeller with a propeller. We used the bilge pumps because they are cost effective, small, and draw limited power. The bilge pumps are mounted and shrouded with custom 3D printed components. The mount is attached to a rotating acrylic piece, allowing for adjustable vectored thrust.

For the bilge pump propellers, we commissioned Harbor Models to machine specialized props and shaft couplings to fit our thrusters. We also vectorized the motors, mounting them to give strong forward thrust, efficient turning, and sideways movement (34°). These mounting positions enable H2rOver to travel in any direction on the horizontal plane. The bilge pumps are also shrouded with extra long 3D printed shrouds to increase and direct thrust.



Modified bilge pump motor with mount and shroud

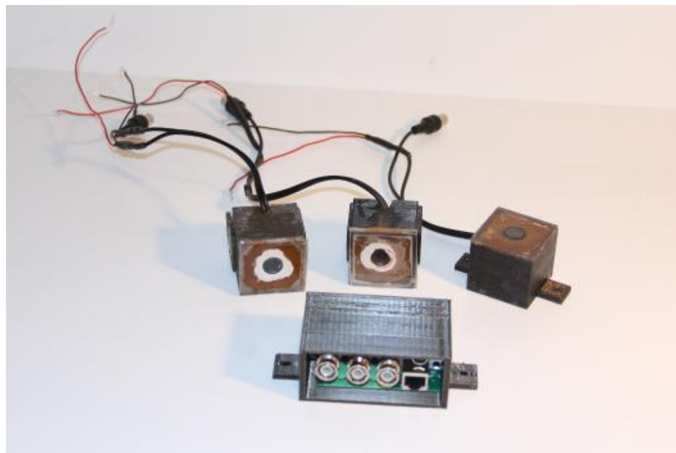


Top of the H2rOver showing T100 placement

Camera System

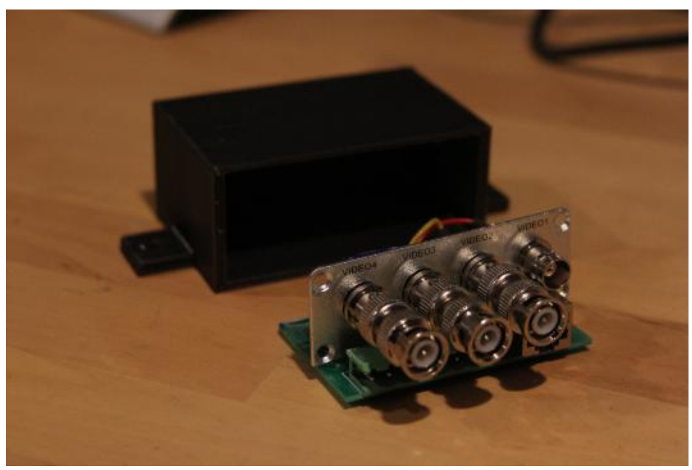
Since visibility is essential to completing the missions, Curiodyssea's vision objective was to build a multi-camera system that provided effective sight lines for all missions and general navigation. In addition, the system had to be cost effective, lightweight, and capable of viewing and managing three video feeds.

H2rOver is equipped with three 800TVL color board cameras. Custom designed, 3D printed cases were created with Solidworks to enable waterproofing and mounting. Two cameras, positioned on the front and bottom of the ROV, are fitted with 180° servo motors that are used to adjust the camera views during missions. This is a big change from our first generation ROV which had cameras mounted in fixed positions, limiting the field of vision. The front servo allows the camera to be used for forward navigation and have an angled view to direct use of the manipulator during missions. The second camera in the back is fixed and used for viewing the spinner that can turn underwater valves. The final camera is located on the ROV's underside to provide visibility when above the mission field and can be rotated to assist with ROV alignment during missions.



Waterproofed cameras with Balun

Two baluns are incorporated into the video system to send video signals to the poolside monitor used by the ROV pilots. One balun is on board the ROV and the other is located in the pool side control system. The baluns enable signal conversion of three BNC cables onto one ethernet cable which minimizes weight and simplifies the tether.



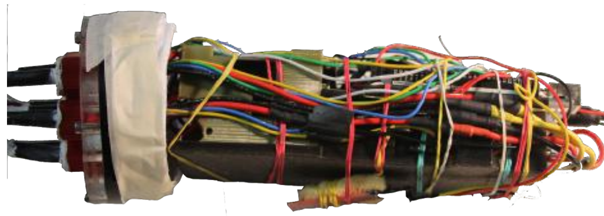
Balun with 3D printed case

To manage the multiple video feeds, we evaluated several video mixer options and ultimately decided to purchase a high quality mixer with a color quad processor. This mixer enables us to view all three cameras at the same time without signal delay as well as offering multiple viewing options for the pilots.

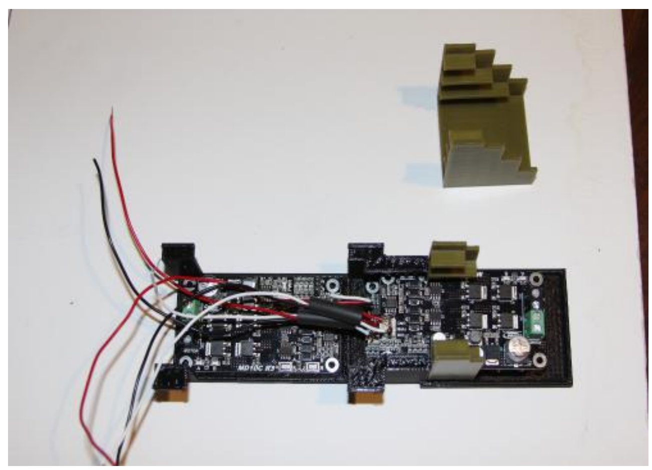
Electronics/Control System

The control system manages the propulsion and sensors on the ROV and adjusts the manipulators and camera mounts. Curiodyssea wanted easy and intuitive controls as well as the ability to maneuver precisely. The control system is similar to last year's system, with key functional improvements including cleaner wiring design, improved power distribution, better accessibility to onboard electronic components and the ability to reprogram the Arduino in cases of troubleshooting or updates.

Onshore Control System - The pilot control station is comprised of two main parts: a Logitech F310 Gamepad and a laptop. The pilot uses the gamepad to steer the ROV by controlling the six directional motors. The gamepad is connected to the laptop which sends motor data to the Arduino through a Processing sketch. The sketch includes slider controls which allow the co-pilot to adjust mission attachments and camera positions during operation. The Processing sketch also displays water sensor alert at the first sign of a leak. We selected Processing for its compatibility with Arduino and its ability to generate user interfaces.

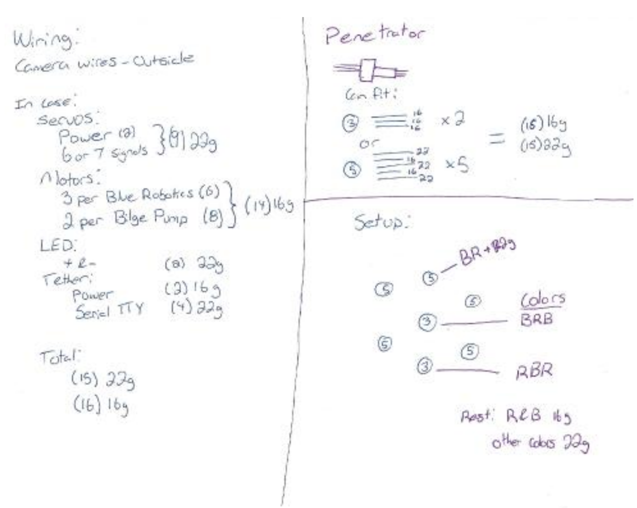


Electronics within the water tight container



Electronics rack and motor controllers

Watertight Case - The watertight case was purchased from Blue Robotics. It is 27.7 cm long and has a 7.6 cm inner diameter. The inside of the case holds a custom designed, 3D printed electronics rack that holds components in an organized and extremely compact space. The wires are strategically organized within the case penetrators so that all of the connections fit into position on one side of the case. The other side, which is wire free, enables the end cap to be quickly removed to provide access to the Arduino's USB connector for software updates (this was a huge time saver because we had to cut and resolder many wires every time we updated the first generation H2rOver).

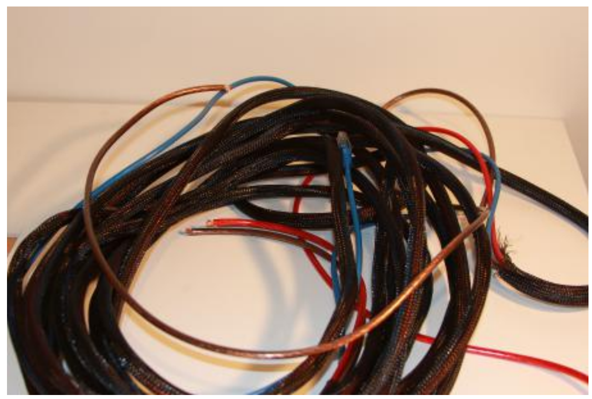


Wiring diagram for WTC penetrators

A major difficulty we encountered last year was that the container leaked, so we devised a series of tests to identify what the problem was and how to fix it. This process is discussed in detail within the Troubleshooting Techniques section.

Water Sensor - We installed a water sensor inside the case for improved safety and to protect the electronic hardware. The water sensor is on the underside of the electronics rack. It is designed as a first response against any leaks. Upon detecting any water inside the case, the on-board Arduino will send a message to the poolside computer and provide immediate notification to the pilots, who will then quickly return the ROV to the surface.

Tether - The tether is designed to be as light as possible while still including all necessary cables to properly run the H2rOver. It is comprised of two 8 gauge wires for power supply, an ethernet cable for video, and an RS232 cable for controlling the onboard Arduino. It is covered with a braided cable wrap. The 8 gauge wires were selected to minimize voltage resistance which enabled delivery of maximum power to the ROV while maintaining the tether's flexibility. We calculated that the tether needed to be 15.25 meters long to reach all areas of the mission field at the lowest possible weight. We designed a rope system, inspired by surfboard leashes, to attach the tether to the ROV. This creates a solid connection to the ROV and relieves tension on the tether. The rope system is made of two kevlar strings. Attached to the top of the ROV, the tether is clearly out of the rear camera's range of view and is in close proximity to the components to which the tether wires need to be distributed.

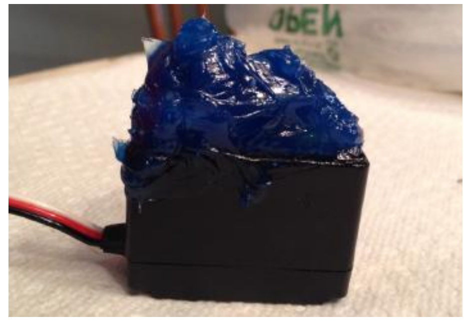


Tether covered in braided wrap

Attachments

Buoy - The buoy attachment, inspired by carabiners, consists of a pool noodle, rope, and 3D clip. We designed the buoy to be as simple and effective as possible. The clip was customized to secure the shipping container without falling off during the mission. We decided against using a commercial carabiner because they are too hard to open; the attachment we made is simple to open and easy to secure.

Buoy on shipping container



Servo being waterproofed

Servos - Curiodyssea decided to use servo motors for mission attachments and cameras in order to increase functionality for powered attachments and reduce power draw. Servos are smaller, reliable and more precise than the bilge pump alternatives that Curiodyssea used last year.

In order to use servos on the ROV, we learned how to waterproof them. We found two methods online, oil based waterproofing and grease based waterproofing, so Curiodyssea tested both methods to choose the superior one.

We waterproofed two servos, one with oil and one with marine grease, and then ran a dry test, a 5 minute water test, and a 1-2 hour "endurance" water test (water tests involved continuously moving the servo underwater for the designated time period). While both types of servos worked after the endurance test, the "oil" servo was significantly slower. From this information we decided to waterproof all servos with the grease method.

There are five servos on the H2rOver. The front and bottom cameras both have 180° servos that allow for a large camera field of vision. The spinner attachment on the back of the ROV is attached to a bi-directional, continuous servo to allow for rotation of the Entertainment Valve. The manipulator has a 180° servo for wrist movement and a bi-directional, continuous servo to open and close the claw. These five servos enable effective vision and manipulation of objects during tasks.

Basket - The basket is a new principle in Curiodyssea's mission strategy. To minimize the number of surface trips required during mission operations, the basket is utilized to hold items needed for transportation to the surface. Inspired by butterfly nets, the net was built with the exact proportions needed to transport the required objects poolside. The final product has a circumference of 92 cm and a height of 40cm and can be carried by the H2rOver without any pieces falling out. Fitted with multiple floats and a fishing weight on the bottom, it is easy to transport around the mission field for object collection.

Basket

Spinner - The spinner attachment is located on the back of the ROV. It includes a continuous servo that rotates the Entertainment Valve. When installed, the spinner hangs too far off the back of the ROV to fit through inspection, so it has a detachable design which consists of (1) the permanently mounted servo and modified servo horn and (2) the detachable arms of the spinner which fit snuggly over the modified horn to quickly mount during setup. Both the horn and the spinner are 3D printed.

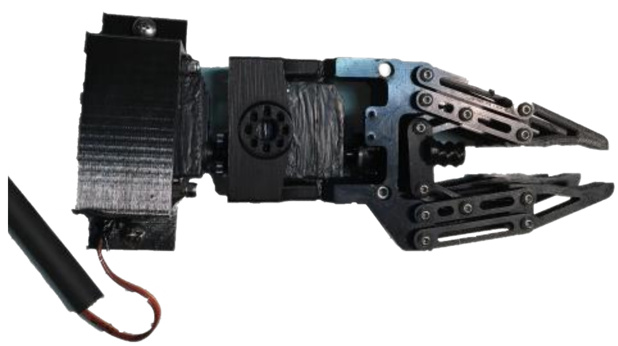
Spinner

Agar collector

Agar Collector - The agar mission attachment went through many design and prototype phases. Our first prototype for the agar collector was a film canister with a wire going across the diameter of its opening. The idea was the ROV would implant the canister into the agar container and rotate so that the wire could cut the bottom part of the agar out, and then the ROV would return to the surface to deposit the sample. When we tested this idea, it did not work because the agar did not stay inside the canister.

Our testing did lead us to the idea of 3D printing a custom cup with a truncated cone inside. This cup matches the exact size of the container that holds in the agar in the mission field. This prototype was effective in collecting the agar, but the agar flowed back out into the water due to suction when the collector was removed from the agar sample during mission simulations. To improve the design, we further truncated the cone, widened the hole, and installed a one-way valve cut from ribbed plastic sheeting. The valve is similar in design to a soda cup top and allows agar to pass through into the collector but not back out in the other direction. When tested, this design collected almost twice the amount of agar compared to the other trials.

Raman Spectrometer (Light Emitting Diode (LED)) - There is an LED located on the H2rOver to simulate the Raman spectrometer for Environmental Cleanup. The LED is secured to the bottom of the ROV, in view of the front camera, and can be turned on and off from the topside control station. The LED is waterproofed by its glass housing and silicone sealant around the wires.



Waterproofed manipulator

Manipulator - One of Curiodyssea's major goals for this year was to improve the manipulator. Last year's manipulator utilized a bilge pump, which was unreliable, inaccurate, and drew large amounts from the power budget. To find a better solution, Curiodyssea investigated manipulator ideas before the season began.

We considered designing one ourselves, but decided that a commercial product would likely be more reliable and effective. After an extensive review of options, we selected the Andromina Gripper 4 V1.1 from Andromina Robotics. We chose this manipulator due to its worm gear design, precision, ability to move on two axes, and reasonable price point. The manipulator was not intended for underwater use, so we needed to waterproof the motors and modify it with several custom 3D printed parts. These modifications mainly served to strengthen the claws of the manipulator to keep it from breaking when stressed during missions.

The manipulator was tested extensively on land with the mission models so we could determine the best options for completing the port harbor missions. The manipulator is used in all missions, and has several custom attachments that enhance its capabilities. These include the buoy and the basket.

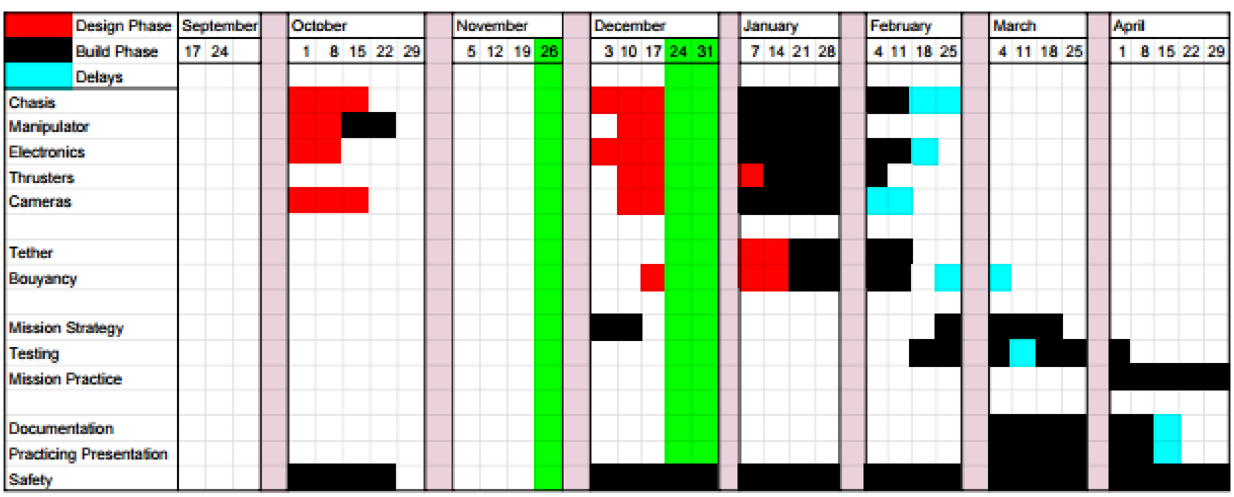
Project Management

Another important improvement that Curiodyssea wanted to make was to create a detailed schedule and ensure that there was plenty of practice time before the competition. To do this, Curiodyssea began to plan prior to the release of the 2017 RFP. We knew that certain systems needed to be upgraded (see Design Rationale), so we set to work on finding solutions.

We decided to divide up work assignments on the ROV because it allowed us to have system leaders who specialized in each area of the ROV's development. Each project leader adhered to the deadlines set forth by the company, which ensured that the project management schedule was followed. This was also a more effective way of working because each project leader was able to focus on their respective system and become our in-house expert in that area. The deep insights gained by the project leaders meshed to increase the extent of our knowledge and made the overall team much stronger when developing of the ROV.

Email was the primary means of communication to set up team meetings. Emails were sent to all members of the team in order to keep everyone updated with meeting schedules. We utilized emails not only to coordinate time, but also to update anyone who was not at previous meetings. Each email contained a small recap of what occurred as well as an outline of our short-term goals.

Each time we met we had a recap and planning session in which we reviewed what we did last session (to make sure everyone was on the same page) and to plan what we would accomplish. During this time, members also were able to ask for assistance and help on assignments if they needed it. This allowed us to plan what we would focus on during each meeting.

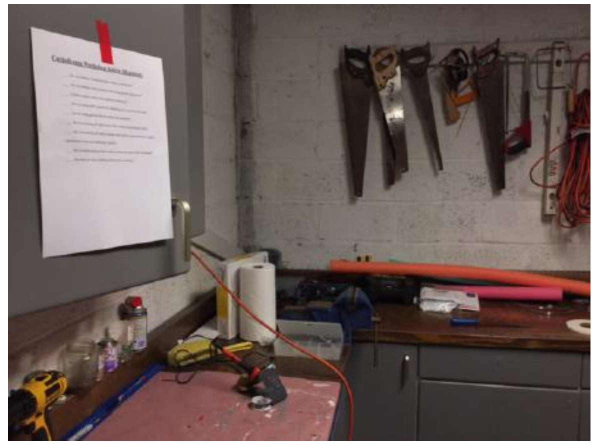


Company schedule

Safety

Safety is a very important part of the MATE experience and Curiodyssea's philosophy is to make sure that every aspect of building and operating our underwater ROV is safe. We identified and implemented safety features and measures on our ROV, in our workshop, and while testing in the pool that would keep all members safe in the three separate areas outlined in the safety checklist.

The most hazardous parts of the ROV are the electrical system and the motors. Curiodyssea wanted to ensure that these areas would not cause any injuries to anyone for the duration of the building and operation of the ROV. To meet this goal, we developed a series of important safety protocols that were followed at all times. Curiodyssea implemented the required 25 amp fuse into the electrical system before testing any components. This, along with an electrical switch that could instantly cut power to the ROV, minimized potential power hazards. Another safety check that prevented any electrical injuries was ensuring that there were no exposed wires before any electrical test. For motor safety, we made sure motors were always securely mounted before running, checked for any wire entanglement, and required verbal confirmation from all members about motor operation. In addition caution signs were installed on motors to warn of dangerous areas on the ROV.



Safety checklist in workshop

Caution signs on motors

Another important part of safety was waterproofing electrical components. Big components were waterproofed with 3D printed cases filled with silicone, marine grease, or other waterproofing material. Some of the big components include: the balun, the RS232 converter, and the cameras. We utilized liquid electrical tape in combination with waterproof-adhesive heat shrink to seal wire connections. The watertight case was used to seal the main electrical controls within the ROV. This includes the Arduino, ESCs, and the 5 volt converter.

When building, Curiodyssea's top priority was to insure the safety of all members. In addition to our workshop protocols, we have a logbook to list safety incidents to help us track and analyze any problems. We are proud to say that we were incident free this year because of our respect and implementation of the safety protocols.

Curiodyssea Safety Checklists

ROV Safety Features:

____ Tether strain relief

____ Shrouded motors

____ Color coded wires

____ Installed fuses

____ Safe and waterproofed wire connections

____ Extra long motor shrouds

____ Caution signs installed on motors

Workshop Safety Measures:

____ Closed toe shoes while in workshop

____ Safety glasses when using power equipment

____ Mentor supervision when in workshop

____ Safety guards for soldering iron to prevent burning

____ Using gloves when handling hot materials

____ Covering all open wires when conducting electrical tests

____ Tracking all safety injuries and making improvements to safety procedures to prevent additional injuries

____ Maintaining a clean work environment when in the workshop

____ No loose clothing when in the workshop

Poolside Safety Measures:

____ Wearing closed toe shoes and safety glasses

____ Installed 25 amp fuse

____ Tether strain relief in place

____ Two control boxes plugged in correctly (check labels)

____ All tether wires properly and securely connected

____ Anderson Power Poles plugged in properly (red is + and black is -)

____ Switches in the off position

____ On-shore components secure

____ All moving parts are secured and clear of possible hazards

____ Verbally confirmed everyone is ready for operating the ROV

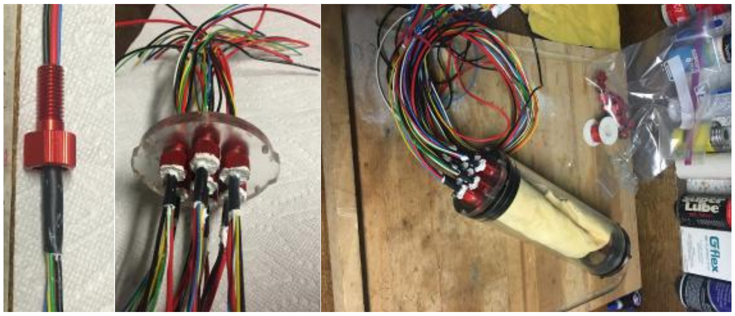
____ Mentor supervision when testing the ROV

Troubleshooting Techniques

We used the scientific method, the process for scientifically testing a hypothesis, and independent variable testing to identify and fix issues encountered while designing, constructing, and troubleshooting the ROV.

An example of this process is illustrated through our waterproofing of the watertight case. Last year, the case leaked on occasion. We did not know why this was occurring and we wanted to ensure a dry case this year, so we implemented a series of tests to identify the issue. We never moved forward without ensuring the case was dry after testing each new change variable.

After doing research, the first change we made was to install a vent penetrator that served to reduce pressure inside the case. We tested this iteration of the case with epoxy sealed penetrators, then moved on to testing the penetrators with "dummy" wires. These wires served to simulate the actual wires that would be running through the case, and were used to test if the seal around the wires was watertight. We found that the case leaked during the wire test, and hypothesized that the water was leaking inside the wire insulation due to high water pressure at the bottom of the pool. To support this hypothesis, we capped the ends of the wires with silicon sealant and conducted another successful water trial. Finally, we installed all of the wires for the working ROV and completed a dry test with these wires prior to installing any electronic components in the case.



Various stages of watertight container testing

Another method of troubleshooting that proved effective was testing all of the systems and attachments thoroughly in the workshop before pool testing. The components were easier to change, if needed, without water on them, and we were able to try and identify all issues before incorporating the system into the final ROV. We tested what the cameras would be able to see, what the manipulator would be able to accomplish, specialty attachments, the entire electrical system and control of all components, and anything else that had a chance to fail. This testing process minimized any errors prior to final assembly of the ROV.

The final testing of the completely assembled ROV was done in stages. We first dry tested all installed systems in the workshop, and than began pool testing. Pool testing was done by submerging the ROV for increasing time intervals, until we were sure all components were waterproof and working. We then moved on to basic navigation, and then mission trials.

Future Improvements

In the future, Curiodyssea would like to build a manipulator in-house. We purchased our manipulator this year because we assumed that building one would take too much time to design and test. We think it would be beneficial to create our own manipulator to improve upon the shortcomings of the manipulator we used this year. Some of the improvements we would like to implement include larger size, increased strength and power, non-slip grip surface, and third axis of movement (e.g. elbow joint). Our company concluded that future efforts to create the envisioned manipulator would deliver the most significant performance returns for a future generation ROV.

Curiodyssea wants to improve upon inventory planning next year to ensure the key parts and components have back up units available in case of failure during development or testing. This type of planning will save us significant amounts of time in our production and testing schedules. For example, this year we had two of our motor mounts break. While it was relatively simple to fix, we wasted valuable time waiting for the motor mounts to be reprinted. It would have been much easier to have had this part ready and available for use so that we could utilize our time more effectively.

We also learned that is makes sense to invest in extra inventory when we are ordering from overseas sources (e.g. cameras) since it can take up to a month to receive our orders. This approach to ordering will save us valuable production time.

Challenges

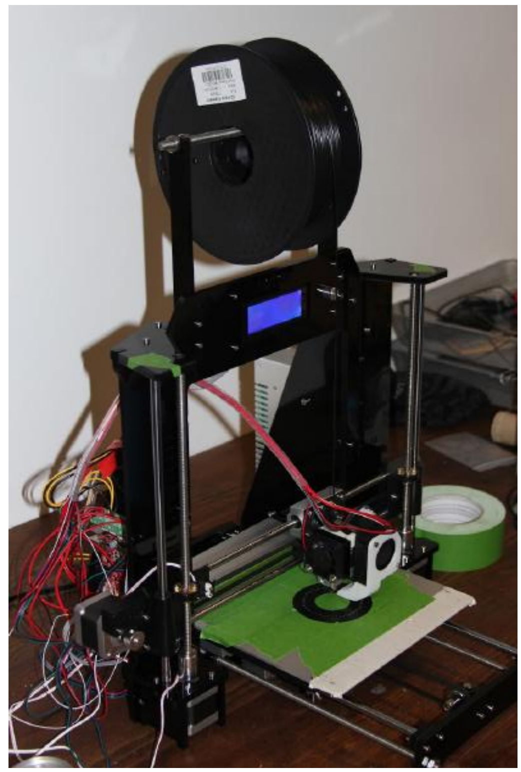
Non-technical - A significant non-technical challenge was gaining timely access to 3D printers. Since our parts required long print times, we had difficulty fitting our production runs into schedules for the school and public library printers. Also, the printers were frequently reserved and we could not use them when needed. We eventually borrowed a 3D printer that we kept at our workshop. This proved extremely effective in allowing us to utilize our time to its fullest extent. Before, when a part broke, we had to go through a lengthy process in order to replace it and our progress for the week was halted since we could not get the parts fast enough to continue. After we secured a printer, when a part broke we could immediately reprint it. It immensely increased the productivity of Curiodyssea and enabled us to better meet our production schedule for the ROV.

Technical - The most prominent technical problem for Curiodyssea was troubleshooting and resolving bugs in the Arduino program which controlled many ROV systems. Issues included: reliable serial communication for data transfer, controlling the servo movements, reliable performance of the ESCs, etc. Since the Arduino interconnects with so many systems and components the challenge is isolating the actual cause of the ROV's technical difficulties. We solved these issues by seeking help from experts, both online and in person, as well as through slow debugging of the programs.

Lessons Learned

Interpersonal - One important lesson we learned relates to scheduling. We originally tried to structure our company such that all members would be present for every meeting. We found that this was a difficult strategy to implement due to scheduling conflicts and commitments that prevented some members from attending. We realized it was better to schedule regular meetings with whoever could attend. To keep everyone coordinated, whether they attended a meeting or not, we used recap sessions and email updates which increased productivity and led to continuous progress.

Technical - Throughout the ROV design and build process, we learned an important new skill: reverse engineering. Many parts on the ROV broke and needed to be replaced. Since ordering new pieces could take weeks to arrive, we decided to 3D print the parts using Solidworks and Sketchup. The process for reverse engineering is: measure all dimensions of the part you want to replicate, create a CAD design, and then 3D print and test the piece. We used this process to rebuild the claw extensions, brackets, and worm gear on the manipulator. One of the benefits of rebuilding these components was it gave us the chance to make them even stronger than originally intended by the original manufacturer, Andromina.


Curiodyssea 3D printer printing an attachment

As a side note, we developed a strong working relationship with Andromina and shared our technical feedback about using the manipulator underwater. Andromina created a blog post featuring our story to share with their community of users internationally. You can find the post at androminarobot.blogspot.com.es.

Community Outreach - We participated in the Westport Maker Faire which hosted 8000 attendees. We displayed our ROV, passed out fliers about the MATE program, and educated people about our STEM project. We learned that sharing experiences is rewarding and we found a lot of people were excited to learn about MATE and the opportunities to get involved with marine engineering and robotics. We also developed several leads with individuals and companies who are interested in helping us support our future efforts to promote and build an ROV.


Curiodyssea with Jim Marpe, First Selectman, at Westport Maker Faire

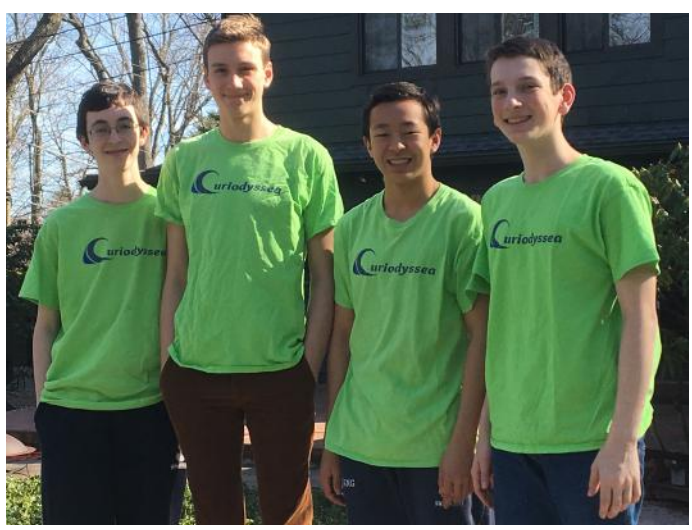
Reflections

Nicholas - As head electrical engineer, I learned more about how to properly build an electronic system this year. I learned about power distribution and the importance of properly planning out every part of the system. Additionally, as CEO, I learned about organizing and delegating tasks to enable a smooth operation. I had to learn to properly manage the team to keep us on schedule and on task.

John - As the team's mechanical engineer, I was responsible for one of the largest changes to the ROV, the chassis design. I learned that the chassis should be designed around the pieces, not the other way around. In order to do this, I spent much of my time planning with Solidworks before bringing the files to life. Because I was the team member experienced with Solidworks, I was also involved in the design of many of our attachments. As I watched these concepts grow and change, I learned that everything is subject to change and can be improved, and the first idea is not necessarily the best idea.

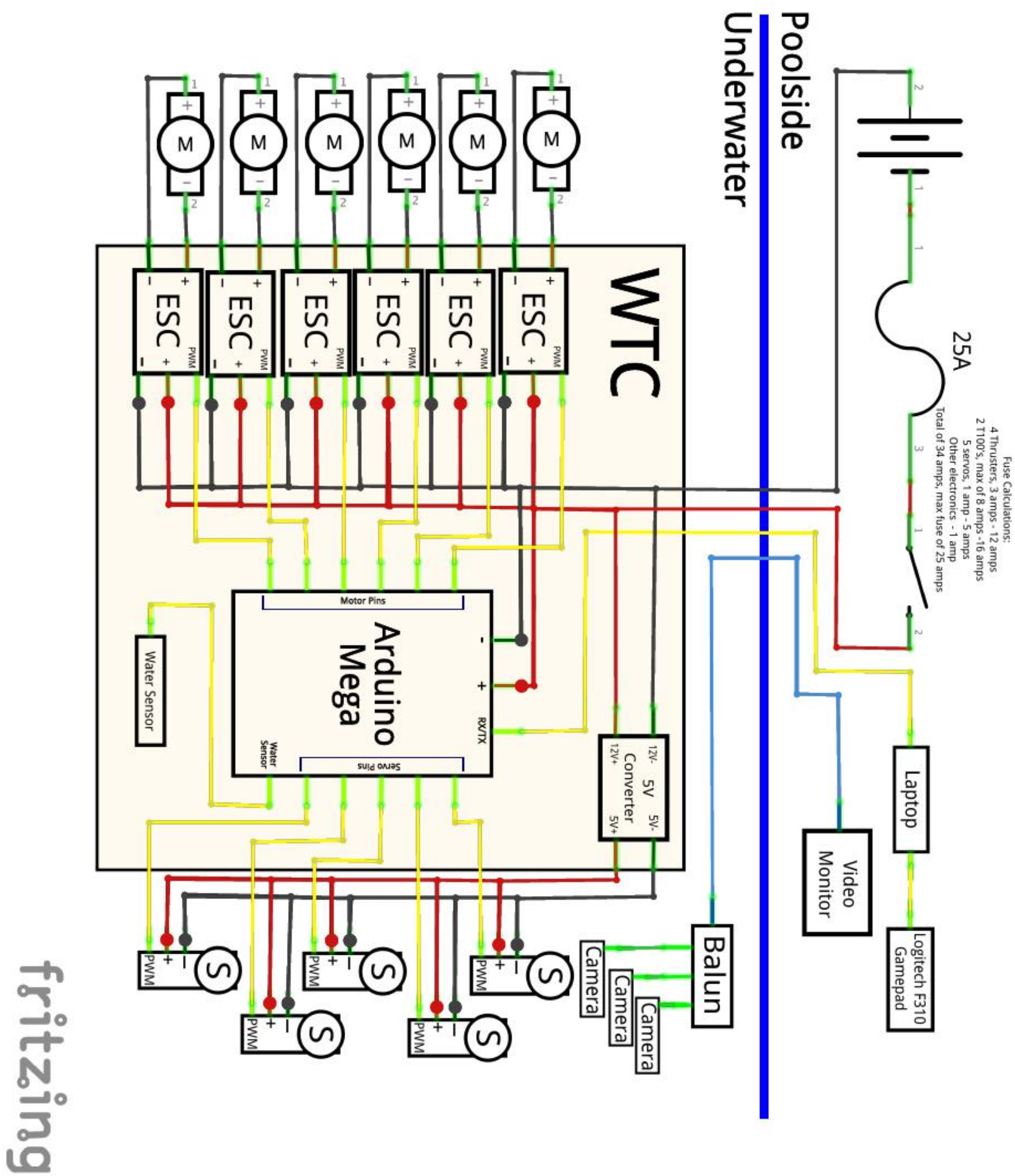
Nathan - As the team's visual system engineer, I was responsible for the camera system. The camera system was similar to last year's however, some major improvements were made to the system, including the additions of servos to the camera cases. I was able to learn about servos and how they could be used for multiple purposes and how to implement them. This process taught me that improvements could always be made, even if something was functioning properly. In addition, as chief safety officer, I was in charge of making sure that all safety procedures were carried out in the workshop, on the ROV, and poolside.

Daniel - As the team's propulsion engineer, I was responsible for the propulsion system. After analyzing the system's effectiveness on last year's mission, it was determined that last year's model was successful and should be reused, which allowed me to get involved in other areas of the ROV, including the electronic system for H2rOver. I became more proficient in and worked on many additional aspects of Project Jellyfish, including: Arduino, Processing, servos, and designing attachments. I spent significant time on waterproofing - trouble shooting and testing the watertight case. Additionally, as the team's Technical Report manager, I learned about managing the group, keeping to deadlines for submissions, and timely finalizing the overall document in compliance with MATE's rubric. This year MATE allowed me to critically think about different aspects of the ROV to find solutions in areas outside of propulsion.

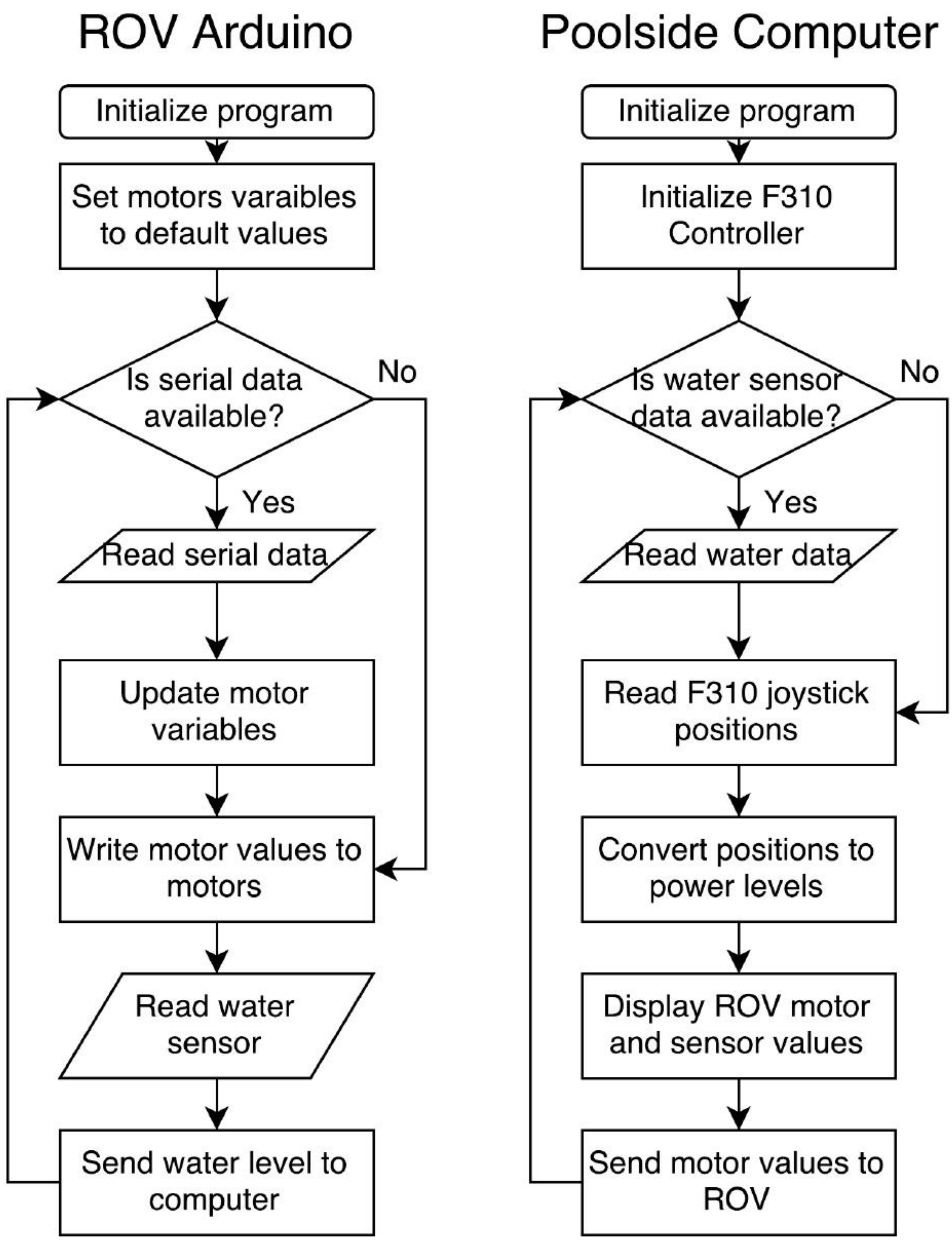


Team Photo (left to right: Nicholas, John, Nathan, and Daniel)

Systems Integrated Design (SID)



Software Flow Charts



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